Thermite Research Report

DOT Contract # 693JK320C000005

U.S. Department of Transportation
Pipeline and Hazardous Materials Safety Administration
(PHMSA)

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SMS®
SAFETY MANAGEMENT SERVICES

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TABLE OF CONTENTS

FIGURES

TABLES

PHOTOS

1.0 STATEMENT OF WORK

DOT Contract # 693JK320C000005 with Safety Management Services, Inc. (SMS) of West Jordan, Utah defines that in conjunction with Task 10, Final Report, SMS shall:

1) Prepare a draft final report that includes all findings, recommendations and adopted suggestions for the characterization and classification of thermites based on the experimental results outlined in the previous tasks.
    a. The recommended characterization methods and classification schemes shall be presented in a fashion suitable for direct inclusion into the HMR, United Nations Manual of Tests and Criteria, and UN Model Regulations on the Transportation of Dangerous Goods.
2) Receive input on the draft final report by the COR, make appropriate updates to the report and then furnish a final Section 508 compliant final report.

2.0 SUMMARY AND CONCLUSIONS

This thermite research report contains all findings, recommendations and adopted suggestions for the characterization and classification of thermites based on the following tasks and deliverables:

<u>Phase 1</u> - DOT Contract # DTPH5616D00001, Task Order 693JK318F000058 (TO# 0002)

- "Energetic Properties of Thermite Formulations, Final Report", Southwest Research Institute (SwRI®), Project # 24178 conducted by Safety Management Services, Inc, November 2019.

<u>Phase 2</u> - DOT Contract # 693JK320C000005 with Safety Management Services, Inc.

- Task 2: "Sensitivity of Various Thermite Formulations", SMS-6265b-R1, October 2021.
- Task 3: "Sensitivity of Fine, Medium, and Coarse Exploding Thermite Iterations", SMS-6265c-R1, February 2022.
- Task 4: "UN Series 6 Testing of Non-Exploding, Large-Scale Thermites", SMS-6265d-R1, January 2022.
- Task 5: "Commercial Thermite in Transport", SMS-6265e-R1, November 2022.
- Task 6:
    - "UN Series 6 (a) Testing of Exploding, Large-Scale Thermites", SMS-6265f-R1, June 2023.
    - "Explosive Power of Unconfined Exploding Thermites", SMS-6265f-R2, August 2023.
- Task 7: "Effect of Confinement on the Reactivity of Exploding Thermites", SMS-6265g-R1, May 2023.
- Task 8: "Examination of the 5-minute Koenen Test Limit", SMS-6265h-R1, .
- Tasks 11 - 14: "Optimization of Base Thermite and Thermite-Additive Formulations", SMS-6265k-R1, September 2023.
- Task 15: "Classification Testing of Optimized Thermites with Additives", SMS-6265k-R2, September 2023.

For many years, the properties of thermites have perplexed test laboratories and regulators; one thermite manufacturer published on their website that they had provided a sample of their thermite to a well-known and respected international test laboratory that performed the UN Test N.1 Flammable solids test on the sample, only to have the thermite pass the test criteria; it was the conclusion of the test laboratory that the thermite was non-regulated for transport. Manufacturers, testing laboratories and regulators have been struggling together with the proper characterization and classification of thermites. U.S. DOT PHMSA, taking a very rational but extremely unpopular position, began regulating thermites, since they were being manufactured with the view to producing a pyrotechnic effect, under the same classification system as explosives.

Understanding the new regulatory burden this would place upon thermite manufacturers, PHMSA permitted in the interim time, while further research was being conducted on the properties and hazards of thermites, a chance for thermites to be excluded from Class 1 through UN Series 2 tests (UN Gap, Koenen and Internal Ignition), which are used in determining whether a substance, not manufactured with the view to producing a practical explosive or pyrotechnic effect, is too insensitive for inclusion in Class 1. PHMSA was not required to provide interim regulatory relief to the thermite industry, but to do so, in our opinion, was very considerate and gracious.

The Phase 1 investigation of thermite properties began November 2018 with a concluding test report published in November 2019; unexpectedly, several thermites were discovered that transitioned to explosion upon unconfined ignition, explaining the evidentiary damage and destruction that were observed and documented after manufacturing incidents involving specific thermite formulations in powder form. However, it was very puzzling that these exploding thermites, unlike conventional explosives, easily and unexpectedly passed the Internal Ignition tests -- a discovery that specific thermites explode when ignited unconfined but will not explode when ignited under confinement in tests designed to exacerbate, promote and reveal a substance's hidden explosive potential.

SMS proposed to further investigate these unexpected and perplexing thermite properties in Phase 2. SMS personnel have been determinedly working with PHMSA since 2018 to understand the unique properties and hazards of thermites in transport. SMS only recently explored the effects of igniting exploding thermites under confinement (Task 7) along with characterizing the heating profile of Koenen test samples (Task 8).

Only within the past two months did SMS discover that thermites with additives have extremely violent and energetic reactions in the Internal ignition test (Task 15), propelling end caps through steel plate yet still managing to achieve a passing test result without fragmenting the pipe or end caps. These same explosions have produced measurable blast waves, disrupted and scattered the confining material but have not damaged the witness plate beneath the package or produced a crater, as conventional explosives do when they explode.

Up to now, the Internal Ignition and Time/pressure tests have been viewed as equivalent. But within the past week, SMS personnel discovered that these thermites, passing the Internal ignition test criteria, are completely and utterly failing the Time/pressure test criteria -- an unexpected discovery that these two tests that are substitutes for one another do not yield equivalent results for all types of energetic materials. In the past, the Internal ignition test has been the preferred test for thermites due to the molten metal reaction and its potential for damaging the costly Time/pressure chamber and associated instrumentation. However, we now understand that the Internal ignition test is a very poor test for thermites and fails to properly characterize them. We also now know that the Time/pressure test, although at risk for slower-reacting thermites, can accurately identify and characterize fast-reacting thermites. SMS is currently in the process of conducting proof-of-concept testing at our own expense and effort to determine whether the Time/pressure apparatus can be safely used to characterize slower-burning thermites that create molten metal deposits.

All of these recent discoveries have led SMS to conclude that the UN Series 2 tests, utilized for interim regulatory relief, result in mischaracterization and misclassification of the hazards of thermites since thermites are generally not shock sensitive (passing result), many have elevated temperatures for onset of thermite reaction resulting in no ignition/reaction in the Koenen test (passing result) and all thermites, even those that result in an explosion upon unconfined ignition, achieve a passing result in the Internal ignition test with no fragmentation of the pipe or end caps. As a further example, Large-scale Mix ID #1, a 1 - 5 micron Al-Fe_2O_3 thermite, easily passes the UN Series 2 UN Gap test, Koenen and Internal ignition tests but explosively reacts upon unconfined ignition with hazards consistent with a very fast-reacting Division 1.3G powder. The following photo shows the type of substance that can be excluded from Class 1 if UN Series 2 with Internal Ignition is used as the criteria for exclusion from Class 1. Note: The steel witness screen frames in the images are four meters (thirteen feet) from the stack of packages; the fireball had a radius of approximately eight meters (twenty-six feet) with a very high output of thermal flux.

Photo 1: Task 4, UN Series 6 (c) External Fire – Test Progression for Fine Al-Fe_2O_3 Thermite – Large-Scale Mix ID #1 (SMS mixed)

However, it appears that replacing the UN Series 2 (c) (ii) Internal ignition test with the UN Series 2 (c) (i) Time/pressure test with an igniter just sufficient to ensure ignition of the substance may result in correct characterization and accurate classification of thermites with the potential for rapid deflagration or explosion (based on the currently limited Time/pressure data set), as shown in the following table. Additional discussion and considerations include:

- Under SMS's proposed thermite classification approach, passing the UN Series 2 (c) (i) Time/pressure and 2 (b) Koenen tests is sufficient information to waive UN Series 6 tests and qualify for a Division 1.4G classification. Further, a passing 2 (c) (i) Time/pressure test result could be used to waive the 3 (d) Small-scale burning test for thermites.
- Both proposals utilize a shock test to demonstrate that the substance will not propagate a detonation; SMS recommends utilizing the UN Series 1 (a) Gap test at zero gap (220-kbar shock) to demonstrate that substances manufactured with the view to producing a practical explosive or pyrotechnic effect are sufficiently desensitized and will not propagate a detonation for exclusion from Class 1.
    - The UN Series 2 (a) Gap test at 2-inch gap (21-kbar shock) is sufficient to demonstrate that substances NOT manufactured with the view to producing a practical explosive or pyrotechnic effect are too insensitive for inclusion in Class 1.
    - Like thermites, self-reactive materials are also capable of self-sustaining exothermic chemical reaction.
        - The UN Gap tests at zero gap (1 (a) / A.5 / A.6) are required for self-reactive substances to demonstrate that they cannot propagate a detonation.
    - Thermites have generally not demonstrated a high susceptibility to shock sensitivity, so a UN Series 2 (a) Gap test at 2-inch gap could be sufficient, even though it provides ten times less shock pressure than the zero gap test.
- SMS recommends additional checks and balances that are not present in the UN Series 2 proposal to justify and show cause for Class 1 exclusion of this pyrotechnic substance

when other Class 1 pyrotechnic substances are not considered for exclusion from Class 1 by UN Series 2 tests alone:

- Onset of reaction greater than 500 °C;
- Unconfined explosive power less than 7% of trinitrotoluene (TNT) in a Thermal explosion test (slow cook-off); and
- Confined explosive power less than 7% of trinitrophenol (picric acid) for thermites containing >15% oxidizing agents.

Table 1: Comparison of Proposals for Excluding Thermites from Class 1

Consideration for Exclusion from Class 1	UN Series 2 Proposal	SMS Proposal	Concern
Unconfined ignition	n/a	Small-scale burning for thermites	Identification of unconfined exploding thermites; test waived based on passing the Time/pressure test.
Detonation propagation	2-inch gap (21 kbar)	0-inch gap (220 kbar)	Not conservative; other self-sustaining substances utilize 0-inch gap with known potential to explode.
			0-inch gap provides high degree of confidence that detonation will not propagate; shows cause for exclusion from Class 1.
Confined heating	2mm orifice for 4.1	2mm orifice for 1.4G	None (same).
Confined ignition	Internal ignition	Time/pressure	Internal ignition results in mischaracterization of fast-reacting thermites; even exploding thermites pass this test when the result is clearly violent.
			Time/pressure results in proper and accurate classification of hazards.
Onset of reaction	n/a	>500 °C	Justifies and shows cause for Class 1 exclusion; also ties back to temperature limits in UN MTC Appendix 6.
Unconfined thermal explosion (slow cook-off)	n/a	<7% trinitrotoluene	Justifies and shows cause for Class 1 exclusion; ties back to tests for other self-sustaining substances.
Confined explosive power for thermites with 15% of more oxidizing agents	n/a	<7% trinitrophenol	Oxidizing agent(s) may create additional explosive properties. Justifies and shows cause for Class 1 exclusion; ties back to tests for other self-sustaining substances.

It is the recommendation of SMS that thermite powders, which are manufactured with the view to producing a pyrotechnic effect, be classed into Class 1 in the condition and form in which they are offered for transport by utilizing UN Series 3 and 6 tests with the thick-layer propagation method of the type 3 (d) Small-scale burning test. SMS also recommends that non-exploding thermites qualifying for Division 1.4G or 1.4S criteria may be considered for exclusion from Class 1 if they have an ignition temperature greater than 500 °C in the type G.1 Thermal explosion test in package (slow cook-off) with an average thermal explosive power less than 7% of the TNT reference standard for blast overpressure and scaled impulse in accordance with the ET Users Group (ETUG) Standard for TNT Equivalency from an Unconfined Explosion on the Surface (ETUG-GS02-23), which is in the process of being finalized for publication. Thermites containing 15% of more of oxidizing agent(s) that are not metal oxides, including fluoropolymers, must also have a "Low" or "No" confined explosive power result in one of the Series F tests. The thermite type is then assigned based on the reactivity of the thermite with less reactive thermites having fewer restrictions. Thermite types 1.3G, 1.4G, 1.4S and type C of Division 4.1 are based on packaging-specific test results; Thermite types 1.1A/G and types D - G of Division 4.1 are based on packaging-independent test results (i.e., intrinsic thermite properties). Thermite type G can be assigned to a packing group of Division 4.1 Flammable solid or may also qualify for further exclusion.

The UN Series 2 (a) UN Gap test is sufficient to demonstrate that a substance not manufactured with the view to producing a practical explosive or pyrotechnic effect can be excluded from Class 1. However, UN Series 1 (a) UN Gap (zero gap) is required to demonstrate that a Division 4.1 Self-reactive substance with explosive properties is sufficiently desensitized and not forbidden from transport. Similarly, UN Series 1 (a) UN Gap test results can also utilized to waive the detonator test in a UN Series 6 (a) Single package test. On the other hand, thermites have not demonstrated a high susceptibility to shock sensitivity. SMS recommends any thermites desiring to be excluded from Class 1 demonstrate that they ignite at temperatures of greater than 500°C.

3.0 FINDINGS

3.1 Historical Misrepresentation and Misclassification

Historically, thermite manufacturers have often classified their thermite as a Division 4.1 flammable solid or as not regulated for transport after passing the UN Test N.1 Test method for flammable solids, UN Test N.4 Test method for self-heating substances and UN Test N.5 Test method for substances which in contact with water emit flammable gases. However, UN Test N.1 utilizes too narrow of a powder train to reliably sustain the reaction of many fast-reacting thermites; a wider width of the same powder readily sustains the reaction, enabling measurement and characterization of the reaction rate. Further, unlike typical flammable solids (e.g., alkali metals, metal powders, charcoal, phosphorus, sulfur, camphor, naphthalene, oily fibers or fabrics), thermites are like explosives and self-reactive materials that undergo exothermic reactions without the participation or presence of oxygen (air), exhibiting explosive properties (detonation, rapid deflagration or thermal explosion hazards) with varying explosive power based on:

- Composition: Specific oxides (e.g., Bi_2O_3, MnO_2, MoO_3) were susceptible to form exploding thermites. An aluminum (Al) - cupric oxide (CuO) thermite, 1 - 5 micrometers (micron), became explosive when 5-micron 50/50 magnalium (magnesium/aluminum) alloy powder was substituted for 5-micron aluminum powder. The oxidation state of the metal oxide (e.g., Fe_2O_3 versus Fe_30_4; CuO versus CuO_2, etc.) also unpredictably affected the sensitivity and reactivity of the thermite. Thermites containing magnesium or titanium were generally more thermally sensitive and had a more violent reaction than aluminum-based thermites. The addition of organic oxidizers lowered the ignition temperature and caused thermites to reliably fail the Koenen test with hazardous overpressurization.

- Particle size: Fine thermites were most susceptible to explosion; increasing the particle size of the metal oxide tended to have a greater influence on the explosivity than increasing the particle size of the metal.
- Confinement: Explosives react with greater violence under confinement as the burn rate is a function of pressure. However, confinement does not appear to increase the burn rate of thermites; rather, it appears to contain and suppress the explosion. Exploding thermites will readily explode upon ignition when unconfined or packaged for transport; exploding thermites were unable to fragment a thick-wall steel pipe or damage a steel witness plate.
- Ignition type: Exploding thermites explode upon ignition with a thermite igniter; ignition by hotwire causes these thermites to react with more violence (higher blast overpressure).
- Form: Specific thermites as loose powder will readily explode when ignited; those same powders may not explode upon ignition if consolidated or pressed into a housing / casing.

Thermites also present an additional and unique hazard: production of molten metal that can melt or cut through containment or cause combustion of most organic materials. Their reaction also produces much higher levels of thermal flux than is produced by reaction of traditional explosives, propellants and pyrotechnics.

3.2 Appendix 6 Screening Procedures

The Appendix 6 Screening Procedures in the United Nations (UN), Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria, Section A6.3.2 identifies that explosive properties are associated with the presence of certain chemical groups in a molecule which can react to produce very rapid increases in temperature or pressure, such as nitrates, nitro compounds, azides, perchlorates, peroxides, etc. It also identifies that explosive properties are associated with mixtures of inorganic oxidizing substances with organic material(s), such as ammonium nitrate and fuel oil. However, the screening procedures neglect to identify that explosive properties are also associated with:

- Mixtures of inorganic oxidizing substance with inorganic materials (like ammonium perchlorate and aluminum).
- Mixtures of organic oxidizing substances with inorganic materials (like magnesium with Teflon).
- Mixtures of inorganic metal oxides with inorganic metals (like iron oxides with aluminum).

Hotwire explosion screening tests have been the best indicator of a thermite's thermal sensitivity and a great predictor of thermite reactivity. High-temperature Differential Scanning Calorimetry (DSC) has been an indicator of thermal sensitivity but has not been a consistent predictor of thermite reactivity using the standard 1-mg sample size.

3.3 UN Series 1 or 2

Thermites were generally not shock sensitive; however, thermites containing bismuth(III) oxide (Bi_2O_3) created a traditional shock wave (unknown whether that exploding thermite is capable of initiating secondary explosives). Addition of 15% or more of stronger oxidizing agents (e.g., ammonium, potassium or barium nitrate; ammonium or potassium perchlorate; etc.) to thermite compositions may introduce shock sensitivity that was not evident in the UN Gap tests.

Many thermites require high temperatures to achieve the onset of thermite reaction; the sample temperatures achieved in the Koenen test over five minutes (600 - 800 °C) are insufficient to start many thermite reactions; extending the test time to fifteen minutes allowed the temperature in the middle third and upper third to reach steady values but the temperature in the bottom of the tube did not increase after the first five minutes. While extending the test duration in Phase 1 made a difference, no difference was observed in extending the test time for thermites from five to fifteen minutes.

The normal Koenen test procedure specifies 80-N tamping for solid samples. Explosive substances generally have a higher reactivity when pressed or consolidated; thermites that explode upon ignition when unconsolidated can steadily burn upon ignition when consolidated or pressed (i.e., the unconsolidated/loose form can be more severe for thermites). The Koenen test should be performed on thermite substances in the condition and form in which they will be offered for transport. Tamping of unconsolidated thermite powder should only be performed if representing a credible condition and form as offered for transport.

The addition of organic oxidizers lowered the ignition temperature and generally caused the thermites to reliably fail the Koenen test with hazardous overpressurization of the steel Koenen tube.

Thermites are generally hard to ignite; however, 20-gram black powder bag igniters were able to reliably ignite all thermites with additives in the Type 1 (c) (ii) Internal ignition test. The thick wall of the Internal ignition test pipe contains and/or suppresses the reactions of exploding thermites; substituting a thin-walled steel tube of the same dimensions manifested the exploding thermite reaction. Thermites were passing the Internal ignition test criteria without fragmenting the tube or one of the end caps into two distinct pieces; however, the reactions were of sufficient violence to explosively propel the end cap through 1/4-inch thick steel plate, bury the full length of an 18-inch long pipe into the solid ground and make the pipe propulsive / take flight.

Utilizing the Type 2 (c) (i) Time/pressure test with an igniter just sufficient to ensure ignition of the substance resulted in accurate identification and characterization of these fast-reacting thermites as having regulated explosive properties; specifically, each had rise times from 100 - 300 psig in less than 30 msec, ranging from 0.2 msec to 5 msec. Components of the Time/pressure test apparatus may be damaged by molten metal deposits from thermite reactions; high-temperature cylindrical crucibles (about 3 mL capacity) may be placed within the chamber to contain the sample and molten-metal reaction products.

Up to this research effort, the Time/pressure and Internal ignition tests have been viewed as equivalent for all Class 1 explosives, propellants and pyrotechnics; a passing or failing result in one test inferred a corresponding passing or failing result in the other. However, thermites easily and dangerously pass the Internal ignition test criteria while clearly and unreservedly failing the Time/pressure test criteria. This test result calls into question what other types of Class 1 materials have been excluded from Class 1 based on a false-negative Internal ignition test result (too insensitive for inclusion in Class 1) when a different test would have indicated that the material should be regulated in Class 1.

Primed cambric, the specified ignition system for the Time/pressure test, was not available for these tests. However, SMS utilized a commercial pyrogen igniter that is utilized for reliable ignition of rocket propellant; the igniter reaches around 40 psi over approximately 100 msec in an empty Time/pressure chamber while providing a high-temperature ignition source. SMS also utilized igniters comprised of an electric match and a few grams of a fine thermite starting powder to start the thermite reaction.

The electrically-conductive thermite powders short circuit electric Nichrome heating wire. SMS insulated the electrical connections utilizing high-temperature ceramic insulation within borosilicate glass but the conductive powders can still divert / circumvent the electricity from the electrical heating circuit. Similar challenges may be encountered with thermocouples that are not electrically isolated from the conductive thermite powders. Heating elements and thermocouples are recommended to be electrically isolated from thermite.

The ignition source appears to make a difference in the reactivity of the thermite, with electric hotwires producing greater violence than thermite starting mix.

3.4 UN Series 3

Generally, thermite additives resulted in increased friction sensitivity of all thermites.

The type N.1 test utilizes an impervious, non-combustible, low heat-conducting plate to support the sample train. Normally reusable for flammable solids, the plate was not reusable for thermites due to their high reaction temperature, reaction violence and molten metal deposits. A non-combustible, low heat-conducting, ceramic board (limited reusability) appeared to provide a better support for the sample bed.

3.5 UN Series 6

For rapid-deflagrating substances packed in drums, the most severe type 6 (a) test results are achieved utilizing loose sand since the preferred method of confinement (containers, similar in shape and size to the test package, completely filled with earth or sand and placed as closely as possible around the test package) and alternative methods of confinement (boxes or bags filled with earth or sand) have interstitial venting spaces that allow for rapid pressure relief that is not present when confined with loose sand or when the substance is packed in boxes.

For the Type 6 (a) Single package and 6 (b) Stack tests, explosion of normal explosive substances is evidenced by disruption and scattering of the confining material, damage to the witness plate, a crater and measurement of a blast. However, exploding thermites have much less explosive power than traditional explosives: as high as 6% of trinitrotoluene (TNT) for blast overpressure and 13% for scaled impulse. Exploding thermites reliably disrupt and scatter the confining material with measurement of a blast; the witness plate may be undamaged and there may not be a crater. A quantity of 25 pounds of exploding thermite did not damage a 0.5-inch-thick ceramic board; conversely, 25 pounds of TNT fractured a 10-inch diameter cylinder from a 4-inch-thick steel plate and punched a hole through a 1.5-inch-thick steel plate while cratering the ground.

The traditional detonation shock wave is characterized by an instantaneous rise from ambient pressure to a peak pressure that quickly decreases to ambient pressure and then a negative phase. While some thermites or thermites with additives experienced detonations producing shock waves, most exploded in a blast; their pressure waveforms were characterized by the typical burn pressure waveform that was preceded by a small positive pressure pulse that traveled as a blast wave, arriving sequentially at inline pressure sensors, decreasing in peak value while increasing in duration with distance. When performing type 6 (a) tests on thermite, disruption and scattering of the confining material was always accompanied with a blast wave.

Large-scale testing demonstrated that although inadvertent thermite reaction can structurally compromise the transport vehicle (motor vehicles, trains, vessels and aircraft), the transport container and adjacent cargo containers, the threat is similar to and comparable in magnitude to that presented by other explosive substances in Class 1.4, such as ignition and burning of propellant.

3.6 UN Series A - G

For the type G.1 Thermal explosion test in package, the auto-ignition temperature of common commercial packaging materials, such as plastic and fiberboard, is below 500 °C. Therefore, this test must be performed on thermite in a stainless-steel pan of appropriate size, covered for protection from weather, about 1.8 mm (0.07 in) thick and surrounded with high-temperature insulation to inhibit heat loss. The test quantity is the same as that to be offered for transport with a maximum quantity of 50 kg (110 lb) per package. Temperatures are monitored utilizing high-temperature thermocouples whose junctions are electrically isolated from the thermite. Air-blast overpressure waveforms are acquired in accordance with the ET Users Group (ETUG) Standard for TNT Equivalency from an Unconfined Explosion on the Surface (ETUG-GS02-23), which is in the process of being finalized for publication.

4.0 RECOMMENDED CHARACTERIZATION AND CLASSIFICATION APPROACH

It is the recommendation of SMS that thermite powders, which are manufactured with the view to producing a pyrotechnic effect, be classed into Class 1 in the condition and form in which they are offered for transport by utilizing UN Series 3 and 6 tests with the following provisions:

UN Series 3

- Perform a type 3 (a) Impact sensitivity test, 3 (b) Friction sensitivity test, 3 (c) Thermal stability test and Thick-layer propagation method (for thermites) of the type 3 (d) Small-scale burning test. The type 3 (d) test may be waived if having no or slow deflagration in a type 2 (c) (i) Time/pressure test with an igniter just sufficient to ensure ignition of the substance.
- A thermite powder failing test type 3 (a), 3 (b) or 3 (d) is categorized as an unstable explosive in the form in which it was tested but may be encapsulated or otherwise desensitized or packaged to reduce sensitiveness to external stimuli and submitted to a type 4 (b) (ii) 12-meter drop test.
    - A substance giving a "+" result (explosion) in the type 3 (d) test with a "-" result in test type 4 (b) (ii) indicates a substance that is not forbidden from transport.
        - If the product is accepted into Division 1.1, further testing is not necessary; otherwise proceed to a test of type 6 (a).

UN Series 6

- **Type 6 (a) Single package test**
    - Perform three trials of the type 6 (a) Single package test with an igniter just sufficient to ensure ignition of the substance in the center of the package.
        - Test type 6 (a) with an igniter may be waived if having no or slow deflagration in a type 2 (c) (i) Time/pressure test with an igniter just sufficient to ensure ignition of the substance.
    - Mass explosion indicates a candidate for Division 1.1.
        - Evidence of such an indication includes disruption and scattering of the confining material and measurement of a blast (i.e., a positive pressure pulse before the negative pressure wave).
            - The witness plate may be undamaged and there may not be a crater.

    - If the product is accepted into Division 1.1, further testing is not necessary; otherwise proceed to a test of type 6 (b).
- **Type 6 (b) Stack test**
  - Perform three trials of the type 6 (b) Stack test with an igniter just sufficient to ensure ignition of the substance in the center of the package.
    - Test type 6 (b) may be waived if test type 6 (a) was waived or if in each type 6 (a) test the contents of the package failed to explode or exploded so feebly as would exclude propagation of the explosive effect from one package to another in test type 6 (b).
  - The product is assigned to Division 1.1 and further testing is not necessary if explosion of the contents of more than one package occurs practically instantaneously.
- **Type 6 (c) External fire (bonfire) test**
  - Perform a type 6 (c) External fire (bonfire) test on sufficient packages to give a total volume not less than 0.15 m^3 with a minimum of three packages.
    - If a mass explosion occurs then the product is assigned to Division 1.1; otherwise, Division 1.3G/1.4G/1.4S is assigned on the basis of fireball size, burn rate and thermal flux at 15 meters for Division 1.3G/1.4G or 5 meters for Division 1.4G/1.4S.
      - The approval is restricted to the tested quantity and materials of construction per inner, intermediate and outer package(s).
  - The bonfire test may be waived for thermites not exceeding 11.4 kg (25 lbs) net weight per package, in plastic packagings with a wall thickness no greater than 3.3 mm (0.13 in) and/or fiberboard packagings, on the following basis:
    - Thermites qualify for Division 1.3G if having no or slow deflagration in a type 2 (c) (i) Time/pressure test with an igniter just sufficient to ensure ignition of the substance, or if in the type 6 (a) Single package test does not result in explosion of the total contents of the package as evidenced by disruption and scattering of the confining material and measurement of a blast.
    - Thermites qualify for Division 1.4G if having no violent effect on heating under confinement (i.e., limiting diameter less than 2.0 mm) in a type 2 (b) Koenen test and qualifying for Division 1.3G.
    - Thermites qualify for Division 1.4S if having no effect on heating under confinement (i.e., limiting diameter less than 1.0 mm) in a type 1 (b) Koenen test and qualifying for Division 1.3G.
    - The tests are performed at the same density as intended for transport.

      Note: Many thermites require high temperatures to achieve the onset of thermite reaction; the sample temperatures achieved in the Koenen test over five minutes (600 - 800 °C) are insufficient to start many thermite *reactions. Thermites that are fast reacting will be identified either in the Series 2(c)(i) "Time/pressure test" or the Series 6(c) "External fire (bonfire) test"; therefore, passing Koenen test results based on no reaction of the thermite is not of concern.*

Note: The normal Koenen test procedure specifies 80-N tamping for solid samples. Explosive substances generally have a higher reactivity when pressed or consolidated; thermites that explode upon ignition when unconsolidated can steadily burn upon ignition when consolidated or pressed (i.e., the unconsolidated/loose form can be more severe for thermites). The Koenen test should be performed on thermite substances in the condition and form in which they will be offered for transport. Tamping of unconsolidated thermite powder should only be performed if representing a credible condition and form as offered for transport.

Thermite Class 1 Exclusion Criteria: SMS also recommends that to qualify for exclusion from Class 1, thermites must qualify for classification as Division 1.4G or Division 1.4S as packaged for transport and have:

1) A "-" result (no explosion) in the type 3 (d) Small-scale burning test for thermites;
2) A "No" detonation result in a type B.1 Detonation test in package or a "Partial" or "No" detonation propagation result in one of the Series A tests;
3) An ignition temperature greater than 500 °C in the type G.1 Thermal explosion test in package with an average thermal explosive power less than 7% of the TNT reference standard for blast overpressure and scaled impulse in accordance with the ET Users Group (ETUG) Standard for TNT Equivalency from an Unconfined Explosion on the Surface (ETUG-GS02-23), which is in the process of being finalized for publication; and
4) A "Low" or "No" confined explosive power result in one of the Series F tests if the thermite contains 15% or more of oxidizing agent(s) that are not metal oxides, including fluoropolymers.

Thermites meeting the recommended thermite Class 1 exclusion criteria above qualify for classification as a Division 4.1 thermite type as follows:

- Thermite type C without any further requirements.
- Thermite type D if also having 1) either "Partial" or "No" detonation propagation result in one of the Series A tests; 2) either "No" or "Yes, slowly" deflagration result in a type C.1 Time/pressure test with an igniter just sufficient to ensure ignition and reaction of the substance; and 3) no "Violent" effect on heating under confinement (i.e., limiting diameter less than 2.0 mm) in a type E.1 Koenen test.
- Thermite type F if also having 1) "No" detonation propagation result in one of the Series A tests; 2) "No" deflagration result in a type C.1 Time/pressure test with an igniter just sufficient to ensure ignition and reaction of the substance; and 3) no effect on heating

under confinement ("-" result, limiting diameter less than 1.0 mm) in a type 1 (b) Koenen test.

Note: The "-" Type 1 (b) result is used in lieu of a "No" type E.1 test result (tube unchanged) since an exothermic thermite reaction can intrinsically damage the steel Koenen tube not by hazardous overpressurization due to restricted venting but by molten metal melting through the tube.

Division 4.1 Thermite Exclusion Criteria: SMS recommends that thermite substances may be excluded from regulation, as a specific Division 4.1 thermite type, when qualifying for classification as Thermite type G:

- Meets requirements for classification as Thermite type F;
- Has an average thermal explosive power in the type G.1 Thermal explosion test in package that is 1% or less of the TNT reference standard for blast overpressure and scaled impulse; and
- Has a "No" confined explosive power result in one of the Series F tests if the thermite contains 15% or more of oxidizing agent(s) that are not metal oxides, including fluoropolymers.

Thermites meeting the recommended Division 4.1 thermite exclusion criteria above qualify for assignment to a Division 4.1 Flammable solid packing group based upon the results of the thick-layer propagation method of the type 3 (d) Small-scale burning test and the type N.1 Test method for flammable solids criteria for metal powders:

- Thermite substances are assigned to Packing Group II/Category 1 if the reaction spreads over the whole length of the sample (i.e., the 100 mm timing zone after the initial 80 mm) in five minutes or less.
- Thermite substances are assigned to Packing Group III/Category 2 if:
  - The reaction spreads over the whole length of the sample (100 mm) in more than five minutes but not more than ten minutes;
  - The reaction spreads over the whole length of the sample (100 mm) in more than ten minutes but creates molten metal deposits; or
  - The reaction does not spread over the whole length of the sample but creates molten metal deposits.

SMS recommends that Thermite type G substances may be excluded from Division 4.1 Flammable solid if:

- The reaction spreads over the whole length of the sample (100 mm) in more than ten minutes without creating molten metal deposits; or
- The reaction does not spread over the whole length of the sample (100 mm) and does not create molten metal deposits.

5.0 ADOPTED SUGGESTIONS

5.1 Code of Federal Regulations, Title 49

5.1.1 § 172.101 Hazardous Materials Table

(1) Symbols; (2) Hazardous materials descriptions and proper shipping names; (3) Hazard class or Division; (4) Identification Numbers; (5) PG; (6) Label Codes; (7) Special provisions (§ 172.102); Packaging (§ 173.***) (8A) Exceptions; (8B) Non-Bulk; (8C) Bulk; Quantity limitations (see §§ 173.27 and 175.75) (9A) Passenger aircraft/rail; (9B) Cargo aircraft only; (10) Vessel stowage; (10A) Location; (10B) Other

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8A)	(8B)	(8C)	(9A)	(9B)	(10A)	(10B)
G	Thermite	1.1A	Unxxxx	*	1.1A	101, 111	None	62	None	Forbidden	Forbidden	05	25.
G	Thermite	1.1G	Unxxxx	*	1.1G	101	None	62	None	Forbidden	Forbidden	03	25.
G	Thermite	1.3G	Unxxxx	*	1.3G	101	None	62	None	Forbidden	Forbidden	03	25.
G	Thermite	1.4G	Unxxxx	*	1.4G	101	None	62	None	Forbidden	75 kg	02	25.
G	Thermite	1.4S	Unxxxx	*	1.4S	101	None	62	None	25 kg	75 kg	01	25.
G	Thermite type C	4.1	Unxxxx	*	4.1	101, 131	151	212	None	5 kg	10 kg	D	25, 52, 53
G	Thermite type D	4.1	Unxxxx	*	4.1	101, 131	151	212	None	5 kg	10 kg	D	25, 52, 53
G	Thermite type F	4.1	Unxxxx	*	4.1	101, 131	151	212	None	10 kg	25 kg	D	25, 52, 53
G	Flammable solid, inorganic, n.o.s.	4.1	UN3178	II	4.1	A1, IB8, IP2, IP4, T3, TP33	151	212	240	15 kg	50 kg	B	
				III	4.1	A1, IB8, IP3, T1, TP33	151	213	240	25 kg	100 kg	B	

* Non-bulk packagings must meet Packing Group II performance levels.

5.1.2 § 173.56 New explosives—definition and procedures for classification and approval.

...

(i) If experience or other data indicate that the hazard of a material or a device containing an explosive composition is greater or less than indicated according to the definition and criteria specified in §§ 173.50, 173.56, and 173.58 of this subchapter, the Associate Administrator may specify a classification or except the material or device from the requirements of this subchapter.

(1) Thermites.

(i) Thermite substances are manufactured with the view to producing a pyrotechnic effect. Thermite substances and articles containing thermite may not be offered for transportation unless approved by the Associate Administrator.

(ii) Thermite substances as prepared for transport are submitted to the acceptance procedure (Series 3 and 4) for explosives manufactured with the view to producing a practical explosive or pyrotechnic effect, as detailed in § 173.57 of this subchapter. Test Method 3(d) is performed utilizing the thick-layer propagation method from the UN Manual of Tests and Criteria (IBR, see § 171.7 of this subchapter); the test may be waived if having no or slow deflagration in a Test Method 2(c)(i) Time/pressure test with an igniter just sufficient to ensure ignition of the substance. If desired, thermite substances may be accepted into Division 1.1 without further testing.

(iii) The hazard of a thermite substance as prepared for transport is evaluated through the Series 6 tests, as detailed in § 173.57 of this subchapter, with the provision that mass explosion is evidenced by disruption and scattering of the confining material and measurement of a blast (i.e., a positive pressure pulse before the negative pressure wave); the witness plate may be undamaged and there may not be a crater. If a mass explosion occurs then the product is assigned to Division 1.1, compatibility group A if the substance is very sensitive to heat, impact, or friction, and even in very small quantities, detonates; otherwise, the thermite is assigned to compatibility group G as a pyrotechnic substance. If there is no mass explosion hazard, Division 1.3G/1.4G/1.4S is assigned on the basis of fireball size, burn rate and thermal flux at 15 meters for Division 1.3G/1.4G or 5 meters for Division 1.4G/1.4S as detailed in the Test Method 6(c) test criteria.

(iv) Test Method 6(a) and/or 6(b) may be waived as detailed in Section 16.2 of the Manual of Tests and Criteria.

(v) Test Method 6(c) may be waived for thermites not exceeding 11.4 kg (25 lbs) net weight per package, in plastic packagings with a wall thickness no greater than 3.3 mm (0.13 in) and/or fiberboard packagings, on the following basis:

(A) Thermites qualify for Division 1.3G if having no or slow deflagration in a Test Method 2(c)(i) Time/pressure test with an igniter just sufficient to ensure ignition of the substance, or if the Test Method 6(a) Single package test does not result in explosion of the total contents of the package as evidenced by disruption and scattering of the confining material and measurement of a blast.

(B) Thermites qualify for Division 1.4G if having no violent effect on heating under confinement (i.e., limiting diameter less than 2.0 mm) in a Test Method 2(b) Koenen test and qualifying for Division 1.3G.

(C) Thermites qualify for Division 1.4S if having no effect on heating under confinement (i.e., limiting diameter less than 1.0 mm) in a Test Method 1(b) Koenen test and qualifying for Division 1.3G.

(vi) To qualify for exclusion from Class 1, thermites must qualify for classification as Division 1.4G or Division 1.4S as packaged for transport and have:

(A) A "-" result (no explosion) in the Series 3(d) “Small-scale burning test” for thermites;

(B) A "No detonation result in a Series B.1 “Detonation test in package” or a "Partial" or "No" detonation propagation result in one of the Series A tests;

(C) An ignition temperature greater than 500 °C in the Series G.1 “Thermal explosion test in package” with an average thermal explosive power less than 7% of the TNT reference standard for blast overpressure and scaled impulse in accordance with the ET Users Group (ETUG) Standard for TNT Equivalency from an Unconfined Explosion on the Surface (ETUG-GS02-23); and

(D) A "Low" or "No" confined explosive power result in one of the Series F tests if the thermite contains 15% or more of oxidizing agent(s) that are not metal oxides, including fluoropolymers.

(vii) Thermites meeting the thermite Class 1 exclusion criteria qualify for classification as a Division 4.1 thermite type as follows:

(A) Thermite type C, without any further requirements.

(B) Thermite type D, if also having: 1) either "Partial" or "No" detonation propagation result in one of the Series A tests; 2) either "No" or "Yes, slowly" deflagration result in a Series C.1 “Time/pressure test” with an igniter just sufficient to ensure ignition and reaction of the substance; and 3) No "Violent" effect on heating under confinement (limiting diameter less than 2.0 mm) in a Series E.1 “Koenen test”.

(C) Thermite type F, if also having: 1) "No" detonation propagation result in one of the Series A tests; 2) "No" deflagration result in a Series C.1 “Time/pressure test” with an igniter just sufficient to ensure ignition and reaction of the substance; and 3) No effect on heating under confinement ("-" result, limiting diameter less than 1.0 mm) in a Series 1(b) “Koenen test”.

(Note: The "-" Series 1(b) test result is accepted in lieu of a "No" Series E.1 test result (tube unchanged) since an exothermic thermite reaction can intrinsically damage the steel Koenen tube not by hazardous overpressurization due to restricted venting but by molten metal melting through the tube.)

(viii) Thermite substances may be excluded from regulation, as a specific Division 4.1 thermite type, when qualifying for classification as Thermite type G:

(A) Meets requirements for classification as Thermite type F;

(B) Has an average thermal explosive power in the Series G.1 “Thermal explosion test in package” that is 1% or less of the TNT reference standard for blast overpressure and scaled impulse; and

(C) Has a "No" confined explosive power result in one of the Series F tests if the thermite contains 15% or more of oxidizing agent(s) that are not metal oxides, including fluoropolymers.

(ix) Assignment to a Division 4.1 Flammable solid packing group is based upon the results of the thick-layer propagation method of the Series 3(d) “Small-scale burning test”:

(A) Thermite substances are assigned to Packing Group II/Category 1 if the reaction spreads over the whole length of the sample (i.e., the 100 mm timing zone after the initial 80 mm) in five minutes or less.

(B) Thermite substances are assigned to Packing Group III/Category 2 if 1) The reaction spreads over the whole length of the sample (100 mm) in more than five minutes but not more than ten minutes; 2) The reaction spreads over the whole length of the sample (100 mm) in more than ten minutes but creates molten metal deposits; or 3) The reaction does not spread over the whole length of the sample but creates molten metal deposits.

(x) Thermite type G substances may be excluded from Division 4.1 Flammable solid if:

(A) The reaction spreads over the whole length of the sample (100 mm) in more than ten minutes without creating molten metal deposits; or

(B) The reaction does not spread over the whole length of the sample (100 mm) and does not create molten metal deposits.

5.1.3 § 173.57 Acceptance criteria for new explosives.

[Comment: The following proposed changes apply to all explosive substances, not just thermites.]

(a) Unless otherwise excepted, an explosive substance must be subjected to the Drop Weight Impact Sensitivity Test (Test Method 3(a)(i)), the Friction Sensitivity Test (Test Method 3(b)(iii)), the Thermal Stability Test (Test Method 3(c)) at 75 °C (167 °F) and the Small-Scale Burning Test (Test Method 3(d)~~(i)~~), each as described in the Explosive Test Manual (UN Manual of Tests and Criteria) (IBR, see § 171.7 of this subchapter). A substance that fails the test criteria specified in the Thermal Stability Test at 75 °C (167 °F) is forbidden for transportation. A substance is unstable in the form it was tested and must be encapsulated, packaged and tested as outlined in paragraph (b) below if any one of the following occurs:

(1) For a liquid, failure to pass the test criteria when tested in the Drop Weight Impact Sensitivity Test apparatus for liquids;

(2) For a solid, failure to pass the test criteria when tested in the Drop Weight Impact Sensitivity Test apparatus for solids;

(3) The substance has a friction sensitiveness equal to or greater than that of dry pentaerythrite tetranitrate (PETN) when tested in the Friction Sensitivity Test; or

(4) ~~The substance fails to pass the test criteria specified in the Thermal Stability Test at 75 °C (167 °F); or~~

~~(5)~~ Explosion occurs when tested in the Small-Scale Burning Test.

…

(d) Explosive properties are associated with the presence of certain chemical groups in a molecule or combinations of inorganic/organic fuels and inorganic/organic oxidizing agents which can react to produce very rapid increases in temperature or pressure. The UN Manual of Tests and Criteria, Appendix 6 "Screening procedure for substances which may have explosive properties" is aimed at identifying the presence of such reactive groups or mixtures and the potential for rapid energy release. When the screening procedure identifies that a substance not manufactured with the view to producing a practical explosive or pyrotechnic effect to be a potential explosive, the Class 1 acceptance procedure must be applied:

> Series 3 tests (Drop Weight Impact Sensitivity, Friction Sensitivity, Thermal Stability at 75 °C and Small-scale Burning) are performed as preliminary screening tests with relatively small samples sizes for the safety of the experimenters; Series 3 tests also determine whether a substance is forbidden from transport. Series 1 tests (UN Gap, Koenen and Time/pressure or Internal Ignition) determine whether the substance has any explosive properties. Series 2 tests (UN Gap, Koenen and Time/pressure or Internal Ignition) determine whether the substance is too insensitive for acceptance into Class 1 (i.e., not an explosive).

5.1.4 § 173.58 Assignment of class and division for new explosives.

(a) Division 1.1, 1.2, 1.3, and 1.4 explosives. In addition to the test prescribed in § 173.57 of this subchapter, a substance or article in these divisions must be subjected to Test Methods 6(a), 6(b), and 6(c), as described in the UN Manual of Tests and Criteria (IBR, see § 171.7 of this subchapter), for assignment to an appropriate division. *[Comment: The following proposed change applies to all rapid-burning substances, not just thermites.]* The geometrical arrangement of the products should be realistic in regard to the packing method and the conditions of transport and should be such as to produce the most severe test results. For rapid-deflagrating substances packed in drums, the most severe type 6(a) test results are achieved utilizing loose sand since the preferred method of confinement (containers, similar in shape and size to the test package, completely filled with earth or sand and placed as closely as possible around the test package) and alternative methods of confinement (boxes or bags filled with earth or sand) have interstitial venting spaces that allow for rapid pressure relief that is not present when confined with loose sand or when the substance is packed in boxes. The criteria for assignment of class and division are as follows:

…

(d) The Associate Administrator may waive or modify certain test(s) identified in §§ 173.57 and 173.58 of this subchapter, or require additional testing, if appropriate. In addition, the Associate Administrator may limit the quantity of explosive in a device.

> (1) Thermites.

(i) Components of the Time/pressure test apparatus may be damaged by molten metal deposits from thermite reactions; high-temperature cylindrical crucibles (about 3 mL capacity) may be placed within the chamber to contain the sample and molten-metal reaction products.

(A) The Internal ignition test is not performed for hazard classification of thermites as it does not accurately represent a thermite's hazard since the pipe's confinement contains and suppresses more violent thermite reactions.

(ii) For the Test Method 6(a) Single package and 6(b) Stack tests, evidence of a mass explosion is disruption and scattering of the confining material and measurement of a blast; the witness plate may be undamaged and there may not be a crater.

(iii) For the Test Method G.1 Thermal explosion test in package, the auto-ignition temperature of common commercial packaging materials, such as plastic and fiberboard, is below 500 °C. Therefore, this test is performed on thermite in a stainless-steel pan of appropriate size, covered for protection from weather, about 1.8 mm (0.07 in) thick and surrounded with high-temperature insulation to inhibit heat loss. The test quantity is the same as that to be offered for transport with a maximum quantity of 50 kg (110 lb) per package. Temperatures are monitored utilizing high-temperature thermocouples whose junctions are electrically isolated from the thermite. Air-blast overpressure waveforms are acquired in accordance with the ET Users Group (ETUG) Standard for TNT Equivalency from an Unconfined Explosion on the Surface (ETUG-GS02-23); the data is analyzed and values for peak overpressure and scaled impulse are compared to that of the TNT reference standard.

5.1.5 § 173.59 Description of terms for explosives.

Thermites. Pyrotechnic substances comprised predominantly of inorganic metals and metal oxides and may include other additives. Thermites undergo a strongly exothermic decomposition even without participation of oxygen (air) upon ignition and have auto-ignition temperatures higher than many organic substances.

5.2 United Nations (UN) Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria.

5.2.1 Type 1 (c) (i), 2 (c) (i) and C.1 Time/pressure Tests

[Comment: References below to "x" is Section 11.6 for type test 1 (c) (i), Section 12.6 for type test 2 (c) (i) and Section 23.4 for type test C.1.]

x.1 ***Time/pressure test***

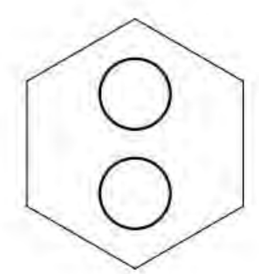
x.1.2 *Apparatus and materials*

…

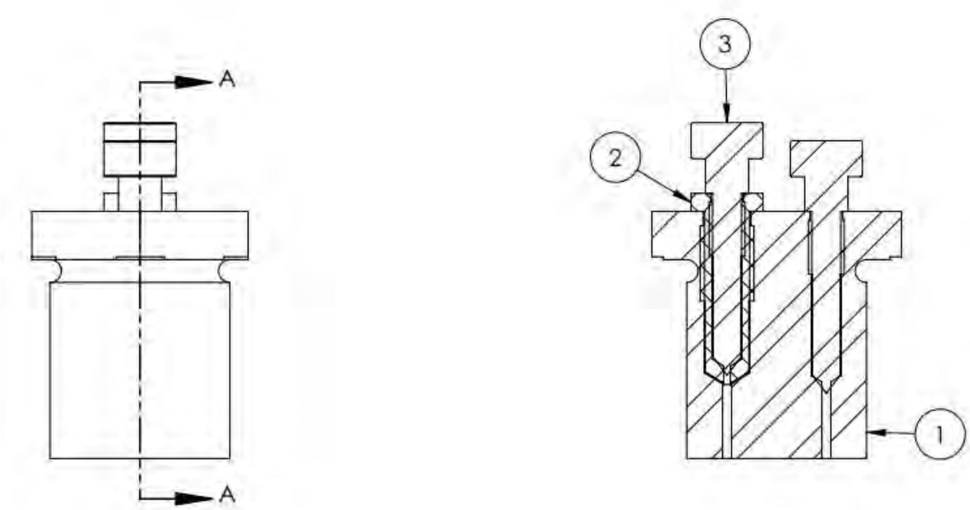
x.1.2.8 Alternately, the sample is ignited with an igniter sufficient to ensure ignition of the substance, such as a pyrogen igniter that provides a high temperature, extended duration (≥30 msec) ignition and about 100 psig pressure. The igniter is installed in the alternate electrically-isolated firing plug (Figure x.1.5) with the tip of the igniter 13mm above the surface of the firing plug.

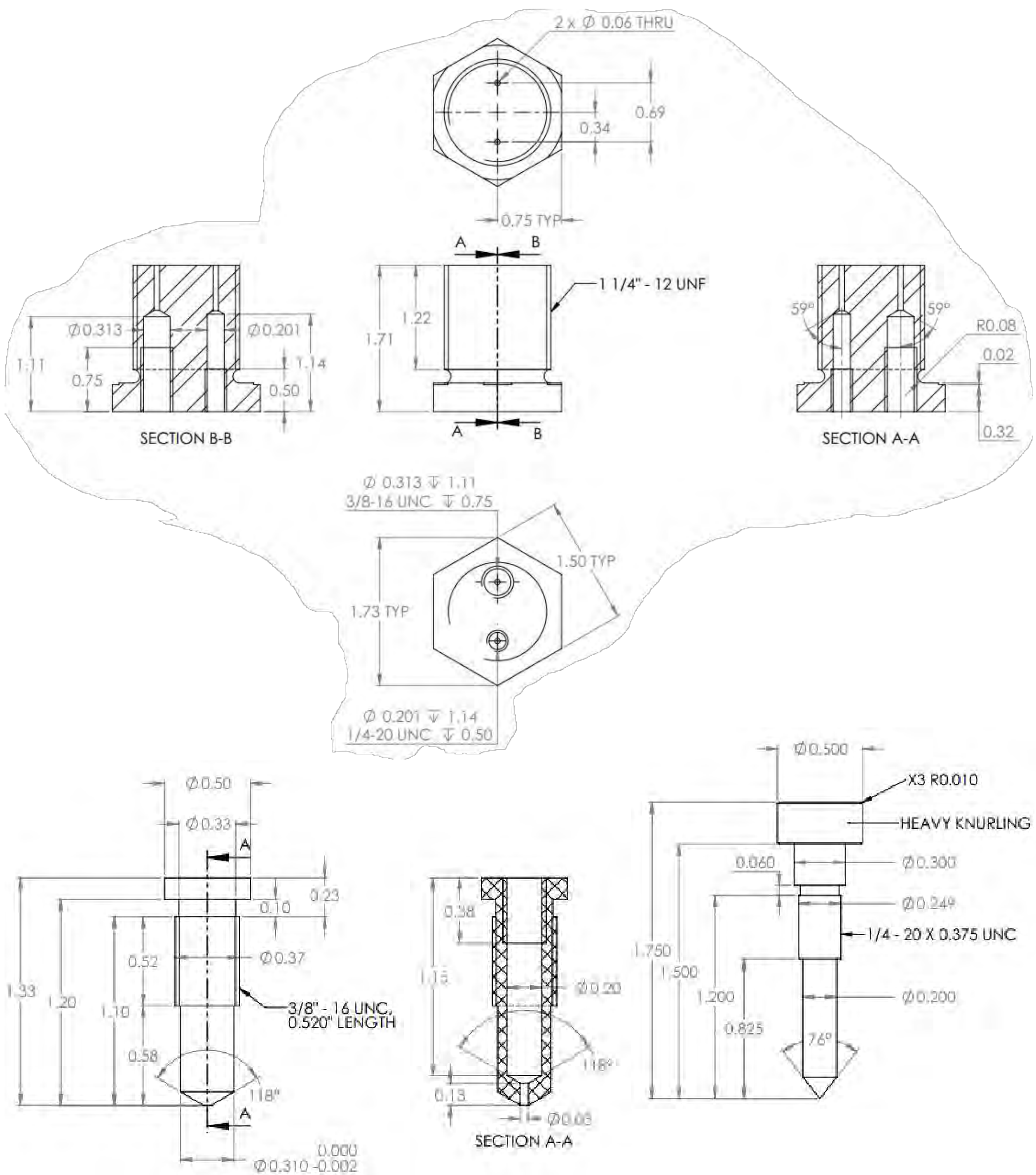
…

Figure x.1.5: Alternate Electrically-Isolated Firing Plug



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	TP-030-1_A	TIME/PRESSURE PLUG	1
2	TP-030-2	TIME/PRESSURE PLUG INSULATOR	1
3	TP-030-3_A	GROUNDED ELECTRODE, THREADED KNOB MODIFICATION	2




2 x Ø 0.06 THRU
0.69
0.34
0.75 TYP
1 1/4" - 12 UNF
SECTION B-B
SECTION A-A
Ø 0.313 ↧ 1.11
3/8-16 UNC ↧ 0.75
1.50 TYP
1.73 TYP
Ø 0.201 ↧ 1.14
1/4-20 UNC ↧ 0.50
Ø0.500
X3 R0.010
HEAVY KNURLING
1/4 - 20 X 0.375 UNC
3/8" - 16 UNC,
0.520" LENGTH
SECTION A-A

5.2.2 Type 3 (d) Small-Scale Burning Test

13.7 Series 3 type (d) test prescription

13.7.1 Test 3 (d): Small-scale burning test

…

13.7.1.1.3 Thick-layer propagation method (for thermites)

A suitable mould for forming a sample bed about 12 cm × 25 cm and 1.3 cm thick. The sample bed is supported by a non-combustible, low heat-conducting surface, such as high-density alumina-silica ceramic fiber board rated for at least 1200 °C about 15 cm × 30 cm and 1.3 cm thick. A suitable means of ignition is used as described in the procedure. Video cameras may be used to record events and for reaction propagation speed determination.

…

13.7.1.2.3 Thick-layer propagation method (for thermites)

The substance, in its commercial form, is formed into a sample bed about 12 cm × 25 cm and 1.3 cm thick on a cool, non-combustible, low heat-conducting surface. For example, powdery or granular substances may be filled into a mould, the board placed on top of the mould, the apparatus inverted and the mould removed. The sample bed is ignited in the middle of one of the short ends using any suitable source of ignition applied at a safe distance, such as a hot wire (preferred), small flame or electrical thermite igniter. The test is performed twice using a clean, cool surface each time, unless an explosion is observed. The reaction propagation speed should be noted as well as whether the thermite reaction creates molten metal deposits.

13.7.1.4 *Examples of results*

Substances	Observations	Result
Liquids		
Nitromethane	Burning	-
Solids, alternative method		
Blasting gelative A (NG 92%, cellulose nitrate 8%)	Burning	-
Black powder Pulverin	Burning	-
Lead azide	Explosion	+
Mercury fulminate	Explosion	+
Solids, thick-layer propagation method		
Aluminum - red iron(III) oxide thermite, 1 - 5 µm powder	Very fast reaction (<1 s)	-
Aluminum - copper(II) oxide thermite, 1 - 5 µm powder	Fast reaction (1 - 2 s)	-
Exploding metal - metal oxide thermite powder	Explosion	+

5.2.3 Section 16, Test Series 6

…

16.3.1 Tests from series 6 should be applied to packages of explosive substances and articles in the condition and form in which they are offered for transport. The geometrical arrangement of the products should be realistic in regard to the packing method and the conditions of transport and should be such as to produce the most severe test results. For rapid-deflagrating substances packed in drums, the most severe type 6(a) test results are achieved utilizing loose sand since the preferred method of confinement (containers, similar in shape and size to the test package, completely filled with earth or sand and placed as closely as possible around the test package) and alternative methods of confinement (boxes or bags filled with earth or sand) have interstitial venting spaces that allow for rapid pressure relief that is not present when confined with loose sand or when the substance is packed in boxes. Where explosive articles are to be classified without packaging, the tests should be applied to the non-packaged articles. All types of packaging containing substances or articles should be subjected to the tests unless:

…

5.2.4 Section 20, Introduction to Part II

20.4.1 General description

20.4.1.1 The principles of classification of self-reactive substances and organic peroxides are given in sub-sections 20.4.2 and 20.4.3 respectively. The general scheme for classification (flow chart) is shown in Figure 20.1. Similarly, the principles of classification of thermites to be excluded from Class 1 are given in sub-section 20.4.5; the general scheme for their classification (flow chart) is shown in Figure 2.4.3 of the Model Regulations. After qualifying for classification in Division 1.4G/S, thermites may be considered for exclusion from Class 1 and regulated as one of four Division 4.1 thermite types provided they 1) do not inherently explode upon unconfined ignition, 2) ignite at temperatures greater than 500 °C, and 3) have low or no explosive power when initiated under confinement (for thermite with oxidizing additives) or during unconfined thermal explosion. Self-reactive substances and organic peroxides are classified into seven types…

20.4.5 *Classification of thermite substances*

Thermite substances are classified in one of the nine thermite types according to the following principles:

(a) Any thermite substance which can detonate, as packaged for transport, will be defined as thermite types 1.1A/1.1G;

(b) Any thermite substance with explosive properties which can deflagrate rapidly or undergo a thermal explosion, will be defined as thermite types 1.3G/1.4G/1.4S;

(c) Any Division 1.4G/S thermite which does not inherently explode upon unconfined ignition, ignites at temperatures greater than 500 °C, has low or no explosive power when initiated under confinement (for thermite with oxidizing additives) or during unconfined thermal explosion, and cannot detonate or deflagrate rapidly as packaged for transport, will be defined as Division 4.1 thermite type C;

(d) Any Division 1.4G/S thermite which does not inherently explode upon unconfined ignition, ignites at temperatures greater than 500 °C, has low or no explosive power when initiated under confinement (for thermite with oxidizing additives) or during unconfined thermal explosion, and in laboratory testing shows no or partial detonation propagation, does not deflagrate rapidly and no violent effect when heated under confinement, will be defined as Division 4.1 thermite type D;

(e) In addition to paragraph (d), any substance which, in laboratory testing, neither detonates nor deflagrates at all and shows no effect when heated under confinement may be considered for transport in packages greater than 400 kg will be (defined as Division 4.1 thermite type F;

(f) In addition to paragraph (d), any substance which, in laboratory testing, neither detonates nor deflagrates at all and shows no effect when heated under confinement nor any explosive power when initiated under confinement (for thermite with oxidizing additives) or during unconfined thermal explosion will be defined as thermite type G and can be considered for regulation as a Division 4.1 Flammable solid.

5.2.5 Type G.1 Thermal Explosion Test in Package

27.4.1 ***Test G.1: Thermal explosion test in package***

…

27.4.1.2.2 Thermites being considered for exclusion from Class 1 are placed in a stainless-steel pan of appropriate size, covered for protection from weather, about 1.8 mm (0.07 in) thick and surrounded with high-temperature insulation to inhibit heat loss. The test quantity is the same as that to be offered for transport with a maximum test quantity of 50 kg (110 lb) per package. High-temperature thermocouples with junctions electrically isolated from the thermite and associated recording equipment are required. Two foil rupture gages, utilized to measure the blast pressures on the Bikini Atolls (i.e., Bikini gages), are used as evidence of a no explosion result; blast gauges and associated recording equipment are required to determine the explosive power.

27.4.1.3 *Procedure*

The test is applied to packed substances in the condition and form in which they are offered for transport; thermites are placed in an insulated, covered pan. The method of obtaining the thermal explosion is by heating the substance as homogeneously as possible with an electric heating coil within the package; for conductive substances, like thermites, it is necessary to electrically isolate the electric heating coil from the substance (e.g., containing the heating element within a thermally-conductive alumina tube). The surface temperature of the heating coil should not be so high that premature ignition of the substance can take place. It may be necessary to use more than one heating coil. For self-reactive materials, the package should be mounted on a stand to keep it upright. For thermites, two Bikini gages and/or two lines of blast gauges each are employed in accordance with the ET Users Group (ETUG) Standard for TNT Equivalency from an Unconfined Explosion on the Surface (ETUG-GS02-23). The heating system is switched on and the temperature of the substance continuously recorded. The heating rate should be about 60 °C/hour. The difference in temperature between the substance at the top and bottom of the package should be as small as possible. It is advisable to make provision in advance for the remote destruction of the package in the event of heater failure. The test is performed in duplicate unless an explosion is observed.

27.4.1.4 *Test criteria and method of assessing results*

27.4.1.4.1 Observations are made on the evidence of an explosion of the package under investigation by fragmentation of the package or blast-pressure measurements. The results obtained are only valid for the package tested; thermites may be excluded from Class 1 in packages no greater than the tested quantity unless 50 kg was tested.

27.4.1.4.2 The test criteria are as follows:

"Yes": A fragmentation of inner and/or outer packaging(s) into more than three pieces (excluding bottom and top parts of the packaging(s)) or, for thermites, measurement of a blast show(s) that the substance under investigation can give an explosion of that package.

"No": For self-reactive materials, no fragmentation or a fragmentation into not more than three pieces shows that the substance under investigation does not explode in the package. For thermites, no rupture of any of the foil Bikini gages at the scaled distance of 1.19 m/kg$^{1/3}$ (3.0 ft/lb$_m^{1/3}$) is evidence of no thermal explosion; substances with greater than 1% TNT equivalence for overpressure at this scaled distance would rupture 38 mm (1.5 in) diameter holes and larger.

27.4.1.5 *Examples of results*

Substance	Packagings	Number of fragments[a]	Result
2,2-Azodi-(isobutyronitrile)	4G, 30 kg	N.F.	No
tert-Butyl peroxybenzoate	1B1, 25 litres	> 30	Yes
tert-Butyl peroxybenzoate	6HG2, 30 litres	N.F.	No
tert-Butyl peroxy-2-ethylhexanoate	1B1, 25 litres	> 5	Yes
tert-Butyl peroxy-2-ethylhexanoate	6HG2, 30 litres	N.F.	No
tert-Butyl peroxy isopropyl carbonate	1B1, 25 litres	> 80	Yes
tert-Butyl peroxy isopropyl carbonate	6HG2, 30 litres	> 20	Yes
tert-Butyl peroxypivalate, 75% in solution	6HG2, 30 litres	N.F.	No
Dibenzoyl peroxide, 75% with water	4G, 25 kg	N.F.	No
2,2-Di-(tert-butylperoxy)butane, 50% in solution	3H1, 25 litres	N.F.	No
2,2-Di-(tert-butylperoxy)butane, 50% in solution	6HG2, 30 litres	N.F.	No

[a] *N.F. means no fragmentation.*

Substance	**Quantity**	**Ignition Temp**	**Smallest Rupture Hole**	**Result**
Aluminum - copper - copper oxides thermite, medium	11.3 kg	TBD*	TBD*	TBD*
Aluminum - iron oxides thermite, coarse	11.3 kg	TBD*	TBD*	TBD*

*Testing in progress; values to be determined and provided to U.S. DOT PHMSA after completion of the tests.

5.2.6 Appendix 6 Screening Procedures

A6.3 Screening procedures for substances which may have explosive properties

…

A6.3.2 Explosive properties are associated with the presence of certain chemical groups in a molecule or combinations of inorganic/organic fuels and inorganic/organic oxidizing agents which can react to produce very rapid increases in temperature or pressure. The screening procedure is aimed at identifying the presence of such reactive groups or mixtures and the potential for rapid energy release. If the screening procedure identifies the material to be a potential explosive, the Class 1 Acceptance Procedure (see 10.3) should be applied.

…

A6.3.3 The acceptance procedure for Class 1 explosives need not be applied:

…

(d) For mixtures of inorganic/organic oxidizing ~~substances~~ agents ~~of Division 5.1~~ with inorganic/organic ~~material~~fuel(s), the concentration of the ~~inorganic~~ oxidizing ~~substance~~ agent(s) is/are:

…

…

5.3 United Nations (UN) Recommendations on the Transport of Dangerous Goods, Model Regulations.

5.3.1 Chapter 2.0, Introduction

…

2.0.3. Precedence of hazard characteristics

2.0.3.1 …

(d) Self-reactive substances, ~~and~~ solid desensitized explosive and thermites of Division 4.1;

2.0.3.3 *Precedence of hazards*

[a] *Substances of Division 4.1 other than self-reactive substances, ~~and~~ solid desensitized explosives and thermites and substances of Class 3 other than liquid desensitized explosives.*

2.0.4.3 *Samples of energetic materials for testing purposes*

2.0.4.3.1 …

(b) For mixtures of inorganic/organic oxidizing ~~substances~~ agents ~~of Division 5.1~~ with inorganic/organic ~~material~~fuel(s), the concentration of the ~~inorganic~~ oxidizing ~~substance~~ agent(s) is/are:

…

5.3.2 Chapter 2.1, Class 1 - Explosives

5.3.3 Chapter 2.4, Class 4 - Flammable Solids; Substances Liable to Spontaneous Combustion; Substances with, in Contact with Water, Emit Flammable Gases

2.4.1 Definitions and general provisions

2.4.1.1 Class 4 is divided into ~~three~~ four divisions as follows:

(a) Division 4.1 - Flammable solids

Solids which, under conditions encountered in transport, are readily combustible or may cause or contribute to fire through friction; self-reactive substances, ~~and~~ polymerizing substances and thermites which are liable to undergo a strongly exothermic reaction; solid desensitized explosives which may explode if not diluted sufficiently;

…

2.4.1.2 As referenced in this Chapter, test methods and criteria, with advice on application of the tests, are given in the *Manual of Tests and Criteria*, for the classification of the following types of substances of Class 4:

…

(f) Self-heating substances (Division 4.2);~~ and~~

(g) Substances which, in contact with water, emit flammable gases (Division 4.3)~~.~~; and

(h) Thermites (Division 4.1).

Test methods and criteria for self-reactive substances, ~~and~~ polymerizing substances and thermites are given in Part II of the *Manual of Tests and Criteria*, and test methods and criteria for the other types of substances of Class 4 are given in the *Maula of Tests and Criteria*, Part III, section 33.

2.4.2 Division 4.1 - Flammable solids, self-reactive substances, thermites and solid desensitized explosives

2.4.2.1 ***General***

Division 4.1 includes the following types of substances:

(a) Flammable solids (see 2.4.2.2);

(b) Self-reactive substances (see 2.4.2.3); ~~and~~

(c) Solid desensitized explosives (see 2.4.2.4); and~~.~~

(d) Thermites (see 2.4.2.5).

…

2.4.2.5 Division 4.1 Thermites

2.4.2.5.1 *Definitions and properties*

2.4.2.5.1.1 Definitions

For the purposes of these Regulations:

Thermites are pyrotechnic substances predominantly comprised of inorganic metals and metal oxides and may include other additives. Thermites undergo a strongly exothermic decomposition even without participation of oxygen (air) upon ignition and can possess elevated auto-ignition temperatures. Thermites are assigned to Class 1 or Division 4.1 on the basis of test data derived from Series 1 - 6 and/or Series A - G. Substances are not considered to be Division 4.1 thermites, if:

(a) They do not meet the definition of a thermite;

(b) They are assigned to Class 1 with no allowances for Class 1 exclusion;

(c) They are explosives according to the criteria of Class 1 that do not meet the thermite Class 1 exclusion criteria; or

(d) They meet the requirements for classification as Thermite type G and are excluded from regulation as a Division 4.1 thermite (considered as a Division 4.1 Flammable solid unless qualifying for further exclusion).

NOTE: *Any substance which shows the properties of a thermite shall be classified as such, even if this substance gives a positive test result according for inclusion in Division 4.2 or 4.3.*

A substance or mixture showing the properties of a thermite type shall be classified as such in Class 1 or Division 4.1.

A substance or mixture showing the properties of a thermite, type G, shall be considered for classification as a Flammable solid of Division 4.1.

2.4.2.5.1.2 Properties

The reaction of thermite substances can be initiated by heat, flame, friction, impact or contact with specific chemicals or catalysts. The rate of reaction can increase with temperature and varies with the substance. Reaction may result in the evolution of toxic gases or vapours. Some thermite substances may react explosively, even when unconfined. Many thermite substances burn vigorously. Thermite substances are, for example, mixtures of inorganic metals (aluminum, boron, magnesium, titanium, zirconium, etc.) and inorganic metal oxides (copper oxides, iron oxides, etc.) and may include other additives.

2.4.2.5.2 *Classification of thermite substances*

2.4.2.5.2.1 Thermite substances are classified into five types within Class 1 or four types in Division 4.1 according to the degree of danger they present. The types of thermite substance range from type 1.1A, which are forbidden for transportation if dry or not desensitized, unless incorporated in a device, to type G in Division 4.1, which is not subject to the provisions for Division 4.1 thermites and may be offered for transport as a Division 4.1 Flammable solid unless qualifying for further exclusion. The classification of each type is directly related to the maximum quantity allowed in one packaging.

2.4.2.5.3 *Principles for classification of thermite substances*

NOTE: *This section refers only to those properties of thermite substances which are decisive for their classification. A flow chart, presenting the classification principles in the form of a graphically arranged scheme of questions concerning the decisive properties together with the possible answers, is given in Figure 2.4.3. These properties shall be determined experimentally using the test methods and criteria given in the Manual of Tests and Criteria, Parts I and II.*

2.4.2.5.3.1 A thermite substance is regarded as possessing explosive properties when in laboratory testing the formulation is liable to detonate, to deflagrate rapidly or to show a violent effect when heated under confinement.

2.4.2.5.3.2 The following principles apply to the classification of thermite substances.

(a) Any substance which can detonate, as packaged for transport, is assigned to the appropriate Class 1 hazard division and compatibility group (defined as thermite types 1.1A/1.1G, exit box A of Figure 2.4.3);

(b) Any substance with explosive properties which can deflagrate rapidly or undergo a thermal explosion, is also assigned to the appropriate Class 1 hazard division and compatibility group in packages of not more than 11.4 kg net mass or that qualified in Series 6 tests (defined as thermite types 1.3G/1.4G/1.4S, exit box B of Figure 2.4.3);

(c) Any Division 1.4G/S thermite which does not inherently explode upon unconfined ignition, ignites at temperatures greater than 500 °C, has low or no explosive power when initiated under confinement (for thermite with oxidizing additives) or during unconfined thermal explosion, and cannot detonate or deflagrate rapidly as packaged for transport, may be excluded from Class 1 in packages of not more than 50 kg net mass (defined as Division 4.1 thermite type C, exit box C of Figure 2.4.3);

(d) Any Division 1.4G/S thermite which does not inherently explode upon unconfined ignition, ignites at temperatures greater than 500 °C, has either low or no explosive power when initiated under confinement (for thermite with oxidizing additives) or during unconfined thermal explosion, and in laboratory testing shows either no or partial detonation propagation, does not deflagrate rapidly and no violent effect when heated under confinement, may be excluded from Class 1 in packages of not more than 50 kg net mass (defined as Division 4.1 thermite type D, exit box D of Figure 2.4.3);

(e) In addition to paragraph (d), any substance which, in laboratory testing, neither detonates nor deflagrates at all and shows no effect when heated under confinement may be considered for transport in packages greater than 400 kg (defined as Division 4.1 thermite type F, exit box F of Figure 2.4.3);

(f) In addition to paragraph (d), any substance which, in laboratory testing, neither detonates nor deflagrates at all and shows no effect when heated under confinement nor any explosive power when initiated under confinement (for thermite with oxidizing additives) or during unconfined thermal explosion may be excluded from classification as a Division 4.1 thermite and be considered for regulation as a Division 4.1 Flammable solid (defined as Division 4.1 thermite type G, exit box G of Figure 2.4.3).

2.4.2.5.3.3 A substance or mixture showing the properties of a thermite, type G, shall be considered for classification as a Flammable solid of Division 4.1 with packing groups based on the reaction propagation rate observed in the Series 3(d) "Small-scale burning test" for thermites.

2.4.2.5.3 *Classification procedures for thermite substances*

2.4.2.5.3.1 Overview

2.4.2.5.3.1.1 Thermite substances are manufactured with the view to producing a pyrotechnic effect. Thermite substances and articles containing thermite require the same level of Competent Authority approval for transport as required for Class 1 explosive and/or Division 4.1 Self-reactive materials.

2.4.2.5.3.1.2 Thermite substances are accepted for transport on the basis of passing Series 3 or 4 tests.

2.4.2.5.3.1.3 Thermite substances are assigned to one of five types of Class 1 explosives based on their response to Series 3 and 6 tests (Division 1.1A/1.1G/1.3G/1.4G/1.4S).

2.4.2.5.3.1.4 Thermite substances that qualify for classification in Division 1.4 may be excluded from Class 1 if meeting specific criteria for ignition temperature, explosive power and shock sensitivity.

2.4.2.5.3.1.5 Thermite substances that are excluded from Class 1 may be assigned to one of four Division 4.1 thermite type (C, D, F and G) based on their response to tests utilized to evaluate the explosive potential of self-reactive materials.

2.4.2.5.3.1.6 Thermite substances that meet the requirements for classification as Thermite type G and are excluded from regulation as a Division 4.1 thermite and are considered for regulation as a Division 4.1 Flammable solid.

2.4.2.5.3.1.7 Thermite substances are evaluated for classification as a Division 4.1 Flammable solid using the reaction propagation rate determined from the thick-layer propagation method of the Series 3(d) “Small-scale burning test”.

2.4.2.5.3.1.8 Thermites can be excluded from regulation as a Division 4.1 Flammable solid if the thermite reaction spreads over the whole length of the sample (100 mm) in greater than ten minutes and the thermite reaction does not create molten metal deposits.

2.4.2.5.3.2 Acceptance procedure for the class of explosives

2.4.2.5.3.2.1 Thermite substances as prepared for transport are submitted to the acceptance procedure for explosives manufactured with the view to producing a practical explosive or pyrotechnic effect, as detailed in Section 10.3 of the Manual of Tests and Criteria (i.e., Series 3 and/or 4 tests). The Series 3(d) “Small-scale burning test” is performed utilizing the thick-layer propagation method; the test may be waived if having no or slow deflagration in a Series 2(c)(i) “Time/pressure test” with an igniter just sufficient to ensure ignition of the substance.

2.4.2.5.3.3 Procedure for assignment to a division of the class of explosives

2.4.2.5.3.3.1 If desired, thermite substances may be accepted into Division 1.1 without further testing.

2.4.2.5.3.3.2 The hazard of a thermite substance as prepared for transport is evaluated through the Series 6 tests, as detailed in Section 10.4 of the Manual of Tests and Criteria, with the provision that mass explosion is evidenced by disruption and scattering of the confining material and measurement of a blast (i.e., a positive pressure pulse before the negative pressure wave); the witness plate may be undamaged and there may not be a crater. If a mass explosion occurs then the product is assigned to Division 1.1, compatibility group A if the substance is very sensitive to heat, impact, or friction, and even in very small quantities, detonates; otherwise, the thermite is assigned to compatibility group G as a pyrotechnic substance. If there is no mass explosion hazard, Division 1.3G/1.4G/1.4S is assigned on the basis of fireball size, burn rate and thermal flux at 15 meters for Division 1.3G/1.4G or 5 meters for Division 1.4G/1.4S as detailed in the Series 6(c) test criteria.

2.4.2.5.3.3.3 The Series 6(a) "Single package test" and/or Series 6(b) "Stack test" may be waived, as detailed in Section 16.2 of the Manual of Tests and Criteria.

2.4.2.5.3.3.4 The Series 6(c) "External fire (bonfire) test" may be waived for thermites not exceeding 11.4 kg (25 lbs) net weight per package, in plastic packagings with a wall thickness no greater than 3.3 mm (0.13 in) and/or fiberboard packagings, on the following basis:

(a) Thermites qualify for Division 1.3G if having no or slow deflagration in a Series 2(c)(i) "Time/pressure test" with an igniter just sufficient to ensure ignition of the substance, or if the Series 6(a) "Single package test" does not result in explosion of the total contents of the package as evidenced by disruption and scattering of the confining material and measurement of a blast.

(b) Thermites qualify for Division 1.4G if having no violent effect on heating under confinement (i.e., limiting diameter less than 2.0 mm) in a Series 2(b) "Koenen test" and qualifying for Division 1.3G.

(c) Thermites qualify for Division 1.4S if having no effect on heating under confinement (i.e., limiting diameter less than 1.0 mm) in a Series 1(b) "Koenen test" and qualifying for Division 1.3G.

NOTE 1: *Many thermites require high temperatures to achieve the onset of thermite reaction; the sample temperatures achieved in the Koenen test over five minutes (600 - 800 °C) are insufficient to start many thermite reactions. Thermites that are fast reacting will be identified either in the Series 2(c)(i) "Time/pressure test" or the Series 6(c) "External fire (bonfire) test"; therefore, passing Koenen test results based on no reaction of the thermite is not of concern.*

NOTE 2: *The normal Koenen test procedure specifies 80-N tamping for solid samples. Explosive substances generally have a higher reactivity when pressed or consolidated; thermites that explode upon ignition when unconsolidated can steadily burn upon ignition when consolidated or pressed (i.e., the unconsolidated/loose form can be more severe for thermites). The Koenen test should be performed on thermite substances in the condition and form in which* *they will be offered for transport. Tamping of unconsolidated thermite powder should only be performed if representing a credible condition and form as offered for transport.*

2.4.2.5.3.4 Procedure for excluding a thermite from Class 1

2.4.2.5.3.4.1 To qualify for exclusion from Class 1, thermites must qualify for classification as Division 1.4G or Division 1.4S as packaged for transport and have:

(a) A "-" result (no explosion) in the Series 3(d) "Small-scale burning test" for thermites;

(b) A "No" detonation result in a Series B.1 "Detonation test in package" or a "Partial" or "No" detonation propagation result in one of the Series A tests;

(c) An ignition temperature greater than 500 °C in the Series G.1 "Thermal explosion test in package" with an average thermal explosive power less than 7% of the TNT reference standard for blast overpressure and scaled impulse in accordance with the ET Users Group (ETUG) Standard for TNT Equivalency from an Unconfined Explosion on the Surface (ETUG-GS02-23); and

(d) A "Low" or "No" confined explosive power result in one of the Series F tests if the thermite contains 15% or more of oxidizing agent(s) that are not metal oxides, including fluoropolymers.

2.4.2.5.3.5 Procedure for assignment to a Division 4.1 thermite type

2.4.2.5.3.5.1 Thermites meeting the thermite Class 1 exclusion criteria qualify for classification as a Division 4.1 thermite type as follows:

(a) Thermite type C, without any further requirements.

(b) Thermite type D, if also having:

(i) Either "Partial" or "No" detonation propagation result in one of the Series A tests;

(ii) Either "No" or "Yes, slowly" deflagration result in a Series C.1 "Time/pressure test" with an igniter just sufficient to ensure ignition and reaction of the substance; and

(iii) No "Violent" effect on heating under confinement (limiting diameter less than 2.0 mm) in a Series E.1 "Koenen test".

(c) Thermite type F, if also having:

(i) "No" detonation propagation result in one of the Series A tests;

(ii) "No" deflagration result in a Series C.1 “Time/pressure test” with an igniter just sufficient to ensure ignition and reaction of the substance; and

(iii) No effect on heating under confinement ("-" result, limiting diameter less than 1.0 mm) in a Series 1(b) “Koenen test”.

NOTE: *The "-" Series 1(b) test result is accepted in lieu of a "No" Series E.1 test result (tube unchanged) since an exothermic thermite reaction can intrinsically damage the steel Koenen tube not by hazardous overpressurization due to restricted venting but by molten metal melting through the tube.*

2.4.2.5.3.6 Procedure for excluding a Division 4.1 Thermite

2.4.2.5.3.6.1 Thermite substances may be excluded from regulation, as a specific Division 4.1 thermite type, when qualifying for classification as Thermite type G:

(a) Meets requirements for classification as Thermite type F;

(b) Has an average thermal explosive power in the Series G.1 “Thermal explosion test in package” that is 1% or less of the TNT reference standard for blast overpressure and scaled impulse; and

(c) Has a "No" confined explosive power result in one of the Series F tests if the thermite contains 15% or more of oxidizing agent(s) that are not metal oxides, including fluoropolymers.

2.4.2.5.3.7 Procedure for assignment as a Division 4.1 Flammable solid

2.4.2.5.3.7.1 Assignment to a Division 4.1 Flammable solid packing group is based upon the results of the thick-layer propagation method of the Series 3(d) “Small-scale burning test” and the Series N.1 “Test method for flammable solids” criteria for metal powders:

(a) Thermite substances are assigned to Packing Group II/Category 1 if the reaction spreads over the whole length of the sample (i.e., the 100 mm timing zone after the initial 80 mm) in five minutes or less.

(b) Thermite substances are assigned to Packing Group III/Category 2 if:

(i) The reaction spreads over the whole length of the sample (100 mm) in more than five minutes but not more than ten minutes;

(ii) The reaction spreads over the whole length of the sample (100 mm) in more than ten minutes but creates molten metal deposits; or

(iii) The reaction does not spread over the whole length of the sample but creates molten metal deposits.

2.4.2.5.3.8 Procedure for excluding a thermite from Division 4.1 Flammable solid

2.4.2.5.3.8.1 Thermite type G substances may be excluded from Division 4.1 Flammable solid if:

(a) The reaction spreads over the whole length of the sample (100 mm) in more than ten minutes without creating molten metal deposits; or

(b) The reaction does not spread over the whole length of the sample (100 mm) and does not create molten metal deposits.

Figure 2.4.3: FLOW CHART SCHEME FOR DIVISION 4.1 THERMITE TYPES

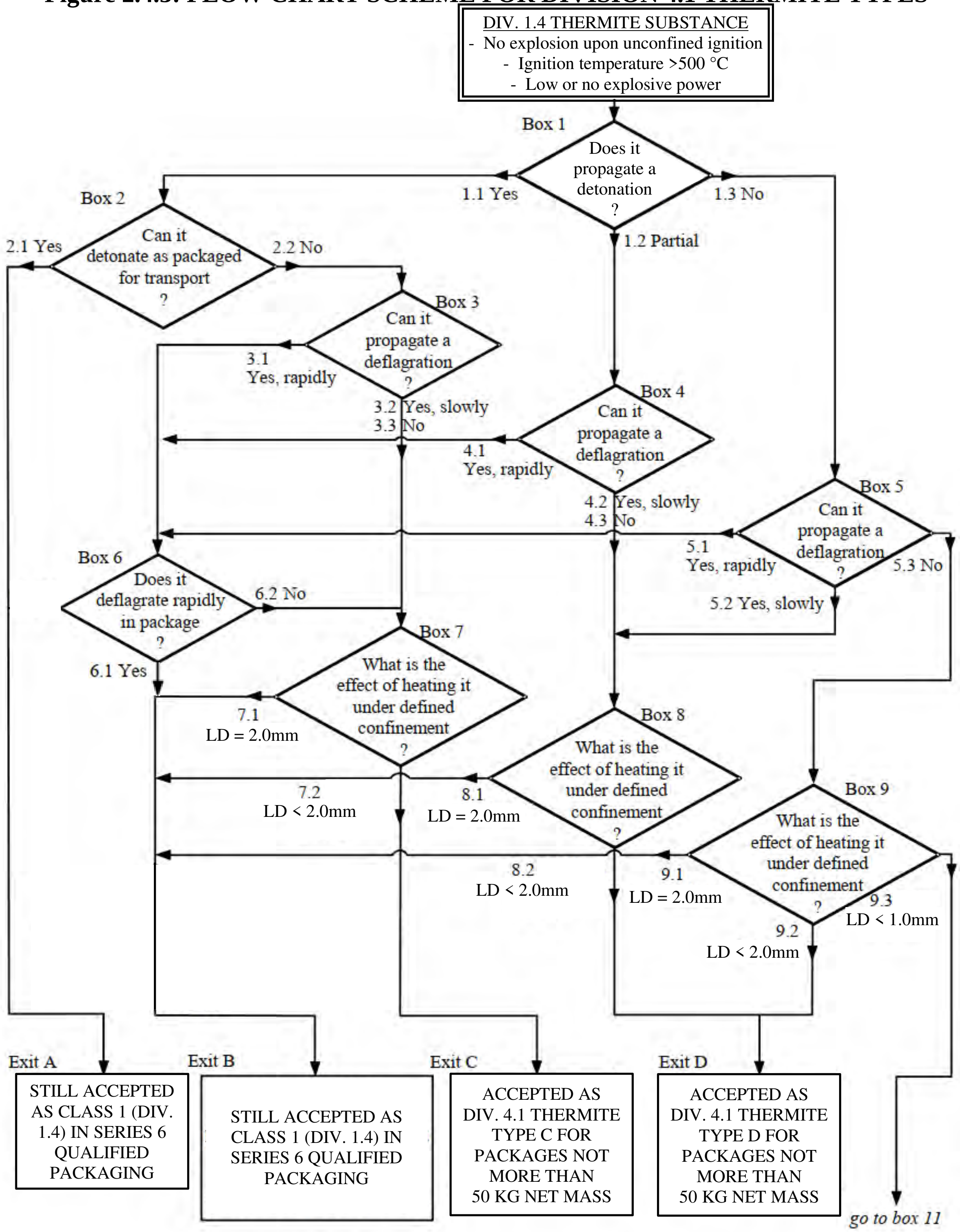
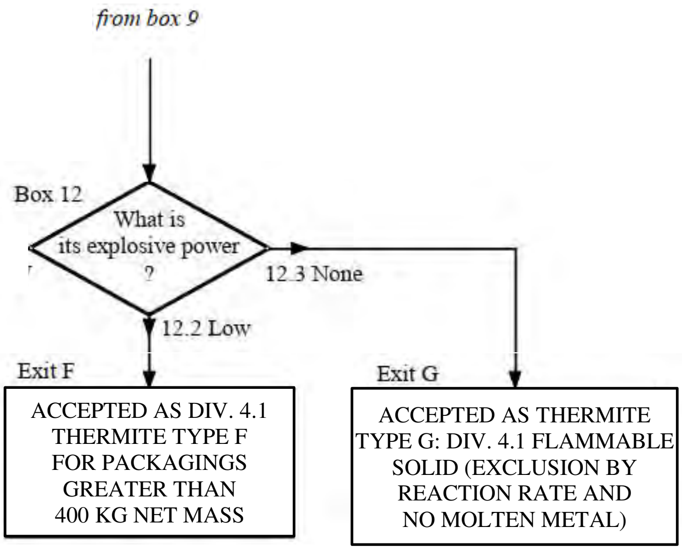


Figure 2.4.3: FLOW CHART SCHEME FOR DIVISION 4.1 THERMITE TYPES (cont'd)



5.3.4 Chapter 3.2, Dangerous Goods List

(1) UN No. [-]; (2) Name and description [3.1.2]; (3) Class or division [2.0]; (4) Subsidiary hazard [2.0]; (5) UN packing group [2.0.1.3]; (6) Special provisions [3.3]; (7a) Limited quantities [3.4]; (7b) Excepted quantities [3.5]; (8) Packing instruction [4.1.4]; (9) Special packing provisions [4.1.4]; (10) Tank/bulk instructions [4.2.5/4.3.2]; (11) Special provisions [4.2.5]

(1)	(2)	(3)	(4)	(5)	(6)	(7a)	(7b)	(8)	(9)	(10)	(11)
xxxx	THERMITE	1.1A			178, 274, 266	0	E0	P110(a), P110(b)	PP42		
xxxx	THERMITE	1.1G			178, 274	0	E0	P114(b)			
xxxx	THERMITE	1.3G			178, 274	0	E0	P114(b)			
xxxx	THERMITE	1.4G			178, 274	0	E0	P114(b)			
xxxx	THERMITE	1.4S			178, 274	0	E0	P114(b)			
xxxx	THERMITE TYPE C	4.1			178, 274	100 g	E0	P520	PP21, PP94, PP95		
xxxx	THERMITE TYPE D	4.1			178, 274	500 g	E0	P520	PP21, PP94, PP95		
xxxx	THERMITE TYPE F	4.1			178, 274	500 g	E0	P520, IBC99		T23	
3178	FLAMMABLE SOLID, INORGANIC, N.O.S.	4.1		II	274	1 kg	E2	P002, IBC08	B2, B4	T3	TP33
3178	FLAMMABLE SOLID, INORGANIC, N.O.S.	4.1		III	223, 274	5 kg	E1	P002, IBC08, LP02	B3	T1	TP33

5.3.5 Appendix B, Glossary of Terms

THERMITE

Pyrotechnic substance which, when ignited, produces a strongly exothermic reaction; it consists of a mixture of inorganic metals and metal oxides and may include other additives.

Energetic Properties of Thermite Formulations

Final Report

DOT Contract # DTPH5616D00001
Task Order 693JK318F000058 (TO# 0002)
SwRI® Project # 24178

Prepared by:

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Jason T. Ford (SMS)
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TABLE OF CONTENTS

TABLES

FIGURES

Photos

1.0 EXECUTIVE SUMMARY

Safety Management Services, Inc. (SMS) performed research on thermite formulations and selected eight thermites for large-scale testing in cooperation with Southwest Research Institute (SwRI) and the U.S. Department of Transportation (DOT) Pipeline and Hazardous Materials Safety Administration (PHMSA). Three of the thermites were available commercially and five were mixed by SMS from raw ingredients that were very fine powders (1 - 5 micron). Each of the thermites was a combination of metal and metal oxide powders; thermite test samples were not selected from nano-thermites (sub-micron particles sizes) nor from thermates (thermites that includes an oxidizer, like sodium nitrate).

Title 49 of the Code of Federal Regulations (CFR), Part 173, Section 124(a)(3)(ii) states that Readily Combustible Solids are materials that show a burning rate faster than 2.2 mm per second (mm/sec) when tested in accordance with the UN Manual of Tests and Criteria. Three of the eight large-scale thermites (Large-scale Mix ID's #1, #4, and #5) burned very rapidly (hundreds of mm/sec), exhibiting hazards more similar to that of explosives classed in Division 1.3G. Two of the five large-scale thermites mixed by SMS (Large-scale Mix ID's #7 and #8) exploded when ignited as unconfined 5-gram quantities, exhibiting hazards similar to that of unconfined flash powders classed in Division 1.1G. The following are additional observations:

- Large-scale Mix ID #7 produced an explosion result in the UN Series 3 (d) Small-scale burning and UN Series 6 (c) External bonfire tests when unconfined but passed the UN Series 2 (b) Koenen test as prescribed with a 5-minute maximum test time; an explosion result was only achieved after the 5-minute test limit at the following timecodes (mm:ss): 05:20, 11:40 and 09:37.
    - Large-scale Mix ID #8 also produced an explosion result in the UN Series 3 (d) Small-scale burning and UN Series 6 (c) External bonfire tests when unconfined; this thermite nearly passed the UN Series 2 (b) Koenen test as prescribed with a 5-minute maximum test time with an explosion result achieved at the following timecodes: 07:10, 9:40 and 01:15.
    - Large-scale Mix ID #6 burns slowly and steadily when unconfined but produced an explosion result in the third and final trial of the UN Series 2 (b) Koenen test at the timecode 04:40 (the prior trials were ended at the prescribed 5-minute test limit).
- Large-scale Mix ID's #7 and #8 each experienced a mass-explosion result in the Unconfined UN Series 6 (a) Single package test but each passed a confined UN Series 2 (c) Internal ignition test.

SMS also mixed an additional fifteen small-scale thermite mixtures for auto-ignition temperature testing on a total of twenty-three thermite mixtures. Only one of these thermite mixtures had an auto-ignition temperature greater than 1200 °C. Six of these additional fifteen small-scale thermite mixtures also exploded when ignited as unconfined 5-gram quantities with the most violent being Small-scale Mix #24. Based on the limited data set, the explosiveness of these thermites appears strongly related to its metal oxide (Bi_2O_3, MnO_2 and SnO_2 have shown a propensity for exploding; CuO and Fe_2O_3 produce low-order explosions) and the particle size of the metal and metal oxide powders. Additional testing is required to further investigate this relationship.

The commercially available thermites (Large-scale Mix ID's #2, #3, and #5) each passed the following standard tests:

- UN Series 3
- UN Series 2
- UN Test N.4 Test method for self-heating substances
- UN Test N.5 Test method for substances which in contact with water emit flammable gases

NOTE: The auto-ignition temperature of traditional explosives is typically around 200 - 300 °C; the average auto-ignition temperature of the twenty-three small-scale thermite test samples was 809 °C with a standard deviation of 240 °C. Therefore, the 5-minute maximum test time of the UN Series 1 or 2 (b) Koenen test may be insufficient to determine whether a specific thermite exhibits a violent effect on heating under confinement.

Large-scale Mix ID's #2 and #3 also passed the standard UN Test N.1 Test method for readily combustible solids with gas torch and hotwire, and could potentially be offered for transport as non-regulated materials in the absence of additional considerations. However, using hotter ignition sources and wider powder train piles than those specified in UN Test N.1, it quickly becomes evident that all three of the tested commercially available thermite mixes exhibit burning rates in excess of the 2.2 mm/sec threshold specified in 49 CFR 173.124(a)(3)(ii).

NOTE: The current UN Test N.1 test methodology could potentially permit these powders to be offered for transport as non-regulated goods since the powder train pile is too narrow to sustain propagation AND/OR if an ignition source is utilized that is around 1000 °C, which could be below the auto-ignition temperature of the thermite, even though in their shipping configuration they would clearly present hazards consistent with that of flammable solids regulated for transport.

The following table contains the proposed classifications based on the test results.

Table 1: Classification Recommendations for Tested Large-Scale Thermites

Item	Sample	Considerations	Proposed Classification
1	Fine Al-Fe_2O_3 Thermite - Mix ID #1 (SMS mixed)	Division 1.3 or 1.4 based on the UN Series 3 (d) Small-scale burning, Unconfined UN Series 6 (a) Single package, Sub-scale UN Series 6 (c) External fire (bonfire), Sub-scale UN Series 7 (e), UN Test N.1 and the Large-scale UN Test N.1 test results; subsidiary hazard as Division 4.3 PG III based on UN Test N.5 test results. Could pose a potential threat to the structural integrity of an aircraft based on the unconfined, suspended UN Series 6 (a) Single package test results.	**Division 1.3 or 1.4 (depending upon the packaging configuration and quantity) with subsidiary Division 4.3 hazard - FORBIDDEN FROM AIRCRAFT**
2	Coarse Al-Fe_2O_3 Thermite A - Mix ID #2 (Commercial)	Division 4.1 based on the Large-scale UN Test N.1 test results using an alternative ignition method. Could pose a potential threat to the structural integrity of an aircraft based on the unconfined, suspended UN Series 6 (a) Single package test results.	**UN3178, Flammable solid, inorganic, n.o.s., 4.1, PG II - FORBIDDEN FROM AIRCRAFT**
3	Coarse Al-Fe_2O_3 Thermite B - Mix ID #3 (Commercial)	Division 4.1 based on the Large-scale UN Test N.1 test results using an alternative ignition method. Could pose a potential threat to the structural integrity of an aircraft based on the unconfined, suspended UN Series 6 (a) Single package test results.	**UN3178, Flammable solid, inorganic, n.o.s., 4.1, PG II - FORBIDDEN FROM AIRCRAFT**
4	Fine Al-CuO Thermite - Mix ID #4 (SMS mixed)	Division 1.3 or 1.4 based on the UN Series 3 (d) Small-scale burning, Unconfined UN Series 6 (a) Single package, Sub-scale UN Series 6 (c) External fire (bonfire) and the Large-scale UN Test N.1 test results. Could pose a potential threat to the structural integrity of an aircraft based on the unconfined, suspended UN Series 6 (a) Single package test results.	**Division 1.3 or 1.4 (depending upon the packaging configuration and quantity) - FORBIDDEN FROM AIRCRAFT**

Item	Sample	Considerations	Proposed Classification
5	Medium Al-CuO Thermite - Mix ID #5 (Commercial)	Division 1.3 or 1.4 based on the Unconfined UN Series 6 (a) Single package, UN Test N.1 and the Large-scale UN Test N.1 test results.	**Division 1.3 or 1.4 (depending upon the packaging configuration and quantity) - FORBIDDEN FROM AIRCRAFT**
6	Fine Al-Ni_2O_3 Thermite - Mix ID #6 (SMS mixed)	Class 1 based on the UN Series 2 (b) Koenen test results, otherwise burning rates consistent with Division 4.1 PG II; subsidiary hazard as Division 4.3 PG III based on UN Test N.5 test results.	**Division 1.3 or 1.4 (depending upon the packaging configuration and quantity) with subsidiary 4.3 hazard OR UN3178, Flammable solid, inorganic, n.o.s., 4.1, (4.3), PG II - FORBIDDEN FROM AIRCRAFT**
7	Fine Al-MnO_2 Thermite - Mix ID #7 (SMS mixed)	Division 1.1G based on UN Series 3 (d) Small-scale burning, Unconfined UN Series 6 (a) Single package, Sub-scale UN Series 6 (c) External fire (bonfire), Sub-scale UN Series 7 (e), UN Test N.1 and the Large-scale UN Test N.1 test results; subsidiary hazard as Division 4.3 PG III based on UN Test N.5 test results.	**UN0476, Substances, explosive, n.o.s., 1.1G, (4.3), PG II**
8	Fine Mg&Al-MoO_3-CuO Thermite - Mix ID #8 (SMS mixed)	Division 1.1G based on UN Series 3 (d) Small-scale burning, Unconfined UN Series 6 (a) Single package, Sub-scale UN Series 6 (c) External fire (bonfire), Sub-scale UN Series 7 (e), UN Test N.1 and the Large-scale UN Test N.1 test results; subsidiary hazard as Division 4.3 PG III based on UN Test N.5 test results.	**UN0476, Substances, explosive, n.o.s., 1.1G, (4.3), PG II**

2.0 OBJECTIVE

The objective of this effort was to 1) identify families of thermite compositions, 2) procure samples of thermite, and 3) conduct testing to determine the hazard presented by thermites in transport. The testing may help form a technical basis for regulation or exemption of certain thermite formulation families.

3.0 SUMMARY AND CONCLUSIONS

The following eight thermites were selected for the large-scale testing:

- Fine Al-Fe_2O_3 Thermite - Mix ID #1 (SMS mixed)
- Coarse Al-Fe_2O_3 Thermite A - Mix ID #2 (Commercial)
- Coarse Al-Fe_2O_3 Thermite B - Mix ID #3 (Commercial)
- Fine Al-CuO Thermite - Mix ID #4 (SMS mixed)
- Medium Al-CuO Thermite - Mix ID #5 (Commercial)
- Fine Al-Ni_2O_3 Thermite - Mix ID #6 (SMS mixed)
- Fine Al-MnO_2 Thermite - Mix ID #7 (SMS mixed)
- Fine Mg&Al-MoO_3-CuO Thermite - Mix ID #8 (SMS mixed)

Testing was conducted by Safety Management Services, Inc. (SMS) at their Tooele, Utah test site. Tests were witnessed by Jason T. Ford, Kirt Sasser, and/or Troy Gardner and performed in accordance with the United Nations (UN) Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria, Sixth revised edition (2015). The test results are summarized in the following tables for each sample.

Table 2: Testing Summary for Fine Al-Fe_2O_3 Thermite - Mix ID #1 (SMS mixed)

Test	Test Name	Conditions and Results	Conclusions
1	UN Series 2 (a) UN Gap	No damage to tubes or witness plates; material in pipe consumed.	Pass
2	UN Series 2 (b) Koenen	Effect Type "O" (tube unchanged) at 2.0 mm; limiting diameter less than 2.0 mm.	Pass
3	UN Series 2 (c) (ii) Internal ignition	For each trial, the thermite ignited and vented out the hole for the ignition wire, enlarging it to approximately 2-cm wide. There was no other damage to the pipe and no damage to either end cap.	Pass (NO transition from deflagration to detonation)
4	UN Series 3 (a) BOE impact sensitivity	No explosion in 6 trials.	Pass (not too dangerous in tested form)

Test	Test Name	Conditions and Results	Conclusions
5	UN Series 3 (b) BAM friction sensitivity	No explosion in 6 trials at a friction load of 80 N (limiting load >80 N).	Pass (not too dangerous in tested form)
6	UN Series 3 (c) Thermal stability	Ignition or explosion did NOT occur, and no evidence of thermal instability (fuming or decomposition); 0.2-grams mass loss.	Pass (not forbidden)
7	UN Series 3 (d) Small-scale burning	The two 100-gram samples ignited and burned for less than 1 second each; explosion of the test samples did NOT occur.	Pass (not too dangerous in tested form)
8	Unconfined UN Series 6 (a) Single package on suspended 2-mm thick 1100-0 aluminum witness plate	Package containing 9.1 kg of thermite ignited and burned; thermite readily melted through a large hole through the aluminum witness plate.	High threat to 2-mm thick 1100-0 aluminum
9	Unconfined UN Series 6 (a) Single package on suspended 3-mm thick mild steel witness plate	Package containing 9.1 kg of thermite ignited and burned in 1 - 2 seconds; no significant damage to the steel witness plate.	Minimal threat to 3-mm thick mild steel
10	Sub-scale UN Series 6 (c) External fire (bonfire)	Package containing 9.1 kg of thermite ignited and rapidly burned over approximately 1 second, producing a fireball with a radius of 3 - 4 meters; no mass explosion.	**Reaction rate and fireball more consistent with the hazards of Division 1.3**
11	Sub-scale UN Series 7 (e) EIS External fire	The three samples ignited, separating end cap from pipe and propelling the pipe beyond 15 meters.	**Elevated reaction hazard consistent with Class 1 when heated under confinement**
12	UN Test N.1 Test method for readily combustible solids (gas torch)	Sample ignited; burning time of powder train pile too fast to be measured (less than 0.1 seconds for the entire 200mm length).	**Rapid burning consistent more with the hazard of Class 1 explosives**

Test	Test Name	Conditions and Results	Conclusions
13	UN Test N.1 Test method for readily combustible solids (hot wire near 1,000 °C)	Sample ignited; burning time of powder train 0.3 seconds for the entire 200mm length.	**Rapid burning consistent more with the hazard of Class 1 explosives**
14	Large-scale UN Test N.1 Test method for readily combustible solids (gas torch, hot wire near 1,000 °C, severe ignition sources)	Flat plate: Sample ignited by gas torch and hot wire with full propagation (250mm) of powder over 0.5 seconds (500 mm/sec). Crucible bowl: Sample ignited by gas torch and pyrogen igniter (remote) with full consumption of powder over 0.5 seconds.	**Rapid burning consistent more with the hazard of Class 1 explosives**
15	UN Test N.4 Test method for self-heating substances	100mm cube at 140°C: Sample did not experience spontaneous ignition and temperature did NOT exceed that of the oven temperature during the 24-hour test.	Pass (NOT Division 4.2)
16	UN Test N.5 Test method for substances which in contact with water emit flammable gases	Maximum gas emission rate of 2.2 L/(kg·hr) without spontaneous ignition.	**FAIL (consistent with Division 4.3 PG III)**

Table 3: Testing Summary for Coarse Al-Fe_2O_3 Thermite - Mix ID #2 (Commercial)

Test	Test Name	Conditions and Results	Conclusions
1	UN Series 2 (a) UN Gap	No damage to tubes or witness plates; material remaining in pipe.	Pass
2	UN Series 2 (b) Koenen	Effect Type "O" (tube unchanged) at 2.0 mm; limiting diameter less than 2.0 mm.	Pass
3	UN Series 2 (c) (ii) Internal ignition	For each trial, the thermite ignited and vented out the hole for the ignition wire, enlarging it to approximately 6-cm wide. There was no other damage to the pipe and no damage to either end cap.	Pass (NO transition from deflagration to detonation)
4	UN Series 3 (a) BOE impact sensitivity	No explosion in 6 trials.	Pass (not too dangerous in tested form)

Test	Test Name	Conditions and Results	Conclusions
5	UN Series 3 (b) BAM friction sensitivity	No explosion in 6 trials at a friction load of 80 N (limiting load >80 N).	Pass (not too dangerous in tested form)
6	UN Series 3 (c) Thermal stability	Ignition or explosion did NOT occur, and no evidence of thermal instability (fuming or decomposition); 0.1-grams mass loss.	Pass (not forbidden)
7	UN Series 3 (d) Small-scale burning	The two 100-gram samples did NOT ignite.	Pass (not too dangerous in tested form)
8	Unconfined UN Series 6 (a) Single package on suspended 2-mm thick 1100-0 aluminum witness plate	Package containing 9.1 kg of thermite ignited and burned; thermite readily melted through the aluminum witness plate.	High threat to 2-mm thick 1100-0 aluminum
9	Unconfined UN Series 6 (a) Single package on suspended 3-mm thick mild steel witness plate	Package containing 9.1 kg of thermite ignited and burned; several holes in the steel witness plate where thermite melted through.	High threat to 3-mm thick mild steel
10	Sub-scale UN Series 6 (c) External fire (bonfire)	Package containing 9.1 kg of thermite ignited and briefly produced local flame enhancement within the flames of the fire.	Sub-scale quantities appear to present minor hazards
11	Sub-scale UN Series 7 (e) EIS External fire	There was no reaction of the three samples.	No reaction when heated under confinement
12	UN Test N.1 Test method for readily combustible solids (gas torch)	Combustion of the sample did not propagate in 5 minutes. *NOTE: Sample could ignite by employing a thermite starting powder or heating element, with only partial propagation down the powder train pile (100 mm) over 50.7 seconds.*	Consistent with exclusion from Division 4.1
13	UN Test N.1 Test method for readily combustible solids (hot wire near 1,000 °C)	Combustion of the sample did not propagate in 5 minutes. NOTE: Sample ignited with heating element but the reaction did not propagate down the powder train pile.	Consistent with exclusion from Division 4.1

Test	Test Name	Conditions and Results	Conclusions
14	Large-scale UN Test N.1 Test method for readily combustible solids (gas torch, hot wire near 1,000 °C, severe ignition sources)	Flat plate & crucible bowl: Combustion of the sample did not propagate in 5 minutes when ignited by hot wire (plate) or gas torch (both). *Alternative ignition method:* Flat plate: Sample ignited by oxy-acetylene torch with full propagation (250mm) of powder over 10 seconds (25.0mm/sec). Crucible bowl: Sample ignited by oxy-acetylene torch with full consumption over 2.7 seconds.	Consistent with exclusion from Division 4.1 for standard ignition; **alternative ignition results in Division 4.1, packing group II**
15	UN Test N.4 Test method for self-heating substances	100mm cube at 140°C: Sample did not experience spontaneous ignition and temperature did NOT exceed that of the oven temperature during the 24-hour test.	Pass (NOT Division 4.2)
16	UN Test N.5 Test method for substances which in contact with water emit flammable gases	No significant gas evolution over 7-hour test period for 25 grams of thermite.	Pass (NOT Division 4.3)

Table 4: Testing Summary for Coarse Al-Fe_2O_3 Thermite - Mix ID #3 (Commercial)

Test	Test Name	Conditions and Results	Conclusions
1	UN Series 2 (a) UN Gap	No damage to tubes or witness plates; material remaining in pipe.	Pass
2	UN Series 2 (b) Koenen	Effect Type "O" (tube unchanged) at 2.0 mm; limiting diameter less than 2.0 mm.	Pass
3	UN Series 2 (c) (ii) Internal ignition	For each trial, the thermite ignited and vented out the hole for the ignition wire, enlarging it to approximately 4-cm wide. There was no other damage to the pipe and no damage to either end cap.	Pass (NO transition from deflagration to detonation)
4	UN Series 3 (a) BOE impact sensitivity	No explosion in 6 trials.	Pass (not too dangerous in tested form)
5	UN Series 3 (b) BAM friction sensitivity	No explosion in 6 trials at a friction load of 80 N (limiting load >80 N).	Pass (not too dangerous in tested form)
6	UN Series 3 (c) Thermal stability	Ignition or explosion did NOT occur, and no evidence of thermal instability (fuming or decomposition); 0.03-grams mass loss.	Pass (not forbidden)
7	UN Series 3 (d) Small-scale burning	The two 100-gram samples did NOT ignite.	Pass (not too dangerous in tested form)
8	Unconfined UN Series 6 (a) Single package on suspended 2-mm thick 1100-0 aluminum witness plate	Package containing 9.1 kg of thermite ignited and burned; several holes in the aluminum witness plate where thermite melted through.	High threat to 2-mm thick 1100-0 aluminum
9	Unconfined UN Series 6 (a) Single package on suspended 3-mm thick mild steel witness plate	Package containing 9.1 kg of thermite ignited and burned; thermite readily melted through the steel witness plate.	High threat to 3-mm thick mild steel
10	Sub-scale UN Series 6 (c) External fire (bonfire)	Package containing 9.1 kg of thermite ignited and briefly produced local flame enhancement within the flames of the fire; package was fully engulfed in the flames of the fire, obscuring the package and reaction.	Sub-scale quantities appear to present minor hazards

Test	Test Name	Conditions and Results	Conclusions
11	Sub-scale UN Series 7 (e) EIS External fire	There was no reaction of the three samples.	No reaction when heated under confinement
12	UN Test N.1 Test method for readily combustible solids (gas torch)	Combustion of the sample did not propagate in 5 minutes. *NOTE: Supplemental magnesium strip was also unable to ignite the sample.*	Consistent with exclusion from Division 4.1
13	UN Test N.1 Test method for readily combustible solids (hot wire near 1,000 °C)	Combustion of the sample did not propagate in 5 minutes.	Consistent with exclusion from Division 4.1
14	Large-scale UN Test N.1 Test method for readily combustible solids (gas torch, hot wire near 1,000 °C, severe ignition sources)	Flat plate & crucible bowl: Combustion of the sample did not propagate in 5 minutes when ignited by hot wire or gas torch. *Alternative ignition method:* Flat plate: Sample ignited by oxy-acetylene torch with partial propagation (170mm) of powder over 75 seconds (2.3 mm/sec). Sample ignited by gas torch (aided by a thermite starting powder) with partial propagation (140mm) of powder over 23 seconds (6.1 mm/sec).	**Burning rate > 2.2 mm/sec (consistent with Division 4.1, packing group II)**
15	UN Test N.4 Test method for self-heating substances	100mm cube at 140°C: Sample did not experience spontaneous ignition and temperature did NOT exceed that of the oven temperature during the 24-hour test.	Pass (NOT Division 4.2)
16	UN Test N.5 Test method for substances which in contact with water emit flammable gases	No significant gas evolution over 7-hour test period for 25 grams of thermite.	Pass (NOT Division 4.3)

Table 5: Testing Summary for Fine Al-CuO Thermite - Mix ID #4 (SMS mixed)

Test	Test Name	Conditions and Results	Conclusions
1	UN Series 2 (a) UN Gap	No damage to tubes or witness plates; material in pipe consumed.	Pass
2	UN Series 2 (b) Koenen	Effect Type "O" (tube unchanged) at 2.0 mm; limiting diameter less than 2.0 mm.	Pass
3	UN Series 2 (c) (ii) Internal ignition	For each trial, the thermite ignited and vented out the hole for the ignition wire, enlarging it to approximately 4-cm wide. There was no other damage to the pipe and no damage to either end cap.	Pass (NO transition from deflagration to detonation)
4	UN Series 3 (a) BOE impact sensitivity	No explosion in 6 trials.	Pass (not too dangerous in tested form)
5	UN Series 3 (b) BAM friction sensitivity	No explosion in 6 trials at a friction load of 80 N (limiting load >80 N).	Pass (not too dangerous in tested form)
6	UN Series 3 (c) Thermal stability	Ignition or explosion did NOT occur, and no evidence of thermal instability (fuming or decomposition); 0.05-grams mass loss.	Pass (not forbidden)
7	UN Series 3 (d) Small-scale burning	The two 100-gram samples ignited and burned for approximately 4 - 7 seconds; explosion of the test samples did NOT occur.	Pass (not too dangerous in tested form)
8	Unconfined UN Series 6 (a) Single package on suspended 2-mm thick 1100-0 aluminum witness plate	Package containing 9.1 kg of thermite ignited and burned; thermite readily melted through the aluminum witness plate.	High threat to 2-mm thick 1100-0 aluminum
9	Unconfined UN Series 6 (a) Single package on suspended 3-mm thick mild steel witness plate	Package containing 9.1 kg of thermite ignited and burned; no significant damage to the steel witness plate but several melt points on underside of the plate.	Moderate threat to 3-mm thick mild steel
10	Sub-scale UN Series 6 (c) External fire (bonfire)	Package containing 9.1 kg of thermite ignited and rapidly burned over approximately 3 seconds, producing a fireball with a radius of 2 meters; no mass explosion.	**Reaction rate and fireball more consistent with the hazards of Division 1.3 or 1.4**

Test	Test Name	Conditions and Results	Conclusions
11	Sub-scale UN Series 7 (e) EIS External fire	Samples ignited; inconclusive whether the reaction resulted in separating end cap from pipe and propelling the pipe beyond 15 meters (Mix ID indiscernible).	Reaction does not appear to be elevated when heated under confinement (inconclusive)
12	UN Test N.1 Test method for readily combustible solids (gas torch)	Sample ignited but the reaction did not propagate down the powder train pile.	Consistent with exclusion from Division 4.1
13	UN Test N.1 Test method for readily combustible solids (hot wire near 1,000 °C)	Sample ignited but the reaction did not propagate down the powder train pile.	Consistent with exclusion from Division 4.1
14	Large-scale UN Test N.1 Test method for readily combustible solids (gas torch, hot wire near 1,000 °C, severe ignition sources)	Flat plate: Sample ignited by torch and hot wire with full propagation (250mm) of powder over 1.3 - 2.1 seconds (119 - 192 mm/sec). Crucible bowl: Sample ignited by torch with full consumption of powder over 7.4 seconds.	**Rapid burning consistent more with the hazard of Class 1 explosives**
15	UN Test N.4 Test method for self-heating substances	100mm cube at 140°C: Sample did not experience spontaneous ignition and temperature did NOT exceed that of the oven temperature during the 24-hour test.	Pass (NOT Division 4.2)
16	UN Test N.5 Test method for substances which in contact with water emit flammable gases	Maximum gas emission rate of 0.5 L/(kg·hr).	Pass (NOT Division 4.3)

Table 6: Testing Summary for Medium Al-CuO Thermite - Mix ID #5 (Commercial)

Test	Test Name	Conditions and Results	Conclusions
1	UN Series 2 (a) UN Gap	No damage to tubes or witness plates; material in pipe consumed.	Pass
2	UN Series 2 (b) Koenen	Effect Type "O" (tube unchanged) at 2.0 mm; limiting diameter less than 2.0 mm.	Pass
3	UN Series 2 (c) (ii) Internal ignition	For each trial, the thermite ignited and vented out the hole for the ignition wire. There was no other damage to the pipe and no damage to either end cap.	Pass (NO transition from deflagration to detonation)
4	UN Series 3 (a) BOE impact sensitivity	No explosion in 6 trials at a drop height of 10 cm.	Pass
5	UN Series 3 (b) BAM friction sensitivity	No explosion in 6 trials.	Pass (not too dangerous in tested form)
6	UN Series 3 (c) Thermal stability	Ignition or explosion did NOT occur, and no evidence of thermal instability (fuming or decomposition); no mass loss.	Pass (not forbidden)
7	UN Series 3 (d) Small-scale burning	The two 100-gram samples did NOT ignite.	Pass (not too dangerous in tested form)
8	Unconfined UN Series 6 (a) Single package on suspended 2-mm thick 1100-0 aluminum witness plate	Package containing 9.1 kg of thermite ignited and burned; several holes in the aluminum witness plate where thermite melted through.	High threat to 2-mm thick 1100-0 aluminum
9	Unconfined UN Series 6 (a) Single package on suspended 3-mm thick mild steel witness plate	Package containing 9.1 kg of thermite ignited and burned; no significant damage to the steel witness plate but one very small hole in plate.	Minimal threat to 3-mm thick mild steel
10	Sub-scale UN Series 6 (c) External fire (bonfire)	Package containing 9.1 kg of thermite ignited and briefly produced local flame enhancement within the flames of the fire.	Sub-scale quantities appear to present minor hazards

Test	Test Name	Conditions and Results	Conclusions
11	Sub-scale UN Series 7 (e) EIS External fire	Samples ignited; inconclusive whether the reaction resulted in separating end cap from pipe and propelling the pipe beyond 15 meters (Mix ID indiscernible).	Reaction does not appear to be elevated when heated under confinement (inconclusive)
12	UN Test N.1 Test method for readily combustible solids (gas torch)	For Trial 1, the sample ignited with a burning time of approximately 2 seconds for the entire length of the powder train pile. For Trial 2, the sample ignited but the reaction did not propagate down the powder train pile.	**Consistent with Division 4.1, packing group II**
13	UN Test N.1 Test method for readily combustible solids (hot wire near 1,000 °C)	Sample ignited but the reaction did not propagate down the powder train pile.	Consistent with exclusion from Division 4.1
14	Large-scale UN Test N.1 Test method for readily combustible solids (gas torch, hot wire near 1,000 °C, severe ignition sources)	Flat plate: Sample ignited by torch and hot wire with full propagation (250mm) of powder over 1.5 - 2.4 seconds (104 - 167mm/sec). Crucible bowl: Sample ignited by torch (aided by a thermite starting powder) with full consumption of powder over 6.4 seconds.	**Rapid burning consistent more with the hazard of Class 1 explosives**
15	UN Test N.4 Test method for self-heating substances	100mm cube at 140°C: Sample did not experience spontaneous ignition and temperature did NOT exceed that of the oven temperature during the 24-hour test.	Pass (NOT Division 4.2)
16	UN Test N.5 Test method for substances which in contact with water emit flammable gases	Maximum gas emission rate of 0.2 L/(kg·hr).	Pass (NOT Division 4.3)

Table 7: Testing Summary for Fine Al-Ni_2O_3 Thermite - Mix ID #6 (SMS mixed)

Test	Test Name	Conditions and Results	Conclusions
1	UN Series 2 (a) UN Gap	No damage to tubes or witness plates; material in pipe consumed.	Pass
2	UN Series 2 (b) Koenen	Effect Type "F" (tube fragmented into three or more mainly large pieces) at 2.0 mm; limiting diameter greater than 2.0 mm.	**FAIL (consistent with Class 1)**
3	UN Series 2 (c) (ii) Internal ignition	For each trial, the thermite ignited and vented out the hole for the ignition wire. There was no other damage to the pipe and no damage to either end cap.	Pass (NO transition from deflagration to detonation)
4	UN Series 3 (a) BOE impact sensitivity	No explosion in 6 trials.	Pass (not too dangerous in tested form)
5	UN Series 3 (b) BAM friction sensitivity	No explosion in 6 trials at a friction load of 80 N (limiting load >80 N).	Pass (not too dangerous in tested form)
6	UN Series 3 (c) Thermal stability	Ignition or explosion did NOT occur, and no evidence of thermal instability (fuming or decomposition); no mass loss.	Pass (not forbidden)
7	UN Series 3 (d) Small-scale burning	The two 100-gram samples did NOT ignite.	Pass (not too dangerous in tested form)
8	Unconfined UN Series 6 (a) Single package on suspended 2-mm thick 1100-0 aluminum witness plate	Package containing 9.1 kg of thermite ignited and burned; thermite readily melted through the aluminum witness plate.	High threat to 2-mm thick 1100-0 aluminum
9	Unconfined UN Series 6 (a) Single package on suspended 3-mm thick mild steel witness plate	Package containing 9.1 kg of thermite ignited and burned; thermite readily melted through the steel witness plate.	High threat to 3-mm thick mild steel
10	Sub-scale UN Series 6 (c) External fire (bonfire)	Package containing 9.1 kg of thermite ignited and burned over approximately 17 seconds, producing local flame enhancement within the flames of the fire.	Reaction rate and fireball more consistent with the hazards of Division 1.4S

Test	Test Name	Conditions and Results	Conclusions
11	Sub-scale UN Series 7 (e) EIS External fire	Samples ignited; inconclusive whether the reaction resulted in separating end cap from pipe and propelling the pipe beyond 15 meters (Mix ID indiscernible).	Reaction does not appear to be elevated when heated under confinement (inconclusive)
12	UN Test N.1 Test method for readily combustible solids (gas torch)	Sample ignited but the reaction did not propagate down the powder train pile.	Consistent with exclusion from Division 4.1
13	UN Test N.1 Test method for readily combustible solids (hot wire near 1,000 °C)	Sample ignited but the reaction did not propagate down the powder train pile.	Consistent with exclusion from Division 4.1
14	Large-scale UN Test N.1 Test method for readily combustible solids (gas torch, hot wire near 1,000 °C, severe ignition sources)	Flat plate: Sample ignited by torch and hot wire with full propagation (250mm) of powder over 36 - 75 seconds (3.3 - 6.9 mm/sec). Crucible bowl: Sample ignited by torch with full consumption of powder over 10.5 seconds.	**Burning rate > 2.2 mm/sec (consistent with Division 4.1, packing group II)**
15	UN Test N.4 Test method for self-heating substances	100mm cube at 140°C: Sample did not experience spontaneous ignition and temperature did NOT exceed that of the oven temperature during the 24-hour test.	Pass (NOT Division 4.2)
16	UN Test N.5 Test method for substances which in contact with water emit flammable gases	Maximum gas emission rate of 1.6 L/(kg·hr) without spontaneous ignition.	**FAIL (consistent with Division 4.3 PG III)**

Table 8: Testing Summary for Fine Al-MnO_2 Thermite - Mix ID #7 (SMS mixed)

Test	Test Name	Conditions and Results	Conclusions
1	UN Series 2 (a) UN Gap	No damage to tubes or witness plates; material in pipe consumed.	Pass
2	UN Series 2 (b) Koenen	Effect Type "O" (tube unchanged) at 2.0 mm during 5-minute test duration; limiting diameter greater than 2.0 mm. Effect Type "F" (tube fragmented into three or more mainly large pieces) at 2.0 mm after 5 minutes; limiting diameter greater than 2.0 mm.	Pass (NO violent effect on heating under confinement) at 5 minutes; **FAIL (consistent with Class 1) after 5 minutes**
3	UN Series 2 (c) (ii) Internal ignition	For each trial, the thermite ignited and vented out the hole for the ignition wire. There was no other damage to the pipe and no damage to either end cap.	Pass (NO transition from deflagration to detonation)
4	UN Series 3 (a) BOE impact sensitivity	No explosion in 6 trials.	Pass (not too dangerous in tested form)
5	UN Series 3 (b) BAM friction sensitivity	No explosion in 6 trials at a friction load of 80 N (limiting load >80 N).	Pass (not too dangerous in tested form)
6	UN Series 3 (c) Thermal stability	Ignition or explosion did NOT occur, and no evidence of thermal instability (fuming or decomposition); no mass loss.	Pass (not forbidden)
7	UN Series 3 (d) Small-scale burning	The two 100-gram samples exploded upon ignition after 1.0 - 1.5 minutes.	**FAIL (12-meter drop test required to determine whether safe for transport; waived based on impact and friction sensitivity test results)**

Test	Test Name	Conditions and Results	Conclusions
8	Unconfined UN Series 6 (a) Single package on suspended 2-mm thick 1100-0 aluminum witness plate	Package containing 9.1 kg of thermite exploded upon ignition of pyrogen match in the center; severe deformation of suspended aluminum witness plate.	**Hazards consistent with Division 1.1**
9	Unconfined UN Series 6 (a) Single package on suspended 3-mm thick mild steel witness plate	Package containing 9.1 kg of thermite exploded upon ignition of pyrogen match in the center slightly bowing the witness plate.	**Hazards consistent with Division 1.1**
10	Sub-scale UN Series 6 (c) External fire (bonfire)	Package containing 9.1 kg of thermite exploded upon ignition with nearly instantaneous consumption of the package contents.	**Hazards consistent with Division 1.1**
11	Sub-scale UN Series 7 (e) EIS External fire	The three samples ignited, separating end cap from pipe and propelling the pipe beyond 15 meters.	**Elevated reaction hazard consistent with Class 1 when heated under confinement**
12	UN Test N.1 Test method for readily combustible solids (gas torch)	Sample ignited; nearly instantaneous consumption of the powder train pile (explosion with less than 0.03 seconds for the entire 200mm length).	**Explosion consistent more with the hazard of Division 1.1 explosives**
13	UN Test N.1 Test method for readily combustible solids (hot wire near 1,000 °C)	Sample ignited; nearly instantaneous consumption of the powder train pile (explosion with less than 0.03 seconds for the entire 200mm length).	**Explosion consistent more with the hazard of Division 1.1 explosives**

Test	Test Name	Conditions and Results	Conclusions
14	Large-scale UN Test N.1 Test method for readily combustible solids (gas torch, hot wire near 1,000 °C, severe ignition sources)	Flat plate: Sample ignited by pyrogen igniter (flame) and hot wire with nearly instantaneous consumption of the powder (explosion with less than 0.03 seconds for the entire quantity): much faster than 8,000 mm/sec. Plate broken into pieces. Crucible bowl: Sample ignited by pyrogen igniter (flame) with nearly instantaneous consumption of the powder (explosion with less than 0.03 seconds for the entire quantity). No visible damage to crucible bowl.	**Explosion consistent more with the hazard of Division 1.1 explosives**
15	UN Test N.4 Test method for self-heating substances	100mm cube at 140°C: Sample did not experience spontaneous ignition and temperature did NOT exceed that of the oven temperature during the 24-hour test.	Pass (NOT Division 4.2)
16	UN Test N.5 Test method for substances which in contact with water emit flammable gases	Maximum gas emission rate of 1.4 L/(kg·hr) without spontaneous ignition.	**FAIL (consistent with Division 4.3 PG III)**

Table 9: Testing Summary for Fine Mg&Al-MoO_3-CuO Thermite - Mix ID #8 (SMS mixed)

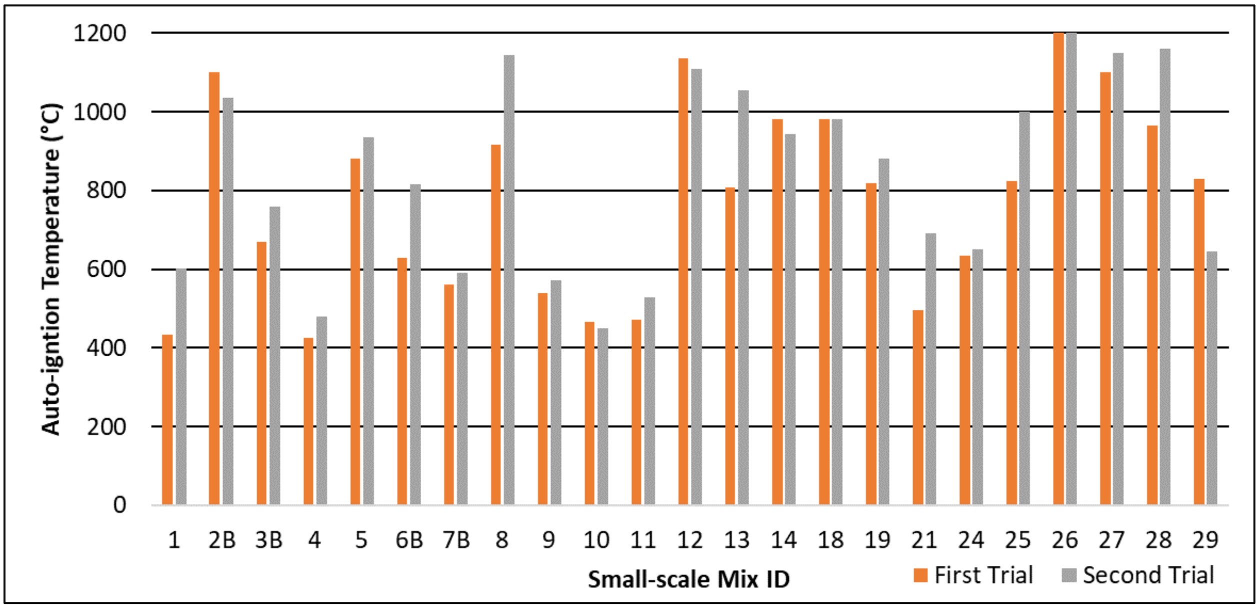
Test	Test Name	Conditions and Results	Conclusions
1	UN Series 2 (a) UN Gap	No damage to tubes and witness plate bent into a “V” shape; material in pipe consumed.	Pass
2	UN Series 2 (b) Koenen	Effect Type "F" (tube fragmented into three or more mainly large pieces) at 2.0 mm; limiting diameter greater than 2.0 mm.	**FAIL (consistent with Class 1)**
3	UN Series 2 (c) (ii) Internal ignition	For each trial, the thermite ignited and vented out the hole for the ignition wire, enlarging it to approximately 4-cm wide. There was no other damage to the pipe and no damage to either end cap.	Pass
4	UN Series 3 (a) BOE impact sensitivity	No explosion in 6 trials.	Pass (not too dangerous in tested form)

Test	Test Name	Conditions and Results	Conclusions
5	UN Series 3 (b) BAM friction sensitivity	No explosion in 6 trials at a friction load of 80 N (limiting load >80 N).	Pass (not too dangerous in tested form)
6	UN Series 3 (c) Thermal stability	Ignition or explosion did NOT occur, and no evidence of thermal instability (fuming or decomposition); no mass loss.	Pass (not forbidden)
7	UN Series 3 (d) Small-scale burning	The two 100-gram samples exploded upon ignition with a loud report.	**FAIL (12-meter drop test required to determine whether safe for transport; waived based on impact and friction sensitivity test results)**
8	Unconfined UN Series 6 (a) Single package on suspended 2-mm thick 1100-0 aluminum witness plate	Package containing 9.1 kg of thermite exploded upon ignition of pyrogen match in the center.	**Hazards consistent with Division 1.1**
9	Unconfined UN Series 6 (a) Single package on suspended 3-mm thick mild steel witness plate	Package containing 9.1 kg of thermite exploded upon ignition of pyrogen match in the center; severe deformation of suspended aluminum witness plate.	**Hazards consistent with Division 1.1**
10	Sub-scale UN Series 6 (c) External fire (bonfire)	Package containing 9.1 kg of thermite exploded upon ignition with nearly instantaneous consumption of the package contents.	**Hazards consistent with Division 1.1**
11	Sub-scale UN Series 7 (e) EIS External fire	The three samples ignited, separating end cap from pipe and propelling the pipe beyond 15 meters.	**Elevated reaction hazard consistent with Class 1 when heated under confinement**

Test	Test Name	Conditions and Results	Conclusions
12	UN Test N.1 Test method for readily combustible solids (gas torch)	Sample ignited; nearly instantaneous consumption of the powder train pile (explosion with less than 0.03 seconds for the entire 200mm length).	**Explosion consistent more with the hazard of Division 1.1 explosives**
13	UN Test N.1 Test method for readily combustible solids (hot wire near 1,000 °C)	Sample ignited; nearly instantaneous consumption of the powder train pile (explosion with less than 0.03 seconds for the entire 200mm length).	**Explosion consistent more with the hazard of Division 1.1 explosives**
14	Large-scale UN Test N.1 Test method for readily combustible solids (gas torch, hot wire near 1,000 °C, severe ignition sources)	<u>Flat plate</u>: Sample ignited by pyrogen igniter (flame) and hot wire with nearly instantaneous consumption of the powder (explosion with less than 0.03 seconds for the entire quantity): much faster than 8,000 mm/sec. Plate broken into pieces. <u>Crucible bowl</u>: Sample ignited by pyrogen igniter (flame) with nearly instantaneous consumption of the powder (explosion with less than 0.03 seconds for the entire quantity). No visible damage to crucible bowl.	**Explosion consistent more with the hazard of Division 1.1 explosives**
15	UN Test N.4 Test method for self-heating substances	<u>100mm cube at 140°C</u>: Sample did not experience spontaneous ignition and temperature did NOT exceed that of the oven temperature during the 24-hour test.	Pass (NOT Division 4.2)
16	UN Test N.5 Test method for substances which in contact with water emit flammable gases	Maximum gas emission rate of 2.2 L/(kg·hr) without spontaneous ignition.	**FAIL (consistent with Division 4.3 PG III)**

The following figure shows a comparison of the auto-ignition temperatures for the various thermite mixtures, organized by Small-scale Mix ID. The average auto-ignition temperature of the twenty-three small-scale thermite test samples was 809 °C with a standard deviation of 240 °C. NOTE: Small-scale Mix ID #26 (Large-scale Mix ID #2) had an auto-ignition temperature greater than 1200 °C.

Figure 1: Comparison of the Auto-ignition Temperatures for the Thermite Mixtures



4.0 BACKGROUND

Historically, industry has offered traditional thermite formulations (containing only metal and metal oxides) for transport in Class 4 as flammable or water-reactive solids. The reaction produces a burst of heat, high temperature, and molten metal for various uses including joining steel railroad ties or copper transmission lines, metal refining, disabling munitions, etc. Traditional thermite formulations pass the UN Manual of Tests and Criteria, Appendix 6 "Screening Procedures" for substances which may have explosive properties as they do not contain any of the chemical groups listed in Table A6.1 that are associated with explosive properties. NOTE: The Appendix 6 Screening Procedures cannot be used for substances manufactured with the view to producing a practical explosive or pyrotechnic effect.

Newer "exotic" thermite formulations include those with additives such as plastics, oxidizers, nano materials, explosives, etc. to confer special compositions or actions upon use. Thermite research is needed to identify families of new and existing thermite compositions and to determine their hazards in transport and to transport vehicles. Forming a technical database can help facilitate PHMSA rulemaking policies and decisions on thermite-based products.

SMS performed research on thermite formulations to arrange the the formulations into the following families:

- Metal & metal oxide formulations: Aluminum powder mixed with another metal oxide, such as iron (II or III), copper (I or II), tin (IV), titanium (IV), manganese (III or IV), chromium (III), cobalt (II), silicon (II), nickel (II), vanadium (V), silver (I), molybdenum (IV). Some firework effects powders appear to contain thermite-like mixtures of copper oxide, magnalium, and titanium. Industrial cutting torches contain powder mixtures of aluminum, magnesium, cupric oxide, and molybdenum oxide. Other thermite-like mixtures include dry ice with a metal powder (such as magnesium, aluminium or boron), and Teflon with magnesium or aluminum (used in flare mixtures). A dry ice mixture is impractical for this effort (not thermally stable).
- Nano-thermite, super-thermite, metastable intermolecular composites (MICs): Generally consist of powders with a particle size less than 100 nm. Particle sizes below three micrometers in diameter have rapidly diminishing returns since irregular distribution of binary constituents limits performance. A highly ordered and optimized microstructure is desired for high energy density and high propagation velocity; procurement of this type of optimized sample may be cost prohibitive, impracticable, and of limited applicability.
- Thermate: Metal & metal oxide thermites enriched with a salt-based oxidizer. For example, thermite with barium nitrate and a binder (Dextrin).
- Exotic thermites: Metal & metal oxide thermites enriched with explosives and binders.

A summary of SMS's research on thermites is contained in the document "Summary of Research on Thermite Compositions for U.S. DOT PHMSA", SMS-5216-M1, Rev 0, Safety Management Services, Inc., 26 Feb 2019.

Thermite subject matter experts provided SMS with the following references that list the calculated energy, gas content, and physical product state for various thermite formulations:

- SAND95-2448C, "A Survey of Combustible Metals, Thermites, and Intermetallics for Pyrotechnic Applications", S. H. Fisher and M. C. Grubelich, Sandia National Laboratories, July 1996, Table 1 - Thermite Reactions.
- SAND98-1176C, "Theoretical Energy Release of Thermites, Intermetallics, and Combustible Metals", S. H. Fisher and M. C. Grubelich, Sandia National Laboratories, July 1998, Table 1b - Thermite Reactions 1c - Thermite Reactions (in Descending Order of Heat of Reaction per Unit Mass)

An extracted table from SAND98-1176C is shown below for the highest energy formulations with the following notes:

1. The list is of simple, two component thermite compositions and does not consider the multi-component thermite compositions.
2. The two most common thermites in industry are iron thermite (Fe_2O_3 + 2 Al) and copper thermite (3 CuO + 2 Al) -- highlighted in yellow in the table below.
    a. Both of these compositions are relatively high in energy (945 - 974 J/gm) and result in liquid-gas products.

   b. The copper thermite has a relatively high gas output (0.54 moles / 100 grams), which may be more prone to fail UN Series 2.
   c. Each reactant is readily available.
   d. As reaction rate will be dependent upon particle size, we may want to consider test samples comprised of large particles (200 microns or similar; slower reaction) and another test sample of the same formulation comprised of small particles (5 microns or similar; faster reaction).
3. Many of the high-energy thermite mixtures contain components that may not be practical to procure or handle for this effort, such as lithium (Li) and Yttrium (Y) metals.
4. The highest energy and highest gas content compositions from metal and metal oxides that should be readily available are highlighted in blue.

Table 1c - Thermite Reactions (in Descending Order of Heat of Reaction per Unit Mass)

reactants		adiabatic reaction temperature (K)		state of products		gas production		heat of reaction	
constituents	ρ_{TMD}, g/cm^3	w/o phase changes	w/ phase changes	state of oxide	state of metal	moles gas per 100 g	g of gas per g	-Q, cal/g	-Q, cal/cm^3
$3Mg + B_2O_3$	1.785	6389	3873	l-g	liquid	0.4981	0.2007	2134	1195
$3Be + B_2O_3$	1.850	3278	2573	liquid	s-l	0.0000	0.0000	1639	3033
$2Be + MnO_2$	3.882	6078	2969	liquid	gas	0.9527	0.5234	1586	6158
$10Al + 3I_2O_5$	4.119	8680	>3253	gas	gas	0.6293	1.0000	1486	6122
$4Li + MnO_2$	1.656	3336	2334	liquid	l-g	0.4098	0.2251	1399	2317
$6Li + MoO_3$	1.688	4035	2873	l-g	solid	0.2155	0.0644	1342	2265
$2Mg + MnO_2$	2.996	5209	3271	liquid	gas	0.7378	0.4053	1322	3961
$6Li + B_2O_3$	0.891	2254	1843	s-l	solid	0.0000	0.0000	1293	1152
$2Al + Ni_2O_3$	4.045	5031	3187	liquid	l-g	0.4650	0.2729	1292	5229
$3Be + Fe_2O_3$	4.163	4244	3135	liquid	l-g	0.1029	0.0568	1281	5332
$Be + CuO$	5.119	3761	2820	s-l	liquid	0.0000	0.0000	1221	6249
$4Be + Fe_3O_4$	4.180	4482	3135	liquid	l-g	0.0336	0.0188	1175	4910
$4Al + 3MnO_2$	4.014	4829	2918	liquid	gas	0.8136	0.4470	1159	4651
$10Y + 3I_2O_5$	4.638	12416	>4573	gas	gas	0.4231	1.0000	1144	5308
$6Li + Fe_2O_3$	1.863	3193	2510	liquid	liquid	0.0000	0.0000	1143	2130
$2Li + CuO$	2.432	4152	2843	liquid	l-g	0.2248	0.1428	1125	2736
$2Al + MoO_3$	3.808	5574	3253	l-g	liquid	0.2425	0.2473	1124	4279
$2Y + Ni_2O_3$	4.636	7614	3955	liquid	gas	0.5827	0.3420	1120	5194
$3Mg + Fe_2O_3$	3.224	4703	3135	liquid	l-g	0.2021	0.1129	1110	3579
$Mg + CuO$	3.934	6502	2843	solid	l-g	0.8186	0.5201	1102	4336
$10Al + 3V_2O_5$	3.107	3953	3273	l-g	liquid	0.0699	0.0356	1092	3394
$8Li + Fe_3O_4$	0.517	3076	2412	liquid	liquid	0.0000	0.0000	1053	2036
$4Mg + Fe_3O_4$	3.274	4446	3135	liquid	l-g	0.1369	0.0764	1033	3383
$4Y + 3MnO_2$	4.690	7405	<5731	gas	gas	0.8110	1.0000	1022	4792
$8Al + 3Co_3O_4$	4.716	3938	3201	liquid	l-g	0.2196	0.1294	1012	4772
$2Y + MoO_3$	4.567	8778	>4572	gas	liquid	0.6215	1.0000	1005	4589
$2Al + 3CuO$	5.109	5718	2843	liquid	l-g	0.5400	0.3431	974.1	4976
$10Y + 3V_2O_5$	3.970	7243	>3652	l-g	gas	0.2130	0.4181	972.5	3861
$2Al + Fe_2O_3$	4.175	4382	3135	liquid	l-g	0.1404	0.0784	945.4	3947
$2Be + SiO_2$	2.410	2580	2482	solid	liquid	0.0000	0.0000	936.0	2256
$2Y + 3CuO$	5.404	7668	3124	liquid	l-g	0.7204	0.4577	926.7	5008
$3Be + Cr_2O_3$	4.089	3107	2820	s-l	liquid	0.0000	0.0000	915.0	3741
$2Al + 3AgO$	6.085	7503	3253	l-g	gas	0.7519	0.8083	896.7	5457
$8Al + 3Fe_3O_4$	4.264	4057	3135	liquid	l-g	0.0549	0.0307	878.8	3747
$2Be + PbO_2$	7.296	8622	4123	l-g	gas	0.4665	0.8250	875.5	6387
$8Y + 3Fe_3O_4$	4.803	5791	3135	liquid	l-g	0.3812	0.2129	856.3	4113
$10La + 3I_2O_5$	5.501	9107	>4472	gas	gas	0.3347	1.0000	849.2	4672
$10Nd + 3I_2O_5$	5.896	10067	<7580	gas	gas	0.3273	1.0000	840.6	4956
$6Li + WO_3$	2.478	3700	2873	l-g	solid	0.0113	0.0034	825.4	2046
$2Al + 3CoO$	5.077	3392	3201	liquid	l-g	0.0430	0.0254	824.7	4187
$2Al + 3NiO$	5.214	3968	3187	liquid	l-g	0.0108	0.0063	822.3	4288

Further, in order to enable assessment of multi-component thermite compositions, thermochemical calculations were performed using FactSage 7.2. The following is a summary of that effort.

4.1 Thermochemical Code calculations to Predict output of thermite compositions

4.1.1 *Abstract*

A need is identified to evaluate a variety of materials for exothermic properties. Testing all materials is cost-prohibitive, so a technical rationale is needed that reduces the number of systems tested. Additionally, high confidence is desired that the full range of energetic performance such as high temperature, thermal energy release, and pressurization rate are sufficiently evaluated, though very few may be considered for testing.

One approach used successfully in prior energetic study efforts[1] used computer simulation to reduce the number of empirical tests. This work follows similar logic, and simulates many systems of interest via computer to guide decisions. In this work, thermochemical calculations using FACTSAGE 7.2 was performed for a few selected thermite systems of interest. Results were compared to reference literature, and upon reasonable agreement, additional chemical composition simulation runs were made that do not appear in literature. The latter is applicable to real world thermite products, which typically use a base simple chemistry modified with additives. This technique using computer simulation allows for efficient screening of both simple and complex thermite systems for consideration in further testing or engineering evaluations.

4.1.2 *Approach*

Two well published systems having aluminum as the metal fuel, one with iron oxide and the other copper oxide were selected for simulation and comparison with open literature. Upon similar results from FACTSAGE version 7.2 software and work by Fischer and Grubelich[2], other systems will be simulated and outputs reported. Common simulation initial material conditions of temperature = 298.15 K and pressure = 1 atm shall be used.

4.1.3 *Results*

For iron oxide and aluminum, the reaction is:

$$3\ Fe_3O_4 + 8\ Al \rightarrow 9\ Fe + 4\ Al_2O_3$$

FACTSAGE predicts an adiabatic reaction temperature of 3129K, which is quite similar with Fischer and Grubelich value of adiabatic reaction temperature of 3135 K.

For the copper oxide and aluminum, the reaction is:

$$3\ CuO + 2\ Al \rightarrow 3\ Cu + Al_2O_3$$

[1] Csernica, Mansfield, Boman Studies on Composition and Manufacturing Process for 5.56mm Tracer Ammunition NDIA Presentation, May 2017.

[2] S.H. Fischer and M.C. Grubelich, Theoretical Energy Release of Thermites, Intermetallics, and Combustible Metals, presented at International Pyrotechnics Seminar, 1998.

FACTSAGE predicts an adiabatic reaction temperature = 2840 K, which is quite similar with Fischer and Grubelich value of adiabatic reaction temperature of 2843 K. With these two common systems verified in simulation, a more complex system not reported in Fischer and Grubelich was selected for evaluation. A thermate mix, known as 'TH3', found in products such as the legacy AN-M14 grenade was selected due to its historical significance and longevity in production articles. US Patent 5,698,812 references[3] a formula for TH3 as 68.7% thermite (Fe_2O_3 + 2 Al), 29.0% barium nitrate, 2% sulfur, and 0.3% binder. Notably, this patent discloses an improved formula using 66.69% potassium nitrate, 14.96% titanium, 7.78% silicon, 8.67% aluminum, and 1.99% nitrocellulose binder. Table 1 below shows a comparison of temperature, energy, and gas evolved from ideal thermodynamic calculations. The patent notes the reaction temperature is increased due to the addition of oxidizer by promoting increased mass transport and has lower ignition temperature than standard binary thermite. It is interesting that the mixture is an intermetallic base, which as a family have lower energy output on average than the same family with an oxide present.

One shortcoming in the FACTSAGE chemical library available are very few polymers and binders. For sake of ease in simulation, the highest molecular weight hydrocarbon available, naphthalene, was used in place of polymeric binders. The quality of this simplifying assumption was checked with additional runs made for comparison with and without naphthalene faux ingredient. When the binder was omitted, simulation predicts the temperature and energy output were similar, however gas generation per mass reactants varied. Therefore, care should be taken if gas output is an important parameter of study when using polymer/binders in simulation for which accurate thermodynamic input properties are unknown or assumed. Results of these runs and all others performed in this work are shown in Table 2.

[3] Song, Thermite Destructive Device US Patent 5,698,812, issued Dec 16, 1997.

Table 10: Two thermate compositions and a thermite compared by computer simulation and literature

System Description	Units	Thermite	Composition TH3	Alternative Composition
Literature citation		Fischer and Grubelich	US 5,698,812	US 5,698,812
	Units			
Composition	wt%		29.0% $Ba(NO_3)_2$	66.7% KNO_3
	wt%	23.7% Al	45.8% Al	14.96% Ti
	wt%	76.3% Fe_3O_4	22.9% Fe_3O_4	8.67% Al
	wt%		2.0% S	7.78% Si
	wt %		0.3% Binder*	1.99% nitrocellulose**
Adiabatic Rxn Temp	K	3135	3273	2755
Gas Evolved	mol/100g	.0549	-	-
Heat of Reaction	Cal/g	878	795	-
Heat of Reaction	J/g	3674	3326	-
FACTSAGE predictions:				
Adiabatic Rxn Temp	K	3129	2510	3024
Mass, Total	Gram	91.045	55.934	62.463
Solids Mass	Gram	90.341	41.674	30.151
Gas Mass	Gram	0.704	14.260	32.312
Energy per Mass (J/g)	J/gram	-3682	-2613	-3302
Gas Evolved	mol/100g	0.0139	0.439	1.423

*assumed binder is PBAN, simulated as naphthalene

** simulated as naphthalene

Having completed analysis in a military composition, another initial candidate was selected from a commercial application having an inter-metallic reactive system, to compare with Fischer and Grubelich. Indium Corporation discloses a basic formula in the Safety Data Sheet (SDS) for a commercial product called Nanofoil™. The basic thermite family is a metal-metal, primarily Ni-Al system with vanadium and indium in lesser amounts. The SDS was unclear as to the levels of minor additives, so for the sake of simplicity, an ideal mixture of nickel and aluminum was modeled:

$$2\ Ni + 3\ Al \rightarrow Ni_2Al_3$$

Using FACTSAGE, the adiabatic reaction temperature was calculated at 2265 K. Energy output per mass was -141,210 J / 99.166 grams = -1424 J/g = -340 cal/g. The Fischer and Grubelich work cited two other molar ratios:

$$2\ Ni + 6\ Al \rightarrow Ni_2Al_3 + 3\ Al$$

$$Ni + Al \rightarrow NiAl\ (l)$$

Using FACTSAGE, the adiabatic reaction temperature for the 1:3 molar ratio scenario was calculated at 1412 K and -138 cal/g, as compared with the Fischer and Grubelich values of 1524 K and -180 cal/g. Similarly, for the 1:1 molar ratio, FACTSAGE calculated adiabatic reaction temperature is 1912 K and -140 cal/g, as compared with the Fischer and Grubelich values of >1910 K and -330 cal/g. There is a much more notable difference between the literature and FACTSAGE calculations in this specific system; additional work is needed to resolve or explain differences in these estimates.

Another system of interest, less common usage, is that of iodine pentoxide and aluminum. Literature search revealed that Dr. Michelle Pantoya has authored/co-authored numerous journal articles involving thermites, including several on the iodine pentoxide-aluminum system. One co-authored work with Oliver Mulamba[4] involved surface chemistry reaction kinetics work on diiodine pentoxide and aluminum. In this work, Mulamba and Pantoya describe the chemical system as potentially attractive due to its high exothermic energy and the reaction products form I_2, which has biocidal effects. Mulamba and Pantoya notes that the pentoxide dissociates in air in the presence of humidity, forming iodic acid, HIO_3, which is reversibly treated with heat to the pentoxide form at around 470 K.

Though desirable to simulate, the standard ingredient library in FACTSAGE does not include iodine pentoxide. This is identified as an area of potential future investigation to either locate literature values or make estimates of the property inputs required by the software. In lieu of simulation, a short review using the Mulamba and Pantoya work is provided below as it relates to the system energy and kinetic rates.

Upon close inspection of the calorimetry in Mulamba and Pantoya's article, an interpretation is proposed here that the reaction rate is slower than typical Class 1 materials given a thermal stimulus. In the Mulamba and Pantoya article, Figure 2 for the pentoxide with aluminum reaction given a heating rate of 25°C per minute by differential scanning calorimetry (DSC), the onset temperature was reported near 300°C (573 K) with peak exotherms at over 400°C (673 K) or about 100 K difference (equating to 4 minutes of heating). As compared with 1, 3, 5- trinitro-1, 3, 5-triazinane (RDX)[5], the difference between onset temperature and peak exotherm is much less at 14 K (less than 45 seconds duration of heating). In this RDX versus iodine pentoxide system example, the temporal ratio is about 5X slower to reach peak exotherm. Therefore, it is conceivable that the reaction rate of iodine pentoxide with aluminum is much slower than typical Class 1 material detonations more broadly. In explosive applications where fast velocity profile is desirable, pentoxide materials may be less versatile, as the reactions cited

[4] Oliver Mulamba, Dr. Michelle Pantoya, Exothermic surface reactions in alumina-aluminum shell-core nanoparticles with iodine oxide decomposition fragments Journal of Nanoparticle Research, 2014.
[5] US Patent 6,406,918 B1 June 18, 2002, Figure 13 shows onset temperature at approximately 225°C and exothermic maximum at 239°C at a heating rate of 20°C per minute.

going through a number of oxidation states may be more susceptible to mass-transport limits and therefore be somewhat slower, even though the iodine is a reactive species. Correlation between pressure wave velocity (and detonation) with DSC may be a safer and simpler way to test more materials with lesser quantities of materials. Iodine pentoxide decomposition and kinetics, through modeling and/or empirical testing is an area recommended for consideration in future studies.

In order to help summarize all runs performed in this work, a summary table of the key outputs from the FACTSAGE simulations is shown below as Table 3. Not discussed previously was a variant of the TH3 replacement formula labeled 'XM89 Grenade' in the table below, which adds a new element, carbon into the composition, which has five different metals (complex intermetallic thermite) and one strong oxidizer, making a heavily nitrated thermate. This composition has the highest gas generation rate of any simulated, which at face value may be a reason why XM89 grenade improvements were pursued.

Table 11: Summary of all FACTSAGE Simulations performed in this work

Name:	Fe Std	Cu Std	TH3	TH3 no bind	TH3 Alt	TH3 Alt no bind	XM89 grenade	2 Ni 3 Al	1 Ni 3 Al	1 Ni 1 Al
Input Composition:										
(wt%)										
Al	23.7	18.4	45.8	45.9	8.67	8.84	8.2	40.8	58.0	31.5
Ti					15.0	15.2	11.2			
Si					7.78	7.93	6.1			
Ni								59.2	42.0	68.5
C							5.1			
S			2.0	2.0			2.0			
Fe_3O_4	76.3	81.6	22.9	23.0						
CuO										
$Ba(NO_3)_2$			29.0	29.1						
KNO_3					66.7	68.0	67.4			
C10H8 (Napth)					1.99					
Outputs:										
Adiabatic T (K)	3129	2840	2510	2518	3024	3026	2901	2265	1412	1912
Mass, Total (g)	91.0	292.6	55.9	99.7	62.5	100.0	100	198.3	139.6	85.7
Solids Mass (g)	90.3	193.4	41.7	61.5	30.2	48.8	39.5	198.3	139.4	85.7
Gas Mass (g)	0.704	99.2	14.3	38.2	32.3	51.2	61.5	0	0	0
Energy (J/g)	-3682	-1600	-2613	-2213	-3302	-3313	-3281	-1424	-577	-586
Gas (mol/100g)	0.0139	.520	0.439	.633	1.42	1.41	1.65	0	0	0

4.1.4 *Conclusions*

This work provides some example thermite reaction systems evaluated by computer simulation. For the iron oxide and copper oxide systems with aluminum, using the computer code FACTSAGE agrees very well with literature values. Therefore, the techniques were used to evaluate two thermite systems with additives, one a common thermite and an alternative formula with entirely different family chemistry (Ti-Al-Si-KNO_3). Both of these formula simulations predict noteworthy performance aspects. In the case of both formulas, there is a much higher gas evolution mass than the standard thermite base, due to the addition of oxygen and nitrogen in the system via oxidizer. Also noteworthy is that the alternative formula based on Ti-Al-Si intermetallic predicts approximately a 500 K increase in temperature as compared with TH3 formula. It also has a much greater gas evolution potential than either the thermite base or the legacy TH3 formula.

A relevant intermetallic thermite system with commercial product examples was selected for simulation and comparison with literature, having Ni-Al composition. Preliminary efforts revealed some differences that could not be explained within the scope of the current effort. Additional work would be needed to resolve or explain differences in these estimates through a more thorough review of the literature and underlying assumptions inherent to the computing routines.

4.2 Test Sample and Test Selection - Large-Scale Thermite Mixes

Based on the research, the following were the proposed test samples for PHMSA's consideration and approval.

Table 12: Potential Thermite Test Samples

ID	Sample Description	Packaging Configuration	Potential Suppliers & Notes
1	Iron thermite, fine particles (~5 micron). Stoichiometric composition by mass: Fe_2O_3 powder (74.7%) Al powder (25.3%)	Custom (no less than 25-lb bags)	SMS (PROS: standard formulation; fine control on thermite composition; flexible packaging. CONS: Not purchased from general thermite industry)
2	Commercial iron thermite A	25-lb bag	CONS: Broad thermite composition as listed in SDS; potentially consider simple/complex analytical tests to determine particle size and composition to greater resolution like pass a sample through different sieve sizes, use magnet to separate ferrous materials, etc.)

ID	Sample Description	Packaging Configuration	Potential Suppliers & Notes
3	Commercial iron thermite B	25-lb bag	CONS: Broad thermite composition as listed in SDS; potentially consider simple/complex analytical tests to determine particle size and composition to greater resolution like pass a sample through different sieve sizes, use magnet to separate ferrous materials, etc.)
4	Copper thermite, fine particles (~5 micron). Stoichiometric composition by mass: CuO powder (81.6%) Al powder (18.4%)	Custom (no less than 25-lb bags)	SMS (PROS: standard formulation; fine control on thermite composition; flexible packaging. CONS: Not purchased from general thermite industry)
5	Commercial copper thermites	25 lbs	CONS: Broad thermite composition as listed in SDS; potentially consider simple/complex analytical tests to determine particle size and composition to greater resolution like pass a sample through different sieve sizes, use magnet to separate ferrous materials, etc.)
6	Al & Ni_2O_3 thermite. Stoichiometric composition by mass: Ni_2O_3 powder (75.4%) Al powder (24.6%)	Custom (no less than 25-lb bags)	SMS (PROS: Very high heat output; fine control on thermite composition; flexible packaging. CONS: Not purchased from general thermite industry)
7	Al & MnO_2 thermite. Stoichiometric composition by mass: MnO_2 powder (70.7%) Al powder (29.3%)	Custom (no less than 25-lb bags)	SMS (PROS: high heat and gas output; fine control on thermite composition; flexible packaging. CONS: Not purchased from general thermite industry)

ID	Sample Description	Packaging Configuration	Potential Suppliers & Notes
8	Thermite similar to NSWC Crane-patented Pyrotechnic Thermite (U.S. Patent 7,632,365; 7,988,802; 7,998,291). Composition by mass (30-micron preferred): Magnalium 50:50 Mg:Al powder (24.2%) CuO powder (39.8%) MoO3 powder (33%) Binder powder (3%) Availability TBD (will coordinate with patent holder)	Custom (no less than 25-lb bags)	SMS (PROS: high heat and gas output; fine control on thermite composition; flexible packaging. CONS: Not purchased from general thermite industry)

The photo below shows examples of thermites with fine particles (left) and fine particles (right).

Photo 1: Examples of Thermite Fine Powder (left) and Coarse Powder (right)

One of the families of thermites is Magnesium/Teflon/Viton thermite mixtures. These have common application in aircraft flares (pyrotechnic effect) and are generally included in Class 1 by definition; therefore, one of these formulations is not currently included in the proposed test matrix (this can be included if desired by PHMSA).

One of the thermite Subject Matter Experts informed us of the following:

1. From SMS's potential thermite report in March, they have never seen Mg & MnO_2 thermite or Al & MnO_2 thermite; they have personally used Al & NiO3 and Mg & CuO

thermites in their research at the university. Based on this feedback, SMS eliminated the first two samples and kept the latter two.
2. Bismuth oxide and molybdenum oxide are common metal oxides in thermites and nanothermites. Nano-magnesium is not readily available; some formulations use nano-boron. SMS will rely on the experience of the subject matter expert for selecting a candidate nanothermite for testing.

Based on SMS's inquiries to thermite manufacturers, packaging of thermite varies but appears to contain between 1 - 25 lbs of thermite.

The following were the list of proposed tests for classification of thermites:
1. UN Series 3 (a) Impact sensitivity
2. UN Series 3 (b) Friction sensitivity
3. UN Series 3 (c) Thermal stability
4. UN Series 3 (d) Small-scale burning
5. Differential Scanning Calorimeter (DSC) for heat capacity with maximum furnace temperature of 700
6. UN Series 2 (a) UN Gap Test
7. UN Series 2 (b) Koenen Test
8. UN Series 2 (c) (ii) Internal Ignition Test
9. UN Series 6 (d) Unconfined package on suspended witness plate (steel) to represent a threat to the structural integrity of aircraft
10. UN Series 6 (d) Unconfined package on suspended witness plate (aluminum) to represent a threat to the structural integrity of normal ground transport vehicles
11. UN Series 6 (c) External fire (bonfire) test
12. Consider an extreme confinement and heating test (no venting) to quantify maximum violence of reaction: One UN Series 6 (c) External fire (bonfire) using liquid fuel (800 °C) with each thermit sample confined in UN Series 7 (f) capped steel pipes, three pipes of each sample on the bonfire. Pipes could explode, spraying molten metal; melt, releasing molten metal into the liquid fuel (in which case SMS would add a layer of water below the liquid fuel to cool any molten metal; or fully contain the reaction.
13. UN Test N.4 Test method for self-heating substances
14. UN Test N.5 Test method for substances which in contact with water emit flammable gases
15. UN Test N.1 Test method for readily combustible solids using gas burner: Preliminary screening test and Burning rate test*
16. UN Test N.1 Test method for readily combustible solids using hot wire near 1,000 °C, Preliminary screening test and Burning rate test*
17. Large-scale UN Test N.1 Test method for readily combustible solids, three trials with gas burner and three trials with hot wire near 1,000 °C.

*This preliminary screening test requires a hot flame (minimum temperature 1,000 °C) from a gas burner (minimum diameter 5 mm) to be applied to one end of the powder train; the Burning rate test uses any suitable ignition source such as a small flame or a hot wire of minimum temperature 1,000 °C to ignite the pile at one end. Some Competent Authorities and manufacturers have claimed that thermite is not regulated as a flammable solid since if it does not ignite at 1,000 °C for five minutes. SMS has used a MAP-Pro (99.5 - 100% propylene, 0 - 0.5% propane) torch with a flame temperature of 3,600 °F (1980 °C) to ignite thermite samples for UN Test N.1. It was proposed that perhaps a test should be performed using a flame near 1,000 °C and another test with a hotter flame (like that from MAP-Pro gas).

Additionally, some thermites may be capable of passing the preliminary screening test since they can experience sporadic / intermittent reactions (not a continuous burn). For example, consider the photos from the following case. The burn time for each trial was around 1 - 3 seconds (very rapid burn). Only one trial is required in the preliminary screening trial; Trial 1 passed the test criteria since the reaction did not propagate along 200mm of the train within 20 minutes for metal powders, even though it consumed half the sample in less than three seconds. Since the reaction was so rapid, SMS performed additional trials even though the thermite sample technically passed the preliminary screening test. Only two of the six trials resulted in reaction of greater than 165mm of the powder train (passing results without regulation), even though the reactions were extremely rapid. It was proposed that perhaps a larger scale linear burn rate test could be appropriate for thermites, giving more mass for the reaction to propagate; we could try a custom test, filling the entire plate with thermite.

Photo 2: UN Test N.1 - Setup

Photo 3: UN Test N.1 - Trial 1 (partial consumption, <180mm)

Photo 4: UN Test N.1 - Trial 4 (full reaction)

Photo 5: UN Test N.1 - Trial 5 (partial consumption, <180mm)

4.3 Test Sample and Test Selection - Small-Scale Thermite Mixes

The following table lists the various thermite mixtures. Thermites highlighted in green identified the proposed compositions for the larger scale tests whereas thermites in grey type were recommended for exclusion from test sample consideration as explained in the "Notes" column.

Table 13: Comparison of Small-scale Thermite Mixes

ID	Fuel	Oxide	Heat, cal/gram	Gas Production, moles/100 grams	Notes
1	Mg	B_2O_3	2134	0.4981	High energy, high cost
2	Be	B_2O_3	1639	0.0000	High energy, high cost
3	Be	MnO_2	1586	0.9527	High energy & gas output
4	Mg	MnO_2	1322	0.7378	High energy & gas output
5	Al	Ni_2O_3	1292	0.4650	High energy, lower cost
6	Be	Fe_2O_3	1281	0.1029	
7	Be	CuO	1221	0.0000	
8	Al	MnO_2	1159	0.8136	High energy & gas, low cost
9	Al	MoO_3	1124	0.2425	
10	Mg	Fe_2O_3	1110	0.2021	
11	Mg	CuO	1102	0.8186	
12	Al	Co_3O_4	1012	0.2196	
13	Al	CuO	974	0.5400	Common thermite, low cost
14	Al	Fe_2O_3	945	0.1404	Common thermite, low cost
15	Be	SiO_2	936	0.0000	High cost, low output
16	Be	Cr_2O_3	915	0.0000	Low energy & gas, high cost
17	Mg	Cr_2O_3	813.1	0.1022	Low energy & gas, high cost
18	Al	WO_3	696	0.1434	
19	Al	SnO_2	687	0.2928	
20	Zr	Fe_2O_3	666	0.0820	Low energy, unique fuel
21	Al	Cr_2O_3	622	0.0000	
22	Ti	Fe_2O_3	612	0.0000	Low energy, unique fuel
23	Nd	CuO	603	0.3699	Low energy, unique fuel
24	Al	Bi_2O_3	506	0.4731	
25	Al	TiO_2	365	0.0000	
26	Coarse Al-Fe_2O_3 A		~945	~0.1404	Commercial
27	Coarse Al-Fe_2O_3 B		~945	~0.1404	Commercial
28	Medium Al-CuO		~974	~0.5400	Commercial

5.0 DESCRIPTION OF THERMITE TEST SAMPLES

5.1 Thermite Compositions Utilized in Main Test Matrix (Large-scale Samples)

A 3-gram sample was taken from each mixture after five minutes of mixing; mixing was discontinued when there was no significant increase in uniformity or reactivity between consecutive samples during a sub-scale torch ignition test. Generally, a mixing time of fifteen minutes was sufficient to achieve an adequate mix.

5.1.1 *Fine Al-Fe_2O_3 Thermite - Mix ID #1 (SMS mixed)*

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 25.26% aluminum (Al) and 74.74% ferric oxide (Fe_2O_3). The aluminum was 3N purity (99.9% pure), 1 - 5 micrometers (microns) in size, and offered for transport as a Division 4.1 flammable solid. The ferric oxide was 2N purity (99% pure), 1 - 5 microns in size, and offered for transport as non-regulated. This thermite was a fine, red powder when fully mixed. SMS mixed this thermite in 332.6-gram batches.

Photo 6: Fine Al-Fe_2O_3 Thermite - Mix ID #1 (SMS mixed)

5.1.2 *Coarse Al-Fe_2O_3 Thermite A - Mix ID #2 (Commercial)*

SMS procured this thermite from a commercial supplier. This thermite contained approximately 25% aluminum (Al) and 75% iron(III)/ferric oxide (Fe_2O_3) by mass. The thermite was a coarse powder that was a mixture of black and light grey particles.

Photo 7: Coarse Al-Fe_2O_3 Thermite A - Mix ID #2 (Commercial)

5.1.3 *Coarse Al-Fe_2O_3 Thermite B - Mix ID #3 (Commercial)*

SMS procured this thermite from a commercial supplier. This thermite contained approximately 25% aluminum (Al), 60% iron(III)/ferric oxide (Fe_2O_3), 5% mild steel, and 10% ferro manganese by mass. The thermite was a coarse powder that was a mixture of black and light grey particles with occasional pieces of steel punching.

Photo 8: Coarse Al-Fe_2O_3 Thermite B - Mix ID #3 (Commercial)

5.1.4 *Fine Al-CuO Thermite - Mix ID #4 (SMS mixed)*

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 18.44% aluminum (Al) and 81.56% copper(II)/cupric oxide (CuO). The aluminum was 3N purity (99.9% pure), 1 - 5 micrometers (microns) in size, and offered for transport as a Division 4.1 flammable solid. The cupric oxide was 3N purity (99.9% pure), 1 - 5 microns in size, and offered for transport as Class 9. This thermite was a very fine, dark grey powder when fully mixed. SMS mixed this thermite in 665.2-gram batches.

Photo 9: Fine Al-CuO Thermite - Mix ID #4 (SMS mixed)

5.1.5 *Medium Al-CuO Thermite - Mix ID #5 (Commercial)*

SMS procured this thermite from a commercial supplier. This thermite contains approximately 18% aluminum (Al) and 82% cupric oxide (CuO). The thermite was grey and silver speckled powder with medium-sized particles.

Photo 10: Medium Al-CuO Thermite - Mix ID #5 (Commercial)

5.1.6 *Fine Al-Ni_2O_3 Thermite - Mix ID #6 (SMS mixed)*

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 24.6% aluminum (Al) and 75.4% nickel(III) oxide (Ni_2O_3). The aluminum was 3N purity (99.9% pure), 1 - 5 micrometers (microns) in size, and offered for transport as a Division 4.1 flammable solid. The nickel(III) oxide was 2N purity (99% pure), 5 microns in size, and offered for transport as non-regulated. This thermite was very fine, light grey powder when fully mixed. SMS mixed this thermite in eleven batches of 757.6 grams and fifty-six batches of 665.2 grams.

Photo 11: Fine Al-Ni_2O_3 Thermite - Mix ID #6 (SMS mixed)

5.1.7 *Fine Al-MnO_2 Thermite - Mix ID #7 (SMS mixed)*

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 29.27% aluminum (Al) and 70.73% manganese(IV) oxide (MnO_2). The aluminum was 3N purity (99.9% pure), 1 - 5 micrometers (microns) in size, and offered for transport as a Division 4.1 flammable solid. The manganese(IV) oxide was 2N purity (99% pure), 5 microns in size, and offered for transport as non-regulated. This thermite was a very fine, dark grey powder when fully mixed. SMS mixed this thermite in 498.8-gram batches.

Photo 12: Fine Al-MnO_2 Thermite - Mix ID #7 (SMS mixed)

5.1.8 *Fine Mg&Al-MoO_3-CuO Thermite - Mix ID #8 (SMS mixed)*

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 25% magnalium (magnesium-aluminum), 34% molybdenum trioxide (MoO_3), and 41% copper(II)/cupric oxide (CuO). The magnalium was 2N purity (99% pure), 44 micrometers (microns) in size, and offered for transport as a Division 4.3 dangerous when wet substance with a subsidiary hazard of Division 4.2 spontaneously combustible. The molybdenum trioxide was 2N purity (99% pure), 44 microns in size, and offered for transport as a Division 6.1 toxic substance. The cupric oxide was 3N purity (99.9% pure), 1 - 5 microns in size, and offered for transport as Class 9. This thermite was a very fine, grey powder when fully mixed. SMS mixed this thermite in three batches of 332.6 grams and ninety-seven batches of 498.8 grams.

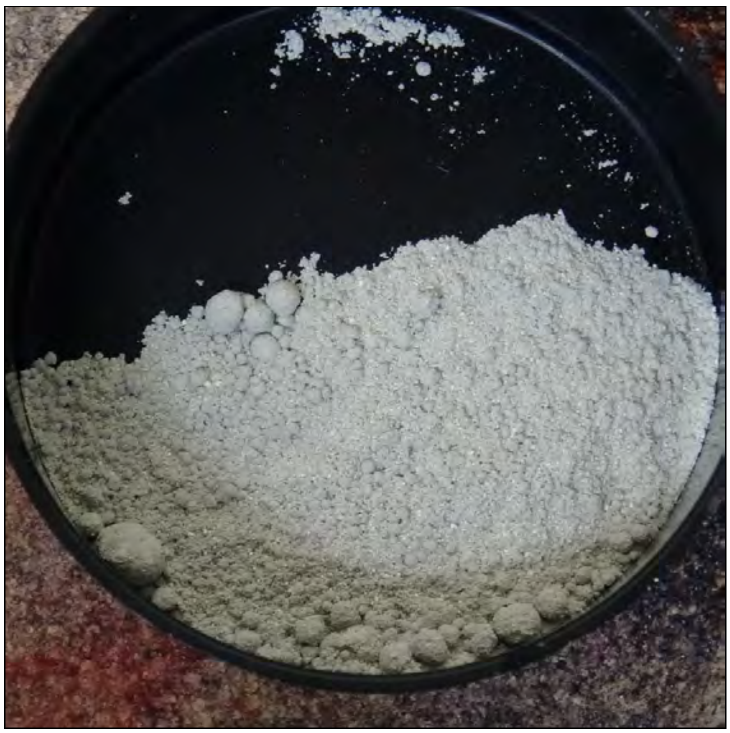
Photo 13: Fine Mg&Al-MoO_3-CuO Thermite - Mix ID #8 (SMS mixed)

5.2 Additional Thermite Compositions Utilized in Auto-Ignition Temperature Testing (Small-scale Samples)

5.2.1 *Fine Al-Bi_2O_3 Thermite - Small-Scale Mix ID #24 (SMS mixed)*

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 10.38% aluminum (Al) and 89.62% bismuth oxide (Bi_2O_3). The aluminum was 3N purity (99.9% pure), 1 - 5 micrometers (microns) in size, and offered for transport as a Division 4.1 flammable solid. This thermite was a very fine, off-white powder when fully mixed. SMS mixed this thermite in 252.7-gram batches.

Photo 14: Fine Al-Bi_2O_3 Thermite - Small-Scale Mix ID #24 (SMS mixed)



5.2.2 *Fine Al-Co_3O_4 Thermite - Small-Scale Mix ID #12 (SMS mixed)*

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 23.01% aluminum (Al) and 76.99% cobalt oxide (Co_3O_4). The aluminum was 3N purity (99.9% pure), 1 - 5 micrometers (microns) in size, and offered for transport as a Division 4.1 flammable solid. This thermite was a very fine, dark grey powder when fully mixed. SMS mixed this thermite in 252.7-gram batches.

Photo 15: Fine Al-Co_3O_4 Thermite - Small-Scale Mix ID #12 (SMS mixed)

5.2.3 *Fine Al-Cr_2O_3 Thermite - Small-Scale Mix ID #21 (SMS mixed)*

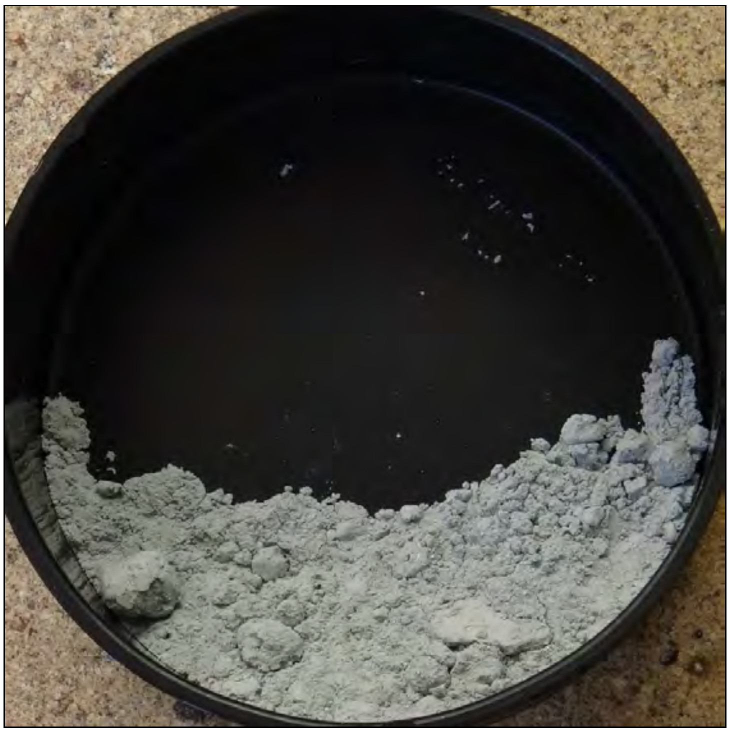
SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 26.20% aluminum (Al) and 73.80% chromium(III) oxide (Cr_2O_3). The aluminum was 3N purity (99.9% pure), 1 - 5 micrometers (microns) in size, and offered for transport as a Division 4.1 flammable solid. This thermite was a fine, light green powder when fully mixed. SMS mixed this thermite in 252.7-gram batches.

Photo 16: Fine Al-Cr_2O_3 Thermite - Small-Scale Mix ID #21 (SMS mixed)

5.2.4 *Fine Al-MoO_3 Thermite - Small-Scale Mix ID #9 (SMS mixed)*

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 27.27% aluminum (Al) and 72.73% molybdenum trioxide (MoO_3). The aluminum was 3N purity (99.9% pure), 1 - 5 micrometers (microns) in size, and offered for transport as a Division 4.1 flammable solid. The molybdenum trioxide was 2N purity (99% pure), 44 microns in size, and offered for transport as a Division 6.1 toxic substance. This thermite was a very fine, off-white powder when fully mixed. SMS mixed this thermite in 252.7-gram batches.

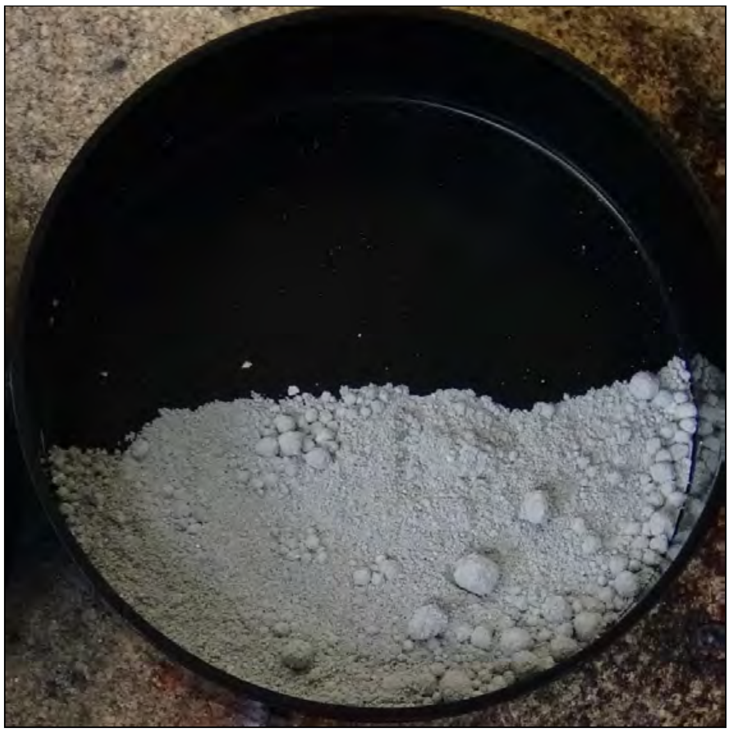
Photo 17: Fine Al-MoO_3 Thermite - Small-Scale Mix ID #9 (SMS mixed)



5.2.5 *Fine Al-SnO_2 Thermite - Small-Scale Mix ID #19 (SMS mixed)*

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 19.27% aluminum (Al) and 80.73% tin(IV) oxide (SnO_2). The aluminum was 3N purity (99.9% pure), 1 - 5 micrometers (microns) in size, and offered for transport as a Division 4.1 flammable solid. This thermite was a very fine, off-white powder when fully mixed. SMS mixed this thermite in 252.7-gram batches.

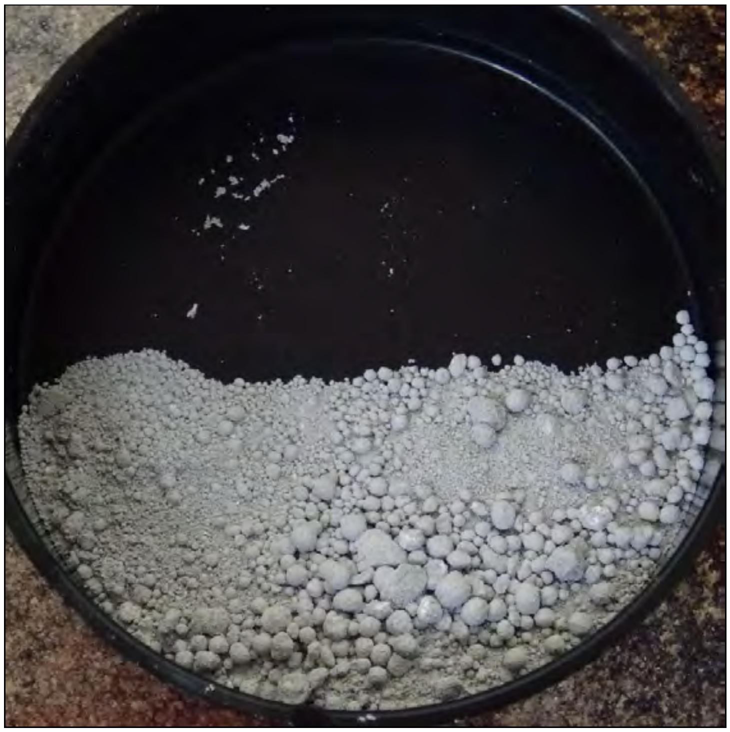
Photo 18: Fine Al-SnO_2 Thermite - Small-Scale Mix ID #19 (SMS mixed)



5.2.6 *Fine Al-TiO_2 Thermite - Small-Scale Mix ID #25 (SMS mixed)*

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 31.06% aluminum (Al) and 68.94% titanium dioxide (TiO_2). The aluminum was 3N purity (99.9% pure), 1 - 5 micrometers (microns) in size, and offered for transport as a Division 4.1 flammable solid. This thermite was a fine, off-white powder when fully mixed. SMS mixed this thermite in 252.7-gram batches.

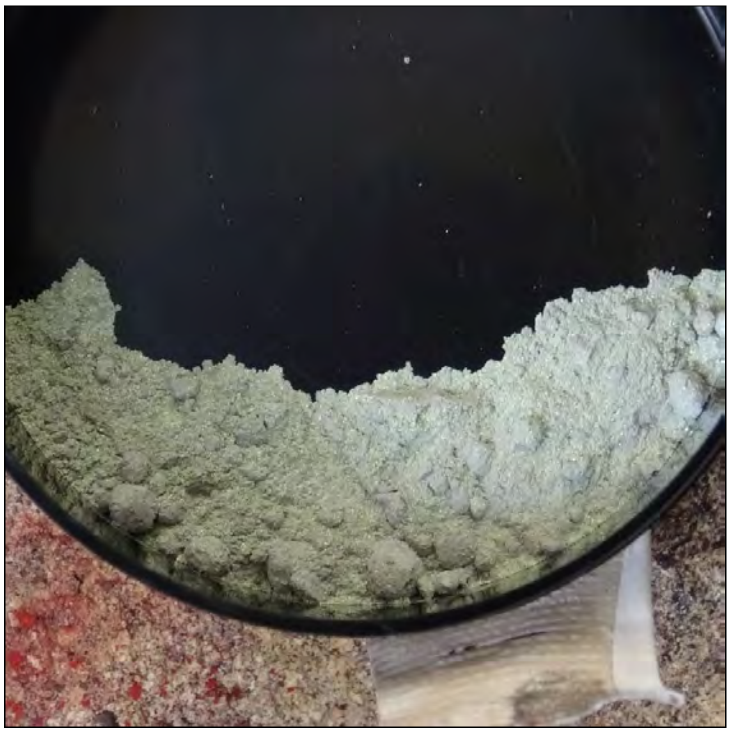
Photo 19: Fine Al-TiO_2 Thermite - Small-Scale Mix ID #25 (SMS mixed)



5.2.7 *Fine Al-WO_3 Thermite - Small-Scale Mix ID #18 (SMS mixed)*

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 18.88% aluminum (Al) and 81.12% tungsten trioxide (WO_3). The aluminum was 3N purity (99.9% pure), 1 - 5 micrometers (microns) in size, and offered for transport as a Division 4.1 flammable solid. This thermite was a very fine, off-white powder when fully mixed. SMS mixed this thermite in 252.7-gram batches.

Photo 20: Fine Al-WO_3 Thermite - Small-Scale Mix ID #18 (SMS mixed)



5.2.8 *Fine Mg-B_2O_3 Thermite - Small-Scale Mix ID #1 (SMS mixed)*

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 51.16% magnesium (Mg) and 48.84% boron trioxide (B_2O_3). This thermite was a very fine, grey powder when fully mixed. SMS mixed this thermite in 252.7-gram batches.

Photo 21: Fine Mg-B_2O_3 Thermite - Small-Scale Mix ID #1 (SMS mixed)

5.2.9 *Fine Mg-CuO Thermite - Small-Scale Mix ID #11 (SMS mixed)*

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 23.40% magnesium (Mg) and 76.60% cupric oxide (CuO). The cupric oxide was 3N purity (99.9% pure), 1 - 5 microns in size, and offered for transport as Class 9. This thermite was a very fine, grey powder when fully mixed. SMS mixed this thermite in 252.7-gram batches.

Photo 22: Fine Mg-CuO Thermite - Small-Scale Mix ID #11 (SMS mixed)

5.2.10 *Fine Mg-Fe_2O_3 Thermite - Small-Scale Mix ID #10 (SMS mixed)*

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 31.35% magnesium (Mg) and 68.65% ferric oxide (Fe_2O_3). The ferric oxide was 2N purity (99% pure), 1 - 5 microns in size, and offered for transport as non-regulated. This thermite was a very fine, rusty brown powder when fully mixed. SMS mixed this thermite in 252.7-gram batches.

Photo 23: Fine Mg-Fe_2O_3 Thermite - Small-Scale Mix ID #10 (SMS mixed)

5.2.11 *Fine Mg-MnO_2 Thermite - Small-Scale Mix ID #4 (SMS mixed)*

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 35.86% magnesium (Mg) and 64.14% manganese(IV) oxide (MnO_2). The manganese(IV) oxide was 2N purity (99% pure), 5 microns in size, and offered for transport as non-regulated. This thermite was a very fine, grey powder when fully mixed. SMS mixed this thermite in 252.7-gram batches.

Photo 24: Fine Mg-MnO_2 Thermite - Small-Scale Mix ID #4 (SMS mixed)

5.2.12 *Fine Ti-B_2O_3 Thermite - Small-Scale Mix ID #2B (SMS mixed)*

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 50.77% titanium (Ti) and 49.23% boron trioxide (B_2O_3). This thermite was a fine, light grey powder when fully mixed. SMS mixed this thermite in 252.7-gram batches.

Photo 25: Fine Ti-B_2O_3 Thermite - Small-Scale Mix ID #2B (SMS mixed)

5.2.13 *Fine Ti-CuO Thermite - Small-Scale Mix ID #7B (SMS mixed)*

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 23.13% titanium (Ti) and 76.87% cupric oxide (CuO). The cupric oxide was 3N purity (99.9% pure), 1 - 5 microns in size, and offered for transport as Class 9. This thermite was a very fine, dark grey powder when fully mixed. SMS mixed this thermite in 252.9-gram batches.

Photo 26: Fine Ti-CuO Thermite - Small-Scale Mix ID #7B (SMS mixed)

5.2.14 *Fine Ti-Fe_2O_3 Thermite - Small-Scale Mix ID #6B (SMS mixed)*

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 31.02% titanium (Ti) and 68.98% ferric oxide (Fe_2O_3). The ferric oxide was 2N purity (99% pure), 1 - 5 microns in size, and offered for transport as non-regulated. This thermite was a fine, red powder when fully mixed. SMS mixed this thermite in 252.7-gram batches.

Photo 27: Fine Ti-Fe_2O_3 Thermite - Small-Scale Mix ID #6B (SMS mixed)

5.2.15 *Fine Ti-MnO_2 Thermite - Small-Scale Mix ID #3B (SMS mixed)*

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 35.51% titanium (Ti) and 64.49% manganese(IV) oxide (MnO_2). The manganese(IV) oxide was 2N purity (99% pure), 5 microns in size, and offered for transport as non-regulated. This thermite was a very fine, light grey powder when fully mixed. SMS mixed this thermite in 257.9-gram batches.

Photo 28: Fine Ti-MnO_2 Thermite - Small-Scale Mix ID #3B (SMS mixed)

6.0 PACKAGING

Packaging typical for thermites consist of inner packagings of plastic bags and outer packagings of fiberboard boxes, as shown in the following photo, or plastic pails.

Photo 29: Packaging for Thermite (typical)

7.0 TEST DESCRIPTIONS AND RESULTS

7.1 UN Series 2 (a) UN Gap test

7.1.1 *Test Description*

This test is used to measure the ability of a substance under confinement to propagate a detonation by subjecting it to a shock impulse from a booster charge. The sample is loaded to the top of a cold-drawn, seamless, carbon steel tube (48.0 ± 2 mm outer diameter, 4 ± 1 mm wall, and 400 ± 5 mm long). Solid samples are loaded to the density attained by tapping the tube until further settling becomes imperceptible. The sample mass is determined and, if solid, the apparent density calculated.

A 160-gram RDX/wax (95/5) or PETN/TNT (50/50) booster of 50 mm diameter and approximately 50mm length is used to provide a known shock source and separated by a polymethyl methacrylate (PMMA) spacer that is 50 ± 1 mm (1.96 ± 0.04 in) in length and diameter (2-inch Gap). The tube is placed over a 150 ± 10mm (6-in) square, 3.2 ± 0.2mm (1/8-in) thick steel witness plate and separated from it by 1.6 ± 0.2mm (1/16-in) thick spacers. An air gap of at least 50 mm (2 in) is provided between the witness plate and the ground. The booster is initiated by a standard detonator.

The test is performed two times unless a positive result is observed earlier. The test result is considered positive and the substance sensitive to shock if the tube is fragmented completely or the witness plate is holed. Any other result is considered negative.

The result is considered positive and the substance sensitive to shock for the UN Series 2 (a) test if the tube is fragmented completely or the witness plate is holed. Any other result is considered negative and the substance not sensitive to detonative shock for the UN Series 2 (a) test.

7.1.2 *Test Configuration*

A PETN/TNT (50/50) booster was utilized for these tests. The dimensions of the steel tubes were 48 mm outer diameter, 4 mm wall (36 mm ID), and 400 mm long. The quantity of material required to fill each tube is listed in the following table; the apparent density was calculated using a calculated internal volume of 503 cm^3.

Table 14: Apparent Density for the UN Gap Test Samples

Item	Sample	Trial	Weight (g)	Density (g/cm^3)
1	Fine Al-Fe_2O_3 Thermite - Mix ID #1 (SMS mixed)	1	459	0.91
		2	455	0.90
2	Coarse Al-Fe_2O_3 Thermite A - Mix ID #2 (Commercial)	1	1009	2.01
		2	1017	2.02
3	Coarse Al-Fe_2O_3 Thermite B - Mix ID #3 (Commercial)	1	1221	2.43
		2	1245	2.48
4	Fine Al-CuO Thermite - Mix ID #4 (SMS mixed)	1	787	1.56
		2	768	1.53
5	Medium Al-CuO Thermite - Mix ID #5 (Commercial)	1	1168	2.32
		2	1175	2.34
6	Fine Al-Ni_2O_3 Thermite - Mix ID #6 (SMS mixed)	1	782	1.55
		2	750	1.49
7	Fine Al-MnO_2 Thermite - Mix ID #7 (SMS mixed)	1	686	1.36
		2	692	1.38
8	Fine Mg&Al-MoO_3-CuO Thermite - Mix ID #8 (SMS mixed)	1	680	1.35
		2	683	1.36

The filled tube was centered over the witness plate, as shown in the following photo.

Photo 30: UN 2-inch Gap Setup (typical)

7.1.3 *Test Results*

The test results are summarized in the following table.

Table 15: Summary of UN Series 2 (a) UN Gap Test Results

Item	Sample	Conditions and Results	Assessment
1	Fine Al-Fe_2O_3 Thermite - Mix ID #1 (SMS mixed)	2-in Gap: - Trial 1: No damage to tube or witness plate; material in pipe consumed. - Trial 2: No damage to tube or witness plate; material in pipe consumed.	Negative (NOT sensitive to detonative shock)
2	Coarse Al-Fe_2O_3 Thermite A - Mix ID #2 (Commercial)	2-in Gap: - Trial 1: No damage to tube or witness plate; material remaining in pipe. - Trial 2: No damage to tube or witness plate; material remaining in pipe.	Negative (NOT sensitive to detonative shock)
3	Coarse Al-Fe_2O_3 Thermite B - Mix ID #3 (Commercial)	2-in Gap: - Trial 1: No damage to tube or witness plate; material remaining in pipe. - Trial 2: No damage to tube or witness plate; material remaining in pipe.	Negative (NOT sensitive to detonative shock)
4	Fine Al-CuO Thermite - Mix ID #4 (SMS mixed)	2-in Gap: - Trial 1: No damage to tube or witness plate; material in pipe consumed. - Trial 2: No damage to tube or witness plate; material in pipe consumed.	Negative (NOT sensitive to detonative shock)
5	Medium Al-CuO Thermite - Mix ID #5 (Commercial)	2-in Gap: - Trial 1: No damage to tube or witness plate; material in pipe consumed. - Trial 2: No damage to tube or witness plate; material in pipe consumed.	Negative (NOT sensitive to detonative shock)
6	Fine Al-Ni_2O_3 Thermite - Mix ID #6 (SMS mixed)	2-in Gap: - Trial 1: No damage to tube or witness plate; material in pipe consumed. - Trial 2: No damage to tube or witness plate; material in pipe consumed.	Negative (NOT sensitive to detonative shock)
7	Fine Al-MnO_2 Thermite - Mix ID #7 (SMS mixed)	2-in Gap: - Trial 1: No damage to tube or witness plate; material in pipe consumed. - Trial 2: No damage to tube or witness plate; material in pipe consumed.	Negative (NOT sensitive to detonative shock)

Item	Sample	Conditions and Results	Assessment
8	Fine Mg&Al-MoO_3-CuO Thermite - Mix ID #8 (SMS mixed)	2-in Gap: - Trial 1: No damage to tube and witness plate bent into a "V" shape; material in pipe consumed. - Trial 2: No damage to tube and witness plate bent into a "V" shape; material in pipe consumed.	Negative (NOT sensitive to detonative shock)

The test results are shown in the following photos; pieces of the tube were included in the photo if found.

Photo 31: UN 2-in Gap Test Results for Fine Al-Fe_2O_3 Thermite - Mix ID #1 (SMS mixed)

Photo 32: UN 2-in Gap Test Results for Coarse Al-Fe_2O_3 Thermite A - Mix ID #2 (Commercial)

Photo 33: UN 2-in Gap Test Results for Coarse Al-Fe_2O_3 Thermite B - Mix ID #3 (Commercial)

Photo 34: UN 2-in Gap Test Results for Fine Al-CuO Thermite - Mix ID #4 (SMS mixed)

Photo 35: UN 2-in Gap Test Results for Medium Al-CuO Thermite - Mix ID #5 (Commercial)

Photo 36: UN 2-in Gap Test Results for Fine Al-Ni_2O_3 Thermite - Mix ID #6 (SMS mixed)

Photo 37: UN 2-in Gap Test Results for Fine Al-MnO_2 Thermite - Mix ID #7 (SMS mixed)

Photo 38: UN 2-in Gap Test Results for Fine Mg&Al-MoO_3-CuO Thermite - Mix ID #8 (SMS mixed)

7.1.4 *Assessment of Test Results*

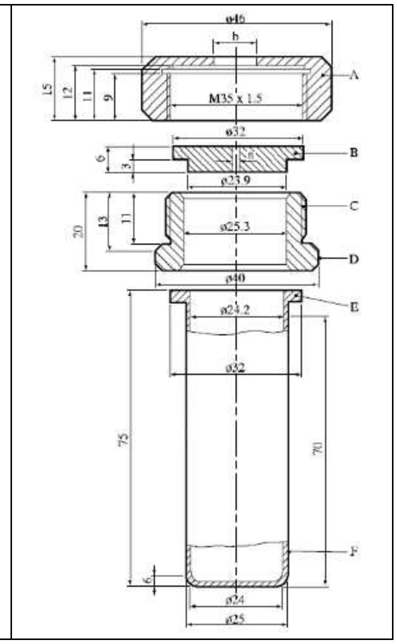
Based on the test results, all samples PASSED the UN Series 2 (a) UN 2-inch Gap test (NOT sensitive to detonative shock).

7.2 UN Series 2 (b) Koenen test

7.2.1 *Test Description*

The Koenen test is used to determine the sensitiveness of solid and liquid substances to intense heat under high confinement. This test utilizes a steel tube to hold the sample. The tube is deep drawn from DC04, A620, or SPCEN sheet steel; 26.5 ± 1.5 grams mass, 75 °C 0.5mm length, 0.5 ± 0.05mm wall, and 30 ± 3 MPa quasi-static bursting pressure. The sample is loaded into the tubes in three equal increments with each increment tamped with an 80 N force applied to the total cross-section of the tube until the tube is filled to 60mm. Liquids are loaded into the tube to a height of 60mm. The tube is assembled into a reusable closing device (threaded nut and collar) and an orifice plate installed on the open end of the tube. Varying the orifice plate over the top of the sample tube changes the degree of confinement of the sample.

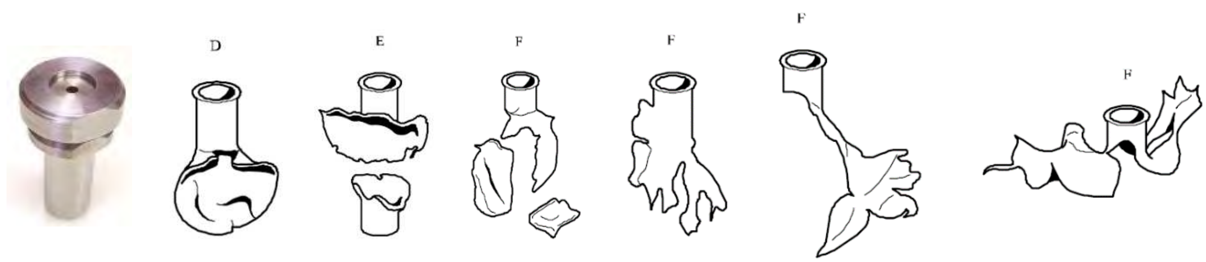
Photo 39: Koenen Tube, Orifice Plates, and Reusable Closing Device



The tube is placed in the heating and protective device, the test area vacated, burners remotely lit, providing a calibrated heating rate to the sample by propane burners located at four locations around the tube for at least 5 minutes or until the tube ruptures. NOTE: The heating rate is calibrated to 3.3 ± 0.3°K/sec using the time for 27 cm³ of dibutyl phthalate to rise from 135°C to 285°C as measured by a 1mm thermocouple placed 43mm below the rim of the tube through a 1.5mm orifice plate (the rise time must be between 41.7 - 50.0 seconds).

After each trial the fragments of the tube, if any, are collected and weighed. The following effects are differentiated:

"O": Tube unchanged;
"A": Bottom of tube bulged out;
"B": Bottom and wall of the tube bulged out;
"C": Bottom of tube split;
"D": Wall of tube split;
"E": Tube split into two fragments;
"F": Tube fragmented into three or more mainly large pieces which in some cases may be connected with each other by a narrow strip;
"G": Tube fragmented into many mainly small pieces, closing device undamaged; and
"H": Tube fragmented into many very small pieces, closing device bulged out or fragmented.



If a trial results in any of the effects "O" to "E", the result is regarded as "no explosion". If a trial gives the effect "F", "G" or "H", the result is evaluated as "explosion". The test is performed three times at the lowest orifice size that the result "no explosion" is observed. The limiting diameter (LD) is the largest orifice diameter at which the result "explosion" is obtained. The orifice sizes are reduced until an explosion effect occurs or the substance passes the test with the smallest orifice (1.0mm).

The result is considered positive for the UN Series 2 (b) test and the substance to show a violent effect on heating under confinement if the LD is 2.0mm or more. The result is considered negative for the UN Series 2 (b) test and the substance to show no violent effect on heating under confinement if the LD is less than 2.0mm.

7.2.2 *Test Configuration*

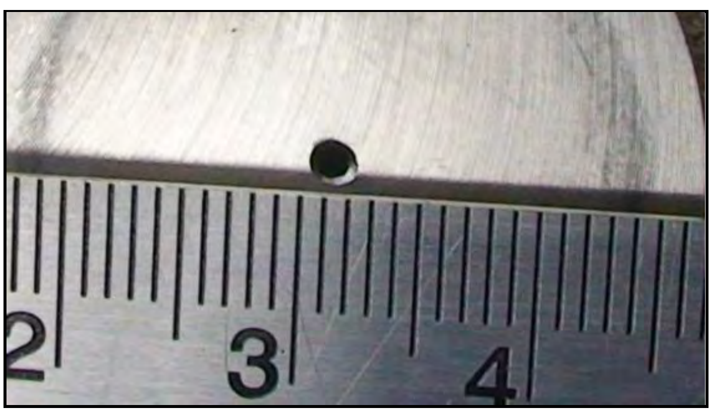
The quantity of sample in each tube, filled in three equal increments with 80 N tamping to a depth of 60mm, is listed in the following table.

Table 16: Sample Quantity Required to Fill Koenen Tubes to a Depth of 60mm

Item	Sample	Trial 1 Mass (g)	Trial 2 Mass (g)	Trial 3 Mass (g)
1	Fine Al-Fe_2O_3 Thermite - Mix ID #1 (SMS mixed)	36.1	36.4	34.1
2	Coarse Al-Fe_2O_3 Thermite A - Mix ID #2 (Commercial)	57.0	58.1	57.0
3	Coarse Al-Fe_2O_3 Thermite B - Mix ID #3 (Commercial)	66.4	65.2	61.9
4	Fine Al-CuO Thermite - Mix ID #4 (SMS mixed)	51.2	45.4	48.7
5	Medium Al-CuO Thermite - Mix ID #5 (Commercial)	61.9	62.3	65.6
6	Fine Al-Ni_2O_3 Thermite - Mix ID #6 (SMS mixed)	54.3	56.5	57.0
7	Fine Al-MnO_2 Thermite - Mix ID #7 (SMS mixed)	49.0	51.4	53.4
8	Fine Mg&Al-MoO_3-CuO Thermite - Mix ID #8 (SMS mixed)	43.4	46.7	44.1

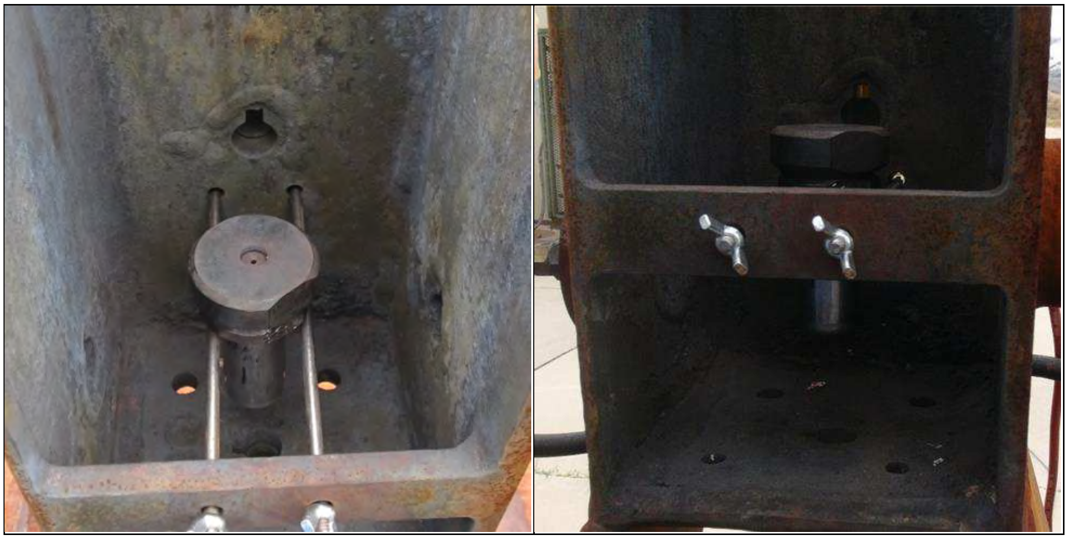
The orifice plates for UN Series 2 (b) had a 2.0mm diameter hole as shown in the following photo.

Photo 40: Orifice Plate with 2.0mm diameter hole



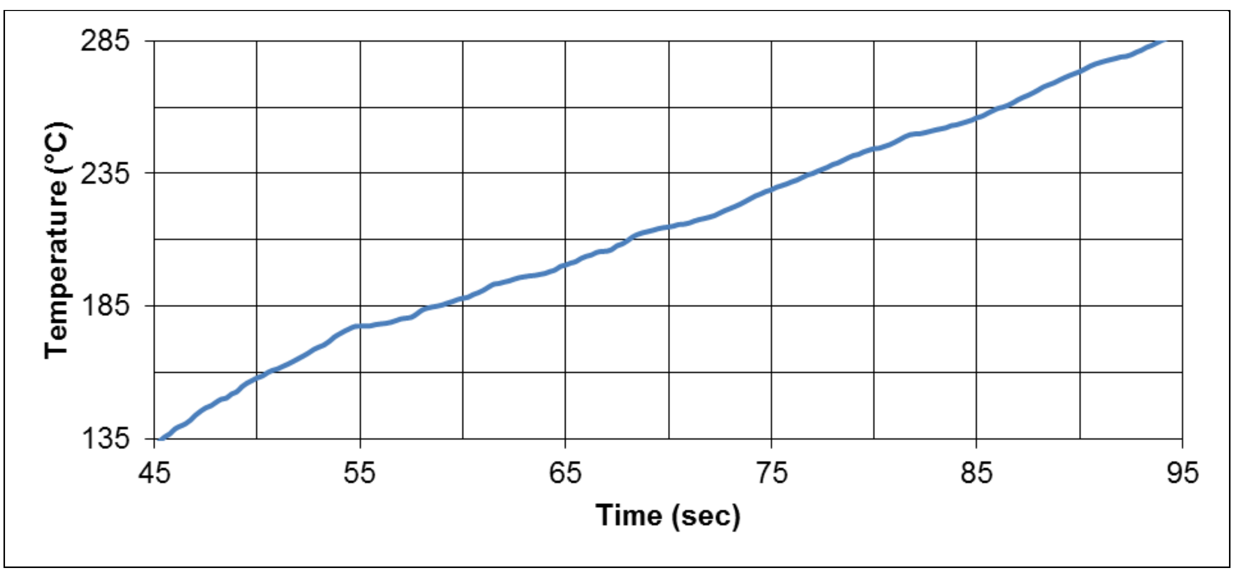
The test tube was centered in the heating and protective device as shown in the following photos.

Photo 41: Koenen Tube Suspended in Heating and Protective Device



For the calibration trial, the time for 27 cm³ of dibutyl phthalate to rise from 135°C to 285°C measured by a 1mm thermocouple placed 43mm below the rim of the tube through a 1.5mm orifice plate was 48.5 seconds (within calibration).

Figure 2: Calibration of Koenen Heating Rate with Dibutyl Phthalate



7.2.3 *Test Results*

The test results are summarized in the following table.

Table 17: Summary of UN Series 2 (b) Koenen Test Results

Item	Sample	Conditions and Results	Assessment
1	Fine Al-Fe_2O_3 Thermite - Mix ID #1 (SMS mixed)	2.0-mm orifice: - Trial 1: Effect type "O", tube unchanged (05:00) - Trial 2: Effect type "O", tube unchanged (05:00) - Trial 3: Effect type "O", tube unchanged (05:00) All trials resulted in "no explosion"; LD less than 2.0mm.	Negative (NO violent effect on heating under confinement)
2	Coarse Al-Fe_2O_3 Thermite A - Mix ID #2 (Commercial)	2.0-mm orifice: - Trial 1: Effect type "O", tube unchanged (05:00) - Trial 2: Effect type "O", tube unchanged (05:00) - Trial 3: Effect type "O", tube unchanged (05:00) All trials resulted in "no explosion"; LD less than 2.0mm.	Negative (NO violent effect on heating under confinement)
3	Coarse Al-Fe_2O_3 Thermite B - Mix ID #3 (Commercial)	2.0-mm orifice: - Trial 1: Effect type "O", tube unchanged (05:00) - Trial 2: Effect type "O", tube unchanged (05:00) - Trial 3: Effect type "O", tube unchanged (05:00) All trials resulted in "no explosion"; LD less than 2.0mm.	Negative (NO violent effect on heating under confinement)
4	Fine Al-CuO Thermite - Mix ID #4 (SMS mixed)	2.0-mm orifice: - Trial 1: Effect type "O", tube unchanged (05:00) - Trial 2: Effect type "O", tube unchanged (05:00) - Trial 3: Effect type "O", tube unchanged (05:00) All trials resulted in "no explosion"; LD less than 2.0mm.	Negative (NO violent effect on heating under confinement)
5	Medium Al-CuO Thermite - Mix ID #5 (Commercial)	2.0-mm orifice: - Trial 1: Effect type "O", tube unchanged (05:00) - Trial 2: Effect type "O", tube unchanged (05:00) - Trial 3: Effect type "O", tube unchanged (05:00) All trials resulted in "no explosion"; LD less than 2.0mm.	Negative (NO violent effect on heating under confinement)
6	Fine Al-Ni_2O_3 Thermite - Mix ID #6 (SMS mixed)	2.0-mm orifice: - Trial 1: Effect type "O", tube unchanged (05:00) - Trial 2: Effect type "O", tube unchanged (05:00) - **Trial 3: Effect type "F", tube fragmented into three or more mainly large pieces (04:40).** **One trial resulted in "explosion"; LD 2.0mm or more.**	**Positive (violent effect on heating under confinement)**

Item	Sample	Conditions and Results	Assessment
7	Fine Al-MnO_2 Thermite - Mix ID #7 (SMS mixed)	2.0-mm orifice: - Trial 1: Effect type "O", tube unchanged (05:00). **NOTE: Later, effect type "F", tube fragmented into three or more mainly large pieces (05:20).** - Trial 2: Effect type "O", tube unchanged (05:00). **NOTE: Later, effect type "F", tube fragmented into three or more mainly large pieces (11:40).** - Trial 3: Effect type "O", tube unchanged (05:00). **NOTE: Effect type "F", tube fragmented into three or more mainly large pieces (09:37).** **One trial resulted in "explosion"; LD 2.0mm or more.**	Negative (NO violent effect on heating under confinement) at 5 minutes; **Positive (violent effect on heating under confinement) after 5 minutes**
8	Fine Mg&Al-MoO_3-CuO Thermite - Mix ID #8 (SMS mixed)	2.0-mm orifice: - Trial 1: Effect type "O", tube unchanged (05:00). **NOTE: Later, effect type "F", tube fragmented into three or more mainly large pieces (07:10).** - Trial 2: Effect type "O", tube unchanged (05:00). **NOTE: Later, effect type "F", tube fragmented into three or more mainly large pieces (09:40).** - **Trial 3: Effect type "F", tube fragmented into three or more mainly large pieces (01:15).** **One trial resulted in "explosion"; LD 2.0mm or more.**	**Positive (violent effect on heating under confinement)**

The test results are shown in the following photos.

Photo 42: Koenen Test Results for Fine Al-Fe_2O_3 Thermite - Mix ID #1 (SMS mixed)

Photo 43: Koenen Test Results for Coarse Al-Fe_2O_3 Thermite A - Mix ID #2 (Commercial)

Photo 44: Koenen Test Results for Coarse Al-Fe_2O_3 Thermite B - Mix ID #3 (Commercial)

Photo 45: Koenen Test Results for Fine Al-CuO Thermite - Mix ID #4 (SMS mixed)

Photo 46: Koenen Test Results for Medium Al-CuO Thermite - Mix ID #5 (Commercial)

Photo 47: Koenen Test Results for Fine Al-Ni_2O_3 Thermite - Mix ID #6 (SMS mixed)

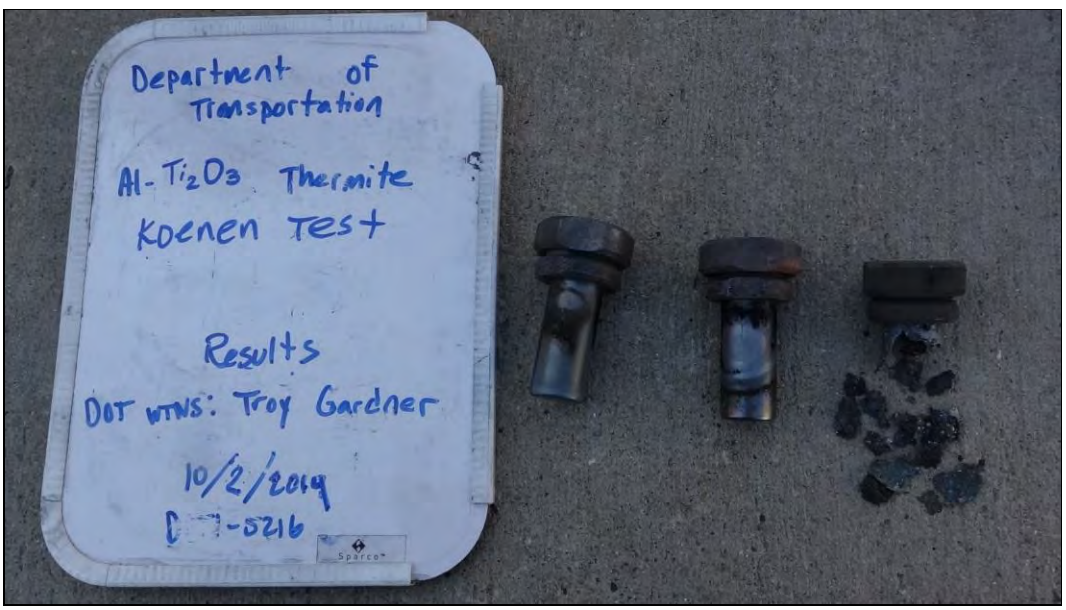


Photo 48: Koenen Test Results for Fine Al-MnO_2 Thermite - Mix ID #7 (SMS mixed)

Photo 49: Koenen Test Results for Fine Mg&Al-MoO_3-CuO Thermite - Mix ID #8 (SMS mixed)

7.2.4 *Assessment of Test Results*

Based on the test results and UN assessment criteria, both the Fine Al-Ni_2O_3 Thermite - Mix ID #6 (SMS mixed) and Fine Mg&Al-MoO_3-CuO Thermite - Mix ID #8 (SMS mixed) samples exploded and FAILED the UN Series 2 (b) Koenen test (violent effect on heating under confinement); the Fine Al-MnO_2 Thermite - Mix ID #7 (SMS mixed) also exploded and would fail the test if the 5-minute maximum test time were extended.

> *NOTE: The auto-ignition temperature of traditional explosives is typically around 200 - 300 °C; the average auto-ignition temperature of the twenty-three small-scale thermite test samples was 809 °C with a standard deviation of 240 °C. Therefore, the 5-minute maximum test time of the UN Series 1 or 2 (b) Koenen test may be insufficient to determine whether a specific thermite exhibits a violent effect on heating under confinement.*

7.3 UN Series 2 (c) (ii) Internal ignition test

7.3.1 *Test Description*

This test is used to determine the tendency of a substance to undergo transition from deflagration to detonation. The sample is loaded into a 45.7-cm long 3-inch schedule 80 carbon (A53 Grade B) steel pipe with 3000-pound forged steel end caps. An igniter consisting of black powder (100% passed through a No. 20 sieve, 100% retained by a No. 50 sieve) is located at the center of the sample vessel; the insulated lead wires are fed through small holes in the wall of the pipe and are sealed with epoxy resin. The tube is placed in a vertical position and the igniter fired.

The test result is considered positive if either the pipe or at least one of the end caps is fragmented into at least two distinct pieces. The test result is considered negative if the pipe is merely split or laid open, or if the end caps are blown off. Three trials are performed unless a positive result occurs earlier.

7.3.2 *Test Configuration*

Each thermite was ignited using a 1.5-gram pyrogen igniter. If the igniter alone was insufficient to ignite the thermite, a bag igniter was added that was comprised of a pyrogen igniter and 10 grams of Mix ID #4 thermite (which is readily ignited by the pyrogen match). The lead wires of the igniters were sealed with epoxy resin and allowed to cure before filling the pipe with sample. Each sample was poured into the steel tubes to a height within one inch of the top of the pipe (to prevent overfilling and contamination of the pipe threads). A typical test setup is shown in the photo below.

Photo 50: Internal Ignition Test Setup (typical)

7.3.3 *Test Results*

The test results are summarized in the following table. For each trial, the thermite ignited and vented out the hole for the ignition wire, enlarging the hole.

Table 18: Summary of UN Series 2 (c) (ii) Test Results

Item	Sample	Conditions and Results	Assessment
1	Fine Al-Fe_2O_3 Thermite - Mix ID #1 (SMS mixed)	Pyrogen igniter: - Trial 1: Full consumption of thermite; no damage to pipe or end caps. - Trial 2: Full consumption of thermite; no damage to pipe or end caps. - Trial 3: Full consumption of thermite; no damage to pipe or end caps. NOTE: Hole expanded to 2-cm wide.	Negative (NO transition from deflagration to detonation)
2	Coarse Al-Fe_2O_3 Thermite A - Mix ID #2 (Commercial)	Pyrogen igniter with 10 grams of Mix ID #4: - Trial 1: Full consumption of thermite; no damage to pipe or end caps. - Trial 2: Full consumption of thermite; no damage to pipe or end caps. - Trial 3: Full consumption of thermite; no damage to pipe or end caps. NOTE: Hole expanded to 6-cm wide.	Negative (NO transition from deflagration to detonation)

Item	Sample	Conditions and Results	Assessment
3	Coarse Al-Fe_2O_3 Thermite B - Mix ID #3 (Commercial)	Pyrogen igniter with 10 grams of Mix ID #4: - Trial 1: Full consumption of thermite; no damage to pipe or end caps. - Trial 2: Full consumption of thermite; no damage to pipe or end caps. - Trial 3: Full consumption of thermite; no damage to pipe or end caps. NOTE: Hole expanded to 4-cm wide.	Negative (NO transition from deflagration to detonation)
4	Fine Al-CuO Thermite - Mix ID #4 (SMS mixed)	Pyrogen igniter: - Trial 1: Full consumption of thermite; no damage to pipe or end caps. - Trial 2: Full consumption of thermite; no damage to pipe or end caps. - Trial 3: Full consumption of thermite; no damage to pipe or end caps. NOTE: Hole expanded to 4-cm wide.	Negative (NO transition from deflagration to detonation)
5	Medium Al-CuO Thermite - Mix ID #5 (Commercial)	Pyrogen igniter with 10 grams of Mix ID #4: - Trial 1: Full consumption of thermite; no damage to pipe or end caps. - Trial 2: Full consumption of thermite; no damage to pipe or end caps. - Trial 3: Full consumption of thermite; no damage to pipe or end caps.	Negative (NO transition from deflagration to detonation)
6	Fine Al-Ni_2O_3 Thermite - Mix ID #6 (SMS mixed)	Pyrogen igniter: - Trial 1: Full consumption of thermite; no damage to pipe or end caps. - Trial 2: Full consumption of thermite; no damage to pipe or end caps. - Trial 3: Full consumption of thermite; no damage to pipe or end caps.	Negative (NO transition from deflagration to detonation)
7	Fine Al-MnO_2 Thermite - Mix ID #7 (SMS mixed)	Pyrogen igniter: - Trial 1: Full consumption of thermite; no damage to pipe or end caps. - Trial 2: Full consumption of thermite; no damage to pipe or end caps. - Trial 3: Full consumption of thermite; no damage to pipe or end caps.	Negative (NO transition from deflagration to detonation)

Item	Sample	Conditions and Results	Assessment
8	Fine Mg&Al-MoO_3-CuO Thermite - Mix ID #8 (SMS mixed)	Pyrogen igniter: - Trial 1: Full consumption of thermite; no damage to pipe or end caps. - Trial 2: Full consumption of thermite; no damage to pipe or end caps. - Trial 3: Full consumption of thermite; no damage to pipe or end caps. NOTE: Hole expanded to 4-cm wide.	Negative (NO transition from deflagration to detonation)

The test results are shown in the following photos.

Photo 51: Internal Ignition Test Results for Fine Al-Fe_2O_3 Thermite - Mix ID #1 (SMS mixed)

Photo 52: Internal Ignition Test Results for Coarse Al-Fe_2O_3 Thermite A - Mix ID #2 (Commercial) - typical

Photo 53: Internal Ignition Test Results for Coarse Al-Fe_2O_3 Thermite B - Mix ID #3 (Commercial) - typical

Photo 54: Internal Ignition Test Results for Fine Al-CuO Thermite - Mix ID #4 (SMS mixed)

Photo 55: Internal Ignition Test Results for Medium Al-CuO Thermite - Mix ID #5 (Commercial)

Photo 56: Internal Ignition Test Results for Fine Al-Ni_2O_3 Thermite - Mix ID #6 (SMS mixed)

Photo 57: Internal Ignition Test Results for Fine Al-MnO_2 Thermite - Mix ID #7 (SMS mixed)

Photo 58: Internal Ignition Test Results for Fine Mg&Al-MoO_3-CuO Thermite - Mix ID #8 (SMS mixed)

7.3.4 *Assessment of Test Results*

Based on the test results, all samples PASSED the UN Series 2 (c) (ii) Internal ignition test (NO transition from deflagration to detonation).

7.4 UN Series 3 (a) (i) Bureau of Explosives (BOE) impact sensitivity test

7.4.1 *Test Description*

The BOE Impact Test is used to measure the sensitiveness of a substance to drop-weight impact and to determine if the substance is too dangerous to transport in the form tested.

For solids, a 10-mg sample is loaded onto a die. The anvil and die are placed in the sample housing and the casing screwed down over them. The plug and plunger are then inserted on top of the sample. The 3.63-kg drop weight is raised to a drop height of 10.0 cm and released. Observations are made on whether an "explosion" occurs as evidenced by flame or audible report (smoke excluded). Up to ten trials are performed for each sample. The material is considered too dangerous for transport in the form in which it was tested if "explosion" occurs in at least five out of the ten trials.

Photo 59: BOE Impact Apparatus

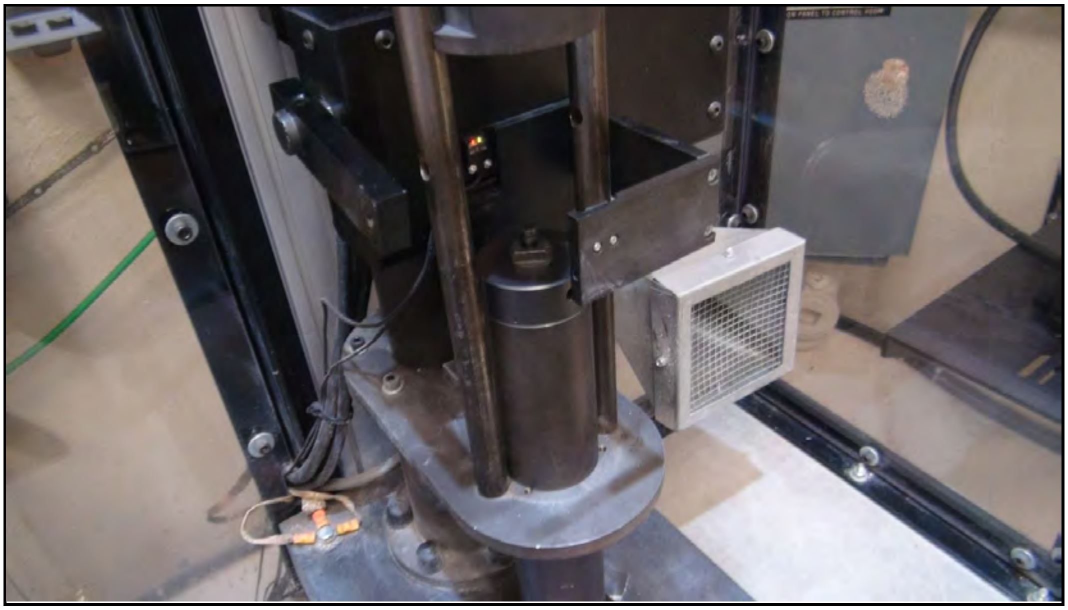
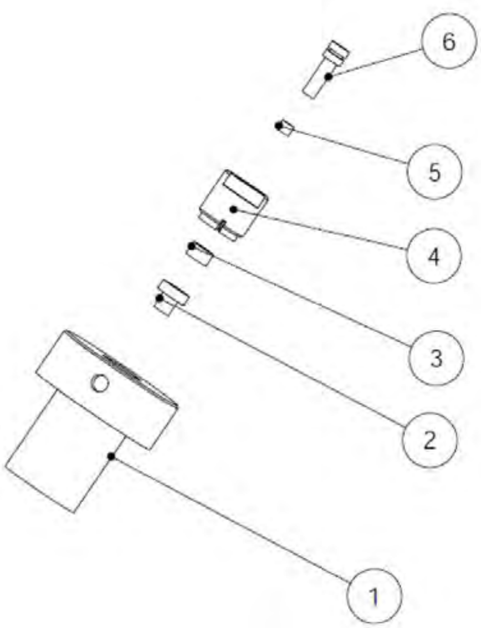


Figure 3: Components of the BOE Impact Apparatus



ITEM NO.	DESCRIPTION
1	BOE Solids Test Housing
2	BOE Solids Test Anvil
3	BOE Impact Solids Test Die
4	BOE Impact Solids Test Casing
5	BOE Impact Solids Test Plug
6	BOE Impact Solids Test Plunger

7.4.2 *Test Results*

The test results are summarized in the following table.

Table 19: Summary of UN Series 3 (a) (i) BOE Impact Test Results

Item	Sample	Conditions and Results	Assessment
1	Fine Al-Fe_2O_3 Thermite - Mix ID #1 (SMS mixed)	No explosion in 6 trials.	Pass (not too dangerous in tested form)
2	Coarse Al-Fe_2O_3 Thermite A - Mix ID #2 (Commercial)	No explosion in 6 trials.	Pass (not too dangerous in tested form)
3	Coarse Al-Fe_2O_3 Thermite B - Mix ID #3 (Commercial)	No explosion in 6 trials.	Pass (not too dangerous in tested form)
4	Fine Al-CuO Thermite - Mix ID #4 (SMS mixed)	No explosion in 6 trials.	Pass (not too dangerous in tested form)
5	Medium Al-CuO Thermite - Mix ID #5 (Commercial)	No explosion in 6 trials.	Pass (not too dangerous in tested form)
6	Fine Al-Ni_2O_3 Thermite - Mix ID #6 (SMS mixed)	No explosion in 6 trials.	Pass (not too dangerous in tested form)
7	Fine Al-MnO_2 Thermite - Mix ID #7 (SMS mixed)	No explosion in 6 trials.	Pass (not too dangerous in tested form)
8	Fine Mg&Al-MoO_3-CuO Thermite - Mix ID #8 (SMS mixed)	No explosion in 6 trials.	Pass (not too dangerous in tested form)

7.4.3 *Assessment of Test Results*

Based on the test results, all samples PASSED the UN Series 3 (a) (i) BOE impact test (not too dangerous in tested form).

7.5 <u>UN Series 3 (b) (i) BAM friction sensitivity test</u>

7.5.1 *Test Description*

This test is used to measure the sensitiveness of the substance to frictional stimuli and to determine if the substance is too dangerous to transport in the form tested.

A porcelain plate is fixed on the carriage of the friction apparatus so that its sponge-mark grooves run transversely to the direction of movement. Approximately 10 mm^3 of the sample is poured into a pile on the porcelain plate. The loading arm is lowered, resting a stationary porcelain peg onto the sample; care is taken so that enough of the substance will come under the peg when the porcelain plate moves forward. The load applied on the pin is provided by varying the actual applied mass and the distance along the loading arm where the mass is placed. The plate is motor driven through a one cycle pass beneath the pin, thereby subjecting the sample to friction created by the rubbing of the pin against the plate.

Observations are made on whether an "explosion" occurs as evidenced by an audible report, crackling, sparking, or flame. Up to six trials are performed for each sample. The material is considered too dangerous for transport in the form in which it was tested if the limiting load (i.e. the lowest friction load at which one "explosion" occurs in six trials) is less than 80 N.

7.5.2 *Test Configuration*

Each thermite mixture was tested as prepared or received; samples were not sieved through a 0.5-mm mesh sieve.

7.5.3 *Test Results*

The test results are summarized in the following table.

Table 20: Summary of UN Series 3 (b) (i) BAM Friction Test Results

Item	Sample	Conditions and Results	Assessment
1	Fine Al-Fe_2O_3 Thermite - Mix ID #1 (SMS mixed)	No explosion in 6 trials at a friction load of 80 N (limiting load >80 N).	Pass (not too dangerous in tested form)
2	Coarse Al-Fe_2O_3 Thermite A - Mix ID #2 (Commercial)	No explosion in 6 trials at a friction load of 80 N (limiting load >80 N).	Pass (not too dangerous in tested form)
3	Coarse Al-Fe_2O_3 Thermite B - Mix ID #3 (Commercial)	No explosion in 6 trials at a friction load of 80 N (limiting load >80 N).	Pass (not too dangerous in tested form)
4	Fine Al-CuO Thermite - Mix ID #4 (SMS mixed)	No explosion in 6 trials at a friction load of 80 N (limiting load >80 N).	Pass (not too dangerous in tested form)
5	Medium Al-CuO Thermite - Mix ID #5 (Commercial)	No explosion in 6 trials at a friction load of 80 N (limiting load >80 N).	Pass (not too dangerous in tested form)
6	Fine Al-Ni_2O_3 Thermite - Mix ID #6 (SMS mixed)	No explosion in 6 trials at a friction load of 80 N (limiting load >80 N).	Pass (not too dangerous in tested form)

Item	Sample	Conditions and Results	Assessment
7	Fine Al-CuO Thermite - Mix ID #4 (SMS mixed)	No explosion in 6 trials at a friction load of 80 N (limiting load >80 N).	Pass (not too dangerous in tested form)
8	Fine Mg&Al-MoO_3-CuO Thermite - Mix ID #8 (SMS mixed)	No explosion in 6 trials at a friction load of 80 N (limiting load >80 N).	Pass (not too dangerous in tested form)

7.5.4 *Assessment of Test Results*

Based on the test results, all samples PASSED the UN Series 3 (b) (i) BAM friction test (not too dangerous in tested form).

7.6 UN Series 3 (c) (i) Thermal stability test - Uninstrumented

7.6.1 *Test Description*

This test is used to measure the stability of the substance when subjected to elevated thermal conditions to determine if the substance is too dangerous to transport.

A 50-gram sample is weighed into a beaker, covered with a watch glass and placed in a constant temperature, explosion-proof oven at 75 °C for 48 hours. The temperature is continuously monitored and recorded. At the completion of the test, the sample is examined for evidence of ignition, explosion, or decomposition/self-heating (discoloration, weight loss, dimensional change, etc.).

The result from the uninstrumented test is considered positive if ignition or explosion occurs. Further testing is required if there is evidence that some self-heating has occurred (e.g. fuming or decomposition); otherwise the substance is regarded as thermally stable.

7.6.2 *Test Configuration*

The following photo shows a representative test setup with 50 grams of sample in a glass beaker, covered with a watch glass, and placed into the heating oven.

Photo60: Thermal Stability Test Setup (typical)

7.6.3 *Test Results*

The test results are summarized in the following table.

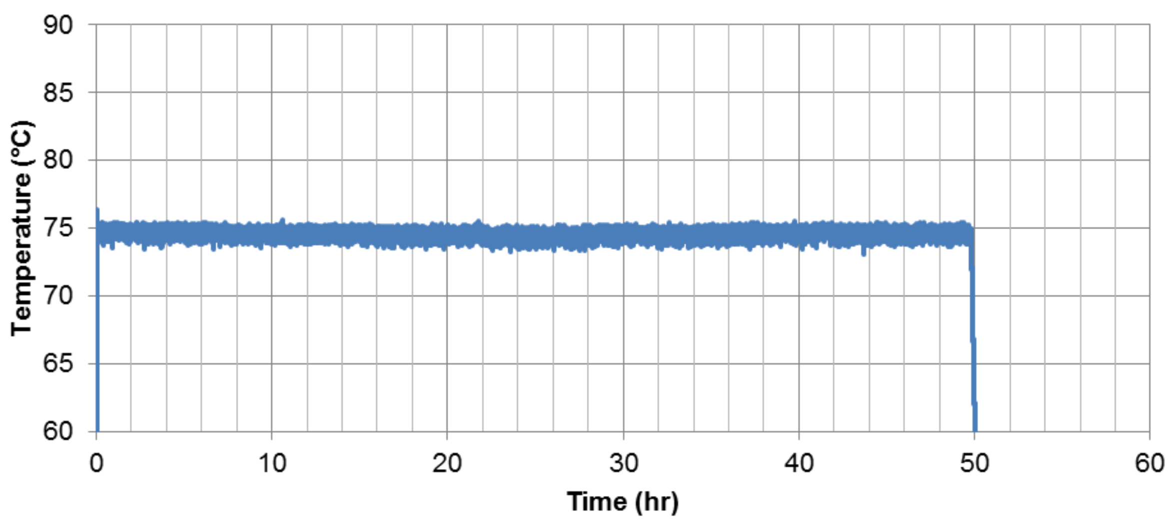
Table 21: Summary of UN Series 3 (c) (i) Thermal Stability Test Results

Item	Sample	Conditions and Results	Assessment
1	Fine Al-Fe_2O_3 Thermite - Mix ID #1 (SMS mixed)	Ignition or explosion did NOT occur, and no evidence of thermal instability (fuming or decomposition); 0.2-grams mass loss.	Pass (not forbidden)
2	Coarse Al-Fe_2O_3 Thermite A - Mix ID #2 (Commercial)	Ignition or explosion did NOT occur, and no evidence of thermal instability (fuming or decomposition); 0.1-grams mass loss.	Pass (not forbidden)
3	Coarse Al-Fe_2O_3 Thermite B - Mix ID #3 (Commercial)	Ignition or explosion did NOT occur, and no evidence of thermal instability (fuming or decomposition); 0.03-grams mass loss.	Pass (not forbidden)

Item	Sample	Conditions and Results	Assessment
4	Fine Al-CuO Thermite - Mix ID #4 (SMS mixed)	Ignition or explosion did NOT occur, and no evidence of thermal instability (fuming or decomposition); 0.05-grams mass loss.	Pass (not forbidden)
5	Medium Al-CuO Thermite - Mix ID #5 (Commercial)	Ignition or explosion did NOT occur, and no evidence of thermal instability (fuming or decomposition); no mass loss.	Pass (not forbidden)
6	Fine Al-Ni_2O_3 Thermite - Mix ID #6 (SMS mixed)	Ignition or explosion did NOT occur, and no evidence of thermal instability (fuming or decomposition); no mass loss.	Pass (not forbidden)
7	Fine Al-MnO_2 Thermite - Mix ID #7 (SMS mixed)	Ignition or explosion did NOT occur, and no evidence of thermal instability (fuming or decomposition); no mass loss.	Pass (not forbidden)
8	Fine Mg&Al-MoO_3-CuO Thermite - Mix ID #8 (SMS mixed)	Ignition or explosion did NOT occur, and no evidence of thermal instability (fuming or decomposition); no mass loss.	Pass (not forbidden)

The following figure is a typical record of the oven temperature for the test.

Figure 4: Oven Temperature Record for the Thermal Stability Test (typical)



7.6.4 *Assessment of Test Results*

Based on the test results, all samples PASSED the uninstrumented UN Series 3 (c) (i) Thermal stability test (not forbidden).

7.7 UN Series 3 (d) Small-scale burning test

7.7.1 *Test Description*

This test is used to determine the response of an unconfined substance to fire. A sample in a thin-walled plastic beaker is placed on a bed of sawdust soaked with kerosene or diesel fuel approximately 30-cm square and 1.3-cm thick. The sawdust is ignited with an electric match or similar device and the burn time is measured. The test is performed two times unless an explosion or detonation occurs. The test is normally performed twice with 10 grams of sample and twice with 100 grams.

7.7.2 *Test Configuration*

The test was performed twice with 100 grams of sample in paper cups. The following photo shows a representative test setup.

Photo61: Small-scale Burning Test Setup (typical)

7.7.3 *Test Results*

The test results are summarized in the following table.

Table 22: Summary of UN Series 3 (d) Small-scale Burning Test Results

Item	Sample	Conditions and Results	Assessment
1	Fine Al-Fe_2O_3 Thermite - Mix ID #1 (SMS mixed)	The two 100-gram samples ignited and burned for 0.6 - 0.8 seconds each after 1 - 2 minutes; explosion of the test samples did NOT occur.	Pass (not too dangerous in tested form)
2	Coarse Al-Fe_2O_3 Thermite A - Mix ID #2 (Commercial)	The two 100-gram samples did NOT ignite.	Pass (not too dangerous in tested form)
3	Coarse Al-Fe_2O_3 Thermite B - Mix ID #3 (Commercial)	The two 100-gram samples did NOT ignite.	Pass (not too dangerous in tested form)
4	Fine Al-CuO Thermite - Mix ID #4 (SMS mixed)	The two 100-gram samples ignited and burned for approximately 3 - 4 seconds after 7 - 11 minutes; explosion of the test samples did NOT occur.	Pass (not too dangerous in tested form)
5	Medium Al-CuO Thermite - Mix ID #5 (Commercial)	The two 100-gram samples did NOT ignite.	Pass (not too dangerous in tested form)
6	Fine Al-Ni_2O_3 Thermite - Mix ID #6 (SMS mixed)	The two 100-gram samples did NOT ignite.	Pass (not too dangerous in tested form)
7	Fine Al-MnO_2 Thermite - Mix ID #7 (SMS mixed)	The two 100-gram samples exploded upon ignition after 1.0 - 1.5 minutes.	**FAIL (12-meter drop test required to determine whether safe for transport; waived based on impact and friction sensitivity test results)**

Item	Sample	Conditions and Results	Assessment
8	Fine Mg&Al-MoO_3-CuO Thermite - Mix ID #8 (SMS mixed)	The two 100-gram samples exploded upon ignition after 37 - 44 seconds with a loud report, clearing the witness plate of sawdust.	**FAIL (12-meter drop test required to determine whether safe for transport; waived based on impact and friction sensitivity test results)**

The test results are shown in the following photos.

Photo 62: Small-scale Burning Test Results for Fine Al-Fe_2O_3 Thermite - Mix ID #1 (SMS mixed)

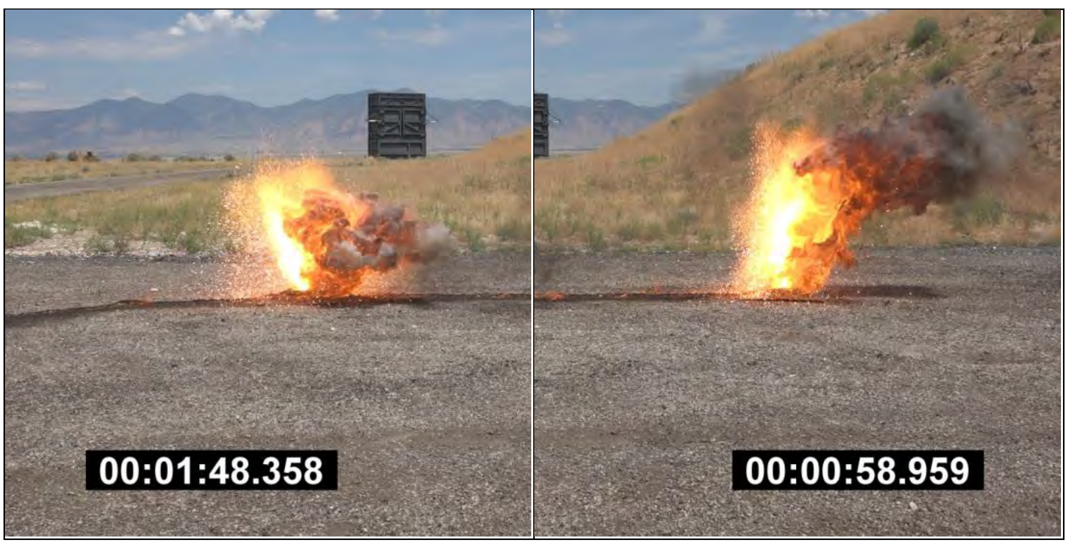


Photo 63: Small-scale Burning Test Results for Coarse Al-Fe_2O_3 Thermite A - Mix ID #2 (Commercial)

Photo 64: Small-scale Burning Test Results for Coarse Al-Fe_2O_3 Thermite B - Mix ID #3 (Commercial)

Photo 65: Small-scale Burning Test Results for Fine Al-CuO Thermite - Mix ID #4 (SMS mixed)

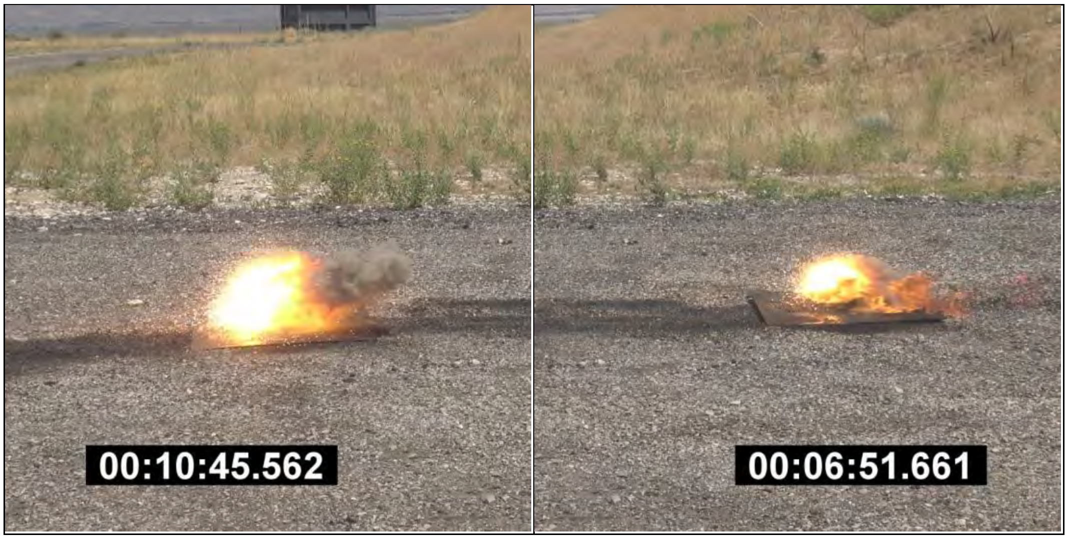


Photo 66: Small-scale Burning Test Results for Medium Al-CuO Thermite - Mix ID #5 (Commercial)

Photo 67: Small-scale Burning Test Results for Fine Al-Ni_2O_3 Thermite - Mix ID #6 (SMS mixed)

Photo 68: Small-scale Burning Test Results for Fine Al-MnO_2 Thermite - Mix ID #7 (SMS mixed)

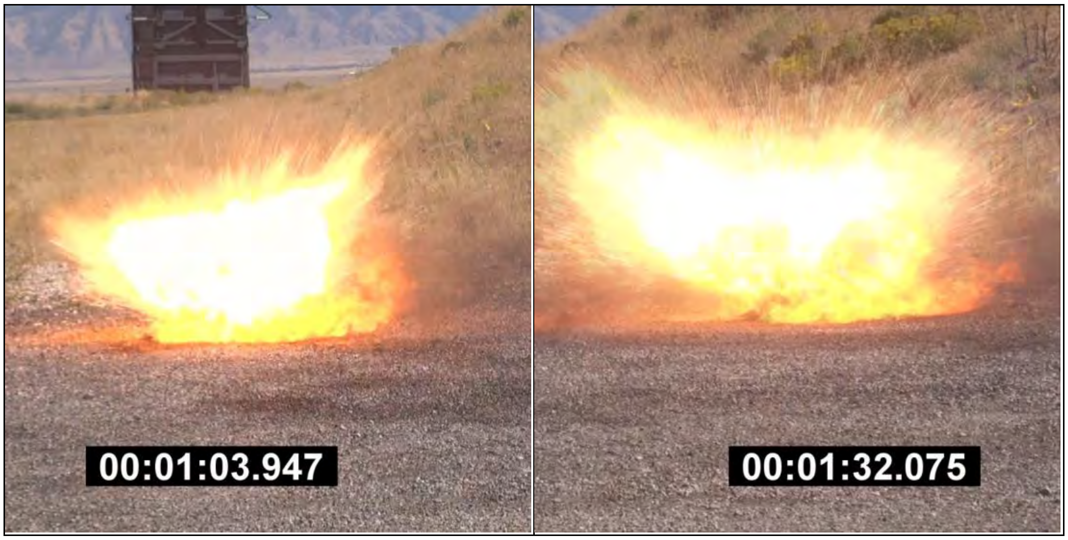
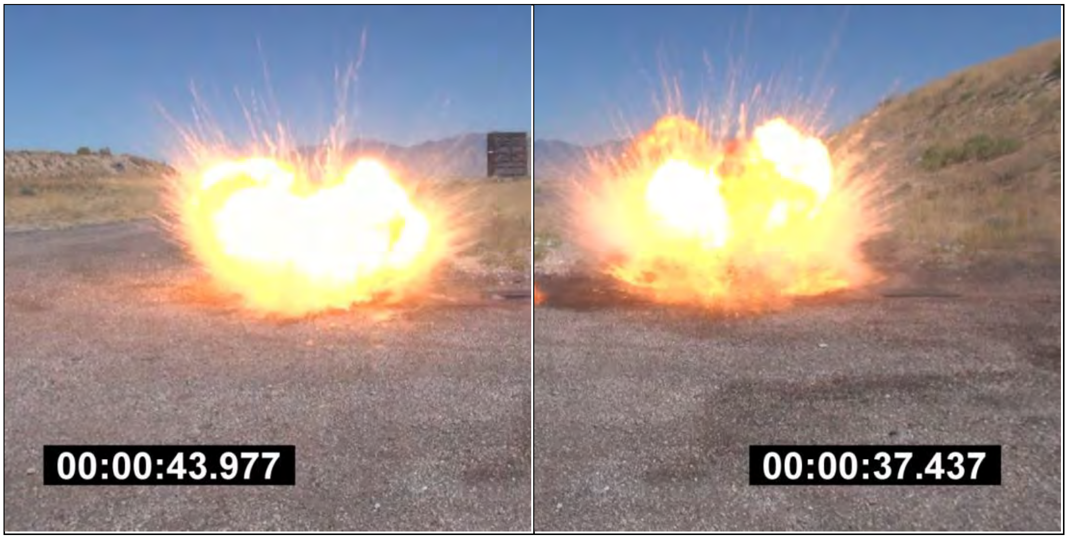


Photo 69: Small-scale Burning Test Results for Fine Mg&Al-MoO_3-CuO Thermite - Mix ID #8 (SMS mixed)



7.7.4 *Assessment of Test Results*

Based on the test criteria and the test results, both the Fine Al-MnO_2 Thermite - Mix ID #7 (SMS mixed) and Fine Mg&Al-MoO_3-CuO Thermite - Mix ID #8 (SMS mixed) samples failed the small-scale burning test criteria requiring a 12-meter drop test to determine whether they are safe for transport; the 12-meter drop test is waived based on the passing impact and friction sensitivity test results. All other samples (Large-scale Mix ID's #1, #2, #3, #4, #5 and #6) passed the small-scale burning test criteria.

7.8 Unconfined UN Series 6 (a) Single Package Test on Suspended Witness Plate

7.8.1 *Test Description*

This test demonstrates the hazardous effects apparent outside of a packaged substance when it is centrally ignited. An igniter is buried in the center of the packaged substance. The package is centered on a suspended witness plate. The igniter is ignited and observations made on the following: evidence of thermal effects, projection effects, detonation, deflagration or explosion of the total contents of the package. Detonation or explosion of the total contents of the package indicates a candidate for Division 1.1. One trial is performed for each configuration (screening test).

7.8.2 *Test Configuration*

One outer package of each product was placed on a witness plate. Each package contained 9.1 kg of thermite in a plastic bag within a fiberboard box, as shown in the following photo.

Photo 70: Unconfined Single Package Test Setup for Fine Al-CuO Thermite - Mix ID #4 (SMS mixed) - typical

Each thermite was ignited using a 1.5-gram pyrogen igniter. If the igniter alone was insufficient to ignite the thermite, a bag igniter was added that was comprised of a pyrogen igniter and 10 grams of Mix ID #4 thermite (which is readily ignited by the pyrogen match). Two witness plate types were tested: 2-mm thick 1100-0 aluminum (standard UN Series 6 (c) External bonfire witness screen) and 3-mm thick mild steel (standard UN Series 6 (a) Single package witness plate). A typical test setup is shown in the photo below.

Photo 71: Suspended, Unconfined Single Package Test Setup - typical

2-mm thick 1100-0 Aluminum Witness Plate	3-mm thick Mild Steel Witness Plate
	

7.8.3 *Test Results*

The test results for the unconfined single package test on suspended 2-mm thick 1100-0 aluminum witness plate (one trial) are summarized in the following table.

Table 23: Summary of Unconfined UN Series 6 (a) Single Package Test Results on a Suspended 2-mm thick 1100-0 Aluminum Witness Plate

Item	Sample	Conditions and Results	Assessment
1	Fine Al-Fe_2O_3 Thermite - Mix ID #1 (SMS mixed)	Package containing 9.1 kg of thermite ignited and burned; thermite readily melted through a large hole through the aluminum witness plate.	High threat to 2-mm thick 1100-0 aluminum
2	Coarse Al-Fe_2O_3 Thermite A - Mix ID #2 (Commercial)	Package containing 9.1 kg of thermite ignited and burned; thermite readily melted through the aluminum witness plate.	High threat to 2-mm thick 1100-0 aluminum
3	Coarse Al-Fe_2O_3 Thermite B - Mix ID #3 (Commercial)	Package containing 9.1 kg of thermite ignited and burned; several holes in the aluminum witness plate where thermite melted through.	High threat to 2-mm thick 1100-0 aluminum
4	Fine Al-CuO Thermite - Mix ID #4 (SMS mixed)	Package containing 9.1 kg of thermite ignited and burned; thermite readily melted through the aluminum witness plate.	High threat to 2-mm thick 1100-0 aluminum
5	Medium Al-CuO Thermite - Mix ID #5 (Commercial)	Package containing 9.1 kg of thermite ignited and burned; several holes in the aluminum witness plate where thermite melted through.	High threat to 2-mm thick 1100-0 aluminum
6	Fine Al-Ni_2O_3 Thermite - Mix ID #6 (SMS mixed)	Package containing 9.1 kg of thermite ignited and burned; thermite readily melted through the aluminum witness plate.	High threat to 2-mm thick 1100-0 aluminum
7	Fine Al-MnO_2 Thermite - Mix ID #7 (SMS mixed)	Package containing 9.1 kg of thermite exploded upon ignition of pyrogen match in the center; severe deformation of suspended aluminum witness plate.	**Hazards consistent with Division 1.1**
8	Fine Mg&Al-MoO_3-CuO Thermite - Mix ID #8 (SMS mixed)	Package containing 9.1 kg of thermite exploded upon ignition of pyrogen match in the center; severe deformation of suspended aluminum witness plate.	**Hazards consistent with Division 1.1**

The test results for the unconfined single package test on suspended 3-mm thick mild steel witness plate (one trial) are summarized in the following table.

Table 24: Summary of Unconfined UN Series 6 (a) Single Package Test Results on a Suspended 3-mm thick Mild Steel Witness Plate

Item	Sample	Conditions and Results	Assessment
1	Fine Al-Fe_2O_3 Thermite - Mix ID #1 (SMS mixed)	Package containing 9.1 kg of thermite ignited and burned in 1 - 2 seconds; no significant damage to the steel witness plate.	Minimal threat to 3-mm thick mild steel
2	Coarse Al-Fe_2O_3 Thermite A - Mix ID #2 (Commercial)	Package containing 9.1 kg of thermite ignited and burned; several holes in the steel witness plate where thermite melted through.	High threat to 3-mm thick mild steel
3	Coarse Al-Fe_2O_3 Thermite B - Mix ID #3 (Commercial)	Package containing 9.1 kg of thermite ignited and burned; thermite readily melted through the steel witness plate.	High threat to 3-mm thick mild steel
4	Fine Al-CuO Thermite - Mix ID #4 (SMS mixed)	Package containing 9.1 kg of thermite ignited and burned; no significant damage to the steel witness plate but several melt points on underside of the plate.	Moderate threat to 3-mm thick mild steel
5	Medium Al-CuO Thermite - Mix ID #5 (Commercial)	Package containing 9.1 kg of thermite ignited and burned; no significant damage to the steel witness plate but one very small hole in plate.	Minimal threat to 3-mm thick mild steel
6	Fine Al-Ni_2O_3 Thermite - Mix ID #6 (SMS mixed)	Package containing 9.1 kg of thermite ignited and burned; thermite readily melted through the steel witness plate.	High threat to 3-mm thick mild steel
7	Fine Al-MnO_2 Thermite - Mix ID #7 (SMS mixed)	Package containing 9.1 kg of thermite exploded upon ignition of pyrogen match in the center slightly bowing the witness plate.	**Hazards consistent with Division 1.1**
8	Fine Mg&Al-MoO_3-CuO Thermite - Mix ID #8 (SMS mixed)	Package containing 9.1 kg of thermite exploded upon ignition of pyrogen match in the center bowing the witness plate.	**Hazards consistent with Division 1.1**

The test results are shown in the following photos.

Photo 72: Suspended, Unconfined Package Test Results for Fine Al-Fe_2O_3 Thermite - Mix ID #1 (SMS mixed)

2-mm thick 1100-0 Aluminum Witness Plate	3-mm thick Mild Steel Witness Plate
	

Photo 73: Suspended, Unconfined Package Test Results for Coarse Al-Fe_2O_3 Thermite A - Mix ID #2 (Commercial)

2-mm thick 1100-0 Aluminum Witness Plate	3-mm thick Mild Steel Witness Plate
	

Photo 74: Suspended, Unconfined Package Test Results for Coarse Al-Fe_2O_3 Thermite B - Mix ID #3 (Commercial)

2-mm thick 1100-0 Aluminum Witness Plate	3-mm thick Mild Steel Witness Plate
	

Photo 75: Suspended, Unconfined Package Test Results for Fine Al-CuO Thermite - Mix ID #4 (SMS mixed)

2-mm thick 1100-0 Aluminum Witness Plate	3-mm thick Mild Steel Witness Plate
	

Photo 76: Suspended, Unconfined Package Test Results for Medium Al-CuO Thermite - Mix ID #5 (Commercial)

2-mm thick 1100-0 Aluminum Witness Plate	3-mm thick Mild Steel Witness Plate
	

Photo 77: Suspended, Unconfined Package Test Results for Fine Al-Ni_2O_3 Thermite - Mix ID #6 (SMS mixed)

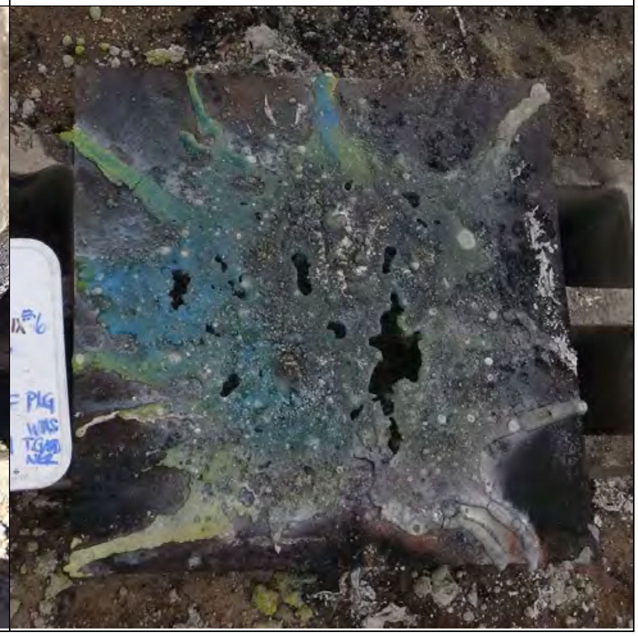
2-mm thick 1100-0 Aluminum Witness Plate	3-mm thick Mild Steel Witness Plate
	

Photo 78: Suspended, Unconfined Package Test Results for Fine Al-MnO_2 Thermite - Mix ID #7 (SMS mixed)

2-mm thick 1100-0 Aluminum Witness Plate	3-mm thick Mild Steel Witness Plate
	

Photo 79: Suspended, Unconfined Package Test Results for Fine Mg&Al-MoO_3-CuO Thermite - Mix ID #8 (SMS mixed)

2-mm thick 1100-0 Aluminum Witness Plate	3-mm thick Mild Steel Witness Plate
	

7.8.4 *Assessment of Test Results*

Based on the test results, both the Fine Al-MnO_2 Thermite - Mix ID #7 (SMS mixed) and Fine Mg&Al-MoO_3-CuO Thermite - Mix ID #8 (SMS mixed) samples explode upon ignition with hazards consistent with that of Division 1.1. Upon ignition, all samples posed a high threat to compromise 2mm-thick or less aluminum plate/sheet supporting the package; the Coarse Al-Fe_2O_3 Thermite A - Mix ID #2 (Commercial), Coarse Al-Fe_2O_3 Thermite B - Mix ID #3 (Commercial), and Fine Al-Ni_2O_3 Thermite - Mix ID #6 (SMS mixed) samples potentially pose a high threat able to compromise 3mm-thick or less mild steel plate/sheet supporting the package.

7.9 <u>Sub-scale UN Series 6 (c) External fire (bonfire) test</u>

7.9.1 *Test Description*

This test is performed on packages of explosives to determine the hazard when involved in a fire. Normally a stack of packages of an explosive material (0.15 cubic meters volume as packaged for transport) is placed on a non-combustible surface (steel grate) above a fuel source. Three 200-cm × 200-cm × 0.2-cm aluminum witness screens are placed 4 meters from the edge of the stack. The fire is ignited simultaneously on at least two sides and the material is observed for a) evidence of detonation, deflagration, or explosion of the total contents; b) potentially hazardous projections; and c) thermal effects (i.e. rate of burn, size of any fireball, etc.). The test is recorded using regular video with audio from two angles and visual distance marking devices.

7.9.2 *Test Configuration*

One outer package of each product was placed on the steel grate with four outer packages per bonfire (one package in each quadrant of the steel grate). Each package contained 9.1 kg of thermite in a plastic bag within a fiberboard box, as shown in the following photo. Several wood pallets were used as the fuel source and liquid fuel as an accelerant for ignition of the wood.

The environmental conditions at the start of the External bonfire tests were as follows:

- <u>Bonfire #1 for Mix IDs #2, #3, #4, and #5</u>: 3.6 m/s wind, 33°C, 19% relative humidity.
- <u>Bonfire #2 for Mix ID #8</u>: 3.6 m/s wind, 32°C, 20% relative humidity.
- <u>Bonfire #3 for Mix ID #7</u>: 2.2 m/s wind, 12°C, 39% relative humidity.
- <u>Bonfire #4 for Mix ID's #1 and #6</u>: 1.8 m/s wind, 12°C, 39% relative humidity.

Photo 80: Packaging Fine Al-CuO Thermite - Mix ID #4 (SMS mixed) for Sub-scale External Fire Test (typical)

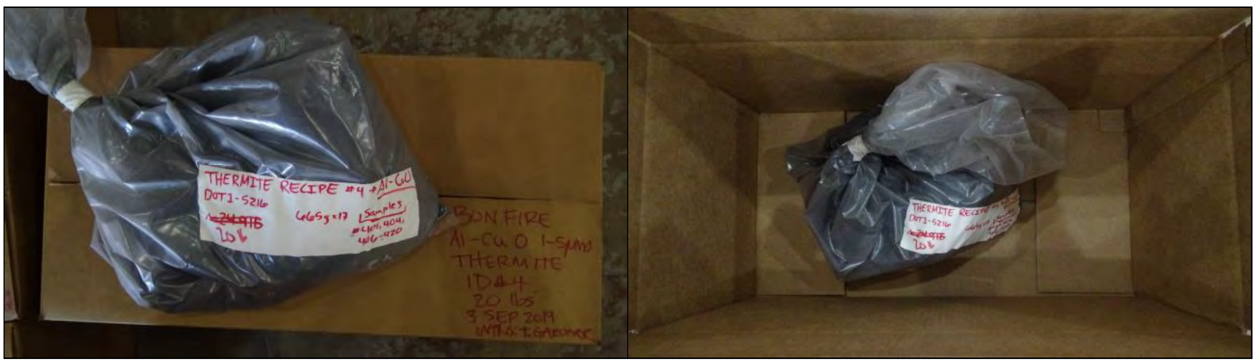


Photo 81: External Bonfire #1 Test Setup for Mix IDs #2, #3, #4, and #5

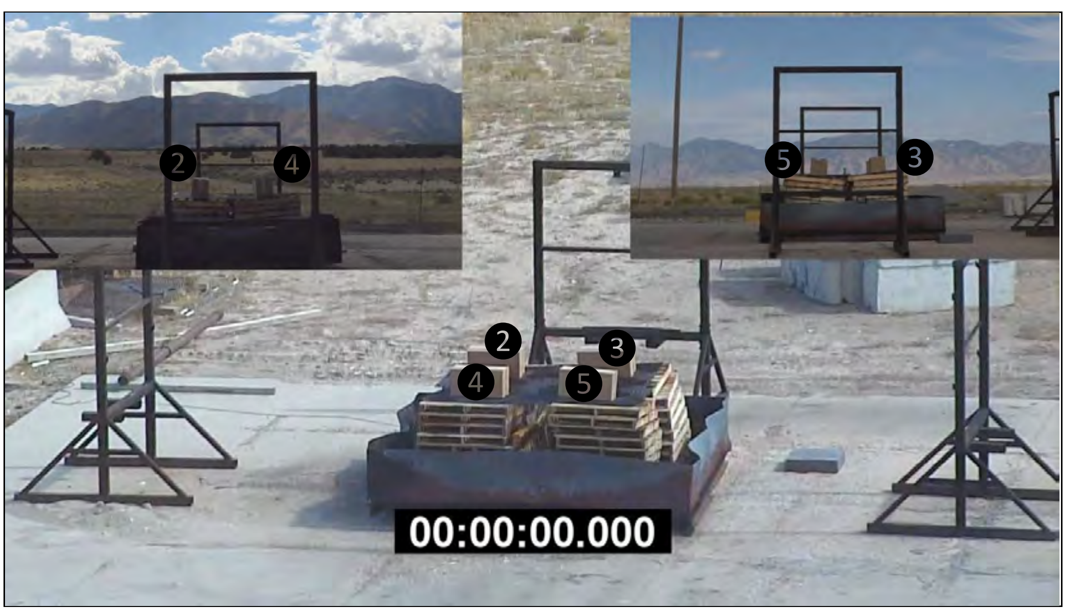


Photo 82: External Bonfire #2 Test Setup for Mix ID #8

Photo 83: External Bonfire #3 Test Setup for Mix ID #7

Photo 84: External Bonfire #4 Test Setup for Mix ID #1 and #6

7.9.3 *Test Results*

The test results are summarized in the following table.

Table 25: Summary of Sub-scale UN Series 6 (c) External Bonfire Test Results

Item	Sample	Conditions and Results	Assessment
1	Fine Al-Fe_2O_3 Thermite - Mix ID #1 (SMS mixed)	Package containing 9.1 kg of thermite ignited and rapidly burned over approximately 1 second, producing a fireball with a radius of 3 - 4 meters; no mass explosion.	Reaction rate and fireball more consistent with the hazards of Division 1.3
2	Coarse Al-Fe_2O_3 Thermite A - Mix ID #2 (Commercial)	Package containing 9.1 kg of thermite ignited and briefly produced local flame enhancement within the flames of the fire.	Sub-scale quantities appear to present minor hazards

Item	Sample	Conditions and Results	Assessment
3	Coarse Al-Fe_2O_3 Thermite B - Mix ID #3 (Commercial)	Package containing 9.1 kg of thermite ignited and briefly produced local flame enhancement within the flames of the fire; package was fully engulfed in the flames of the fire, obscuring the package and reaction.	Sub-scale quantities appear to present minor hazards
4	Fine Al-CuO Thermite - Mix ID #4 (SMS mixed)	Package containing 9.1 kg of thermite ignited and rapidly burned over approximately 3 seconds, producing a fireball with a radius of 2 meters; no mass explosion.	Reaction rate and fireball more consistent with the hazards of Division 1.3 or 1.4
5	Medium Al-CuO Thermite - Mix ID #5 (Commercial)	Package containing 9.1 kg of thermite ignited and briefly produced local flame enhancement within the flames of the fire.	Sub-scale quantities appear to present minor hazards
6	Fine Al-Ni_2O_3 Thermite - Mix ID #6 (SMS mixed)	Package containing 9.1 kg of thermite ignited and burned over approximately 17 seconds, producing local flame enhancement within the flames of the fire.	Reaction rate and fireball more consistent with the hazards of Division 1.4S
7	Fine Al-MnO_2 Thermite - Mix ID #7 (SMS mixed)	Package containing 9.1 kg of thermite exploded upon ignition with nearly instantaneous consumption of the package contents.	**Hazards consistent with Division 1.1**
8	Fine Mg&Al-MoO_3-CuO Thermite - Mix ID #8 (SMS mixed)	Package containing 9.1 kg of thermite exploded upon ignition with nearly instantaneous consumption of the package contents.	**Hazards consistent with Division 1.1**

The test results are shown in the following photos.

Photo 85: External Bonfire #1 Test Progression - Typical Flames

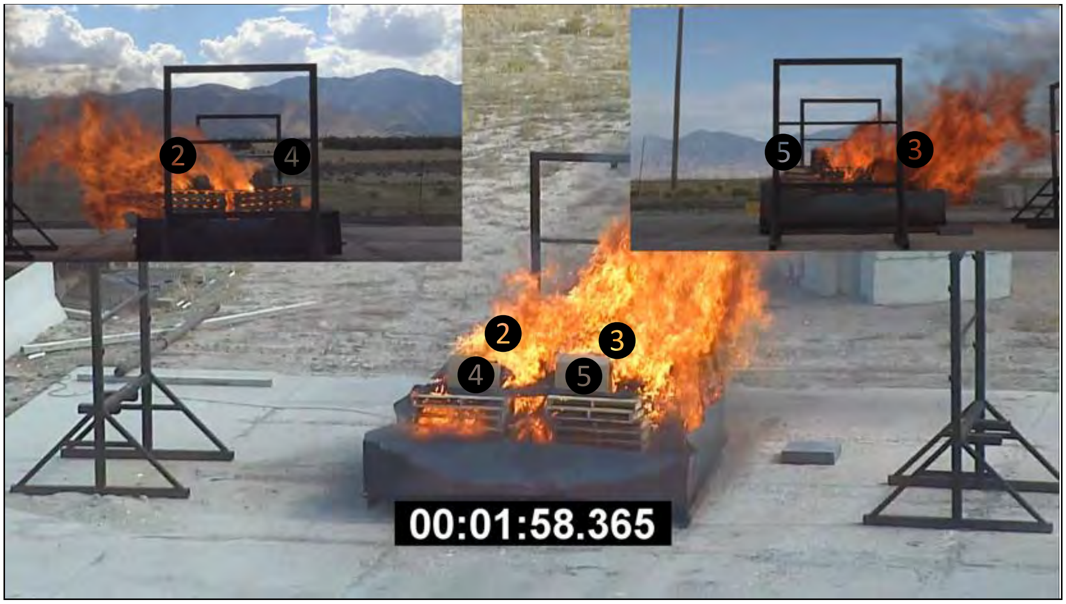


Photo 86: External Bonfire #1 Test Progression - Burning of Fine Al-CuO Thermite - Mix ID #4 (SMS mixed)

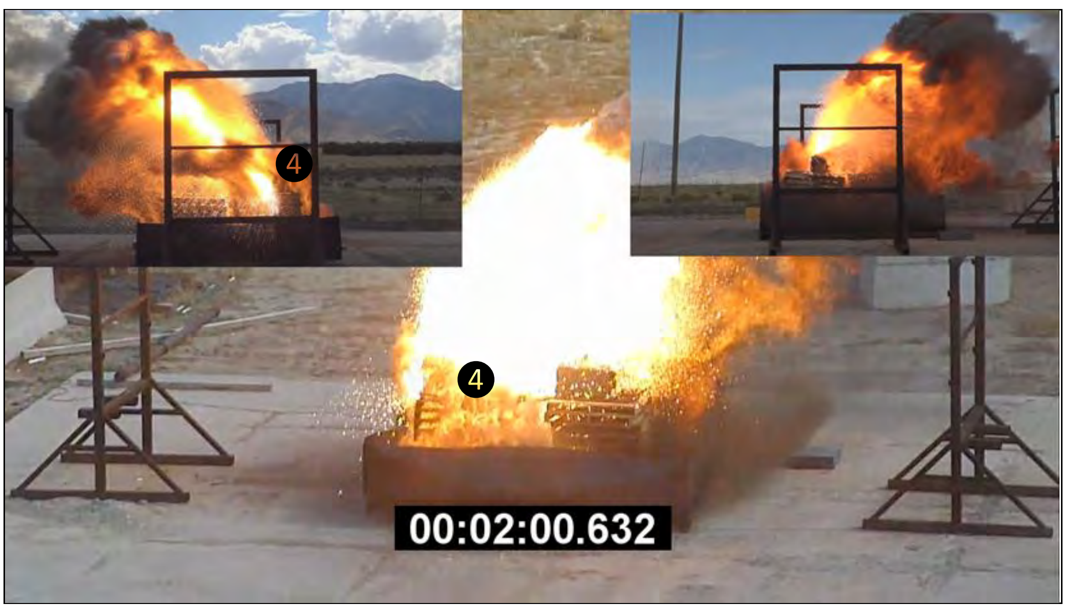


Photo 87: External Bonfire #1 Test Progression - Burning of Medium Al-CuO Thermite - Mix ID #5 (Commercial)

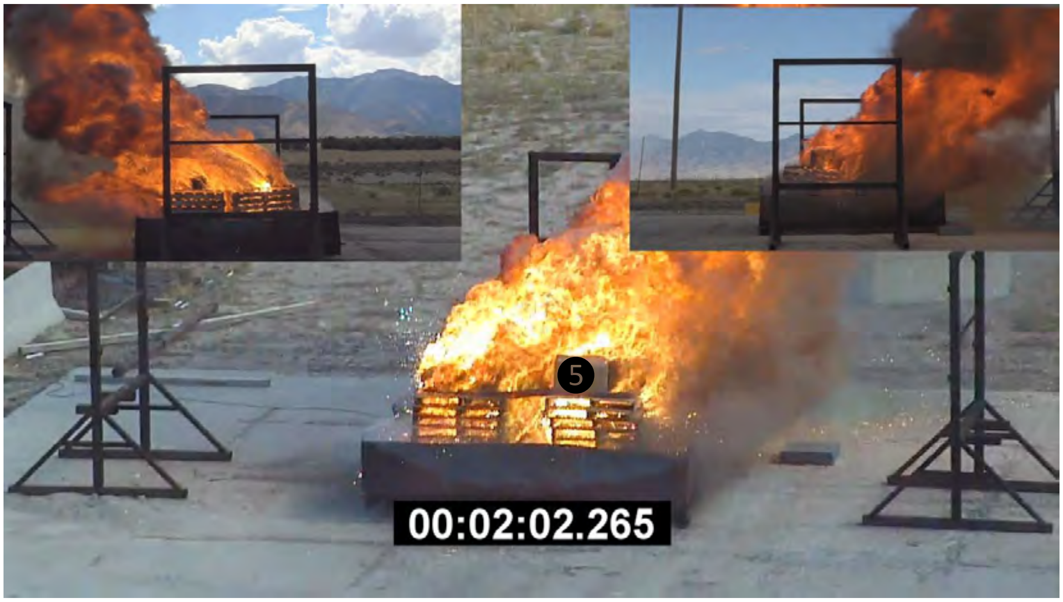


Photo 88: External Bonfire #1 Test Progression - Burning of Coarse Al-Fe_2O_3 Thermite A - Mix ID #2 (Commercial)

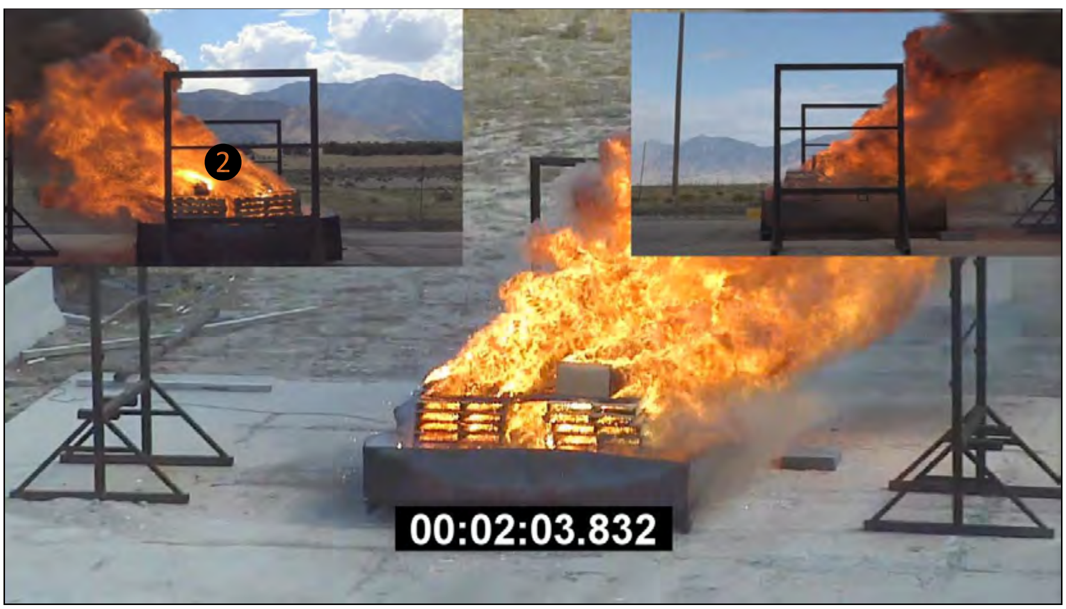


Photo 89: External Bonfire #1 Test Progression - Burning of Coarse Al-Fe_2O_3 Thermite B - Mix ID #3 (Commercial)

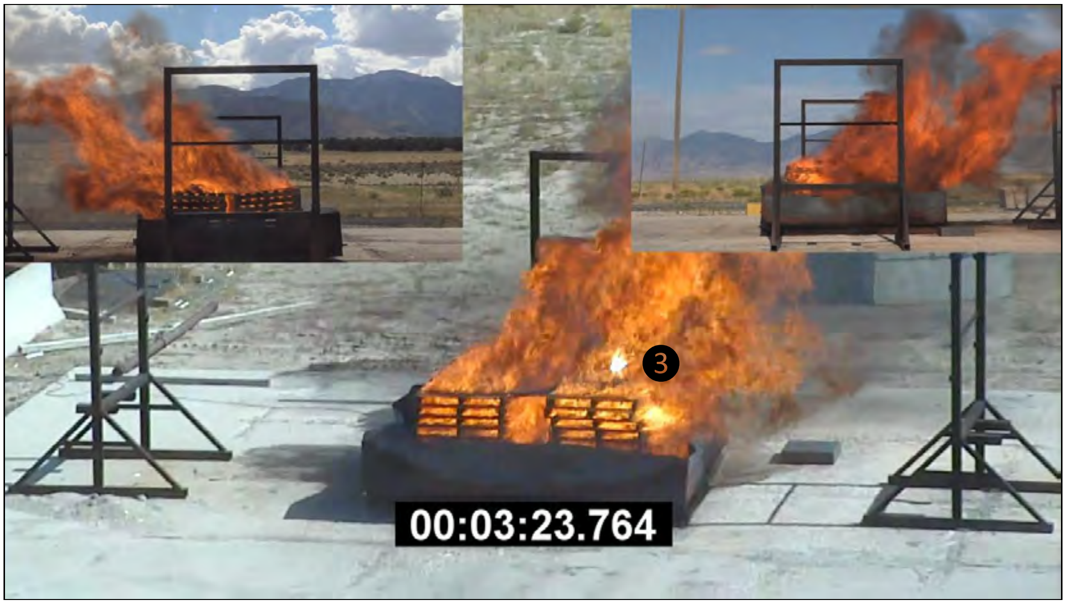


Photo 90: External Bonfire #2 Test Progression - Explosion of Fine Mg&Al-MoO_3-CuO Thermite - Mix ID #8 (SMS mixed)

Photo 91: External Bonfire #4 Test Progression - Explosion of Fine Al-MnO_2 Thermite - Mix ID #7 (SMS mixed)

Photo 92: External Bonfire #4 Test Progression - Burning of Fine Al-Fe_2O_3 Thermite - Mix ID #1 (SMS mixed)

Photo 93: External Bonfire #4 Test Progression - Burning of Fine Al-Ni_2O_3 Thermite - Mix ID #6 (SMS mixed)

7.9.4 *Assessment of Test Results*

Based on the test results, the Fine Al-MnO2 Thermite - Mix ID #7 (SMS mixed) and Fine Mg&Al-MoO3-CuO Thermite - Mix ID #8 (SMS mixed) samples have hazards consistent with that of explosives with a Division 1.1 mass explosion hazard. The Fine Al-Fe2O3 Thermite - Mix ID #1 (SMS mixed) and Fine Al-CuO Thermite - Mix ID #4 (SMS mixed) samples had reaction rates and fireball sizes more consistent with the hazards of Division 1.3 or 1.4.

7.10 Sub-scale UN Series 7 (e) EIS External fire test

7.10.1 *Test Description*

This test is used to determine the reaction of a substance to external fire when it is confined. The substance is loaded into seamless steel pipe having an inside diameter of 40.5 - 49.5 mm, a wall thickness of 3.6 - 4.4 mm, and a length of 200 mm. The pipes are closed with steel or cast iron end caps, at least as strong as the tube, torqued to 204 N·m.

The sub-scale test is performed with three confined samples of each product, each secured away from adjacent samples, to a non-combustible surface (steel grate) centered within a fuel basin. The fuel basin is at least 3 ft (1 m) larger than the stack in every direction with a wall height sufficient to contain a quantity of fuel sufficient to maintain a fully developed fire for a 30-minute fire and not block the flight of projections.

The fire is ignited on at least two sides and the material is observed for a) evidence of detonation, deflagration, or explosion of the total contents; and b) potentially hazardous fragments. The test is recorded using regular video with audio from two angles and visual distance marking devices. A substance shows explosive properties under confinement during fast cook-off which detonates or reacts violently with fragments thrown more than 15 meters.

7.10.2 *Test Configuration*

The pipe nipples utilized were 1-1/2 inch standard A106B seamless pipe (1.90 inches outer diameter, 0.145 inch wall, 1.61 inch inner diameter) cut to a length of 7-7/8 inches. The end caps were 1-1/2 inch standard threaded caps. Three pipes were loaded for each of the eight products (twenty-four capped pipes total). The capped pipes were secured to the grating immediately before each end cap using baling wire. The following figure and photo illustrate the configuration of the confined samples.

Figure 5: Confined Samples for the EIS External Fire Test

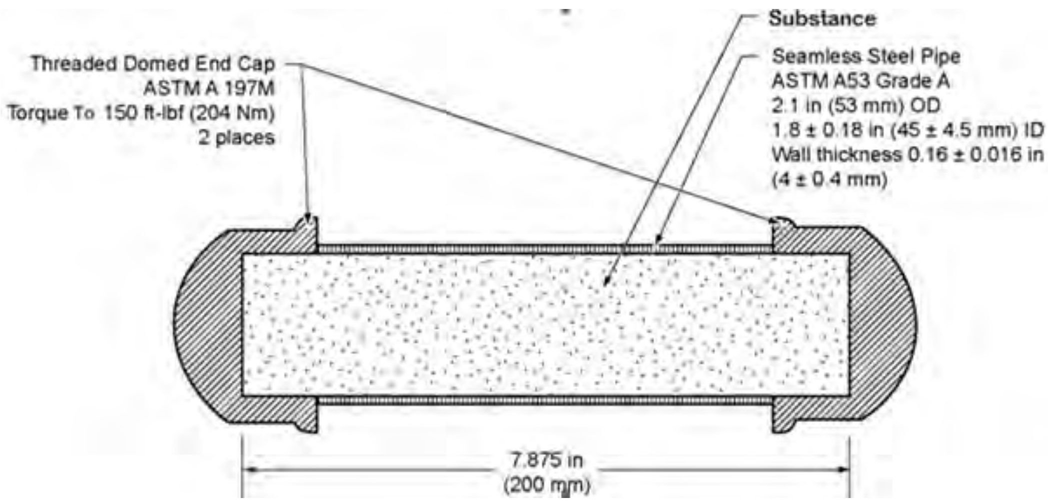


Photo 94: EIS External Fire Test Setup

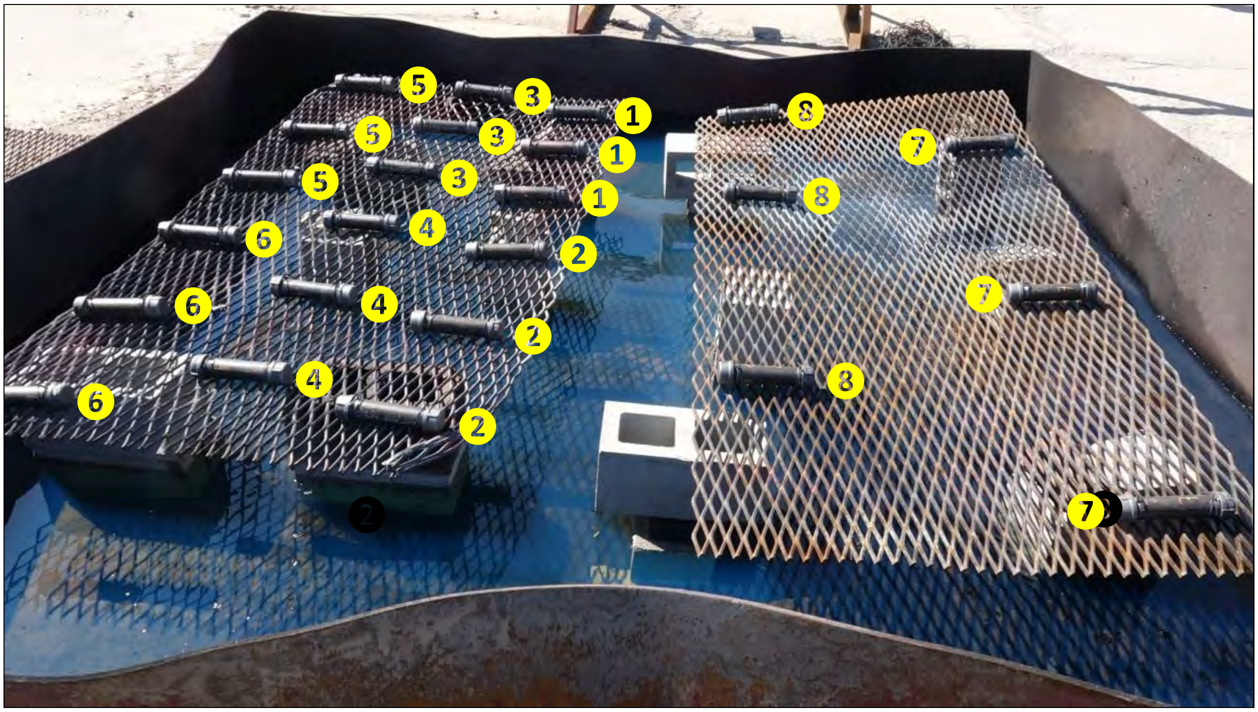
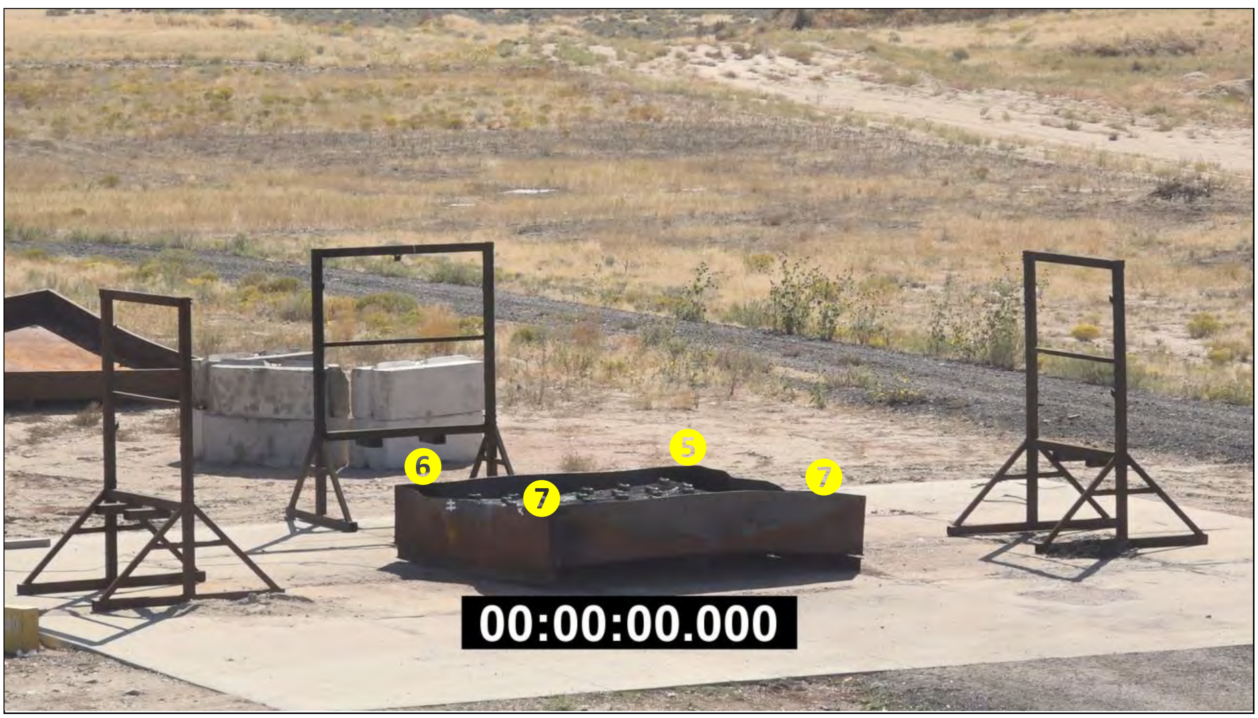


Photo 95: EIS External Fire Test Setup



The fuel basin (12-ft square, 2-ft high walls) was 0.5 meters larger than the stack in every direction. The fuel basin was filled with approximately 600 gallons of Jet-A fuel with 10 inches from the packages to the fuel surface. The environmental conditions at the start of the test were 1.3 m/s wind, 16°C, 32% relative humidity.

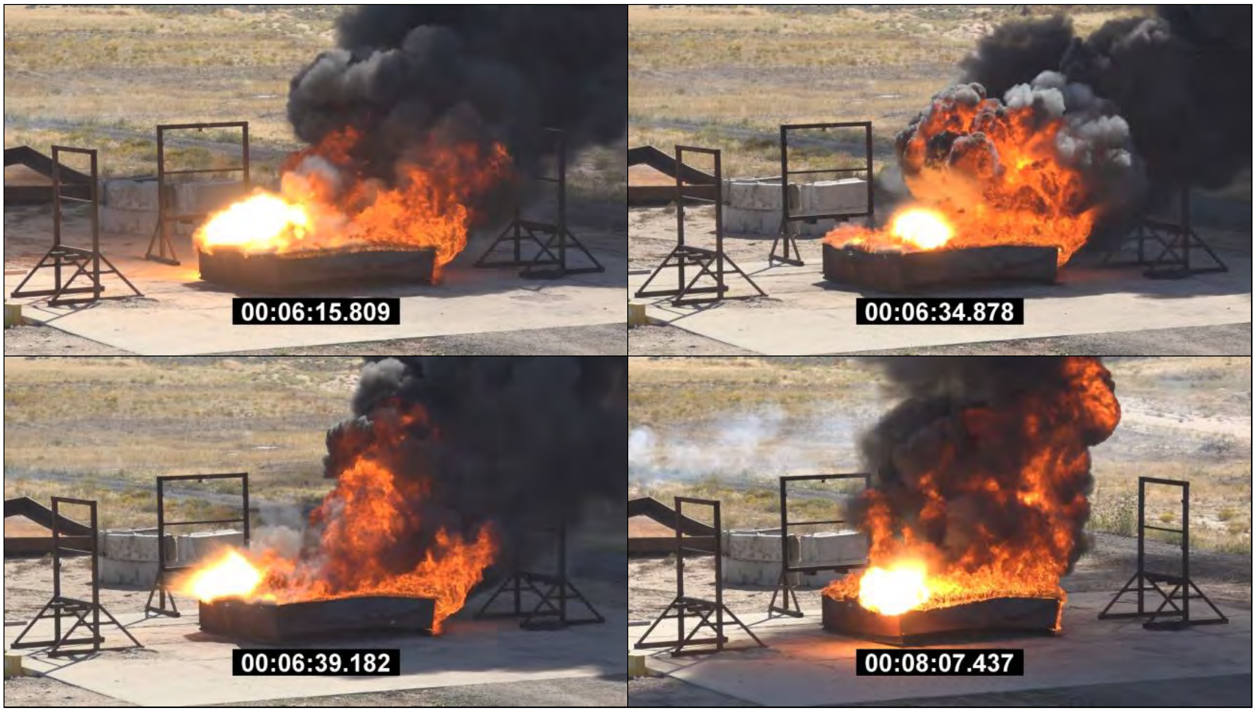
7.10.3 *Test Results*

A total of twenty-four samples were initially secured to the grating. A total of fourteen reactions were observed during the test; a total of four reactions were not detected. The following photo shows the start and time of occurrence of each reaction. The reactions varied in origin, intensity, and severity.

Photo 96: EIS External Fire Test Progression - Flames of Fire (typical)

Photo 97: EIS External Fire Test Progression - Visible Reactions of Samples (typical)


00:04:07.864
00:04:49.039
00:04:50.624
00:04:55.762
00:05:00.467
00:05:17.801
00:05:18.952
00:05:27.010



The duration of the bonfire was 65 minutes. Upon post-test inspection, ten samples remained secured to the grating, of which six samples (Mix ID's #2 and #3) were unreacted.

Photo 98: EIS External Fire Test Results - Pipes Still Secured to the Steel Grating

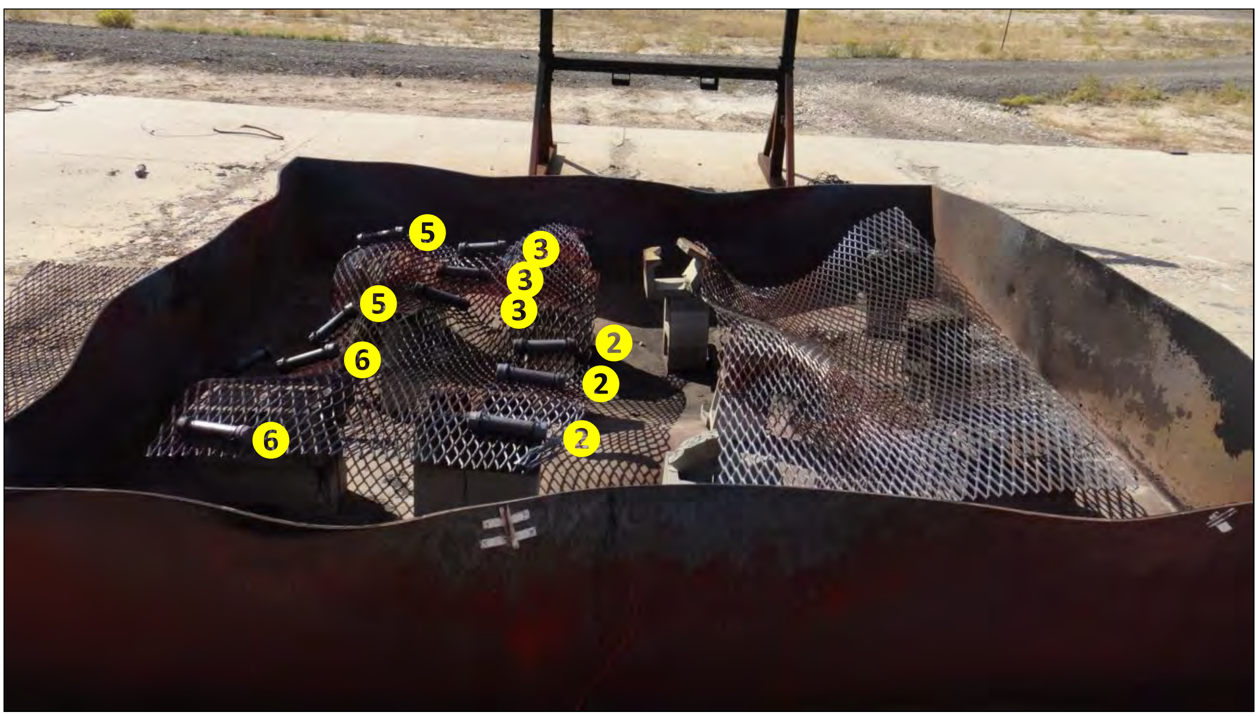


Photo 99: EIS External Fire Test Results - Unreacted Pipes

A total of seventeen reacted pipes were recovered as shown in the following photo; only one pipe was not found. A total of eight of the recovered reacted pipes were missing their end caps. Pipes thrown from the fuel basin and recovered include:

- Mix #1: 31 and 4 m
- Mix #7: 12 m
- Mix #8: 20 and 1 m
- Unknown ID: 19, 9, and 1 m

Photo 100: EIS External Fire Test Results - Reacted Pipes

Table 26: Summary of UN Series 7(e) Test Results

Item	Sample	Conditions and Results	Assessment
1	Fine Al-Fe_2O_3 Thermite - Mix ID #1 (SMS mixed)	The three samples ignited, separating end cap from pipe and propelling the pipe beyond 15 meters.	**Elevated reaction hazard (Class 1) when heated under confinement**
2	Coarse Al-Fe_2O_3 Thermite A - Mix ID #2 (Commercial)	There was no reaction of the three samples.	No reaction when heated under confinement
3	Coarse Al-Fe_2O_3 Thermite B - Mix ID #3 (Commercial)	There was no reaction of the three samples.	No reaction when heated under confinement

Item	Sample	Conditions and Results	Assessment
4	Fine Al-CuO Thermite - Mix ID #4 (SMS mixed)	Samples ignited; inconclusive whether the reaction resulted in separating end cap from pipe and propelling the pipe beyond 15 meters (Mix ID indiscernible).	Reaction does not appear to be elevated when heated under confinement (inconclusive)
5	Medium Al-CuO Thermite - Mix ID #5 (Commercial)	Samples ignited; inconclusive whether the reaction resulted in separating end cap from pipe and propelling the pipe beyond 15 meters (Mix ID indiscernible).	Reaction does not appear to be elevated when heated under confinement (inconclusive)
6	Fine Al-Ni_2O_3 Thermite - Mix ID #6 (SMS mixed)	Samples ignited; inconclusive whether the reaction resulted in separating end cap from pipe and propelling the pipe beyond 15 meters (Mix ID indiscernible).	Reaction does not appear to be elevated when heated under confinement (inconclusive)
7	Fine Al-CuO Thermite - Mix ID #4 (SMS mixed)	The three samples ignited, separating end cap from pipe and propelling the pipe beyond 15 meters.	**Elevated reaction hazard (Class 1) when heated under confinement**
8	Fine Mg&Al-MoO_3-CuO Thermite - Mix ID #8 (SMS mixed)	The three samples ignited, separating end cap from pipe and propelling the pipe beyond 15 meters.	**Elevated reaction hazard (Class 1) when heated under confinement**

7.10.4 *Assessment of Test Results*

Three of the thermites failed the UN Series 7 (e) EIS External Fire Tests: Fine Al-Fe_2O_3 Thermite - Mix ID #1 (SMS mixed) Fine Al-CuO Thermite - Mix ID #4 (SMS mixed) and the Fine Mg&Al-MoO_3-CuO Thermite - Mix ID #8 (SMS mixed). In each case three samples ignited, separating end cap from pipe and propelled the pipe beyond 15 meters. This the thermites are Class 1 when heated under confinement.

7.11 UN Test N.1 Test method for readily combustible solids

7.11.1 *Test Description*

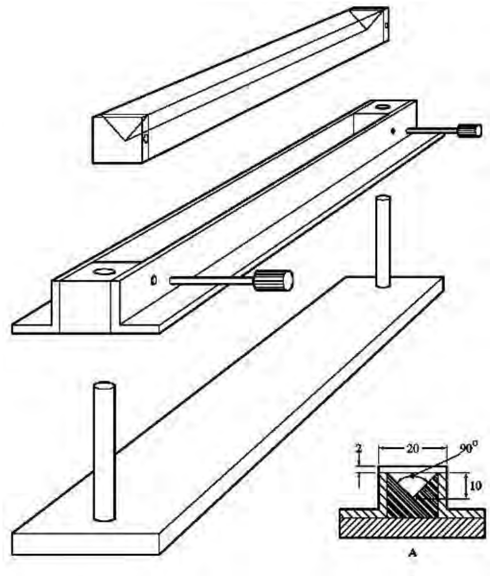
UN Test N.1 is used to determine the ability of a substance to propagate combustion.

For the preliminary screening test, the substance is formed into an unbroken strip or powder train about 250 mm long by 20 mm wide by 10 mm high on a cool, impervious, low heat-conducting base plate. A hot flame (minimum temperature 1000°C) from a gas torch (minimum diameter 5 mm) is applied to one end of the powder train until the powder ignites or for a maximum of 2 minutes (5 minutes for powders of metals or metal-alloys). It is noted whether combustion propagates along 200 mm of the train within the 2-minute test period (or 20 minutes for metal powders). If the substance does not ignite and propagate combustion either by burning with flame or smoldering along 200 mm of the powder train within the 2 minute test period (or 20 minutes), then the substance is not classified as a flammable solid and no further testing is required. If the substance propagates burning of a 200 mm length of the powder train in less than 2 minutes or 20 minutes for metal powders, the full test program is carried out to determine the severity of reaction.

For the burning rate test, the powdered or granular substance, in its commercial form, is loosely filled into the mold. The mold is then dropped three times from a height of 20 mm onto a solid surface. The lateral limitations are then removed and the impervious, non-combustible, low heat-conducting plate is placed on top of the mold, the apparatus inverted and the mold removed. For substances other than metal powders, 1 ml of a wetting solution is added to the pile 30 - 40 mm beyond the 100 mm timing zone; the wetting solution is applied to the ridge drop by drop, ensuring the whole cross-section of the pile is wetted without loss of liquid from the sides (wetting agents free from combustible diluents may be added if necessary). Any suitable ignition source such as a small flame or a hot wire of minimum temperature 1,000 ºC is used to ignite the pile at one end. When the pile has burned a distance of 80 mm, the rate of burning is measured over the next 100 mm. For substances other than metal powders, it is noted whether or not the wetted zone stops propagation of the flame for at least 4 minutes. The test is performed six times using a clean cool plate each time, unless a positive result is observed earlier.

Powdered, granular or pasty substances are classified in Division 4.1 when the time of burning of one or more of the test runs is less than 45 seconds or the rate of burning is more than 2.2 mm/s.

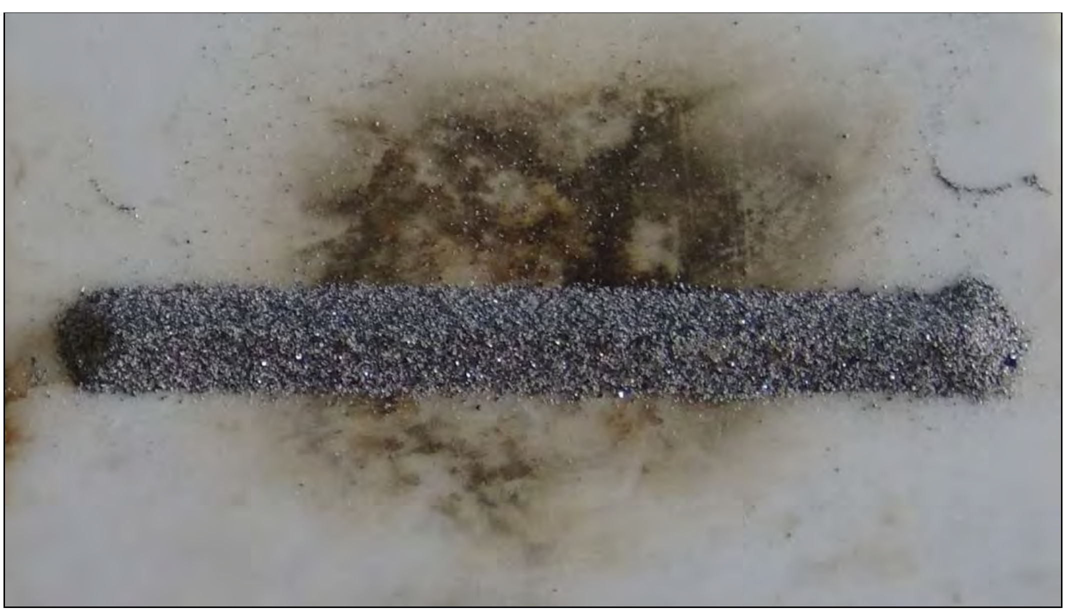
Figure 6: Burning Rate Test - Triangular Mold for Forming the Powder Train Pile.



7.11.2 *Test Configuration*

For the gas torch trials, the hot flame was provided by a MAP-Pro gas torch with a flame temperature of over 2000 °C and a flame diameter of approximately 25 mm. For the hot wire trials, an 18-gauge 80/20 nickel/chromium resistance heating wire (Type A) was supplied with 23 Amps to achieve the test temperature of around 1000 °C. The photo below shows a typical test configuration.

Photo 101: Readily Combustible Solids Test Setup (typical)



7.11.3 *Test Results*

The test results for ignition by 2000 °C gas torch are summarized in the following table.

Table 27: Summary for UN Test N.1 "Test Method for Readily Combustible Solids" - Ignition by 2000 °C Gas torch

Item	Sample	Conditions and Results	Assessment
1	Fine Al-Fe_2O_3 Thermite - Mix ID #1 (SMS mixed)	Sample ignited; burning time of powder train pile too fast to be measured (less than 0.1 seconds for the entire 200mm length).	**Rapid burning consistent more with the hazard of Class 1 explosives**
2	Coarse Al-Fe_2O_3 Thermite A - Mix ID #2 (Commercial)	Combustion of the sample did not propagate in 5 minutes. *NOTE: Sample could ignite by employing a thermite starting powder or heating element, with only partial propagation down the powder train pile (100 mm) over 50.7 seconds.*	Consistent with exclusion from Division 4.1
3	Coarse Al-Fe_2O_3 Thermite B - Mix ID #3 (Commercial)	Combustion of the sample did not propagate in 5 minutes. *NOTE: Supplemental magnesium strip was also unable to ignite the sample.*	Consistent with exclusion from Division 4.1
4	Fine Al-CuO Thermite - Mix ID #4 (SMS mixed)	Sample ignited but the reaction did not propagate down the powder train pile.	Consistent with exclusion from Division 4.1
5	Medium Al-CuO Thermite - Mix ID #5 (Commercial)	For Trial 1, the sample ignited with a burning time of approximately 2 seconds for the entire length of the powder train pile. For Trial 2, the sample ignited but the reaction did not propagate down the powder train pile.	**Consistent with Division 4.1, packing group II**
6	Fine Al-Ni_2O_3 Thermite - Mix ID #6 (SMS mixed)	Sample ignited but the reaction did not propagate down the powder train pile.	Consistent with exclusion from Division 4.1

Item	Sample	Conditions and Results	Assessment
7	Fine Al-MnO_2 Thermite - Mix ID #7 (SMS mixed)	Sample ignited; nearly instantaneous consumption of the powder train pile (explosion with less than 0.03 seconds for the entire 200mm length).	**Explosion consistent more with the hazard of Division 1.1 explosives**
8	Fine Mg&Al-MoO_3-CuO Thermite - Mix ID #8 (SMS mixed)	Sample ignited; nearly instantaneous consumption of the powder train pile (explosion with less than 0.03 seconds for the entire 200mm length).	**Explosion consistent more with the hazard of Division 1.1 explosives**

The test results are shown in the following photos.

Photo 102: Readily Combustible Test Results - Gas Torch for Fine Al-Fe_2O_3 Thermite - Mix ID #1 (SMS mixed) with Ignition and Rapid Burning

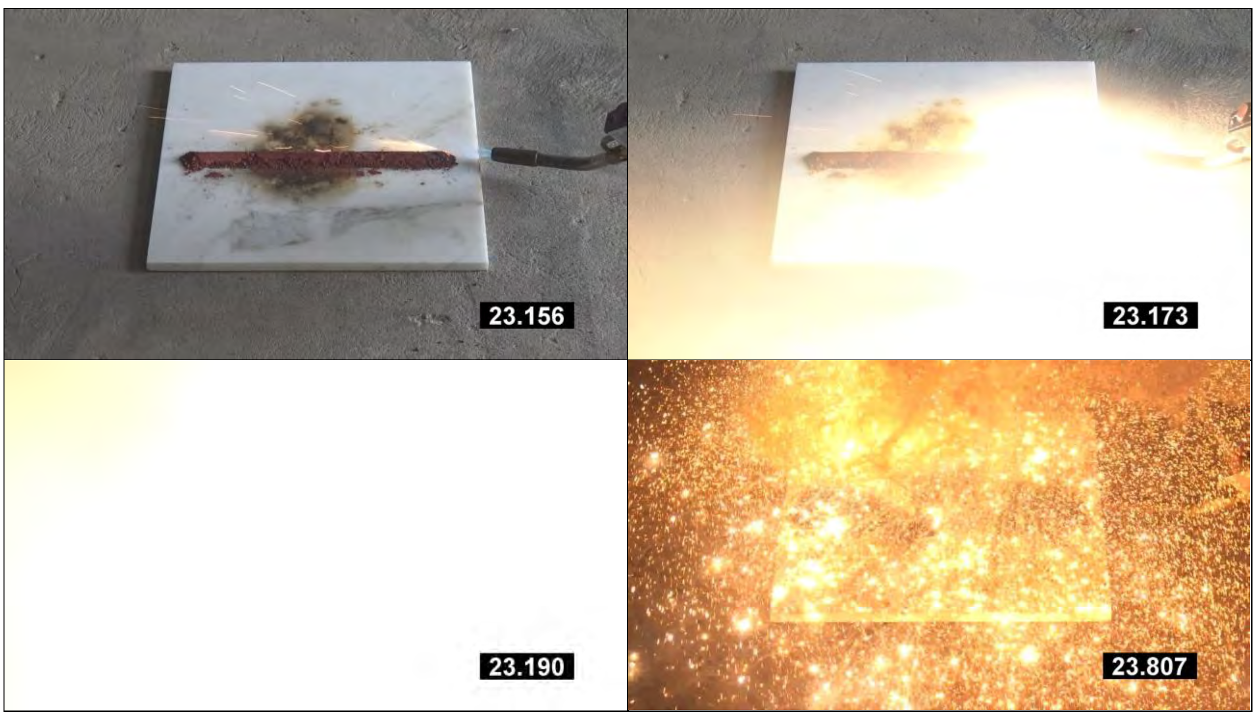


Photo 103: Readily Combustible Test Results - Gas Torch for Coarse Al-Fe_2O_3 Thermite A - Mix ID #2 (Commercial) with No Reaction in 5 minutes

Photo 104: Readily Combustible Test Results - Gas Torch & Magnesium Strip for Coarse Al-Fe_2O_3 Thermite A - Mix ID #2 (Commercial) with Ignition without Propagation

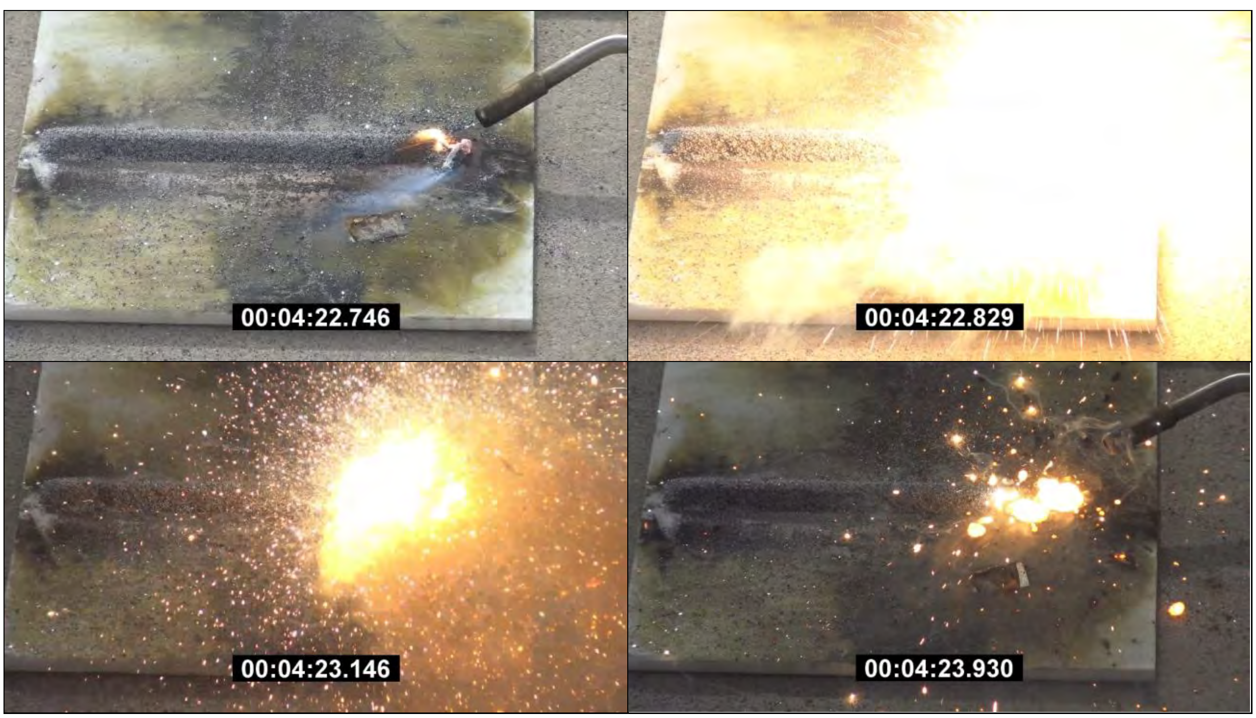


Photo 105: Readily Combustible Test Results - Gas Torch, Sparkler & Thermite Starter Powder for Coarse Al-Fe_2O_3 Thermite A - Mix ID #2 (Commercial) with Ignition and Partial Propagation over 50.7 seconds

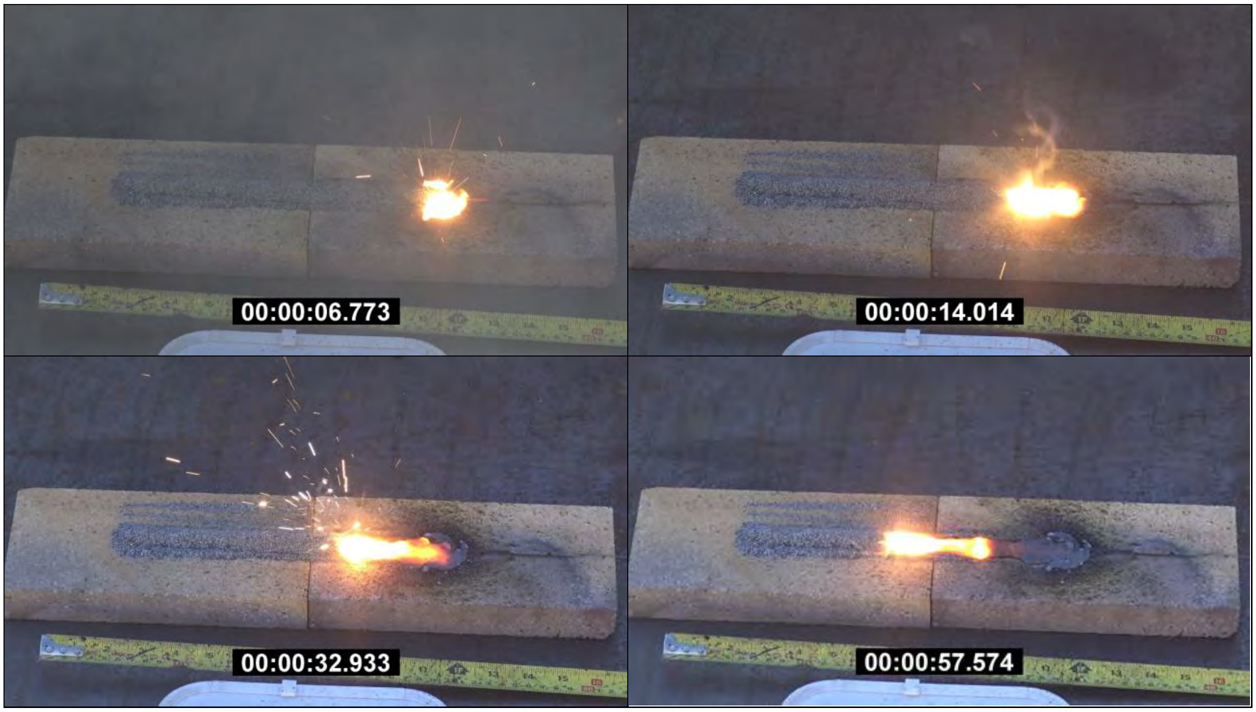


Photo 106: Readily Combustible Test Results - Gas Torch for Coarse Al-Fe_2O_3 Thermite B - Mix ID #3 (Commercial) with No Reaction in 5 minutes

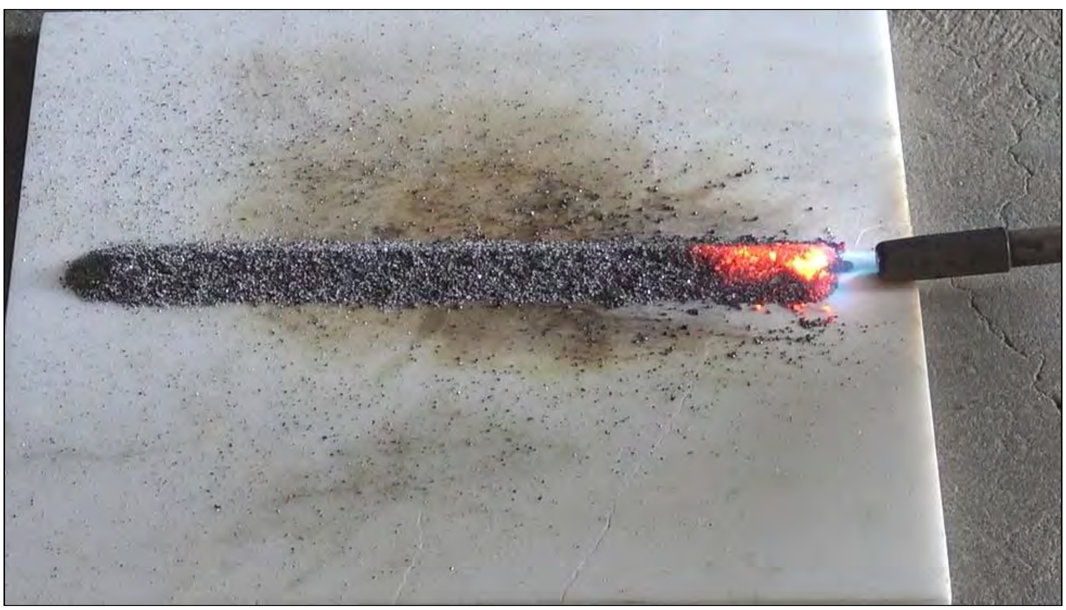


Photo 107: Readily Combustible Test Results - Gas Torch for Fine Al-CuO Thermite - Mix ID #4 (SMS mixed) with Ignition but No Propagation in 5 minutes

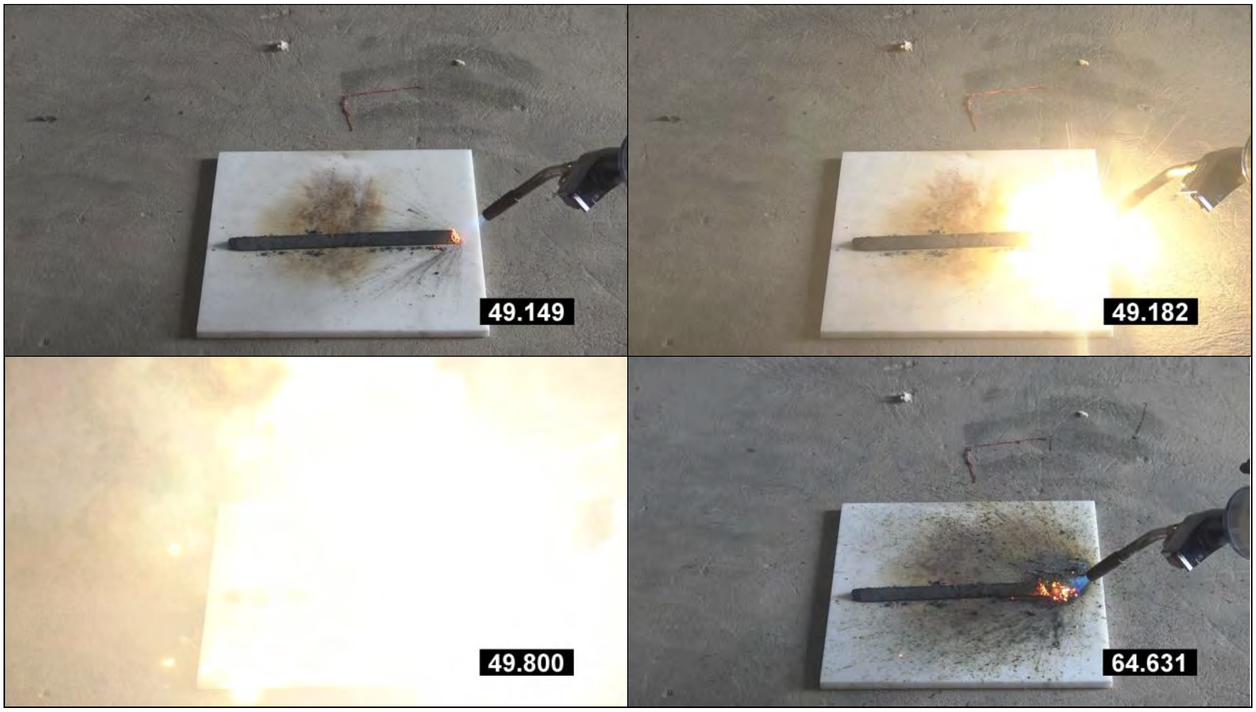


Photo 108: Readily Combustible Test Results - Gas Torch for Medium Al-CuO Thermite - Mix ID #5 (Commercial) with Ignition and Propagation (Trial 1)

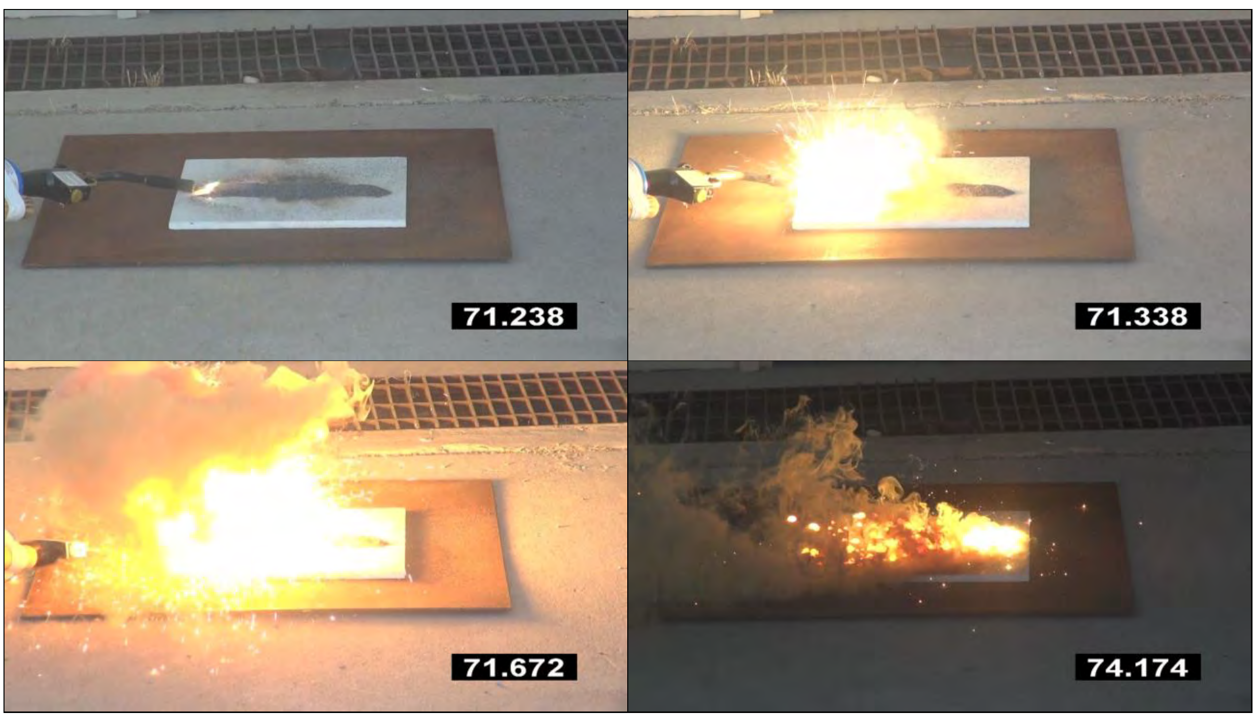


Photo 109: Readily Combustible Test Results - Gas Torch for Medium Al-CuO Thermite - Mix ID #5 (Commercial) with Ignition and Propagation (Trial 2)

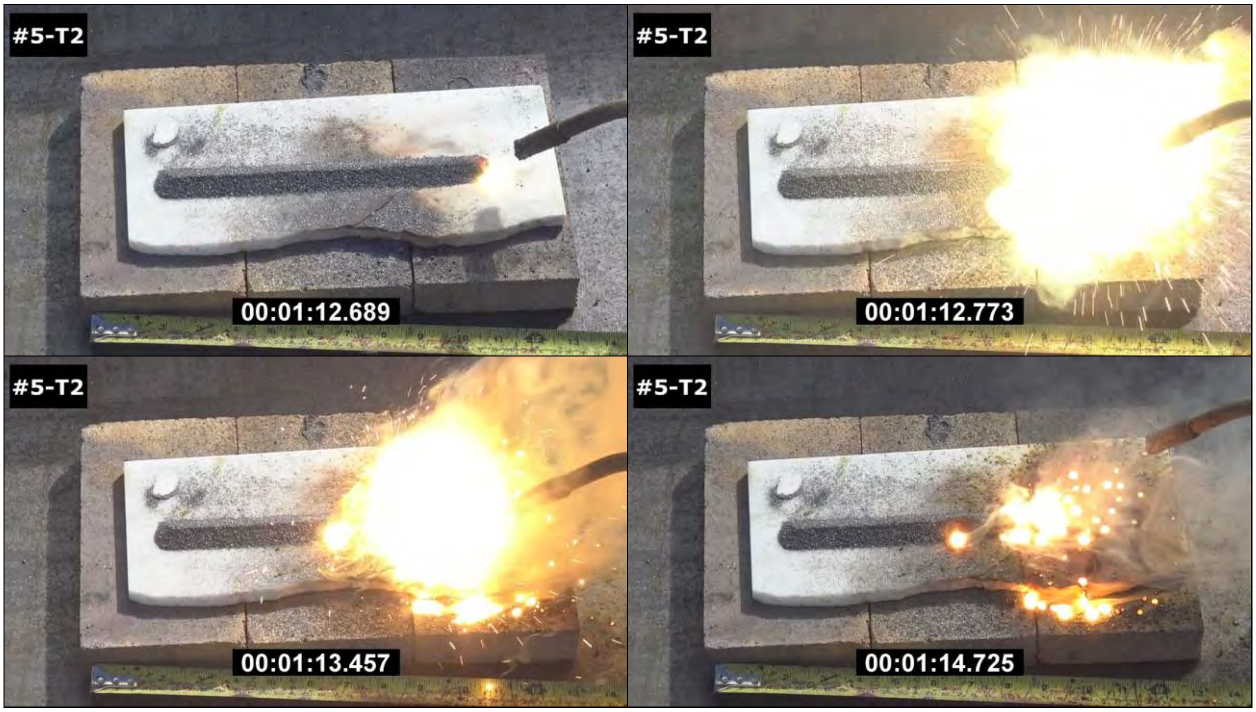


Photo 110: Readily Combustible Test Results - Gas Torch for Fine Al-Ni_2O_3 Thermite - Mix ID #6 (SMS mixed) with Ignition and Partial Propagation over 6.2 seconds

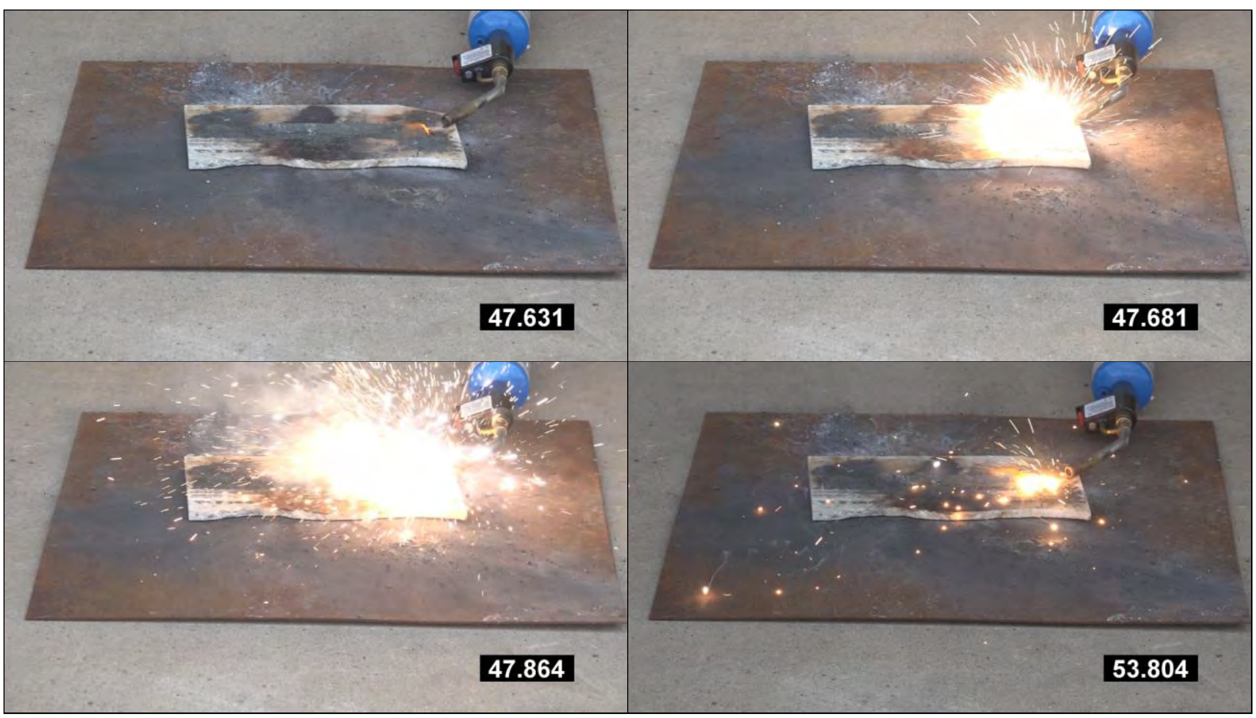


Photo 111: Readily Combustible Test Results - Gas Torch for Fine Al-MnO_2 Thermite - Mix ID #7 (SMS mixed) with Ignition and Explosion

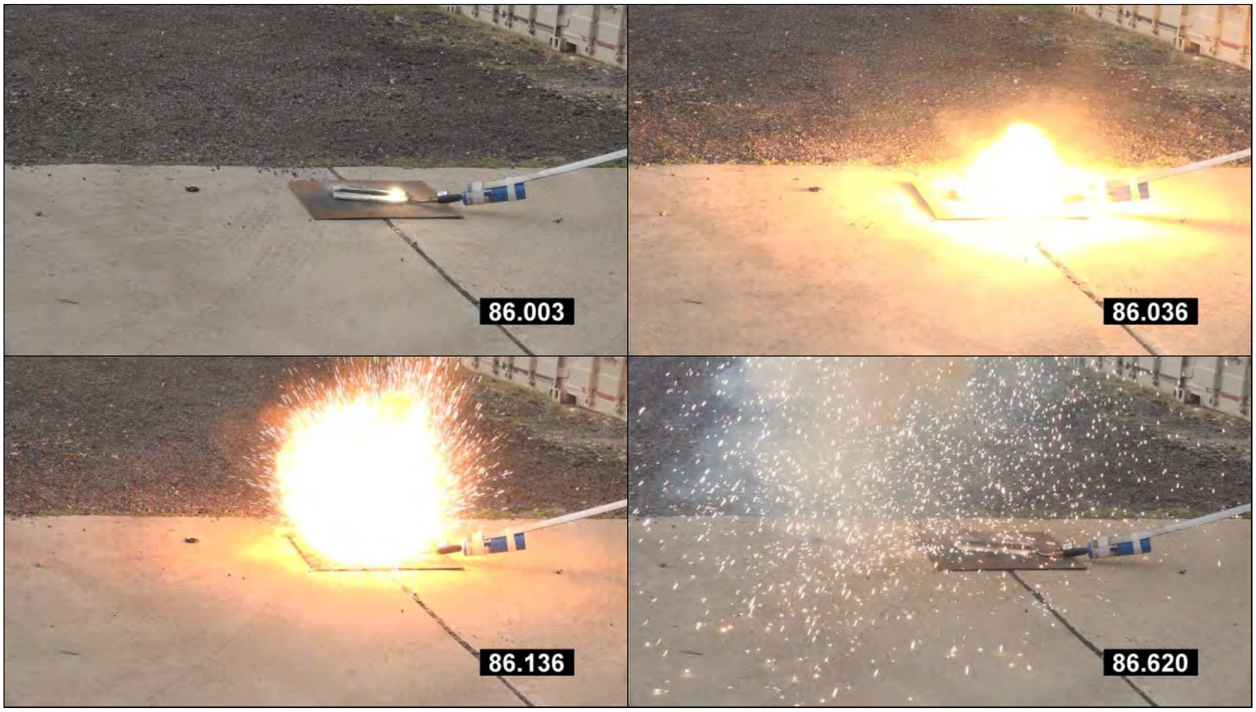
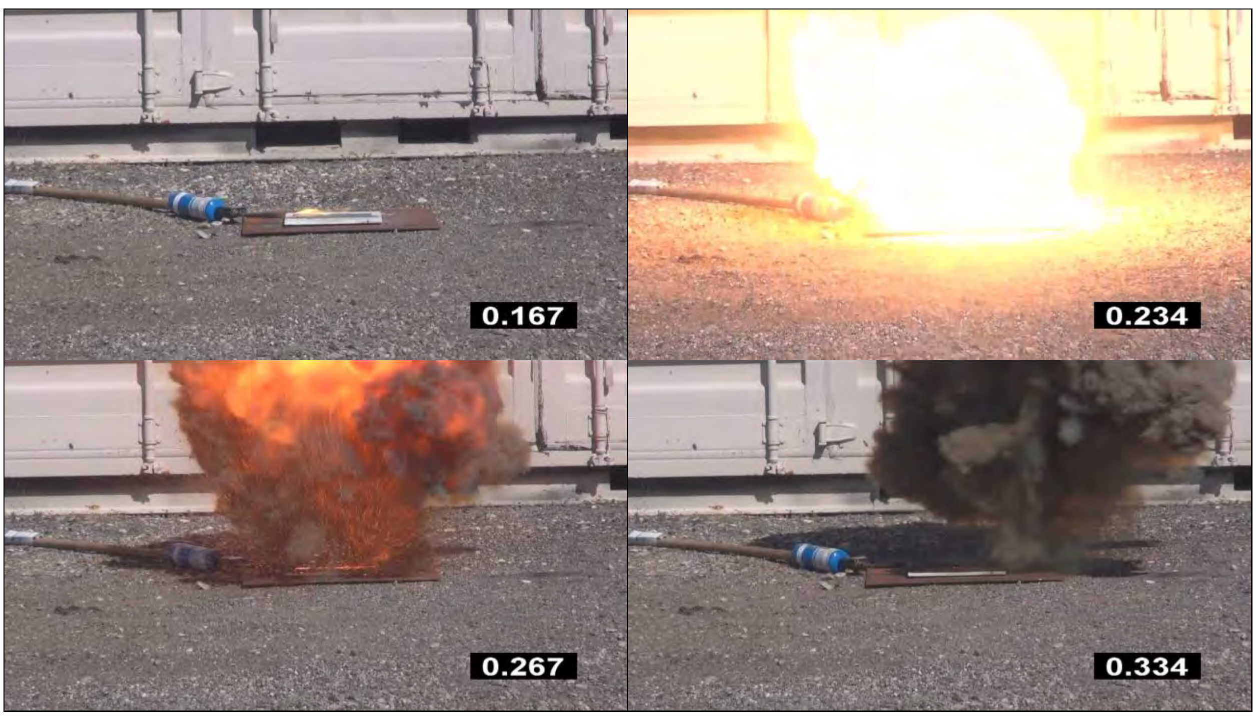


Photo 112: Readily Combustible Test Results - Gas Torch for Fine Mg&Al-MoO_3-CuO Thermite - Mix ID #8 (SMS mixed) with Ignition and Explosion



The test results for ignition by 1000 °C hot wire are summarized in the following table.

Table 28: Summary for UN Test N.1 "Test Method for Readily Combustible Solids" - Ignition by 1000 °C Hot Wire

Item	Sample	Conditions and Results	Assessment
1	Fine Al-Fe_2O_3 Thermite - Mix ID #1 (SMS mixed)	Sample ignited; burning time of powder train 0.3 seconds for the entire 200mm length.	**Rapid burning consistent more with the hazard of Class 1 explosives**
2	Coarse Al-Fe_2O_3 Thermite A - Mix ID #2 (Commercial)	Combustion of the sample did not propagate in 5 minutes. NOTE: Sample ignited with heating element but the reaction did not propagate down the powder train pile.	Consistent with exclusion from Division 4.1
3	Coarse Al-Fe_2O_3 Thermite B - Mix ID #3 (Commercial)	Combustion of the sample did not propagate in 5 minutes.	Consistent with exclusion from Division 4.1
4	Fine Al-CuO Thermite - Mix ID #4 (SMS mixed)	Sample ignited but the reaction did not propagate down the powder train pile.	Consistent with exclusion from Division 4.1
5	Medium Al-CuO Thermite - Mix ID #5 (Commercial)	Sample ignited but the reaction did not propagate down the powder train pile.	Consistent with exclusion from Division 4.1
6	Fine Al-Ni_2O_3 Thermite - Mix ID #6 (SMS mixed)	Sample ignited but the reaction did not propagate down the powder train pile.	Consistent with exclusion from Division 4.1

Item	Sample	Conditions and Results	Assessment
7	Fine Al-MnO_2 Thermite - Mix ID #7 (SMS mixed)	Sample ignited; nearly instantaneous consumption of the powder train pile (explosion with less than 0.03 seconds for the entire 200mm length).	**Explosion consistent more with the hazard of Division 1.1 explosives**
8	Fine Mg&Al-MoO_3-CuO Thermite - Mix ID #8 (SMS mixed)	Sample ignited; nearly instantaneous consumption of the powder train pile (explosion with less than 0.03 seconds for the entire 200mm length).	**Explosion consistent more with the hazard of Division 1.1 explosives**

The test results are shown in the following photos.

Photo 113: Readily Combustible Test Results - Hot Wire for Fine Al-Fe_2O_3 Thermite - Mix ID #1 (SMS mixed) with Ignition and Full Propagation over 0.3 seconds

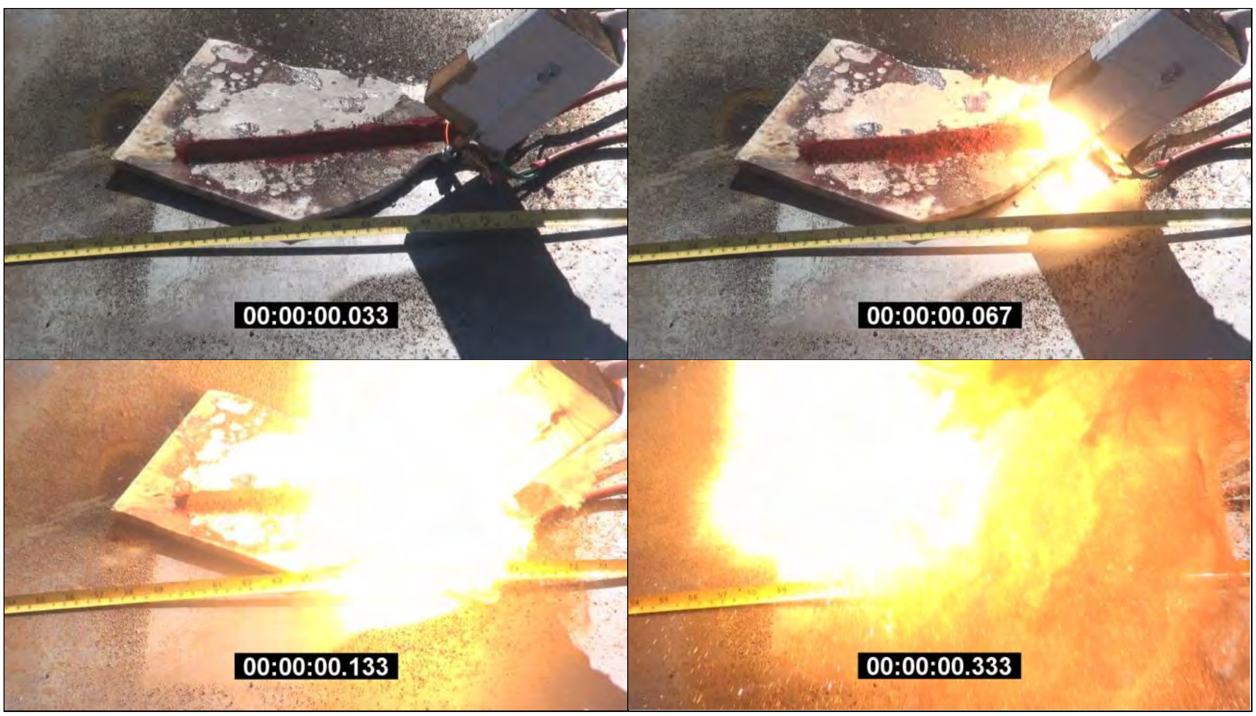


Photo 114: Readily Combustible Test Results - Hot Wire for Coarse Al-Fe_2O_3 Thermite A - Mix ID #2 (Commercial) with No Reaction in 5 minutes

Photo 115: Readily Combustible Test Results - Heating Element for Coarse Al-Fe_2O_3 Thermite A - Mix ID #2 (Commercial) with Ignition and Partial Propagation over 22 seconds

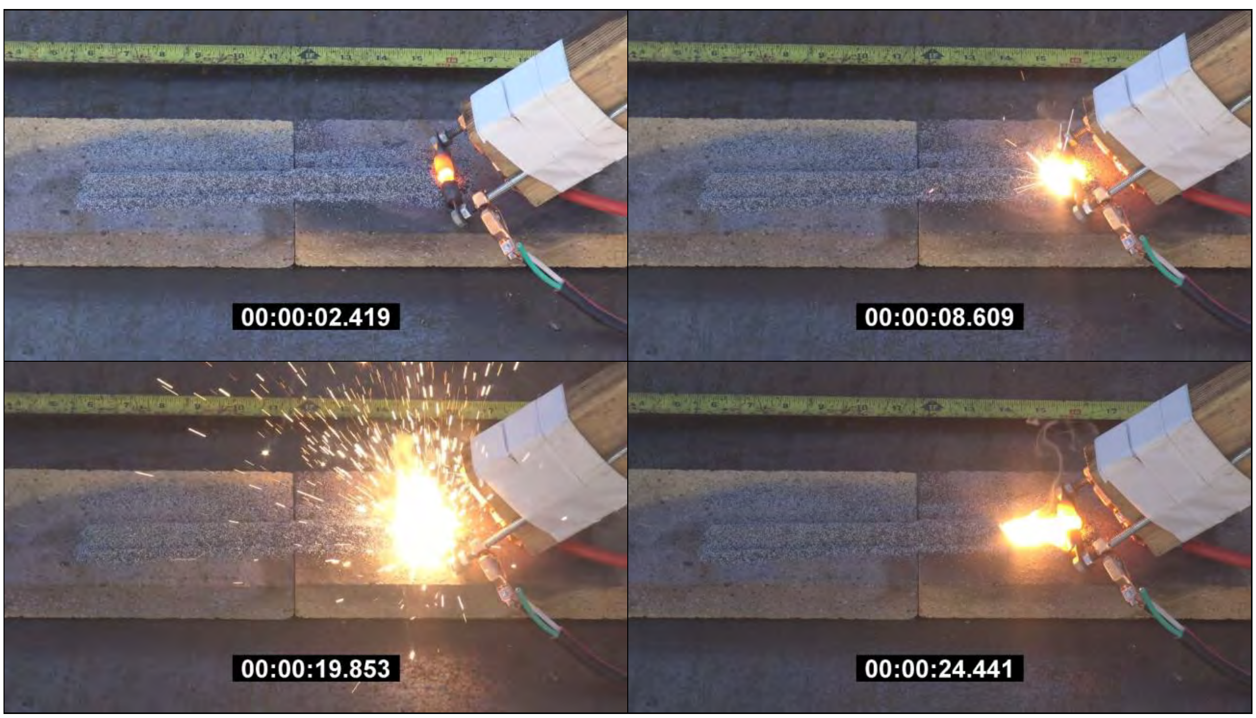


Photo 116: Readily Combustible Test Results - Hot Wire for Coarse Al-Fe_2O_3 Thermite B - Mix ID #3 (Commercial) with No Reaction in 5 minutes

Photo 117: Readily Combustible Test Results - Hot Wire for Fine Al-CuO Thermite - Mix ID #4 (SMS mixed) with Ignition and Partial Propagation over 1.4 seconds

Photo 118: Readily Combustible Test Results - Hot Wire for Medium Al-CuO Thermite - Mix ID #5 (Commercial) with Ignition and Partial Propagation over 2.4 seconds

Photo 119: Readily Combustible Test Results - Hot Wire for Fine Al-Ni_2O_3 Thermite - Mix ID #6 (SMS mixed) with Ignition and Partial Propagation over 9.3 seconds

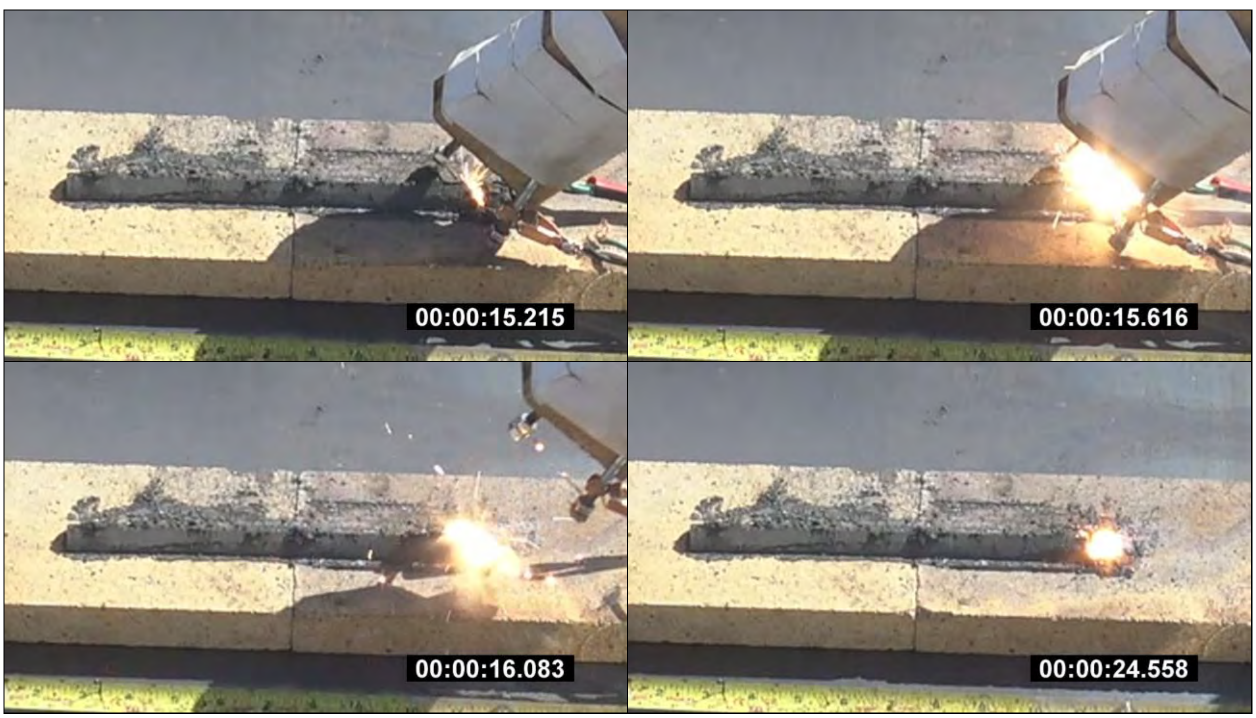


Photo 120: Readily Combustible Test Results - Hot Wire for Fine Al-MnO_2 Thermite - Mix ID #7 (SMS mixed) with Explosion

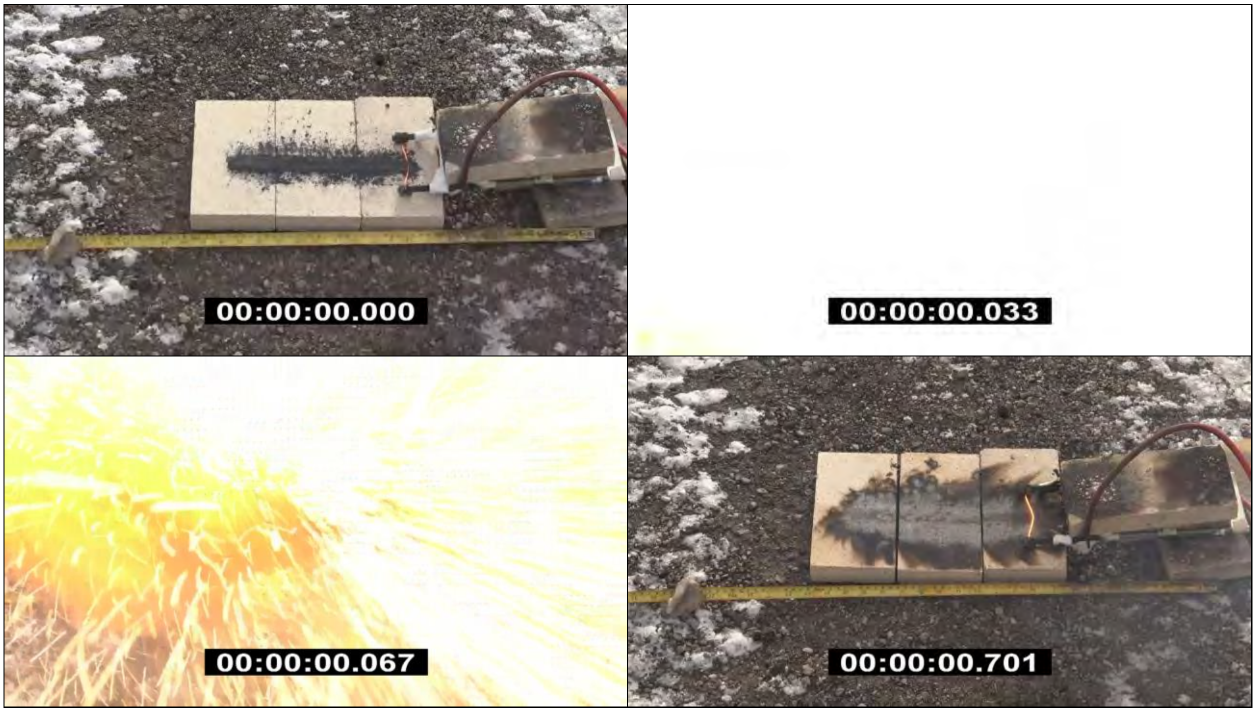


Photo 121: Readily Combustible Test Results - Hot Wire for Fine Mg&Al-MoO_3-CuO Thermite - Mix ID #8 (SMS mixed) with Explosion

7.11.4 *Assessment of Test Results*

Based on the UN Test N.1 gas torch and hot wire test results, the Fine Al-Fe2O3 Thermite - Mix ID #1 (SMS mixed), Fine Al-MnO_2 Thermite - Mix ID #7 (SMS mixed) and Fine Mg&Al-MoO_3-CuO Thermite - Mix ID #8 (SMS mixed) samples exhibited burn rates consistent with that of Division 1.1; the ignition and propagation of Mix ID's #2, #3, #4 and #6 were consistent with exclusion from Division 4.1. Burning of the Medium Al-CuO Thermite - Mix ID #5 (Commercial) sample was consistent with assignment into Division 4.1, packing group II.

7.12 Large-scale UN Test N.1 Test method for readily combustible solids

7.12.1 *Test Description*

The Large-scale UN Test N.1 is used to determine the ability of a bulk substance to propagate combustion.

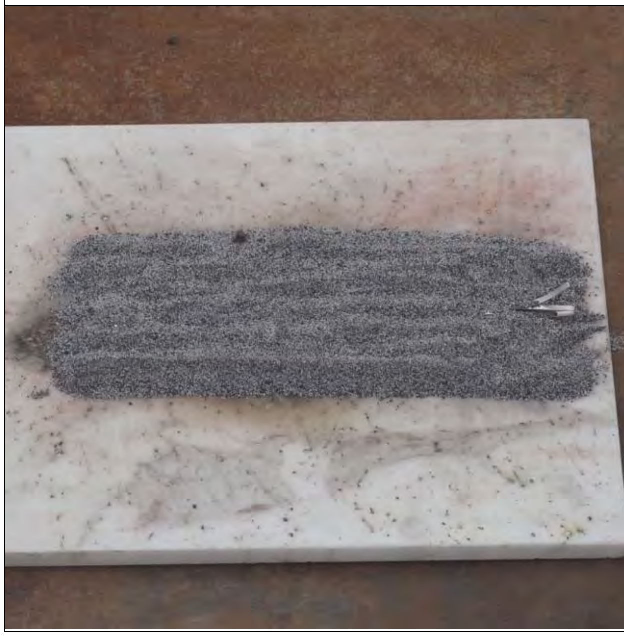
The test may be performed with the powdered or granular substance is formed into an unbroken strip or powder train approximately 250 mm long by 80 mm wide by 10 mm high on a cool, impervious, low heat-conducting base plate. Alternately, the substance is poured into a 60-mm diameter, 80-mm tall, low heat-conducting crucible bowl.

Any suitable ignition source is used to ignite the strip near the center of one end. The test is performed six times using a clean cool plate each time, unless a positive result is observed earlier. Powdered, granular or pasty substances are classified in Division 4.1 when the time of burning of one or more of the test runs is less than 45 seconds or the rate of burning is more than 2.2 mm/s.

7.12.2 *Test Configuration*

The crucible bowl had an 89-mm outer diameter, 9.5-mm wall thickness, and 89-mm height. For ignition by gas torch, a hot flame was provided by a MAP-Pro gas torch with a flame temperature of over 2000 °C and a flame diameter of approximately 25 mm. For ignition by hot wire, an 18-gauge 80/20 Nickel/Chromium resistance heating wire (Type A) was supplied with 23 Amps to achieve the test temperature of around 1000 °C. For compositions that were difficult to ignite, a hot flame was provided by an oxy-acetylene torch with a flame temperature of around 3500 °C and a flame diameter of approximately 3 mm. The photo below shows the typical test configurations.

Photo 122: Large-scale Readily Combustible Solids Test Setup (typical)

Flat Plate	Crucible Bowl
	

7.12.3 *Test Results*

The test results are summarized in the following table.

Table 29: Summary for Large-Scale UN Test N.1 "Test Method for Readily Combustible Solids"

Item	Sample	Conditions and Results	Assessment
1	Fine Al-Fe_2O_3 Thermite - Mix ID #1 (SMS mixed)	<u>Flat plate</u>: Sample ignited by gas torch and hot wire with full propagation (250mm) of powder over 0.5 seconds (500 mm/sec). <u>Crucible bowl</u>: Sample ignited by gas torch and pyrogen igniter (remote) with full consumption of powder over 0.5 seconds.	**Rapid burning consistent more with the hazard of Class 1 explosives**

Item	Sample	Conditions and Results	Assessment
2	Coarse Al-Fe_2O_3 Thermite A - Mix ID #2 (Commercial)	Flat plate & crucible bowl: Combustion of the sample did not propagate in 5 minutes when ignited by hot wire (plate) or gas torch (both). *Alternative ignition method:* Flat plate: Sample ignited by oxy-acetylene torch with full propagation (250mm) of powder over 10 seconds (25.0mm/sec). Crucible bowl: Sample ignited by oxy-acetylene torch with full consumption over 2.7 seconds.	Consistent with exclusion from Division 4.1 for standard ignition; **alternative ignition results in Division 4.1, packing group II**
3	Coarse Al-Fe_2O_3 Thermite B - Mix ID #3 (Commercial)	Flat plate & crucible bowl: Combustion of the sample did not propagate in 5 minutes when ignited by hot wire or gas torch. *Alternative ignition method:* Flat plate: Sample ignited by oxy-acetylene torch with partial propagation (170mm) of powder over 75 seconds (2.3 mm/sec). Sample ignited by gas torch (aided by a thermite starting powder) with partial propagation (140mm) of powder over 23 seconds (6.1 mm/sec).	**Burning rate > 2.2 mm/sec (consistent with Division 4.1, packing group II)**
4	Fine Al-CuO Thermite - Mix ID #4 (SMS mixed)	Flat plate: Sample ignited by torch and hot wire with full propagation (250mm) of powder over 1.3 - 2.1 seconds (119 - 192 mm/sec). Crucible bowl: Sample ignited by torch with full consumption of powder over 7.4 seconds.	**Rapid burning consistent more with the hazard of Class 1 explosives**
5	Medium Al-CuO Thermite - Mix ID #5 (Commercial)	Flat plate: Sample ignited by torch and hot wire with full propagation (250mm) of powder over 1.5 - 2.4 seconds (104 - 167mm/sec). Crucible bowl: Sample ignited by torch (aided by a thermite starting powder) with full consumption of powder over 6.4 seconds.	**Rapid burning consistent more with the hazard of Class 1 explosives**

Item	Sample	Conditions and Results	Assessment
6	Fine Al-Ni_2O_3 Thermite - Mix ID #6 (SMS mixed)	Flat plate: Sample ignited by torch and hot wire with full propagation (250mm) of powder over 36 - 75 seconds (3.3 - 6.9 mm/sec). Crucible bowl: Sample ignited by torch with full consumption of powder over 10.5 seconds.	**Burning rate > 2.2 mm/sec (consistent with Division 4.1, packing group II)**
7	Fine Al-MnO_2 Thermite - Mix ID #7 (SMS mixed)	Flat plate: Sample ignited by pyrogen igniter (flame) and hot wire with nearly instantaneous consumption of the powder (explosion with less than 0.03 seconds for the entire quantity): much faster than 8,000 mm/sec. Plate broken into pieces. Crucible bowl: Sample ignited by pyrogen igniter (flame) with nearly instantaneous consumption of the powder (explosion with less than 0.03 seconds for the entire quantity). No visible damage to crucible bowl.	**Explosion consistent more with the hazard of Division 1.1 explosives**
8	Fine Mg&Al-MoO_3-CuO Thermite - Mix ID #8 (SMS mixed)	Flat plate: Sample ignited by pyrogen igniter (flame) and hot wire with nearly instantaneous consumption of the powder (explosion with less than 0.03 seconds for the entire quantity): much faster than 8,000 mm/sec. Plate broken into pieces. Crucible bowl: Sample ignited by pyrogen igniter (flame) with nearly instantaneous consumption of the powder (explosion with less than 0.03 seconds for the entire quantity). No visible damage to crucible bowl.	**Explosion consistent more with the hazard of Division 1.1 explosives**

The test results are shown in the following photos.

Photo 123: Large-Scale Readily Combustible Test Results - Gas Torch on Plate for Fine Al-Fe_2O_3 Thermite - Mix ID #1 (SMS mixed) with Ignition and Full Consumption over 0.5 seconds

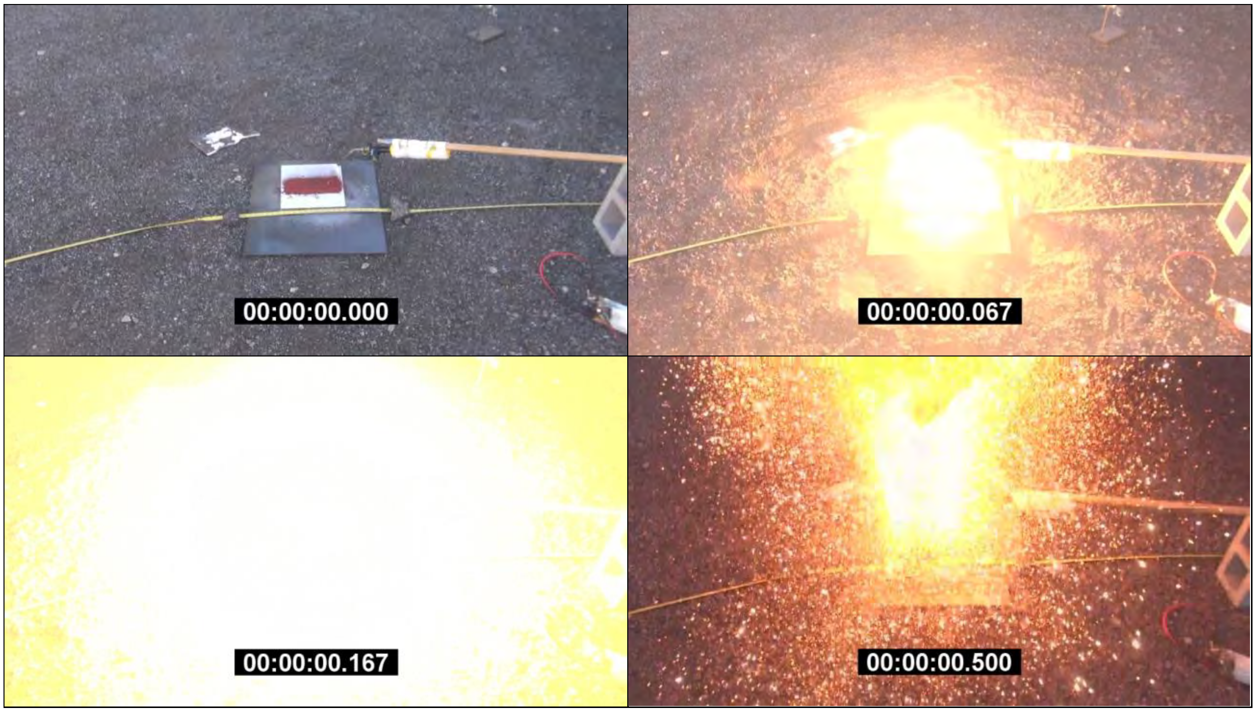


Photo 124: Large-Scale Readily Combustible Test Results - Hot Wire on Plate for Fine Al-Fe_2O_3 Thermite - Mix ID #1 (SMS mixed) with Ignition and Full Consumption over 0.5 seconds

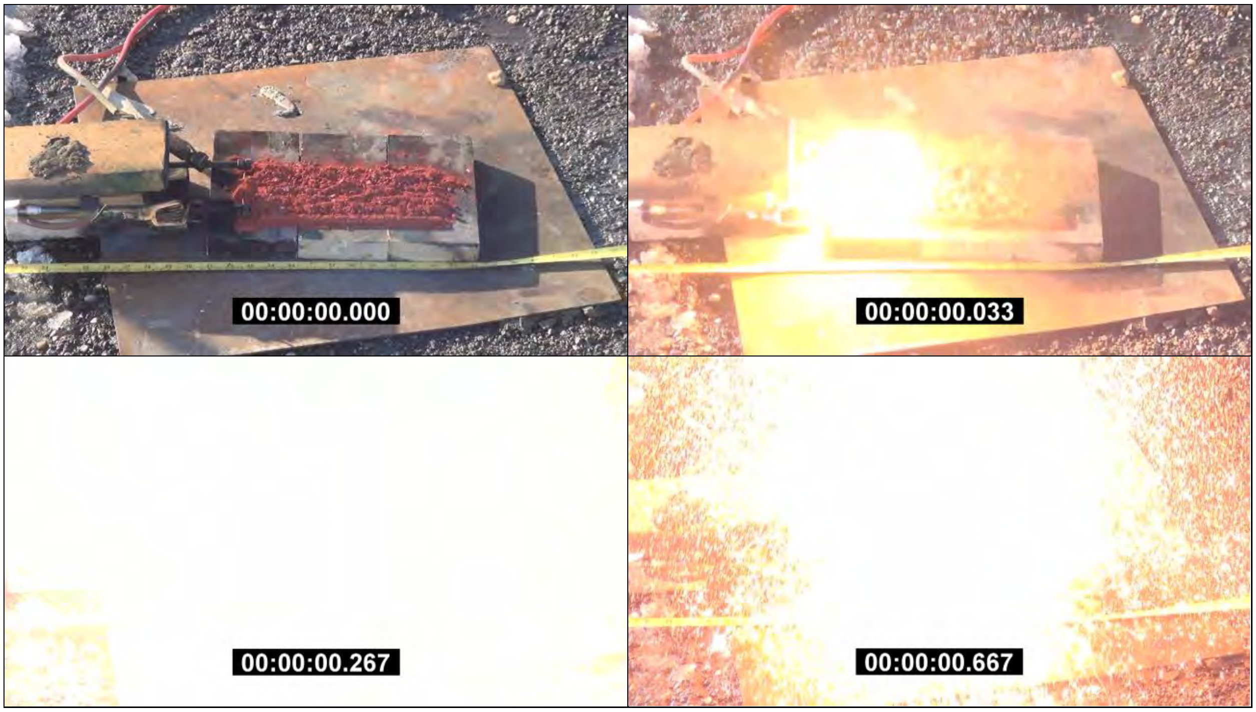


Photo 125: Large-Scale Readily Combustible Test Results - Gas Torch in Crucible for Fine Al-Fe_2O_3 Thermite - Mix ID #1 (SMS mixed) with Ignition and Full Consumption over 0.5 seconds

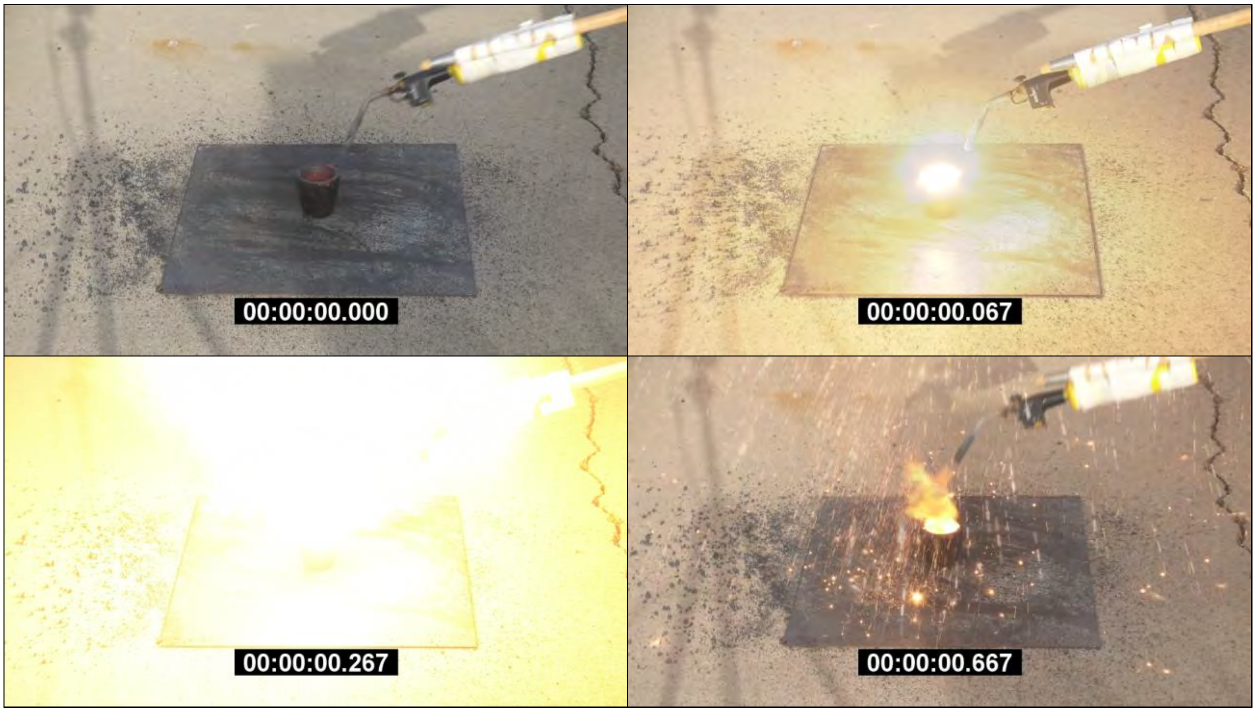


Photo 126: Large-Scale Readily Combustible Test Results - Pyrogen Match in Crucible for Fine Al-Fe_2O_3 Thermite - Mix ID #1 (SMS mixed) with Ignition and Full Consumption over 0.5 seconds

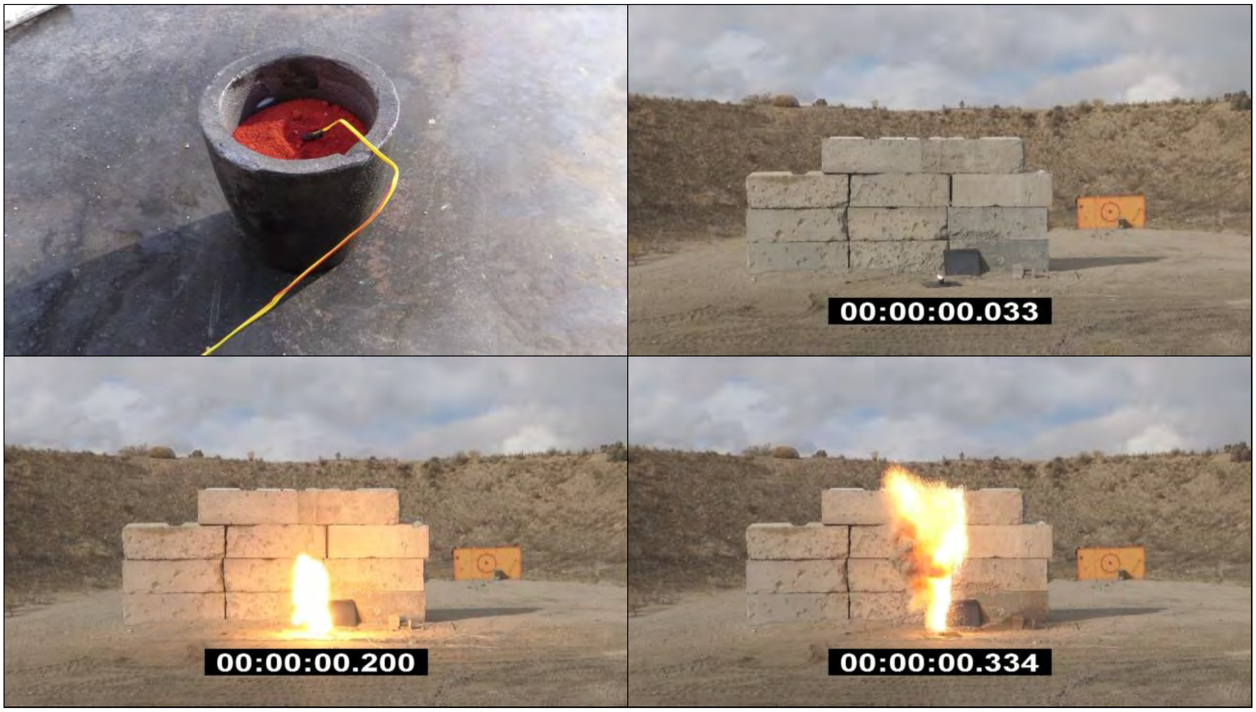


Photo 127: Large-Scale Readily Combustible Test Results - Gas Torch and Hot Wire on Plate / Crucible for Coarse Al-Fe_2O_3 Thermite A - Mix ID #2 (Commercial) without Ignition

Flat Plate

Crucible Bowl

Photo 128: Large-Scale Readily Combustible Test Results - Acetylene Torch on Plate for Coarse Al-Fe_2O_3 Thermite A - Mix ID #2 (Commercial) with Ignition and Full Consumption over 10 seconds

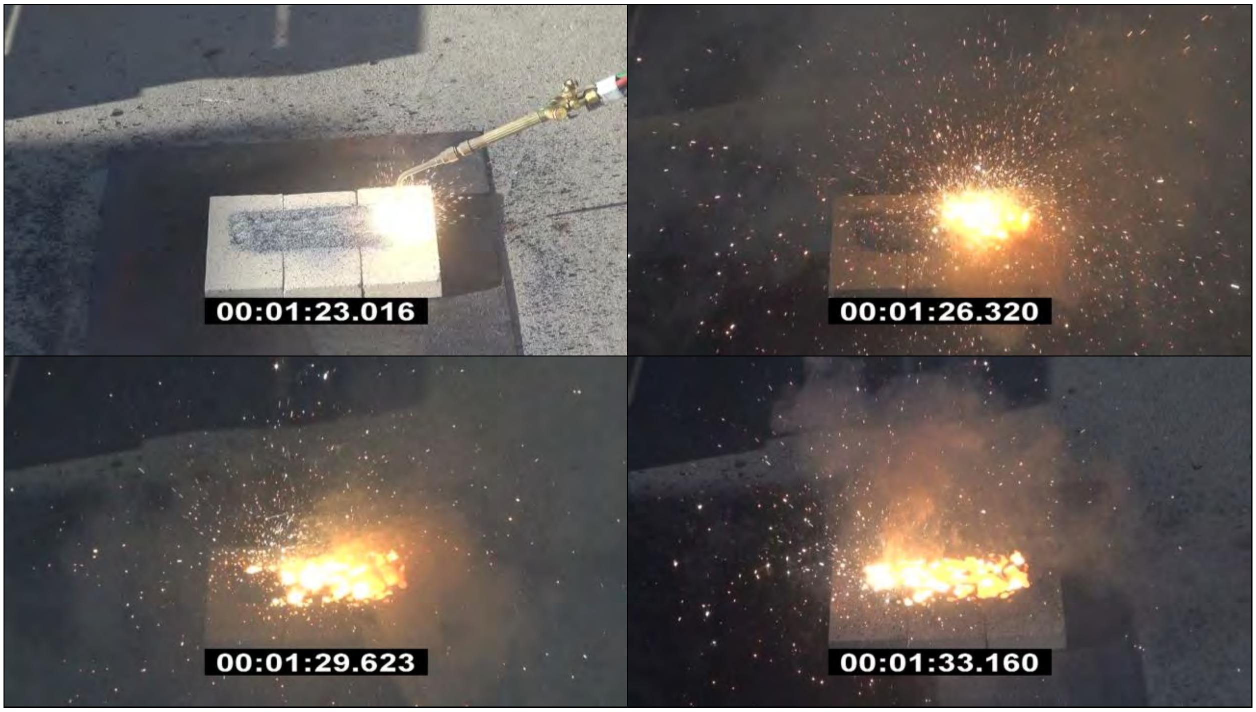


Photo 129: Large-Scale Readily Combustible Test Results - Acetylene Torch in Crucible for Coarse Al-Fe_2O_3 Thermite A - Mix ID #2 (Commercial) with Ignition and Full Consumption over 2.7 seconds

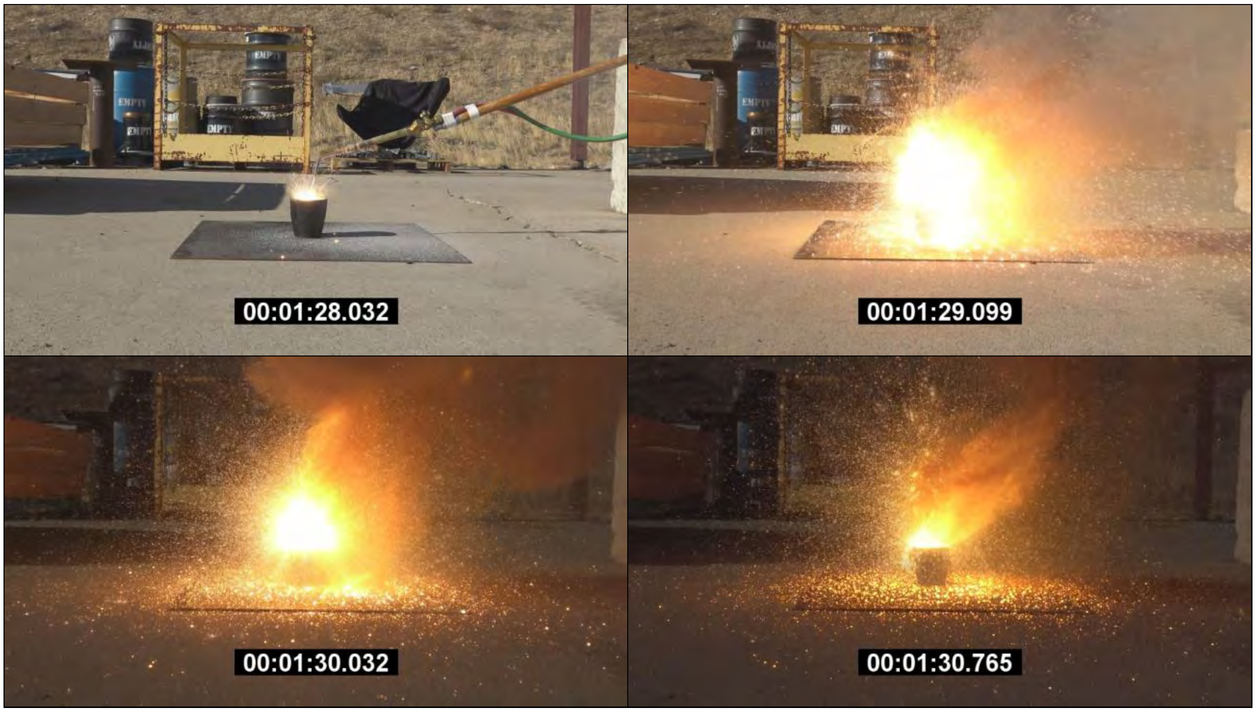


Photo 130: Large-Scale Readily Combustible Test Results - Gas Torch on Plate for Coarse Al-Fe_2O_3 Thermite B - Mix ID #3 (Commercial) with No Reaction in 5 minutes

Photo 131: Large-Scale Readily Combustible Test Results - Hot Wire on Plate for Coarse Al-Fe_2O_3 Thermite B - Mix ID #3 (Commercial) with No Reaction in 5 minutes

Photo 132: Large-Scale Readily Combustible Test Results - Acetylene Torch on Plate for Coarse Al-Fe_2O_3 Thermite B - Mix ID #3 (Commercial) with Ignition and Partial Consumption over 75 seconds

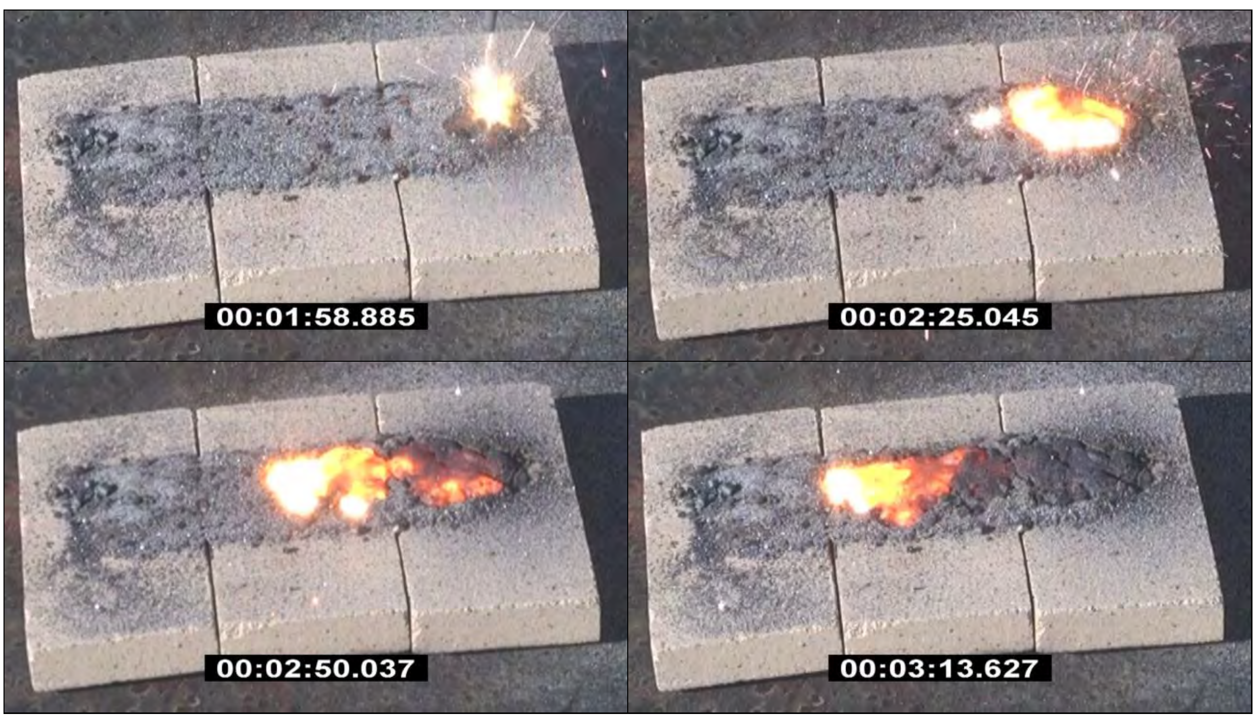


Photo 133: Large-Scale Readily Combustible Test Results - Gas Torch (aided by a thermite starting powder) on Plate for Coarse Al-Fe_2O_3 Thermite B - Mix ID #3 (Commercial) with Ignition and Partial Consumption over 23 seconds

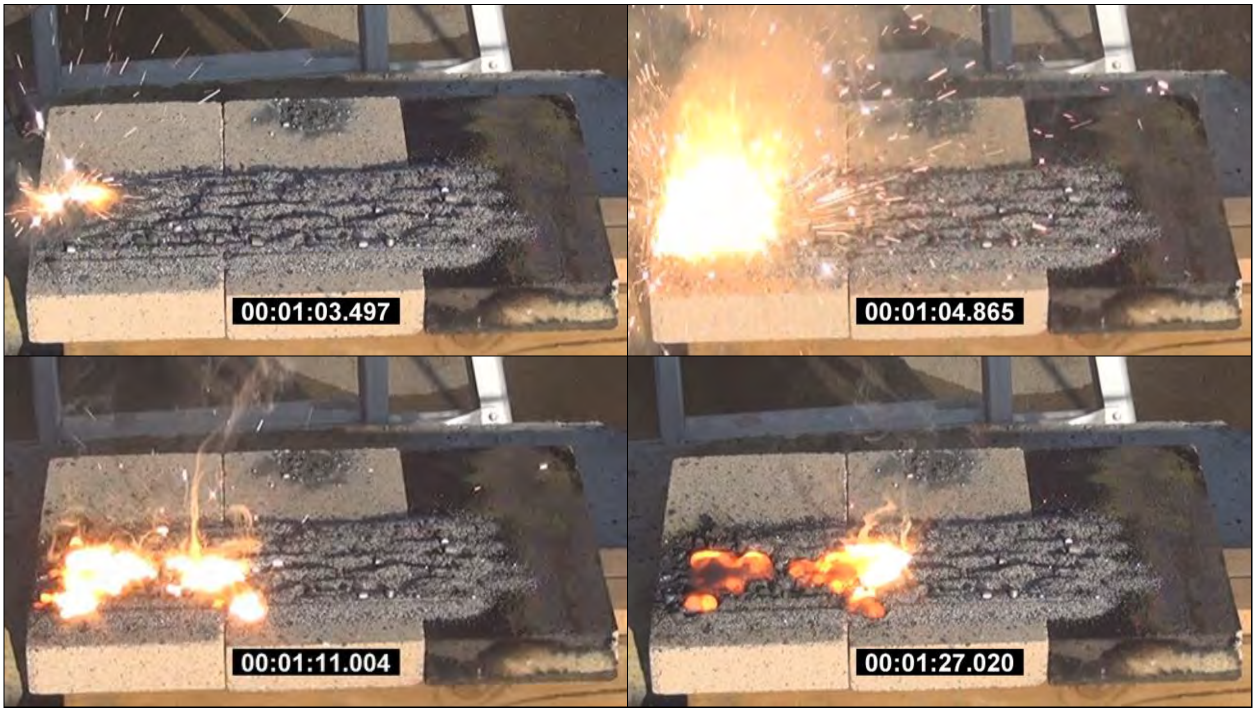


Photo 134: Large-Scale Readily Combustible Test Results - Gas Torch on Plate for Fine Al-CuO Thermite - Mix ID #4 (SMS mixed) with Ignition and Full Consumption over 2.1 seconds

Photo 135: Large-Scale Readily Combustible Test Results - Hot Wire on Plate for Fine Al-CuO Thermite - Mix ID #4 (SMS mixed) with Ignition and Full Consumption over 1.3 seconds

Photo 136: Large-Scale Readily Combustible Test Results - Gas Torch in Crucible for Fine Al-CuO Thermite - Mix ID #4 (SMS mixed) with Ignition and Full Consumption over 7.4 seconds

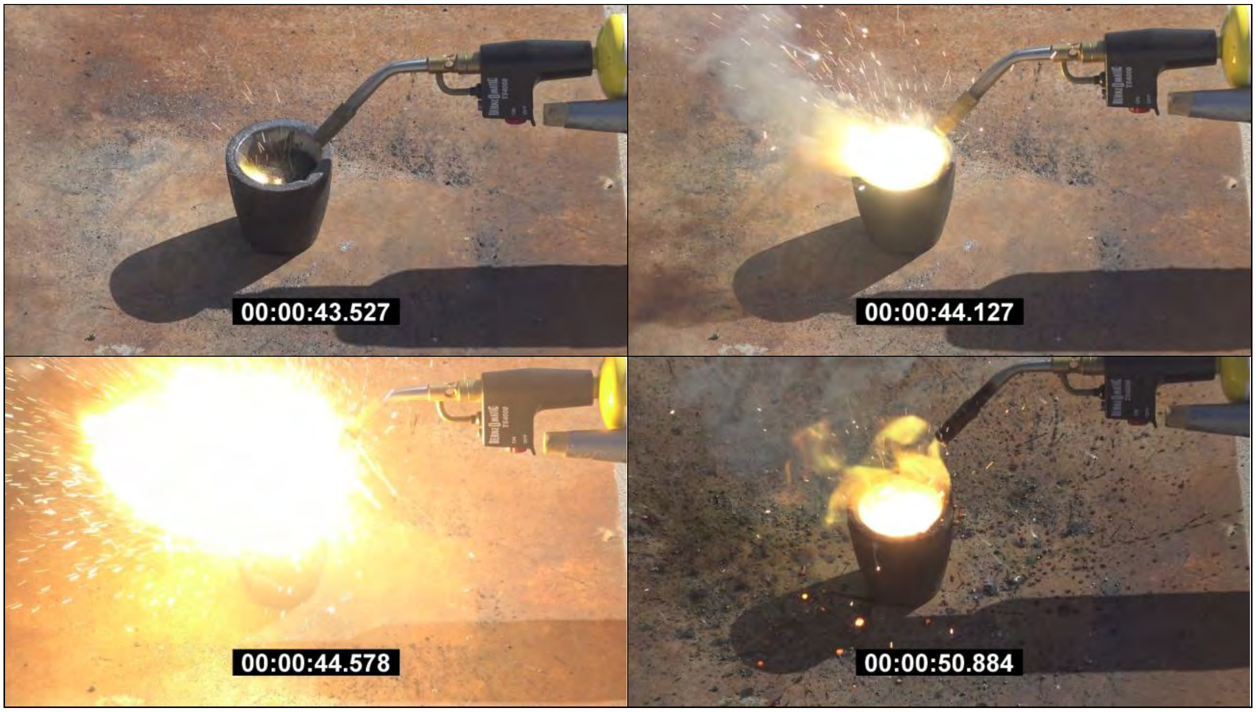


Photo 137: Large-Scale Readily Combustible Test Results - Gas Torch on Plate for Medium Al-CuO Thermite - Mix ID #5 (Commercial) with Ignition and Full Propagation over 1.5 seconds

Photo 138: Large-Scale Readily Combustible Test Results - Hot Wire on Plate for Medium Al-CuO Thermite - Mix ID #5 (Commercial) with Ignition and Full Propagation over 2.4 seconds

Photo 139: Large-Scale Readily Combustible Test Results - Gas Torch (aided by a thermite starting powder) in Crucible for Medium Al-CuO Thermite - Mix ID #5 (Commercial) with Ignition and Full Propagation over 6.4 seconds

Photo 140: Large-Scale Readily Combustible Test Results - Gas Torch on Plate for Fine Al-Ni_2O_3 Thermite - Mix ID #6 (SMS mixed) with Ignition and Full Propagation over 36 seconds

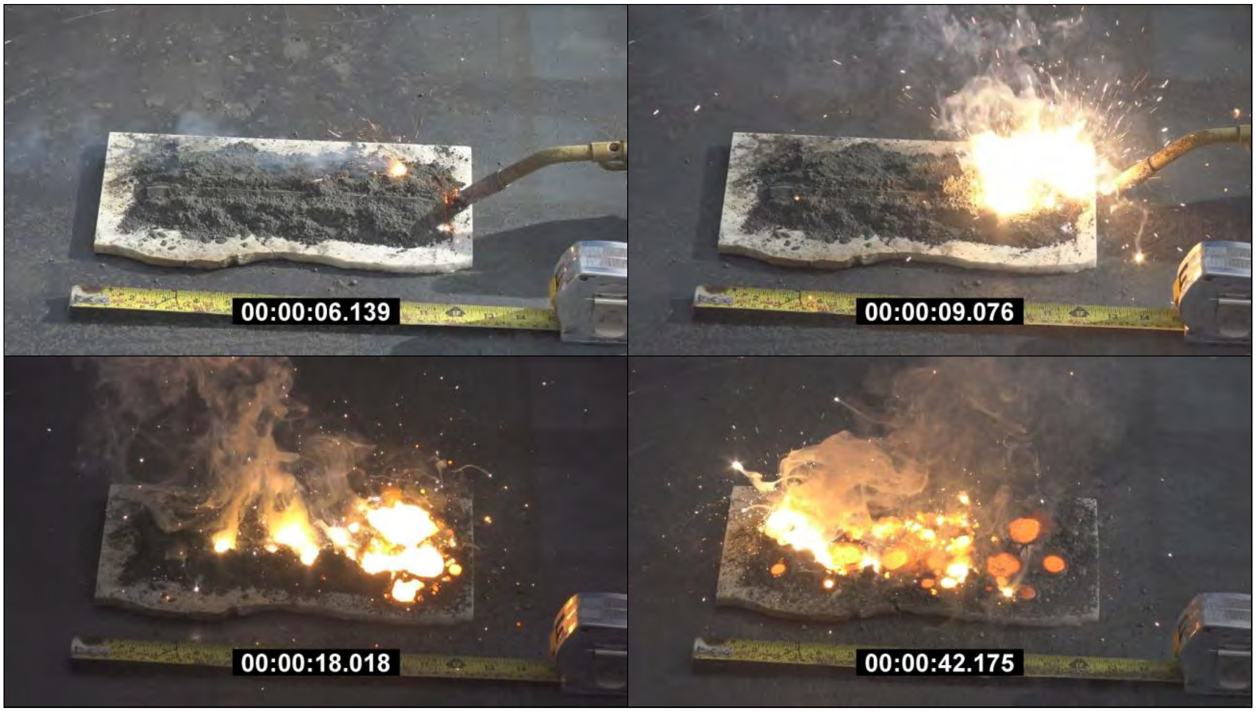


Photo 141: Large-Scale Readily Combustible Test Results - Hot Wire on Plate for Fine Al-Ni_2O_3 Thermite - Mix ID #6 (SMS mixed) with Ignition and Full Propagation over 75 seconds

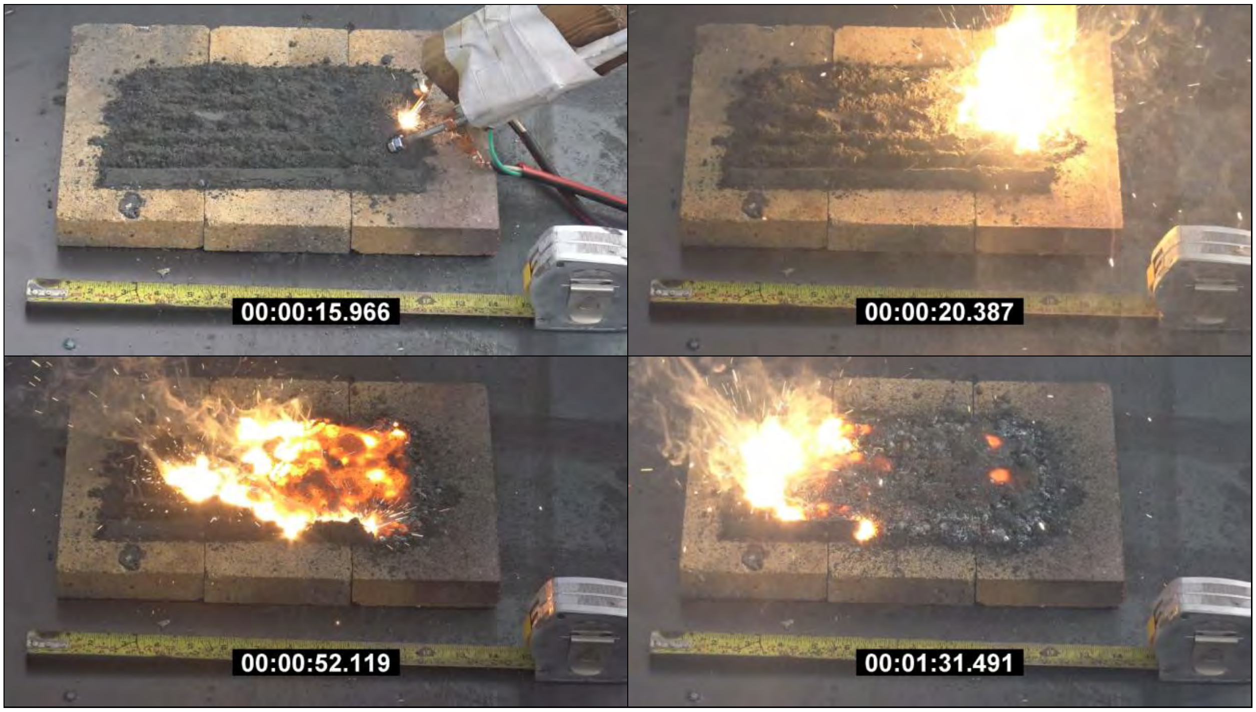


Photo 142: Large-Scale Readily Combustible Test Results - Gas Torch in Crucible for Fine Al-Ni_2O_3 Thermite - Mix ID #6 (SMS mixed) with Ignition and Full Consumption over 10.5 seconds

Photo 143: Large-Scale Readily Combustible Test Results - Pyrogen Match on Plate for Fine Al-MnO_2 Thermite - Mix ID #7 (SMS mixed) with Explosion

Photo 144: Large-Scale Readily Combustible Test Results - Hot Wire on Plate for Fine Al-MnO_2 Thermite - Mix ID #7 (SMS mixed) with Explosion

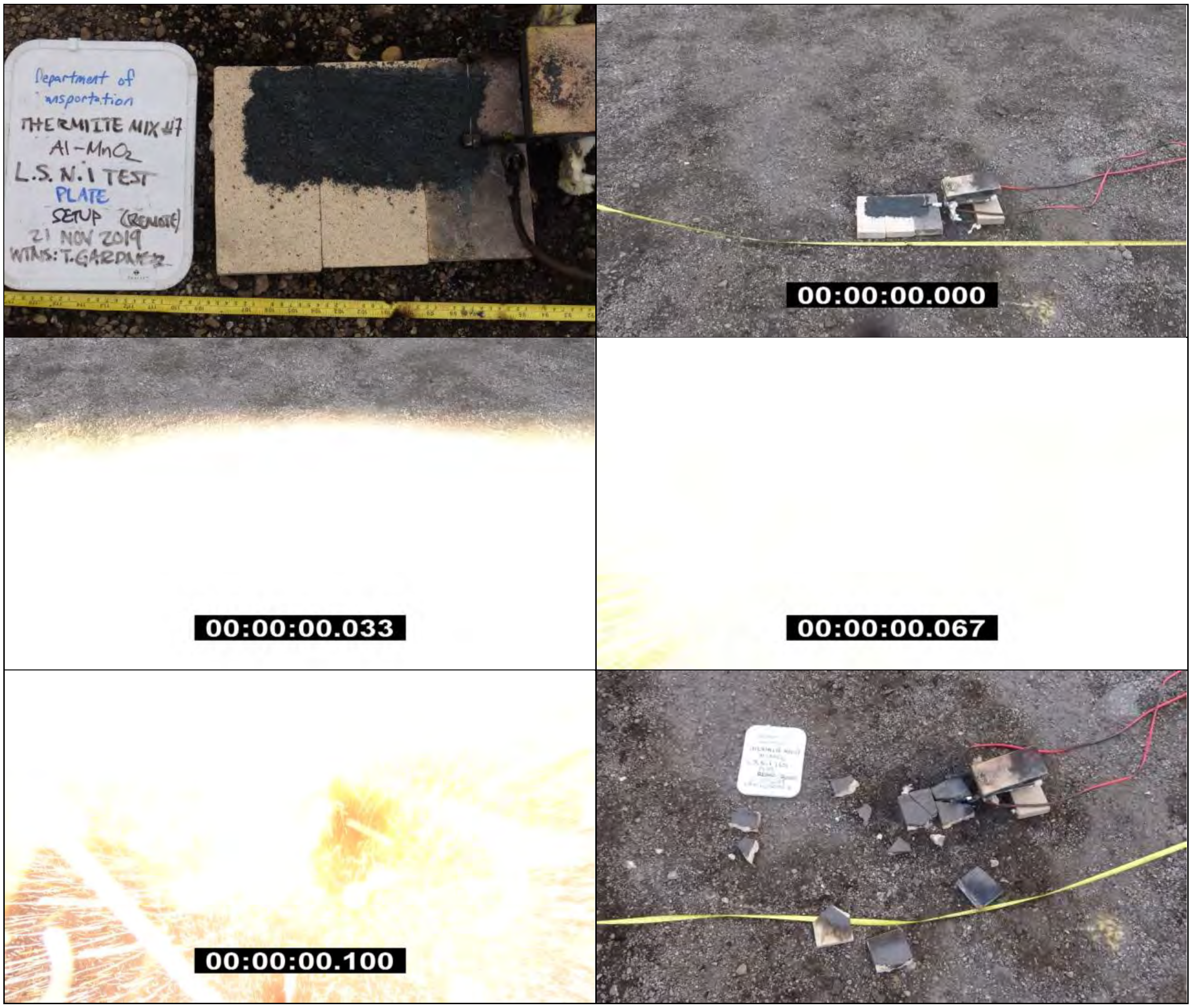


Photo 145: Large-Scale Readily Combustible Test Results - Pyrogen Match in Top of Crucible for Fine Al-MnO_2 Thermite - Mix ID #7 (SMS mixed) with Explosion

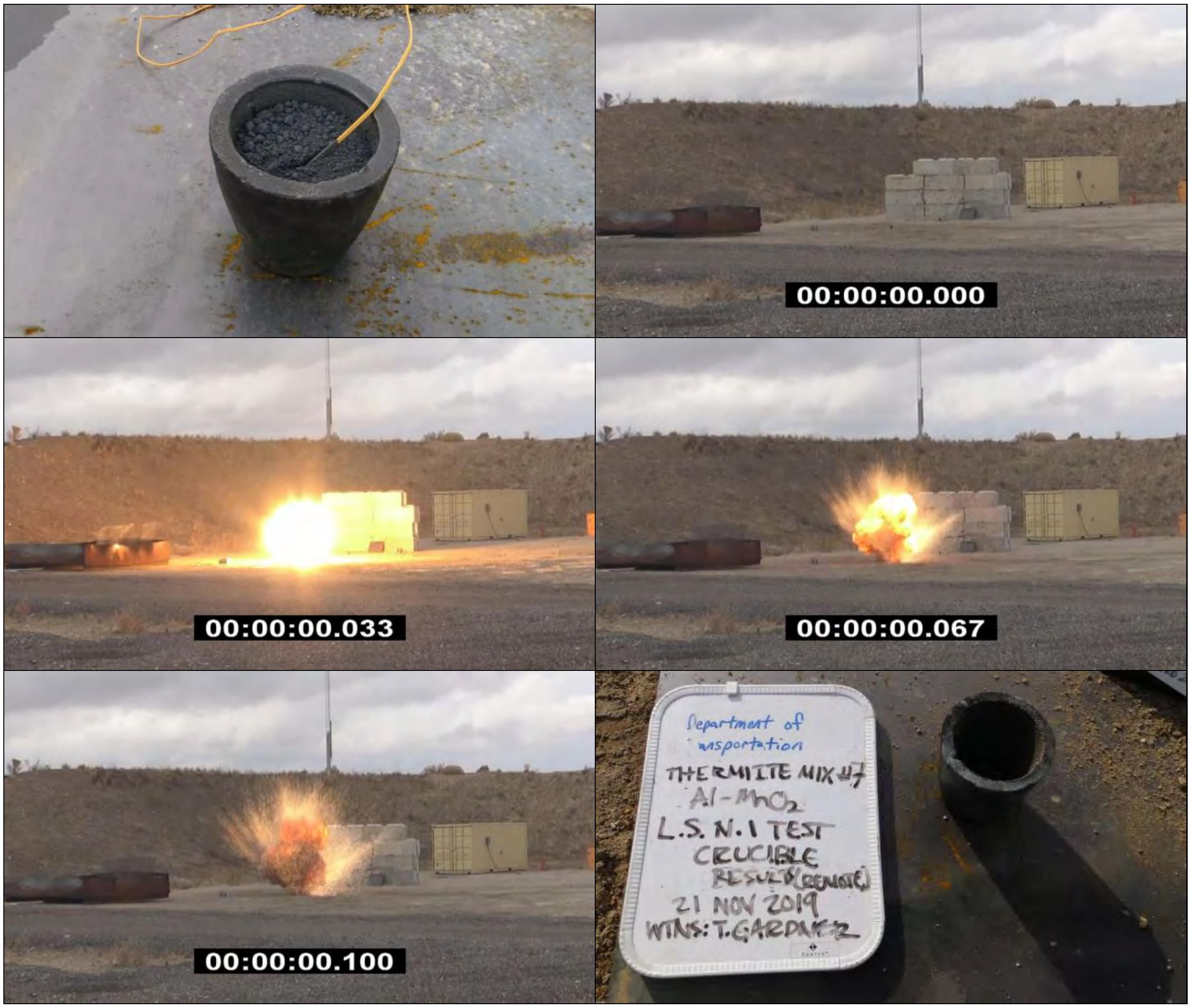


Photo 146: Large-Scale Readily Combustible Test Results - Pyrogen Match on Plate for Fine Mg&Al-MoO_3-CuO Thermite - Mix ID #8 (SMS mixed) with Explosion

Photo 147: Large-Scale Readily Combustible Test Results - Hot Wire on Plate for Fine Mg&Al-MoO_3-CuO Thermite - Mix ID #8 (SMS mixed) with Explosion

Photo 148: Large-Scale Readily Combustible Test Results - Pyrogen Match in Top of Crucible for Fine Mg&Al-MoO_3-CuO Thermite - Mix ID #8 (SMS mixed) with Explosion

7.12.4 *Assessment of Test Results*

An assessment of the results of the large-scale UN Test N.1 indicates the Fine Al-Fe_2O_3 Thermite - Mix ID #1 (SMS mixed), Fine Al-CuO Thermite - Mix ID #4 (SMS mixed), and Medium Al-CuO Thermite - Mix ID #5 (Commercial) exhibited rapid burning consistent with the hazard of a Class 1 explosive. The Coarse Al-Fe2O3 Thermite A - Mix ID #2 (Commercial), Coarse Al-Fe2O3 Thermite B - Mix ID #3 (Commercial), and Fine Al-Ni2O3 Thermite - Mix ID #6 (SMS mixed) each had burn rates >2.2 mm/sec which is consistent with Division 4.1, Packing Group II. Both the Fine Al-MnO2 Thermite - Mix ID #7 (SMS mixed) and Fine Mg&Al-MoO3-CuO Thermite - Mix ID #8 (SMS mixed) exploded and are consistent more with the hazard of Division 1.1 explosives.

7.13 UN Test N.4 Test method for self-heating substances screen (one trial using a 100 mm cube at 140 °C)

7.13.1 *Test Description*

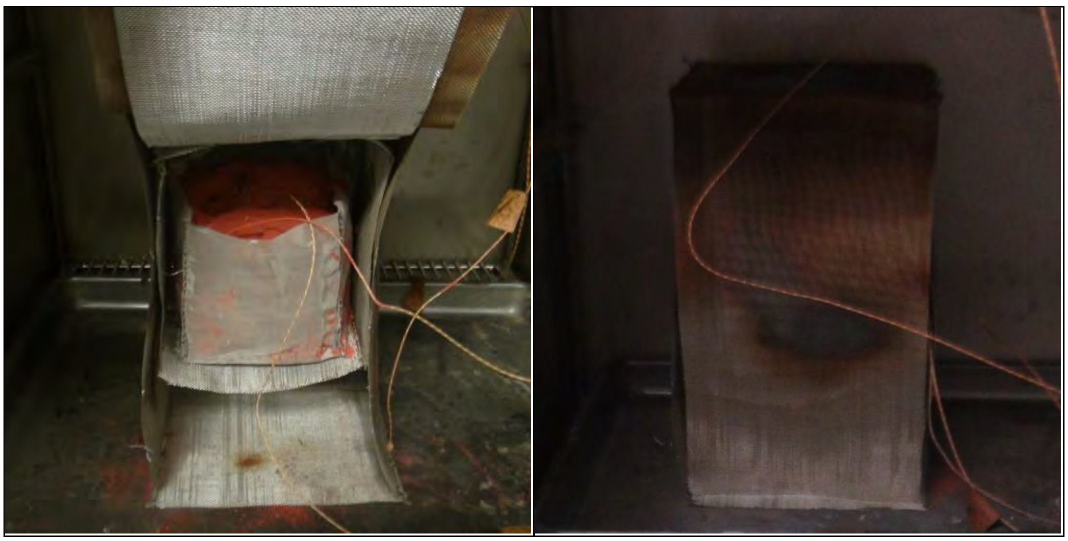
UN Test N.4, “Test method for self-heating substances”, is used to determine the ability of a substance to undergo oxidative self-heating. The sample is placed in a 100 cubic mm, stainless steel mesh sample container. The sample container is placed inside of a slightly larger stainless-steel mesh cover box which hangs in the center of a larger stainless steel mesh cage box. The three boxes are placed in the center of an oven and heated at 140 °C for 24 hours. The temperature of the sample and oven are recorded throughout the test.

A substance is considered a self-heating substance if spontaneous ignition occurs or if the temperature of the sample exceeds the oven temperature by 60 °C.

7.13.2 *Test Configuration*

Each sample was filled to the brim of the 100mm cubic sample container. Thermocouples were inserted into the center of the test samples. The following photo shows a typical test configuration for UN Test N.4 in a 100mm cubic sample container suspended in a slightly larger stainless-steel cover box hanging in the center of a larger stainless-steel mesh cage box.

Photo149: Self-Heating Test Setup for a 100-mm Cube (typical)



7.13.3 *Test Results*

The test results are summarized in the following table and temperature plots.

Table 30: Summary of UN Series Test Results

Item	Sample	Conditions and Results	Assessment
1	Fine Al-Fe_2O_3 Thermite - Mix ID #1 (SMS mixed)	<u>100mm cube at 140°C</u>: Sample did not experience spontaneous ignition and temperature did NOT exceed that of the oven temperature during the 24-hour test.	Pass (NOT Division 4.2)
2	Coarse Al-Fe_2O_3 Thermite A - Mix ID #2 (Commercial)	<u>100mm cube at 140°C</u>: Sample did not experience spontaneous ignition and temperature did NOT exceed that of the oven temperature during the 24-hour test.	Pass (NOT Division 4.2)

Item	Sample	Conditions and Results	Assessment
3	Coarse Al-Fe_2O_3 Thermite B - Mix ID #3 (Commercial)	100mm cube at 140°C: Sample did not experience spontaneous ignition and temperature did NOT exceed that of the oven temperature during the 24-hour test.	Pass (NOT Division 4.2)
4	Fine Al-CuO Thermite - Mix ID #4 (SMS mixed)	100mm cube at 140°C: Sample did not experience spontaneous ignition and temperature did NOT exceed that of the oven temperature during the 24-hour test.	Pass (NOT Division 4.2)
5	Medium Al-CuO Thermite - Mix ID #5 (Commercial)	100mm cube at 140°C: Sample did not experience spontaneous ignition and temperature did NOT exceed that of the oven temperature during the 24-hour test.	Pass (NOT Division 4.2)
6	Fine Al-Ni_2O_3 Thermite - Mix ID #6 (SMS mixed)	100mm cube at 140°C: Sample did not experience spontaneous ignition and temperature did NOT exceed that of the oven temperature during the 24-hour test.	Pass (NOT Division 4.2)
7	Fine Al-MnO_2 Thermite - Mix ID #7 (SMS mixed)	100mm cube at 140°C: Sample did not experience spontaneous ignition and temperature did NOT exceed that of the oven temperature during the 24-hour test.	Pass (NOT Division 4.2)
8	Fine Mg&Al-MoO_3-CuO Thermite - Mix ID #8 (SMS mixed)	100mm cube at 140°C: Sample did not experience spontaneous ignition and temperature did NOT exceed that of the oven temperature during the 24-hour test.	Pass (NOT Division 4.2)

Figure 7: Oven Temperature Record for the UN Test N.4 Self-Heating Test on Fine Al-Fe_2O_3 Thermite - Mix ID #1 (SMS mixed)

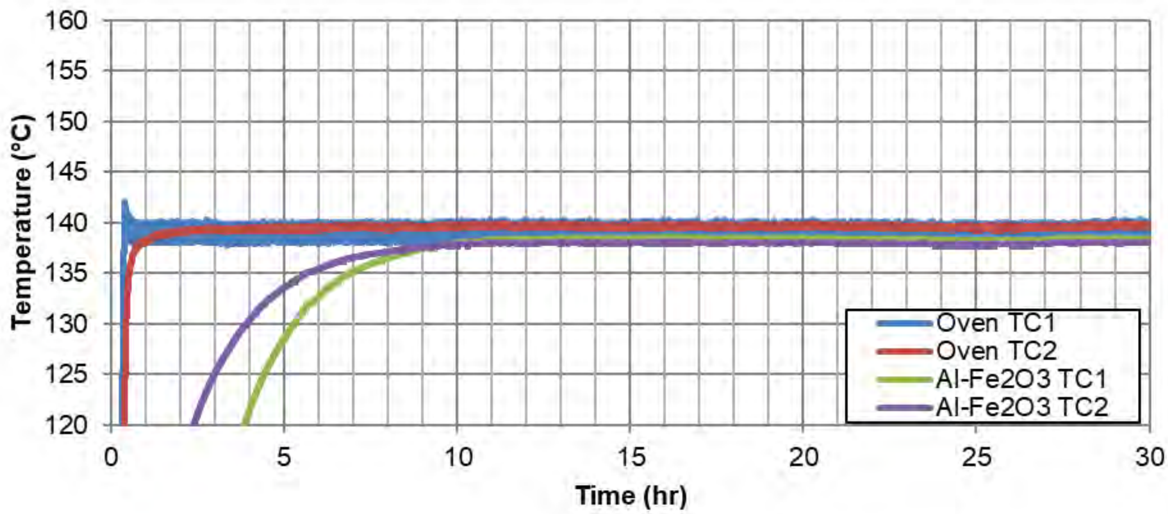


Figure 8: Oven Temperature Record for the UN Test N.4 Self-Heating Test on Coarse Al-Fe_2O_3 Thermite A - Mix ID #2 (Commercial)

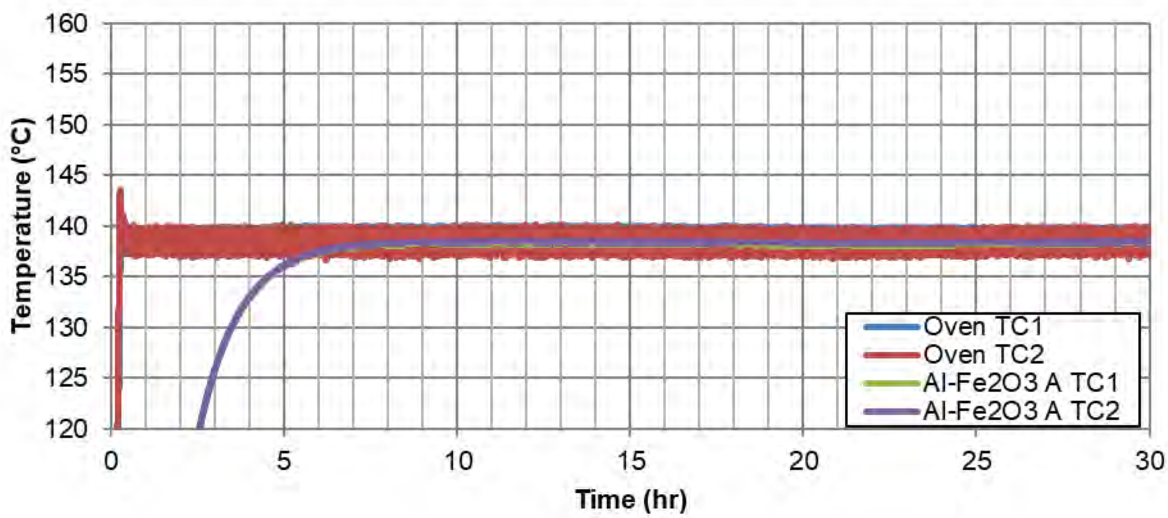


Figure 9: Oven Temperature Record for the UN Test N.4 Self-Heating Test on Coarse Al-Fe_2O_3 Thermite B - Mix ID #3 (Commercial)

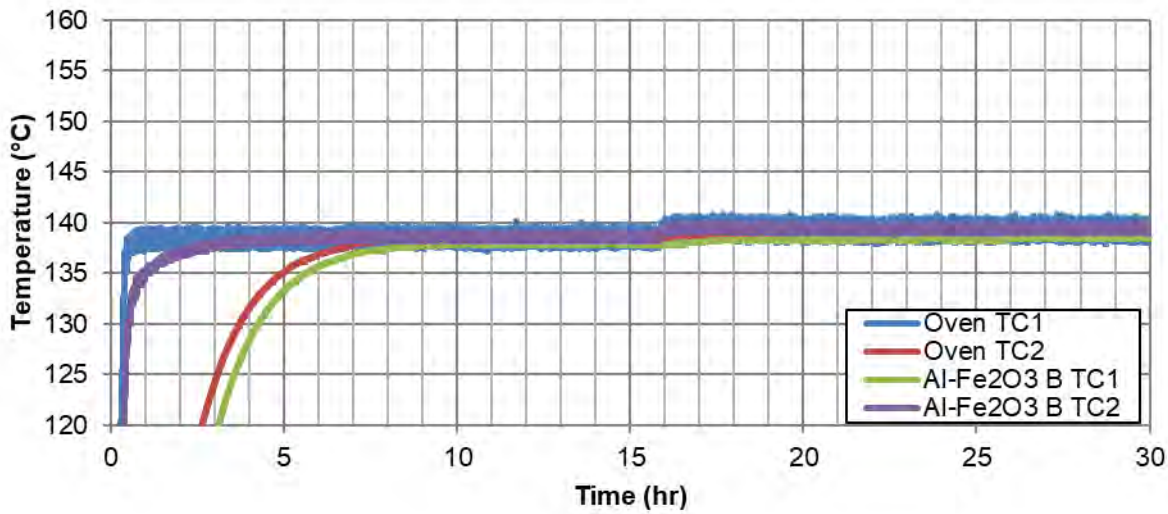


Figure 10: Oven Temperature Record for the UN Test N.4 Self-Heating Test on Fine Al-CuO Thermite - Mix ID #4 (SMS mixed)

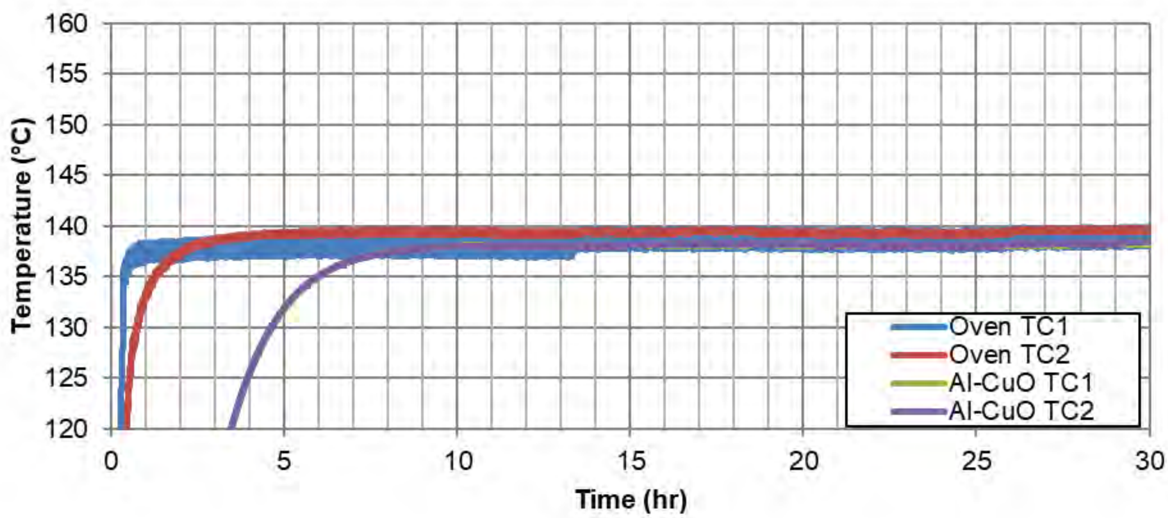


Figure 11: Oven Temperature Record for the UN Test N.4 Self-Heating Test on Medium Al-CuO Thermite - Mix ID #5 (Commercial)

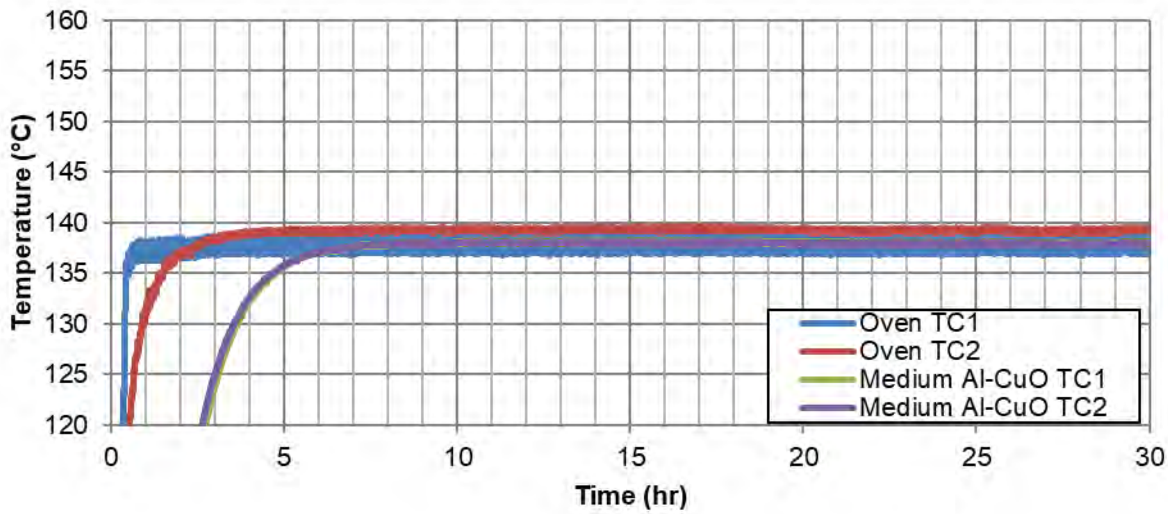


Figure 12: Oven Temperature Record for the UN Test N.4 Self-Heating Test on Fine Al-Ni_2O_3 Thermite - Mix ID #6 (SMS mixed)

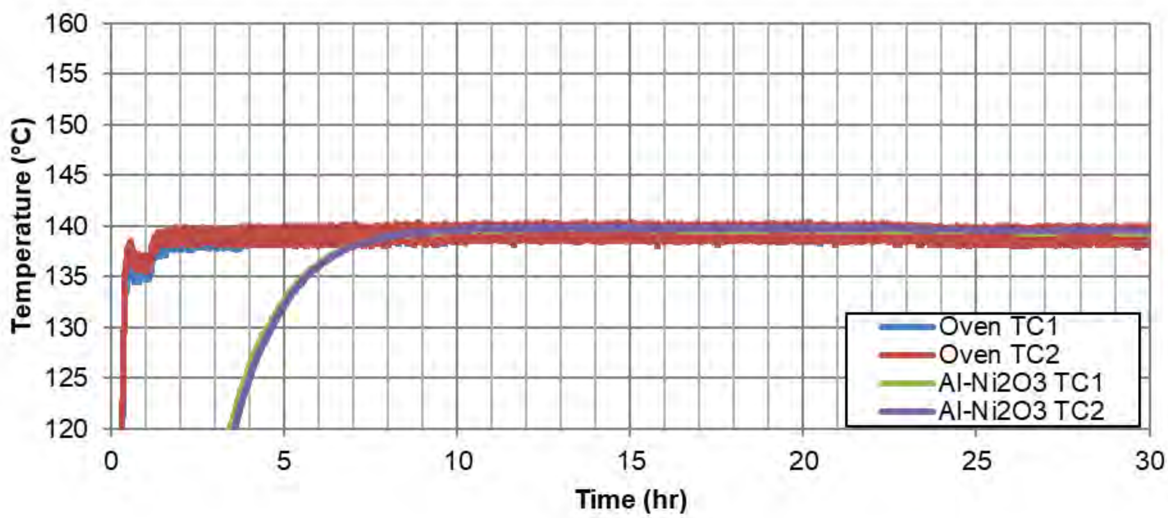


Figure 13: Oven Temperature Record for the UN Test N.4 Self-Heating Test on Fine Al-MnO_2 Thermite - Mix ID #7 (SMS mixed)

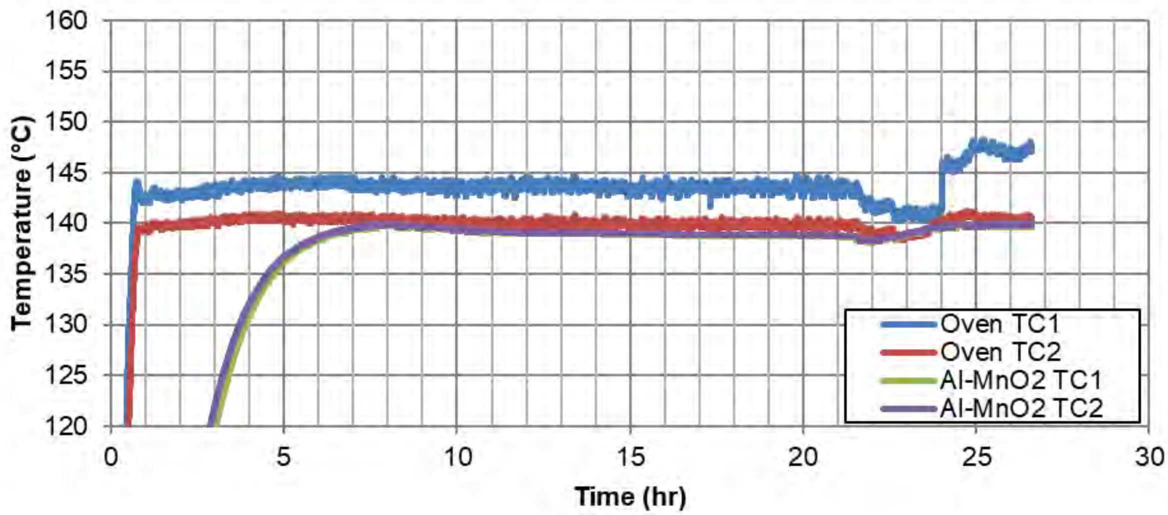
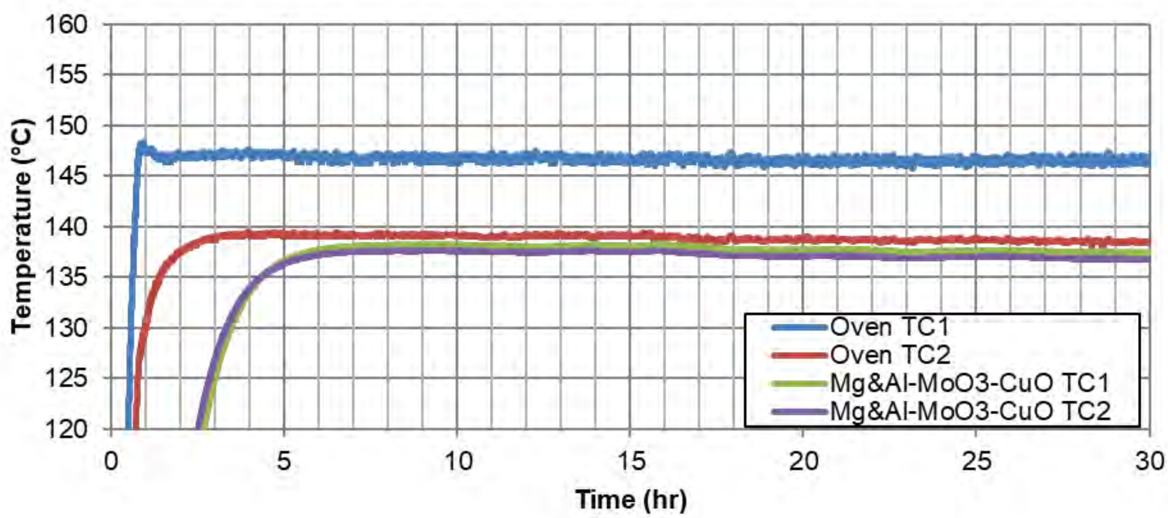


Figure 14: Oven Temperature Record for the UN Test N.4 Self-Heating Test on Fine Mg&Al-MoO_3-CuO Thermite - Mix ID #8 (SMS mixed)



7.13.4 *Assessment of Test Results*

Based on the test results, the samples passed UN Test N.4, "Test method for self-heating substances" and are NOT classified in Division 4.2.

7.14 UN Test N.5 Test method for substances which in contact with water emit flammable gases

7.14.1 *Test Description*

This test determines whether a substance which in contact with water will emit a significant quantity of flammable gases. The substance is tested by bringing it into contact with water under a variety of conditions provided by a series of safety tests and a quantification test.

The safety tests consist of the following:

(1) a small quantity (approximately 2 mm diameter) of the test substance should be placed in a trough of distilled water at 20°C;
(2) a small quantity of the test substance (approximately 2 mm diameter) should be placed on the center of a filter paper which is floated flat on the surface of distilled water at 20 °C in a suitable vessel; and
(3) the test substance should be made into a pile approximately 20 mm high and 30 mm diameter with a hollow in the top. A few drops of water are added to the hollow.

In each of the tests, it is noted whether any gas is evolved; and if spontaneous ignition of the gas occurs.

Upon completion of the safety tests, the quantification test is performed. For solids, the sample is ground to a powder before testing if the substance is friable (i.e. readily crumbled; brittle) or if any particles of less than 500 µm diameter constitute more than 1% mass of the total weight (accounting for reduction[s] in particle size during handling and transport). Otherwise, as for liquids, the [solid] substance should be tested in its commercial state.

The quantification test should be performed three times at ambient temperature (20°C) and atmospheric pressure. Water is put into a dropping funnel and enough of the substance (up to a maximum mass of 25 g) to produce between 100 ml and 250 ml of gas is weighed and placed in a conical flask. The tap of the dropping funnel is opened to let the water into the conical flask and a stopwatch is started. The volume of gas evolved is measured by any suitable means.

The time taken for all the gas to be evolved is noted and where possible, intermediate readings are taken. The rate of evolution of gas is calculated over 7 hours at 1 hour intervals. If the rate of evolution is erratic or is increasing after 7 hours, the measuring time should be extended to a maximum time of 5 days. The five day test may be stopped if the rate of evolution becomes steady or continually decreases and sufficient data has been established to assign a packing group to the substance or to determine that the substance should not be classified in Division 4.3.

If the chemical identity of the gas is unknown, the gas should be tested for flammability.

NOTE: Per 49 CFR 173.124(c), a material should be classified as a Division 4.3 Dangerous when wet material if it by contact with water, is liable to become spontaneously flammable or to give off flammable or toxic gas at a rate greater than 1 L per kilogram of the material, per hour. Packing group I is assigned if the rate of evolution is 10 L/(kg·hr) or greater over any one minute period or the gas produced ignites spontaneously. Packing group II is assigned if the rate of evolution is 20 L/(kg·hr) or greater. Otherwise, Packing group III is assigned.

7.14.2 *Test Configuration*

For the safety tests, water was added to a small pile of each sample (~1 gram) contained in a small sample container.

For the quantification test, an Erlenmeyer filter flask, burette, graduated cylinder, and water reservoir were used to measure the volume of gas evolved, as shown in Figure 2. The graduated cylinder is filled with water and placed inverted in a reservoir of water. A 25-gram sample of the test substance is loaded into a 50-mL Erlenmeyer filter flask. Approximately 26-mL of water is added to the substance using a 100-mL glass burette seated in a rubber stopper (results in approximately 0.75-in standing water). Gas evolved by the sample is carried from the side port of the filter flask to the inverted graduated cylinder through a piece of natural rubber tubing. The volume of gas evolved is determined by the amount of water that was displaced out of the inverted graduated cylinder with time. The test configuration is shown in the following figure and photo.

Figure 15: Method for Measuring Volume of Gas Evolved

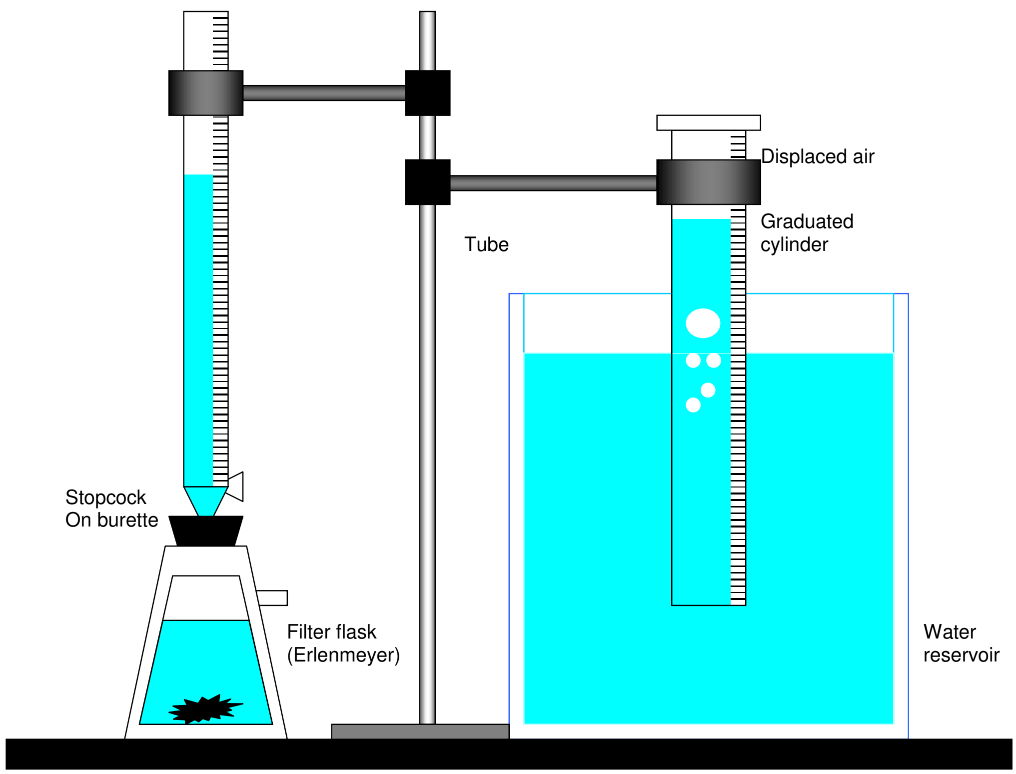


Photo 150: UN Test N.5 Test Setup (typical)

7.14.3 *Test Results*

Safety Tests

For each of the samples, addition of water to a small pile of each sample (~1 gram) contained in a small sample container did not result in any significant quantity of gas evolution and did not result in spontaneous ignition of the gas. The other safety tests were waived based on the results of this safety test.

Quantification Test

The collected test data is summarized in the following tables.

Table 31: UN Test N.5 Test Data for Fine $Al-Fe_2O_3$ Thermite - Mix ID #1 (SMS mixed)

Trial 1 with 25 mL water
Sample: 25 gm

Time (hr)	Total (mL)	Delta (mL)	Rate L/(kg·hr)
0	14.5		
1	34	19.5	0.8
2	70 → 0	36	**1.4**
3	38	38	**1.5**
4	76	38	**1.5**
5	120 → 0	44	**1.8**
6	19	19	0.8
7	72	53	**2.1**

Trial 2 with 15 mL water
Sample: 5.0 gm

Time (hr)	Total (mL)	Delta (mL)	Rate L/(kg·hr)
0	6		
1	11	5	**1.0**
2	25	14	**2.8**
3	32	7	**1.4**
4	40	8	**1.6**
5	50	10	**2.0**
6	60	10	**2.0**
7	76	16	**3.2**

Trial 3 with 25 mL water
Sample: 10 gm

Time (hr)	Total (mL)	Delta (mL)	Rate L/(kg·hr)
0	50		
1	70	20	**2.0**
2	89	19	**1.9**
3	96	7	0.7
4	107	11	**1.1**
5	115	8	0.8
6	124	9	0.9
7	126	2	0.2

Table 32: UN Test N.5 Test Data for Coarse Al-Fe_2O_3 Thermite A - Mix ID #2 (Commercial)

Trial 1 with 25 mL water
Sample: 25 gm

Time (hr)	Total (mL)	Delta (mL)	Rate L/(kg·hr)
0	19		
1	19	0	0
2	19	0	0
3	19	0	0
4	19	0	0
5	19	0	0
6	19	0	0
7	19	0	0

Trial 2 with 15 mL water
Sample: 5.0 gm

Time (hr)	Total (mL)	Delta (mL)	Rate L/(kg·hr)
0	1		
1	1	0	0
2	1	0	0
3	1	0	0
4	1	0	0
5	1	0	0
6	1	0	0
7	1	0	0

Trial 3 with 25 mL water
Sample: 25 gm

Time (hr)	Total (mL)	Delta (mL)	Rate L/(kg·hr)
0	2		
1	2	0	0
2	2	0	0
3	2	0	0
4	2	0	0
5	2	0	0
6	2	0	0
7	2	0	0

Table 33: UN Test N.5 Test Data for Coarse Al-Fe_2O_3 Thermite B - Mix ID #3 (Commercial)

Trial 1 with 25 mL water
Sample: 25 gm

Time (hr)	Total (mL)	Delta (mL)	Rate L/(kg·hr)
0	20		
1	20	0	0
2	20	0	0
3	20	0	0
4	20	0	0
5	20	0	0
6	20	0	0
7	20	0	0

Trial 2 with 15 mL water
Sample: 5.0 gm

Time (hr)	Total (mL)	Delta (mL)	Rate L/(kg·hr)
0	2		
1	2	0	0
2	2	0	0
3	2	0	0
4	2	0	0
5	2	0	0
6	2	0	0
7	2	0	0

Trial 3 with 25 mL water
Sample: 25 gm

Time (hr)	Total (mL)	Delta (mL)	Rate L/(kg·hr)
0	20		
1	20	0	0
2	21	1	0
3	22	1	0
4	22	0	0
5	23	1	0
6	24	1	0
7	24	0	0

Table 34: UN Test N.5 Test Data for Fine Al-CuO Thermite - Mix ID #4 (SMS mixed)

Trial 1 with 25 mL water
Sample: 25 gm

Time (hr)	Total (mL)	Delta (mL)	Rate L/(kg·hr)
0	12.5		
1	20	7.5	0.3
2	24	4	0.2
3	27.5	3.5	0.1
4	34	6.5	0.3
5	45	11	0.4
6	49	4	0.2
7	62	13	0.5

Trial 2 with 15 mL water
Sample: 5.0 gm

Time (hr)	Total (mL)	Delta (mL)	Rate L/(kg·hr)
0	3		
1	4	1	0.2
2	5	1	0.2
3	5	0	0.0
4	7	2	0.4
5	9	2	0.4
6	11	2	0.4
7	13	2	0.4

Trial 3 with 25 mL water
Sample: 10 gm

Time (hr)	Total (mL)	Delta (mL)	Rate L/(kg·hr)
0	3		
1	4	1	0.1
2	5	1	0.1
3	5	0	0.0
4	7	2	0.2
5	9	2	0.2
6	11	2	0.2
7	13	2	0.2

Table 35: UN Test N.5 Test Data for Medium Al-CuO Thermite - Mix ID #5 (Commercial)

Trial 1 with 25 mL water
Sample: 25 gm

Time (hr)	Total (mL)	Delta (mL)	Rate L/(kg·hr)
0	14		
1	14	0	0
2	14	0	0
3	14	0	0
4	14	0	0
5	15	1	0.04
6	15	0	0
7	15	0	0

Trial 2 with 15 mL water
Sample: 5.0 gm

Time (hr)	Total (mL)	Delta (mL)	Rate L/(kg·hr)
0	4		
1	4	0	0.0
2	4	0	0.0
3	4	0	0.0
4	5	1	0.2
5	5	0	0.0
6	6	1	0.2
7	6	0	0.0

Trial 3 with 25 mL water
Sample: 25 gm

Time (hr)	Total (mL)	Delta (mL)	Rate L/(kg·hr)
0	25		
1	25	0	0
2	25	0	0
3	25	0	0
4	25	0	0
5	25	0	0
6	25	0	0
7	25	0	0

Table 36: UN Test N.5 Test Data for Fine Al-Ni_2O_3 Thermite - Mix ID #6 (SMS mixed)

Trial 1 with 25 mL water
Sample: 5.0 gm

Time (hr)	Total (mL)	Delta (mL)	Rate L/(kg·hr)
0	27		
1	34	7	**1.4**
2	36	2	0.4
3	39	3	0.6
4	42	3	0.6
5	43	1	0.2
6	44	1	0.2
7	47	3	0.6

Trial 2 with 15 mL water
Sample: 15 gm

Time (hr)	Total (mL)	Delta (mL)	Rate L/(kg·hr)
0	14		
1	34	20	**1.3**
2	45	11	0.7
3	55	10	0.7
4	60	5	0.3
5	69	9	0.6
6	77	8	0.5
7	90	13	0.9

Trial 3 with 25 mL water
Sample: 25 gm

Time (hr)	Total (mL)	Delta (mL)	Rate L/(kg·hr)
0	28		
1	68	40	**1.6**
2	90	22	0.9
3	110	20	0.8
4	132	22	0.9
5	145	13	0.5
6	158	13	0.5
7	186	28	**1.1**

Table 37: UN Test N.5 Test Data for Fine Al-MnO_2 Thermite - Mix ID #7 (SMS mixed)

Trial 1 with 25 mL water
Sample: 5.0 gm

Time (hr)	Total (mL)	Delta (mL)	Rate L/(kg·hr)
0	18		
1	25	7	**1.4**
2	29	4	0.8
3	33	4	0.8
4	38	5	**1.0**
5	40	2	0.4
6	43	3	0.6
7	49	6	**1.2**

Trial 2 with 15 mL water
Sample: 15 gm

Time (hr)	Total (mL)	Delta (mL)	Rate L/(kg·hr)
0	30		
1	31	1	0.1
2	31	0	0.0
3	31	0	0.0
4	31	0	0.0
5	31	0	0.0
6	31	0	0.0
7	31	0	0.0

Trial 3 with 25 mL water
Sample: 25 gm

Time (hr)	Total (mL)	Delta (mL)	Rate L/(kg·hr)
0	33		
1	35	2	0.1
2	35	0	0.0
3	35	0	0.0
4	35	0	0.0
5	35	0	0.0
6	35	0	0.0
7	35	0	0.0

Table 38: UN Test N.5 Test Data for Fine Mg&Al-MoO_3-CuO Thermite - Mix ID #8 (SMS mixed)

Trial 1 with 25 mL water
Sample: 25 gm

Time (hr)	Total (mL)	Delta (mL)	Rate L/(kg·hr)
0	45		
1	50 → 12	17	0.7
2	16	4	0.2
3	17	1	0.1
4	17	0	0
5	17	0	0
6	17	0	0
7	17	0	0

Trial 2 with 15 mL water
Sample: 5.0 gm

Time (hr)	Total (mL)	Delta (mL)	Rate L/(kg·hr)
0	5		
1	16	11	**2.2**
2	17	1	0.2
3	18	1	0.2
4	19	1	0.2
5	20	1	0.2
6	20	0	0.0
7	20	0	0.0

Trial 3 with 25 mL water
Sample: 10 gm

Time (hr)	Total (mL)	Delta (mL)	Rate L/(kg·hr)
0	80		
1	83	3	0.3
2	88	5	0.5
3	94	6	0.6
4	95	1	0.1
5	96	1	0.1
6	97	1	0.1
7	97	0	0.0

The test results are summarized in the following table.

Table 39: Summary of UN Test N.5 Test Results

Item	Sample	Conditions and Results	Assessment
1	Fine Al-Fe_2O_3 Thermite - Mix ID #1 (SMS mixed)	Maximum gas emission rate of 2.8 L/(kg·hr) without spontaneous ignition.	**FAIL (consistent with Division 4.3 PG III)**
2	Coarse Al-Fe_2O_3 Thermite A - Mix ID #2 (Commercial)	No significant gas evolution over 7-hour test period for 25 grams of thermite.	Pass (NOT Division 4.3)
3	Coarse Al-Fe_2O_3 Thermite B - Mix ID #3 (Commercial)	No significant gas evolution over 7-hour test period for 25 grams of thermite.	Pass (NOT Division 4.3)
4	Fine Al-CuO Thermite - Mix ID #4 (SMS mixed)	Maximum gas emission rate of 0.5 L/(kg·hr) without spontaneous ignition.	Pass (NOT Division 4.3)
5	Medium Al-CuO Thermite - Mix ID #5 (Commercial)	Maximum gas emission rate of 0.2 L/(kg·hr) without spontaneous ignition.	Pass (NOT Division 4.3)
6	Fine Al-Ni_2O_3 Thermite - Mix ID #6 (SMS mixed)	Maximum gas emission rate of 1.6 L/(kg·hr) without spontaneous ignition.	**FAIL (consistent with Division 4.3 PG III)**
7	Fine Al-MnO_2 Thermite - Mix ID #7 (SMS mixed)	Maximum gas emission rate of 1.4 L/(kg·hr) without spontaneous ignition.	**FAIL (consistent with Division 4.3 PG III)**
8	Fine Mg&Al-MoO_3-CuO Thermite - Mix ID #8 (SMS mixed)	Maximum gas emission rate of 2.2 L/(kg·hr) without spontaneous ignition.	**FAIL (consistent with Division 4.3 PG III)**

Gas Analysis

Based on the known composition of each sample, the evolved gas is expected to be spontaneously flammable (hydrogen); further chemical analysis was not performed.

The test results are shown in the following photos.

Photo 151: UN Test N.5 Test Results for Fine Al-Fe_2O_3 Thermite - Mix ID #1 (SMS mixed)

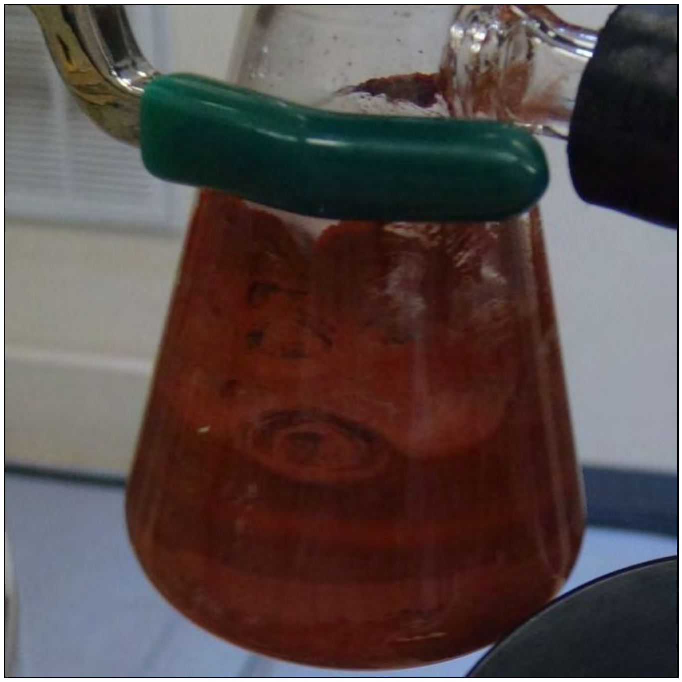


Photo 152: UN Test N.5 Test Results for Coarse Al-Fe_2O_3 Thermite A - Mix ID #2 (Commercial)

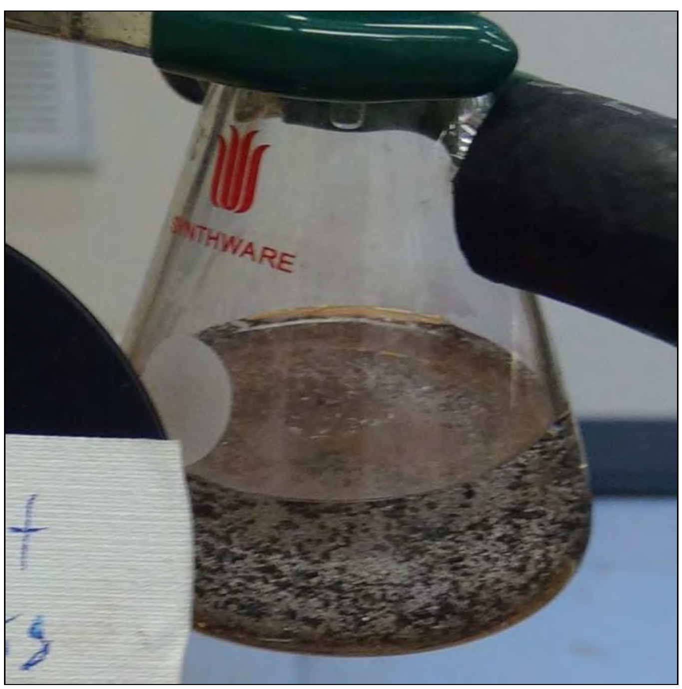


Photo 153: UN Test N.5 Test Results for Coarse Al-Fe_2O_3 Thermite B - Mix ID #3 (Commercial)

Photo 154: UN Test N.5 Test Results for Fine Al-CuO Thermite - Mix ID #4 (SMS mixed)

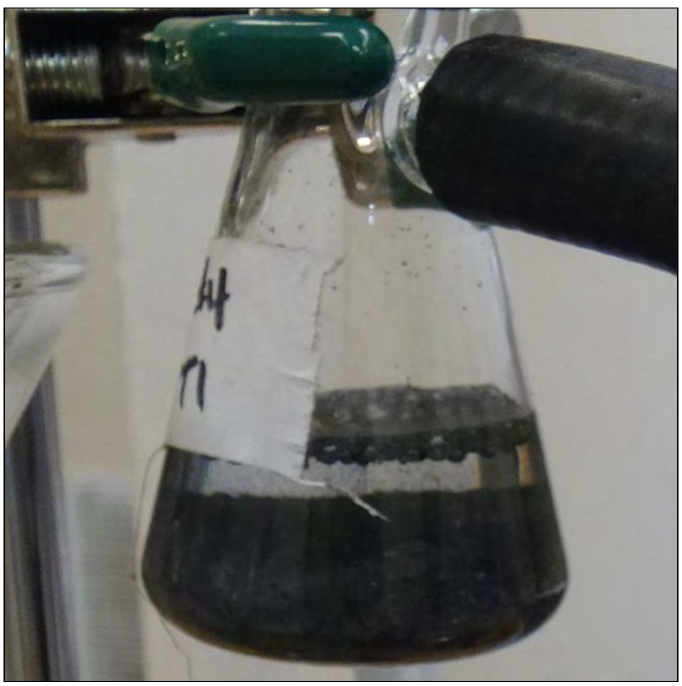


Photo 155: UN Test N.5 Test Results for Medium Al-CuO Thermite - Mix ID #5 (Commercial)

Photo 156: UN Test N.5 Test Results for Fine Al-Ni_2O_3 Thermite - Mix ID #6 (SMS mixed)

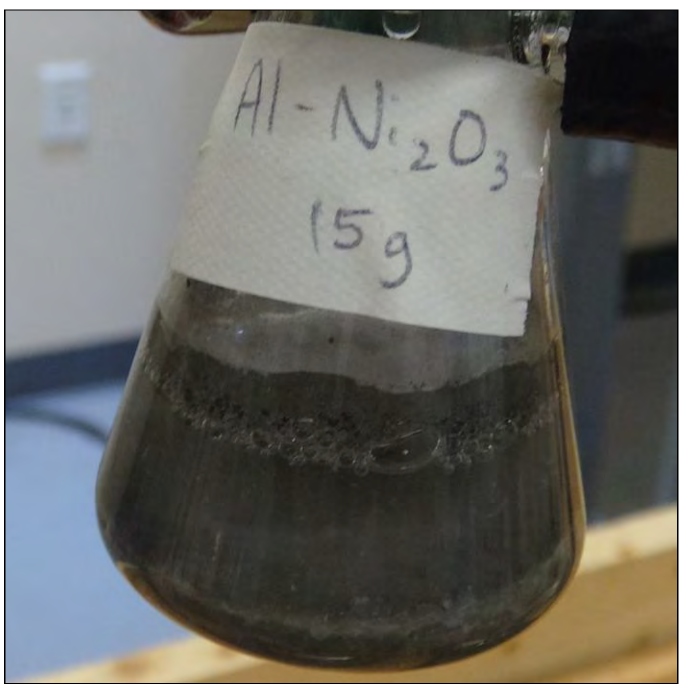


Photo 157: UN Test N.5 Test Results for Fine Al-MnO_2 Thermite - Mix ID #7 (SMS mixed)

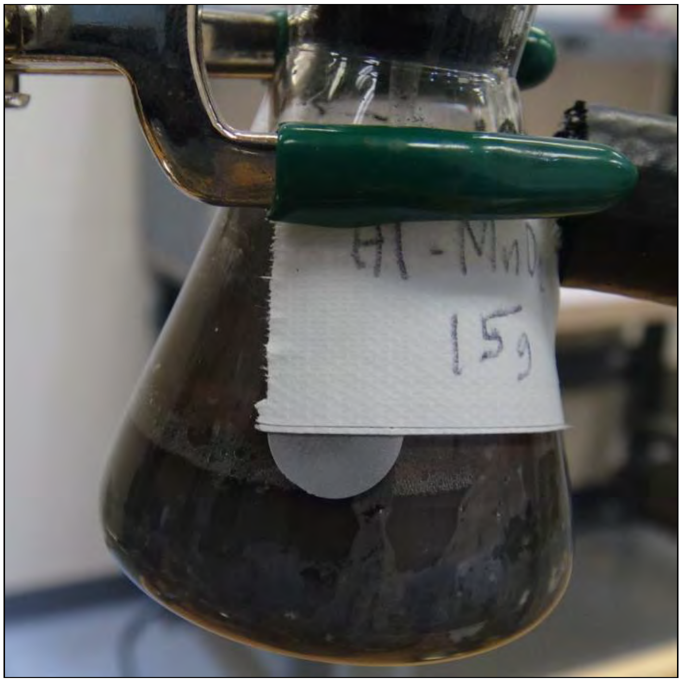
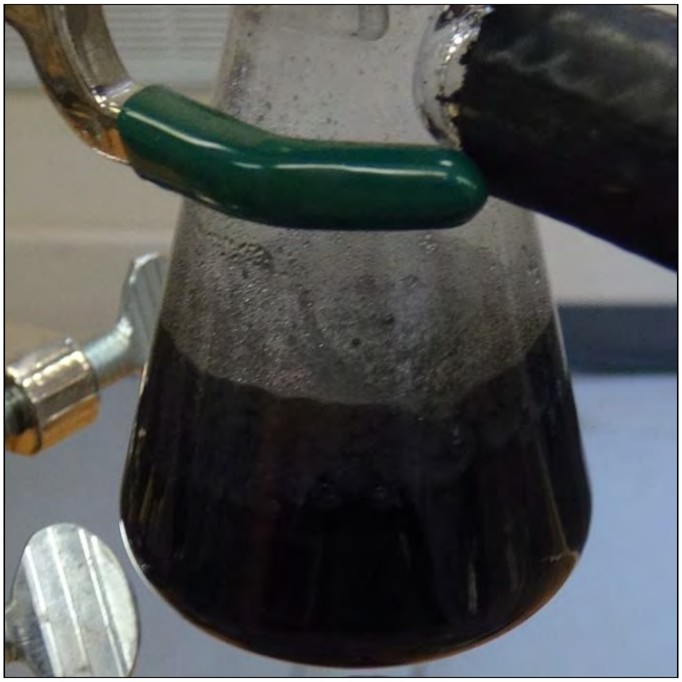


Photo 158: UN Test N.5 Test Results for Fine Mg&Al-MoO_3-CuO Thermite - Mix ID #8 (SMS mixed)



7.14.4 *Assessment of Test Results*

A substance is classified in Division 4.3 if either (a) spontaneous ignition takes place in any step of the test procedure; or (b) there is an evolution of a flammable gas at a rate greater than 1 liter per kilogram of the substance per hour.

For each of the test samples, spontaneous ignition did not take place. There was no evolution of a gas at a rate equal to or greater than 20 liters per kilogram of the substance per hour for Thermite Large-scale Mix ID's #1, #6, #7, and #8 and greater than 1 liter per kilogram of the substance per hour for Thermite Large-scale Mix ID's #2, #3, #4, and #5. Based on these test results, Thermite Large-scale Mix ID's #1, #6, #7, and #8 present a hazard consistent with Division 4.3 PG III; Thermite Large-scale Mix ID's #2, #3, #4, and #5 passed UN Test N.5, "Test Method for Substances which in Contact with Water Emit Flammable Gases" and are NOT classified in Division 4.3.

7.15 Hotwire auto-ignition temperature screening test

7.15.1 *Test Description*

This screening test determines the approximate temperature at which a substance is ignited by a hotwire. The substance is placed on an impervious, non-combustible, low heat-conducting surface over a heating resistance wire instrumented with thermocouples. The temperature of a heating resistance wire is increased until the substance ignites or until the maximum test temperature is reached. Normally two trials are performed.

7.15.2 *Test Configuration*

Each end of a 105-mm long, 18-gauge 80/20 nickel/chromium (ni-chrome) resistance heating wire (Type A) was attached to electrodes suspended just above an insulating clay-based firebrick. Two quick-responding thermocouples (30 gauge) were wrapped over the heating wire; approximately 5 grams of the test sample was poured over the heating wire and thermocouples, as shown in the following photo. The resistance heating wire could achieve a maximum test temperature of 1200°C. Generally, each substance was tested with a fast heating rate (increasing the amperage approximately 1 amp every 10 seconds) and a slow heating rate (increasing the amperage approximately 1 amp every 30 seconds). NOTE: Type K thermocouples were normally utilized; when Type B thermocouples were utilized, the actual temperature of the sample was not measured until the temperature was above 100°C (minimum temperature measurement limit).

Photo 159: Hotwire Auto-ignition Temperature Apparatus with Dual Thermocouples

Photo 160: Test Sample Loaded onto Hotwire Auto-ignition Temperature Apparatus

7.15.3 *Test Results*

The test results are summarized in the following table. NOTE: The auto-ignition temperature of Small-scale Mix #26 exceeded that of the ni-chrome heating wire (>1200 °C).

NOTE: Originally, high-energy thermites utilizing beryllium as their fuel were to be tested for auto-ignition temperature. However, titanium was substituted for beryllium due to the potential health hazard of beryllium to test personnel in very small quantities (toxic by inhalation).

Table 40: Summary of Auto-Ignition Temperature Test Results for SMS Mixes

Item	Metal Oxide	Metal	Small-Scale Mix ID	Ignition 1st Trial (°C)	Ignition 2nd Trial (°C)	Reaction Type
1	B_2O_3	Mg	1	440 [TC1] 425 [TC2]	595 [TC1] 610 [TC2]	Burned for 2 seconds
2	B_2O_3	Ti	2B	1100 [TC1]	1030 [TC1] 1040 [TC2]	Very slow, subtle burn
3	Bi_2O_3	Al	24	560 [TC1]	710 [TC1] 650 [TC2]	**Exploded**
4	Co_3O_4	Al	12	1210 [TC1] 1060 [TC2]	1130 [TC1] 1090 [TC2]	Burned for 2 - 3 seconds
5	Cr_2O_3	Al	21	~400 [TC1]	~590 [TC1] ~690 [TC2]	Endotherm preceding exotherm; slow reaction
6	CuO	Ti	7B	560 [TC1]	640 [TC1] 540 [TC2]	**Low-order explosion (burned <0.1 seconds)**
7	CuO	Mg	11	460 [TC1] 485 [TC2]	575 [TC1] 480 [TC2]	Burned for 1 second
8*	CuO	Al	13	815 [TC1] 800 [TC2]	970 [TC1] 1140 [TC2]	Burned for 3 seconds
9	Fe_2O_3	Ti	6B	630 [TC1]	790 [TC1] 840 [TC2]	Burned for 1 - 2 seconds
10	Fe_2O_3	Mg	10	510 [TC1] 420 [TC2]	470 [TC1] 430 [TC2]	Burned for 1 - 2 seconds
11*	Fe_2O_3	Al	14	980 [TC1] --- [TC2]	965 [TC1] 920 [TC2]	**Low-order explosion (burned <0.1 seconds)**
12	MnO_2	Ti	3B	670 [TC1]	780 [TC1] 740 [TC2]	**Exploded**
13	MnO_2	Mg	4	425 [TC1]	480 [TC1]	**Exploded**
14*	MnO_2	Al	8	915 [TC1] 915 [TC2]	1140 [TC1] 1150 [TC2]	**Exploded**
15	MoO_3	Al	9	540 [TC1] 540 [TC2]	550 [TC1] 595 [TC2]	**Exploded**
16*	MoO_3 &CuO	Mg&Al	29	860 [TC1] 800 [TC2]	600 [TC1] 690 [TC2]	**Exploded**
17*	Ni_2O_3	Al	5	~880 [TC1]	915 [TC1] 955 [TC2]	Burned for 15 seconds
18	SnO_2	Al	19	775 [TC1] 860 [TC2]	900 [TC1] 860 [TC2]	**Exploded**
19	TiO_2	Al	25	800 [TC1] 850 [TC2]	1010 [TC1] 990 [TC2]	Burned for 20 seconds
20	WO_3	Al	18	980 [TC1] --- [TC2]	--- [TC1] ~980 [TC2]	Sporadic thermal behavior; burned for 3 seconds

*Large-scale testing mixtures

Table 41: Summary of Auto-Ignition Temperature Test Results for Commercial Mixes

Item	Sample	Small-Scale Mix ID	Ignition Trial 1 (°C)	Ignition Trial 2 (°C)	Reaction Type
1*	Coarse Al-Fe_2O_3 Thermite A - Mix ID #2 (Commercial)	26	>1200 [TC1]	n/a	Unable to ignite using 18-gauge ni-chrome wire
2*	Coarse Al-Fe_2O_3 Thermite B - Mix ID #3 (Commercial)	27	1100 [TC1]	>1050 [TC1] >1050 [TC2]	Burned for 2 seconds
3*	Medium Al-CuO Thermite - Mix ID #5 (Commercial)	28	~750 [TC1]	1180 [TC1] 1160 [TC2]	Burned for 1 - 2 seconds

*Large-scale testing mixtures

Figure 16: Auto-ignition Temperature Plots for Small-Scale Mix ID #1: Mg-B_2O_3

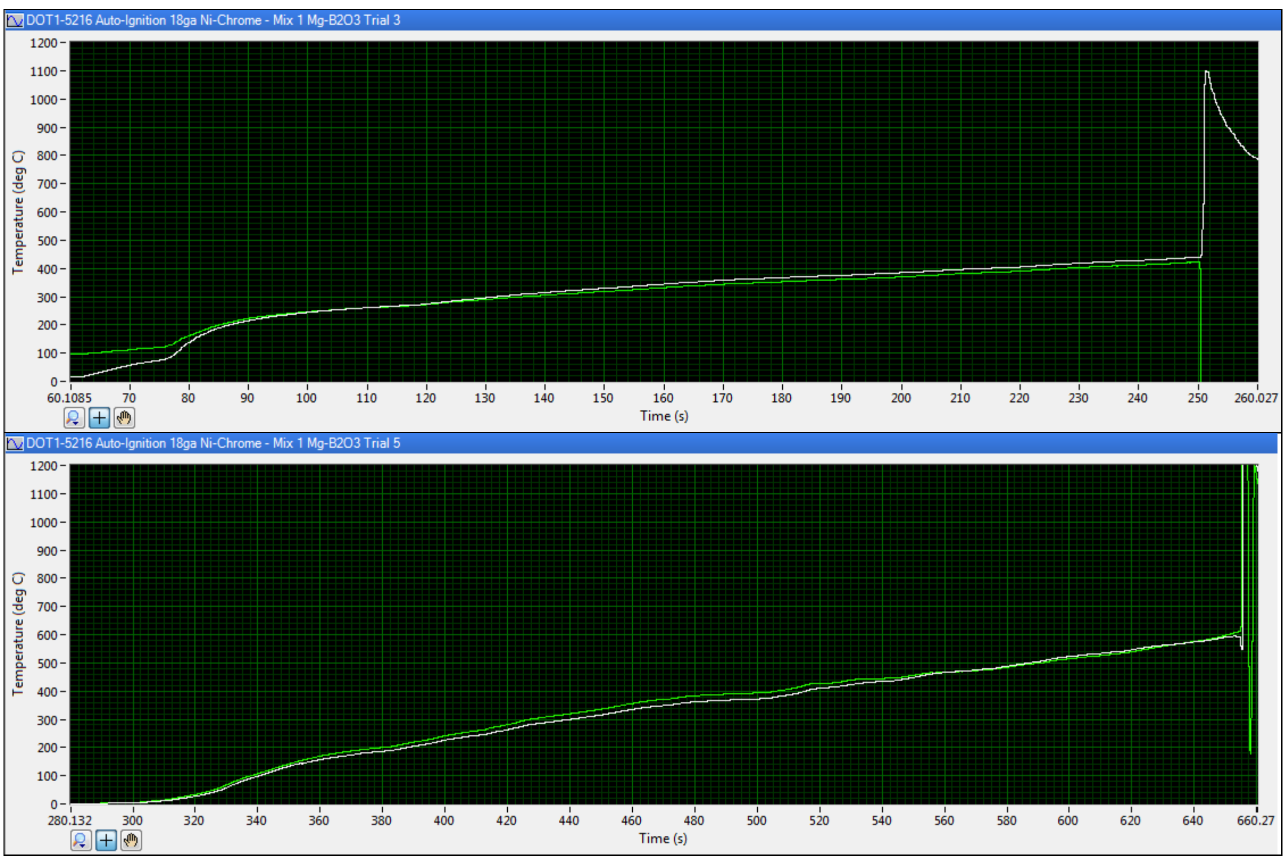


Figure 17: Auto-ignition Temperature Plots for Small-Scale Mix ID #2B: Ti-B_2O_3

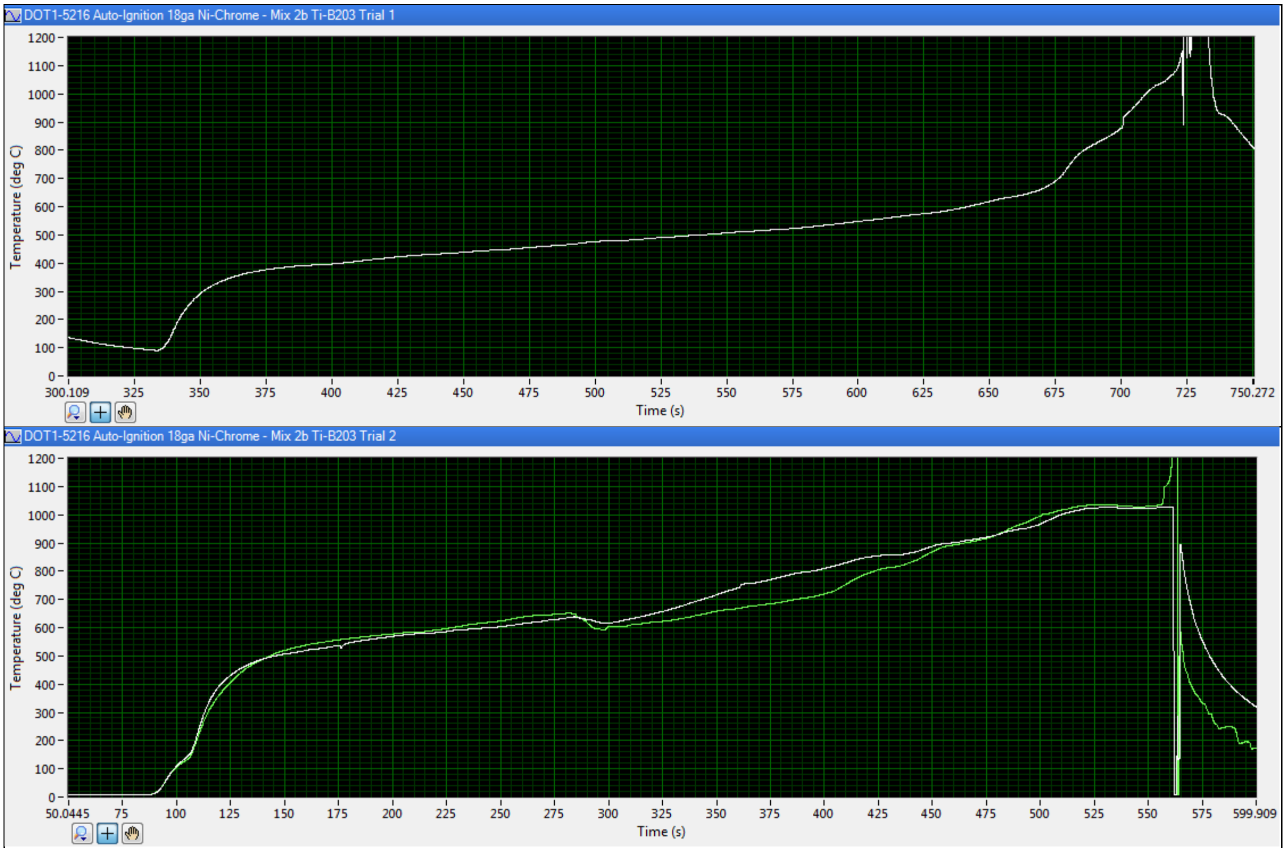
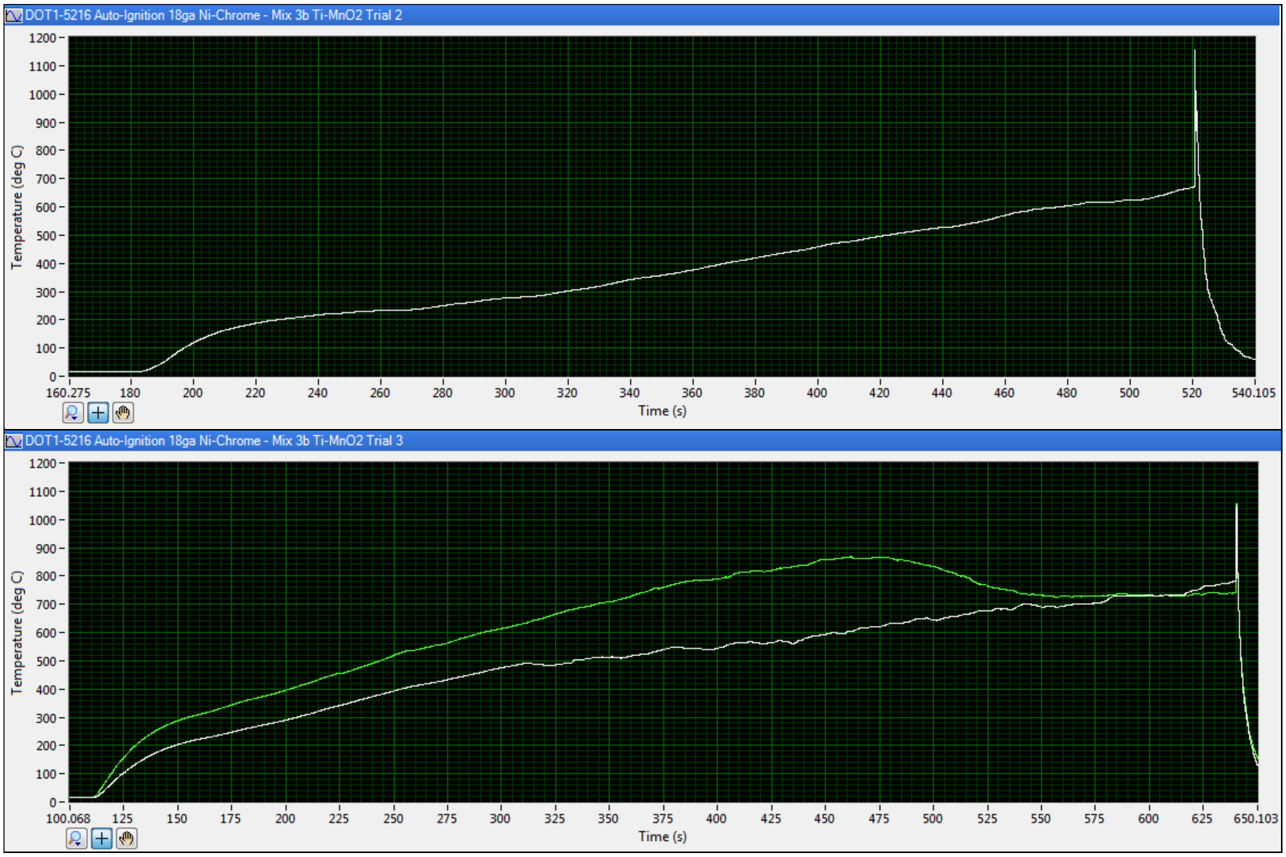


Figure 18: Auto-ignition Temperature Plots for Small-Scale Mix ID #3B: Ti-MnO_2



NOTE: For the second trial on this mix, one of the thermocouples unexpectedly departs from the baseline and then returns prior to auto-ignition of the sample; the cause for the departure is unknown.

Figure 19: Auto-ignition Temperature Plots for Small-Scale Mix ID #4: Mg-MnO_2

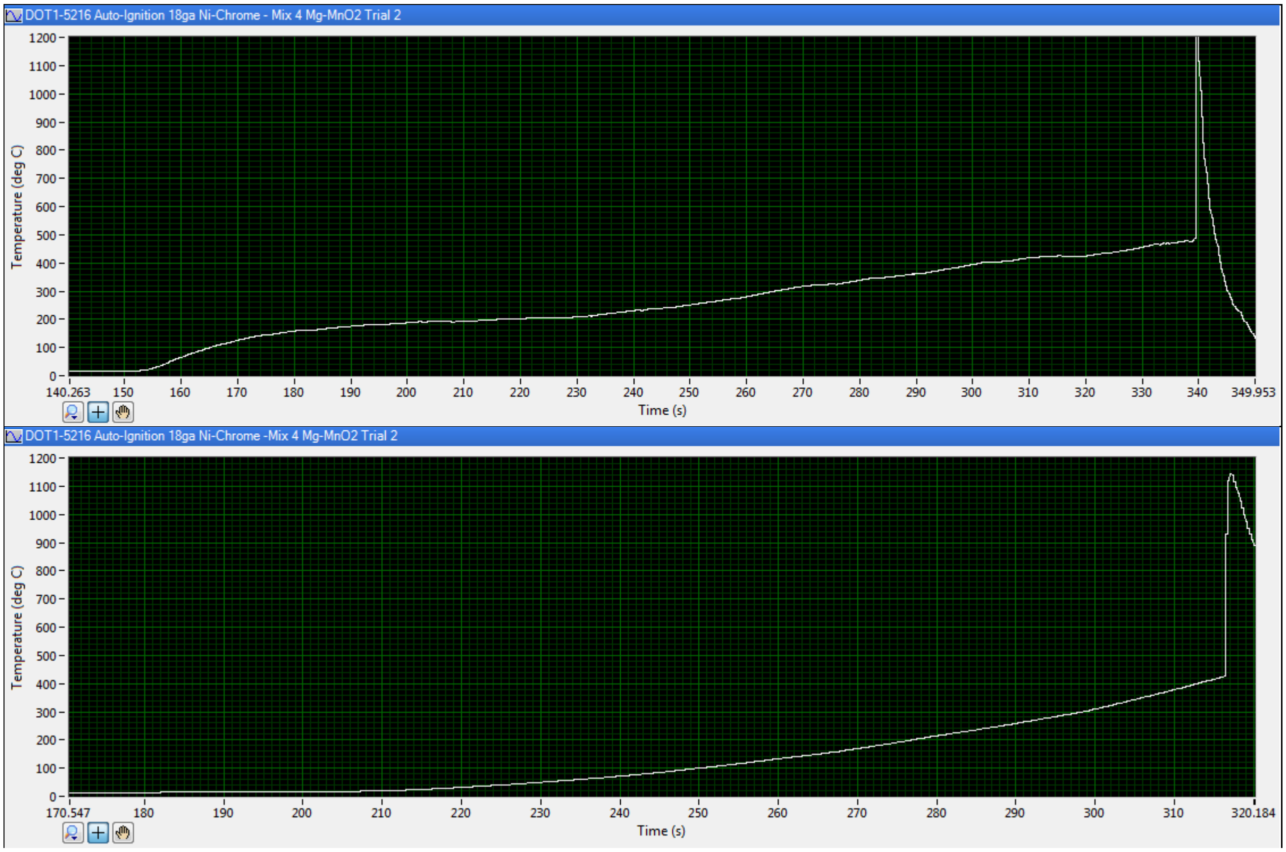
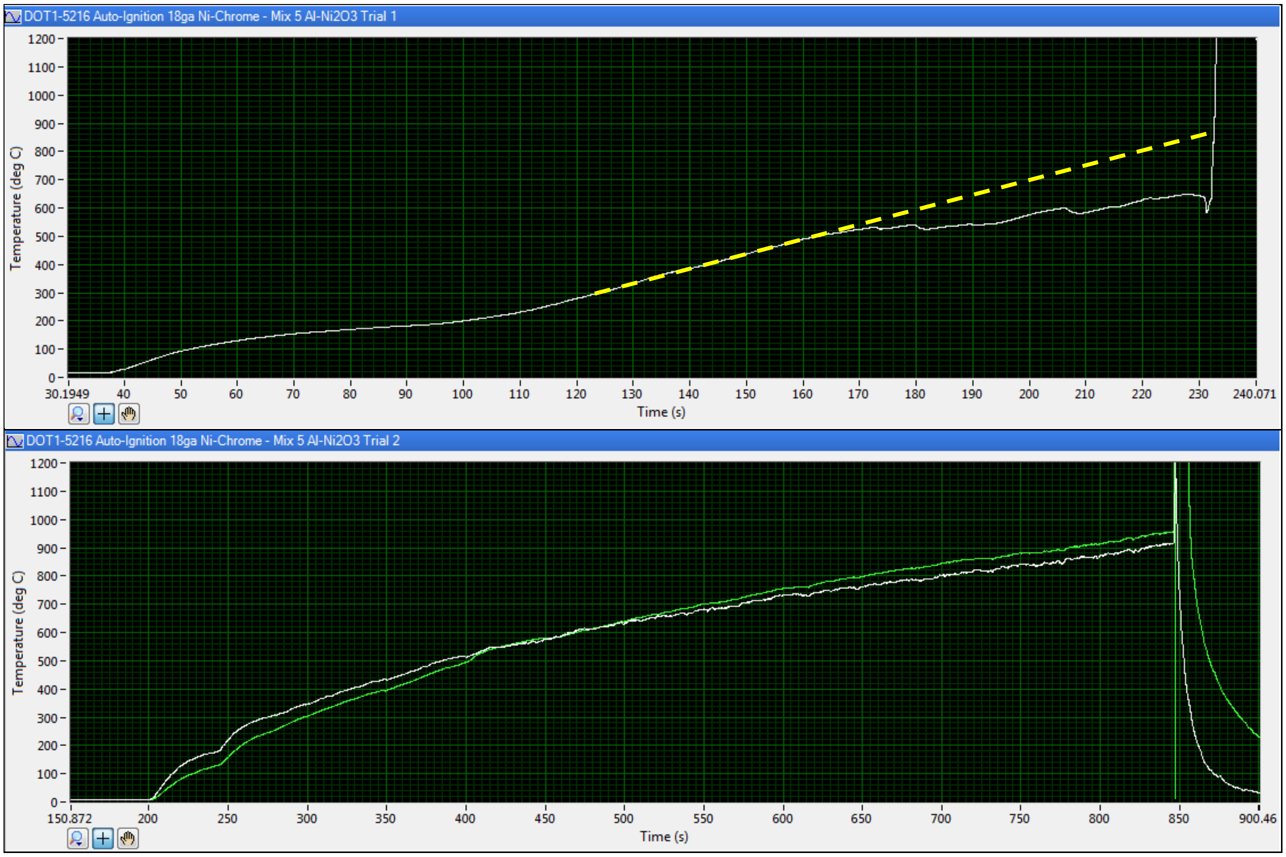
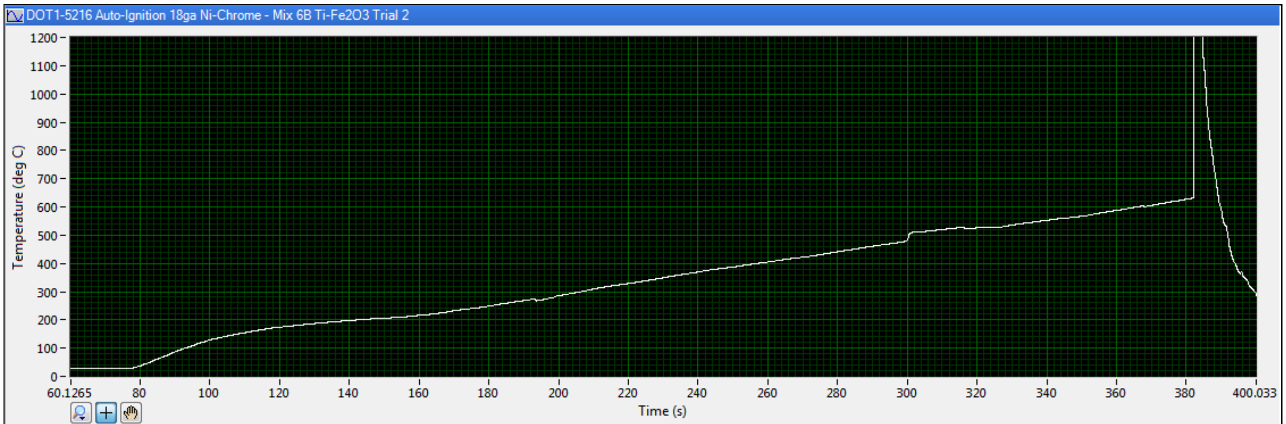


Figure 20: Auto-ignition Temperature Plots for Small-Scale Mix ID #5: Al-Ni_2O_3



NOTE: For this mix, one of the thermocouples unexpectedly departs from the baseline; a dashed line has been added to smooth out this departure. The cause for the departure is unknown but could be due to the thermocouple detaching from the ni-chrome heating wire as it experiences greater elongation and deformation at higher temperatures.

Figure 21: Auto-ignition Temperature Plots for Small-Scale Mix ID #6B: Ti-Fe_2O_3



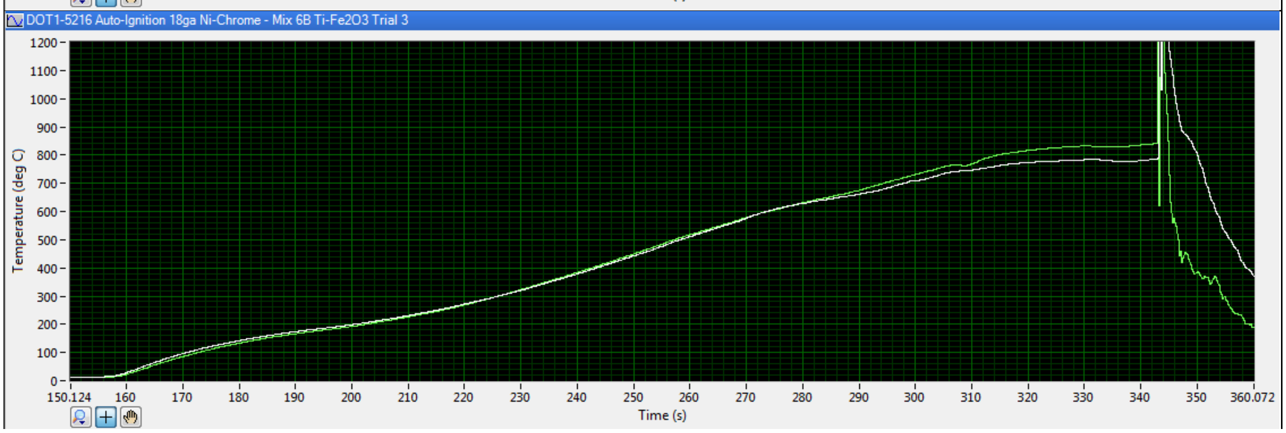


Figure 22: Auto-ignition Temperature Plots for Small-Scale Mix ID #7B: Ti-CuO

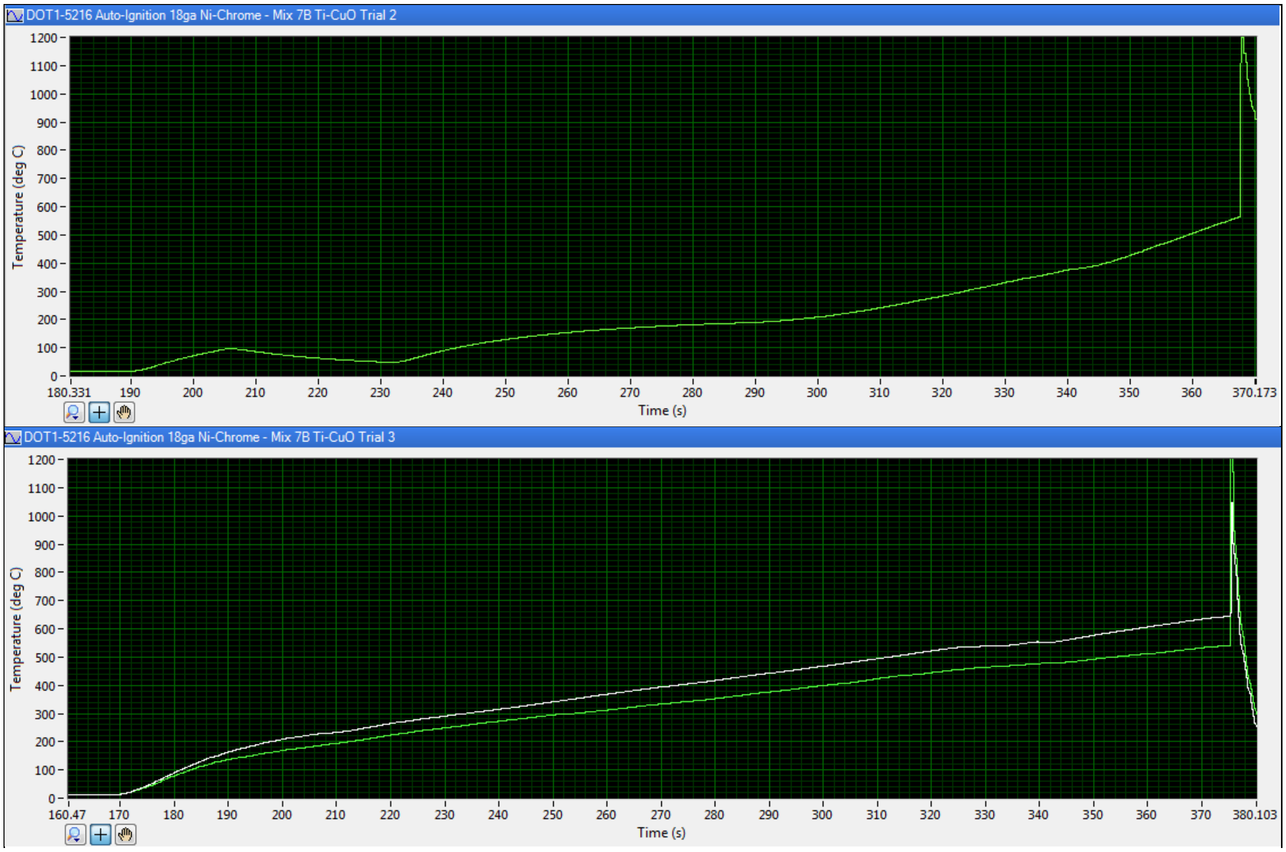


Figure 23: Auto-ignition Temperature Plots for Small-Scale Mix ID #8: Al-MnO_2

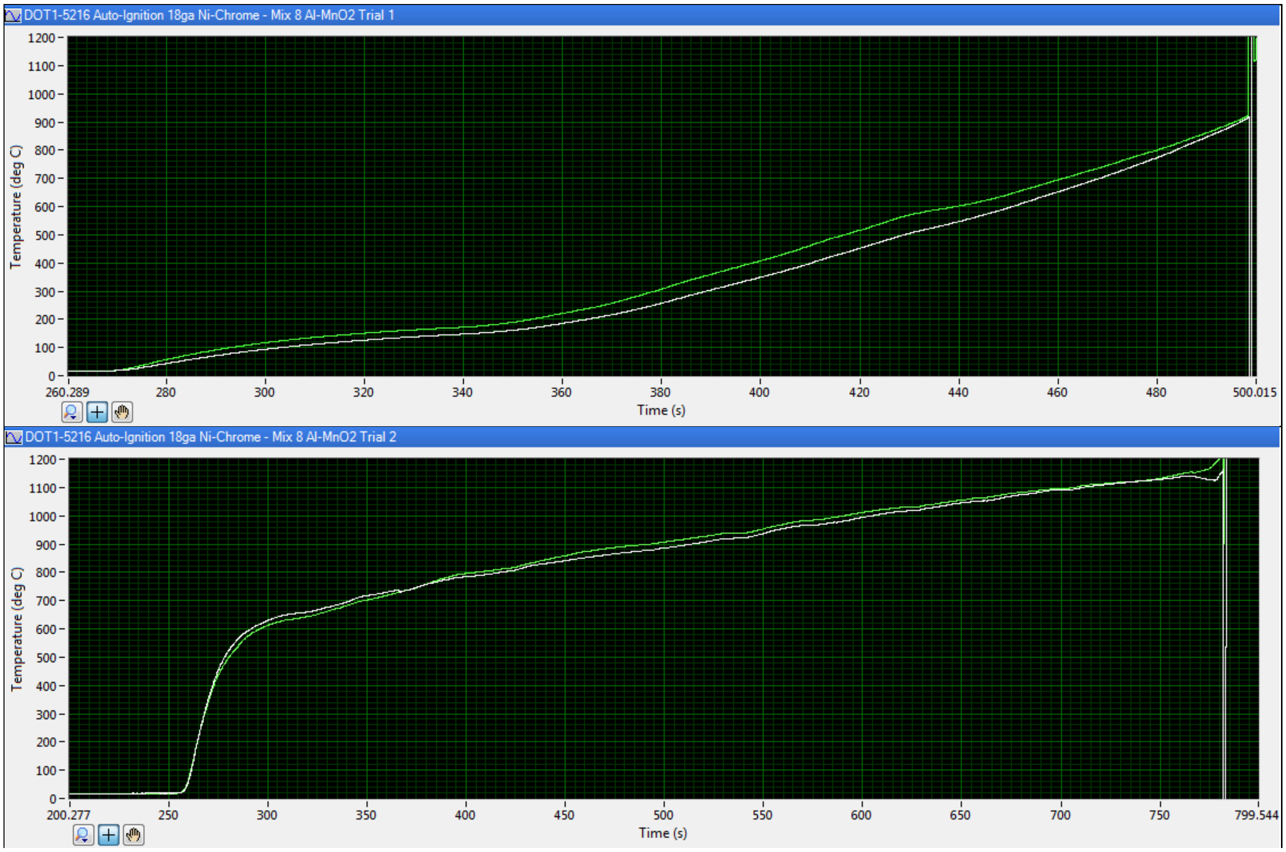
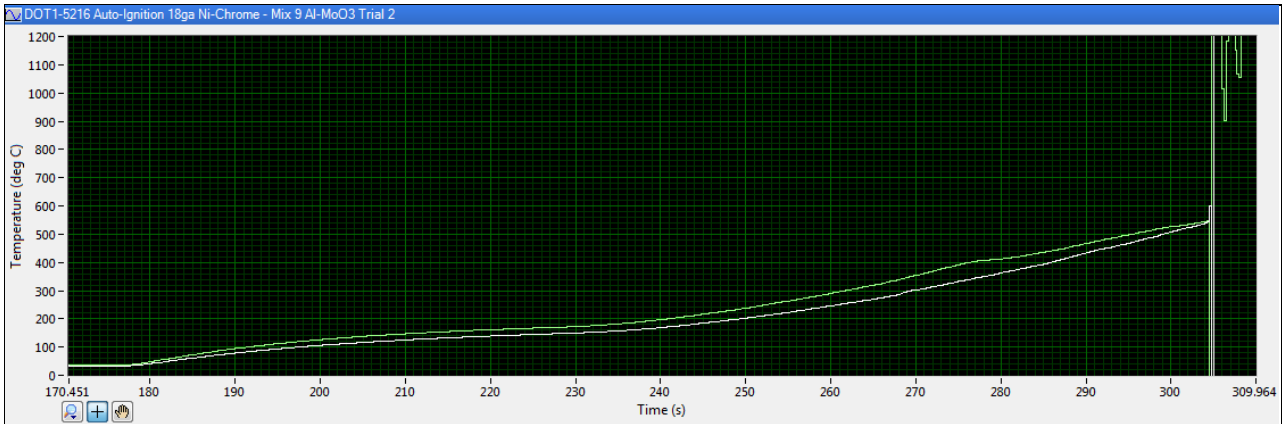


Figure 24: Auto-ignition Temperature Plots for Small-Scale Mix ID #9: Al-MoO3



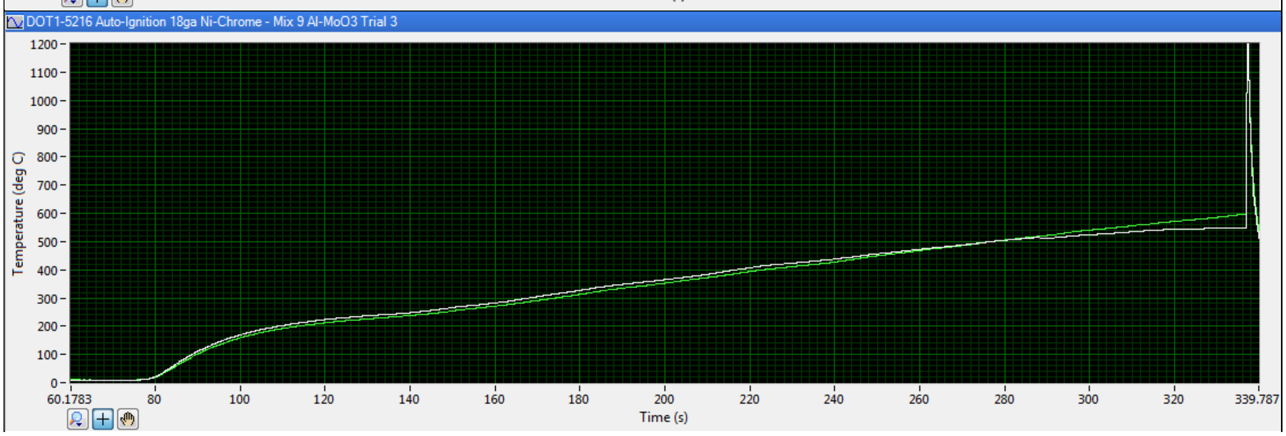


Figure 25: Auto-ignition Temperature Plots for Small-Scale Mix ID #10: $Mg\text{-}Fe_2O_3$

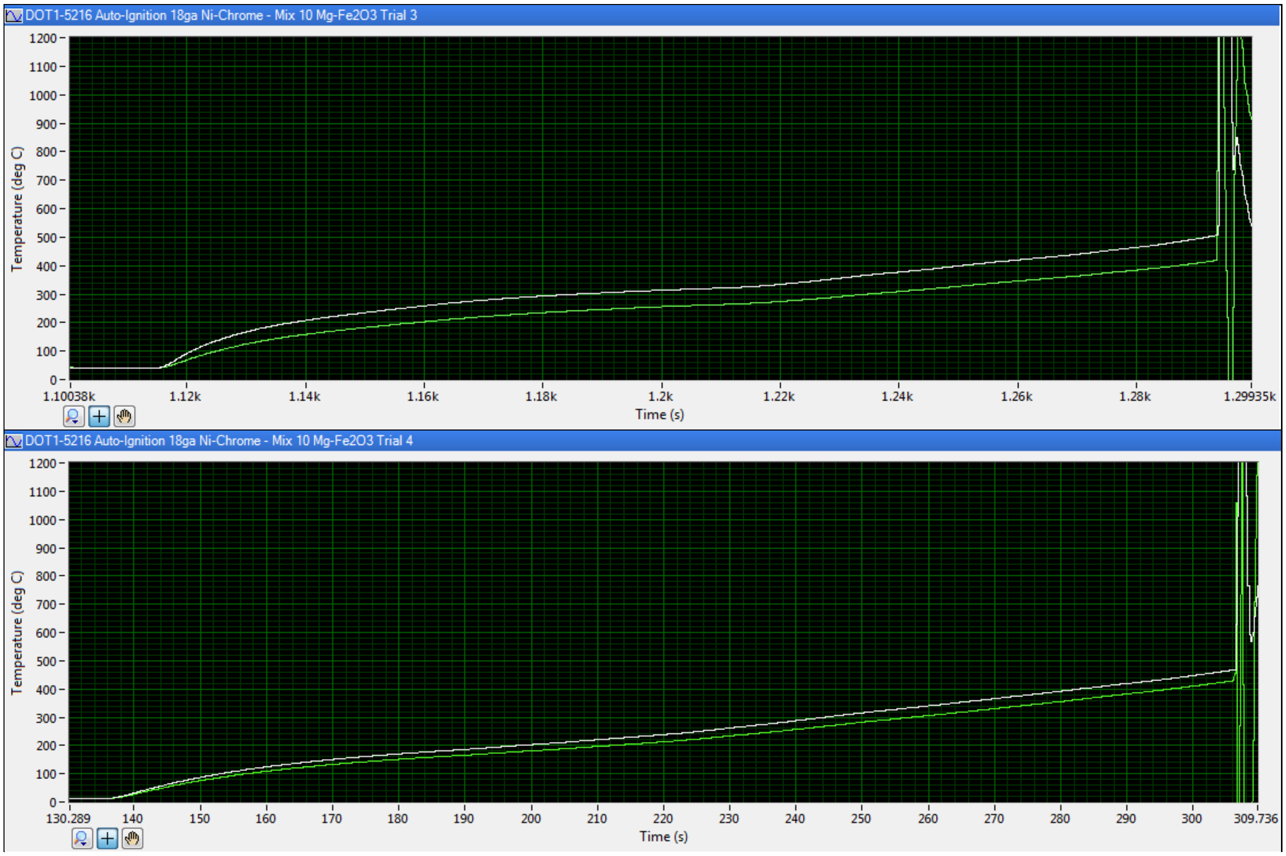


Figure 26: Auto-ignition Temperature Plots for Small-Scale Mix ID #11: Mg-CuO

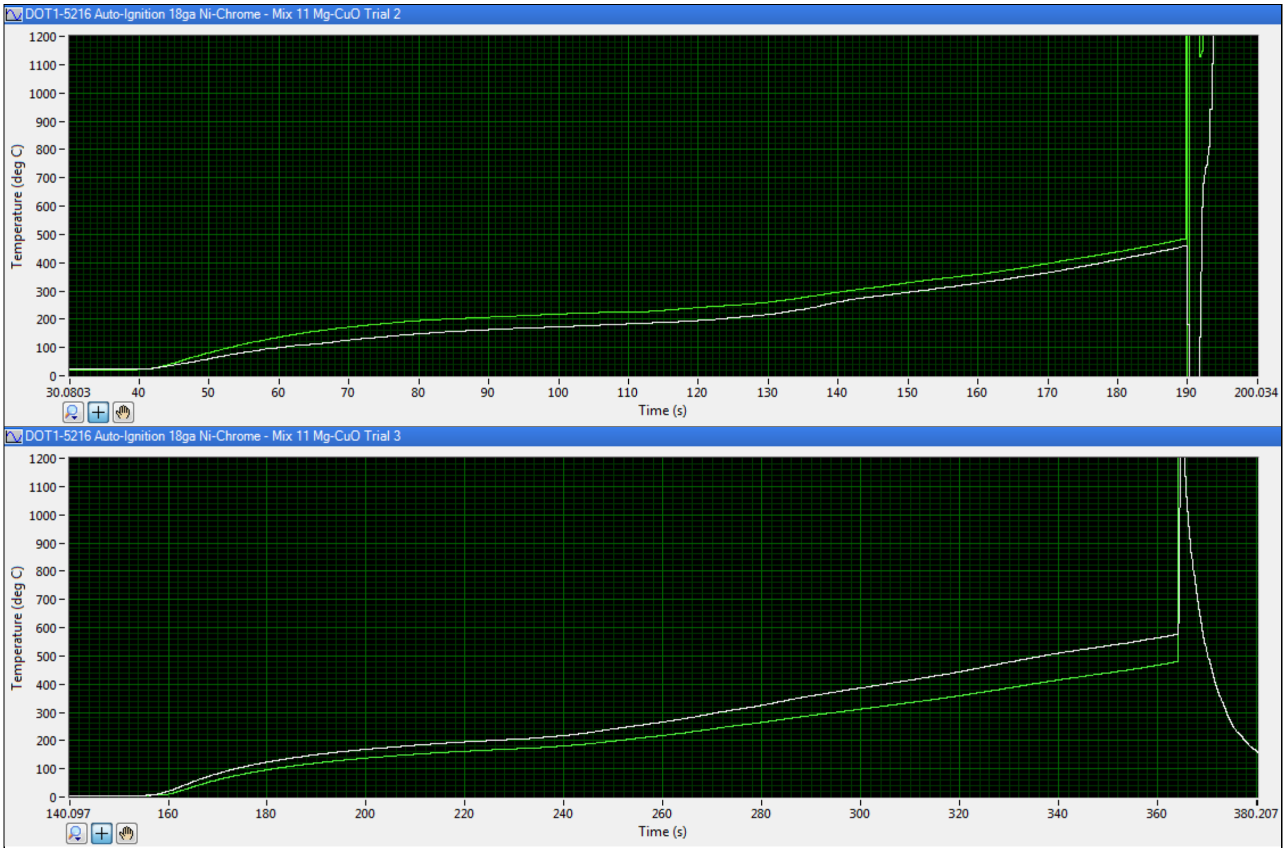


Figure 27: Auto-ignition Temperature Plots for Small-Scale Mix ID #12: Al-Co_3O_4

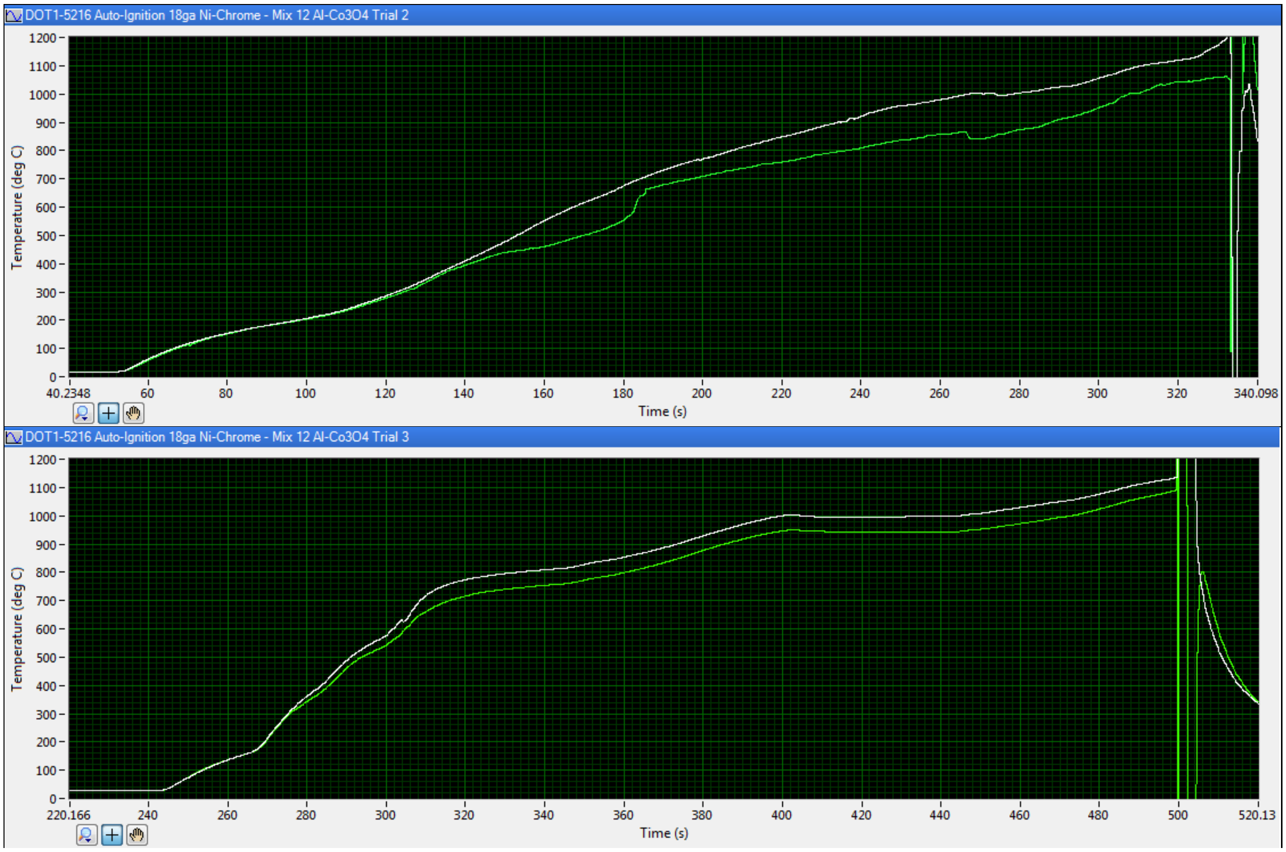
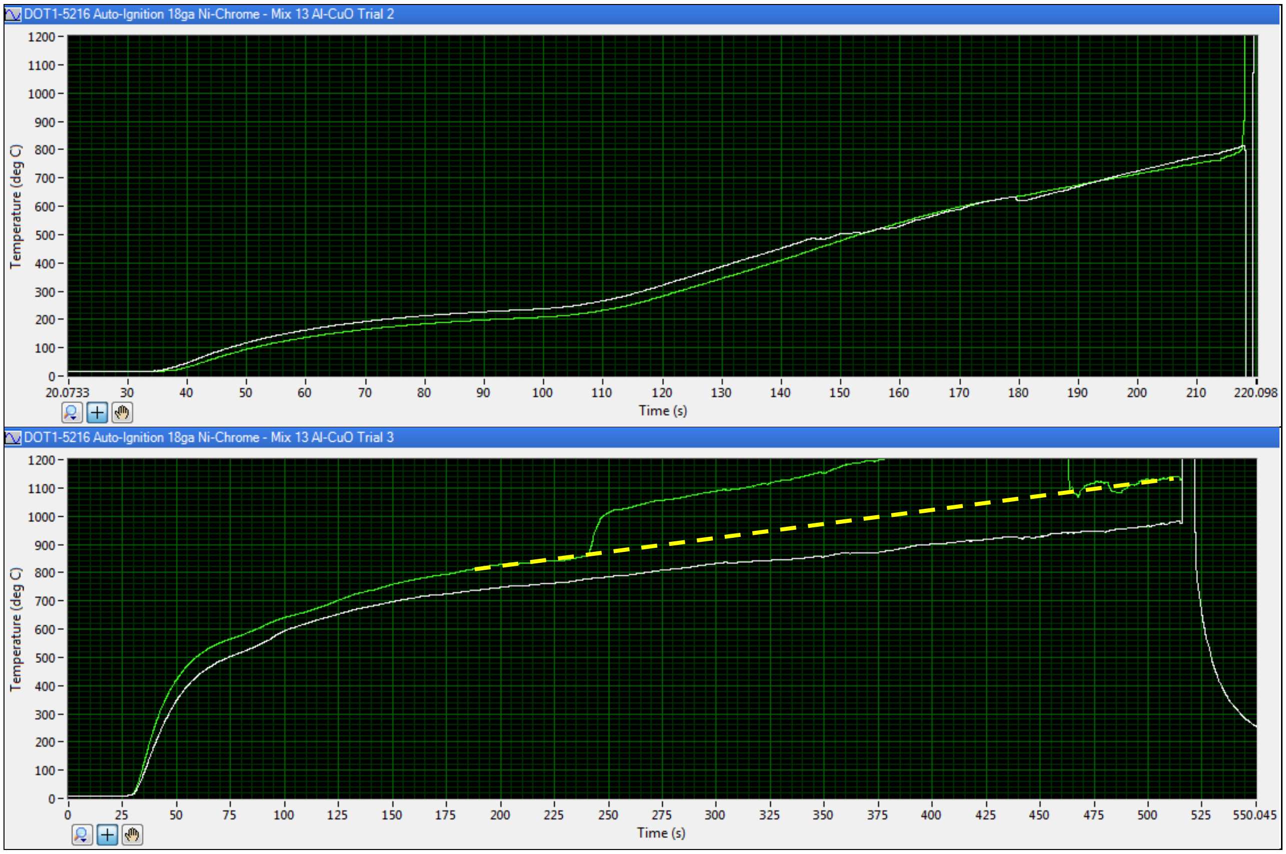


Figure 28: Auto-ignition Temperature Plots for Small-Scale Mix ID #13: Al-CuO



NOTE: For this mix, one of the thermocouples unexpectedly departs from the baseline and then returns prior to auto-ignition of the sample (a dashed line has been added to smooth out this departure); the cause for the departure is unknown.

Figure 29: Auto-ignition Temperature Plots for Small-Scale Mix ID #14: Al-Fe_2O_3

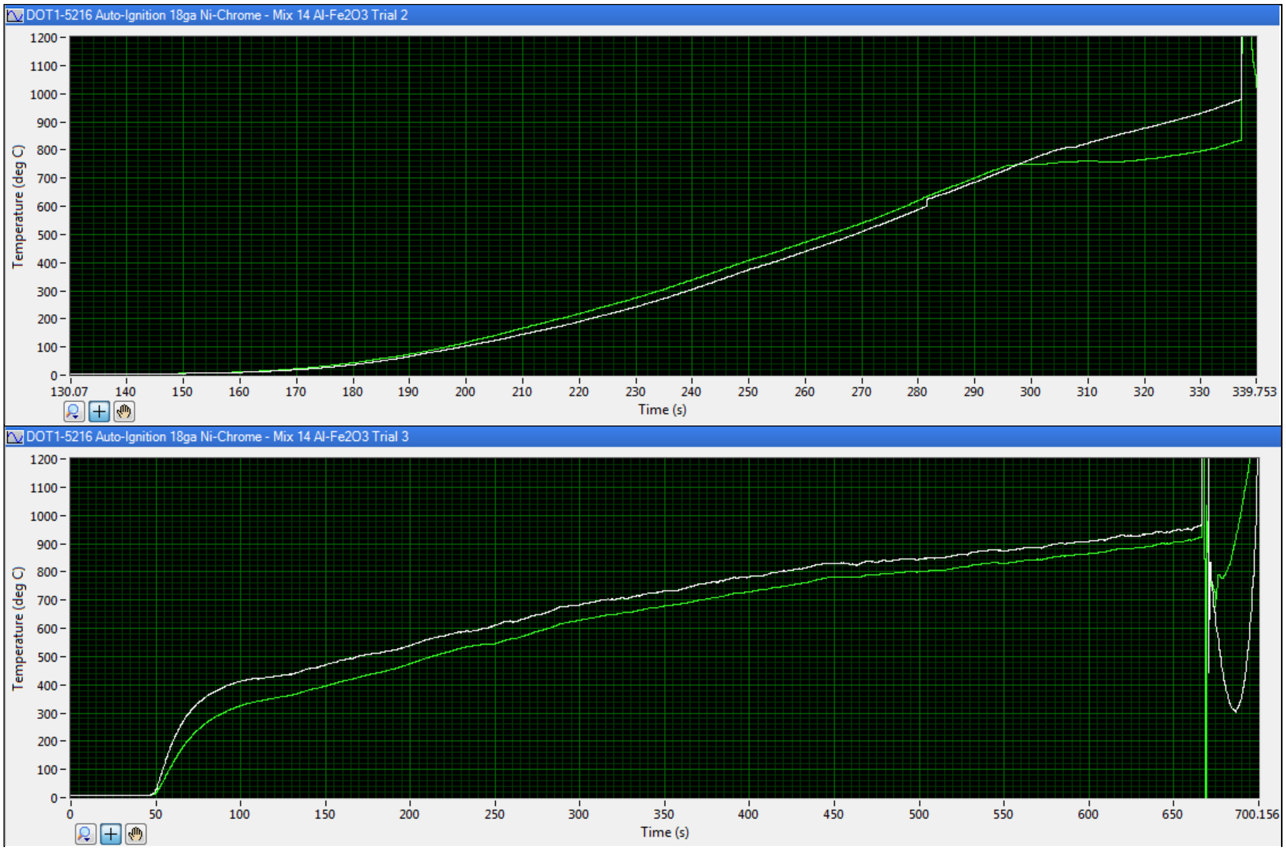
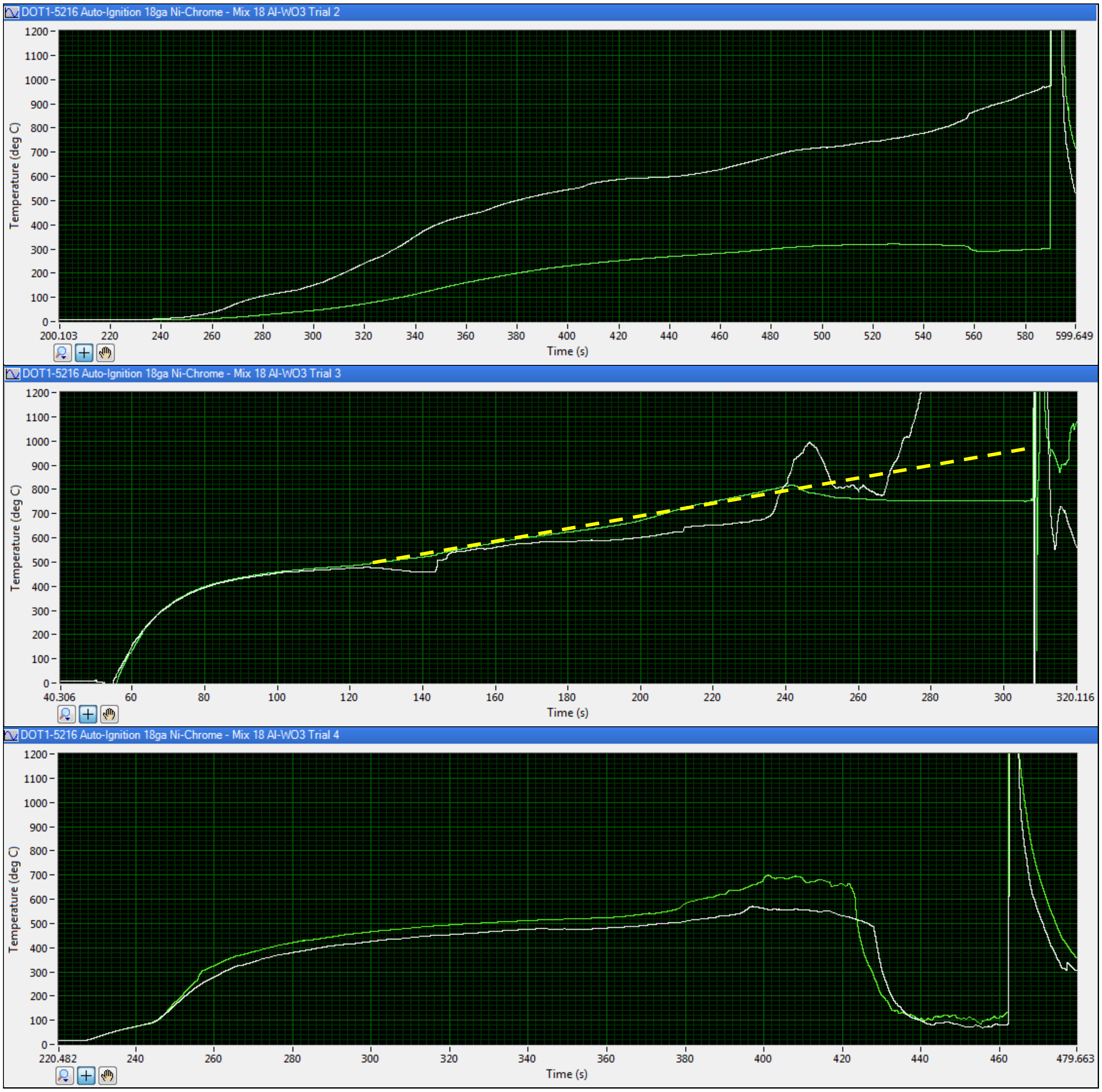
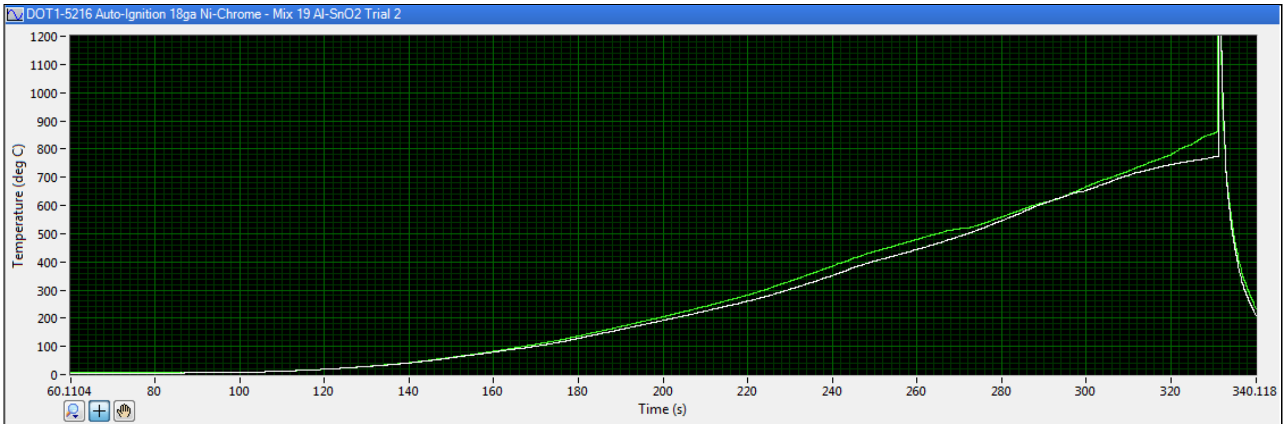


Figure 30: Auto-ignition Temperature Plots for Small-Scale Mix ID #18: Al-WO_3



NOTE: For this mix, one thermocouple in each of the first two trials unexpectedly departs from the baseline; for the second trial, a dashed line has been added to smooth out its departure. The cause for the departure is unknown but could be due to the thermocouple detaching from the ni-chrome heating wire as it experiences greater elongation and deformation at higher temperatures. Examining the temperature plots for the first two trials, one of the thermocouples appears to be providing very different measurements; a third trial was performed to increase confidence and repeatability but resulted in very different results from either of the first two trials. The cause of the variation between these trials is unknown.

Figure 31: Auto-ignition Temperature Plots for Small-Scale Mix ID #19: Al-SnO_2



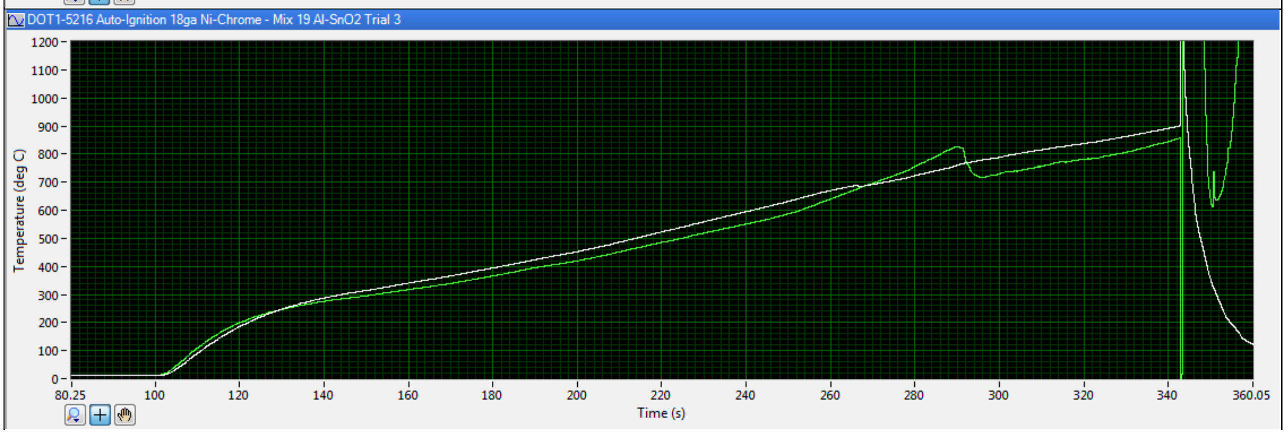
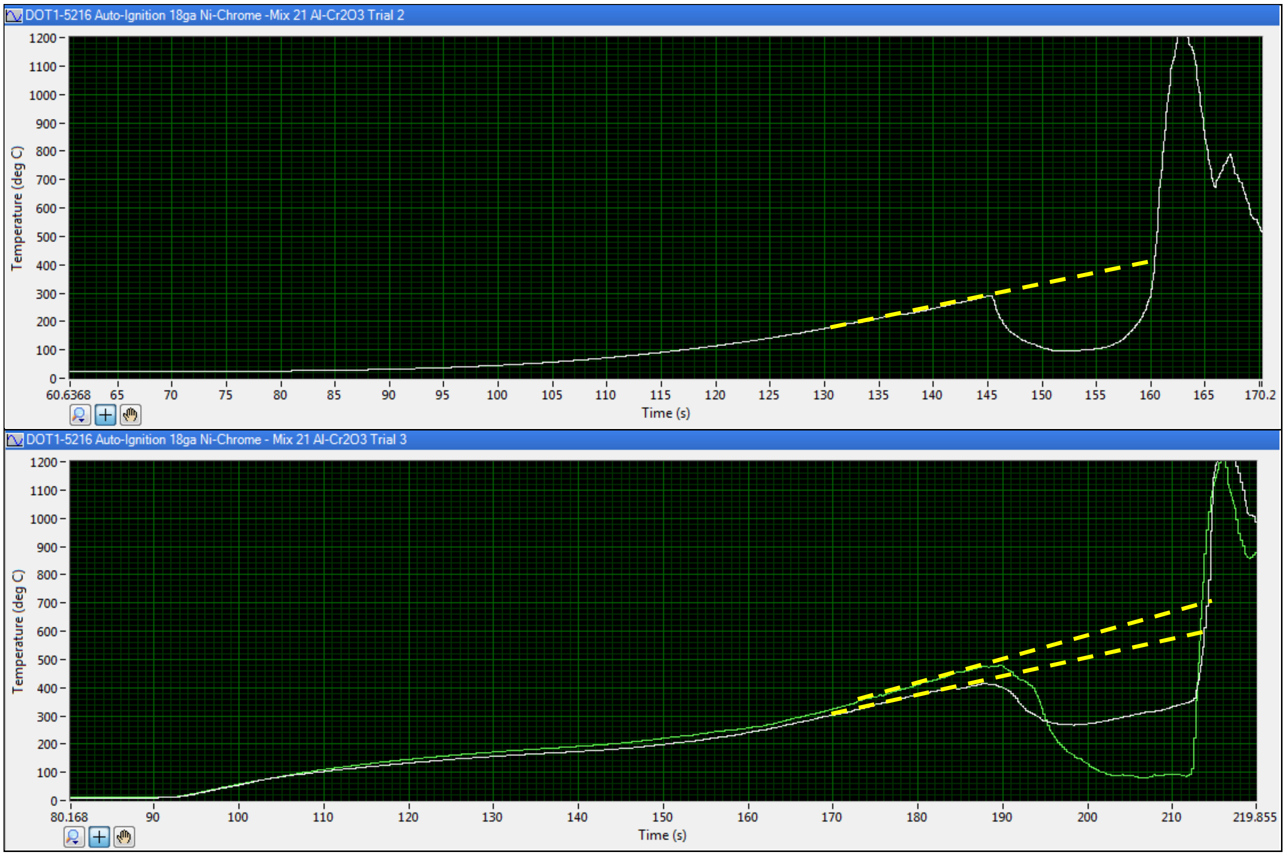


Figure 32: Auto-ignition Temperature Plots for Small-Scale Mix ID #21: Al-Cr_2O_3



NOTE: For this mix, the thermocouples depart from the baseline; a dashed line has been added to estimate the temperature of the hot wire at auto-ignition. The departure appears to be repeatable and may be the result of endothermic activity.

Figure 33: Auto-ignition Temperature Plots for Small-Scale Mix ID #24: Al-Bi_2O_3

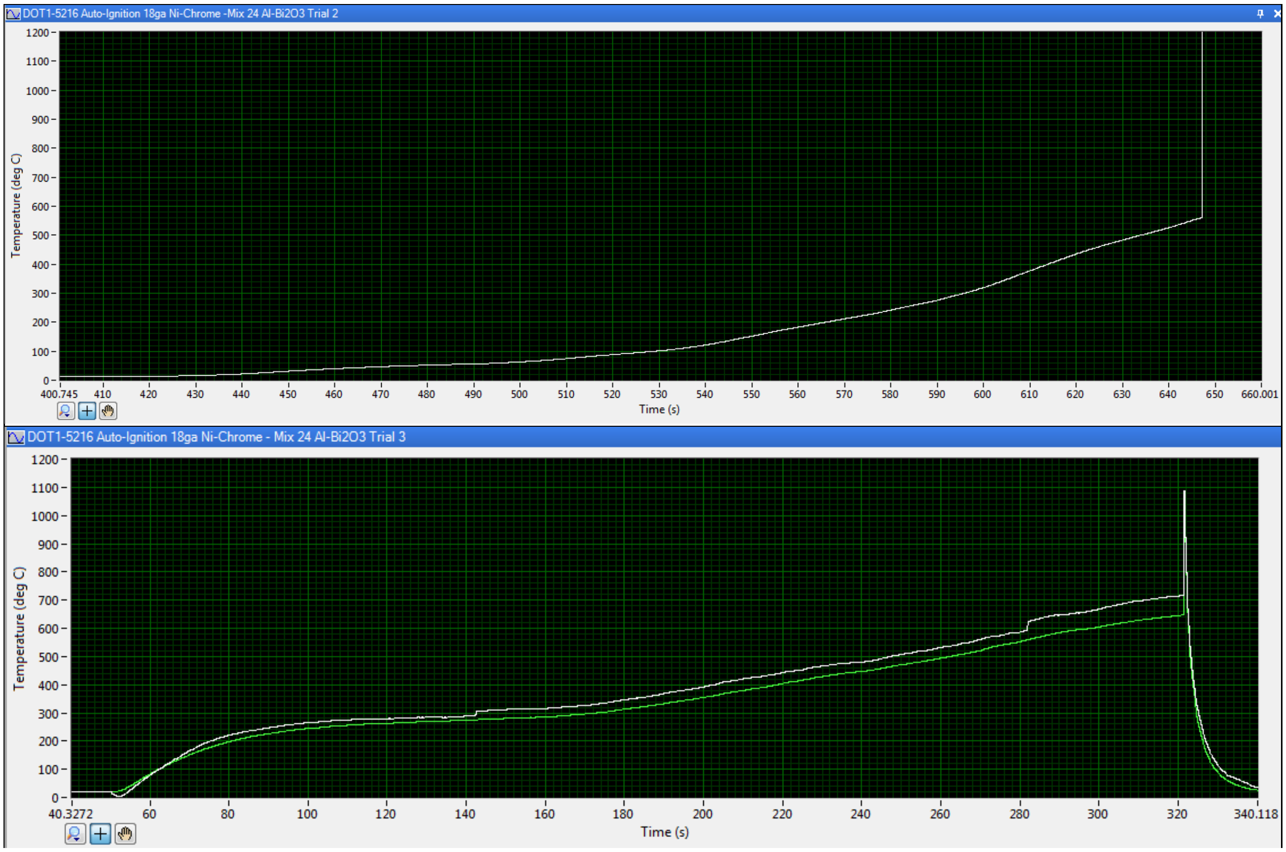
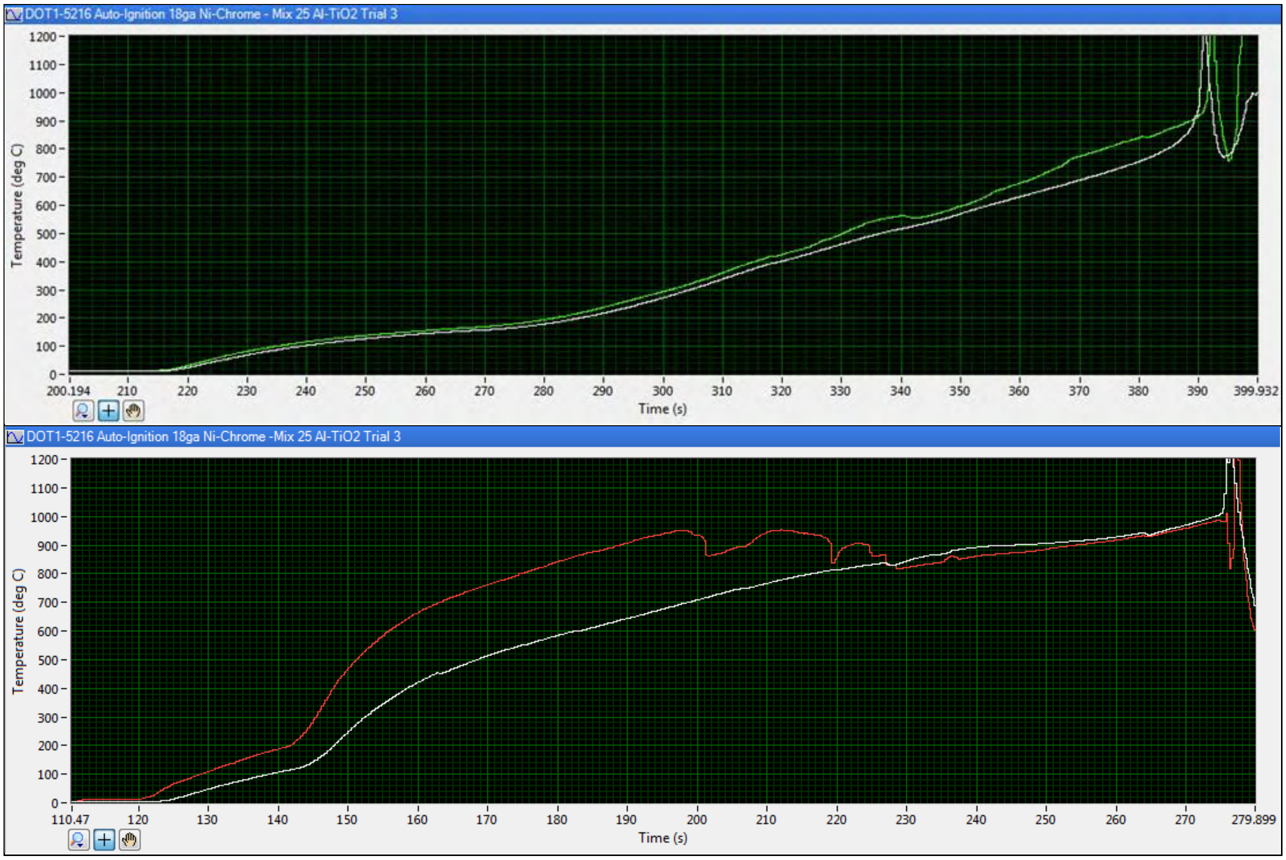


Figure 34: Auto-ignition Temperature Plots for Small-Scale Mix ID #25: Al-TiO_2



NOTE: For the second trial on this mix, one of the thermocouples unexpectedly departs from the baseline and then returns prior to auto-ignition of the sample; the cause for the departure is unknown.

Figure 35: Auto-ignition Temperature Plots for Small-Scale Mix ID #26: Coarse Al-Fe_2O_3 Thermite A - Mix ID #2 (Commercial)

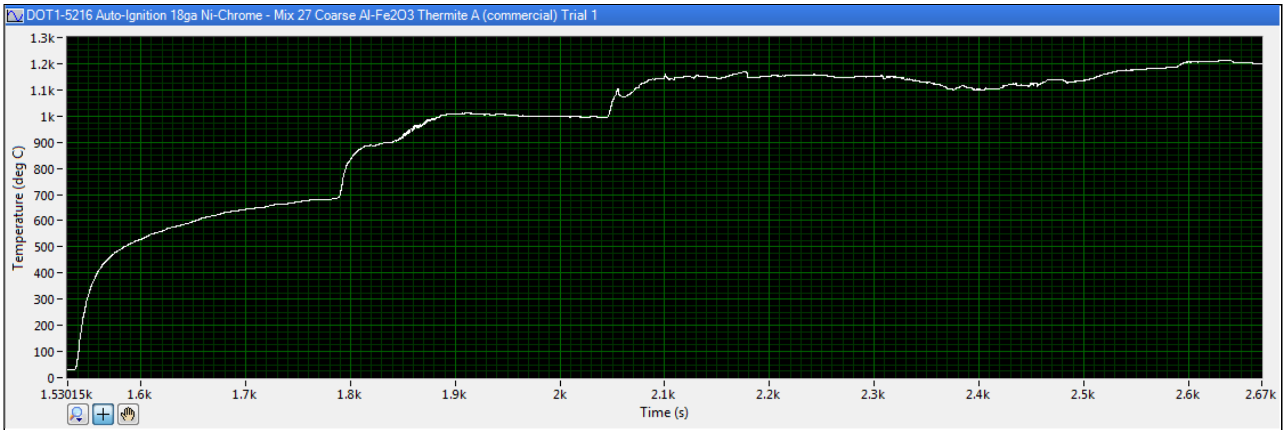


Figure 36: Auto-ignition Temperature Plots for Small-Scale Mix ID #27: Coarse Al-Fe_2O_3 Thermite B - Mix ID #3 (Commercial)

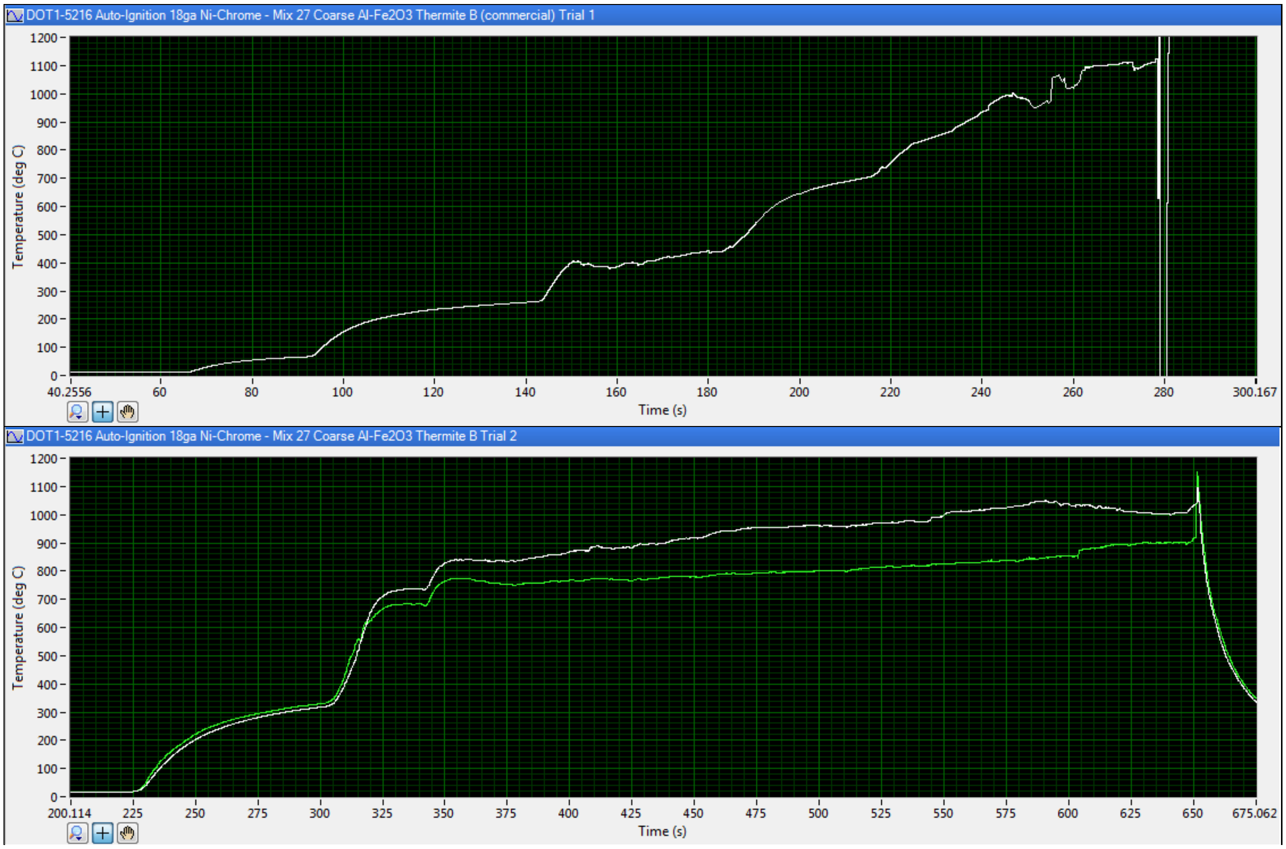
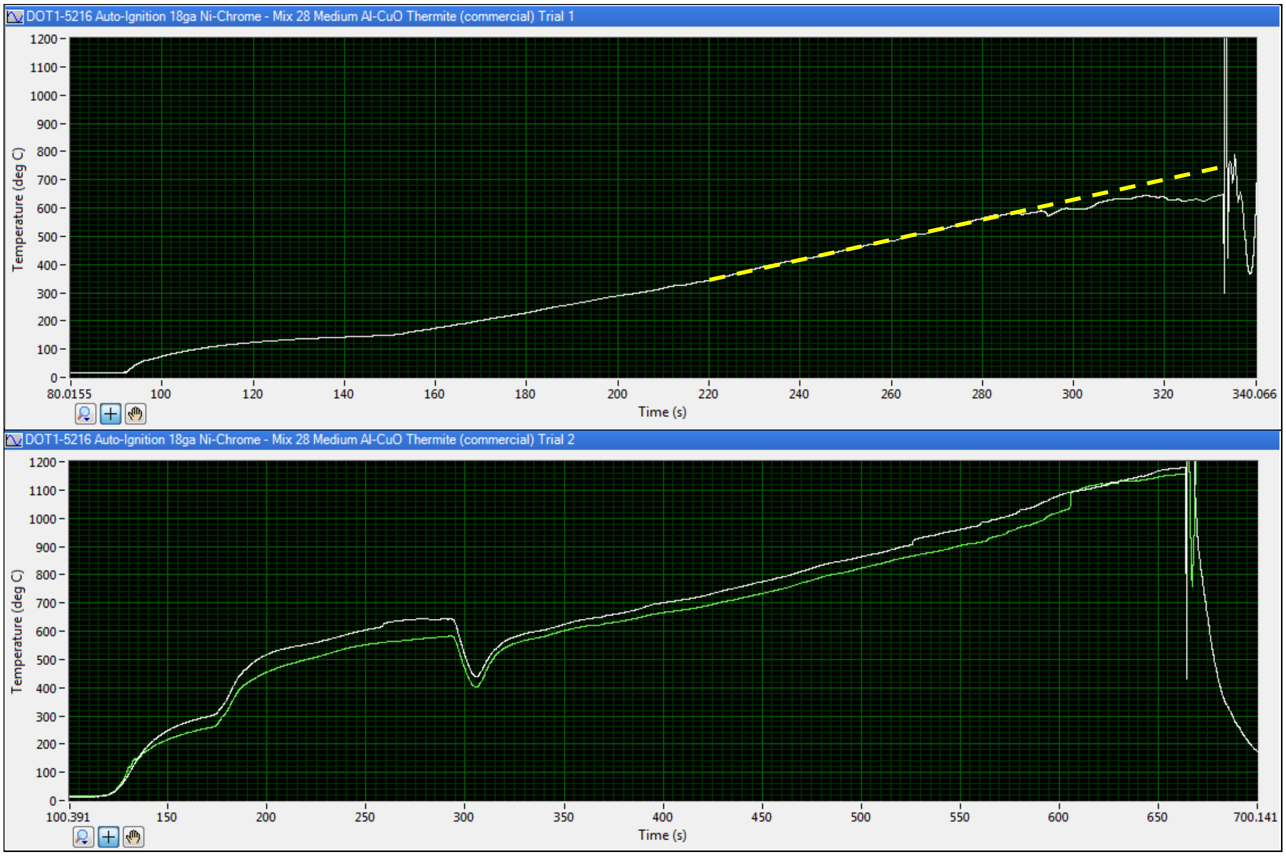
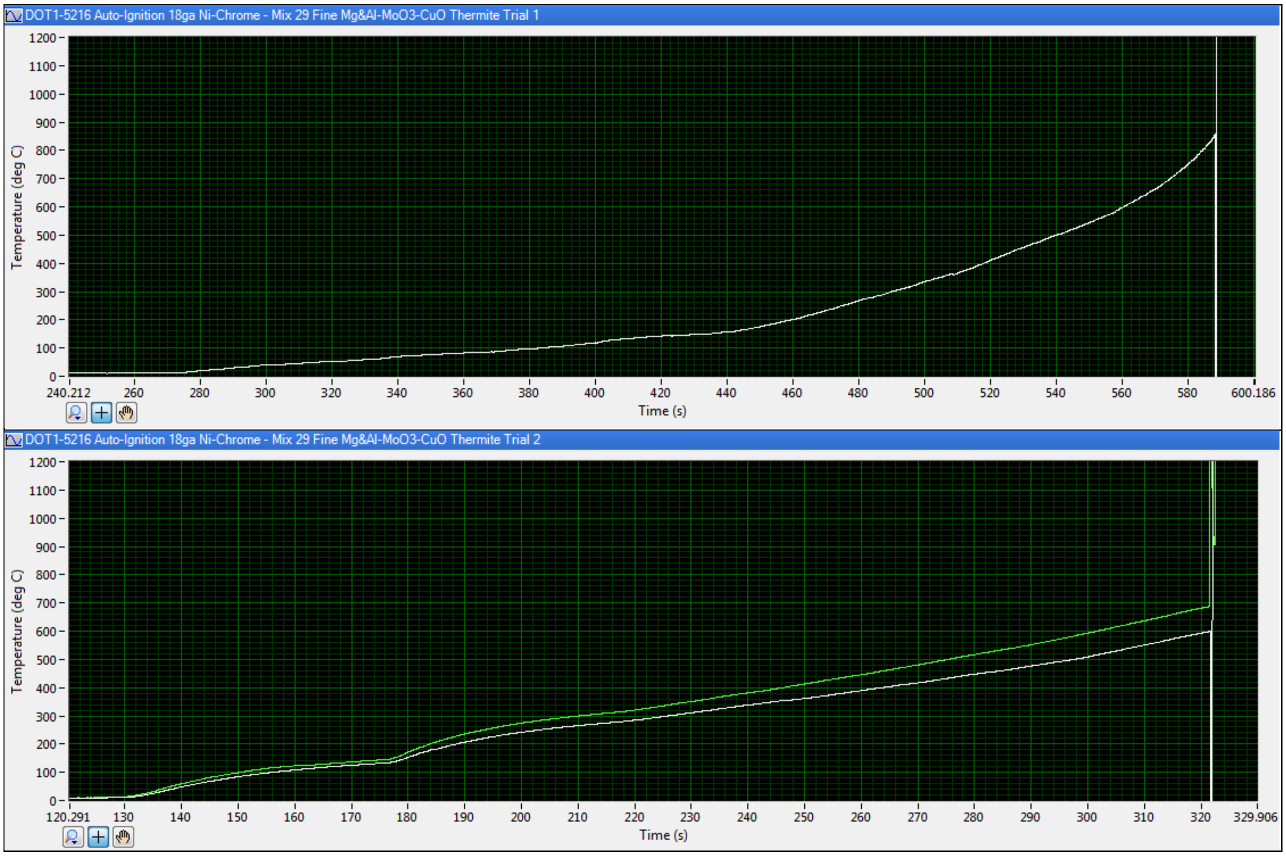


Figure 37: Auto-ignition Temperature Plots for Small-Scale Mix ID #28: Medium Al-CuO Thermite - Mix ID #5 (Commercial)



NOTE: For the first trial on this mix, one of the thermocouples unexpectedly departs from the baseline; a dashed line has been added to smooth out this departure). The cause for the departure is unknown but could be due to the thermocouple detaching from the ni-chrome heating wire as it experiences greater elongation and deformation at higher temperatures.

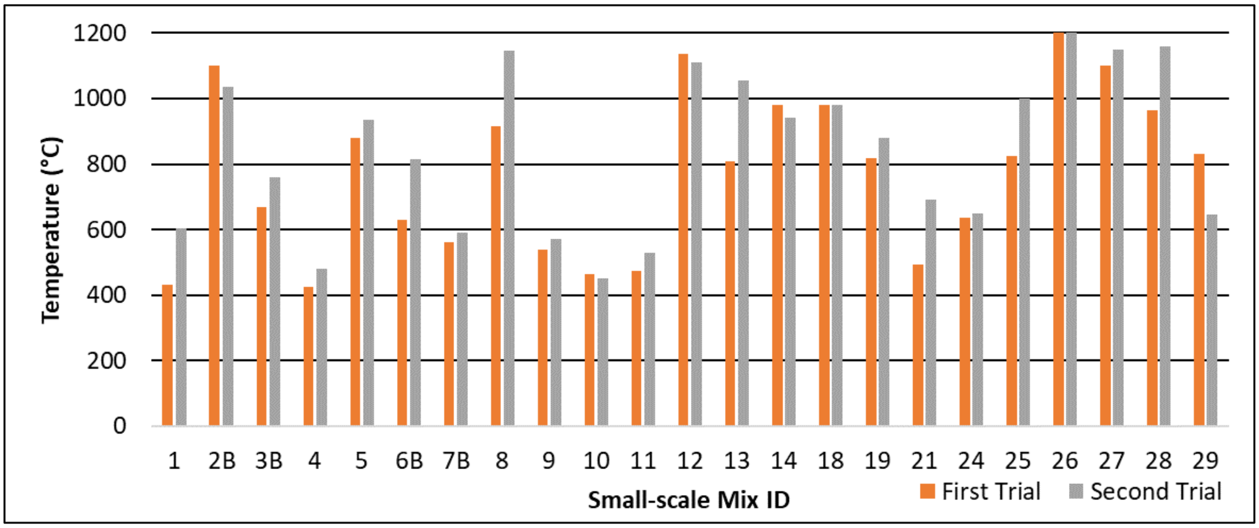
Figure 38: Auto-ignition Temperature Plots for Small-Scale Mix ID #29: Fine Mg&Al-MoO_3-CuO Thermite - Mix ID #8 (SMS mixed)



7.15.4 *Assessment of Test Results*

The follow figure contains a comparison of the auto-ignition temperatures for the various thermite mixtures, organized by Small-scale Mix ID. NOTE: The auto-ignition temperature of Small-scale Mix #26 exceeded that of the ni-chrome heating wire (>1200 °C).

Figure 39: Comparison of the Auto-ignition Temperatures for the Thermite Mixtures



The auto-ignition temperature of traditional explosives is typically around 200 - 300 °C; the average auto-ignition temperature of the twenty-three small-scale thermite test samples was 809 °C with a standard deviation of 240 °C.

8.0 ASSESSMENT AND EXAMINATION OF TEST RESULTS

Two of the five thermites mixed by SMS (Large-scale Mix ID's 7 and 8) exploded when ignited as unconfined 5 gram quantities, exhibiting hazards similar to that of explosives classed in Division 1.1; one of the five thermites mixed by SMS (Large-scale Mix ID 1) burned very rapidly, exhibiting hazards similar to that of explosives classed in Division 1.3.

SMS also mixed an additional fifteen small-scale thermite mixtures for auto-ignition temperature testing on a total of twenty-three thermite mixtures. Only one of these thermite mixtures had an auto-ignition temperature greater than 1200 °C. Six of these additional fifteen thermite mixtures also exploded when ignited as unconfined 5 gram quantities; based on the limited data set, the explosiveness of these thermites appears strongly related to its metal oxide (Bi_2O_3, MnO_2 and SnO_2 have each shown a propensity for exploding; CuO and Fe_2O_3 produce low-order explosions) and the particle size of the metal and metal oxide powders. Additional testing is required to further investigate this relationship.

The commercially available thermites (Large-scale Mix ID's 2, 3, and 5) each passed the following standard tests:

- UN Series 3

- UN Series 2
- UN Test N.4 Test method for self-heating substances
- UN Test N.5 Test method for substances which in contact with water emit flammable gases

Large-scale Mix ID's 2 and 3 also passed the standard UN Test N.1 Test method for readily combustible solids with gas torch and hotwire, and could potentially be offered for transport as non-regulated materials in the absence of additional considerations. However, using hotter ignition sources and wider powder train piles than those specified in UN Test N.1, it quickly becomes evident that all three of these commercially available thermite mixes exhibit burning rates in excess of the regulated 2.2 mm/sec threshold.

NOTE: The current UN Test N.1 test methodology could potentially permit these powders to be offered for transport as non-regulated goods since the powder train pile is too narrow to sustain propagation AND the ignition source is specified around 1000 °C, which is below the auto-ignition temperature of some thermites, even though in their shipping configuration they would clearly present hazards consistent with that of flammable solids regulated for transport.

9.0 FURTHER RESEARCH

1. Conduct further testing to determine critical parameters that influence the propensity of a thermite formulation to explode upon ignition, such as selection of metal oxide, particle size of metal or metal oxide, confinement (or lack thereof) and/or packing density. Further investigating these critical parameters will aid in determining which types of thermites should or should not be regulated for transport.

2. Determine whether other families of fine metal oxides have a propensity to explode. Based on the current limited data set, it appears that all fine metal powders mixed with fine MnO_2, MoO_3, or SnO_2 will have a propensity to explode. Are there other powders of metal oxides that also have a propensity to explode when ignited?

3. A majority of thermites have a lower auto-ignition temperature than previously anticipated; perform Differential Scanning Calorimetry (DSC) tests on the thermite mixtures to determine their auto-ignition temperature with further confidence and certainty.

4. Perform the full UN Series 6 tests on the thermites. Specially, perform a UN Series 6 (b) Stack test on thermites that are exploding. Also, the UN Series 6 (c) External fire (bonfire) test was performed using only one 20-lb package of each thermite as a screening test; perform the full bonfire test on each thermite, increasing the quantity to an equivalent of 0.15 m^3 with a minimum of three packages each.

5. To aid in developing an Emergency Response Guide for thermites, perform an unconfined UN Series 6 (a) test on thermites that explode and measure their strength in comparison to known reference explosives, such as trinitrotoluene (TNT).

6. Develop a proposed procedure for characterization of thermites that can be presented at the United Nations (UN) for incorporation into international transport regulations.

7. The 5-minute maximum test time of the Koenen test may be insufficient to determine whether a specific thermite exhibits a violent effect on heating under confinement. Perform further UN Series 1 or 2 (b) Koenen testing to determine the recommended maximum test time limit for thermites.

10.0 PRODUCT CERTIFICATIONS

10.1 Mix ID #2 and #3

[redacted]

[redacted]

[redacted]

[redacted]

September 26, 2019

Certificate of Compliance

Customer: SMS
Description:[redacted]oarse Al- Fe_2O_3 Thermite A – Mix ID #2 (Commercial) and[redacted]oarse Al- Fe_2O_3 Thermite B – Mix ID # 3 (Commercial)
Portion batch number: Mix ID # 2 manufactured 5/29 AND 8/16/2019 and Mix ID # 3 manufactured 6/17 and 8/16/2019

The material send to SMS is characterized by the ingredients and the weight amount of these different ingredients in the powder mixtures:

[redacted]**(Coarse Al- Fe_2O_3 Thermite A – Mix ID #2 (Commercial)**
Consist of approximately 25% aluminum (Al) and 75% iron (III)/Ferric oxide (Fe_2O_3) by mass. This thermite is a coarse powder that is a mixture of black and light grey particles.

[redacted]**(Coarse Al- Fe_2O_3 Thermite B – Mix ID # 3 (Commercial)**
Consist of approximately 25% aluminum (Al), 60% iron (III)/Ferric oxide (Fe_2O_3), 5% mild steel, and 10% Ferro-manganese by mass. This thermite is a coarse powder that is a mixture of black and light grey particles with occasional pieces of steel punching.

[redacted]

[redacted]
Director R&D/Quality
[redacted]
9/26/2019

10.2 Mix ID #5

[PRODUCT CERTIFICATION PENDING]

10.3 Aluminum (Al) powder

ATLANTIC EQUIPMENT ENGINEERS
HIGH PURITY METALS AND COMPOUNDS

Certificate of Analysis

ALUMINUM METAL POWDER
AL-100

1.1 General

SOLD TO	PURCHASE ORDER #	SHIP DATE	DOCUMENT NUMBER
SAFETY MANAGEMENT SERVICES	1446	11 JUL 2019	1906116
CATALOG NUMBER	LOT NUMBER	QUANTITY	CAS NUMBER
AL-100	1702536-21	340 LBS	7429-90-5

2.1 Chemical Analysis (in percentage (%) unless otherwise stated)

Al	Ti	Si	Fe
99.9%	<0.06	<0.10	<0.20

3.1 Screen Analysis (percent passing) / Other

Size	D 10	D 50	D 90
1-5 microns	1.8 microns	3.6 microns	9.0 microns

4.1 Notes

5.1 Statement

Shelf life is indefinite when material is stored in a tightly sealed container in a cool, dry place.

The above analysis is carried out as part of our internal quality control testing and is based upon our analysis methods.

We do not assume any warranty, liability, or risk based on such findings. Our quality is warranted within the scope of our general sales conditions.

Please refer to SDS for material handling instructions.

Very Truly Yours,

M. Gerald, QA

24 Industrial Ave, Upper Saddle River, NJ 07458 Tel: 201.828.9400 Fax: 201.387.0291
On the web at: www.micronmetals.com Email: info@micronmetals.com

10.4 Bismuth Oxide (Bi_2O_3) powder

Inframat® Advanced Materials™

440 Lawrence Bell Drive, Suite 8, Amherst, NY 14221. tel: (860) 553-6154, fax: (860) 553-6645
www.advancedmaterials.us

CERTIFICATE OF ANALYSIS

Product: **Bi_2O_3 Powder (83R-0803)**
Lot No: ***IAM11307BIO3***

Impurities (%)	
As	<0.0005
Cd	<0.005
Cu	<0.001
Fe	<0.0003
K	<0.001
Na	<0.001
Pb	<0.0005
Sb	<0.002
Sn	<0.005

Average particle size 1.4 µm

10.5 Boron Oxide (B_2O_3) powder

Intelligent Materials Pvt. Ltd.
www.nanoshel.com, sales@nanoshel.com

NANOSHEL
Creating Miracles in Black

Certificate of Analysis

Boron Oxide Powder
(B_2O_3, APS: 0.5-1um, Purity: 99.9%)
Stock No: NS6130-12-000790, CAS: 1303-86-2

Product Name	**:**	**Boron Oxide Powder**
Stock No	:	NS6130-12-000790
CAS	:	1303-86-2
Assay	:	99.9%
Other Metal	:	850ppm

Note 1: Values are given in ppm(%) unless otherwise specified.

Note 2: All figures above are weight for weight as determined by ICP

Page **1** of **1**

NANOSHEL LLC *(In Collaboration)*
3422 Old Capitol Trial Suit 1305, Wilmington DE - 19808 USA
(001) 302 652-3464, + 91 9779-880077

10.6 Chromium oxide (Cr_2O_3) powder

ATLANTIC EQUIPMENT ENGINEERS
HIGH PURITY METALS AND COMPOUNDS

Certificate of Analysis
CHROMIUM OXIDE, GREEN
CR-601

1.1 General

SOLD TO	PURCHASE ORDER #	SHIP DATE	DOCUMENT NUMBER
SAFETY MANAGEMENT SERVICES	1458	09-13-2019	1908121
CATALOG NUMBER	LOT NUMBER	QUANTITY	CAS NUMBER
CR-601	1704521	1 LB	1308-38-9

2.1 Chemical Analysis (in percentage (%) unless otherwise stated)

Cr2O3	Water Soluble Substances	Moisture	pH
99.6% min	0.07	0.09	6.2

3.1 Screen Analysis (percent passing) / Other

Size	
1-5 microns	

4.1 Notes

5.1 Statement

The above analysis is carried out as part of our internal quality control testing and is based upon our analysis methods.

We do not assume any warranty, liability, or risk based on such findings. Our quality is warranted within the scope of our general sales conditions.

Please refer to SDS for material handling instructions.

Very Truly Yours,

M. Gerald, QA

24 Industrial Ave, Upper Saddle River, NJ 07458 Tel: 201.828.9400 Fax: 201.387.0291
On the web at: www.micronmetals.com Email: info@micronmetals.com

10.7 Cobalt oxide (Co_3O_4) powder

ATLANTIC EQUIPMENT ENGINEERS

HIGH PURITY METALS AND COMPOUNDS

Certificate of Analysis

COBALT OXIDE POWDER

CO 601

1.1 General

SOLD TO	PURCHASE ORDER #	SHIP DATE	DOCUMENT NUMBER
SAFETY MANAGEMENT SERVICES	1458	09-13-2019	1908121
CATALOG NUMBER	LOT NUMBER	QUANTITY	CAS NUMBER
CO 601	1706516	1 LB	1309-06-1

2.1 Chemical Analysis (in percentage (%) unless other wise stated)

Co	Ni	Fe	Ca	Cu	Pb
72.99	0.0007	0.0013	0.0023	0.0005	0.0005

3.1 Screen Analysis (percent passing) / Other

Size	D 50
-400 mesh	4.52 microns

4.1 Notes

5.1 Statement

The above analysis is carried out as part of our internal quality control testing and is based upon our analysis methods.

We do not assume any warranty, liability, or risk based on such findings. Our quality is warranted within the scope of our general sales conditions.

Please refer to MSDS for material handling instructions.

Very Truly Yours,

M. Gerald, QA

24 Industrial Ave, Upper Saddle River, NJ 07458 Tel: 201.828.9400 Fax: 201.387.0291
On the web at: www.micronmetals.com Email: info@micronmetals.com

10.8 Cupric oxide (CuO) powder

FIRST BATCH

ATLANTIC EQUIPMENT ENGINEERS
HIGH PURITY METALS AND COMPOUNDS

Certificate of Analysis
CUPRIC OXIDE
CU-602

1.1 General

SOLD TO	PURCHASE ORDER #	SHIP DATE	DOCUMENT NUMBER
SAFETY MANAGEMENT SERVICES	1446	11 JUL 2019	1906116
CATALOG NUMBER	LOT NUMBER	QUANTITY	CAS NUMBER
CU-602	1907506	70 LBS	1317-38-0

2.1 Chemical Analysis (in percentage (%) unless otherwise stated)

Cu	CuO	Cu2O	Zn	Fe	Ca	Mg
75	94	3	0.3	0.02	0.01	0.002
Mn	Pb	Cd	As	Sb	Moisture	
0.001	0.05	0.01	0.01	0.01	0.2	

3.1 Screen Analysis (percent passing) / Other

Size	Specific Gravity	-325 mesh	Loose Bulk Density
1-5 microns	8.7 g/cc	99.9	80 lbs / ft^3

4.1 Notes

5.1 Statement

The above analysis is carried out as part of our internal quality control testing and is based upon our analysis methods.

We do not assume any warranty, liability, or risk based on such findings. Our quality is warranted within the scope of our general sales conditions.

Please refer to SDS for material handling instructions.

Very Truly Yours,

M. Gerald, QA

24 Industrial Ave, Upper Saddle River, NJ 07458 Tel: 201.828.9400 Fax: 201.387.0291
On the web at: www.micronmetals.com Email: info@micronmetals.com

SECOND BATCH

ATLANTIC EQUIPMENT ENGINEERS
HIGH PURITY METALS AND COMPOUNDS

Certificate of Analysis
CUPRIC OXIDE
CU-602

1.1 General

SOLD TO	PURCHASE ORDER #	SHIP DATE	DOCUMENT NUMBER
SAFETY MANAGEMENT SERVICES	1454	27 AUG 2019	1908044
CATALOG NUMBER	LOT NUMBER	QUANTITY	CAS NUMBER
CU-602	1907506	30.2 LBS	1317-38-0

2.1 Chemical Analysis (in percentage (%) unless otherwise stated)

Cu	CuO	Cu2O	Zn	Fe	Ca	Mg
75	94	3	0.3	0.02	0.01	0.002
Mn	Pb	Cd	As	Sb	Moisture	
0.001	0.05	0.01	0.01	0.01	0.2	

3.1 Screen Analysis (percent passing) / Other

Size	Specific Gravity	-325 mesh	Loose Bulk Density
1-5 microns	8.7 g/cc	99.9	80 lbs / ft^3

4.1 Notes

Partial shipment on PO 1454.

5.1 Statement

The above analysis is carried out as part of our internal quality control testing and is based upon our analysis methods.

We do not assume any warranty, liability, or risk based on such findings. Our quality is warranted within the scope of our general sales conditions.

Please refer to SDS for material handling instructions.

Very Truly Yours,

M. Gerald, QA

24 Industrial Ave, Upper Saddle River, NJ 07458 Tel: 201.828.9400 Fax: 201.387.0291
On the web at: www.micronmetals.com Email: info@micronmetals.com

10.9 Iron oxide (Fe_2O_3) powder

FIRST BATCH

ATLANTIC EQUIPMENT ENGINEERS
HIGH PURITY METALS AND COMPOUNDS

Certificate of Analysis

RED IRON OXIDE POWDER
FE-601

1.1 General

SOLD TO	PURCHASE ORDER #	SHIP DATE	DOCUMENT NUMBER
SAFETY MANAGEMENT SERVICES	1446	11 JUL 2019	1906116
CATALOG NUMBER	LOT NUMBER	QUANTITY	CAS NUMBER
FE-601	1904528	35 LBS	1309-37-1

2.1 Chemical Analysis (in percentage (%) unless otherwise stated)

Tint strength	Moisture	Water soluble
99.15	0.8	0.34
Fe2O3	pH	
99 min	6.4	

3.1 Screen Analysis (percent passing) / Other

Size	+325 mesh
1-5 microns	0.0079

4.1 Notes

5.1 Statement

The above analysis is carried out as part of our internal quality control testing and is based upon our analysis methods.

We do not assume any warranty, liability, or risk based on such findings. Our quality is warranted within the scope of our general sales conditions.

Please refer to SDS for material handling instructions.

Very Truly Yours,

M. Gerald, QA

24 Industrial Ave, Upper Saddle River, NJ 07458 **Tel: 201.828.9400 Fax: 201.387.0291**
On the web at: www.micronmetals.com **Email: info@micronmetals.com**

Page 1 of 1

SECOND BATCH

ATLANTIC EQUIPMENT ENGINEERS
HIGH PURITY METALS AND COMPOUNDS

Certificate of Analysis

RED IRON OXIDE POWDER
FE-601

1.1 General

SOLD TO	PURCHASE ORDER #	SHIP DATE	DOCUMENT NUMBER
SAFETY MANAGEMENT SERVICES	1454	3 SEP 2019	1908091
CATALOG NUMBER	LOT NUMBER	QUANTITY	CAS NUMBER
FE-601	1908519-2	50 LBS	1309-37-1

2.1 Chemical Analysis (in percentage (%) unless otherwise stated)

Tint strength	Moisture	Water soluble
99.15	0.8	0.34
Fe2O3	pH	
99 min	6.4	

3.1 Screen Analysis (percent passing) / Other

Size	+325 mesh
1-5 microns	0.0079

4.1 Notes

5.1 Statement

The above analysis is carried out as part of our internal quality control testing and is based upon our analysis methods.

We do not assume any warranty, liability, or risk based on such findings. Our quality is warranted within the scope of our general sales conditions.

Please refer to SDS for material handling instructions.

Very Truly Yours,

M. Gerald, QA

24 Industrial Ave, Upper Saddle River, NJ 07458 Tel: 201.828.9400 Fax: 201.387.0291
On the web at: www.micronmetals.com Email: info@micronmetals.com

10.10 Magnalium (Mg&Al) powder

FIREWORKS COOKBOOK

FIREWORKS
COOKBOOK

1134 GA HWY 247 South (229)400-9078
Americus GA 31719 Info@FireworksCookbook.com

Derek Holmstead,

This letter is to inform you on the Magnalium you purchased from Fireworks Cookbook. The Magnalium you purchased was a 50% Magnesium and a 50% Aluminum alloy manufactured locally in Georgia. It was then ground up and classified into different sizes ranging from 8 mesh to -325 mesh. The material you purchased was the material classified at -325 mesh.

Please let me know if you need any further information.

Thanks,

Chris Bruce

Fireworks Cookbook

10.11 Magnesium (Mg) powder

SIGMA-ALDRICH® sigma-aldrich.com

3050 Spruce Street, Saint Louis, MO 63103, USA
Website: www.sigmaaldrich.com
Email USA: techserv@sial.com
Outside USA: eurtechserv@sial.com

Certificate of Analysis

Product Name:
Magnesium – ReagentPlus®, powder, −325 mesh, 99.5% trace metals basis

Product Number:	**465666**
Batch Number:	**MKCJ4557**
Brand:	SIAL
CAS Number:	7439-95-4
MDL Number:	MFCD00085308
Formula:	Mg
Formula Weight:	24.31 g/mol
Quality Release Date:	20 FEB 2019

Mg

Test	Specification	Result
Appearance (Color)	White to Dark Grey and Silver	Grey
Appearance (Form)	Powder	Powder
Complexometric EDTA	95.0 - 105.0 %	96.8 %
Particle Size -325 Mesh	Confirmed	Confirmed
ICP Major Analysis Confirms Magnesium Component	Confirmed	Confirmed
Purity 99.5% Purity Based on Trace Metals Analysis	Meets Requirements	Meets Requirements
Trace Metal Analysis	≤ 5500.0 ppm	834.3 ppm
Aluminum (Al)		105.2 ppm
Barium (Ba)		1.2 ppm
Calcium (Ca)		11.7 ppm
Chromium (Cr)		2.1 ppm
Copper (Cu)		3.2 ppm
Iron (Fe)		565.4 ppm
Lithium (Li)		12.0 ppm
Manganese (Mn)		123.4 ppm
Sodium (Na)		2.8 ppm
Strontium (Sr)		0.1 ppm
Titanium (Ti)		1.2 ppm
Zinc (Zn)		4.4 ppm
Zirconium (Zr)		1.6 ppm

Michael Grady, Manager
Quality Control
Milwaukee, WI US

10.12 Manganese oxide (MnO_2) powder

FIRST BATCH

AMERICAN ELEMENTS

World's Leading Manufacturer of Rare Earth and Advanced Material Products

A MERELEX CORPORATION • 10884 WEYBURN AVE. LOS ANGELES, CA 90024
TEL. 310-208-0551 • FAX 310-208-0351 • E-MAIL: customerservice@americanelements.com

CERTIFICATE OF COMPLIANCE

99+% (metals basis) Manganese Oxide Powder

MnO2

Product Code: MN-OX-021M-P.5UM

CAS #: 1313-13-9

LOT #: 1441516447-403

American Elements certifies that the materials listed below and shipped on 9/5/19 meets the purity and dimensional requirements set forth in Safety Management Services purchase order: DOT1-5216.

99+% (metals basis) Manganese Oxide Powder
MnO2
APS: 5 um

AMERICAN ELEMENTS

By ____________

AEC FORM 102:CA REV. APP. 2/3/99

SECOND BATCH

AMERICAN ELEMENTS
THE ADVANCED MATERIALS MANUFACTURER®
MERELEX CORPORATION • 10884 WEYBURN AVE. LOS ANGELES, CA 90024
TEL. 310-208-0551 • FAX 310-208-0351 • E-MAIL: orders@americanelements.com

CERTIFICATE OF ANALYSIS

99+% (metals basis) Manganese Oxide Powder

MnO_2

Product Code: MN-OX-021M-P.5UM
Lot #: 1441516447-405
CAS #: 1313-13-9
Description: APS: 5 um

Analysis	
Si	0.008
Fe	0.029
Al	0.008
Mg	0.008
Ca	0.010
Pb	0.002
Ni	0.001
Co	0.001

AMERICAN ELEMENTS

By ____________________

AEC FORM 102:CA REV. APP. 2/3/99

10.13 Molybdenum trioxide (MoO_3) powder

23661 Birtcher Drive
Lake Forest, CA 92630
Tel: (949) 407 8904 Fax: (949) 812 6690

STANFORD
ADVANCED MATERIALS

Certificate of Compliance

September 25, 2019

Commander Tooele Army Depot
1 Tooele Army Depot
Attn: AED Test Site, Roger Hale, SMS
Tooele, UT 84074

Packing List #: O190819WO
Date: 8/19/19
PO #: DOT1-5216
Product: Molybdenum Trioxide (MoO3) Powder
Work Order Number: DOT1-5216
Purity: ≥99.5%
Particlie Size: -325mesh
Quantity: 40 Lbs

I hereby certify compliance with the above purchase order number. The products shipped have been manufactured in accordance with and verified to applicable drawings and specifications. The material and functional test reports and inspection records are on file at our facility and are available for Commander Tooele Army Depot and government review.

Rita Wang

Rita Wang

Stanford Advanced Materials
23661 Birtcher Drive
Lake Forest, CA 92630
Tel: (949) 407-8904
Fax: (949) 812-6690
Website: www.samaterials.com

10.14 Nickel oxide (Ni_2O_3) powder

FIRST BATCH

AMERICAN ELEMENTS

World's Leading Manufacturer of Rare Earth and Advanced Material Products

A MERELEX CORPORATION • 10884 WEYBURN AVE. LOS ANGELES, CA 90024
TEL. 310-208-0551 • FAX 310-208-0351 • E-MAIL: customerservice@americanelements.com

CERTIFICATE OF COMPLIANCE

99+% (metals basis) Nickel Oxide Powder

Ni2O3

Product Code: NI-OX-021M-P.5UM

CAS #: 1314-06-3

LOT #: 1471516447-400

American Elements certifies that the materials listed below and shipped on 9/5/19 meets the purity and dimensional requirements set forth in Safety Management Services purchase order: DOT1-5216.

99+% (metals basis) Nickel Oxide Powder
Ni2O3
APS: 5 um

AMERICAN ELEMENTS

By ______________

AEC FORM 102:CA REV. APP. 2/3/99

SECOND BATCH

AMERICAN ELEMENTS
THE ADVANCED MATERIALS MANUFACTURER®
MERELEX CORPORATION • 10884 WEYBURN AVE. LOS ANGELES, CA 90024
TEL. 310-208-0551 • FAX 310-208-0351 • E-MAIL: orders@americanelements.com

CERTIFICATE OF ANALYSIS

99+% (metals basis) Nickel Oxide Powder

Ni_2O_3

Product Code: NI-OX-021M-P.5UM
Lot #: 1471516447-402
CAS #: 1314-06-3
Description: APS: 5 um

Analysis	%
S	0.005
Fe	0.045
Co	0.013
Cu	0.008
Zn	0.008
Mg	0.003
Ca	0.002
Na	0.002

AMERICAN ELEMENTS

By ____________________

AEC FORM 102:CA REV. APP. 2/3/99

10.15 Tin oxide (SnO_2) powder

ATLANTIC EQUIPMENT ENGINEERS
HIGH PURITY METALS AND COMPOUNDS

Certificate of Analysis

TIN OXIDE, WHITE
SN-601

1.1 General

SOLD TO	PURCHASE ORDER #	SHIP DATE	DOCUMENT NUMBER
SAFETY MANAGEMENT SERVICES	1458	09-13-2019	1908121
CATALOG NUMBER	LOT NUMBER	QUANTITY	CAS NUMBER
SN-601	1903509	1 LBS	18282-10-5

2.1 Chemical Analysis (in ppm unless other wise stated)

SnO2	CuO	Sb2O3	ZnO	PbO
99.9% min	11	21	<2.0	128
SiO2	NiO	CdO	Bi2O3	CoO
59	4.5	<0.2	13	<2.0
Fe2O3	Al2O3	Cr2O3	MgO	As2O3
38	49	2	<10	<50

3.1 Screen Analysis (percent passing) / Other

Size	D 50
-325 mesh	2-3 microns

4.1 Notes

5.1 Statement

The above analysis is carried out as part of our internal quality control testing and is based upon our analysis methods.

We do not assume any warranty, liability, or risk based on such findings. Our quality is warranted within the scope of our general sales conditions.

Please refer to MSDS for material handling instructions.

Very Truly Yours,

M. Gerald, QA

24 Industrial Ave, Upper Saddle River, NJ 07458 Tel: 201.828.9400 Fax: 201.387.0291
On the web at: www.micronmetals.com Email: info@micronmetals.com

10.16 Titanium dioxide (TiO_2) powder

ATLANTIC EQUIPMENT ENGINEERS
HIGH PURITY METALS AND COMPOUNDS

Certificate of Analysis

TITANIUM DIOXIDE POWDER
TI-603

1.1 General

SOLD TO	PURCHASE ORDER #	SHIP DATE	DOCUMENT NUMBER
SAFETY MANAGEMENT SERVICES	1458	09-13-2019	1908121
CATALOG NUMBER	LOT NUMBER	QUANTITY	CAS NUMBER
TI-603	1808516	1 LB	13463-67-7

2.1 Chemical Analysis (in percentage (%) unless other wise stated)

Al	Fe	Ca	Mg	Ca	Mn	C
0.003	0.005	0.003	0.002	0.002	0.001	0.002
Na	Co	Ni	Si	P	K	S
0.005	0.002	0.001	0.004	0.002	0.003	0.002

3.1 Screen Analysis (percent passing) / Other

Size	
-325 mesh	

4.1 Notes

5.1 Statement

The above analysis is carried out as part of our internal quality control testing and is based upon our analysis methods.

We do not assume any warranty, liability, or risk based on such findings. Our quality is warranted within the scope of our general sales conditions.

Please refer to MSDS for material handling instructions.

Very Truly Yours,

M. Gerald, QA

24 Industrial Ave, Upper Saddle River, NJ 07458 Tel: 201.828.9400 Fax: 201.387.0291
On the web at: www.micronmetals.com Email: info@micronmetals.com

10.17 Titanium (Ti) powder

ATLANTIC EQUIPMENT ENGINEERS
HIGH PURITY METALS AND COMPOUNDS

Certificate of Analysis

TITANIUM METAL POWDER
TI 101

1.1 General

SOLD TO	PURCHASE ORDER #	SHIP DATE	DOCUMENT NUMBER
SMS	DOT1-5216	10/15/2019	1910078
CATALOG NUMBER	LOT NUMBER	QUANTITY	CAS NUMBER
TI 101	1903529	1 LB	7440-32-6

2.1 Chemical Analysis (in percentage (%) unless otherwise stated)

Al	Cl	Cr	Fe	H	Mg	Mn
<0.005	<0.025	0.004	0.019	0.326	<0.010	<0.005
Mo	N	Na	Ni	O	P	Pb & Cd
<0.005	0.022	<0.001	0.003	0.422	<0.010	<0.002
Si	Sn	V	Zr	Ti		
<0.005	<0.010	<0.005	<0.005	99.8% min		

3.1 Screen Analysis (percent passing) / Other

Size	
<20 MICRON	

4.1 Notes
99.8% min metals basis

5.1 Statement

The above analysis is carried out as part of our internal quality control testing and is based upon our analysis methods.

We do not assume any warranty, liability, or risk based on such findings. Our quality is warranted within the scope of our general sales conditions.

Please refer to SDS for material handling instructions.

Very Truly Yours,

M. Gerald, QA

24 Industrial Ave, Upper Saddle River, NJ 07458 Tel: 201.828.9400 Fax: 201.387.0291
On the web at: www.micronmetals.com Email: info@micronmetals.com

10.18 Tungsten trioxide (WO_3) powder

ATLANTIC EQUIPMENT ENGINEERS
HIGH PURITY METALS AND COMPOUNDS

Certificate of Analysis

TUNGSTEN TRIOXIDE POWDER
WP-602

1.1 General

SOLD TO	PURCHASE ORDER #	SHIP DATE	DOCUMENT NUMBER
SAFETY MANAGEMENT SERVICES	1458	09-13-2019	1908121
CATALOG NUMBER	LOT NUMBER	QUANTITY	CAS NUMBER
WP-602	1803537	1 LB	1314-35-8

2.1 Chemical Analysis (in percentage (%) unless other wise stated)

Al	As	S	Ca	Cd	Co	Cr
<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cu	Fe	K	Mg	Mn	Mo	Na
<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.0026
Ni	P	Pb	Sb	Si	Sn	Ta
<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ti	V	Zn	WO3			
<0.001	<0.001	<0.001	99.99			

3.1 Screen Analysis (percent passing) / Other

Size	FSSS
-325 mesh	24.8 microns

4.1 Notes

5.1 Statement

The above analysis is carried out as part of our internal quality control testing and is based upon our analysis methods.

We do not assume any warranty, liability, or risk based on such findings. Our quality is warranted within the scope of our general sales conditions.

Please refer to MSDS for material handling instructions.

Very Truly Yours,

M. Gerald, QA

24 Industrial Ave, Upper Saddle River, NJ 07458 Tel: 201.828.9400 Fax: 201.828.9414
On the web at: www.micronmetals.com Email: info@micronmetals.com

TEST REPORT

Sensitivity of Various Thermite Formulations

DOT Contract # 693JK320C000005

U.S. Department of Transportation
Pipeline and Hazardous Materials Safety Administration
(PHMSA)

Attention: PHH-20
Hazardous Materials Technology
1200 New Jersey Avenue, SE
E21-317
Washington, DC 20590

Troy A. Gardner, PE, CSP
Jackson Zarbock

October 6, 2021

SMS-6265b-R1, Rev 1

1847 West 9000 South, Suite 205 • West Jordan, Utah 84088 • 801-567-0456 • www.smsenergetics.com

Test Report

Sensitivity of Various Thermite Formulations

October 6, 2021
SMS-6265b-R1, Rev 1

Troy A. Gardner, PE, CSP
Testing & Classifications Manager
Safety Management Services, Inc.

Jackson D. Zarbock
Project Engineer

TABLE OF CONTENTS

TABLES

FIGURES

Photos

1.0 STATEMENT OF WORK

DOT Contract # 693JK320C000005 with Safety Management Services, Inc. (SMS) of West Jordan, Utah defines that for Task 2, "Conduct Hotwire Explosion Screening Test for Additional Fine Metal Oxides; High-Temperature DSC", SMS shall:

1) Propose thirty fine metal oxides for the explosion screening test.
2) Order and receive the thirty additional fine metal oxides.
3) Mix the additional thirty small-scale thermite mixes.
4) Perform impact sensitivity, friction sensitivity, ESD sensitivity, and hotwire sensitivity tests.
5) Perform high-temperature DSC on each small-scale thermite mix.
6) Provide the COR with a test report and video(s).

2.0 SUMMARY AND CONCLUSIONS

In cooperation with the U.S. Department of Transportation (DOT) Pipeline and Hazardous Materials Safety Administration (PHMSA), SMS has proposed, procured, and mixed thirty additional metal-metal oxide thermite mixtures. SMS performed impact, friction, electrostatic discharge (ESD), high-temperature DSC and hotwire sensitivity tests on fifty-three thermite mixtures as documented in this test report. A test video of the hotwire explosion screening test (SMS-6265b-V1) is being sent to the attention of the Contracting Officer's Representative (COR).

Based on the test results, the following fine thermites are considered potential primary explosives based on their extreme friction sensitivity and ability to transition to explosion when unconfined:

- SS #3B Ti-MnO_2
- SS #9 Al-MoO_3

The following fine thermites transition to explosion when ignited unconfined in small quantities but were not overly impact or friction sensitive:

- LS #7 Al-MnO_2
- LS #8 Mg & Al-MoO_3 & CuO
- SS #4 Mg-MnO_2
- SS #19 Al-SnO_2
- SS #24 Al-Bi_2O_3
- SS #27 Al-Fe_3O_4
- SS #30 Al-NiO
- SS #38 Mg-CrO_3
- SS #47 Ti-CrO_3
- SS #48 Ti-Bi_2O_3
- SS #56 Mg & Al-MoO_3 & CuO

The potential for unconfined explosion of fine thermites appears to be heavily influenced by the metal oxide. Metal oxides with a propensity to transition to explosion with various metals include bismuth trioxide, molybdenum trioxide, manganese(IV) oxide and chromium trioxide. The following fine thermites were fast reacting (i.e., consumed in less than one second) when unconfined and in small quantities:

- LS #1 Al-Fe_2O_3
- SS #7B Ti-CuO
- SS #42 Mg-MoO_3
- SS #43 Mg-SiO_2

- SS #11 Mg-CuO
- SS #28 Al-Mn_2O_3
- SS #34 Al-SnO
- SS #39 Mg-Bi_2O_3
- SS #40 Mg-Co_3O_4
- SS #41 Mg-Cr_2O_3
- SS #45 Mg-WO_3
- SS #49 Ti-Co_3O_4
- SS #51 Ti-Cu_2O
- SS #52 Ti-MoO_3
- SS #54 Ti-SnO_2
- SS #55 Ti-WO_3

It is noted that several of the metal oxides from the list of fast reacting thermites were contained in the list of exploding thermites (e.g., bismuth trioxide, molybdenum trioxide, tin dioxide).

3.0 ACKNOWLEDGEMENTS

Mixing of fine thermites was performed by Greg J. Dohm, Jordan D. Dzubak, Derek J. Holmstead, and Derek M. Sutton and Jackson D. Zarbock. Sensitivity testing of thermites was performed by Rustyn K. Christensen, Jackson D. Zarbock, Derek J. Holmstead and Derek M. Sutton. High-temperature Differential Scanning Calorimetry (DSC) was performed by Jordan D. Dzubak and Derek M. Sutton.

4.0 BACKGROUND

Historically, industry has offered traditional thermite formulations (containing only metal and metal oxides) for transport in Class 4 as flammable or water-reactive solids. The reaction produces a burst of heat, high temperature, and molten metal for various uses including joining steel railroad ties or copper transmission lines, metal refining, disabling munitions, etc. Traditional thermite formulations pass the UN Manual of Tests and Criteria, Appendix 6 “Screening Procedures” for substances which may have explosive properties as they do not contain any of the chemical groups listed in Table A6.1 that are associated with explosive properties. NOTE: The Appendix 6 Screening Procedures cannot be used for substances manufactured with the view to producing a practical explosive or pyrotechnic effect.

Newer “exotic” thermite formulations include those with additives such as plastics, oxidizers, nano materials, explosives, etc. to confer special compositions or actions upon use. Thermite research was needed to identify families of new and existing thermite compositions and to determine their hazards in transport and to transport vehicles.

Safety Management Services, Inc. (SMS) was contracted to perform research on thermite formulations in cooperation with Southwest Research Institute (SwRI) and the U.S. Department of Transportation (DOT) Pipeline and Hazardous Materials Safety Administration (PHMSA). This effort is considered to be Phase I of thermite testing. During Phase I, eight thermites for large-scale testing and fifteen thermite formulations were selected for small-scale testing. It was discovered that thermite mixtures exhibited hazards from ranging from rapid reactions that were consistent with 1.3G materials to exploding when ignited in unconfined 5-gram quantities, similar to 1.1G flash powders. Two of the eight large-scale thermite mixtures and six of the fifteen small-scale thermite mixtures mixed by SMS also exploded in unconfined 5-gram quantities.

These findings prompted the request for SMS to perform additional testing to further research the energetic properties of thermite and develop the technical basis to base policies and decision on thermite-based products.

The thirty additional thermite samples were selected based on the following rationales:

- Several metal oxides exploded or burned rapidly when mixed with aluminum during previous testing. To analyze the effect of these metal oxides on reaction violence, they should be mixed with different metal powders and tested.
- Thermite reactions are typically reduction-oxidation reactions where the metal powder is reduced, and the metal oxide is oxidized. Different oxidation states of previously tested metal oxides (i.e. Fe_3O_4 for Fe_2O_3) should be mixed with the same metal powder tested to assess the effect of oxidation state on the violence of the thermite reaction.
- The variability seen during previous testing suggests that there are many factors influencing thermite reaction violence. Several metal oxides that could feasibly be used in thermite mixtures should be tested. Feasibility is to be based on economic factors (i.e. price, availability, etc.) and potential hazards (i.e. toxicity, stability, radioactivity, etc.).

In order to select thirty thermites from all the identified potential metal-metal oxide combinations, thermochemical code calculations were performed using FACTSAGE 8.0 and FACSTAGE 8.1 to determine reaction violence of stoichiometric combinations of metal and metal oxides. The accuracy of the FACTSAGE software was determined in Phase I. Simulations were performed on stoichiometric combinations of metal and metal oxides. Initial temperature and pressure of 298 K and 1 atm, respectively, were used during simulations. Once simulations were complete, thermite mixtures were selected based on adiabatic reaction temperature, gas generation, and heat of reaction. Table 1 shows the thirty additional thermite mixtures initially recommended to DOT PHMSA for testing.

Table 1: Thirty Thermite mixtures Recommended for Testing

Reactants		Stoichiometric Ratio		Thermodynamic Characteristics		
Metal	Metal Oxide	Metal	Metal Oxide	Adiabatic Reaction Temperature (K)	Gas Generation (mol/100 g)	Heat of Reaction (cal/g)
Al	SiO_2	4	3	1889	0.0000	513.3
Al	Fe_3O_4	8	3	3135	0.0549	878.8
Al	NiO	2	3	3187	0.0108	822.3
Ti	Cu_2O	1	2	2843	0.1221	575.5
Al	SnO	2	3	2876	0.1070	427.0

Reactants		Stoichiometric Ratio		Thermodynamic Characteristics		
Metal	Metal Oxide	Metal	Metal Oxide	Adiabatic Reaction Temperature (K)	Gas Generation (mol/100 g)	Heat of Reaction (cal/g)
Al	CrO_3	2	1	3311	0.6977	897.7
Al	Mn_2O_3	2	1	2336	0.3130	1074.4
Al	MnO	2	3	2214	0.0000	1034.6
Al	Sb_2O_3	2	1	2747	0.4531	498.3
Al	Sb_2O_5	10	3	3527	0.5311	561.8
Al	ZnO	2	3	1580	1.0064	843.0
Al	ZrO_2	4	3	517	0.0000	1647.6
Mg	Al_2O_3	3	1	941	0.0000	2264.5
Mg	B_2O_3	3	1	2095	0.4896	2132.7
Mg	Bi_2O_3	3	1	3098	0.4577	256.4
Mg	Co_3O_4	4	1	3140	0.1579	643.5
Mg	Cr_2O_3	3	1	2662	0.0871	1214.0
Mg	MoO_3	3	1	3181	0.2719	821.2
Mg	SiO_2	2	1	2123	0.0335	2002.5
Mg	SnO_2	2	1	2691	0.4599	692.6
Mg	WO_3	3	1	3198	0.1496	661.0
Ti	Al_2O_3	3	2	639	0.0000	2279.0
Ti	B_2O_3	3	2	1799	0.0000	2149.6
Ti	Bi_2O_3	3	2	2561	0.3070	219.6
Ti	Co_3O_4	2	1	3182	0.0002	646.3
Ti	Cr_2O_3	3	2	1850	0.0000	1203.7
Ti	MoO_3	3	2	3144	0.0653	846.3
Ti	SiO_2	1	1	1367	0.0000	2016.3
Ti	SnO_2	1	1	2480	0.1567	695.2
Ti	WO_3	3	2	3027	0.0230	663.5

While procuring thermite raw materials, Ti-B_2O_3, Mg-B_2O_3, and Al-Sb_2O_5 were eliminated from testing based on availability of metal oxides in desired particle sizes. Ti-CrO_3, Mg-CrO_3, and two commercially available thermites were substituted. All tested thermite mixtures from Phase 1 and the current effort are detailed below.

5.0 DESCRIPTION OF THERMITE TEST SAMPLES

5.1 Large-Scale Thermite Samples from Phase 1

5.1.1 Fine Al-Fe_2O_3 Thermite – Large-Scale Mix ID #1 (SMS mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 25.26% aluminum (Al) and 74.74% ferric oxide (Fe_2O_3). The aluminum was 3N purity (99.9% pure), 1 - 5 micrometers (microns) in size, and offered for transport as a Division 4.1 flammable solid. The ferric oxide was 2N purity (99% pure), 1 - 5 microns in size, and offered for transport as non-regulated. This thermite was a fine, red powder when fully mixed.

Photo 1: Fine Al-Fe_2O_3 Thermite – Large-Scale Mix ID #1 (SMS mixed)

5.1.2 Coarse Al-Fe_2O_3 Thermite A – Large-Scale Mix ID #2 (Commercial)

SMS procured this thermite from a commercial supplier. This thermite contained approximately 25% aluminum (Al) and 75% iron(III)/ferric oxide (Fe_2O_3) by mass. The thermite was a coarse powder that was a mixture of black and light gray particles.

Photo 2: Coarse Al-Fe_2O_3 Thermite A – Large-Scale Mix ID #2 (Commercial)

5.1.3 Coarse Al-Fe_2O_3 Thermite B – Large-Scale Mix ID #3 (Commercial)

SMS procured this thermite from a commercial supplier. This thermite contained approximately 25% aluminum (Al), 60% iron(III)/ferric oxide (Fe_2O_3), 5% mild steel, and 10% ferro manganese by mass. The thermite was a coarse powder that was a mixture of black and light gray particles with occasional pieces of steel punching.

Photo 3: Coarse Al-Fe_2O_3 Thermite B – Large-Scale Mix ID #3 (Commercial)

-

5.1.4 Fine Al-CuO Thermite – Large-Scale Mix ID #4 (SMS mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 18.44% aluminum (Al) and 81.56% copper(II)/cupric oxide (CuO). The aluminum was 3N purity (99.9% pure), 1 - 5 micrometers (microns) in size, and offered for transport as a Division 4.1 flammable solid. The cupric oxide was 3N purity (99.9% pure), 1 - 5 microns in size, and offered for transport as Class 9. This thermite was a very fine, dark gray powder when fully mixed.

Photo 4: Fine Al-CuO Thermite – Large-Scale Mix ID #4 (SMS mixed)

5.1.5 Medium Al-CuO Thermite – Large-Scale Mix ID #5 (Commercial)

SMS procured this thermite from a commercial supplier. This thermite contains approximately 18% aluminum (Al) and 82% cupric oxide (CuO). The thermite was gray and silver speckled powder with medium-sized particles.

Photo 5: Medium Al-CuO Thermite – Large-Scale Mix ID #5 (Commercial)

5.1.6 Fine Al-Ni_2O_3 Thermite – Large-Scale Mix ID #6 (SMS mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 24.6% aluminum (Al) and 75.4% nickel(III) oxide (Ni_2O_3). The aluminum was 3N purity (99.9% pure), 1 - 5 micrometers (microns) in size, and offered for transport as a Division 4.1 flammable solid. The nickel(III) oxide was 2N purity (99% pure), 5 microns in size, and offered for transport as non-regulated. This thermite was very fine, light gray powder when fully mixed.

Photo 6: Fine Al-Ni_2O_3 Thermite – Large-Scale Mix ID #6 (SMS mixed)

5.1.7 Fine Al-MnO_2 Thermite – Large-Scale Mix ID #7 (SMS mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 29.27% aluminum (Al) and 70.73% manganese(IV) oxide (MnO_2). The aluminum was 3N purity (99.9% pure), 1 - 5 micrometers (microns) in size, and offered for transport as a Division 4.1 flammable solid. The manganese(IV) oxide was 2N purity (99% pure), 5 microns in size, and offered for transport as non-regulated. This thermite was a very fine, dark gray powder when fully mixed.

Photo 7: Fine Al-MnO_2 Thermite – Large-Scale Mix ID #7 (SMS mixed)

5.1.8 Fine Mg & Al-MoO_3 & CuO Thermite – Large-Scale Mix ID #8 (SMS mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 25% magnalium (magnesium-aluminum), 34% molybdenum trioxide (MoO_3), and 41% copper(II)/cupric oxide (CuO). The magnalium was 2N purity (99% pure), 44 micrometers (microns) in size, and offered for transport as a Division 4.3 dangerous when wet substance with a subsidiary hazard of Division 4.2 spontaneously combustible. The molybdenum trioxide was 2N purity (99% pure), 44 microns in size, and offered for transport as a Division 6.1 toxic substance. The cupric oxide was 3N purity (99.9% pure), 1 - 5 microns in size, and offered for transport as Class 9. This thermite was a very fine, gray powder when fully mixed.

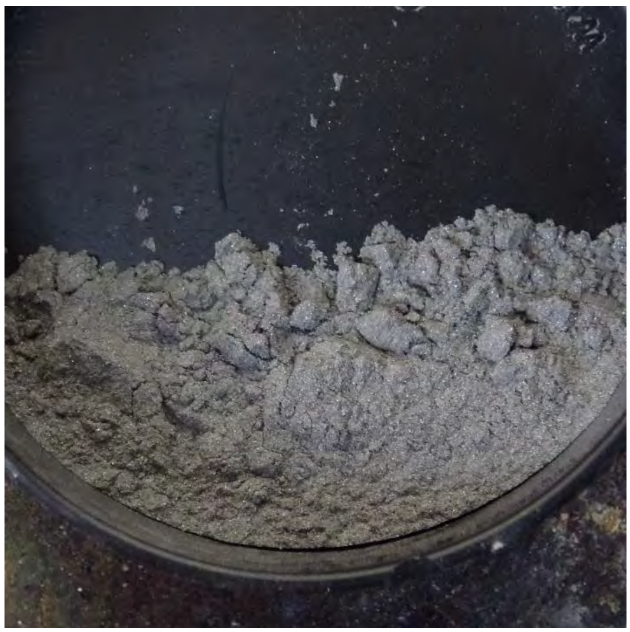


Photo 8: Fine Mg&Al-MoO_3-CuO Thermite – Large-Scale Mix ID #8 (SMS mixed)

5.2 Small-Scale Thermite Samples from Phase 1

5.2.1 Fine Mg-B_2O_3 Thermite – Small-Scale Mix ID #1 (SMS mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 51.16% magnesium (Mg) and 48.84% boron trioxide (B_2O_3). This thermite was a very fine, gray powder when fully mixed.

Photo 9: Fine Mg-B_2O_3 Thermite – Small-Scale Mix ID #1 (SMS mixed)

5.2.2 Fine Ti-B_2O_3 Thermite – Small-Scale Mix ID #2B (SMS mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 50.77% titanium (Ti) and 49.23% boron trioxide (B_2O_3). This thermite was a fine, light gray powder when fully mixed.

Photo 10: Fine Ti-B_2O_3 Thermite – Small-Scale Mix ID #2B (SMS mixed)

5.2.3 Fine Ti-MnO_2 Thermite – Small-Scale Mix ID #3B (SMS mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 35.51% titanium (Ti) and 64.49% manganese(IV) oxide (MnO_2). The manganese(IV) oxide was 2N purity (99% pure), 5 microns in size, and offered for transport as non-regulated. This thermite was a very fine, light gray powder when fully mixed.

Photo 11: Fine Ti-MnO_2 Thermite – Small-Scale Mix ID #3B (SMS mixed)

5.2.4 Fine Mg-MnO_2 Thermite – Small-Scale Mix ID #4 (SMS mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 35.86% magnesium (Mg) and 64.14% manganese(IV) oxide (MnO_2). The manganese(IV) oxide was 2N purity (99% pure), 5 microns in size, and offered for transport as non-regulated. This thermite was a very fine, gray powder when fully mixed.

Photo 12: Fine Mg-MnO_2 Thermite – Small-Scale Mix ID #4 (SMS mixed)

5.2.5 Fine Ti-Fe_2O_3 Thermite – Small-Scale Mix ID #6B (SMS mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 31.02% titanium (Ti) and 68.98% ferric oxide (Fe_2O_3). The ferric oxide was 2N purity (99% pure), 1 - 5 microns in size, and offered for transport as non-regulated. This thermite was a fine, red powder when fully mixed.

Photo 13: Fine Ti-Fe_2O_3 Thermite – Small-Scale Mix ID #6B (SMS mixed)

5.2.6 Fine Ti-CuO Thermite – Small-Scale Mix ID #7B (SMS mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 23.13% titanium (Ti) and 76.87% cupric oxide (CuO). The cupric oxide was 3N purity (99.9% pure), 1 - 5 microns in size, and offered for transport as Class 9. This thermite was a very fine, dark gray powder when fully mixed.

Photo 14: Fine Ti-CuO Thermite – Small-Scale Mix ID #7B (SMS mixed)

5.2.7 Fine Al-MoO_3 Thermite – Small-Scale Mix ID #9 (SMS mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 27.27% aluminum (Al) and 72.73% molybdenum trioxide (MoO_3). The aluminum was 3N purity (99.9% pure), 1 - 5 micrometers (microns) in size, and offered for transport as a Division 4.1 flammable solid. The molybdenum trioxide was 2N purity (99% pure), 44 microns in size, and offered for transport as a Division 6.1 toxic substance. This thermite was a very fine, off-white powder when fully mixed.

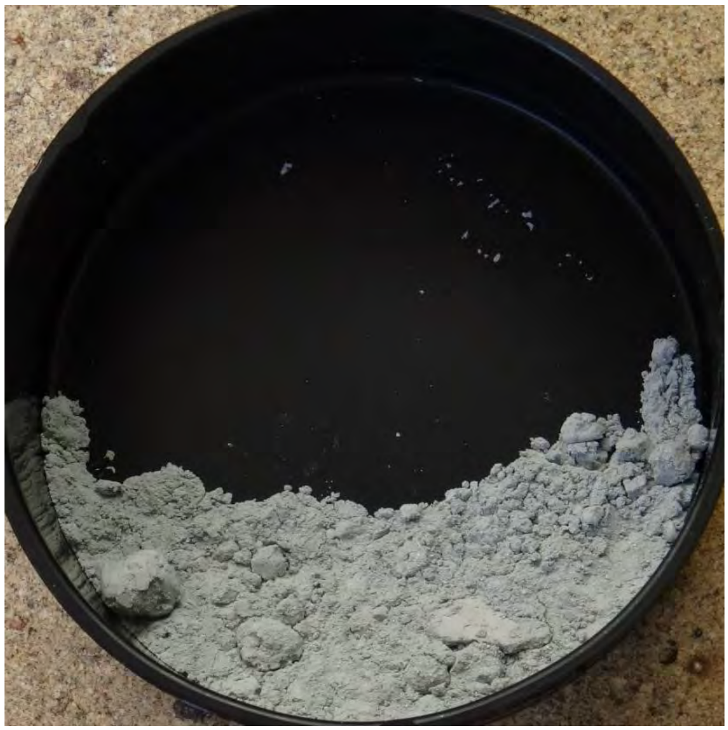


Photo 15: Fine Al-MoO_3 Thermite – Small-Scale Mix ID #9 (SMS mixed)

5.2.8 Fine Mg-Fe_2O_3 Thermite – Small-Scale Mix ID #10 (SMS mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 31.35% magnesium (Mg) and 68.65% ferric oxide (Fe_2O_3). The ferric oxide was 2N purity (99% pure), 1 - 5 microns in size, and offered for transport as non-regulated. This thermite was a very fine, rusty brown powder when fully mixed.

Photo 16: Fine Mg-Fe_2O_3 Thermite – Small-Scale Mix ID #10 (SMS mixed)

5.2.9 Fine Mg-CuO Thermite – Small-Scale Mix ID #11 (SMS mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 23.40% magnesium (Mg) and 76.60% cupric oxide (CuO). The cupric oxide was 3N purity (99.9% pure), 1 - 5 microns in size, and offered for transport as Class 9. This thermite was a very fine, gray powder when fully mixed.

Photo 17: Fine Mg-CuO Thermite – Small-Scale Mix ID #11 (SMS mixed)

5.2.10 Fine Al-Co_3O_4 Thermite – Small-Scale Mix ID #12 (SMS mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 23.01% aluminum (Al) and 76.99% cobalt oxide (Co_3O_4). The aluminum was 3N purity (99.9% pure), 1 - 5 micrometers (microns) in size, and offered for transport as a Division 4.1 flammable solid. This thermite was a very fine, dark gray powder when fully mixed.

Photo 18: Fine Al-Co_3O_4 Thermite – Small-Scale Mix ID #12 (SMS mixed)

5.2.11 Fine Al-WO_3 Thermite – Small-Scale Mix ID #18 (SMS mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 18.88% aluminum (Al) and 81.12% tungsten trioxide (WO_3). The aluminum was 3N purity (99.9% pure), 1 - 5 micrometers (microns) in size, and offered for transport as a Division 4.1 flammable solid. This thermite was a very fine, off-white powder when fully mixed.

Photo 19: Fine Al-WO_3 Thermite – Small-Scale Mix ID #18 (SMS mixed)

5.2.12 Fine Al-SnO_2 Thermite – Small-Scale Mix ID #19 (SMS mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 19.27% aluminum (Al) and 80.73% tin(IV) oxide (SnO_2). The aluminum was 3N purity (99.9% pure), 1 - 5 micrometers (microns) in size, and offered for transport as a Division 4.1 flammable solid. This thermite was a very fine, off-white powder when fully mixed.

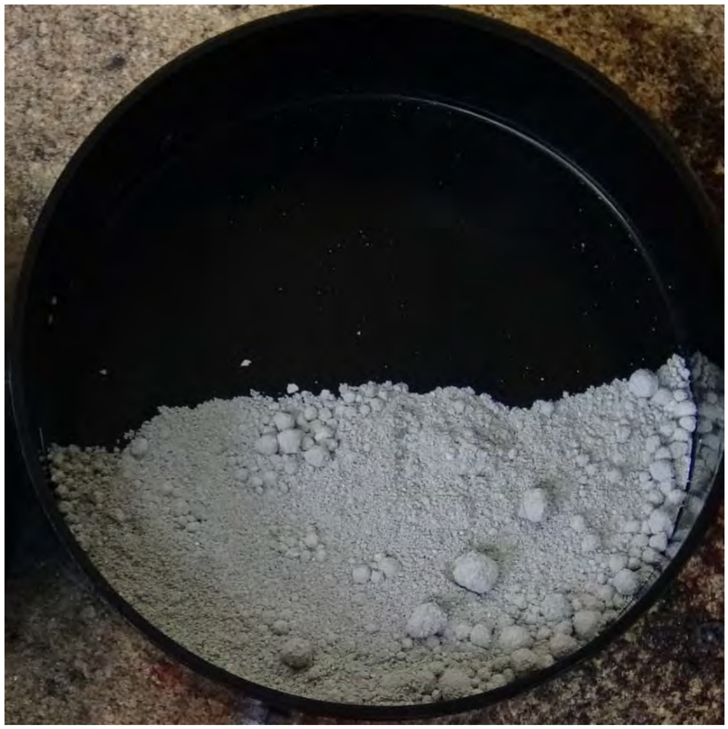


Photo 20: Fine Al-SnO_2 Thermite – Small-Scale Mix ID #19 (SMS mixed)

5.2.13 Fine Al-Cr_2O_3 Thermite – Small-Scale Mix ID #21 (SMS mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 26.20% aluminum (Al) and 73.80% chromium(III) oxide (Cr_2O_3). The aluminum was 3N purity (99.9% pure), 1 - 5 micrometers (microns) in size, and offered for transport as a Division 4.1 flammable solid. This thermite was a fine, light green powder when fully mixed.

Photo 21: Fine Al-Cr_2O_3 Thermite – Small-Scale Mix ID #21 (SMS mixed)

5.2.14 Fine Al-Bi_2O_3 Thermite – Small-Scale Mix ID #24 (SMS mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 10.38% aluminum (Al) and 89.62% bismuth oxide (Bi_2O_3). The aluminum was 3N purity (99.9% pure), 1 - 5 micrometers (microns) in size, and offered for transport as a Division 4.1 flammable solid. This thermite was a very fine, off-white powder when fully mixed.

Photo 22: Fine Al-Bi_2O_3 Thermite – Small-Scale Mix ID #24 (SMS mixed)

5.2.15 Fine Al-TiO_2 Thermite – Small-Scale Mix ID #25 (SMS mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 31.06% aluminum (Al) and 68.94% titanium dioxide (TiO_2). The aluminum was 3N purity (99.9% pure), 1 - 5 micrometers (microns) in size, and offered for transport as a Division 4.1 flammable solid. This thermite was a fine, off-white powder when fully mixed.

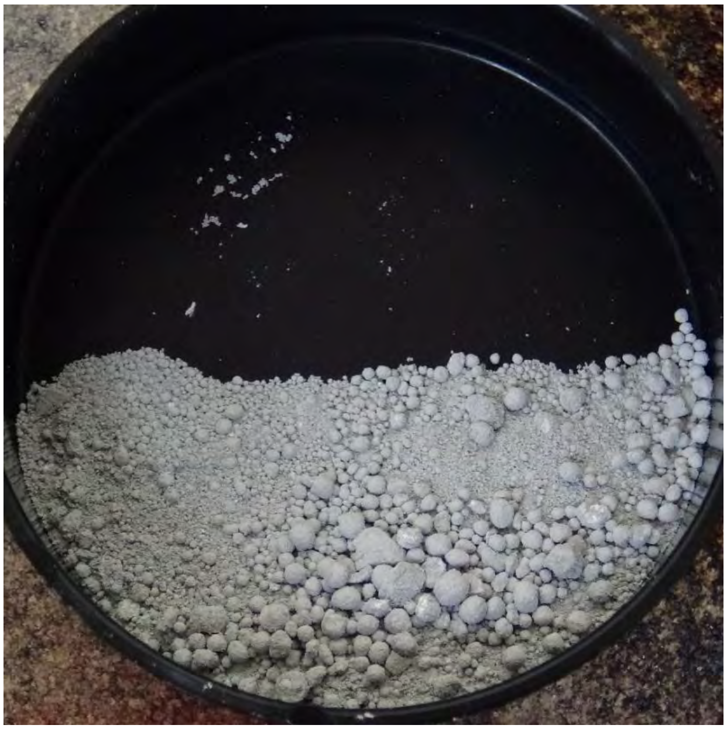


Photo 23: Fine Al-TiO_2 Thermite – Small-Scale Mix ID #25 (SMS mixed)

5.3 Additional Small-Scale Thermite Samples

5.3.1 Fine Al-CrO_3 – Small-Scale Mix ID #26 (SMS Mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 25.26% aluminum (Al) and 74.74% chromium trioxide (CrO_3). The aluminum was 3N purity (99.9% pure), 1 - 5 micrometers (microns) in size, and offered for transport as a Division 4.1 flammable solid. The chromium trioxide was 4N purity (99.99% pure) and was ground via mortar and pestle then sieved until a fine powder was produced. This thermite was a fine, red-gray powder when fully mixed.

Photo 24: Fine Al-CrO_3 – Small-Scale Mix ID #26 (SMS Mixed)

5.3.2 Fine Al-Fe_3O_4 – Small-Scale Mix ID #27 (SMS Mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 23.71% aluminum (Al) and 76.29% iron tetroxide (Fe_3O_4). The aluminum was 3N purity (99.9% pure), 1 - 5 micrometers (microns) in size, and offered for transport as a Division 4.1 flammable solid. The iron tetroxide was 3N purity (99.9% pure) and 1-5 micrometers (microns) in size. This thermite was a fine, dark gray powder when fully mixed.

Photo 25: Fine Al-Fe_3O_4 – Small-Scale Mix ID #27

5.3.3 Fine Al-Mn_2O_3 – Small-Scale Mix ID #28 (SMS Mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 25.47% aluminum (Al) and 74.53% manganese trioxide (Mn_2O_3). The aluminum was 3N purity (99.9% pure), 1 - 5 micrometers (microns) in size, and offered for transport as a Division 4.1 flammable solid. The manganese trioxide was 1N purity (99% pure) and 1-5 micrometers (microns) in size. This thermite was a fine, dark gray powder when fully mixed.

Photo 26: Fine Al-Mn_2O_3 – Small-Scale Mix ID #28

5.3.4 Fine Al-MnO – Small-Scale Mix ID #29 (SMS Mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 20.23% aluminum (Al) and 79.77% manganese oxide (MnO). The aluminum was 3N purity (99.9% pure), 1 - 5 micrometers (microns) in size, and offered for transport as a Division 4.1 flammable solid. The manganese oxide was 1N purity (99% pure) fine powder. This thermite was a fine green powder when fully mixed.

Photo 27: Fine Al-MnO – Small-Scale Mix ID #29

5.3.5 Fine Al-NiO – Small-Scale Mix ID #30 (SMS Mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 19.41% aluminum (Al) and 80.59% nickel oxide (NiO). The aluminum was 3N purity (99.9% pure), 1 - 5 micrometers (microns) in size, and offered for transport as a Division 4.1 flammable solid. The nickel oxide was 1N purity (99% pure) and 1 - 5 micrometers (microns) in size. This thermite was a fine light green powder when fully mixed.

Photo 28: Fine Al-NiO – Small-Scale Mix ID #30

5.3.6 Fine Al-Sb_2O_3 – Small-Scale Mix ID #31 (SMS Mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 15.62% aluminum (Al) and 84.38% antimony trioxide (Sb_2O_3). The aluminum was 3N purity (99.9% pure), 1 - 5 micrometers (microns) in size, and offered for transport as a Division 4.1 flammable solid. The antimony trioxide was 3N purity (99.9% pure) and 1 - 5 micrometers (microns) in size. This thermite was a fine white powder when fully mixed.

Photo 29: Fine Al-Sb_2O_3 – Small-Scale Mix ID #31

5.3.7 Fine Al-SiO_2 – Small-Scale Mix ID #33 (SMS Mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 37.45% aluminum (Al) and 62.55% silicon dioxide (SiO_2). The aluminum was 3N purity (99.9% pure), 1 - 5 micrometers (microns) in size, and offered for transport as a Division 4.1 flammable solid. The silicon dioxide was a 2N (99.9% pure) fine powder. This thermite was a fine orange powder when fully mixed.

Photo 30: Fine Al-SiO_2 – Small-Scale Mix ID #33

5.3.8 Fine Al-SnO – Small-Scale Mix ID #34 (SMS Mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 11.78% aluminum (Al) and 88.22% tin oxide (SnO). The aluminum was 3N purity (99.9% pure), 1 - 5 micrometers (microns) in size, and offered for transport as a Division 4.1 flammable solid. The tin oxide was 3N purity (99.9% pure) and 1 - 5 micrometers (microns) in size. This thermite was a fine light gray powder when fully mixed.

Photo 31: Fine Al-SnO – Small-Scale Mix ID #34

5.3.9 Fine Al-ZnO – Small-Scale Mix ID #35 (SMS Mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 18.10% aluminum (Al) and 81.90% zinc oxide (ZnO). The aluminum was 3N purity (99.9% pure), 1 - 5 micrometers (microns) in size, and offered for transport as a Division 4.1 flammable solid. The zinc oxide was 3N purity (99.9% pure) and 1 - 5 micrometers (microns) in size. This thermite was a fine light gray powder when fully mixed.

Photo 32: Fine Al-ZnO – Small-Scale Mix ID #34

5.3.10 Fine Al-ZrO_2 – Small-Scale Mix ID #36 (SMS Mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 22.60% aluminum (Al) and 77.40% zirconium dioxide (ZrO_2). The aluminum was 3N purity (99.9% pure), 1 - 5 micrometers (microns) in size, and offered for transport as a Division 4.1 flammable solid. The zirconium dioxide was 2N purity (99% pure) and 1 - 5 micrometers (microns) in size. This thermite was a fine light gray powder when fully mixed.

Photo 33: Fine Al-ZrO_2 – Small-Scale Mix ID #36

5.3.11 Fine Mg-Al_2O_3 – Small-Scale Mix ID #37 (SMS Mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 41.70% magnesium (Mg) and 58.30% aluminum trioxide (Al_2O_3). The magnesium was 1N purity (99% pure) fine powder and offered for transport as a Division 4.1 flammable solid. The aluminum trioxide was 3N purity (99.9% pure) and 5 - 75 micrometers (microns) in size. This thermite was a fine off white powder when fully mixed.

Photo 34: Fine Mg-Al_2O_3 – Small-Scale Mix ID #37

5.3.12 Fine Mg-CrO_3 – Small-Scale Mix ID #38 (SMS Mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 51.15% magnesium (Mg) and 48.85% chromium trioxide (CrO_3). The magnesium was 1N purity (99% pure) fine powder and offered for transport as a Division 4.1 flammable solid. The chromium trioxide was 4N purity (99.99% pure) and was ground via mortar and pestle then sieved until a fine powder was produced. This thermite was a fine, red-gray powder when fully mixed.

Photo 35: Fine Mg-CrO_3 – Small-Scale Mix ID #38

5.3.13 Fine Mg-Bi_2O_3 – Small-Scale Mix ID #39 (SMS Mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 13.53% magnesium (Mg) and 86.47% bismuth trioxide (Bi_2O_3). The magnesium was 1N purity (99% pure) fine powder and offered for transport as a Division 4.1 flammable solid. The bismuth trioxide was 3N purity (99.9% pure) and 1- 5 micrometers (micron) in size. This thermite was a fine, light-yellow powder when fully mixed.

Photo 36: Fine Mg-Bi_2O_3 – Small-Scale Mix ID #39

5.3.14 Fine Mg-Co_3O_4 – Small-Scale Mix ID #40 (SMS Mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 28.76% magnesium (Mg) and 71.24% cobalt tetroxide (Co_3O_4). The magnesium was 1N purity (99% pure) fine powder and offered for transport as a Division 4.1 flammable solid. The cobalt tetroxide was 3N purity (99.9% pure) and 1- 5 micrometers (micron) in size. This thermite was a fine, dark gray powder when fully mixed.

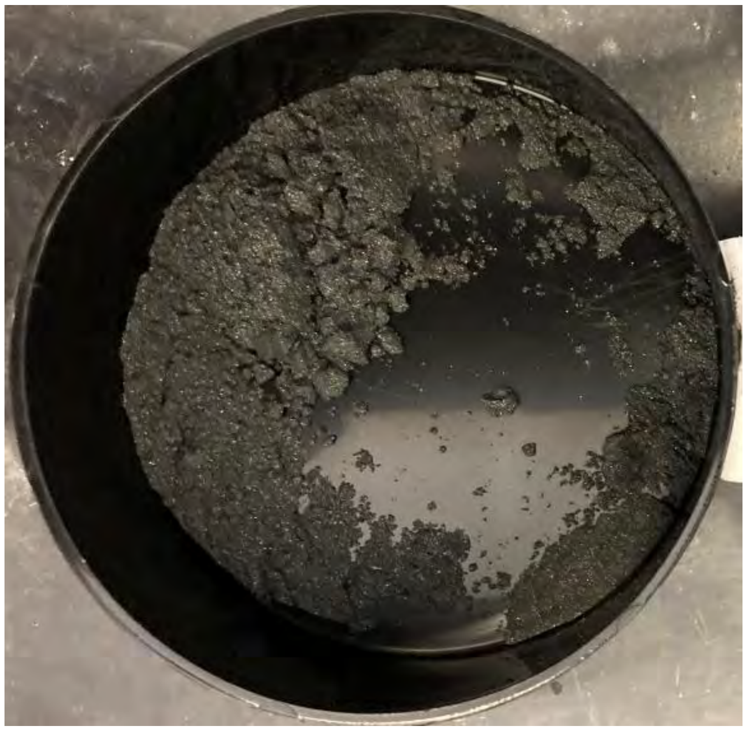


Photo 37: Fine Mg-Co_3O_4 – Small-Scale Mix ID #40

5.3.15 Fine Mg-Cr_2O_3 – Small-Scale Mix ID #41 (SMS Mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 32.42% magnesium (Mg) and 67.58% chromium(III) trioxide (Cr_2O_3). The magnesium was 1N purity (99% pure) fine powder and offered for transport as a Division 4.1 flammable solid. The chromium (III) trioxide was 2N purity (99.9% pure) and 1- 5 micrometers (micron) in size. This thermite was a bright green powder when fully mixed.

Photo 38: Fine Mg-Cr_2O_3 – Small-Scale Mix ID #41

5.3.16 Fine Mg-MoO_3 – Small-Scale Mix ID #42 (SMS Mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 33.62% magnesium (Mg) and 66.38% molybdenum trioxide (MoO_3). The magnesium was 1N purity (99% pure) fine powder and offered for transport as a Division 4.1 flammable solid. The molybdenum trioxide was 2N purity (99.9% pure) and 1- 5 micrometers (micron) in size. This thermite was a fine off-white powder when fully mixed.

Photo 39: Fine Mg-MoO_3 – Small-Scale Mix ID #42

5.3.17 Fine Mg-SiO_2 – Small-Scale Mix ID #43 (SMS Mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 44.72% magnesium (Mg) and 55.28% silicon dioxide (SiO_2). The magnesium was 1N purity (99% pure) fine powder and offered for transport as a Division 4.1 flammable solid. The silicon dioxide was a 2N (99.9% pure) fine powder. This thermite was a fine orange powder when fully mixed.

Photo 40: Fine Mg-SiO_2 – Small-Scale Mix ID #43

5.3.18 Fine Mg-SnO_2 – Small-Scale Mix ID #44 (SMS Mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 24.39% magnesium (Mg) and 75.61% tin dioxide (SnO_2). The magnesium was 1N purity (99% pure) fine powder and offered for transport as a Division 4.1 flammable solid. The tin dioxide was a 2N (99.9% pure) and 1 – 5 micrometers (micron) in size. This thermite was a fine off-white powder when fully mixed.

Photo 41: Fine Mg-SnO_2 – Small-Scale Mix ID #44

5.3.19 Fine Mg-WO_3 – Small-Scale Mix ID #45 (SMS Mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 23.93% magnesium (Mg) and 76.07% tungsten trioxide (WO_3). The magnesium was 1N purity (99% pure) fine powder and offered for transport as a Division 4.1 flammable solid. The tungsten trioxide was a 2N (99.9% pure) and 1 -5 micrometers (micron) in size. This thermite was a gray-green powder when fully mixed.

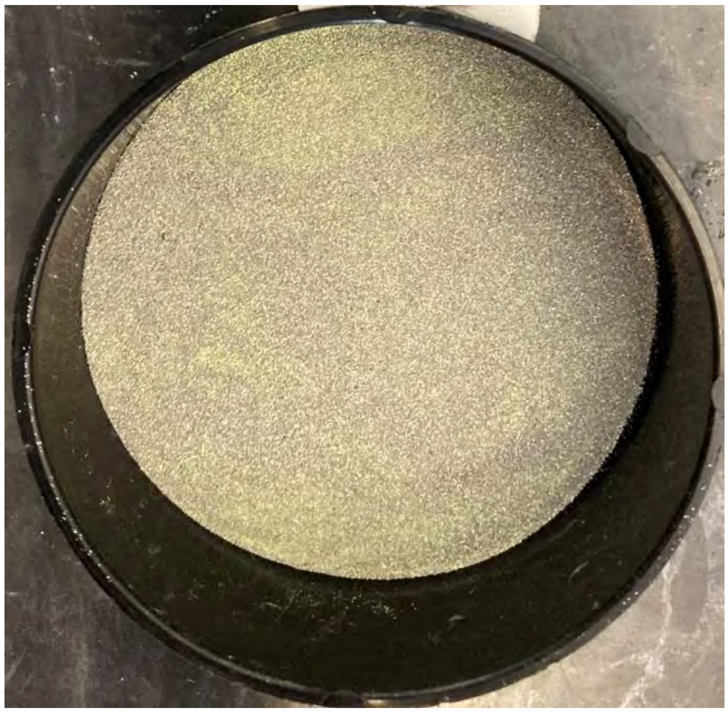


Photo 42: Fine Mg-WO_3 – Small-Scale Mix ID #45

5.3.20 Fine Ti-Al_2O_3 – Small-Scale Mix ID #46 (SMS Mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 41.32 % titanium (Ti) and 58.68% aluminum trioxide (Al_2O_3). The titanium was 2N purity (99.9% pure), less than 20 micrometers in size, and offered for transport as a Division 4.1 flammable solid. The aluminum trioxide was 3N purity (99.9% pure) and 5 - 75 micrometers (microns) in size. This thermite was a fine light gray powder when fully mixed.

Photo 43: Fine Ti-Al_2O_3 – Small-Scale Mix ID #46

5.3.21 Fine Ti-CrO_3 – Small-Scale Mix ID #47 (SMS Mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 50.77% titanium (Ti) and 49.23% chromium trioxide (CrO_3). The titanium was 2N purity (99.9% pure), less than 20 micrometers in size, and offered for transport as a Division 4.1 flammable solid. The chromium trioxide was 4N purity (99.99% pure) and was ground via mortar and pestle then sieved until a fine powder was produced. This thermite was a fine, red-gray powder when fully mixed.

Photo 44: Fine Ti-CrO_3 – Small-Scale Mix ID #47

5.3.22 Fine Ti-Bi_2O_3 – Small-Scale Mix ID #48 (SMS Mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 13.35% titanium (Ti) and 86.65% bismuth trioxide (Bi_2O_3). The titanium was 2N purity (99.9% pure), less than 20 micrometers in size, and offered for transport as a Division 4.1 flammable solid. The bismuth trioxide was 3N purity (99.9% pure) and 1- 5 micrometers (micron) in size. This thermite was a fine, light-yellow powder when fully mixed.

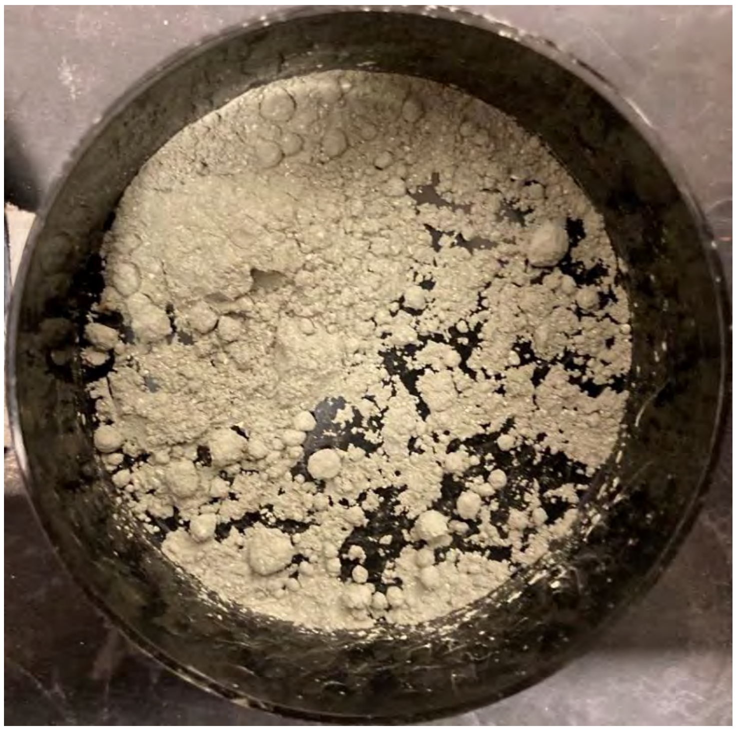


Photo 45: Fine Ti-Bi_2O_3 – Small-Scale Mix ID #48

5.3.23 Fine Ti-Co_3O_4 – Small-Scale Mix ID #49 (SMS Mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 28.45% titanium (Ti) and 71.55% cobalt tetroxide (Co_3O_4). The titanium was 2N purity (99.9% pure), less than 20 micrometers in size, and offered for transport as a Division 4.1 flammable solid. The cobalt tetroxide was 3N purity (99.9% pure) and 1- 5 micrometers (micron) in size. This thermite was a fine, light gray powder when fully mixed.

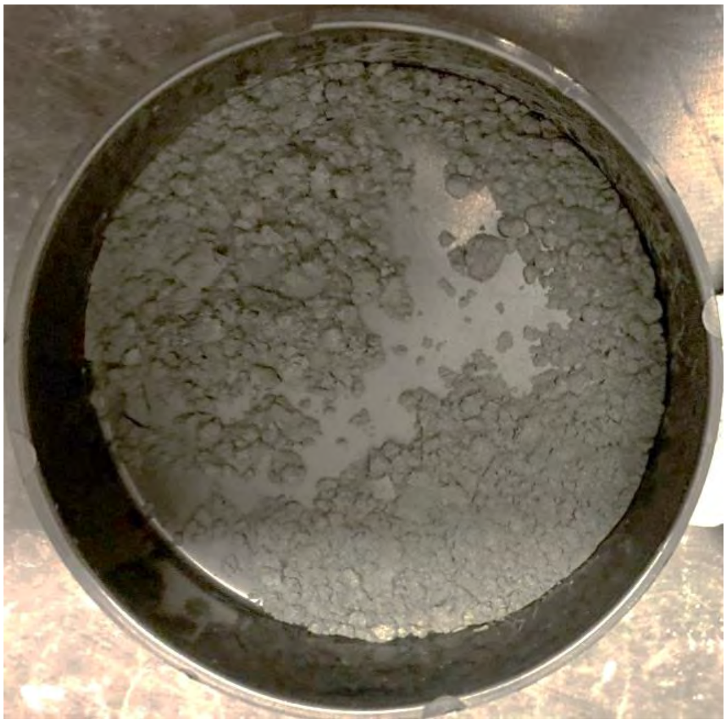


Photo 46: Fine Ti-Co_3O_4 – Small-Scale Mix ID #49

5.3.24 Fine Ti-Cr_2O_3 – Small-Scale Mix ID #50 (SMS Mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 32.09% titanium (Ti) and 67.91% chromium (III) trioxide (Cr_2O_3). The titanium was 2N purity (99.9% pure), less than 20 micrometers in size, and offered for transport as a Division 4.1 flammable solid. The chromium (III) trioxide was 2N purity (99.9% pure) and 1-5 micrometers (micron) in size. This thermite was a bright green powder when fully mixed.

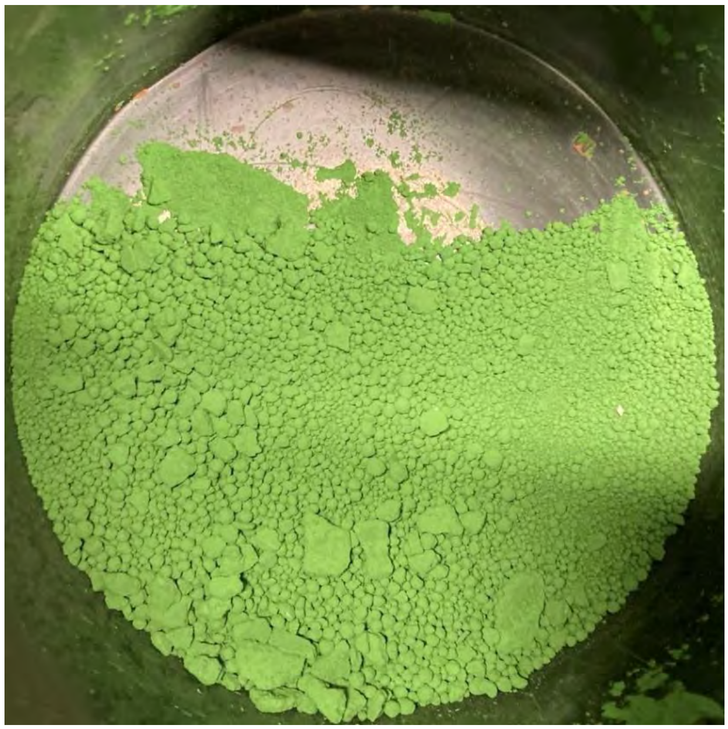


Photo 47: Fine Ti-Cr_2O_3 – Small-Scale Mix ID #50

5.3.25 Fine Ti-Cu_2O – Small-Scale Mix ID #51 (SMS Mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 14.33% titanium (Ti) and 85.67% copper (I) oxide (Cu_2O). The titanium was 2N purity (99.9% pure), less than 20 micrometers in size, and offered for transport as a Division 4.1 flammable solid. The copper (I) oxide was 97% pure and less than 7 micrometers (micron) in size. This thermite was a fine red powder when fully mixed.

Photo 48: Fine Ti-Cu_2O – Small-Scale Mix ID #51

5.3.26 Fine Ti-MoO_3 – Small-Scale Mix ID #52 (SMS Mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 14.33% titanium (Ti) and 85.67% molybenum trioxide (MoO_3). The titanium was 2N purity (99.9% pure), less than 20 micrometers in size, and offered for transport as a Division 4.1 flammable solid. The molybdenum trioxide was 2N purity (99.9% pure) and 1- 5 micrometers (micron) in size. This thermite was a fine off-white powder when fully mixed. This thermite was a light gray powder when fully mixed.

Photo 49: Fine Ti-MoO_3 – Small-Scale Mix ID #52

5.3.27 Fine Ti-SiO_2 – Small-Scale Mix ID #53 (SMS Mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 44.34% titanium (Ti) and 55.66% silicon dioxide (SiO_2). The titanium was 2N purity (99.9% pure), less than 20 micrometers in size, and offered for transport as a Division 4.1 flammable solid. The molybdenum trioxide was 2N purity (99.9% pure) and 1- 5 micrometers (micron) in size. The silicon dioxide was a 2N (99.9% pure) fine powder. This thermite was a fine orange powder when fully mixed.

Photo 50: Fine Ti-SiO_2 – Small-Scale Mix ID #53

5.3.28 Fine Ti-SnO_2 – Small-Scale Mix ID #54 (SMS Mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 24.11% titanium (Ti) and 75.89% tin dioxide (SnO_2). The titanium was 2N purity (99.9% pure), less than 20 micrometers in size, and offered for transport as a Division 4.1 flammable solid. The molybdenum trioxide was 2N purity (99.9% pure) and 1- 5 micrometers (micron) in size. The tin dioxide was a 2N (99.9% pure) and 1 – 5 micrometers (micron) in size. This thermite was a fine off-white powder when fully mixed.

Photo 51: Fine Ti-SnO_2 – Small-Scale Mix ID #54

5.3.29 Fine Ti-WO_3 – Small-Scale Mix ID #55 (SMS Mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 23.65% titanium (Ti) and 76.35% tungsten trioxide (WO_3). The titanium was 2N purity (99.9% pure), less than 20 micrometers in size, and offered for transport as a Division 4.1 flammable solid. The tungsten trioxide was a 2N (99.9% pure) and 1 -5 micrometers (micron) in size. This thermite was a gray-green powder when fully mixed.

Photo 52: Fine Ti-WO_3 – Small-Scale Mix ID #55

5.3.30 Fine Mg & Al-MoO_3 & CuO – Small-Scale Mix ID #56 (Commercial)

SMS procured this thermite from a commercial supplier. This thermite contained magnesium, aluminum, molybdenum trioxide, and cupric oxide. The compositions of each material were proprietary. The thermite was a fine gray powder.

Photo 53: Fine Mg&Al-MoO_3-CuO – Small-Scale Mix ID #56

6.0 TEST DESCRIPTIONS AND RESULTS

6.1 Modified Bureau of Mines (MBOM) Impact Sensitivity Testing

6.1.1 Test Description

The MBOM Impact Test is used to measure the sensitiveness of a substance to drop-weight impact and to determine if the substance is too dangerous to transport in the form tested.

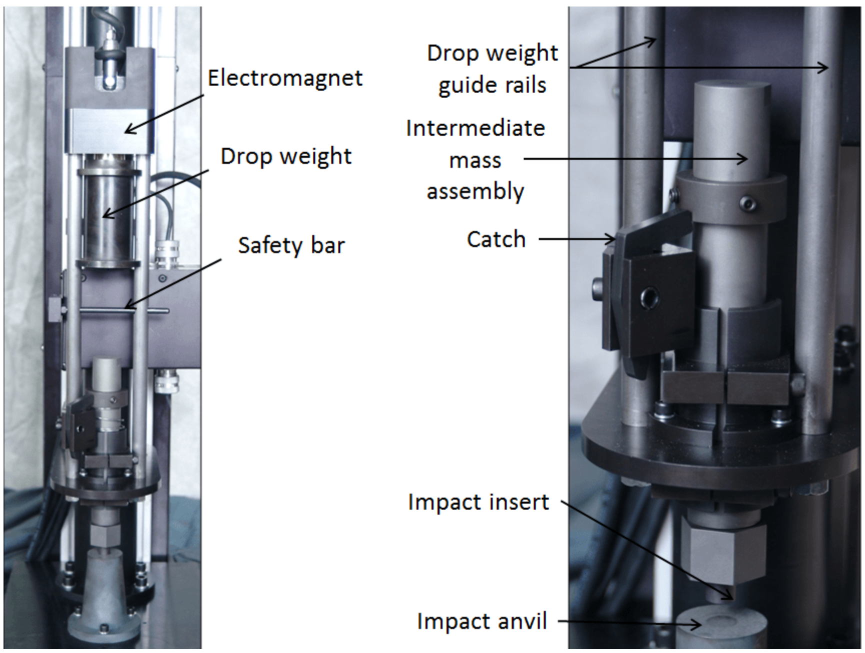


Figure 1: Modified Bureau of Mines (MBOM) Impact Apparatus

For solids, a 10-mg sample is loaded onto the impact anvil. The intermediate mass is slowly lowered onto the anvil until the sample is impinged between the anvil and impact insert. A 2.5-kg drop weight is raised to the desired drop height and released. The drop weight strikes the intermediate mass and delivers an impact stimulus to the sample. The catch prevents multiple impacts from occurring.

Observations are made on whether an "explosion" occurs as evidenced by flame or audible report (smoke excluded). Thermite mixtures were analyzed via a 30-shot Bruceton Method as described in Appendix 2 of the UN Manual of Tests and Criteria to determine the Bruceton 50% Point of Ignition. If a negative result was observed at the maximum height of the apparatus (100 cm) at any point during testing, the sample was tested again at the maximum height. If an explosion occurred at the minimum height of the apparatus (3.2 cm), the sample was tested again at the minimum height. For thermite mixtures that did not exhibit any explosions at the maximum height for all 30 shots, the Bruceton 50% Point is shown as ≥100 cm. For samples that exhibited multiple explosions at the minimum height, the Bruceton 50% point is shown as <3.2 cm.

6.1.2 Test Results

Impact sensitivity testing was performed on the large-scale (LS) and small-scale (SS) thermite test samples. The laboratory data sheets are provided in the Appendix along with the calculations for the 50% initiation level (H_{50}) and standard deviation (s). The test results are summarized in the following table.

Table 2: Summary of MBOM Impact Sensitivity Test Results

Sample ID	Metal	Metal Oxide	50% Initiation Level (cm)	Standard Deviation (cm)
LS #1	Al	Fe_2O_3	≥100	N/A
LS #2	Al	Fe_2O_3	≥100	N/A
LS #3	Al	Fe_2O_3	≥100	N/A
LS #4	Al	CuO	≥100	N/A
LS #5	Al	CuO	≥100	N/A
LS #6	Al	Ni_2O_3	≥100	N/A
LS #7	Al	MnO_2	≥100	N/A
LS #8	Mg & Al	MoO_3 & CuO	≥100	N/A
SS #1	Mg	B_2O_3	81.2	1.1
SS #2B	Ti	B_2O_3	79.4	1.1
SS #3B	Ti	MnO_2	≥100	N/A
SS #4	Mg	MnO_2	≥100	N/A
SS #6B	Ti	Fe_2O_3	≥100	N/A
SS #7B	Ti	CuO	≥100	N/A
SS #9	Al	MoO_3	≥100	N/A
SS #10	Mg	Fe_2O_3	≥100	N/A
SS #11	Mg	CuO	≥100	N/A
SS #12	Al	Co_3O_4	≥100	N/A
SS #18	Al	WO_3	≥100	N/A
SS #19	Al	SnO_2	≥100	N/A
SS #21	Al	Cr_2O_3	≥100	N/A
SS #24	Al	Bi_2O_3	≥100	N/A
SS #25	Al	TiO_2	≥100	N/A
SS #26	Al	CrO_3	33.4	4.2
SS #27	Al	Fe_3O_4	≥100	N/A
SS #28	Al	Mn_2O_3	≥100	N/A
SS #29	Al	MnO	≥100	N/A
SS #30	Al	NiO	≥100	N/A

Sample ID	Metal	Metal Oxide	50% Initiation Level (cm)	Standard Deviation (cm)
SS #31	Al	Sb_2O_3	≥100	N/A
SS #33	Al	SiO_2	≥100	N/A
SS #34	Al	SnO	≥100	N/A
SS #35	Al	ZnO	≥100	N/A
SS #36	Al	ZrO_2	≥100	N/A
SS #37	Mg	Al_2O_3	≥100	N/A
SS #38	Mg	CrO_3	44.6	1.4
SS #39	Mg	Bi_2O_3	58.0	2.6
SS #40	Mg	Co_3O_4	89.2	1.0
SS #41	Mg	Cr_2O_3	>100	N/A
SS #42	Mg	MoO_3	≥100	N/A
SS #43	Mg	SiO_2	≥100	N/A
SS #44	Mg	SnO_2	≥100	N/A
SS #45	Mg	WO_3	≥100	N/A
SS #46	Ti	Al_2O_3	≥100	N/A
SS #47	Ti	CrO_3	24.7	5.4
SS #48	Ti	Bi_2O_3	≥100	N/A
SS #49	Ti	Co_3O_4	>100	N/A
SS #50	Ti	Cr_2O_3	>100	N/A
SS #51	Ti	Cu_2O	>100	N/A
SS #52	Ti	MoO_3	>100	N/A
SS #53	Ti	SiO_2	>100	N/A
SS #54	Ti	SnO_2	>100	N/A
SS #55	Ti	WO_3	>100	N/A
SS #56	Mg & Al	MoO_3 & CuO	89.2	1.0

6.1.3 Assessment of Test Results

The majority of thermite samples tested were extremely insensitive to impact stimulus, with Bruceton 50% Points greater than 100 cm. However, four thermite samples had Bruceton 50% Points that were significantly lower than all the other tested samples. The four samples and their metal and metal oxides are shown in Table 3; three of the four impact sensitive samples had chromium(III) trioxide (Cr_2O_3) as the metal oxide.

Table 3: Fine Thermite Samples That Were Impact Sensitive

Sample ID	Metal	Metal Oxide
SS #26	Al	CrO_3
SS #38	Mg	CrO_3
SS #39	Mg	Bi_2O_3

Sample ID	Metal	Metal Oxide
SS #47	Ti	CrO_3

Fine thermites that were impact sensitive were NOT also extremely friction sensitive. Small-scale samples #38 and #47 were determined to be exploding thermites in Section 6.4.

6.2 ABL Friction Sensitivity Testing

6.2.1 Test Description

This test is used to measure the sensitiveness of the substance to frictional stimuli and to determine if the substance is too dangerous to transport in the form tested.

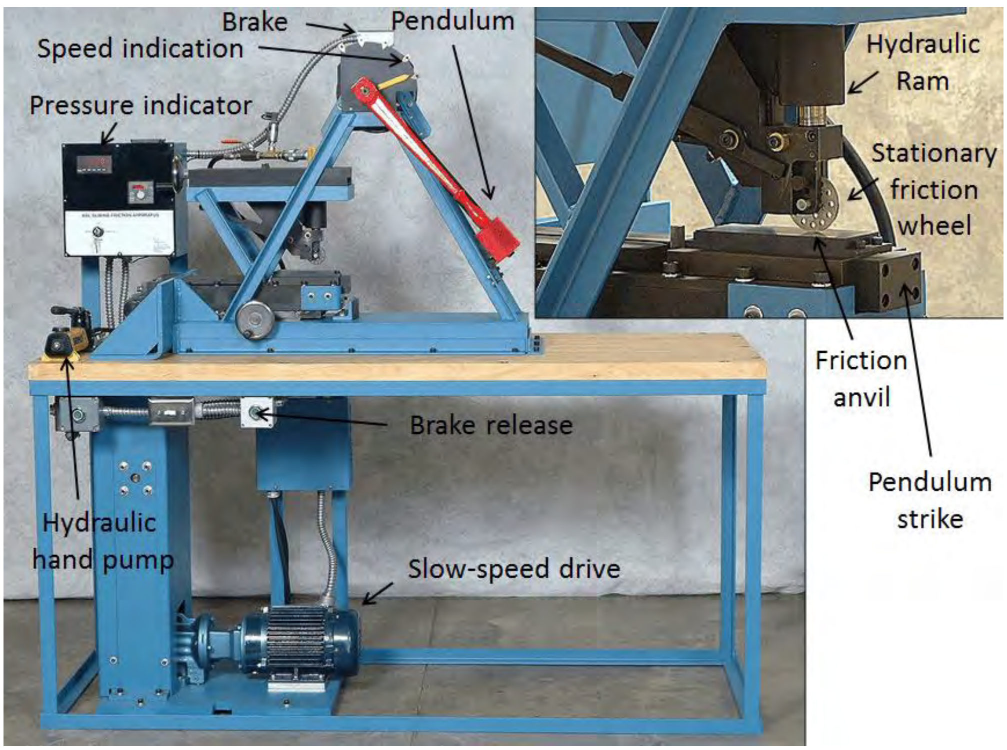


Figure 2: ABL Friction Sensitivity Apparatus

A 10-mg sample is placed on the friction anvil, and the stationary friction wheel is lowered via the hydraulic ram until the sample is impinged between the anvil and the wheel at a desired pressure. The friction anvil is then either struck by the pendulum or dragged by the slow-speed drive at a desired speed so that it travels one inch. The combination of pressure supplied by the stationary wheel and lateral movement of the anvil delivers a frictional stimulus to the sample. Each thermite sample test was conducted at a speed of 3 ft/sec. Initially, the maximum force used during testing was 1280 lb_f. However, repeated testing at this force was causing excessive damage to the machine. As such, the maximum force used during testing was reduced to 1000 lb_f.

Observations are made on whether an "explosion" occurs as evidenced by an audible report, crackling, sparking, or flame. Thermite mixtures were analyzed via a 30-shot Bruceton Method as described in Appendix 2 of the UN Manual of Tests and Criteria to determine the Bruceton 50% Point of Ignition.

If a negative result was observed at the maximum force of the apparatus (1000 - 1280 lb_f) at any point during testing, the sample was tested again at the maximum force. If an explosion occurred at the minimum pressure of the apparatus (51 lb_f), the sample was tested again at the minimum force. For thermite mixtures that did not exhibit any explosions at the maximum force for all 30 shots, the Bruceton 50% Point is shown as ≥1280 lb_f or ≥1000 lb_f. For samples that exhibited multiple explosions at the minimum height, the Bruceton 50% point is shown as <51 lb_f.

6.2.2 Test Results

Friction sensitivity testing was performed on the large-scale (LS) and small-scale (SS) thermite test samples. The laboratory data sheets are provided in the Appendix along with the calculations for the 50% initiation level (H_{50}) and standard deviation (s). The test results are summarized in the following table.

Table 4: Summary of ABL Friction Test Results

Sample ID	Metal	Metal Oxide	50% Initiation Level (lb_f)	Standard Deviation (lb_f)
LS #1	Al	Fe_2O_3	686.8	2.1
LS #2	Al	Fe_2O_3	≥1280	N/A
LS #3	Al	Fe_2O_3	≥1280	N/A
LS #4	Al	CuO	916.5	1.4
LS #5	Al	CuO	1141.3	1.0
LS #6	Al	Ni_2O_3	≥1280	N/A
LS #7	Al	MnO_2	475.2	2.0
LS #8	Mg & Al	MoO_3 & CuO	368.6	2.7
SS #1	Mg	B_2O_3	≥1000	N/A
SS #2B	Ti	B_2O_3	≥1000	N/A
SS #3B	Ti	MnO_2	≤51	N/A
SS #4	Mg	MnO_2	≥1280	N/A
SS #6B	Ti	Fe_2O_3	200.5	2.1
SS #7B	Ti	CuO	255.3	2.2
SS #9	Al	MoO_3	≤51	N/A
SS #10	Mg	Fe_2O_3	≥1280	N/A

Sample ID	Metal	Metal Oxide	50% Initiation Level (lb_f)	Standard Deviation (lb_f)
SS #11	Mg	CuO	≥1000	N/A
SS #12	Al	Co_3O_4	1000.0	1.1
SS #18	Al	WO_3	118.6	29.2
SS #19	Al	SnO_2	≥1280	N/A
SS #21	Al	Cr_2O_3	≥1280	N/A
SS #24	Al	Bi_2O_3	1071.2	1.1
SS #25	Al	TiO_2	≥1000	N/A
SS #26	Al	CrO_3	488.9	2.3
SS #27	Al	Fe_3O_4	461.6	3.1
SS #28	Al	Mn_2O_3	712.3	1.5
SS #29	Al	MnO	≥1000	N/A
SS #30	Al	NiO	≥1000	N/A
SS #31	Al	Sb_2O_3	770.2	1.6
SS #33	Al	SiO_2	≥1000	N/A
SS #34	Al	SnO	832.3	1.1
SS #35	Al	ZnO	≥1000	N/A
SS #36	Al	ZrO_2	≥1000	N/A
SS #37	Mg	Al_2O_3	891.7	1.0
SS #38	Mg	CrO_3	>1000	N/A
SS #39	Mg	Bi_2O_3	862.8	1.1
SS #40	Mg	Co_3O_4	891.7	1.0
SS #41	Mg	Cr_2O_3	891.7	1.0
SS #42	Mg	MoO_3	835.0	1.1
SS #43	Mg	SiO_2	≥1000	N/A
SS #44	Mg	SnO_2	≥1000	N/A
SS #45	Mg	WO_3	891.7	1.0
SS #46	Ti	Al_2O_3	≥1000	N/A
SS #47	Ti	CrO_3	452.4	2.5
SS #48	Ti	Bi_2O_3	866.4	1.1
SS #49	Ti	Co_3O_4	<51	N/A
SS #50	Ti	Cr_2O_3	891.7	1.0
SS #51	Ti	Cu_2O	891.7	1.0
SS #52	Ti	MoO_3	212.8	1.7
SS #53	Ti	SiO_2	>1000	N/A
SS #54	Ti	SnO_2	732.9	1.3
SS #55	Ti	WO_3	787.5	1.2
SS #56	Mg & Al	MoO_3 & CuO	811.2	1.2

6.2.3 Assessment of Test Results

The friction sensitivity of the thermite samples varied significantly, with the majority being relatively insensitive (e.g., Bruceton 50% Point >800 lb_f). However, four thermite samples were extremely sensitive to friction, as shown in Table 5.

Table 5: Fine Thermite Samples That Were Extremely Friction Sensitive

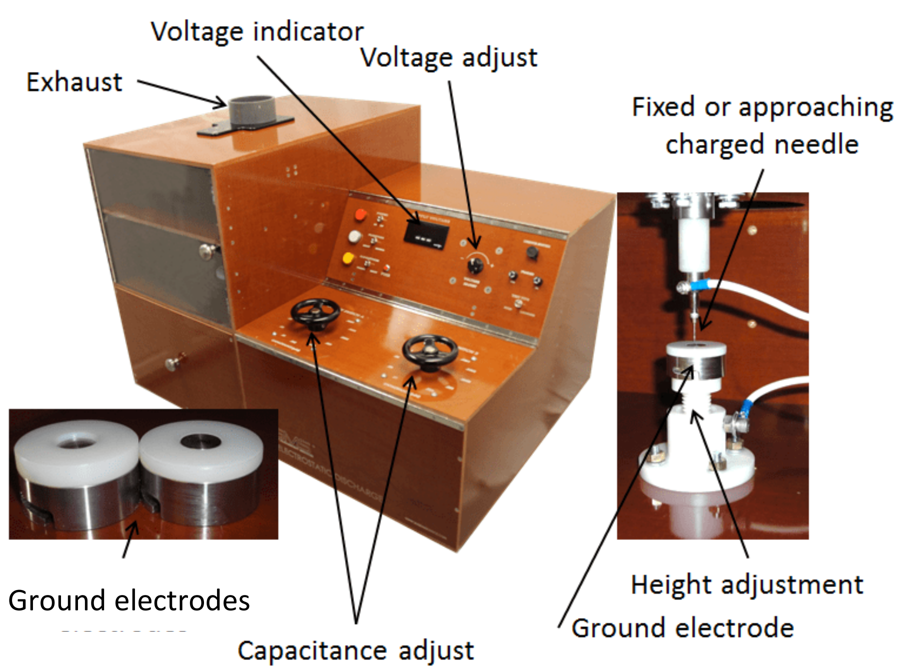
Sample ID	Metal	Metal Oxide
SS #3B	Ti	MnO_2
SS #9	Al	MoO_3
SS #18	Al	WO_3
SS #49	Ti	Co_3O_4

Fine thermites that were extremely impact sensitive were NOT also extremely friction sensitive. Small-scale samples #3B and #9 were determined to be exploding thermites in Section 6.4.

6.3 ABL Electrostatic Discharge (ESD) Sensitivity Testing

6.3.1 Test Description

This test is used to measure the sensitiveness of the substance to electrostatic discharge and to assess how the substance may response to static discharge that may result from in-process conditions.



A 10-mg sample is placed on a ground electrode and placed on the ground post inside the ESD machine underneath the charged needle. The total energy discharged from the needle to the ground electrode is determined by the following equation:

$$E = \frac{1}{2}CV^2$$

Where E is the total energy discharged, C is the capacitance of the system, and V is the voltage difference between the grounding electrode and needle. All thermite samples were tested at a voltage of 5000 VDC. The discharge energy is varied by selecting the desired capacitance. After the capacitance is selected, the capacitor is charged to 5000 VDC. The needle is then lower via hydraulic press until the electrostatic discharge arcs from the needle to the ground electrode, delivering ESD stimulus to the substance.

Because the light intensity emitted from ignited thermites can be hazardous, a high-speed camera and GoDetect ESD™ were used to determine whether an explosion occurred. GoDetect ESD™ is a software developed by Safety Management Services that uses image-based machine learning to determine the severity of a given reaction. Images of the test are collected via high-speed camera and the reaction severity is calculated using an image-based machine learning algorithm. Thermite mixtures were analyzed via a 30-shot Bruceton Method as described in Appendix 2 of the UN Manual of Tests and Criteria to determine the Bruceton 50% Point of Ignition.

6.3.2 Test Results

ESD sensitivity testing was performed on the large-scale (LS) and small-scale (SS) thermite test samples. The laboratory data sheets are provided in the Appendix along with the calculations for the 50% initiation level (H_{50}) and standard deviation (s). The H_{50} calculations are summarized in the following table.

Sample ID	Metal	Metal Oxide	50% Initiation Level (J)
LS #1	Al	Fe_2O_3	0.0031
LS #2	Al	Fe_2O_3	0.0371
LS #3	Al	Fe_2O_3	0.0330
LS #4	Al	CuO	0.0148
LS #5	Al	CuO	0.5465
LS #6	Al	Ni_2O_3	0.0444
LS #7	Al	MnO_2	0.0005
LS #8	Mg & Al	MoO_3 & CuO	0.1596
SS #1	Mg	B_2O_3	0.5465
SS #2B	Ti	B_2O_3	0.0007
SS #3B	Ti	MnO_2	≤0.0002

Sample ID	Metal	Metal Oxide	50% Initiation Level (J)
SS #4	Mg	MnO_2	0.0023
SS #6B	Ti	Fe_2O_3	≤0.0002
SS #7B	Ti	CuO	0.0008
SS #9	Al	MoO_3	0.0073
SS #10	Mg	Fe_2O_3	0.0008
SS #11	Mg	CuO	0.0033
SS #12	Al	Co_3O_4	0.0030
SS #18	Al	WO_3	0.0075
SS #19	Al	SnO_2	0.0099
SS #21	Al	Cr_2O_3	0.0061
SS #24	Al	Bi_2O_3	0.0246
SS #25	Al	TiO_2	0.0045
SS #26	Al	CrO_3	0.3995
SS #27	Al	Fe_3O_4	0.197
SS #28	Al	Mn_2O_3	0.0144
SS #29	Al	MnO	0.0917
SS #30	Al	NiO	≤0.0002
SS #31	Al	Sb_2O_3	0.0601
SS #33	Al	SiO_2	0.3292
SS #34	Al	SnO	0.0113
SS #35	Al	ZnO	0.0352
SS #36	Al	ZrO_2	0.0141
SS #37	Mg	Al_2O_3	0.015
SS #38	Mg	CrO_3	≥0.750
SS #39	Mg	Bi_2O_3	0.226
SS #40	Mg	Co_3O_4	0.35
SS #41	Mg	Cr_2O_3	0.292
SS #42	Mg	MoO_3	0.0509
SS #43	Mg	SiO_2	0.0486
SS #44	Mg	SnO_2	0.1444
SS #45	Mg	WO_3	0.0349
SS #46	Ti	Al_2O_3	≤0.0002
SS #47	Ti	CrO_3	0.0013
SS #48	Ti	Bi_2O_3	0.0014
SS #49	Ti	Co_3O_4	≤0.0002
SS #50	Ti	Cr_2O_3	0.0048
SS #51	Ti	Cu_2O	0.0011
SS #52	Ti	MoO_3	0.0004

Sample ID	Metal	Metal Oxide	50% Initiation Level (J)
SS #53	Ti	SiO_2	0.0006
SS #54	Ti	SnO_2	≤0.0002
SS #55	Ti	WO_3	≤0.0002
SS #56	Mg & Al	MoO_3 & CuO	0.0018

6.3.3 Assessment of Test Results

GoDetect ESD™ detects reactions at the threshold of ignition with a high degree of sensitivity, resulting in ESD sensitivity levels that represent small consumption of the sample. Based on the high-speed video and GoDetect ESD™ algorithm, reactions were detected at low ESD levels for most of the thermites. Thermites containing titanium metal or manganese dioxide were highly sensitive to ESD stimulus.

6.4 <u>Hotwire Explosion Screening Test</u>

6.4.1 Test Description

This test was performed to screen for thermite mixtures that would explode when exposed to high temperature. Each end of a 105-mm long, 18-gauge 80/20 nickel/chromium (ni-chrome) resistance heating wire (Type A) was attached to electrodes suspended just above an insulating clay-based firebrick. A 5-gram test sample was poured over the heating wire, as shown in photo. The resistance heating wire could achieve a maximum test temperature of 1200°C. All thermite samples were tested at 10 volts and 21 amps. The test was conducted for two minutes or until the sample was consumed. Two trials were performed for each thermite material. Test results were determined visually.

It was determined that each thermite mixture could be placed into one of four categories:

- Explosion – the entire thermite sample was consumed with an audible report and pressure wave.
- Fast Reaction – the entire thermite sample was consumed in less than two seconds, but no audible report or pressure wave was detected.
- Moderate Reaction - the entire sample was consumed between two to ten seconds.
- Slow Reaction – the entire sample was consumed in greater than ten seconds, or a reaction was detected but the entire sample was not consumed.
- Negligible Reaction – no reaction was detected

Photo 54: Test Sample Loaded onto Hotwire Auto-ignition Temperature Apparatus

6.4.2 Test Results

The test results are summarized in the following table. Large-scale samples 1 - 8 and small-scale samples 1 - 25 were conducted in the previous effort; small-scale samples 26 - 56 were conducted as part of the current effort. Observations on the nature of the reaction were recorded for all samples.

Table 6: Summary of Hotwire Explosion Screening Test Results

Sample ID	Metal	Metal Oxide	Trial 1 Result	Trial 2 Result	Observations
Phase 1 Test Samples					
LS #1	Al	Fe_2O_3	Fast Reaction	Fast Reaction	**Burned <0.1 seconds**
LS #2	Al	Fe_2O_3	No Ignition	No Ignition	Unable to ignite using 18-gauge ni-chrome wire
LS #3	Al	Fe_2O_3	Moderate Reaction	Moderate Reaction	Burned for 2 seconds
LS #4	Al	CuO	Moderate Reaction	Moderate Reaction	Burned for 3 seconds
LS #5	Al	CuO	Moderate Reaction	Moderate Reaction	Burned for 1 - 2 seconds
LS #6	Al	Ni_2O_3	Moderate Reaction	Moderate Reaction	Burned for 15 seconds
LS #7	Al	MnO_2	**Explosion**	**Explosion**	

Sample ID	Metal	Metal Oxide	Trial 1 Result	Trial 2 Result	Observations
LS #8	Mg & Al	MoO_3 & CuO	**Explosion**	**Explosion**	
SS #1	Mg	B_2O_3	Moderate Reaction	Moderate Reaction	Burned for 2 seconds
SS #2B	Ti	B_2O_3	Slow Reaction	Slow Reaction	Very slow, subtle burn
SS #3B	Ti	MnO_2	**Explosion**	**Explosion**	
SS #4	Mg	MnO_2	**Explosion**	**Explosion**	
SS #6B	Ti	Fe_2O_3	Moderate Reaction	Moderate Reaction	Burned for 1 - 2 seconds
SS #7B	Ti	CuO	Fast Reaction	Fast Reaction	**Low-order explosion (burned <0.1 seconds)**
SS #9	Al	MoO_3	**Explosion**	**Explosion**	
SS #10	Mg	Fe_2O_3	Moderate Reaction	Moderate Reaction	Burned for 1 - 2 seconds
SS #11	Mg	CuO	Fast Reaction	Fast Reaction	Burned for 1 second
SS #12	Al	Co_3O_4	Moderate Reaction	Moderate Reaction	Burned for 2 - 3 seconds
SS #18	Al	WO_3	Moderate Reaction	Moderate Reaction	Sporadic thermal behavior; burned for 3 seconds
SS #19	Al	SnO_2	**Explosion**	**Explosion**	
SS #21	Al	Cr_2O_3	Slow Reaction	Slow Reaction	
SS #24	Al	Bi_2O_3	**Explosion**	**Explosion**	
SS #25	Al	TiO_2	Slow Reaction	Slow Reaction	Burned for 20 seconds
Test Samples from Current Effort (Phase 2)					
SS #26	Al	CrO_3	Slow Reaction	Slow Reaction	A small amount of sample was consumed in >30 seconds.
SS #27	Al	Fe_3O_4	**Explosion**	**Explosion**	An audible report was heard. The sample was consumed in less than 0.1 seconds. A pressure wave was detected.
SS #28	Al	Mn_2O_3	Fast Reaction	Fast Reaction	Sample consumed in approximately 0.2 seconds. An audible report was heard. No pressure wave was detected.

Sample ID	Metal	Metal Oxide	Trial 1 Result	Trial 2 Result	Observations
SS #29	Al	MnO	Negligible Reaction	Negligible Reaction	No reaction was visually detected.
SS #30	Al	NiO	**Explosion**	**Explosion**	An audible report was heard. The sample was consumed in less than 0.1 seconds. A pressure wave was detected.
SS #31	Al	Sb_2O_3	Slow Reaction	Slow Reaction	Reaction was sporadic. Crackling and popping sparks were observed, a small amount of the sample was consumed.
SS #33	Al	SiO_2	Slow Reaction	Slow Reaction	A slow, smoldering reaction was observed, a small amount of sample was consumed.
SS #34	Al	SnO	Fast Reaction	Fast Reaction	Sample was consumed in approximately 1-2 seconds.
SS #35	Al	ZnO	Slow Reaction	Slow Reaction	Slow reaction was visually detected over three minutes.
SS #36	Al	ZrO_2	Slow Reaction	Slow Reaction	A small amount of sample was consumed.
SS #37	Mg	Al_2O_3	Slow Reaction	Slow Reaction	A small amount of sample was consumed.
SS #38	Mg	CrO_3	**Explosion**	**Explosion**	An audible report was heard. The sample was consumed in less than 0.1 seconds.
SS #39	Mg	Bi_2O_3	Fast Reaction	Fast Reaction	Sample was consumed in less than 0.2 seconds with no audible report.
SS #40	Mg	Co_3O_4	Fast Reaction	Fast Reaction	Sample was consumed in approximately 0.5 seconds.
SS #41	Mg	Cr_2O_3	Fast Reaction	Fast Reaction	Sample was consumed in approximately 1-2 seconds.
SS #42	Mg	MoO_3	Fast Reaction	Fast Reaction	Sample was consumed in less than 0.2 seconds with no audible report.
SS #43	Mg	SiO_2	Fast Reaction	Fast Reaction	Sample was consumed in approximately 1-2 seconds.
SS #44	Mg	SnO_2	Slow Reaction	Slow Reaction	A small amount of sample was consumed in approximately 30 seconds.
SS #45	Mg	WO_3	Fast Reaction	Fast Reaction	Sample was consumed in approximately 1-2 seconds.

Sample ID	Metal	Metal Oxide	Trial 1 Result	Trial 2 Result	Observations
SS #46	Ti	Al_2O_3	Slow Reaction	Slow Reaction	Slow, smoldering reaction detected, a small amount of sample was consumed.
SS #47	Ti	CrO_3	**Explosion**	**Explosion**	An audible report was heard. The sample was consumed in less than 0.1 seconds. A pressure wave was detected.
SS #48	Ti	Bi_2O_3	**Explosion**	**Explosion**	An audible report was heard. The sample was consumed in less than 0.1 seconds. A pressure wave was detected.
SS #49	Ti	Co_3O_4	Fast Reaction	Fast Reaction	Sample was consumed in approximately 1-2 seconds with crackling and popping sparks.
SS #50	Ti	Cr_2O_3	Slow Reaction	Slow Reaction	Sample was consumed in 20-30 seconds.
SS #51	Ti	Cu_2O	Fast Reaction	Fast Reaction	Sample was consumed in approximately 0.5 seconds.
SS #52	Ti	MoO_3	Fast Reaction	Fast Reaction	Sample was consumed in approximately 0.2 seconds.
SS #53	Ti	SiO_2	Slow Reaction	Slow Reaction	A small amount of the sample was consumed in a slow, smoldering reaction in each trial.
SS #54	Ti	SnO_2	Fast Reaction	Fast Reaction	Sample was consumed in approximately 1-2 seconds.
SS #55	Ti	WO_3	Fast Reaction	Fast Reaction	Sample was consumed in approximately 0.5 seconds.
SS #56	Mg & Al	MoO_3 & CuO	**Explosion**	**Explosion**	Sample was consumed in less than 0.1 seconds. An audible report was heard.

6.4.3 Assessment of Test Results

The fine thermites listed in Table 7 exploded upon ignition when unconfined and in small quantities. Based on the test results, it appears that the potential for unconfined explosion of fine thermites is influenced heavily by the metal oxide, as evidenced by several metal oxides, most notably bismuth trioxide, molybdenum trioxide, manganese(IV) oxide and chromium trioxide, to explode when mixed with various metals.

Table 7: List of Fine Thermites that Explode in Small Quantities, Unconfined

Metal Oxide	Metal	Sample ID
Bi_2O_3	Al	SS #24
Bi_2O_3	Ti	SS #48
CrO_3	Mg	SS #38
CrO_3	Ti	SS #47
Fe_3O_4	Al	SS #27
MnO_2	Al	LS #7
MnO_2	Mg	SS #4
MnO_2	Ti	SS #3B
MoO_3	Al	SS #9
MoO_3 & CuO	Mg & Al	SS #56
MoO_3 & CuO	Mg & Al	LS #8
NiO	Al	SS #30
SnO_2	Al	SS #19

The fine thermites listed in Table 8 were fast reacting (i.e., consumed in less than one second) when unconfined and in small quantities. It is noted that several of the metal oxides were contained in the exploding thermites listed in Table 7 (e.g., bismuth trioxide, molybdenum trioxide, tin dioxide).

Table 8: List of Fine Thermites that are Fast Reacting in Small Quantities, Unconfined

Metal Oxide	Metal	Sample ID
Bi_2O_3	Mg	SS #39
Co_3O_4	Mg	SS #40
Co_3O_4	Ti	SS #49
Cr_2O_3	Mg	SS #41
Cu_2O	Ti	SS #51
CuO	Mg	SS #11
CuO	Ti	SS #7B
Fe_2O_3	Al	LS #1
Mn_2O_3	Al	SS #28
MoO_3	Mg	SS #42
MoO_3	Ti	SS #52
SiO_2	Mg	SS #43
SnO	Al	SS #34
SnO_2	Ti	SS #54
WO_3	Mg	SS #45
WO_3	Ti	SS #55

6.5 High-Temperature Differential Scanning Calorimeter (DSC) Testing

6.5.1 Test Description

This test is used to evaluate the behavior of energetic materials when subjected to a temperature rise. Characteristics displayed on the thermograms can be used to monitor samples in comparison to controls and to examine whether changes that may affect stability have occurred in a sample. Results provide onset temperature and peak maxima for any endothermic or exothermic event.

An instrument employing heat flow DSC was utilized. The test specimen and a thermally-inert reference material are loaded into separate crucibles. The crucibles are placed in the test chamber in separate holders. As the presence of air may critically affect the measured decomposition energy, the atmosphere in the test chamber is continuously purged with an inert atmosphere (oxygen deficient). The specimen and reference material are simultaneously heated at a controlled rate over a specified temperature range.

Thermocouples near the sample containers detect differences between the temperatures of the crucibles. The difference between these two temperatures is correlated to heat flow. A record of the change in heat flow is plotted against the furnace temperature or time. When the sample undergoes a transition involving a change of enthalpy, that change is indicated by a departure from the initially established baseline of the heat flow record.

For the self-heating test, the minimum temperature for exotherm onset and the ignition temperature are reported.

6.5.2 Test Configuration

The DSC instrument is a Themys One+ DSC using a nitrogen purge gas flow rate of 7 L/min at ambient pressure. After each completed test, the test chamber was cooled by a Julabo FL1703 chiller. The sample is contained in a SETARAM 100 µL alumina crucible. The test specimens were heated from 30°C to 1400°C using a heating rate of 20°C/min. The testing was not conducted at an elevated pressure. The reference material was selected as an empty crucible.

The instrument was calibrated the week of September 3, 2021, to generate temperature correction coefficients and a sensitivity coefficient to convert the heat flow in terms of energy by measurement of the melting points and heats of fusion of three standard reference materials (indium, bismuth, and tin) at two different heating rates (5 and 10°C/min) per the apparatus manufacturer's recommendations. The calibration trials were performed using the same type of crucible, purge gas, and flow rates specified above. The results of the calibration to determine the Temperature Correction Coefficients are as follows:

Table 9: September 3, 2021: Temperature Correction Coefficients

Material	Melt (°C)	Melt Measured (°C)	
		5°C/min	10°C/min
Indium	156.59	153.22	152.72
Tin	231.94	228.30	230.64
Lead	327.50	322.36	322.58
Zinc	419.60	415.60	415.52
Aluminum	660.30	654.67	658.29
Silver	961.80	952.50	953.05
Gold	1064.20	1058.00	1059.01

Based on these values, the constants for the temperature correction coefficients for the SETARAM 100 µL alumina crucible were determined to be:

$$C = B_0 + B_1 T + B_2 R$$

Where: C = Correction (°C)
T = Temperature (°C)
R = Heating rate (K/min)
B_0 = -3.9898
B_1 = -4.363 x 10^{-3}
B_2 = 2.0546 x 10^{-1}

The results of the calibration to determine the Sensitivity Coefficients are as follows:

Table 10: September Calibration: Sensitivity Coefficients

Material	Enthalpy (J/g)	Enthalpy Measured (J/g·K)	
		Sensitivity	Delta
Indium	28.5	0.2940	-0.00091
Tin	60.2	0.2870	0.00242
Lead	23	0.2797	-0.00182
Aluminum	401	0.2864	0.00052
Silver	104.8	0.2474	-0.00039
Gold	64.5	0.2258	0.00019

Based on these values, the manufacturer's default Sensitivity Coefficients were the best fit to convert the heat flow:

$$S = A0 + A1 \cdot T + A2 \cdot T^2 + A3 \cdot T^3 + A4 \cdot T^4$$

Where: S = Sensitivity (µV/mW)
T = Temperature (°C)
$A0$ = 3.5095 x 10^{-1}
$A1$ = -5.7595 x 10^{-4}
$A2$ = 1.6236x 10^{-6}
$A3$ = -1.759942 x 10^{-9}
$A4$ = 5.9925 x 10^{-13}

Test specimens were weighed using a calibrated Sartorius CPA225D balance with a weighing capacity of 100 grams and a sensitivity of ±10 µg.

6.5.3 Test Results

The test results are summarized in the following table. The DSC thermograms for each trial are provided in the Appendix. A nominal sample size of 1 milligram was utilized for each trial.

Table 11: Summary of High-Temperature DSC Test Results

Sample ID	Metal	Metal Oxide	Reaction Onset Temperature (°C)		Observations
			Trial 1	Trial 2	
LS #1	Al	Fe_2O_3	n/e*	923	Trial 2 shows a small exotherm and change in mass

Sample ID	Metal	Metal Oxide	Reaction Onset Temperature (°C)		Observations
			Trial 1	Trial 2	
LS #2	Al	Fe_2O_3	n/e	n/e	No significant change in mass; exotherm > 1400 °C
LS #3	Al	Fe_2O_3	n/e	n/e	No significant change in mass; exotherm > 1400 °C
LS #4	Al	CuO	992	990	Large mass change around 990 °C without apparent exotherm
LS #5	Al	CuO	988	991	Large mass change around 990 °C without apparent exotherm
LS #6	Al	Ni_2O_3	n/e	n/e	Exotherm > 1400 °C
LS #7	Al	MnO_2	949	999	Mass change and reaction around 600°C, small exotherms
LS #8	Mg & Al	MoO_3 & CuO	564	567	Moderate exotherms and changes in mass
SS #1	Mg	B_2O_3	623	620	Very distinct exotherms and large changes in mass
SS #2B	Ti	B_2O_3	n/e	n/e	Large mass change around 116 °C; possible onset of reaction around 1074 - 1334 °C
SS #3B	Ti	MnO_2	588	588	Large mass change and small, broad exotherm onset around 588 °C
SS #4	Mg	MnO_2	568	569	Very distinct exotherms and large changes in mass
SS #6B	Ti	Fe_2O_3	732	736	Apparent mass change and very small exotherm
SS #7B	Ti	CuO	991	992	Subtle mass change begins around 650 °C with large change around 990 °C
SS #9	Al	MoO_3	878	883	Very subtle change in mass around 650 °C; Trial 1 mass changes sporadically and Trial 2 mass is steady until small exotherm
SS #10	Mg	Fe_2O_3	587	575	Very distinct exotherms and large changes in mass
SS #11	Mg	CuO	572	568	Distinct exotherms and changes in mass
SS #12	Al	Co_3O_4	904	904	Large mass change and reaction
SS #18	Al	WO_3	1100	1174	Subtle mass change around 900 °C

Sample ID	Metal	Metal Oxide	Reaction Onset Temperature (°C)		Observations
			Trial 1	Trial 2	
SS #19	Al	SnO_2	926	931	Mass change around exotherm peak; Trial 2 mass changes earlier around 620 °C
SS #21	Al	Cr_2O_3	886	890	Distinct exotherms
SS #24	Al	Bi_2O_3	812	812	Small exotherm with slight mass change
SS #25	Al	TiO_2	936	931	Small exotherm with slight mass change
SS #26	Al	CrO_3	775	968	Trials 1 & 2 show sporadic thermal behavior and mass between 450 - 650 °C; mass changes significantly upon small exotherms
SS #27	Al	Fe_3O_4	892	889	Moderate exotherms and changes in mass
SS #28	Al	Mn_2O_3	1002	1004	Initial, very small exotherm and/or mass change at 655 °C followed by a second larger exotherm and mass change
SS #29	Al	MnO	585	561	Very small exotherm for Trial 1; small exotherm for Trial 2 followed by mass change
SS #30	Al	NiO	593	600	Very small exotherm around 600 °C without change in mass; significant change in mass beginning around 900 °C without apparent exotherm
SS #31	Al	Sb_2O_3	653	n/e	Very small exotherm; large change in mass around 600 °C
SS #33	Al	SiO_2	653	n/e	Very small exotherm with no significant change in mass
SS #34	Al	SnO	n/e	n/e	No significant change in mass or exothermic activity
SS #35	Al	ZnO	n/e	n/e	No significant exothermic activity with gradual changes in mass
SS #36	Al	ZrO_2	655	n/e	Step changes in Trial 1 mass around 655 °C and 967 °C; Trial 2 no significant change in mass or exothermic activity

Sample ID	Metal	Metal Oxide	Reaction Onset Temperature (°C)		Observations
			Trial 1	Trial 2	
SS #37	Mg	Al_2O_3	598	603	Very distinct exotherms and large changes in mass
SS #38	Mg	CrO_3	588	n/e	Trial 1 shows a very distinct exotherm and change in mass; no apparent reaction in Trial 2
SS #39	Mg	Bi_2O_3	585	587	Moderate exotherms and changes in mass
SS #40	Mg	Co_3O_4	619	n/e	Trial 1 shows a moderate exotherm without change in mass; no apparent reaction in Trial 2
SS #41	Mg	Cr_2O_3	618	619	Very distinct exotherms and slight changes in mass
SS #42	Mg	MoO_3	608	605	Very distinct exotherms and slight changes in mass
SS #43	Mg	SiO_2	597	594	Very distinct exotherms and slight changes in mass
SS #44	Mg	SnO_2	590	592	Very distinct exotherms and large changes in mass
SS #45	Mg	WO_3	598	596	Very distinct exotherms and large changes in mass
SS #46	Ti	Al_2O_3	786	792	Gradual change in mass between two exotherms
SS #47	Ti	CrO_3	761	760	Moderate exotherms and large changes in mass
SS #48	Ti	Bi_2O_3	962	957	Changes in mass apparent around 700 °C for Trial 1 and 600 °C for Trial 2; very small exotherms
SS #49	Ti	Co_3O_4	n/e	n/e	No significant exothermic activity with gradual changes in mass
SS #50	Ti	Cr_2O_3	733	n/e	Trial 1 shows a very small exotherm with slight mass change; no significant exothermic activity with gradual changes in mass for Trial 2
SS #51	Ti	Cu_2O	n/e	n/e	No significant exothermic activity with abrupt change in mass around 1000 °C

Sample ID	Metal	Metal Oxide	Reaction Onset Temperature (°C)		Observations
			Trial 1	Trial 2	
SS #52	Ti	MoO_3	n/e	n/e	No significant exothermic activity with gradual changes in mass
SS #53	Ti	SiO_2	1005	n/e	Trial 1 shows a very small exotherm with slight mass change beginning around 700 °C; no significant exothermic activity with a small change in mass around 900 °C for Trial 2
SS #54	Ti	SnO_2	873	843	Very small exotherm with apparent change in mass around 650 °C
SS #55	Ti	WO_3	n/e	n/e	No significant exothermic activity with gradual changes in mass
SS #56	Mg & Al	MoO_3 & CuO	578	561	Small, distinct exotherm with change in mass

*n/e - No evidence of an exotherm for test sample.

6.5.4 Assessment of Test Results

All thermites containing magnesium metal yielded very distinct, characteristic exothermic reactions beginning around 600 °C (lowest measured exothermic onset temperature). Thermites containing titanium metal yielded subtle exothermic reactions beginning around 750 °C. Thermites containing aluminum metal yielded slightly stronger exothermic reactions beginning around 900 °C. Thermites containing cobalt tetroxide experienced an endotherm (phase or crystalline change) around 900 °C. A few of the thermites and/or specific thermite trials did not yield any discernible exotherms; this may be due to the homogeneity and uniformity of the metal – metal oxide mixture, the small test specimen size required for protection of the instrument (nominally 1 milligram), and the maximum test temperature (1400 °C). Increasing the test specimen size and the maximum test temperature may yield additional test results and data for further assessment.

Figure 3: Exothermic Onset Temperatures for Phase 1 Thermites

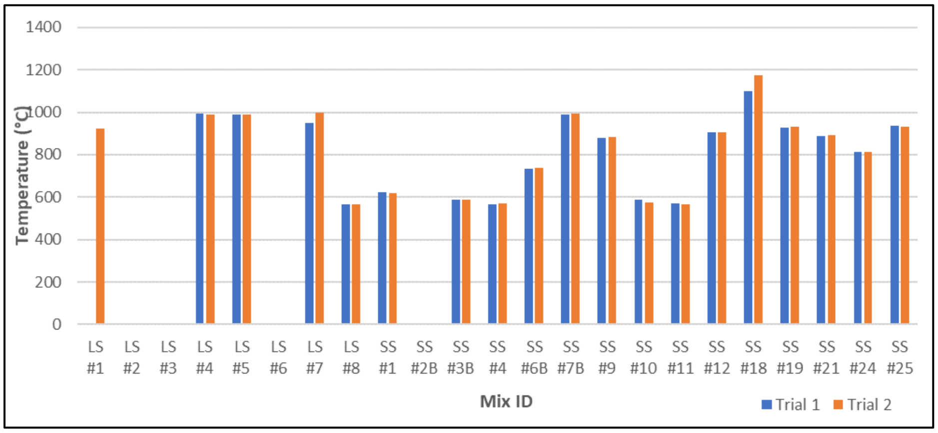
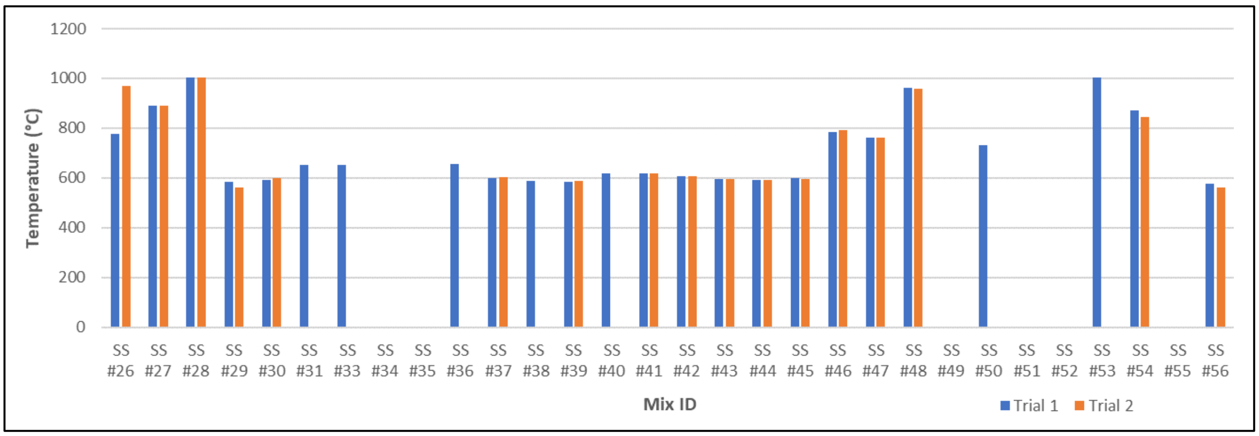


Figure 4: Exothermic Onset Temperatures for Phase 2 Thermites



APPENDIX A
– Laboratory Data Sheets

Figure A1: Laboratory Data Sheets for Mix ID LS #1 - Fine Al-Fe_2O_3

Material: LS #1 **Start Time:** **Stop Time:** **Operator:** RKC
Date: 5/19/2021 **Relative Humidty:** 32% **Temperature:** 71°F **Project:** DOT1-6265b

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI Level	100	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
RSI Level	79.4																															0	0

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass with a 2.5 or 5.0 kg drop mass**

Material: LS #1 **Start Time:** **Stop Time:** **Operator:** JDZ
Date: 5/19/2021 **Relative Humidty:** 31% **Temperature:** 66°F **Project:** DOT1-6265b

ABL Friction	lbf (3 ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI Level	1280	F	S Z		S Z																											2	1
RSI Level	1000			F		S Z		S Z														S Z										3	1
RSI Level	795						F		S Z										S Z		F		S Z						S Z			4	2
RSI Level	635									S Z		S Z		S Z				F		F				S Z				F		S Z		5	3
RSI Level	505										F		F		S Z		F								S Z		F				F	2	5
RSI Level	400															F										F						0	2

Material: LS #1 **Start Time:** **Stop Time:** **Operator:** DJH
Date: 8/9/2021 **Relative Humidty:** 40% **Temperature:** 71°F **Project:** DOT1-6265b

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI Level	0.015 [0.19]	S Z																														1	0
RSI Level	0.010 [0.13]		S Z		S Z		S Z								S Z								S Z								S Z	6	0
RSI Level	0.0050 [0.063]			F		F		S Z						F		S Z						F		S Z						F		3	5
RSI Level	0.0025 [0.031]								S Z				F				S Z		S Z		F				S Z		S Z		F			5	3
RSI Level	0.0012 [0.015]									S Z		F						F		F						F		F				1	5
RSI Level	0.0007 [0.0088]										F																					0	1

Figure A2: Laboratory Data Sheets for Mix ID LS #2 - Coarse Al-Fe_2O_3 Thermite A

Material: LS #2 **Start Time:** **Stop Time:** **Operator:** JDZ
Date: 5/18/2021 **Relative Humidty:** 36% **Temperature:** 67°F **Project:** DOT1-6265b

MBOM Impact	**cm**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**+**	**-**
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																
RSI																																0	0
Level	79.4																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: LS #2 **Start Time:** **Stop Time:** **Operator:** RKC
Date: 5/18/2021 **Relative Humidty:** 38% **Temperature:** 68°F **Project:** DOT1-6265b

ABL Friction	**lbf (3 ft/sec)**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**+**	**-**
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	1280																																
RSI																																0	0
Level	1000																																

Material: LS #2 **Start Time:** **Stop Time:** **Operator:** DJH
Date: 8/9/2021 **Relative Humidty:** 39% **Temperature:** 73°F **Project:** DOT1-6265b

ABL ESD	**µF [J] @ 5000V**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**+**	**-**
RSI						S																				S		S				3	0
Level	0.200 [2.50]					Z																				Z		Z					
RSI					F		S																		F		F		S			2	3
Level	0.120 [1.50]						Z																						Z				
RSI				F				S		S														F						S		3	2
Level	0.060 [0.75]							Z		Z																				Z			
RSI			F						F		S				S		S						F								F	3	4
Level	0.030 [0.38]										Z				Z		Z																
RSI		F										S		F		F		S		S		F										3	4
Level	0.015 [0.19]											Z						Z		Z													
RSI													F						F		F											0	3
Level	0.010 [0.13]																																

Figure A3: Laboratory Data Sheets for Mix ID LS #3 - Coarse Al-Fe_2O_3 Thermite B

Material: LS #3 **Start Time:** **Stop Time:** **Operator:** JDZ
Date: 5/18/2021 **Relative Humidty:** 36% **Temperature:** 67°F **Project:** DOT1-6265b

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																
RSI																																0	0
Level	79.4																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: LS #3 **Start Time:** **Stop Time:** **Operator:** RKC
Date: 5/18/2021 **Relative Humidty:** 38% **Temperature:** 68°F **Project:** DOT1-6265b

ABL Friction	lbf (3 ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	1280																																
RSI																																0	0
Level	1000																																

Material: LS #3 **Start Time:** **Stop Time:** **Operator:** DJH
Date: 8/9/2021 **Relative Humidty:** 39% **Temperature:** 72°F **Project:** DOT1-6265b

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI			S																													1	0
Level	0.750 [9.38]		Z																														
RSI					S																											1	0
Level	0.350 [4.38]				Z																												
RSI				F		S																										1	1
Level	0.200 [2.50]					Z																											
RSI							S										S															2	0
Level	0.120 [1.50]						Z										Z																
RSI								S		S						F		S						S								4	1
Level	0.060 [0.75]							Z		Z								Z						Z									
RSI									F		S				F				S		S		F		S							4	3
Level	0.030 [0.38]										Z								Z		Z				Z								
RSI		F										S		F						F		F				S		S		S		4	4
Level	0.015 [0.19]											Z														Z		Z		Z			
RSI													F														F		F		F	0	4
Level	0.010 [0.13]																																

Figure A4: Laboratory Data Sheets for Mix ID LS #4 - Fine Al-CuO

Material: LS #4 Start Time: Stop Time: Operator: JDZ
Date: 6/2/2021 Relative Humidty: 28% Temperature: 73°F Project: DOT1-6265b

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																
RSI																																0	0
Level	79.4																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; 2.5 kg intermediate mass with a 2.5 or 5.0 kg drop mass

Material: LS #4 Start Time: Stop Time: Operator: RKC
Date: 5/18/2021 Relative Humidty: 37% Temperature: 69°F Project: DOT1-6265b

ABL Friction	lbf (3 ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI																																0	0
Level	1590																																
RSI											F	S				F	F	F	S						S		F	F	F	F	S	4	8
Level	1280											Z							Z						Z						Z		
RSI						S				F			S		F					S		S		F		F						4	4
Level	1000					Z							Z							Z		Z											
RSI					F		S		F					F							F		F									1	5
Level	795						Z																										
RSI		S		F				F																								1	2
Level	635	Z																															
RSI			F																													0	1
Level	505																																

Material: LS #4 Start Time: Stop Time: Operator: DJH
Date: 8/11/2021 Relative Humidty: 40% Temperature: 70°F Project: DOT1-6265b

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI														S																		1	0
Level	0.060 [0.75]													Z																			
RSI													F		S		S		S												S	4	1
Level	0.030 [0.38]														Z		Z		Z												Z		
RSI		S						S		S		F				F		F		S				S		S		S		F		7	4
Level	0.015 [0.19]	Z						Z		Z										Z				Z		Z		Z					
RSI							F		F		F										S		F		F		F		F			1	7
Level	0.010 [0.13]																				Z												
RSI				S		F																F										1	2
Level	0.0050 [0.063]			Z																													
RSI			F		F																											0	2
Level	0.0025 [0.031]																																

Figure A5: Laboratory Data Sheets for Mix ID LS #5 – Medium Al-CuO

Material: LS #5 | Start Time: | Stop Time: | Operator: JDZ
Date: 5/18/2021 | Relative Humidity: 36% | Temperature: 67°F | Project: DOT1-6265b

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																
RSI																																0	0
Level	79.4																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; 2.5 kg intermediate mass with a 2.5 or 5.0 kg drop mass

Material: LS #5 | Start Time: | Stop Time: | Operator: RKC
Date: 5/18/2021 | Relative Humidity: 36% | Temperature: 67°F | Project: DOT1-6265b

ABL Friction	lbf (3 ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	S		F	F	F	S		F	F	F	F	F	F	F	F	S		3	24
Level	1280														Z					Z										Z			
RSI																F					F										F	0	3
Level	1000																																

Material: LS #5 | Start Time: | Stop Time: | Operator: JDZ
Date: 7/21/2021 | Relative Humidity: 38% | Temperature: 75°F | Project: DOT1-6265b

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI			F	F	F	F	F	S		F	F	F	F	F	S		F	F	F	F	F	F	F	F	F	F	F	F	F	S		3	23
Level	0.750 [9.38]							Z							Z															Z			
RSI									F							F															F	0	3
Level	0.350 [4.38]																																
RSI																																0	0
Level	0.200 [2.50]																																
RSI																																0	0
Level	0.120 [1.50]																																
RSI																																0	0
Level	0.060 [0.75]																																
RSI																																0	0
Level	0.030 [0.38]																																
RSI		F																														0	1
Level	0.015 [0.19]																																

Figure A6: Laboratory Data Sheets for Mix ID LS #6 – Fine Al-Ni_2O_3

Material: LS #6 Start Time: Stop Time: Operator: JDZ
Date: 6/3/2021 Relative Humidty: 28% Temperature: 73°F Project: DOT1-6265b

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI Level	100	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
RSI Level	79.4																															0	0

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; 2.5 kg intermediate mass with a 2.5 or 5.0 kg drop mass

Material: LS #6 Start Time: Stop Time: Operator:
Date: Relative Humidty: % Temperature: °F Project: DOT1-6265b

ABL Friction	lbf (3 ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI Level	1280	F	F	F	F	F	F	F	F	F	F	S Z		F	F	F	F	F	S Z		F	F	F	F	F	F	F	F	F	S Z		3	24
RSI Level	1000												F							F											F	0	3

Material: LS #6 Start Time: Stop Time: Operator: JDZ
Date: 7/21/2021 Relative Humidty: 37% Temperature: 73°F Project: DOT1-6265b

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI Level	0.750 [9.38]		F	F	F	F	S Z																									1	4
RSI Level	0.350 [4.38]							S Z		S Z																						2	0
RSI Level	0.200 [2.50]								F		S Z																					1	1
RSI Level	0.120 [1.50]											S Z				S Z		S Z		S Z												4	0
RSI Level	0.060 [0.75]												S Z		F		F		F		S Z						S Z					3	3
RSI Level	0.030 [0.38]													F								S Z		S Z		F		S Z				3	2
RSI Level	0.015 [0.19]	F																					F		F				S Z		S Z	2	3
RSI Level	0.010 [0.13]																													F		0	1

Figure A7: Laboratory Data Sheets for Mix ID LS #7 – Fine Al-MnO_2

Material: LS #7 **Start Time:** **Stop Time:** **Operator:** RKC
Date: 5/19/2021 **Relative Humidity:** 36% **Temperature:** 70°F **Project:** DOT1-6265b

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																
RSI																																0	0
Level	79.4																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; 2.5 kg intermediate mass with a 2.5 or 5.0 kg drop mass

Material: LS #7 **Start Time:** **Stop Time:** **Operator:** JDZ
Date: 5/19/2021 **Relative Humidity:** 31% **Temperature:** 66°F **Project:** DOT1-6265b

ABL Friction	lbf (3 ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI			S																													1	0
Level	1000		Z																														
RSI		F		S														S														2	1
Level	795			Z														Z															
RSI					S				S				S		S		F		S													5	1
Level	635				Z				Z				Z		Z				Z														
RSI						S		F		S		F		F		F				S		S										4	4
Level	505					Z				Z										Z		Z											
RSI							F				F										F		S		S						F	2	4
Level	400																						Z		Z								
RSI																								F		S		S		F		2	2
Level	320																									Z		Z					
RSI																											F		F			0	2
Level	255																																

Material: LS #7 **Start Time:** **Stop Time:** **Operator:** JDZ
Date: 8/4/2021 **Relative Humidity:** 47% **Temperature:** 70°F **Project:** DOT1-6265b

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		S																														1	0
Level	0.015 [0.19]	Z																															
RSI																																0	0
Level	0.010 [0.13]																																
RSI																																0	0
Level	0.0050 [0.063]																																
RSI																																0	0
Level	0.0025 [0.031]																																
RSI																S																1	0
Level	0.0012 [0.015]															Z																	
RSI									S		S		S		F		S				S											5	1
Level	0.0007 [0.0088]								Z		Z		Z				Z				Z												
RSI								F		F		F		F				S		F		S			S		S					4	5
Level	0.0003 [0.0038]																	Z				Z			Z		Z						
RSI			S	S	S	S	F												F				S	F		F		S	S	S	F	8	5
Level	0.0002 [0.0025]		Z	Z	Z	Z																	Z					Z	Z	Z			

Figure A8: Laboratory Data Sheets for Mix ID LS #8 – Fine Mg&Al-MoO_3&CuO

Material: LS #8 Start Time: Stop Time: Operator: RKC
Date: 5/19/2021 Relative Humidity: 30% Temperature: 71°F Project: DOT1-6265b

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI Level	100	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
RSI Level	79.4																															0	0

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; 2.5 kg intermediate mass with a 2.5 or 5.0 kg drop mass

Material: LS #8 Start Time: Stop Time: Operator: JDZ
Date: 5/19/2021 Relative Humidity: 31% Temperature: 66°F Project: DOT1-6265b

ABL Friction	lbf (3 ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI Level	795																		S Z													1	0
RSI Level	635																	F		S Z												1	1
RSI Level	505								S Z								F				S Z						S Z		S Z		F	4	2
RSI Level	400							F		S Z						F						S Z				F		F		F		2	5
RSI Level	320						F				S Z				F								S Z		F							2	3
RSI Level	255					F						S Z		F										F								1	3
RSI Level	200				F								F																			0	2
RSI Level	160			F																												0	1
RSI Level	127		F																													0	1
RSI Level	100	F																														0	1

Material: LS #8 Start Time: Stop Time: Operator: JDZ
Date: 8/4/2021 Relative Humidity: 47% Temperature: 70°F Project: DOT1-6265b

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI Level	0.750 [9.38]		S Z																													1	0
RSI Level	0.350 [4.38]			S Z																												1	0
RSI Level	0.200 [2.50]				S Z																											1	0
RSI Level	0.120 [1.50]					S Z																										1	0
RSI Level	0.060 [0.75]						S Z																									1	0
RSI Level	0.030 [0.38]							S Z		S Z						S Z						S Z						S Z				5	0
RSI Level	0.015 [0.19]	F							F		S Z		S Z		F		S Z		S Z		F		S Z		S Z		F		S Z			7	5
RSI Level	0.010 [0.13]											F		F				F		F				F		F				S Z		1	6
RSI Level	0.0050 [0.063]																														F	0	1

Figure A9: Laboratory Data Sheets for Mix ID SS #1 – Fine Mg-B_2O_3

Material: SS #1 **Start Time:** **Stop Time:** **Operator:** JDZ
Date: 5/18/2021 **Relative Humidity:** 35% **Temperature:** 67°F **Project:** DOT1-6265b

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	S				F	F	F	F	F	F	F	F	S		F	F	F	F	F				F	F	F	F	F	F	F	2	21
Level	100		Z												Z																		
RSI				S		F										F						S		F								2	3
Level	79.4			Z																		Z											
RSI					F																		F									0	2
Level	63.1																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; 2.5 kg intermediate mass with a 2.5 or 5.0 kg drop mass

Material: SS #1 **Start Time:** **Stop Time:** **Operator:** RKC
Date: 5/18/2021 **Relative Humidity:** 33% **Temperature:** 71°F **Project:** DOT1-6265b

ABL Friction	lbf (3 ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	1280																																
RSI																																0	0
Level	1000																																

Material: SS #1 **Start Time:** **Stop Time:** **Operator:** JDZ
Date: 7/21/2021 **Relative Humidity:** 38% **Temperature:** 73°F **Project:** DOT1-6265b

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	S		F	F	S		F	S		F	F	S		F	F	F	F	F	S		F	S		F	F	F	F	F	F	6	18
Level	0.750 [9.38]		Z				Z			Z				Z							Z			Z									
RSI				F				F			F				F							F			F							0	6
Level	0.350 [4.38]																																

Figure A10: Laboratory Data Sheets for Mix ID SS #2B – Fine Ti-B_2O_3

Material: SS #2B | **Start Time:** | **Stop Time:** | **Operator:** JDZ
Date: 5/18/2021 | **Relative Humidty:** 36% | **Temperature:** 67°F | **Project:** DOT1-6265b

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	S				F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	1	26
Level	100		Z																														
RSI				S		F																										1	1
Level	79.4			Z																													
RSI					F																											0	1
Level	63.1																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; 2.5 kg intermediate mass with a 2.5 or 5.0 kg drop mass

Material: SS #2B | **Start Time:** | **Stop Time:** | **Operator:** RKC
Date: 5/18/2021 | **Relative Humidty:** 33% | **Temperature:** 71°F | **Project:** DOT1-6265b

ABL Friction	lbf (3 ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	1280																																
RSI																																0	0
Level	1000																																

Material: SS #2B | **Start Time:** | **Stop Time:** | **Operator:** JDZ
Date: 7/21/2021 | **Relative Humidty:** 38% | **Temperature:** 73°F | **Project:** DOT1-6265b

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI																																0	0
Level	0.750 [9.38]																																
RSI																																0	0
Level	0.350 [4.38]																																
RSI																																0	0
Level	0.200 [2.50]																																
RSI																																0	0
Level	0.120 [1.50]																																
RSI																																0	0
Level	0.060 [0.75]																																
RSI																																0	0
Level	0.030 [0.38]																																
RSI		S																														1	0
Level	0.015 [0.19]	Z																															
RSI																																0	0
Level	0.010 [0.13]																																
RSI																																0	0
Level	0.0050 [0.063]																																
RSI									S																						S	2	0
Level	0.0025 [0.031]								Z																						Z		
RSI								F		S						S						S				S		S		F		5	2
Level	0.0012 [0.015]									Z						Z						Z				Z		Z					
RSI							F				S		S		F		S		S		F		S		F		F		F			5	6
Level	0.0007 [0.0088]										Z		Z				Z		Z				Z										
RSI						F						F		F				F		F				F								0	6
Level	0.0003 [0.0038]																																
RSI			S	S	F																											2	1
Level	0.0002 [0.0025]		Z	Z																													

Figure A11: Laboratory Data Sheets for Mix ID SS #3B – Fine Ti-MnO_2

Material: SS #3B Start Time: Stop Time: Operator: JDZ
Date: 6/2/2021 Relative Humidty: 29% Temperature: 73°F Project: DOT1-6265b

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																
RSI																																0	0
Level	79.4																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; 2.5 kg intermediate mass with a 2.5 or 5.0 kg drop mass

Material: SS #3B Start Time: Stop Time: Operator: JDZ
Date: 4/21/2021 Relative Humidty: 28% Temperature: 64°F Project: DOT1-6265b

ABL Friction	lbf (3 ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI										S			S								S			S								4	0
Level	64									Z			Z								Z			Z									
RSI		S	S	S	S	S	S	S	F		S	F		S	S	S	S	S	S	F		S	F		S	S	S	S	S	S	S	22	4
Level	51	Z	Z	Z	Z	Z	Z	Z			Z			Z	Z	Z	Z	Z	Z			Z			Z	Z	Z	Z	Z	Z	Z		

Material: SS #3B Start Time: Stop Time: Operator: JDZ
Date: 8/4/2021 Relative Humidty: 47% Temperature: 70°F Project: DOT1-6265b

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI																																0	0
Level	0.750 [9.38]																																
RSI																																0	0
Level	0.350 [4.38]																																
RSI																																0	0
Level	0.200 [2.50]																																
RSI																																0	0
Level	0.120 [1.50]																																
RSI																																0	0
Level	0.060 [0.75]																																
RSI																																0	0
Level	0.030 [0.38]																																
RSI		S																														1	0
Level	0.015 [0.19]	Z																															
RSI																																0	0
Level	0.010 [0.13]																																
RSI																																0	0
Level	0.0050 [0.063]																																
RSI																																0	0
Level	0.0025 [0.031]																																
RSI																																0	0
Level	0.0012 [0.015]																																
RSI																																0	0
Level	0.0007 [0.0088]																																
RSI				F																												0	1
Level	0.0003 [0.0038]																																
RSI			S		S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	28	0
Level	0.0002 [0.0025]		Z		Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z		

Figure A12: Laboratory Data Sheets for Mix ID SS #4 – Fine Mg-MnO_2

Material: SS #4 **Start Time:** **Stop Time:** **Operator:** JDZ
Date: 5/24/2021 **Relative Humidty:** 28% **Temperature:** 64°F **Project:** DOT1-6265b

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																
RSI																																0	0
Level	79.4																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; 2.5 kg intermediate mass with a 2.5 or 5.0 kg drop mass

Material: SS #4 **Start Time:** **Stop Time:** **Operator:** JDZ
Date: 5/24/2021 **Relative Humidty:** 28% **Temperature:** 64°F **Project:** DOT1-6265b

ABL Friction	lbf (3 ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	1280																																
RSI																																0	0
Level	1000																																

Material: SS #4 **Start Time:** **Stop Time:** **Operator:**
Date: **Relative Humidty:** % **Temperature:** °F **Project:** DOT1-6265b

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		S																														1	0
Level	0.015 [0.19]	Z																															
RSI																													S			1	0
Level	0.010 [0.13]																												Z				
RSI										S				S				S										F		S		4	1
Level	0.0050 [0.063]									Z				Z				Z												Z			
RSI							S		F		S		F		S		F		S		S						F				S	6	4
Level	0.0025 [0.031]						Z				Z				Z				Z		Z										Z		
RSI						F		F				F				F				F		S		S		F						2	6
Level	0.0012 [0.015]																					Z		Z									
RSI					F																		F		F							0	3
Level	0.0007 [0.0088]																																
RSI				F																												0	1
Level	0.0003 [0.0038]																																
RSI			F																													0	1
Level	0.0002 [0.0025]																																

Figure A13: Laboratory Data Sheets for Mix ID SS #6B – Fine Ti-Fe_2O_3

Material: SS #6B | Start Time: | Stop Time: | Operator: JDZ
Date: 5/18/2021 | Relative Humidity: 36% | Temperature: 67°F | Project: DOT1-6265b

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																
RSI																																0	0
Level	79.4																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; 2.5 kg intermediate mass with a 2.5 or 5.0 kg drop mass

Material: SS #6B | Start Time: | Stop Time: | Operator: RKC
Date: 5/18/2021 | Relative Humidity: 34% | Temperature: 71°F | Project: DOT1-6265b

ABL Friction	lbf (3 ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI																									S							1	0
Level	400																								Z								
RSI								S																F		S		S				3	1
Level	320							Z																		Z		Z					
RSI			S		S		F		S														F				F		S		S	5	3
Level	255		Z		Z				Z																				Z		Z		
RSI		F		F		F				S												F								F		1	5
Level	200									Z																							
RSI											S		S		S				S		F											4	1
Level	160										Z		Z		Z				Z														
RSI												F		F		S		F		F												1	4
Level	127															Z																	
RSI																	F															0	1
Level	100																																

Material: SS #6B | Start Time: | Stop Time: | Operator: JDZ
Date: 8/6/2021 | Relative Humidity: 41% | Temperature: 71°F | Project: DOT1-6265b

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		S																														1	0
Level	0.015 [0.19]	Z																															
RSI																																0	0
Level	0.010 [0.13]																																
RSI																																0	0
Level	0.0050 [0.063]																																
RSI																																0	0
Level	0.0025 [0.031]																																
RSI																																0	0
Level	0.0012 [0.015]																																
RSI								S				S		S				S		S											S	6	0
Level	0.0007 [0.0088]							Z				Z		Z				Z		Z											Z		
RSI							F		S		F		F		S		F		F		S									F		3	6
Level	0.0003 [0.0038]								Z						Z						Z												
RSI			S	S	S	F				F						F						S	S	S	S	S	S	S	F			10	4
Level	0.0002 [0.0025]		Z	Z	Z																	Z	Z	Z	Z	Z	Z	Z					

Figure A14: Laboratory Data Sheets for Mix ID SS #7B – Fine Ti-CuO

Material: SS #7B Start Time: Stop Time: Operator: RKC
Date: 8/19/2021 Relative Humidty: 32% Temperature: 68°F Project: DOT1-6265b

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																
RSI																																0	0
Level	79.4																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; 2.5 kg intermediate mass with a 2.5 or 5.0 kg drop mass

Material: SS #7B Start Time: Stop Time: Operator: JDZ
Date: 5/19/2021 Relative Humidty: 31% Temperature: 66°F Project: DOT1-6265b

ABL Friction	lbf (3 ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		S																S														2	0
Level	505	Z																Z															
RSI			S														F		S		S											3	1
Level	400		Z																Z		Z												
RSI				S												F				F		S										2	2
Level	320			Z																		Z											
RSI					S		S						S		F								S				S					5	1
Level	255				Z		Z						Z										Z				Z						
RSI						F		S		S		F		F										S		F		S		S		5	4
Level	200							Z		Z														Z				Z		Z			
RSI									F		F														F				F		S	1	4
Level	160																														Z		

Material: SS #7B Start Time: Stop Time: Operator: DJH
Date: 8/17/2021 Relative Humidty: 38% Temperature: 73°F Project: DOT1-6265b

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		S																														1	0
Level	0.015 [0.19]	Z																															
RSI																																0	0
Level	0.010 [0.13]																																
RSI				S																												1	0
Level	0.0050 [0.063]			Z																													
RSI			F		S				S																							2	1
Level	0.0025 [0.031]				Z				Z																								
RSI						S		F		S													S		S				S		F	5	2
Level	0.0012 [0.015]					Z				Z													Z		Z				Z				
RSI							F				S							S				F		F		S		F		F		3	5
Level	0.0007 [0.0088]										Z							Z								Z							
RSI												S			S		F		S		F						F					3	3
Level	0.0003 [0.0038]											Z			Z				Z														
RSI													S	F		F				F												1	3
Level	0.0002 [0.0025]												Z																				

Figure A15: Laboratory Data Sheets for Mix ID SS #9 – Fine Al-MoO_3

Material: SS #9 | Start Time: | Stop Time: | Operator: JDZ
Date: 5/24/2021 | Relative Humidity: 28% | Temperature: 64°F | Project: DOT1-6265b

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																
RSI																																0	0
Level	79.4																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass with a 2.5 or 5.0 kg drop mass**

Material: SS #9 | Start Time: | Stop Time: | Operator: JDZ
Date: 5/24/2021 | Relative Humidity: 28% | Temperature: 64°F | Project: DOT1-6265b

ABL Friction	lbf (3 ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI												S																				1	0
Level	80											Z																					
RSI							S		S		F		S				S															4	1
Level	64						Z		Z				Z				Z																
RSI		S	S	S	S	F		F		F				S	S	F		S	S	S	S	S	S	S	S	S	S	S	S	S	S	20	4
Level	51	Z	Z	Z	Z									Z	Z			Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z		

Material: SS #9 | Start Time: | Stop Time: | Operator: DJH
Date: 8/17/2021 | Relative Humidity: 38% | Temperature: 71°F | Project: DOT1-6265b

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		S				S		S		S								S												S		6	0
Level	0.015 [0.19]	Z				Z		Z		Z								Z												Z			
RSI			S		F		F		F		S		S				F		S						S		S		F		F	6	6
Level	0.010 [0.13]		Z								Z		Z						Z						Z		Z						
RSI				F								F		S		F				S		S		F		F		F				3	6
Level	0.0050 [0.063]													Z						Z		Z											
RSI															F						F		F									0	3
Level	0.0025 [0.031]																																

Figure A16: Laboratory Data Sheets for Mix ID SS #10 – Fine Mg-Fe_2O_3

Material: SS #10 **Start Time:** **Stop Time:** **Operator:** RKC
Date: 5/19/2021 **Relative Humidty:** 32% **Temperature:** 66°F **Project:** DOT1-6265b

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	S		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	1	28
Level	100					Z																											
RSI							F																									0	1
Level	79.4																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass with a 2.5 or 5.0 kg drop mass**

Material: SS #10 **Start Time:** **Stop Time:** **Operator:** JDZ
Date: 5/24/2021 **Relative Humidty:** 28% **Temperature:** 64°F **Project:** DOT1-6265b

ABL Friction	lbf (3 ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	1280																																
RSI																																0	0
Level	1000																																

Material: SS #10 **Start Time:** **Stop Time:** **Operator:** DJH
Date: 8/17/2021 **Relative Humidty:** 41% **Temperature:** 69°F **Project:** DOT1-6265b

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		S					S						S				S		S				S						S		S	8	0
Level	0.015 [0.19]	Z					Z						Z				Z		Z				Z						Z		Z		
RSI				S		F		S		S		F		S		F		F		S		F		S				F		F		6	7
Level	0.010 [0.13]			Z				Z		Z				Z						Z				Z									
RSI			F		F				F		F				F						F				S		F					1	7
Level	0.0050 [0.063]																								Z								
RSI																										F						0	1
Level	0.0025 [0.031]																																

Figure A17: Laboratory Data Sheets for Mix ID SS #11 – Fine Mg-CuO

Material: SS #11 | Start Time: | Stop Time: | Operator: RKC
Date: 5/19/2021 | Relative Humidty: 33% | Temperature: 67°F | Project: DOT1-6265b

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																
RSI																																0	0
Level	79.4																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass with a 2.5 or 5.0 kg drop mass**

Material: SS #11 | Start Time: | Stop Time: | Operator: JDZ
Date: 5/19/2021 | Relative Humidty: 31% | Temperature: 66°F | Project: DOT1-6265b

ABL Friction	lbf (3 ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	1280																																
RSI																																0	0
Level	1000																																

Material: SS #11 | Start Time: | Stop Time: | Operator: DJH
Date: 8/20/2021 | Relative Humidty: 46% | Temperature: 69°F | Project: DOT1-6265b

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		S																				S		S						S		4	0
Level	0.015 [0.19]	Z																				Z		Z						Z			
RSI					S								S						S		F		F		S				F		F	4	4
Level	0.010 [0.13]				Z								Z						Z						Z								
RSI				F		S		S				F		S		S		F		F						S		F				5	5
Level	0.0050 [0.063]					Z		Z						Z		Z										Z							
RSI			F				F		S		F				F		F										F					1	6
Level	0.0025 [0.031]								Z																								
RSI										F																						0	1
Level	0.0012 [0.015]																																

Figure A18: Laboratory Data Sheets for Mix ID SS #12 – Fine Al-Co_3O_4

Material: SS #12 | Start Time: | Stop Time: | Operator: JDZ
Date: 6/7/2021 | Relative Humidty: 28% | Temperature: 73°F | Project: DOT1-6265b

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																
RSI																																0	0
Level	79.4																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass with a 2.5 or 5.0 kg drop mass**

Material: SS #12 | Start Time: | Stop Time: | Operator: JDZ
Date: 6/7/2021 | Relative Humidty: 28% | Temperature: 73°F | Project: DOT1-6265b

ABL Friction	lbf (3 ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI																																0	0
Level	1590																																
RSI		F	F	S		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F						1	23
Level	1280			Z																													
RSI					F																						S		F	F	F	1	4
Level	1000																										Z						
RSI																												F				0	1
Level	795																																

Material: SS #12 | Start Time: | Stop Time: | Operator: DJH
Date: 8/18/2021 | Relative Humidty: 50% | Temperature: 69°F | Project: DOT1-6265b

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		S																														1	0
Level	0.015 [0.19]	Z																															
RSI										S																		S				2	0
Level	0.010 [0.13]									Z																		Z					
RSI							S		F		S				S				S		S		S				F		S		F	7	3
Level	0.0050 [0.063]						Z				Z				Z				Z		Z		Z						Z				
RSI			S			F		F				S		F		S		F		F		F		S		F				F		4	8
Level	0.0025 [0.031]		Z									Z				Z								Z									
RSI					F								F				F								F							0	4
Level	0.0012 [0.015]																																
RSI				F																												0	1
Level	0.0007 [0.0088]																																

Figure A19: Laboratory Data Sheets for Mix ID SS #18 – Fine Al-WO_3

Material: SS #18 | Start Time: | Stop Time: | Operator: JDZ
Date: 6/7/2021 | Relative Humidty: 28% | Temperature: 73°F | Project: DOT1-6265b

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																
RSI																																0	0
Level	79.4																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass with a 2.5 or 5.0 kg drop mass**

Material: SS #18 | Start Time: | Stop Time: | Operator: RKC
Date: 6/8/2021 | Relative Humidty: 19% | Temperature: 73°F | Project: DOT1-6265b

ABL Friction	lbf (3 ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		S		S																												2	0
Level	1000	Z		Z																													
RSI			F		S																											1	1
Level	795				Z																												
RSI						S																										1	0
Level	635					Z																											
RSI							S																									1	0
Level	505						Z																										
RSI								S		S																						2	0
Level	400							Z		Z																							
RSI									F		S																					1	1
Level	320										Z																						
RSI												S																				1	0
Level	255											Z																					
RSI													S																			1	0
Level	200												Z																				
RSI														S												S				S		3	0
Level	160													Z												Z				Z			
RSI															S		S								F		S		F		F	3	3
Level	127														Z		Z										Z						
RSI																F		S				S		F				F				2	3
Level	100																	Z				Z											
RSI																			S		F		F									1	2
Level	80																		Z														
RSI																				F												0	1
Level	64																																

Material: SS #18 | Start Time: | Stop Time: | Operator: DJH
Date: 8/18/2021 | Relative Humidty: 51% | Temperature: 70°F | Project: DOT1-6265b

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		S																				S		S				S		S		5	0
Level	0.015 [0.19]	Z																				Z		Z				Z		Z			
RSI					S						S		S		S		S				F		F		S		F		F		F	6	5
Level	0.010 [0.13]				Z						Z		Z		Z		Z								Z								
RSI				F		S		S		F		F		F		F		S		F						F						3	7
Level	0.0050 [0.063]					Z		Z										Z															
RSI			F				F		F										F													0	4
Level	0.0025 [0.031]																																

Figure A20: Laboratory Data Sheets for Mix ID SS #19 – Fine Al-SnO_2

Material: SS #19 | Start Time: | Stop Time: | Operator: JDZ
Date: 5/24/2021 | Relative Humidty: 28% | Temperature: 64°F | Project: DOT1-6265b

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																
RSI																																0	0
Level	79.4																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass with a 2.5 or 5.0 kg drop mass**

Material: SS #19 | Start Time: | Stop Time: | Operator: JDZ
Date: 5/24/2021 | Relative Humidty: 28% | Temperature: 64°F | Project: DOT1-6265b

ABL Friction	lbf (3 ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	1280																																
RSI																																0	0
Level	1000																																

Material: SS #19 | Start Time: | Stop Time: | Operator: DJH
Date: 8/20/2021 | Relative Humidty: 45% | Temperature: 74°F | Project: DOT1-6265b

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI												S						S		S						S		S		S		6	0
Level	0.030 [0.38]											Z						Z		Z						Z		Z		Z			
RSI		S							S		F		S		S		F		F		S		S		F		F		F		S	7	6
Level	0.015 [0.19]	Z							Z				Z		Z						Z		Z								Z		
RSI								F		F				F		F						F		F								0	6
Level	0.010 [0.13]																																
RSI							F																									0	1
Level	0.0050 [0.063]																																
RSI				S		F																										1	1
Level	0.0025 [0.031]			Z																													
RSI					F																											0	1
Level	0.0012 [0.015]																																
RSI																																0	0
Level	0.0007 [0.0088]																																
RSI																																0	0
Level	0.0003 [0.0038]																																
RSI			F																													0	1
Level	0.0002 [0.0025]																																

Figure A21: Laboratory Data Sheets for Mix ID SS #21 – Fine Al-Cr_2O_3

Material: SS #21 **Start Time:** **Stop Time:** **Operator:** RKC
Date: 6/8/2021 **Relative Humidty:** 20 **Temperature:** 70°F **Project:** DOT1-6265b

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																
RSI																																0	0
Level	79.4																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass with a 2.5 or 5.0 kg drop mass**

Material: SS #21 **Start Time:** **Stop Time:** **Operator:** RKC
Date: 6/8/2021 **Relative Humidty:** 19% **Temperature:** 73°F **Project:** DOT1-6265b

ABL Friction	lbf (3 ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	1000																																
RSI																																0	0
Level	795																																

Material: SS #21 **Start Time:** **Stop Time:** **Operator:** DJH
Date: 8/18/2021 **Relative Humidty:** 50% **Temperature:** 70°F **Project:** DOT1-6265b

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		S						S										S		S												4	0
Level	0.015 [0.19]	Z						Z										Z		Z													
RSI					S		F		S		S		S		S		F		F		S		S		S						S	9	3
Level	0.010 [0.13]				Z				Z		Z		Z		Z						Z		Z		Z						Z		
RSI				F		F				F		F		F		F						F		F		S		S		F		2	9
Level	0.0050 [0.063]																									Z		Z					
RSI			F																								F		F			0	3
Level	0.0025 [0.031]																																

Figure A22: Laboratory Data Sheets for Mix ID SS #24 – Fine Al-Bi_2O_3

Material: SS #24 | Start Time: | Stop Time: | Operator: JDZ
Date: 5/24/2021 | Relative Humidity: 28% | Temperature: 64°F | Project: DOT1-6265b

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																
RSI																																0	0
Level	79.4																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; 2.5 kg intermediate mass with a 2.5 or 5.0 kg drop mass

Material: SS #24 | Start Time: | Stop Time: | Operator: JDZ
Date: 5/24/2021 | Relative Humidity: 28% | Temperature: 64°F | Project: DOT1-6265b

ABL Friction	lbf (3 ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	S				F	F	F	F	F	F	F	F	F	F	S		F	F	F	F	F	F	F	S		F	S	4	21
Level	1280				Z														Z									Z			Z		
RSI						S		F												F									F			1	3
Level	1000					Z																											
RSI							F																									0	1
Level	795																																

Material: SS #24 | Start Time: | Stop Time: | Operator: DJH
Date: 8/20/2021 | Relative Humidity: 44% | Temperature: 71°F | Project: DOT1-6265b

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI			S																													1	0
Level	0.750 [9.38]		Z																														
RSI				S																												1	0
Level	0.350 [4.38]			Z																													
RSI					S																											1	0
Level	0.200 [2.50]				Z																												
RSI						S				S																						2	0
Level	0.120 [1.50]					Z				Z																							
RSI							S		F		S																				S	3	1
Level	0.060 [0.75]						Z				Z																				Z		
RSI								F				S				S								S		S				F		4	2
Level	0.030 [0.38]											Z				Z								Z		Z							
RSI		F											S		F		S		S		S		F		F		S		F			5	5
Level	0.015 [0.19]												Z				Z		Z		Z						Z						
RSI														F				F		F		F						F				0	5
Level	0.010 [0.13]																																

Figure A23: Laboratory Data Sheets for Mix ID SS #25 – Fine Al-TiO_2

Material: SS #25 | Start Time: | Stop Time: | Operator: RKC
Date: 6/8/2021 | Relative Humidty: | Temperature: 76°F | Project: DOT1-6265b

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																
RSI																																0	0
Level	79.4																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; 2.5 kg intermediate mass with a 2.5 or 5.0 kg drop mass

Material: SS #25 | Start Time: | Stop Time: | Operator: RKC
Date: 6/8/2021 | Relative Humidty: 20% | Temperature: 71°F | Project: DOT1-6265b

ABL Friction	lbf (3 ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	1000																																
RSI																																0	0
Level	795																																

Material: SS #25 | Start Time: | Stop Time: | Operator: DJH
Date: 8/20/2021 | Relative Humidty: 43% | Temperature: 72°F | Project: DOT1-6265b

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		S										S																				2	0
Level	0.015 [0.19]	Z										Z																					
RSI							S		S		F		S				S															4	1
Level	0.010 [0.13]						Z		Z				Z				Z																
RSI				S		F		F		F				S		F		S		S		S		S		S		S		S		9	4
Level	0.0050 [0.063]			Z										Z				Z		Z		Z		Z		Z		Z		Z			
RSI			F		F										F				F		F		F		F		F		F		S	1	9
Level	0.0025 [0.031]																														Z		

Figure A24: Laboratory Data Sheets for Mix ID SS #26 – Fine Al-CrO_3

Material: SS #26 Start Time: Stop Time: Operator: JDZ
Date: 7/14/2021 Relative Humidty: 37% Temperature: 73°F Project: DOT1-6265b

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI Level	79.4																												S Z			1	0
RSI Level	63.1																											F		S Z		1	1
RSI Level	50.1																S Z				S Z						F				S Z	2	1
RSI Level	39.8															F		S Z		F		S Z		S Z		F						3	3
RSI Level	31.6								S Z		S Z		S Z		F				F				F		F							3	4
RSI Level	25.1							F		F		F		F																		0	4
RSI Level	20.0						F																									0	1
RSI Level	15.8					F																										0	1
RSI Level	12.6			S Z		F																										1	1
RSI Level	10.0	F		F																												0	2

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; 2.5 kg intermediate mass with a 2.5 or 5.0 kg drop mass

Material: SS #26 Start Time: Stop Time: Operator: JDZ
Date: 7/13/2021 Relative Humidty: 31% Temperature: 73°F Project: DOT1-6265b

ABL Friction	lbf (3 ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI Level	1000	F	S Z																												S Z	2	1
RSI Level	795			S Z																										F		1	1
RSI Level	635				S Z																		S Z		S Z		S Z		F			4	1
RSI Level	505					S Z		S Z		S Z								S Z				F		F		F		F				4	4
RSI Level	400						F		F		S Z						F		S Z		F											2	4
RSI Level	320											S Z		S Z		F				F												2	2
RSI Level	255												F		F																	0	2

Material: SS #26 Start Time: Stop Time: Operator: DJH
Date: 7/20/2021 Relative Humidty: 41% Temperature: 72°F Project: DOT1-6265b

ABL ESD	μF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI Level	0.750 [9.38]		S Z		F	F	F	F	F	F	F	S Z		F	S Z		S Z		S Z		F	F	F	S Z		F						6	12
RSI Level	0.350 [4.38]			F									F			F		F		F					F		S Z					1	6
RSI Level	0.200 [2.50]																											S Z				1	0
RSI Level	0.120 [1.50]																												S Z			1	0
RSI Level	0.060 [0.75]																													S Z		1	0
RSI Level	0.030 [0.38]																														F	0	1
RSI Level	0.015 [0.19]	F																														0	1

Figure A25: Laboratory Data Sheets for Mix ID SS #27 – Fine Al-Fe_3O_4

Material: SS #27 | Start Time: | Stop Time: | Operator: JDZ
Date: 6/10/2021 | Relative Humidity: 21% | Temperature: 73°F | Project: DOT1-6265b

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																
RSI																																0	0
Level	79.4																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass with a 2.5 or 5.0 kg drop mass**

Material: SS #27 | Start Time: | Stop Time: | Operator: JDZ
Date: 6/10/2021 | Relative Humidity: 21% | Temperature: 73°F | Project: DOT1-6265b

ABL Friction	lbf (3 ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	S																													1	1
Level	1000		Z																														
RSI				S		S		S																								3	0
Level	795			Z		Z		Z																									
RSI					F		F		S								S														F	2	3
Level	635								Z								Z																
RSI										S				S		F		S				S								F		4	2
Level	505									Z				Z				Z				Z											
RSI											S		F		F				S		F		S						F			3	4
Level	400										Z								Z				Z										
RSI												F								F				S				F				1	3
Level	320																							Z									
RSI																									S		F					1	1
Level	255																								Z								
RSI																										F						0	1
Level	200																																

Material: SS #27 | Start Time: | Stop Time: | Operator: DJH
Date: 7/20/2021 | Relative Humidity: 41% | Temperature: 75°F | Project: DOT1-6265b

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI			S																													1	0
Level	0.750 [9.38]		Z																														
RSI				S																												1	0
Level	0.350 [4.38]			Z																													
RSI					S																											1	0
Level	0.200 [2.50]				Z																												
RSI						S						S																				2	0
Level	0.120 [1.50]					Z						Z																					
RSI							S				F		S																			2	1
Level	0.060 [0.75]						Z						Z																				
RSI								S		F				S		S				S												4	1
Level	0.030 [0.38]							Z						Z		Z				Z													
RSI		F							F						F		S		F		S		S		S						F	4	5
Level	0.015 [0.19]																Z				Z		Z		Z								
RSI																		F				F		F		S		S		S		3	3
Level	0.010 [0.13]																									Z		Z		Z			
RSI																											F		F			0	2
Level	0.0050 [0.063]																																

Figure A26: Laboratory Data Sheets for Mix ID SS #28 – Fine Al-Mn_2O_3

Material: SS #28 | Start Time: | Stop Time: | Operator: JDZ
Date: 6/10/2021 | Relative Humidty: 21% | Temperature: 73°F | Project: DOT1-6265b

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																
RSI																																0	0
Level	79.4																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass with a 2.5 or 5.0 kg drop mass**

Material: SS #28 | Start Time: | Stop Time: | Operator: JDZ
Date: 6/10/2021 | Relative Humidty: 21% | Temperature: 73°F | Project: DOT1-6265b

ABL Friction	lbf (3 ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI									F	F	F	F	F	F	F	F	F	F	F	F	F	F	S		S		S		F	S		4	15
Level	1000																						Z		Z		Z			Z			
RSI						S		F																F		F		F			S	2	4
Level	795					Z																									Z		
RSI					F		F																									0	2
Level	635																																
RSI		S		F																												1	1
Level	505	Z																															
RSI			F																													0	1
Level	400																																

Material: SS #28 | Start Time: | Stop Time: | Operator: DJH
Date: 7/21/2021 | Relative Humidty: 40% | Temperature: 74°F | Project: DOT1-6265b

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI					S				S		S		S		S										S				S			7	0
Level	0.030 [0.38]				Z				Z		Z		Z		Z										Z				Z				
RSI		S		F		S		F		F		F		F		S		S						F		S		F		S		6	7
Level	0.015 [0.19]	Z				Z										Z		Z								Z				Z			
RSI			F				F										F		S				F				F				F	1	6
Level	0.010 [0.13]																		Z														
RSI																				S		F										1	1
Level	0.0050 [0.063]																			Z													
RSI																					F											0	1
Level	0.0025 [0.031]																																

Figure A27: Laboratory Data Sheets for Mix ID SS #29 – Fine Al-MnO

Material: SS #29 Start Time: Stop Time: Operator: JDZ
Date: 6/10/2021 Relative Humidity: 21% Temperature: 73°F Project: DOT1-6265b

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																
RSI																																0	0
Level	79.4																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass with a 2.5 or 5.0 kg drop mass**

Material: SS #29 Start Time: Stop Time: Operator: JDZ
Date: 6/10/2021 Relative Humidity: 21% Temperature: 73°F Project: DOT1-6265b

ABL Friction	lbf (3 ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	1000																																
RSI																																0	0
Level	795																																

Material: SS #29 Start Time: Stop Time: Operator: DJH
Date: 7/21/2021 Relative Humidity: 39% Temperature: 75°F Project: DOT1-6265b

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI			F	F	S										S																	2	2
Level	0.750 [9.38]				Z										Z																		
RSI						S						S		F		S																3	1
Level	0.350 [4.38]					Z						Z				Z																	
RSI							S		S		F		F				S		S													4	2
Level	0.200 [2.50]						Z		Z								Z		Z														
RSI								F		F								F		S												1	3
Level	0.120 [1.50]																			Z													
RSI																					S						S		S		S	4	0
Level	0.060 [0.75]																				Z						Z		Z		Z		
RSI																						S				F		F		F		1	3
Level	0.030 [0.38]																					Z											
RSI		F																					S		F							1	2
Level	0.015 [0.19]																						Z										
RSI																								F								0	1
Level	0.010 [0.13]																																

Figure A28: Laboratory Data Sheets for Mix ID SS #30 – Fine Al-NiO

Material: SS #30 | Start Time: | Stop Time: | Operator: JDZ
Date: 6/10/2021 | Relative Humidty: 21% | Temperature: 73°F | Project: DOT1-6265b

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																
RSI																																0	0
Level	79.4																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass with a 2.5 or 5.0 kg drop mass**

Material: SS #30 | Start Time: | Stop Time: | Operator: JDZ
Date: 6/10/2021 | Relative Humidty: 21% | Temperature: 73°F | Project: DOT1-6265b

ABL Friction	lbf (3 ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	S		F	F	F	F	F	F	F	F	F	F	1	28
Level	1000																			Z													
RSI																					F											0	1
Level	795																																

Material: SS #30 | Start Time: | Stop Time: | Operator: DJH
Date: 7/28/2021 | Relative Humidty: 46% | Temperature: 71°F | Project: DOT1-6265b

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		S																														1	0
Level	0.015 [0.19]	Z																															
RSI			S																													1	0
Level	0.010 [0.13]		Z																														
RSI				S																												1	0
Level	0.0050 [0.063]			Z																													
RSI					S																											1	0
Level	0.0025 [0.031]				Z																												
RSI						S																										1	0
Level	0.0012 [0.015]					Z																											
RSI							S																									1	0
Level	0.0007 [0.0088]						Z																										
RSI								S																						S		2	0
Level	0.0003 [0.0038]							Z																						Z			
RSI									S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	F		S	21	1
Level	0.0002 [0.0025]								Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z			Z		

Figure A29: Laboratory Data Sheets for Mix ID SS #31 – Fine Al-Sb_2O_3

Material: SS #31 | Start Time: | Stop Time: | Operator:
Date: 6/10/2021 | Relative Humidty: 21% | Temperature: 73°F | Project: DOT1-6265b

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	S		F	F	F	F	F	S		F	F	F	F	F	F	F	F	F	F	F	F	F	F	2	26
Level	100								Z							Z																	
RSI										F							F															0	2
	79.4																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; 2.5 kg intermediate mass with a 2.5 or 5.0 kg drop mass

Material: SS #31 | Start Time: | Stop Time: | Operator: JDZ
Date: 6/10/2021 | Relative Humidty: 21% | Temperature: 73°F | Project: DOT1-6265b

ABL Friction	lbf (3 ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	S		S		S		F	S		S		S																		6	2
Level	1000		Z		Z		Z			Z		Z		Z																			
RSI				F		F		F			F		F		S		S		S				S						S			5	5
Level	795														Z		Z		Z				Z						Z				
RSI																F		F		S		F		S				F		S		3	4
Level	635																			Z				Z						Z			
RSI																					F				S		F				S	2	2
Level	505																								Z						Z		
RSI																										F						0	1
Level	400																																

Material: SS #31 | Start Time: | Stop Time: | Operator: DJH
Date: 7/28/2021 | Relative Humidty: 44% | Temperature: 71°F | Project: DOT1-6265b

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI			S																													1	0
Level	0.750 [9.38]		Z																														
RSI				S		S																										2	0
Level	0.350 [4.38]			Z		Z																											
RSI					F		S												S													2	1
Level	0.200 [2.50]						Z												Z														
RSI								S				S		S		S		F		S				S								6	1
Level	0.120 [1.50]							Z				Z		Z		Z				Z				Z									
RSI									S		F		F		F		F				S		F		S		S		S		S	6	5
Level	0.060 [0.75]								Z												Z				Z		Z		Z		Z		
RSI										F												F				F		F		F		0	5
Level	0.030 [0.38]																																
RSI		F																														0	1
Level	0.015 [0.19]																																

Figure A30: Laboratory Data Sheets for Mix ID SS #33 – Fine Al-SiO_2

Material: SS #33 **Start Time:** **Stop Time:** **Operator:** RKC
Date: 6/9/2021 **Relative Humidity:** 18% **Temperature:** 74°F **Project:** DOT1-6265b

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI Level	100	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
RSI Level	79.4																															0	0

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; 2.5 kg intermediate mass with a 2.5 or 5.0 kg drop mass

Material: SS #33 **Start Time:** **Stop Time:** **Operator:** JDZ
Date: 6/20/2021 **Relative Humidity:** 20% **Temperature:** 73°F **Project:** DOT1-6265b

ABL Friction	lbf (3 ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI Level	1000	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
RSI Level	795																															0	0

Material: SS #33 **Start Time:** **Stop Time:** **Operator:** DJH
Date: 7/28/2021 **Relative Humidity:** 45% **Temperature:** 73°F **Project:** DOT1-6265b

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI Level	0.750 [9.38]		S Z																													1	0
RSI Level	0.350 [4.38]			S Z																												1	0
RSI Level	0.200 [2.50]				S Z																											1	0
RSI Level	0.120 [1.50]					S Z										S Z						S Z										3	0
RSI Level	0.060 [0.75]						S Z				S Z				F		S Z				F		S Z								S Z	5	2
RSI Level	0.030 [0.38]							S Z		F		S Z		F				S Z		F				S Z		S Z				F		5	4
RSI Level	0.015 [0.19]	F							F				F						F						F		S Z		F			1	6
RSI Level	0.010 [0.13]																											F				0	1

Figure A31: Laboratory Data Sheets for Mix ID SS #34 – Fine Al-SnO

Material: SS #34 | Start Time: | Stop Time: | Operator: RKC
Date: 6/9/2021 | Relative Humidty: 19% | Temperature: 73°F | Project: DOT1-6265b

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																
RSI																																0	0
Level	79.4																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; 2.5 kg intermediate mass with a 2.5 or 5.0 kg drop mass

Material: SS #34 | Start Time: | Stop Time: | Operator: RKC
Date: 6/9/2021 | Relative Humidty: 19% | Temperature: 70°F | Project: DOT1-6265b

ABL Friction	lbf (3 ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	S		F	F	S		S				F	S						F	F	S		F	S		F	S		F	F	7	10
Level	1000		Z				Z		Z					Z								Z			Z			Z					
RSI				F				F		S		F			S		S		F				F			F			F			3	7
Level	795									Z					Z		Z																
RSI											F					F		F														0	3
Level	635																																

Material: SS #34 | Start Time: | Stop Time: | Operator: DJH
Date: 7/28/2021 | Relative Humidty: 44% | Temperature: 73°F | Project: DOT1-6265b

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI			S																													1	0
Level	0.750 [9.38]		Z																														
RSI																																0	0
Level	0.350 [4.38]																																
RSI																																0	0
Level	0.200 [2.50]																																
RSI																																0	0
Level	0.120 [1.50]																																
RSI				S																												1	0
Level	0.060 [0.75]			Z																													
RSI					S																								S			2	0
Level	0.030 [0.38]				Z																								Z				
RSI		F				S				S						S				S		S		S				F		S		7	2
Level	0.015 [0.19]					Z				Z						Z				Z		Z		Z						Z			
RSI							S		F		S		S		F		S		F		F		F		S		F				F	5	7
Level	0.010 [0.13]						Z				Z		Z				Z								Z								
RSI								F				F		F				F								F						0	5
Level	0.0050 [0.063]																																

Figure A32: Laboratory Data Sheets for Mix ID SS #35 – Fine Al-ZnO

Material: SS #35 | Start Time: | Stop Time: | Operator: RKC
Date: 6/9/2021 | Relative Humidty: 18% | Temperature: 70°F | Project: DOT1-6265b

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																
RSI																																0	0
Level	79.4																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass with a 2.5 or 5.0 kg drop mass**

Material: SS #35 | Start Time: | Stop Time: | Operator: JDZ
Date: 6/20/2021 | Relative Humidty: 20% | Temperature: 73°F | Project: DOT1-6265b

ABL Friction	lbf (3 ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	1000																																
RSI																																0	0
Level	795																																

Material: SS #35 | Start Time: | Stop Time: | Operator: DJH
Date: 8/2/2021 | Relative Humidty: 52% | Temperature: 70°F | Project: DOT1-6265b

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI																	S															1	0
Level	0.120 [1.50]																Z																
RSI								S				S		S		F		S		S		S		S		S		S		S		10	1
Level	0.060 [0.75]							Z				Z		Z				Z		Z		Z		Z		Z		Z		Z			
RSI							F		S		F		F		F				F		F		F		F		F		F		F	1	11
Level	0.030 [0.38]								Z																								
RSI		S				F				F																						1	2
Level	0.015 [0.19]	Z																															
RSI					F																											0	1
Level	0.010 [0.13]																																
RSI				F																												0	1
Level	0.0050 [0.063]																																
RSI																																0	0
Level	0.0025 [0.031]																																
RSI																																0	0
Level	0.0012 [0.015]																																
RSI																																0	0
Level	0.0007 [0.0088]																																
RSI																																0	0
Level	0.0003 [0.0038]																																
RSI			F																													0	1
Level	0.0002 [0.0025]																																

Figure A33: Laboratory Data Sheets for Mix ID SS #36 – Fine Al-ZrO_2

Material: SS #36 **Start Time:** **Stop Time:** **Operator:** RKC
Date: 6/9/2021 **Relative Humidty:** 19% **Temperature:** 70°F **Project:** DOT1-6265b

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																
RSI																																0	0
Level	79.4																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; 2.5 kg intermediate mass with a 2.5 or 5.0 kg drop mass

Material: SS #36 **Start Time:** **Stop Time:** **Operator:** JDZ
Date: 6/20/2021 **Relative Humidty:** 20% **Temperature:** 73°F **Project:** DOT1-6265b

ABL Friction	lbf (3 ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	1000																																
RSI																																0	0
Level	795																																

Material: SS #36 **Start Time:** **Stop Time:** **Operator:** DJH
Date: 8/2/2021 **Relative Humidty:** 53% **Temperature:** 70°F **Project:** DOT1-6265b

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI					S				S		S														S							4	0
Level	0.030 [0.38]				Z				Z		Z														Z								
RSI		S		F		S		F		F		S		S		S				S				F		S		S		S		9	4
Level	0.015 [0.19]	Z				Z						Z		Z		Z				Z						Z		Z		Z			
RSI			F				F						F		F		S		F		S		F				F		F		S	2	8
Level	0.010 [0.13]																Z				Z										Z		
RSI																		F				F										0	2
Level	0.0050 [0.063]																																

Figure A34: Laboratory Data Sheets for Mix ID SS #37 – Fine Mg-Al_2O_3

Material: SS #37 | Start Time: | Stop Time: | Operator: JDZ
Date: 6/20/2021 | Relative Humidty: 20% | Temperature: 73°F | Project: DOT1-6265b

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																
RSI																																0	0
Level	79.4																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; 2.5 kg intermediate mass with a 2.5 or 5.0 kg drop mass

Material: SS #37 | Start Time: | Stop Time: | Operator: JDZ
Date: 6/20/2021 | Relative Humidty: 20% | Temperature: 73°F | Project: DOT1-6265b

ABL Friction	lbf (3 ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	S		F	F	F	F	F	F	F	F	1	28
Level	1000																					Z											
RSI																							F									0	1
Level	795																																

Material: SS #37 | Start Time: | Stop Time: | Operator: DJH
Date: 8/11/2021 | Relative Humidty: 40% | Temperature: 71°F | Project: DOT1-6265b

ABL ESD	μF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI			S																													1	0
Level	0.750 [9.38]		Z																														
RSI																																0	0
Level	0.350 [4.38]																																
RSI																																0	0
Level	0.200 [2.50]																																
RSI				S																												1	0
Level	0.120 [1.50]			Z																													
RSI					S																											1	0
Level	0.060 [0.75]				Z																												
RSI						S				S		S										S						S				5	0
Level	0.030 [0.38]					Z				Z		Z										Z						Z					
RSI		F					S		F		F		S				S		S		F		S		S		F		S			7	5
Level	0.015 [0.19]						Z						Z				Z		Z				Z		Z				Z				
RSI								F						S		F		F		F				F		F				S		2	6
Level	0.010 [0.13]													Z																Z			
RSI															F																F	0	2
Level	0.0050 [0.063]																																

Figure A35: Laboratory Data Sheets for Mix ID SS #38 – Fine Mg-CrO_3

Material: SS #38 **Start Time:** **Stop Time:** **Operator:** JDZ
Date: 7/14/2021 **Relative Humidty:** 37% **Temperature:** 73°F **Project:** DOT1-6265b

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI																													S			1	0
Level	79.4																												Z				
RSI																								S				F		S		2	1
Level	63.1																							Z						Z			
RSI									S				S				S				S		F		S		F				F	5	3
Level	50.1								Z				Z				Z			F	Z				Z								
RSI						S		F		S		F		S		F		S		F		F				F						4	6
Level	39.8					Z				Z				Z				Z		S													
RSI					F		F				F				F				F													0	5
Level	31.6																																
RSI				F																												0	1
Level	25.1																																
RSI			F																													0	1
Level	20.0																																
RSI		F																														0	1
Level	15.8																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass with a 2.5 or 5.0 kg drop mass**

Material: SS #38 **Start Time:** **Stop Time:** **Operator:** JDZ
Date: 7/13/2021 **Relative Humidty:** 31% **Temperature:** 73°F **Project:** DOT1-6265b

ABL Friction	lbf (3 ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	S				F	S				S						F	F	F	F	S										4	6
Level	1000		Z					Z				Z										Z											
RSI				S		F			S		F		S				F						S								F	4	4
Level	795			Z					Z				Z										Z										
RSI					F					F				S		F								S		S		S		F		4	4
Level	635													Z										Z		Z		Z					
RSI															F										F		F		F			0	4
Level	505																																

Material: SS #38 **Start Time:** **Stop Time:** **Operator:** DMS
Date: 7/20/2021 **Relative Humidty:** % **Temperature:** °F **Project:** DOT1-6265b

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	0.750 [9.38]																																
RSI																																0	0
Level	0.350 [4.38]																																

Figure A36: Laboratory Data Sheets for Mix ID SS #39 – Fine Mg-Bi_2O_3

Material: SS #39 | Start Time: | Stop Time: | Operator: JDZ
Date: 6/20/2021 | Relative Humidity: 20% | Temperature: 73°F | Project: DOT1-6265b

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	S		F	F	S		F	S		F	F	S																	4	7
Level	100			Z				Z			Z				Z																		
RSI					F				F			F				S		S														2	3
Level	79.4															Z		Z															
RSI																	F		S		S		S		S							4	1
Level	63.1																		Z		Z		Z		Z								
RSI																				F		F		F		S						1	3
Level	50.1																									Z							
RSI																											S				S	2	0
Level	39.8																										Z				Z		
RSI																												S		F		1	1
Level	31.6																											Z					
RSI																													F			0	1
Level	25.1																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass with a 2.5 or 5.0 kg drop mass**

Material: SS #39 | Start Time: | Stop Time: | Operator: JDZ
Date: 6/20/2021 | Relative Humidity: 73% | Temperature: 73°F | Project: DOT1-6265b

ABL Friction	lbf (3 ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	S		F	S		F	F	S		S				F	S				F	S		S		F	F	F	F	F	7	12
Level	1000			Z			Z				Z		Z					Z					Z		Z								
RSI					F			F				F		S		F			S		F			F		F						2	7
Level	795													Z					Z														
RSI															F					F												0	2
Level	635																																

Material: SS #39 | Start Time: | Stop Time: | Operator: DMS
Date: 7/20/2021 | Relative Humidity: % | Temperature: °F | Project: DOT1-6265b

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI			F	F	F	F	F	S		F	F	F	F	F	S																F	2	11
Level	0.750 [9.38]							Z							Z																		
RSI									F							S														F		1	2
Level	0.350 [4.38]															Z																	
RSI																	S		F				S		S		S		F			4	2
Level	0.200 [2.50]																Z						Z		Z		Z						
RSI																		F		S		F		F		F		F				1	5
Level	0.120 [1.50]																			Z													
RSI																					F											0	1
Level	0.060 [0.75]																																
RSI																																0	0
Level	0.030 [0.38]																																
RSI		F																														0	1
Level	0.015 [0.19]																																

Figure A37: Laboratory Data Sheets for Mix ID SS #40 – Fine Mg-Co_3O_4

Material: SS #40 | Start Time: | Stop Time: | Operator: JDZ
Date: 6/20/2021 | Relative Humidty: 20% | Temperature: 73°F | Project: DOT1-6265b

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	S		S		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	2	26
Level	100		Z		Z																												
RSI				F		F																										0	2
Level	79.4																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass with a 2.5 or 5.0 kg drop mass**

Material: SS #40 | Start Time: | Stop Time: | Operator: JDZ
Date: 6/20/2021 | Relative Humidty: 20% | Temperature: 73°F | Project: DOT1-6265b

ABL Friction	lbf (3 ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	1000																																
RSI																																0	0
Level	795																																

Material: SS #40 | Start Time: | Stop Time: | Operator: DMS
Date: 7/20/2021 | Relative Humidty: % | Temperature: °F | Project: DOT1-6265b

ABL ESD	μF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI			S								F	F	F	F	S		F	F	F	F	F	F	F	S		F	F	F	F	F	F	3	17
Level	0.750 [9.38]		Z												Z									Z									
RSI				S		S		S		F						F									F							3	3
Level	0.350 [4.38]			Z		Z		Z																									
RSI					F		F		F																							0	3
Level	0.200 [2.50]																																
RSI																																0	0
Level	0.120 [1.50]																																
RSI																																0	0
Level	0.060 [0.75]																																
RSI																																0	0
Level	0.030 [0.38]																																
RSI		F																														0	1
Level	0.015 [0.19]																																

Figure A38: Laboratory Data Sheets for Mix ID SS #41 – Fine $Mg-Cr_2O_3$

Material: SS #41 **Start Time:** **Stop Time:** **Operator:** JDZ
Date: 7/14/2021 **Relative Humidty:** 37% **Temperature:** 73°F **Project:** DOT1-6265b

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																
RSI																																0	0
Level	79.4																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass with a 2.5 or 5.0 kg drop mass**

Material: SS #41 **Start Time:** **Stop Time:** **Operator:** JDZ
Date: 7/13/2021 **Relative Humidty:** 31% **Temperature:** 73°F **Project:** DOT1-6265b

ABL Friction	lbf (3 ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		S		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	1	28
Level	1000	Z																															
RSI			F																													0	1
Level	795																																

Material: SS #41 **Start Time:** **Stop Time:** **Operator:** DJH
Date: 8/11/2021 **Relative Humidty:** 39% **Temperature:** 72°F **Project:** DOT1-6265b

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI			S																													1	0
Level	0.750 [9.38]		Z																														
RSI																																0	0
Level	0.350 [4.38]																																
RSI					S		S																									2	0
Level	0.200 [2.50]				Z		Z																										
RSI				F		F		S																				S				2	2
Level	0.120 [1.50]							Z																				Z					
RSI									S														S				F		S		S	4	1
Level	0.060 [0.75]								Z														Z						Z		Z		
RSI										S		S										F		S		F				F		3	3
Level	0.030 [0.38]									Z		Z												Z									
RSI		F									F		S								F				F							1	4
Level	0.015 [0.19]												Z																				
RSI														S		S		S		F												3	1
Level	0.010 [0.13]													Z		Z		Z															
RSI															F		F		F													0	3
Level	0.0050 [0.063]																																

Figure A39: Laboratory Data Sheets for Mix ID SS #42 – Fine Mg-MoO_3

Material: SS #42 | Start Time: | Stop Time: | Operator: JDZ
Date: 6/29/2021 | Relative Humidty: 20% | Temperature: 73°F | Project: DOT1-6265b

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI Level	100	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
RSI Level	79.4																															0	0

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; 2.5 kg intermediate mass with a 2.5 or 5.0 kg drop mass

Material: SS #42 | Start Time: | Stop Time: | Operator: JDZ
Date: 6/29/2021 | Relative Humidty: 20% | Temperature: 73°F | Project: DOT1-6265b

ABL Friction	lbf (3 ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI Level	1000	F	F	F	F	S Z		F	S Z		F	S Z						F	F	F	F	F	F	F	F	S Z		S Z		F	F	5	16
RSI Level	795						F			F			S Z		S Z		F										F		F			2	5
RSI Level	635													F		F																0	2

Material: SS #42 | Start Time: | Stop Time: | Operator: DMS
Date: 7/29/2021 | Relative Humidty: % | Temperature: °F | Project: DOT1-6265b

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI Level	0.750 [9.38]		S Z																													1	0
RSI Level	0.350 [4.38]			S Z										S Z																		2	0
RSI Level	0.200 [2.50]				S Z								F		S Z		S Z															3	1
RSI Level	0.120 [1.50]					S Z						F				F		S Z														2	2
RSI Level	0.060 [0.75]						S Z				F								S Z		S Z				S Z		S Z		S Z		F	6	2
RSI Level	0.030 [0.38]							S Z		F										F		S Z		F		F		F		F		2	6
RSI Level	0.015 [0.19]	F							F														F									0	3

Figure A40: Laboratory Data Sheets for Mix ID SS #43 – Fine $Mg-SiO_2$

Material: SS #43 | Start Time: | Stop Time: | Operator: JDZ
Date: 6/29/2021 | Relative Humidty: 20% | Temperature: 73°F | Project: DOT1-6265b

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI Level	100	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
RSI Level	79.4																															0	0

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; 2.5 kg intermediate mass with a 2.5 or 5.0 kg drop mass

Material: SS #43 | Start Time: | Stop Time: | Operator: JDZ
Date: 6/29/2021 | Relative Humidty: 20% | Temperature: 73°F | Project: DOT1-6265b

ABL Friction	lbf (3 ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI Level	1000	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
RSI Level	795																															0	0

Material: SS #43 | Start Time: | Stop Time: | Operator: DMS
Date: | Relative Humidty: % | Temperature: °F | Project: DOT1-6265b

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI Level	0.750 [9.38]		S Z																													1	0
RSI Level	0.350 [4.38]			S Z		S Z		S Z																								3	0
RSI Level	0.200 [2.50]				F		F		S Z		S Z																					2	2
RSI Level	0.120 [1.50]									F		S Z																				1	1
RSI Level	0.060 [0.75]												S Z		S Z		S Z		S Z						S Z		S Z				F	6	1
RSI Level	0.030 [0.38]													F		F		F		S Z		S Z		F		F		S Z		F		3	6
RSI Level	0.015 [0.19]	F																			F		F						F			0	4

Figure A41: Laboratory Data Sheets for Mix ID SS #44 – Fine Mg-SnO_2

Material: SS #44 **Start Time:** **Stop Time:** **Operator:** JDZ
Date: 6/24/2021 **Relative Humidty:** 20% **Temperature:** 73°F **Project:** DOT1-6265b

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																
RSI																																0	0
Level	79.4																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; 2.5 kg intermediate mass with a 2.5 or 5.0 kg drop mass

Material: SS #44 **Start Time:** **Stop Time:** **Operator:** JDZ
Date: 6/29/2021 **Relative Humidty:** 20% **Temperature:** 73°F **Project:** DOT1-6265b

ABL Friction	lbf (3 ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	1000																																
RSI																																0	0
Level	795																																

Material: SS #44 **Start Time:** **Stop Time:** **Operator:** DMS
Date: 7/24/2021 **Relative Humidty:** 45% **Temperature:** 87°F **Project:** DOT1-6265b

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI			S				S																				S					3	0
Level	0.750 [9.38]		Z				Z																				Z						
RSI				S		F		S		S				S		S										F		S				6	2
Level	0.350 [4.38]			Z				Z		Z				Z		Z												Z					
RSI					F				F		S		F		F		S								F				S			3	5
Level	0.200 [2.50]										Z						Z												Z				
RSI												F						S						F						S		2	2
Level	0.120 [1.50]																	Z												Z			
RSI																			S		S		F								S	3	1
Level	0.060 [0.75]																		Z		Z										Z		
RSI																				F		F										0	2
Level	0.030 [0.38]																																
RSI		F																														0	1
Level	0.015 [0.19]																																

Figure A42: Laboratory Data Sheets for Mix ID SS #45 – Fine Mg-WO_3

Material: SS #45 Start Time: Stop Time: Operator: JDZ
Date: 6/29/2021 Relative Humidty: 25% Temperature: 73°F Project: DOT1-6265b

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																
RSI																																0	0
Level	79.4																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass with a 2.5 or 5.0 kg drop mass**

Material: SS #45 Start Time: Stop Time: Operator: JDZ
Date: 6/29/2021 Relative Humidty: 20% Temperature: 73°F Project: DOT1-6265b

ABL Friction	lbf (3 ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	S		S		F	F	S		F	F	F	F	S	4	23
Level	1000																		Z		Z				Z						Z		
RSI																				F		F				F						0	3
Level	795																																

Material: SS #45 Start Time: Stop Time: Operator: DMS
Date: 7/29/2021 Relative Humidty: % Temperature: °F Project: DOT1-6265b

ABL ESD	pF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI			S																													1	0
Level	0.750 [9.38]		Z																														
RSI				S																												1	0
Level	0.350 [4.38]			Z																													
RSI					S																											1	0
Level	0.200 [2.50]				Z																												
RSI						S																										1	0
Level	0.120 [1.50]					Z																											
RSI							S				S		S		S		S		S		S		S		S		S		S			11	0
Level	0.060 [0.75]						Z				Z		Z		Z		Z		Z		Z		Z		Z		Z		Z				
RSI								S		F		F		F		F		F		F		F		F		F		F		S		2	10
Level	0.030 [0.38]							Z																						Z			
RSI		F							F																						S	1	2
Level	0.015 [0.19]																														Z		

Figure A43: Laboratory Data Sheets for Mix ID SS #46 – Fine Ti-Al_2O_3

Material: SS #46 **Start Time:** **Stop Time:** **Operator:** JDZ
Date: 6/29/2021 **Relative Humidty:** 20% **Temperature:** 73°F **Project:** DOT1-6265b

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																
RSI																																0	0
Level	79.4																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; 2.5 kg intermediate mass with a 2.5 or 5.0 kg drop mass

Material: SS #46 **Start Time:** **Stop Time:** **Operator:** JDZ
Date: 6/29/2021 **Relative Humidty:** 26% **Temperature:** 73°F **Project:** DOT1-6265b

ABL Friction	lbf (3 ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	S		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	1	28
Level	1000							Z																									
RSI									F																							0	1
Level	795																																

Material: SS #46 **Start Time:** **Stop Time:** **Operator:** DMS
Date: 7/30/2021 **Relative Humidty:** 49% **Temperature:** 66°F **Project:** DOT1-6265b

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		S																														1	0
Level	0.015 [0.19]	Z																															
RSI																																0	0
Level	0.010 [0.13]																																
RSI																																0	0
Level	0.0050 [0.063]																																
RSI																																0	0
Level	0.0025 [0.031]																																
RSI											S																					1	0
Level	0.0012 [0.015]										Z																						
RSI										F		S										S										2	1
Level	0.0007 [0.0088]											Z										Z											
RSI					S		S		F				S		S		S		S		F		S					S		S		9	2
Level	0.0003 [0.0038]				Z		Z						Z		Z		Z		Z				Z					Z		Z			
RSI			S	F		F		F						F		F		F		F				S	S	S	F		F		F	4	10
Level	0.0002 [0.0025]		Z																					Z	Z	Z							

Figure A44: Laboratory Data Sheets for Mix ID SS #47 – Fine Ti-CrO_3

Material: SS #47 | Start Time: | Stop Time: | Operator: JDZ
Date: 7/14/2021 | Relative Humidty: 37% | Temperature: 73°F | Project: DOT1-6265b

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI Level	63.1																			S Z		S Z										2	0
RSI Level	50.1																		F		F		S Z									1	2
RSI Level	39.8															S Z		F						S Z								2	1
RSI Level	31.6														F		F								S Z		S Z					2	2
RSI Level	25.1									S Z		S Z		F												F		S Z				3	2
RSI Level	20.0		S Z						F		F		F																S Z		F	2	4
RSI Level	15.8	F		S Z				F																						S Z		2	2
RSI Level	12.6				S Z		F																									1	1
RSI Level	10.0					F																										0	1

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; 2.5 kg intermediate mass with a 2.5 or 5.0 kg drop mass

Material: SS #47 | Start Time: | Stop Time: | Operator: JDZ
Date: 7/13/2021 | Relative Humidty: 31% | Temperature: 73°F | Project: DOT1-6265b

ABL Friction	lbf (3 ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI Level	1000	F	S Z																													1	1
RSI Level	795			S Z																												1	0
RSI Level	635				S Z				S Z		S Z		S Z						S Z													5	0
RSI Level	505					S Z		F		F		F		S Z				F		S Z												3	4
RSI Level	400						F								S Z		F				S Z				S Z		S Z				S Z	5	2
RSI Level	320															F						S Z		F		F		S Z		F		2	4
RSI Level	255																						F						F			0	2

Material: SS #47 | Start Time: | Stop Time: | Operator: DJH
Date: 8/16/2021 | Relative Humidty: 39% | Temperature: 71°F | Project: DOT1-6265b

ABL ESD	pF (J) @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI Level	0.015 [0.19]	S Z																														1	0
RSI Level	0.010 [0.13]																															0	0
RSI Level	0.0050 [0.063]								S Z												S Z											2	0
RSI Level	0.0025 [0.031]		S Z					F		S Z		S Z		S Z				S Z		F		S Z										6	2
RSI Level	0.0012 [0.015]				S Z		F				F		F		S Z		F		F				S Z				S Z					4	5
RSI Level	0.0007 [0.0088]			F		F										F								S Z		F		S Z				2	4
RSI Level	0.0003 [0.0038]																								F				S Z			1	1
RSI Level	0.0002 [0.0025]																													S Z	F	1	1

Figure A45: Laboratory Data Sheets for Mix ID SS #48 – Fine Ti-Bi_2O_3

Material: SS #48 Start Time: Stop Time: Operator: JDZ
Date: 6/29/2021 Relative Humidty: 20% Temperature: 73°F Project: DOT1-6265b

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	S				S		F	F	F	F	F	S		F	F	F	F	F	F	F	F	F	F	F	F	F	3	22
Level	100					Z				Z							Z																
RSI							S		F		F							F														1	3
Level	79.4						Z																										
RSI								F																								0	1
Level	63.1																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass with a 2.5 or 5.0 kg drop mass**

Material: SS #48 Start Time: Stop Time: Operator: JDZ
Date: 6/29/2021 Relative Humidty: 20% Temperature: 73°F Project: DOT1-6265b

ABL Friction	lbf (3 ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	S		F	F	F	F	F	F	F	F	F	F	F	F	S		F	S		S		S		S		S		7	16
Level	1000				Z														Z			Z		Z		Z		Z		Z			
RSI						F														F			F		F		F		F		S	1	6
Level	795																														Z		

Material: SS #48 Start Time: Stop Time: Operator: DJH
Date: 8/16/2021 Relative Humidty: 39% Temperature: 72°F Project: DOT1-6265b

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		S																														1	0
Level	0.015 [0.19]	Z																															
RSI																													S			1	0
Level	0.010 [0.13]																												Z				
RSI				S								S																F		S		3	1
Level	0.0050 [0.063]			Z								Z																		Z			
RSI			F		S				S		F		S												S		F				S	5	3
Level	0.0025 [0.031]				Z				Z				Z												Z						Z		
RSI						S		F		F				S				S		S		S		F		F						5	4
Level	0.0012 [0.015]					Z								Z				Z		Z		Z											
RSI							F								S		F		F		F		F									1	5
Level	0.0007 [0.0088]														Z																		
RSI																F																0	1
Level	0.0003 [0.0038]																																

Figure A46: Laboratory Data Sheets for Mix ID SS #49 – Fine Ti-Co_3O_4

Material: SS #49 **Start Time:** **Stop Time:** **Operator:** JDZ
Date: 7/14/2021 **Relative Humidty:** 37% **Temperature:** 73°F **Project:** DOT1-6265b

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																
RSI																																0	0
Level	79.4																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or **5.0 kg drop mass**

Material: SS #49 **Start Time:** **Stop Time:** **Operator:** JDZ
Date: 7/13/2021 **Relative Humidty:** 31% **Temperature:** 73°F **Project:** DOT1-6265b

ABL Friction	lbf (3 ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		S																														1	0
Level	80	Z																															
RSI			S																			S										2	0
Level	64		Z																			Z											
RSI				S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	F		S	S	S	S	S	S	S	S	S	26	1
Level	51			Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z			Z	Z	Z	Z	Z	Z	Z	Z	Z		

Material: SS #49 **Start Time:** **Stop Time:** **Operator:** DMS
Date: 8/10/2021 **Relative Humidty:** 39% **Temperature:** 72°F **Project:** DOT1-6265b

ABL ESD	μF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		S																														1	0
Level	0.015 [0.19]	Z																															
RSI																																0	0
Level	0.010 [0.13]																																
RSI																																0	0
Level	0.0050 [0.063]																																
RSI																																0	0
Level	0.0025 [0.031]																																
RSI																																0	0
Level	0.0012 [0.015]																																
RSI																	S															1	0
Level	0.0007 [0.0088]																Z																
RSI				S					S					S		F		S		S			S								F	6	2
Level	0.0003 [0.0038]			Z					Z					Z				Z		Z			Z										
RSI			F		S	S	S	F		S	S	S	F		F				F		S	F		S	S	S	S	S	S	S		14	6
Level	0.0002 [0.0025]				Z	Z	Z			Z	Z	Z									Z			Z	Z	Z	Z	Z	Z	Z			

Figure A47: Laboratory Data Sheets for Mix ID SS #50 – Fine Ti-Cr_2O_3

Material: SS #50 **Start Time:** **Stop Time:** **Operator:** JDZ
Date: 7/14/2021 **Relative Humidity:** 37% **Temperature:** 73°F **Project:** DOT1-6265b

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																
RSI																																0	0
Level	79.4																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass with a 2.5 or 5.0 kg drop mass**

Material: SS #50 **Start Time:** **Stop Time:** **Operator:** JDZ
Date: 7/13/2021 **Relative Humidity:** 31% **Temperature:** 73°F **Project:** DOT1-6265b

ABL Friction	lbf (3 ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	S		F	F	F	F	F	F	F	F	F	F	F	F	F	F	1	28
Level	1000															Z																	
RSI																	F															0	1
Level	795																																

Material: SS #50 **Start Time:** **Stop Time:** **Operator:** DMS
Date: 8/10/2021 **Relative Humidity:** 39% **Temperature:** 75°F **Project:** DOT1-6265b

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		S																														1	0
Level	0.015 [0.19]	Z																															
RSI											S		S		S				S		S								S		S	7	0
Level	0.010 [0.13]										Z		Z		Z				Z		Z								Z		Z		
RSI								S		F		F		F		S		F		F		S		S		S		F		F		5	7
Level	0.0050 [0.063]							Z								Z						Z		Z		Z							
RSI							F		F								F						F		F		F					0	6
Level	0.0025 [0.031]																																
RSI						F																										0	1
Level	0.0012 [0.015]																																
RSI					F																											0	1
Level	0.0007 [0.0088]																																
RSI				F																												0	1
Level	0.0003 [0.0038]																																
RSI			F																													0	1
Level	0.0002 [0.0025]																																

Figure A48: Laboratory Data Sheets for Mix ID SS #51 – Fine Ti-Cu_2O

Material: SS #51 | Start Time: | Stop Time: | Operator: JDZ
Date: 7/14/2021 | Relative Humidty: 37% | Temperature: 73°F | Project: DOT1-6265b

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																
RSI																																0	0
Level	79.4																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass with a 2.5 or 5.0 kg drop mass**

Material: SS #51 | Start Time: | Stop Time: | Operator: JDZ
Date: 7/13/2021 | Relative Humidty: 31% | Temperature: 73°F | Project: DOT1-6265b

ABL Friction	lbf (3 ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		S		F	F	F	F	F	S		F	F	S		F	S		F	F	F	F	F	F	F	F	F	F	S		F	F	5	20
Level	1000	Z							Z				Z			Z												Z					
RSI			F							F				F			F												F			0	5
Level	795																																

Material: SS #51 | Start Time: | Stop Time: | Operator: DMS
Date: 8/12/2021 | Relative Humidty: 38% | Temperature: 71°F | Project: DOT1-6265b

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		S																														1	0
Level	0.015 [0.19]	Z																															
RSI																																0	0
Level	0.010 [0.13]																																
RSI																																0	0
Level	0.0050 [0.063]																																
RSI															S		S														F	2	1
Level	0.0025 [0.031]														Z		Z																
RSI								S		S		S		F		F		S		S				S		S				F		7	3
Level	0.0012 [0.015]							Z		Z		Z						Z		Z				Z		Z							
RSI					S		F		F		F		F						F		S		F		F		S		F			3	8
Level	0.0007 [0.0088]				Z																Z						Z						
RSI				F		F																F						F				0	4
Level	0.0003 [0.0038]																																
RSI			F																													0	1
Level	0.0002 [0.0025]																																

Figure A49: Laboratory Data Sheets for Mix ID SS #52 – Fine Ti-MoO₃

Material: SS #52 | Start Time: | Stop Time: | Operator: JDZ
Date: 7/24/2021 | Relative Humidty: 37% | Temperature: 73°F | Project: DOT1-6265b

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																
RSI																																0	0
Level	79.4																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; 2.5 kg intermediate mass with a 2.5 or 5.0 kg drop mass

Material: SS #52 | Start Time: | Stop Time: | Operator: JDZ
Date: 7/14/2021 | Relative Humidty: 37% | Temperature: 73°F | Project: DOT1-6265b

ABL Friction	lbf (3 ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI													S																			1	0
Level	400												Z																				
RSI												F		S																		1	1
Level	320													Z																			
RSI											F				S		S		S				S		S				S			6	1
Level	255														Z		Z		Z				Z		Z				Z				
RSI										F						F		F		S		F		F		S		F		S		3	6
Level	200																			Z						Z				Z			
RSI									F												F						F				F	0	4
Level	160																																
RSI						S		F																								1	1
Level	127					Z																											
RSI					F		F																									0	2
Level	100																																
RSI				F																												0	1
Level	80																																
RSI			F																													0	1
Level	64																																
RSI		F																														0	1
Level	51																																

Material: SS #52 | Start Time: | Stop Time: | Operator: DMS
Date: 8/12/2021 | Relative Humidty: 38% | Temperature: 73°F | Project: DOT1-6265b

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		S																														1	0
Level	0.015 [0.19]	Z																															
RSI																																0	0
Level	0.010 [0.13]																																
RSI																																0	0
Level	0.0050 [0.063]																																
RSI																																0	0
Level	0.0025 [0.031]																																
RSI										S																						1	0
Level	0.0012 [0.015]									Z																							
RSI					S				F		S		S				S								S						S	6	1
Level	0.0007 [0.0088]				Z						Z		Z				Z								Z						Z		
RSI				F		S		F				F		S		F		S		S		S		F		S		S		F		7	6
Level	0.0003 [0.0038]					Z								Z				Z		Z		Z				Z		Z					
RSI			F				F								F				F		F		F				F		F			0	8
Level	0.0002 [0.0025]																																

Figure A50: Laboratory Data Sheets for Mix ID SS #53 – Fine Ti-SiO_2

Material: SS #53 Start Time: Stop Time: Operator: JDZ
Date: 7/15/2021 Relative Humidty: 37% Temperature: 73°F Project: DOT1-6265b

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																
RSI																																0	0
Level	79.4																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass with a 2.5 or 5.0 kg drop mass**

Material: SS #53 Start Time: Stop Time: Operator: JDZ
Date: 7/14/2021 Relative Humidty: 37% Temperature: 73°F Project: DOT1-6265b

ABL Friction	lbf (3 ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	1000																																
RSI																																0	0
Level	795																																

Material: SS #53 Start Time: Stop Time: Operator: DMS
Date: 8/16/2021 Relative Humidty: 38% Temperature: 72°F Project: DOT1-6265b

ABL ESD	μF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		S																														1	0
Level	0.015 [0.19]	Z																															
RSI																																0	0
Level	0.010 [0.13]																																
RSI																																0	0
Level	0.0050 [0.063]																																
RSI																																0	0
Level	0.0025 [0.031]																																
RSI								S						S								S		S		S		S		S		7	0
Level	0.0012 [0.015]							Z						Z								Z		Z		Z		Z		Z			
RSI							F		S		S		F		S						F		F		F		F		F		F	3	8
Level	0.0007 [0.0088]								Z		Z				Z																		
RSI				S		F				F		F				S		S		F												3	4
Level	0.0003 [0.0038]			Z												Z		Z															
RSI			F		F												F		F													0	4
Level	0.0002 [0.0025]																																

Figure A51: Laboratory Data Sheets for Mix ID SS #54 – Fine Ti-SnO_2

Material: SS #54 Start Time: Stop Time: Operator: JDZ
Date: 7/15/2021 Relative Humidty: 37% Temperature: 73°F Project: DOT1-6265b

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																
RSI																																0	0
Level	79.4																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; 2.5 kg intermediate mass with a 2.5 or 5.0 kg drop mass

Material: SS #54 Start Time: Stop Time: Operator: JDZ
Date: 7/14/2021 Relative Humidty: 37% Temperature: 73°F Project: DOT1-6265b

ABL Friction	lbf (3 ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	S		F	F	S						F	S								F	3	14
Level	1000											Z				Z							Z										
RSI													F				S		S		F			S						F		3	3
Level	795																Z		Z					Z									
RSI																		F		F					S		S		F			2	3
Level	635																								Z		Z						
RSI																										F		F				0	2
Level	505																																

Material: SS #54 Start Time: Stop Time: Operator: DMS
Date: 8/16/2021 Relative Humidty: 38% Temperature: 72°F Project: DOT1-6265b

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		S																														1	0
Level	0.015 [0.19]	Z																															
RSI																																0	0
Level	0.010 [0.13]																																
RSI																																0	0
Level	0.0050 [0.063]																																
RSI																																0	0
Level	0.0025 [0.031]																																
RSI																																0	0
Level	0.0012 [0.015]																																
RSI																																0	0
Level	0.0007 [0.0088]																																
RSI									S									S										S		S	4	0
Level	0.0003 [0.0038]									Z									Z										Z		Z		
RSI			S	S	S	S	S	S	F		S	S	S	S	S	S	S	F		S	S	S	S	S	S	S	S	F		F		21	4
Level	0.0002 [0.0025]		Z	Z	Z	Z	Z	Z			Z	Z	Z	Z	Z	Z	Z			Z	Z	Z	Z	Z	Z	Z	Z						

Figure A52: Laboratory Data Sheets for Mix ID SS #55 – Fine Ti-WO_3

Material: SS #55 Start Time: Stop Time: Operator: JDZ
Date: 7/15/2021 Relative Humidty: 37% Temperature: °F Project: DOT1-6265b

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																
RSI																																0	0
Level	79.4																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; 2.5 kg intermediate mass with a 2.5 or 5.0 kg drop mass

Material: SS #55 Start Time: Stop Time: Operator: JDZ
Date: 7/14/2021 Relative Humidty: 37% Temperature: 73°F Project: DOT1-6265b

ABL Friction	lbf (3 ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		S		S				S		S		S		S						F	F	S		S		F	S					9	3
Level	1000	Z		Z				Z		Z		Z		Z								Z		Z			Z						
RSI			F		S		F		F		F		F		S				F				F		F			S		S		4	8
Level	795				Z										Z													Z		Z			
RSI						F										S		F											F		S	2	3
Level	635															Z															Z		
RSI																	F															0	1
Level	505																																

Material: SS #55 Start Time: Stop Time: Operator: JDZ
Date: 9/21/2021 Relative Humidty: 20% Temperature: 72°F Project: DOT1-6265b

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		S																														1	0
Level	0.750 [9.38]	Z																															
RSI																																0	0
Level	0.350 [4.38]																																
RSI																																0	0
Level	0.200 [2.50]																																
RSI			S																													1	0
Level	0.120 [1.50]		Z																														
RSI																																0	0
Level	0.060 [0.75]																																
RSI																																0	0
Level	0.030 [0.38]																																
RSI				S																												1	0
Level	0.015 [0.19]			Z																													
RSI																																0	0
Level	0.010 [0.13]																																
RSI																																0	0
Level	0.0050 [0.063]																																
RSI					S																											1	0
Level	0.0025 [0.031]				Z																												
RSI						S																										1	0
Level	0.0012 [0.015]					Z																											
RSI							S																									1	0
Level	0.0007 [0.0088]						Z																										
RSI								S																								1	0
Level	0.0003 [0.0038]							Z																									
RSI									S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	23	0
Level	0.0002 [0.0025]								Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z		

Figure A53: Laboratory Data Sheets for Mix ID SS #56 – Fine Mg & Al-MoO_3 & CuO

Material: SS #56 Start Time: Stop Time: Operator: DMS
Date: 9/21/2021 Relative Humidity: Temperature: °F Project: DOT1-6265b

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI Level	100	S Z		F	F	F	F	F	F	F	F	F	F	F	F	F	F	S Z		F	S Z		F	F	F	F	F	F	F	F	F	3	24
RSI Level	79.4		F																F			F										0	3

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass with a 2.5 or 5.0 kg drop mass**

Material: SS #56 Start Time: Stop Time: Operator: JDZ
Date: 9/21/2021 Relative Humidity: 20% Temperature: 72°F Project: DOT1-6265b

ABL Friction	lbf (3 ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI Level	1000	S Z																							S Z							2	0
RSI Level	795			S Z												S Z		S Z		S Z				F		S Z		S Z		S Z		7	1
RSI Level	635		F		S Z				S Z		S Z		S Z		F		F		F		S Z		F				F		F		F	5	8
RSI Level	505					S Z		F		F		F		F								F										1	5
RSI Level	400						F																									0	1

Material: SS #56 Start Time: Stop Time: Operator: JDZ
Date: 9/21/2021 Relative Humidity: 20% Temperature: 72°F Project: DOT1-6265b

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI Level	0.010 [0.13]	S Z																		S Z												2	0
RSI Level	0.0050 [0.063]		S Z		S Z														F		S Z								S Z			4	1
RSI Level	0.0025 [0.031]			F		S Z		S Z								S Z		F				S Z		S Z		S Z		F		S Z		7	3
RSI Level	0.0012 [0.015]						F		S Z						F		F						F		F		F				F	1	7
RSI Level	0.0007 [0.0088]									S Z				F																		1	1
RSI Level	0.0003 [0.0038]										S Z		F																			1	1
RSI Level	0.0002 [0.0025]											F																				0	1

APPENDIX B

– Bruceton H_{50} Calculations

Figure B1: H_{50} Calculations for Mix ID LS #1 - Fine Al-Fe_2O_3

Calculation of 50% impact initiation level from Bruceton data

Modified Bureau of Mines (MBOM) Impact Sensitivity Test

Sample: **LS #1**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
c	N_S	A	B	d
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
c	N_S	A	B	d
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#NAME?	log(cm)
#NAME?	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Calculation of 50% friction initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **LS #1**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(lbf)	log(lbf)	+	-
1590	3.2	0	0
1280.0	3.1	2	1
1000.0	3.0	3	1
795.0	2.9	4	2
635.0	2.8	5	3
505.0	2.7	2	5
400.0	2.6	0	2
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	16	14

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
6	0	0	0	
5	1	5	25	0.094
4	1	4	16	0.107
3	2	6	18	0.100
2	3	6	12	0.098
1	5	5	5	0.099
0	2	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	N_S	A	B	d
2.602	14	26	76	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
5	0	0	0	
4	2	8	32	0.094
3	3	9	27	0.107
2	4	8	16	0.100
1	5	5	5	0.098
0	2	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	N_S	A	B	d
2.703	16	30	80	0.100

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.837 log(lbf)
686.8 lbf

s (using negatives)
0.3241 log(lbf)
2.1 lbf

H_{50} (using positives)
2.840 log(lbf)
692.2 lbf

s (using positives)
0.2442 log(lbf)
1.8 lbf

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **LS #1**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance		Frequency	
(microF)	log(microF)	+	-
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	0	0
0.030	-1.5	0	0
0.015	-1.8	1	0
0.010	-2.0	6	0
0.0050	-2.3	3	5
0.0025	-2.6	5	3
0.0012	-2.9	1	5
0.0007	-3.2	1	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
	SUM	17	13

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
10	0	0	0	
9	0	0	0	0.331
8	0	0	0	0.243
7	0	0	0	0.222
6	0	0	0	0.301
5	0	0	0	0.301
4	0	0	0	0.301
3	0	0	0	0.176
2	5	10	20	0.301
1	3	3	3	0.301
0	5	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
c	N_S	A	B	d
-2.921	13	13	23	0.275

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
11	0	0	0	
10	0	0	0	0.331
9	0	0	0	0.243
8	0	0	0	0.222
7	0	0	0	0.301
6	0	0	0	0.301
5	1	5	25	0.301
4	6	24	96	0.176
3	3	9	27	0.301
2	5	10	20	0.301
1	1	1	1	0.319
0	1	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
c	N_S	A	B	d
-3.155	17	49	169	0.275

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
-2.508	log(microF)
0.0031	microF
s (using negatives)	
0.3555	log(microF)
2.3	microF

H_{50} (using positives)	
-2.500	log(microF)
0.0	microF
s (using positives)	
0.7403	log(microF)
5.5	microF

Figure B2: H_{50} Calculations for Mix ID LS #2 - Coarse Al-Fe_2O_3 Thermite A

Calculation of 50% impact initiation level from Bruceton data

Modified Bureau of Mines (MBOM) Impact Sensitivity Test

Sample: **LS #2**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#NAME?	log(cm)
#NAME?	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Calculation of 50% friction initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **LS #2**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(lbf)	log(lbf)	+	-
1590	3.2	0	0
1280.0	3.1	0	30
1000.0	3.0	0	0
795.0	2.9	0	0
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	**0**	**30**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
1	0	0	0	
0	30	0	0	0.094
FALSE	0	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
3.107	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.094
FALSE	0	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
3.157	log(lbf)
1435.5	lbf
s (using negatives)	
0.0047	log(lbf)
1.0	lbf

H_{50} (using positives)	
#NAME?	log(lbf)
#NAME?	lbf
s (using positives)	
#DIV/0!	log(lbf)
#DIV/0!	lbf

Calculation of 50% initiation level from Bruceton data

Impact Sensitivity Test - ERL (Explosives Research Laboratory)/Bruceton Apparatus per AOP-7 (Edition 2) Rev. 1, U.S. 201.01.001
Sample: LS #2

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance		Frequency	
(microF)	log(microF)	+	-
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	3	0
0.120	-0.9	2	3
0.060	-1.2	3	2
0.030	-1.5	3	4
0.015	-1.8	3	4
0.010	-2.0	0	3
0.0050	-2.3	0	0
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	14	16

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
7	0	0	0	
6	0	0	0	0.331
5	0	0	0	0.243
4	3	12	48	0.222
3	2	6	18	0.301
2	4	8	16	0.301
1	4	4	4	0.301
0	3	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	N_S	A	B	d
-2.000	16	30	86	0.275

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
6	0	0	0	
5	0	0	0	0.331
4	3	12	48	0.243
3	2	6	18	0.222
2	3	6	12	0.301
1	3	3	3	0.301
0	3	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	N_S	A	B	d
-1.824	14	27	81	0.275

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-1.347 log(microF)
0.0 microF
s (using negatives)
0.8410 log(microF)
6.9 microF

H_{50} (using positives)
-1.431 log(microF)
0.0371 microF
s (using positives)
0.9332 log(microF)
8.6 microF

Figure B3: H_{50} Calculations for Mix ID LS #3 - Coarse Al-Fe_2O_3 Thermite B

Calculation of 50% impact initiation level from Bruceton data

Modified Bureau of Mines (MBOM) Impact Sensitivity Test

Sample: **LS #3**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#NAME?	log(cm)
#NAME?	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Calculation of 50% friction initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **LS #3**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(lbf)	log(lbf)	+	-
1590	3.2	0	0
1280.0	3.1	0	30
1000.0	3.0	0	0
795.0	2.9	0	0
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	**0**	**30**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
1	0	0	0	
0	30	0	0	0.094
FALSE	0	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
3.107	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.094
FALSE	0	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
3.157	log(lbf)
1435.5	lbf
s (using negatives)	
0.0047	log(lbf)
1.0	lbf

H_{50} (using positives)	
#NAME?	log(lbf)
#NAME?	lbf
s (using positives)	
#DIV/0!	log(lbf)
#DIV/0!	lbf

Calculation of 50% initiation level from Bruceton data

Impact Sensitivity Test - ERL (Explosives Research Laboratory)/Bruceton Apparatus per AOP-7 (Edition 2) Rev. 1, U.S. 201.01.001
Sample: LS #3

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.
where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$
where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	1	0
0.350	-0.5	1	0
0.200	-0.7	1	1
0.120	-0.9	2	0
0.060	-1.2	4	1
0.030	-1.5	4	3
0.015	-1.8	4	4
0.010	-2.0	0	4
0.0050	-2.3	0	0
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	17	13

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
7	0	0	0	
6	0	0	0	0.331
5	1	5	25	0.243
4	0	0	0	0.222
3	1	3	9	0.301
2	3	6	12	0.301
1	4	4	4	0.301
0	4	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.000	13	18	50	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
6	1	6	36	
5	1	5	25	0.331
4	1	4	16	0.243
3	2	6	18	0.222
2	4	8	16	0.301
1	4	4	4	0.301
0	4	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-1.824	17	33	115	0.275

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-1.482 log(microF)
0.0330 microF
s (using negatives)
0.8720 log(microF)
7.4 microF

H_{50} (using positives)
-1.428 log(microF)
0.0 microF
s (using positives)
1.3475 log(microF)
22.3 microF

Figure B4: H_{50} Calculations for Mix ID LS #4 - Fine Al-CuO

Calculation of 50% impact initiation level from Bruceton data

Modified Bureau of Mines (MBOM) Impact Sensitivity Test

Sample: **LS #4**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	**0**	**30**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#NAME?	log(cm)
#NAME?	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Calculation of 50% friction initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **LS #4**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	4	8
1000.0	3.0	4	4
795.0	2.9	1	5
635.0	2.8	1	2
505.0	2.7	0	1
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	**10**	**20**

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
5	0	0	0	
4	8	32	128	0.094
3	4	12	36	0.107
2	5	10	20	0.100
1	2	2	2	0.098
0	1	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.703	20	56	186	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
4	0	0	0	
3	4	12	36	0.094
2	4	8	16	0.107
1	1	1	1	0.100
0	1	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.803	10	21	53	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
3.032 log(lbf)
1076.3 lbf
s (using negatives)
0.2402 log(lbf)
1.7 lbf

H_{50} (using positives)
2.962 log(lbf)
916.5 lbf
s (using positives)
0.1483 log(lbf)
1.4 lbf

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **LS #4**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance		Frequency	
(microF)	log(microF)	+	-
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	1	0
0.030	-1.5	4	1
0.015	-1.8	7	4
0.010	-2.0	1	7
0.0050	-2.3	1	2
0.0025	-2.6	0	2
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	14	16

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
9	0	0	0	
8	0	0	0	0.331
7	0	0	0	0.243
6	0	0	0	0.222
5	0	0	0	0.301
4	1	4	16	0.301
3	4	12	36	0.301
2	7	14	28	0.176
1	2	2	2	0.301
0	2	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.602	16	32	82	0.275

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
8	0	0	0	
7	0	0	0	0.331
6	0	0	0	0.243
5	0	0	0	0.222
4	1	4	16	0.301
3	4	12	36	0.301
2	7	14	28	0.301
1	1	1	1	0.176
0	1	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.301	14	31	81	0.275

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-1.915 log(microF)
0.0 microF
s (using negatives)
0.5140 log(microF)
3.3 microF

H_{50} (using positives)
-1.830 log(microF)
0.0148 microF
s (using positives)
0.4060 log(microF)
2.5 microF

Figure B5: H_{50} Calculations for Mix ID LS #5 – Medium Al-CuO

Calculation of 50% impact initiation level from Bruceton data

Modified Bureau of Mines (MBOM) Impact Sensitivity Test

Sample: **LS #5**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	**0**	**30**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.050 log(cm)
112.2 cm
s (using negatives)
0.0047 log(cm)
1.0 cm

H_{50} (using positives)
#NAME? log(cm)
#NAME? cm
s (using positives)
#DIV/0! log(cm)
#DIV/0! cm

Calculation of 50% friction initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **LS #5**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(lbf)	log(lbf)	+	-
1590	3.2	0	0
1280.0	3.1	3	24
1000.0	3.0	0	3
795.0	2.9	0	0
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	**3**	**27**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
2	0	0	0	
1	24	24	24	0.094
0	3	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
3.000	27	24	24	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
1	0	0	0	
0	3	0	0	0.094
FALSE	0	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
3.107	3	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
3.138 log(lbf)
1375.0 lbf
s (using negatives)
0.0206 log(lbf)
1.0 lbf

H_{50} (using positives)
3.057 log(lbf)
1141.3 lbf
s (using positives)
0.0047 log(lbf)
1.0 lbf

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **LS #5**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	3	24
0.350	-0.5	0	3
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	0	0
0.030	-1.5	0	0
0.015	-1.8	0	0
0.010	-2.0	0	0
0.0050	-2.3	0	0
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	3	27

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
1	24	24	24	
0	3	0	0	0.331
FALSE	0	0	0	0.243
FALSE	0	0	0	0.222
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-0.456	27	24	24	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
0	3	0	0	
FALSE	0	0	0	0.331
FALSE	0	0	0	0.243
FALSE	0	0	0	0.222
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-0.125	3	0	0	0.275

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
-0.074	log(microF)
0.8	microF
s (using negatives)	
0.0569	log(microF)
1.1	microF

H_{50} (using positives)	
-0.262	log(microF)
0.5465	microF
s (using positives)	
0.0129	log(microF)
1.0	microF

Figure B6: H_{50} Calculations for Mix ID LS #6 – Fine $Al\text{-}Ni_2O_3$

Calculation of 50% impact initiation level from Bruceton data

Modified Bureau of Mines (MBOM) Impact Sensitivity Test

Sample: **LS #6**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	3	24
79.4	1.9	0	3
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	3	27

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
1	24	24	24	
0	3	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
1.900	27	24	24	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
0	3	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
2.000	3	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.038 log(cm)
109.2 cm
s (using negatives)
0.0206 log(cm)
1.0 cm

H_{50} (using positives)
1.950 log(cm)
89.2 cm
s (using positives)
0.0047 log(cm)
1.0 cm

Calculation of 50% friction initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **LS #6**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(lbf)	log(lbf)	+	-
1590	3.2	0	0
1280.0	3.1	0	30
1000.0	3.0	0	0
795.0	2.9	0	0
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	**0**	**30**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
1	0	0	0	
0	30	0	0	0.094
FALSE	0	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
3.107	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.094
FALSE	0	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
3.157	log(lbf)
1435.5	lbf
s (using negatives)	
0.0047	log(lbf)
1.0	lbf

H_{50} (using positives)	
#NAME?	log(lbf)
#NAME?	lbf
s (using positives)	
#DIV/0!	log(lbf)
#DIV/0!	lbf

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: LS #6

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	1	4
0.350	-0.5	0	2
0.200	-0.7	1	1
0.120	-0.9	4	0
0.060	-1.2	3	3
0.030	-1.5	3	2
0.015	-1.8	2	3
0.010	-2.0	0	1
0.0050	-2.3	0	0
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	14	16

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
7	4	28	196	
6	2	12	72	0.331
5	1	5	25	0.243
4	0	0	0	0.222
3	3	9	27	0.301
2	2	4	8	0.301
1	3	3	3	0.301
0	1	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.000	16	61	331	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
6	1	6	36	
5	0	0	0	0.331
4	1	4	16	0.243
3	4	12	36	0.222
2	3	6	12	0.301
1	3	3	3	0.301
0	2	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-1.824	14	31	103	0.275

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-0.814 log(microF)
0.2 microF
s (using negatives)
2.7530 log(microF)
566.3 microF

H_{50} (using positives)
-1.353 log(microF)
0.0444 microF
s (using positives)
1.1059 log(microF)
12.8 microF

Figure B7: H_{50} Calculations for Mix ID LS #7 – Fine Al-MnO_2 LS #7

Calculation of 50% friction initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **LS #7**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	1	0
795.0	2.9	2	1
635.0	2.8	5	1
505.0	2.7	4	4
400.0	2.6	2	4
320.0	2.5	2	2
255.0	2.4	0	2
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	16	14

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
8	0	0	0	
7	0	0	0	0.094
6	0	0	0	0.107
5	1	5	25	0.100
4	1	4	16	0.098
3	4	12	36	0.099
2	4	8	16	0.101
1	2	2	2	0.097
0	2	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.407	14	31	95	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
7	0	0	0	
6	0	0	0	0.094
5	1	5	25	0.107
4	2	8	32	0.100
3	5	15	45	0.098
2	4	8	16	0.099
1	2	2	2	0.101
0	2	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.505	16	38	120	0.100

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.677 log(lbf)
475.2 lbf
s (using negatives)
0.3084 log(lbf)
2.0 lbf

H_{50} (using positives)
2.692 log(lbf)
491.9 lbf
s (using positives)
0.3047 log(lbf)
2.0 lbf

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **LS #7**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(micro F)	Frequency +	Frequency -
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	0	0
0.030	-1.5	0	0
0.015	-1.8	1	0
0.010	-2.0	0	0
0.0050	-2.3	0	0
0.0025	-2.6	0	0
0.0012	-2.9	0	1
0.0007	-3.2	5	1
0.0003	-3.5	4	5
0.0002	-3.7	8	5
0.0000	0	0	0
	SUM	18	12

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
13	0	0	0	
12	0	0	0	0.331
11	0	0	0	0.243
10	0	0	0	0.222
9	0	0	0	0.301
8	0	0	0	0.301
7	0	0	0	0.301
6	0	0	0	0.176
5	0	0	0	0.301
4	0	0	0	0.301
3	1	3	9	0.319
2	1	2	4	0.234
1	5	5	5	0.368
0	5	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-3.699	12	10	18	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
13	0	0	0	
12	0	0	0	0.331
11	0	0	0	0.243
10	0	0	0	0.222
9	0	0	0	0.301
8	0	0	0	0.301
7	1	7	49	0.301
6	0	0	0	0.176
5	0	0	0	0.301
4	0	0	0	0.301
3	0	0	0	0.319
2	5	10	20	0.234
1	4	4	4	0.368
0	8	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-3.699	18	21	73	0.275

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-3.332 log(microF)
0.0005 microF
s (using negatives)
0.3717 log(microF)
2.4 microF

H_{50} (using positives)
-3.516 log(microF)
0.0 microF
s (using positives)
1.2130 log(microF)
16.3 microF

Figure B8: H_{50} Calculations for Mix ID LS #8 – Fine Mg&Al-MoO_3&CuO LS #8

Calculation of 50% friction initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **LS #8**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(lbf)	log(lbf)	+	-
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	0	0
795.0	2.9	1	0
635.0	2.8	1	1
505.0	2.7	4	2
400.0	2.6	2	5
320.0	2.5	2	3
255.0	2.4	1	3
200.0	2.3	1	1
160.0	2.2	0	1
127.0	2.1	0	1
100.0	2.0	0	1
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	12	18

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
12	0	0	0	
11	0	0	0	0.094
10	0	0	0	0.107
9	0	0	0	0.100
8	1	8	64	0.098
7	2	14	98	0.099
6	5	30	180	0.101
5	3	15	75	0.097
4	3	12	48	0.099
3	1	3	9	0.106
2	1	2	4	0.097
1	1	1	1	0.100
0	1	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	N_S	A	B	d
2.000	18	85	479	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
9	0	0	0	
8	0	0	0	0.094
7	0	0	0	0.107
6	1	6	36	0.100
5	1	5	25	0.098
4	4	16	64	0.099
3	2	6	18	0.101
2	2	4	8	0.097
1	1	1	1	0.099
0	1	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	N_S	A	B	d
2.301	12	38	152	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.520 log(lbf)
331.2 lbf
s (using negatives)
0.7003 log(lbf)
5.0 lbf

H_{50} (using positives)
2.567 log(lbf)
368.6 lbf
s (using positives)
0.4304 log(lbf)
2.7 lbf

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **LS #8**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance		Frequency	
(microF)	log(microF)	+	-
0.750	-0.1	1	0
0.350	-0.5	1	0
0.200	-0.7	1	0
0.120	-0.9	1	0
0.060	-1.2	1	0
0.030	-1.5	5	0
0.015	-1.8	7	5
0.010	-2.0	1	6
0.0050	-2.3	0	1
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	**18**	**12**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
8	0	0	0	
7	0	0	0	0.331
6	0	0	0	0.243
5	0	0	0	0.222
4	0	0	0	0.301
3	0	0	0	0.301
2	5	10	20	0.301
1	6	6	6	0.176
0	1	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.301	12	16	26	0.275

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
7	1	7	49	
6	1	6	36	0.331
5	1	5	25	0.243
4	1	4	16	0.222
3	1	3	9	0.301
2	5	10	20	0.301
1	7	7	7	0.301
0	1	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.000	18	42	162	0.275

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
-1.797	log(microF)
0.01596	microF
s (using negatives)	
0.1861	log(microF)
1.5	microF

H_{50} (using positives)	
-1.496	log(microF)
0.0	microF
s (using positives)	
1.5965	log(microF)
39.5	microF

Figure B9: H_{50} Calculations for Mix ID SS #1 – Fine $Mg\text{-}B_2O_3$

Calculation of 50% impact initiation level from Bruceton data

Modified Bureau of Mines (MBOM) Impact Sensitivity Test

Sample: **SS #1**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	3	20
79.4	1.9	2	3
63.1	1.8	0	2
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	5	25

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
2	20	40	80	
1	3	3	3	0.100
0	2	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
1.800	25	43	83	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
1	3	3	3	
0	2	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
1.900	5	3	3	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.021 log(cm)
105.0 cm
s (using negatives)
0.0631 log(cm)
1.2 cm

H_{50} (using positives)
1.910 log(cm)
81.2 cm
s (using positives)
0.0434 log(cm)
1.1 cm

Calculation of 50% friction initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #1**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	0	30
795.0	2.9	0	0
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
2	0	0	0	
1	0	0	0	0.094
0	30	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
3.000	30	0	0	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.094
FALSE	0	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
3.050	log(lbf)
1121.5	lbf
s (using negatives)	
0.0047	log(lbf)
1.0	lbf

H_{50} (using positives)	
#NAME?	log(lbf)
#NAME?	lbf
s (using positives)	
#DIV/0!	log(lbf)
#DIV/0!	lbf

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: SS #1

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance		Frequency	
(microF)	log(microF)	+	-
0.750	-0.1	6	18
0.350	-0.5	0	6
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	0	0
0.030	-1.5	0	0
0.015	-1.8	0	0
0.010	-2.0	0	0
0.0050	-2.3	0	0
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	**6**	**24**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
1	18	18	18	
0	6	0	0	0.331
FALSE	0	0	0	0.243
FALSE	0	0	0	0.222
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-0.456	24	18	18	0.275

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
0	6	0	0	
FALSE	0	0	0	0.331
FALSE	0	0	0	0.243
FALSE	0	0	0	0.222
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-0.125	6	0	0	0.275

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-0.112 log(microF)
0.8 microF
s (using negatives)
0.0964 log(microF)
1.2 microF

H_{50} (using positives)
-0.262 log(microF)
0.5465 microF
s (using positives)
0.0129 log(microF)
1.0 microF

Figure B10: H_{50} Calculations for Mix ID SS #2B – Fine Ti-B_2O_3

Calculation of 50% impact initiation level from Bruceton data

Modified Bureau of Mines (MBOM) Impact Sensitivity Test

Sample: **SS #2B**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	1	26
79.4	1.9	1	1
63.1	1.8	0	1
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	2	28

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
2	26	52	104	
1	1	1	1	0.100
0	1	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
1.800	28	53	105	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
1	1	1	1	
0	1	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
1.900	2	1	1	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.038 log(cm)
109.3 cm

s (using negatives)
0.0317 log(cm)
1.1 cm

H_{50} (using positives)
1.900 log(cm)
79.4 cm

s (using positives)
0.0450 log(cm)
1.1 cm

Calculation of 50% friction initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: SS #2B

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(lbf)	log(lbf)	+	-
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	0	30
795.0	2.9	0	0
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
2	0	0	0	
1	0	0	0	0.094
0	30	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	N_S	A	B	d
3.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.094
FALSE	0	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	N_S	A	B	d
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
3.050	log(lbf)
1121.5	lbf
s (using negatives)	
0.0047	log(lbf)
1.0	lbf

H_{50} (using positives)	
#NAME?	log(lbf)
#NAME?	lbf
s (using positives)	
#DIV/0!	log(lbf)
#DIV/0!	lbf

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #2B**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(micro F)	Frequency +	Frequency -
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	0	0
0.030	-1.5	0	0
0.015	-1.8	1	0
0.010	-2.0	0	0
0.0050	-2.3	0	0
0.0025	-2.6	2	0
0.0012	-2.9	5	2
0.0007	-3.2	6	5
0.0003	-3.5	0	6
0.0002	-3.7	2	1
0.0000	0		
	SUM	**16**	**14**

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
13	0	0	0	
12	0	0	0	0.331
11	0	0	0	0.243
10	0	0	0	0.222
9	0	0	0	0.301
8	0	0	0	0.301
7	0	0	0	0.301
6	0	0	0	0.176
5	0	0	0	0.301
4	0	0	0	0.301
3	2	6	18	0.319
2	5	10	20	0.234
1	6	6	6	0.368
0	1	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-3.699	14	22	44	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
13	0	0	0	
12	0	0	0	0.331
11	0	0	0	0.243
10	0	0	0	0.222
9	0	0	0	0.301
8	0	0	0	0.301
7	1	7	49	0.301
6	0	0	0	0.176
5	0	0	0	0.301
4	2	8	32	0.301
3	5	15	45	0.319
2	6	12	24	0.234
1	0	0	0	0.368
0	2	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-3.699	16	42	150	0.275

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-3.129 log(microF)
0.00074 microF

s (using negatives)
0.3129 log(microF)
2.1 microF

H_{50} (using positives)
-3.115 log(microF)
0.00077 microF

s (using positives)
1.1194 log(microF)
13.2 microF

Figure B11: H_{50} Calculations for Mix ID SS #3B – Fine $Ti-MnO_2$

Calculation of 50% impact initiation level from Bruceton data

Modified Bureau of Mines (MBOM) Impact Sensitivity Test

Sample: **SS #3B**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height (cm)	log(cm)	Frequency +	Frequency -
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#NAME?	log(cm)
#NAME?	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Calculation of 50% friction initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #3B**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	0	0
795.0	2.9	0	0
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	4	0
51.0	1.7	22	4
0.0000	0	0	0
	SUM	26	4

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
15	0	0	0	
14	0	0	0	0.094
13	0	0	0	0.107
12	0	0	0	0.100
11	0	0	0	0.098
10	0	0	0	0.099
9	0	0	0	0.101
8	0	0	0	0.097
7	0	0	0	0.099
6	0	0	0	0.106
5	0	0	0	0.097
4	0	0	0	0.100
3	0	0	0	0.104
2	0	0	0	0.097
1	0	0	0	0.097
0	4	0	0	0.099
FALSE	0	0	0	
c	N_S	A	B	d
1.708	4	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
15	0	0	0	
14	0	0	0	0.094
13	0	0	0	0.107
12	0	0	0	0.100
11	0	0	0	0.098
10	0	0	0	0.099
9	0	0	0	0.101
8	0	0	0	0.097
7	0	0	0	0.099
6	0	0	0	0.106
5	0	0	0	0.097
4	0	0	0	0.100
3	0	0	0	0.104
2	0	0	0	0.097
1	4	4	4	0.097
0	22	0	0	0.099
FALSE	0	0	0	0.000
c	N_S	A	B	d
1.708	26	4	4	0.100

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
1.757	log(lbf)
57.2	lbf
s (using negatives)	
0.0047	log(lbf)
1.0	lbf

H_{50} (using positives)	
1.673	log(lbf)
47.1	lbf
s (using positives)	
0.0257	log(lbf)
1.1	lbf

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #3B**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	0	0
0.030	-1.5	0	0
0.015	-1.8	1	0
0.010	-2.0	0	0
0.0050	-2.3	0	0
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	1	0
0.0002	-3.7	27	2
0.0000	0		
	SUM	29	2

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
13	0	0	0	
12	0	0	0	0.331
11	0	0	0	0.243
10	0	0	0	0.222
9	0	0	0	0.301
8	0	0	0	0.301
7	0	0	0	0.301
6	0	0	0	0.176
5	0	0	0	0.301
4	0	0	0	0.301
3	0	0	0	0.319
2	0	0	0	0.234
1	0	0	0	0.368
0	2	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-3.699	2	0	0	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
13	0	0	0	
12	0	0	0	0.331
11	0	0	0	0.243
10	0	0	0	0.222
9	0	0	0	0.301
8	0	0	0	0.301
7	1	7	49	0.301
6	0	0	0	0.176
5	0	0	0	0.301
4	0	0	0	0.301
3	0	0	0	0.319
2	0	0	0	0.234
1	1	1	1	0.368
0	27	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-3.699	29	8	50	0.275

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-3.562 log(microF)
0.0 microF

s (using negatives)
0.0129 log(microF)
1.0 microF

H_{50} (using positives)
-3.761 log(microF)
0.0 microF

s (using positives)
0.7469 log(microF)
5.6 microF

Figure B12: H_{50} Calculations for Mix ID SS #4 – Fine Mg-MnO_2

Calculation of 50% impact initiation level from Bruceton data

Modified Bureau of Mines (MBOM) Impact Sensitivity Test

Sample: **SS #4**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#NAME?	log(cm)
#NAME?	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Calculation of 50% friction initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #4**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i{\cdot}n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2{\cdot}n_i$

Drop Height (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	30
1000.0	3.0	0	0
795.0	2.9	0	0
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
1	0	0	0	
0	30	0	0	0.094
FALSE	0	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
3.107	30	0	0	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.094
FALSE	0	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
3.157	log(lbf)
1435.5	lbf
s (using negatives)	
0.0047	log(lbf)
1.0	lbf

H_{50} (using positives)	
#NAME?	log(lbf)
#NAME?	lbf
s (using positives)	
#DIV/0!	log(lbf)
#DIV/0!	lbf

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #4**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	0	0
0.030	-1.5	0	0
0.015	-1.8	1	0
0.010	-2.0	1	0
0.0050	-2.3	4	1
0.0025	-2.6	6	4
0.0012	-2.9	2	6
0.0007	-3.2	0	3
0.0003	-3.5	0	1
0.0002	-3.7	0	1
0.0000	0		
	SUM	14	16

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
13	0	0	0	
12	0	0	0	0.331
11	0	0	0	0.243
10	0	0	0	0.222
9	0	0	0	0.301
8	0	0	0	0.301
7	0	0	0	0.301
6	0	0	0	0.176
5	1	5	25	0.301
4	4	16	64	0.301
3	6	18	54	0.319
2	3	6	12	0.234
1	1	1	1	0.368
0	1	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-3.699	16	46	156	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
10	0	0	0	
9	0	0	0	0.331
8	0	0	0	0.243
7	0	0	0	0.222
6	0	0	0	0.301
5	0	0	0	0.301
4	1	4	16	0.301
3	1	3	9	0.176
2	4	8	16	0.301
1	6	6	6	0.301
0	2	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.921	14	21	47	0.275

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
-2.771	log(microF)
0.0017	microF
s (using negatives)	
0.6740	log(microF)
4.7	microF

H_{50} (using positives)	
-2.646	log(microF)
0.0023	microF
s (using positives)	
0.5060	log(microF)
3.2	microF

Figure B13: H_{50} Calculations for Mix ID SS #6B – Fine Ti-Fe_2O_3

Calculation of 50% impact initiation level from Bruceton data

Modified Bureau of Mines (MBOM) Impact Sensitivity Test

Sample: **SS #6b**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i{\cdot}n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2{\cdot}n_i$

Drop Height (cm)	log(cm)	Frequency +	Frequency -
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.050 log(cm)
112.2 cm

s (using negatives)
0.0047 log(cm)
1.0 cm

H_{50} (using positives)
#NAME? log(cm)
#NAME? cm

s (using positives)
#DIV/0! log(cm)
#DIV/0! cm

Calculation of 50% friction initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #6b**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	0	0
795.0	2.9	0	0
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	1	0
320.0	2.5	3	1
255.0	2.4	5	3
200.0	2.3	1	5
160.0	2.2	4	1
127.0	2.1	1	4
100.0	2.0	0	1
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	15	15

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
12	0	0	0	
11	0	0	0	0.094
10	0	0	0	0.107
9	0	0	0	0.100
8	0	0	0	0.098
7	0	0	0	0.099
6	0	0	0	0.101
5	1	5	25	0.097
4	3	12	48	0.099
3	5	15	45	0.106
2	1	2	4	0.097
1	4	4	4	0.100
0	1	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	N_S	A	B	d
2.000	15	38	126	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
11	0	0	0	
10	0	0	0	0.094
9	0	0	0	0.107
8	0	0	0	0.100
7	0	0	0	0.098
6	0	0	0	0.099
5	1	5	25	0.101
4	3	12	48	0.097
3	5	15	45	0.099
2	1	2	4	0.106
1	4	4	4	0.097
0	1	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	N_S	A	B	d
2.104	15	38	126	0.100

USE EITHER NEGATIVES OR POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.302 log(lbf)
200.5 lbf
s (using negatives)
0.3245 log(lbf)
2.1 lbf

H_{50} (using positives)
2.306 log(lbf)
202.4 lbf
s (using positives)
0.3245 log(lbf)
2.1 lbf

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #6b**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	0	0
0.030	-1.5	0	0
0.015	-1.8	1	0
0.010	-2.0	0	0
0.0050	-2.3	0	0
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	6	0
0.0003	-3.5	3	6
0.0002	-3.7	10	4
0.0000	0	0	0
	SUM	20	10

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
13	0	0	0	
12	0	0	0	0.331
11	0	0	0	0.243
10	0	0	0	0.222
9	0	0	0	0.301
8	0	0	0	0.301
7	0	0	0	0.301
6	0	0	0	0.176
5	0	0	0	0.301
4	0	0	0	0.301
3	0	0	0	0.319
2	0	0	0	0.234
1	6	6	6	0.368
0	4	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-3.699	10	6	6	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
13	0	0	0	
12	0	0	0	0.331
11	0	0	0	0.243
10	0	0	0	0.222
9	0	0	0	0.301
8	0	0	0	0.301
7	1	7	49	0.301
6	0	0	0	0.176
5	0	0	0	0.301
4	0	0	0	0.301
3	0	0	0	0.319
2	6	12	24	0.234
1	3	3	3	0.368
0	10	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-3.699	20	22	76	0.275

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-3.397 log(microF)
0.0004 microF
s (using negatives)
0.1198 log(microF)
1.3 microF

H_{50} (using positives)
-3.534 log(microF)
0.0 microF
s (using positives)
1.1664 log(microF)
14.7 microF

Figure B14: H_{50} Calculations for Mix ID SS #7B – Fine Ti-CuO

Calculation of 50% impact initiation level from Bruceton data

Modified Bureau of Mines (MBOM) Impact Sensitivity Test

Sample: **SS #7b**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#NAME?	log(cm)
#NAME?	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Calculation of 50% friction initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #7B**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(lbf)	log(lbf)	+	-
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	0	0
795.0	2.9	0	0
635.0	2.8	0	0
505.0	2.7	2	0
400.0	2.6	2	2
320.0	2.5	2	2
255.0	2.4	5	1
200.0	2.3	5	4
160.0	2.2	1	4
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	17	13

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
10	0	0	0	
9	0	0	0	0.094
8	0	0	0	0.107
7	0	0	0	0.100
6	0	0	0	0.098
5	0	0	0	0.099
4	2	8	32	0.101
3	2	6	18	0.097
2	1	2	4	0.099
1	4	4	4	0.106
0	4	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	N_S	A	B	d
2.204	13	20	58	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
10	0	0	0	
9	0	0	0	0.094
8	0	0	0	0.107
7	0	0	0	0.100
6	0	0	0	0.098
5	2	10	50	0.099
4	2	8	32	0.101
3	2	6	18	0.097
2	5	10	20	0.099
1	5	5	5	0.106
0	1	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	N_S	A	B	d
2.204	17	39	125	0.100

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.407 log(lbf)
255.3 lbf
s (using negatives)
0.3426 log(lbf)
2.2 lbf

H_{50} (using positives)
2.383 log(lbf)
241.4 lbf
s (using positives)
0.3419 log(lbf)
2.2 lbf

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #7B**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	0	0
0.030	-1.5	0	0
0.015	-1.8	1	0
0.010	-2.0	0	0
0.0050	-2.3	1	0
0.0025	-2.6	2	1
0.0012	-2.9	5	2
0.0007	-3.2	3	5
0.0003	-3.5	3	3
0.0002	-3.7	1	3
0.0000	0	0	0
	SUM	**16**	**14**

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
13	0	0	0	
12	0	0	0	0.331
11	0	0	0	0.243
10	0	0	0	0.222
9	0	0	0	0.301
8	0	0	0	0.301
7	0	0	0	0.301
6	0	0	0	0.176
5	0	0	0	0.301
4	1	4	16	0.301
3	2	6	18	0.319
2	5	10	20	0.234
1	3	3	3	0.368
0	3	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-3.699	14	23	57	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
13	0	0	0	
12	0	0	0	0.331
11	0	0	0	0.243
10	0	0	0	0.222
9	0	0	0	0.301
8	0	0	0	0.301
7	1	7	49	0.301
6	0	0	0	0.176
5	1	5	25	0.301
4	2	8	32	0.301
3	5	15	45	0.319
2	3	6	12	0.234
1	3	3	3	0.368
0	1	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-3.699	16	44	166	0.275

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-3.110 log(microF)
0.0008 microF

s (using negatives)
0.6242 log(microF)
4.2 microF

H_{50} (using positives)
-3.080 log(microF)
0.0 microF

s (using positives)
1.2655 log(microF)
18.4 microF

Figure B15: H_{50} Calculations for Mix ID SS #9 – Fine Al-MoO_3

Calculation of 50% impact initiation level from Bruceton data

Modified Bureau of Mines (MBOM) Impact Sensitivity Test

Sample: **SS #9**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#NAME?	log(cm)
#NAME?	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Calculation of 50% friction initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #9**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(lbf)	log(lbf)	+	-
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	0	0
795.0	2.9	0	0
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	1	0
64.0	1.8	4	1
51.0	1.7	21	3
0.0000	0	0	0
	SUM	26	4

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
15	0	0	0	
14	0	0	0	0.094
13	0	0	0	0.107
12	0	0	0	0.100
11	0	0	0	0.098
10	0	0	0	0.099
9	0	0	0	0.101
8	0	0	0	0.097
7	0	0	0	0.099
6	0	0	0	0.106
5	0	0	0	0.097
4	0	0	0	0.100
3	0	0	0	0.104
2	0	0	0	0.097
1	1	1	1	0.097
0	3	0	0	0.099
FALSE	0	0	0	
c	N_S	A	B	d
1.708	4	1	1	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
15	0	0	0	
14	0	0	0	0.094
13	0	0	0	0.107
12	0	0	0	0.100
11	0	0	0	0.098
10	0	0	0	0.099
9	0	0	0	0.101
8	0	0	0	0.097
7	0	0	0	0.099
6	0	0	0	0.106
5	0	0	0	0.097
4	0	0	0	0.100
3	0	0	0	0.104
2	1	2	4	0.097
1	4	4	4	0.097
0	21	0	0	0.099
FALSE	0	0	0	0.000
c	N_S	A	B	d
1.708	26	6	8	0.100

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
1.782 log(lbf)
60.6 lbf
s (using negatives)
0.0349 log(lbf)
1.1 lbf

H_{50} (using positives)
1.681 log(lbf)
47.9 lbf
s (using positives)
0.0457 log(lbf)
1.1 lbf

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #9**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance		Frequency	
(microF)	log(microF)	+	-
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	0	0
0.030	-1.5	0	0
0.015	-1.8	6	0
0.010	-2.0	6	6
0.0050	-2.3	3	6
0.0025	-2.6	0	3
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	15	15

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
9	0	0	0	
8	0	0	0	0.331
7	0	0	0	0.243
6	0	0	0	0.222
5	0	0	0	0.301
4	0	0	0	0.301
3	0	0	0	0.301
2	6	12	24	0.176
1	6	6	6	0.301
0	3	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.602	15	18	30	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
8	0	0	0	
7	0	0	0	0.331
6	0	0	0	0.243
5	0	0	0	0.222
4	0	0	0	0.301
3	0	0	0	0.301
2	6	12	24	0.301
1	6	6	6	0.176
0	3	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.301	15	18	30	0.275

USE EITHER NEGATIVES OR POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-2.135 log(microF)
0.0073 microF
s (using negatives)
0.2623 log(microF)
1.8 microF

H_{50} (using positives)
-2.109 log(microF)
0.0078 microF
s (using positives)
0.2623 log(microF)
1.8 microF

Figure B16: H_{50} Calculations for Mix ID SS #10 – Fine Mg-Fe_2O_3

Calculation of 50% impact initiation level from Bruceton data

Modified Bureau of Mines (MBOM) Impact Sensitivity Test

Sample: **SS #10**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	1	28
79.4	1.9	0	1
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	1	29

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
1	28	28	28	
0	1	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
1.900	29	28	28	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
0	1	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
2.000	1	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.046 log(cm)
111.1 cm
s (using negatives)
0.0101 log(cm)
1.0 cm

H_{50} (using positives)
1.950 log(cm)
89.2 cm
s (using positives)
0.0047 log(cm)
1.0 cm

Calculation of 50% friction initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #10**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(lbf)	log(lbf)	+	-
1590	3.2	0	0
1280.0	3.1	0	30
1000.0	3.0	0	0
795.0	2.9	0	0
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
1	0	0	0	
0	30	0	0	0.094
FALSE	0	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	N_S	A	B	d
3.107	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.094
FALSE	0	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	N_S	A	B	d
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
3.157	log(lbf)
1435.5	lbf
s (using negatives)	
0.0047	log(lbf)
1.0	lbf

H_{50} (using positives)	
#NAME?	log(lbf)
#NAME?	lbf
s (using positives)	
#DIV/0!	log(lbf)
#DIV/0!	lbf

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #10**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance		Frequency	
(microF)	log(micro F)	+	-
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	0	0
0.030	-1.5	0	0
0.015	-1.8	1	0
0.010	-2.0	0	0
0.0050	-2.3	1	0
0.0025	-2.6	2	1
0.0012	-2.9	5	2
0.0007	-3.2	3	5
0.0003	-3.5	3	3
0.0002	-3.7	1	3
0.0000	0	0	0
	SUM	**16**	**14**

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
13	0	0	0	
12	0	0	0	0.331
11	0	0	0	0.243
10	0	0	0	0.222
9	0	0	0	0.301
8	0	0	0	0.301
7	0	0	0	0.301
6	0	0	0	0.176
5	0	0	0	0.301
4	1	4	16	0.301
3	2	6	18	0.319
2	5	10	20	0.234
1	3	3	3	0.368
0	3	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-3.699	14	23	57	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
13	0	0	0	
12	0	0	0	0.331
11	0	0	0	0.243
10	0	0	0	0.222
9	0	0	0	0.301
8	0	0	0	0.301
7	1	7	49	0.301
6	0	0	0	0.176
5	1	5	25	0.301
4	2	8	32	0.301
3	5	15	45	0.319
2	3	6	12	0.234
1	3	3	3	0.368
0	1	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-3.699	16	44	166	0.275

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-3.110 log(microF)
0.0008 microF
s (using negatives)
0.6242 log(microF)
4.2 microF

H_{50} (using positives)
-3.080 log(microF)
0.0 microF
s (using positives)
1.2655 log(microF)
18.4 microF

Figure B17: H_{50} Calculations for Mix ID SS #11 – Fine Mg-CuO

Calculation of 50% impact initiation level from Bruceton data

Modified Bureau of Mines (MBOM) Impact Sensitivity Test

Sample: **SS #11**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height (cm)	log(cm)	Frequency +	Frequency -
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#NAME?	log(cm)
#NAME?	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Calculation of 50% friction initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #11**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(lbf)	log(lbf)	+	-
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	0	30
795.0	2.9	0	0
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	**0**	**30**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
2	0	0	0	
1	0	0	0	0.094
0	30	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
3.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.094
FALSE	0	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
3.050	log(lbf)
1121.5	lbf
s (using negatives)	
0.0047	log(lbf)
1.0	lbf

H_{50} (using positives)	
#NAME?	log(lbf)
#NAME?	lbf
s (using positives)	
#DIV/0!	log(lbf)
#DIV/0!	lbf

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #11**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	0	0
0.030	-1.5	0	0
0.015	-1.8	0	4
0.010	-2.0	4	4
0.0050	-2.3	5	5
0.0025	-2.6	1	6
0.0012	-2.9	1	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	**11**	**19**

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
9	0	0	0	
8	0	0	0	0.331
7	0	0	0	0.243
6	0	0	0	0.222
5	0	0	0	0.301
4	0	0	0	0.301
3	4	12	36	0.301
2	4	8	16	0.176
1	5	5	5	0.301
0	6	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.602	19	25	57	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
10	0	0	0	
9	0	0	0	0.331
8	0	0	0	0.243
7	0	0	0	0.222
6	0	0	0	0.301
5	0	0	0	0.301
4	0	0	0	0.301
3	4	12	36	0.176
2	5	10	20	0.301
1	1	1	1	0.301
0	1	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.921	11	23	57	0.275

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-2.103 log(microF)
0.0 microF
s (using negatives)
0.5780 log(microF)
3.8 microF

H_{50} (using positives)
-2.483 log(microF)
0.0033 microF
s (using positives)
0.3736 log(microF)
2.4 microF

Figure B18: H_{50} Calculations for Mix ID SS #12 – Fine Al-Co_3O_4

Calculation of 50% impact initiation level from Bruceton data

Modified Bureau of Mines (MBOM) Impact Sensitivity Test

Sample: **SS #12**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i{\cdot}n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2{\cdot}n_i$

Drop Height (cm)	log(cm)	Frequency +	Frequency -
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#NAME?	log(cm)
#NAME?	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Calculation of 50% friction initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #12**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(lbf)	log(lbf)	+	-
1590	3.2	0	0
1280.0	3.1	1	23
1000.0	3.0	1	4
795.0	2.9	0	1
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	**2**	**28**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
3	0	0	0	
2	23	46	92	0.094
1	4	4	4	0.107
0	1	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.900	28	50	96	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
2	0	0	0	
1	1	1	1	0.094
0	1	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
3.000	2	1	1	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
3.128	log(lbf)
1342.8	lbf
s (using negatives)	
0.0434	log(lbf)
1.1	lbf

H_{50} (using positives)	
3.000	log(lbf)
1000.0	lbf
s (using positives)	
0.0450	log(lbf)
1.1	lbf

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #12**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.
where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$
where $B = \Sigma i^2 \cdot n_i$

Capacitance		Frequency	
(microF)	log(micro F)	+	-
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	0	0
0.030	-1.5	0	0
0.015	-1.8	1	0
0.010	-2.0	2	0
0.0050	-2.3	7	3
0.0025	-2.6	4	8
0.0012	-2.9	0	4
0.0007	-3.2	1	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	**15**	**15**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
10	0	0	0	
9	0	0	0	0.331
8	0	0	0	0.243
7	0	0	0	0.222
6	0	0	0	0.301
5	0	0	0	0.301
4	0	0	0	0.301
3	0	0	0	0.176
2	3	6	12	0.301
1	8	8	8	0.301
0	4	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.921	15	14	20	0.275

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
11	0	0	0	
10	0	0	0	0.331
9	0	0	0	0.243
8	0	0	0	0.222
7	0	0	0	0.301
6	0	0	0	0.301
5	1	5	25	0.301
4	2	8	32	0.176
3	7	21	63	0.301
2	4	8	16	0.301
1	0	0	0	0.319
0	1	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-3.155	15	42	136	0.275

USE EITHER NEGATIVES OR POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
-2.527	log(microF)
0.0030	microF
s (using negatives)	
0.2188	log(microF)
1.7	microF

H_{50} (using positives)	
-2.523	log(microF)
0.0030	microF
s (using positives)	
0.5592	log(microF)
3.6	microF

Figure B19: H_{50} Calculations for Mix ID SS #18 – Fine Al-WO_3

Calculation of 50% impact initiation level from Bruceton data

Modified Bureau of Mines (MBOM) Impact Sensitivity Test

Sample: **SS #18**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height (cm)	log(cm)	Frequency +	Frequency -
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.050 log(cm)
112.2 cm
s (using negatives)
0.0047 log(cm)
1.0 cm

H_{50} (using positives)
#NAME? log(cm)
#NAME? cm
s (using positives)
#DIV/0! log(cm)
#DIV/0! cm

Calculation of 50% friction initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #18**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(lbf)	log(lbf)	+	-
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	2	0
795.0	2.9	1	0
635.0	2.8	1	1
505.0	2.7	1	0
400.0	2.6	2	0
320.0	2.5	1	0
255.0	2.4	1	1
200.0	2.3	1	0
160.0	2.2	3	0
127.0	2.1	3	0
100.0	2.0	2	3
80.0	1.9	1	3
64.0	1.8	0	2
51.0	1.7	0	1
0.0000	0	0	0
	SUM	**19**	**11**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
15	0	0	0	
14	0	0	0	0.094
13	0	0	0	0.107
12	0	0	0	0.100
11	1	11	121	0.098
10	0	0	0	0.099
9	0	0	0	0.101
8	0	0	0	0.097
7	1	7	49	0.099
6	0	0	0	0.106
5	0	0	0	0.097
4	0	0	0	0.100
3	3	9	27	0.104
2	3	6	12	0.097
1	2	2	2	0.097
0	1	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
1.708	11	35	211	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
13	0	0	0	
12	0	0	0	0.094
11	2	22	242	0.107
10	1	10	100	0.100
9	1	9	81	0.098
8	1	8	64	0.099
7	2	14	98	0.101
6	1	6	36	0.097
5	1	5	25	0.099
4	1	4	16	0.106
3	3	9	27	0.097
2	3	6	12	0.100
1	2	2	2	0.104
0	1	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
1.903	19	95	703	0.100

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.074 log(lbf)
118.6 lbf

s (using negatives)
1.4660 log(lbf)
29.2 lbf

H_{50} (using positives)
2.351 log(lbf)
224.5 lbf

s (using positives)
1.9407 log(lbf)
87.2 lbf

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #18**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(micro F)	Frequency +	Frequency -
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	0	0
0.030	-1.5	0	0
0.015	-1.8	5	0
0.010	-2.0	6	5
0.0050	-2.3	3	7
0.0025	-2.6	0	4
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	14	16

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
9	0	0	0	
8	0	0	0	0.331
7	0	0	0	0.243
6	0	0	0	0.222
5	0	0	0	0.301
4	0	0	0	0.301
3	0	0	0	0.301
2	5	10	20	0.176
1	7	7	7	0.301
0	4	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.602	16	17	27	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
8	0	0	0	
7	0	0	0	0.331
6	0	0	0	0.243
5	0	0	0	0.222
4	0	0	0	0.301
3	0	0	0	0.301
2	5	10	20	0.301
1	6	6	6	0.176
0	3	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.301	14	16	26	0.275

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
-2.172	log(microF)
0.0	microF
s (using negatives)	
0.2617	log(microF)
1.8	microF

H_{50} (using positives)	
-2.124	log(microF)
0.00751	microF
s (using positives)	
0.2583	log(microF)
1.8	microF

Figure B20: H_{50} Calculations for Mix ID SS #19 – Fine Al-SnO_2

Calculation of 50% impact initiation level from Bruceton data

Modified Bureau of Mines (MBOM) Impact Sensitivity Test

Sample: **SS #19**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.050 log(cm)
112.2 cm
s (using negatives)
0.0047 log(cm)
1.0 cm

H_{50} (using positives)
#NAME? log(cm)
#NAME? cm
s (using positives)
#DIV/0! log(cm)
#DIV/0! cm

Calculation of 50% friction initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #19**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(lbf)	log(lbf)	+	-
1590	3.2	0	0
1280.0	3.1	0	30
1000.0	3.0	0	0
795.0	2.9	0	0
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	**0**	**30**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
1	0	0	0	
0	30	0	0	0.094
FALSE	0	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
3.107	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.094
FALSE	0	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
3.157	log(lbf)
1435.5	lbf
s (using negatives)	
0.0047	log(lbf)
1.0	lbf

H_{50} (using positives)	
#NAME?	log(lbf)
#NAME?	lbf
s (using positives)	
#DIV/0!	log(lbf)
#DIV/0!	lbf

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #19**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance		Frequency	
(microF)	log(microF)	+	-
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	0	0
0.030	-1.5	6	0
0.015	-1.8	7	6
0.010	-2.0	0	6
0.0050	-2.3	1	0
0.0025	-2.6	1	1
0.0012	-2.9	0	1
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	1
0.0000	0	0	0
	SUM	**15**	**15**

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
13	0	0	0	
12	0	0	0	0.331
11	0	0	0	0.243
10	0	0	0	0.222
9	0	0	0	0.301
8	0	0	0	0.301
7	6	42	294	0.301
6	6	36	216	0.176
5	0	0	0	0.301
4	1	4	16	0.301
3	1	3	9	0.319
2	0	0	0	0.234
1	0	0	0	0.368
0	1	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-3.699	15	85	535	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
9	0	0	0	
8	0	0	0	0.331
7	0	0	0	0.243
6	0	0	0	0.222
5	0	0	0	0.301
4	6	24	96	0.301
3	7	21	63	0.301
2	0	0	0	0.176
1	1	1	1	0.301
0	1	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.602	15	46	160	0.275

USE EITHER NEGATIVES OR POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-2.004 log(microF)
0.00992 microF
s (using negatives)
1.5965 log(microF)
39.5 microF

H_{50} (using positives)
-1.896 log(microF)
0.01269 microF
s (using positives)
0.5751 log(microF)
3.8 microF

Figure B21: H_{50} Calculations for Mix ID SS #21 – Fine Al-Cr_2O_3

Calculation of 50% impact initiation level from Bruceton data

Modified Bureau of Mines (MBOM) Impact Sensitivity Test

Sample: **SS #21**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height (cm)	log(cm)	Frequency +	Frequency -
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#NAME?	log(cm)
#NAME?	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Calculation of 50% friction initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #21**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(lbf)	log(lbf)	+	-
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	0	30
795.0	2.9	0	0
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	**0**	**30**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
2	0	0	0	
1	0	0	0	0.094
0	30	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
3.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.094
FALSE	0	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
3.050	log(lbf)
1121.5	lbf
s (using negatives)	
0.0047	log(lbf)
1.0	lbf

H_{50} (using positives)	
#NAME?	log(lbf)
#NAME?	lbf
s (using positives)	
#DIV/0!	log(lbf)
#DIV/0!	lbf

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #21**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance		Frequency	
(microF)	log(microF)	+	-
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	0	0
0.030	-1.5	0	0
0.015	-1.8	0	4
0.010	-2.0	9	3
0.0050	-2.3	2	9
0.0025	-2.6	0	3
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	**11**	**19**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
9	0	0	0	
8	0	0	0	0.331
7	0	0	0	0.243
6	0	0	0	0.222
5	0	0	0	0.301
4	0	0	0	0.301
3	4	12	36	0.301
2	3	6	12	0.176
1	9	9	9	0.301
0	3	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.602	19	27	57	0.275

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
8	0	0	0	
7	0	0	0	0.331
6	0	0	0	0.243
5	0	0	0	0.222
4	0	0	0	0.301
3	0	0	0	0.301
2	0	0	0	0.301
1	9	9	9	0.176
0	2	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.301	11	9	9	0.275

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-2.074 log(microF)
0.0 microF
s (using negatives)
0.4497 log(microF)
2.8 microF

H_{50} (using positives)
-2.214 log(microF)
0.0061 microF
s (using positives)
0.0792 log(microF)
1.2 microF

Figure B22: H_{50} Calculations for Mix ID SS #24 – Fine Al-Bi_2O_3

Calculation of 50% impact initiation level from Bruceton data

Modified Bureau of Mines (MBOM) Impact Sensitivity Test

Sample: **SS #24**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#NAME?	log(cm)
#NAME?	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Calculation of 50% friction initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #24**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(lbf)	log(lbf)	+	-
1590	3.2	0	0
1280.0	3.1	4	23
1000.0	3.0	1	1
795.0	2.9	0	1
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	5	25

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
3	0	0	0	
2	23	46	92	0.094
1	1	1	1	0.107
0	1	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	N_S	A	B	d
2.900	25	47	93	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
2	0	0	0	
1	4	4	4	0.094
0	1	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	N_S	A	B	d
3.000	5	4	4	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
3.137	log(lbf)
1372.1	lbf
s (using negatives)	
0.0346	log(lbf)
1.1	lbf

H_{50} (using positives)	
3.030	log(lbf)
1071.2	lbf
s (using positives)	
0.0305	log(lbf)
1.1	lbf

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #24**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(micro F)	Frequency +	Frequency -
0.750	-0.1	1	0
0.350	-0.5	1	0
0.200	-0.7	1	0
0.120	-0.9	2	0
0.060	-1.2	3	1
0.030	-1.5	4	2
0.015	-1.8	5	5
0.010	-2.0	0	5
0.0050	-2.3	0	0
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	17	13

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
7	0	0	0	
6	0	0	0	0.331
5	0	0	0	0.243
4	0	0	0	0.222
3	1	3	9	0.301
2	2	4	8	0.301
1	5	5	5	0.301
0	5	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.000	13	12	22	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
6	1	6	36	
5	1	5	25	0.331
4	1	4	16	0.243
3	2	6	18	0.222
2	3	6	12	0.301
1	4	4	4	0.301
0	5	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-1.824	17	31	111	0.275

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-1.609 log(microF)
0.0246 microF
s (using negatives)
0.3871 log(microF)
2.4 microF

H_{50} (using positives)
-1.460 log(microF)
0.0 microF
s (using positives)
1.4400 log(microF)
27.5 microF

Figure B23: H_{50} Calculations for Mix ID SS #25 – Fine Al-TiO_2

Calculation of 50% impact initiation level from Bruceton data

Modified Bureau of Mines (MBOM) Impact Sensitivity Test

Sample: **SS #25**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#NAME?	log(cm)
#NAME?	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Calculation of 50% friction initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #25**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i{\cdot}n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2{\cdot}n_i$

Drop Height		Frequency	
(lbf)	log(lbf)	+	-
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	0	30
795.0	2.9	0	0
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
2	0	0	0	
1	0	0	0	0.094
0	30	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	N_S	A	B	d
3.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.094
FALSE	0	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	N_S	A	B	d
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
3.050	log(lbf)
1121.5	lbf
s (using negatives)	
0.0047	log(lbf)
1.0	lbf

H_{50} (using positives)	
#NAME?	log(lbf)
#NAME?	lbf
s (using positives)	
#DIV/0!	log(lbf)
#DIV/0!	lbf

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #25**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	0	0
0.030	-1.5	0	0
0.015	-1.8	2	0
0.010	-2.0	4	1
0.0050	-2.3	9	4
0.0025	-2.6	1	9
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	16	14

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
9	0	0	0	
8	0	0	0	0.331
7	0	0	0	0.243
6	0	0	0	0.222
5	0	0	0	0.301
4	0	0	0	0.301
3	0	0	0	0.301
2	1	2	4	0.176
1	4	4	4	0.301
0	9	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.602	14	6	8	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
9	0	0	0	
8	0	0	0	0.331
7	0	0	0	0.243
6	0	0	0	0.222
5	0	0	0	0.301
4	0	0	0	0.301
3	2	6	18	0.301
2	4	8	16	0.176
1	9	9	9	0.301
0	1	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.602	16	23	43	0.275

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-2.347 log(microF)
0.00450 microF

s (using negatives)
0.1856 log(microF)
1.5 microF

H_{50} (using positives)
-2.344 log(microF)
0.0 microF

s (using positives)
0.2895 log(microF)
1.9 microF

Figure B24: H_{50} Calculations for Mix ID SS #26 – Fine Al-CrO_3

Calculation of 50% impact initiation level from Bruceton data

Modified Bureau of Mines (MBOM) Impact Sensitivity Test

Sample: **SS #26**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	0
79.4	1.9	1	0
63.1	1.8	1	1
50.1	1.7	2	1
39.8	1.6	3	3
31.6	1.5	3	4
25.1	1.4	1	4
20.0	1.3	0	1
15.8	1.2	0	1
12.6	1.1	1	1
10.0	1.0	0	2
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	12	18

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
10	0	0	0	
9	0	0	0	0.100
8	1	8	64	0.100
7	1	7	49	0.100
6	3	18	108	0.100
5	4	20	100	0.100
4	4	16	64	0.100
3	1	3	9	0.099
2	1	2	4	0.102
1	1	1	1	0.098
0	2	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
1.000	18	75	399	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
9	0	0	0	
8	1	8	64	0.100
7	1	7	49	0.100
6	2	12	72	0.100
5	3	15	75	0.100
4	3	12	48	0.100
3	1	3	9	0.100
2	0	0	0	0.099
1	0	0	0	0.102
0	1	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
1.100	12	57	317	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
1.465 log(cm)
29.2 cm
s (using negatives)
0.7805 log(cm)
6.0 cm

H_{50} (using positives)
1.524 log(cm)
33.4 cm
s (using positives)
0.6269 log(cm)
4.2 cm

Calculation of 50% friction initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #26**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force		Frequency	
(lbf)	log(lbf)	+	-
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	2	1
795.0	2.9	1	1
635.0	2.8	4	1
505.0	2.7	4	4
400.0	2.6	2	4
320.0	2.5	2	2
255.0	2.4	0	2
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	15	15

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
8	0	0	0	
7	0	0	0	0.094
6	1	6	36	0.107
5	1	5	25	0.100
4	1	4	16	0.098
3	4	12	36	0.099
2	4	8	16	0.101
1	2	2	2	0.097
0	2	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	N_S	A	B	d
2.407	15	37	131	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
7	0	0	0	
6	0	0	0	0.094
5	2	10	50	0.107
4	1	4	16	0.100
3	4	12	36	0.098
2	4	8	16	0.099
1	2	2	2	0.101
0	2	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	N_S	A	B	d
2.505	15	36	120	0.100

USE EITHER NEGATIVES OR POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.702	log(lbf)
503.5	lbf
s (using negatives)	
0.4320	log(lbf)
2.7	lbf

H_{50} (using positives)	
2.694	log(lbf)
494.7	lbf
s (using positives)	
0.3661	log(lbf)
2.3	lbf

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #26**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	7	13
0.350	-0.5	1	5
0.200	-0.7	1	0
0.120	-0.9	1	0
0.060	-1.2	0	1
0.030	-1.5	0	0
0.015	-1.8	0	1
0.010	-2.0	0	0
0.0050	-2.3	0	0
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	**10**	**20**

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
6	13	78	468	
5	5	25	125	0.331
4	0	0	0	0.243
3	0	0	0	0.222
2	1	2	4	0.301
1	0	0	0	0.301
0	1	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-1.824	20	105	597	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
3	7	21	63	
2	1	2	4	0.331
1	1	1	1	0.243
0	1	0	0	0.222
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-0.921	10	24	68	0.275

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-0.243 log(microF)
0.6 microF
s (using negatives)
1.0317 log(microF)
10.8 microF

H_{50} (using positives)
-0.398 log(microF)
0.3995 microF
s (using positives)
0.4761 log(microF)
3.0 microF

Figure B25: H_{50} Calculations for Mix ID SS #27 – Fine Al-Fe_3O_4

Calculation of 50% impact initiation level from Bruceton data

Modified Bureau of Mines (MBOM) Impact Sensitivity Test

Sample: **SS #27**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.050 log(cm)
112.2 cm
s (using negatives)
0.0047 log(cm)
1.0 cm

H_{50} (using positives)
#NAME? log(cm)
#NAME? cm
s (using positives)
#DIV/0! log(cm)
#DIV/0! cm

Calculation of 50% friction initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #27**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	1	1
795.0	2.9	3	0
635.0	2.8	3	2
505.0	2.7	4	2
400.0	2.6	3	4
320.0	2.5	1	3
255.0	2.4	1	1
200.0	2.3	0	1
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	16	14

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
9	0	0	0	
8	0	0	0	0.094
7	1	7	49	0.107
6	0	0	0	0.100
5	2	10	50	0.098
4	2	8	32	0.099
3	4	12	36	0.101
2	3	6	12	0.097
1	1	1	1	0.099
0	1	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.301	14	44	180	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
8	0	0	0	
7	0	0	0	0.094
6	1	6	36	0.107
5	3	15	75	0.100
4	3	12	48	0.098
3	4	12	36	0.099
2	3	6	12	0.101
1	1	1	1	0.097
0	1	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.407	16	52	208	0.100

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.664 log(lbf)
461.1 lbf

s (using negatives)
0.4854 log(lbf)
3.1 lbf

H_{50} (using positives)
2.680 log(lbf)
479.1 lbf

s (using positives)
0.3979 log(lbf)
2.5 lbf

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #27**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.
where c is the lowest test level, d is the test level interval, $A = \Sigma i{\cdot}n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$
where $B = \Sigma i^2{\cdot}n_i$

Capacitance		Frequency	
(microF)	log(micro F)	+	-
0.750	-0.1	1	0
0.350	-0.5	1	0
0.200	-0.7	1	0
0.120	-0.9	2	0
0.060	-1.2	2	1
0.030	-1.5	4	1
0.015	-1.8	4	5
0.010	-2.0	3	3
0.0050	-2.3	0	2
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	**18**	**12**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
8	0	0	0	
7	0	0	0	0.331
6	0	0	0	0.243
5	0	0	0	0.222
4	1	4	16	0.301
3	1	3	9	0.301
2	5	10	20	0.301
1	3	3	3	0.176
0	2	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.301	12	20	48	0.275

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
7	1	7	49	
6	1	6	36	0.331
5	1	5	25	0.243
4	2	8	32	0.222
3	2	6	18	0.301
2	4	8	16	0.301
1	4	4	4	0.301
0	3	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.000	18	44	180	0.275

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-1.705 log(microF)
0.0197 microF
s (using negatives)
0.5573 log(microF)
3.6 microF

H_{50} (using positives)
-1.465 log(microF)
0.0 microF
s (using positives)
1.8054 log(microF)
63.9 microF

Figure B26: H_{50} Calculations for Mix ID SS #28 – Fine Al-Mn_2O_3

Calculation of 50% impact initiation level from Bruceton data

Modified Bureau of Mines (MBOM) Impact Sensitivity Test

Sample: **SS #28**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height (cm)	log(cm)	Frequency +	Frequency -
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#NAME?	log(cm)
#NAME?	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Calculation of 50% friction initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #28**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	4	15
795.0	2.9	2	4
635.0	2.8	2	0
505.0	2.7	1	1
400.0	2.6	0	1
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	**9**	**21**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
6	0	0	0	
5	0	0	0	0.094
4	15	60	240	0.107
3	4	12	36	0.100
2	0	0	0	0.098
1	1	1	1	0.099
0	1	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.602	21	73	277	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
5	0	0	0	
4	0	0	0	0.094
3	4	12	36	0.107
2	2	4	8	0.100
1	2	2	2	0.098
0	1	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.703	9	18	46	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.998 log(lbf)
995.5 lbf
s (using negatives)
0.1832 log(lbf)
1.5 lbf

H_{50} (using positives)
2.853 log(lbf)
712.3 lbf
s (using positives)
0.1839 log(lbf)
1.5 lbf

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #28**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance		Frequency	
(microF)	log(microF)	+	-
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	0	0
0.030	-1.5	7	0
0.015	-1.8	6	7
0.010	-2.0	1	6
0.0050	-2.3	1	1
0.0025	-2.6	0	1
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	**15**	**15**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
9	0	0	0	
8	0	0	0	0.331
7	0	0	0	0.243
6	0	0	0	0.222
5	0	0	0	0.301
4	0	0	0	0.301
3	7	21	63	0.301
2	6	12	24	0.176
1	1	1	1	0.301
0	1	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.602	15	34	88	0.275

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
8	0	0	0	
7	0	0	0	0.331
6	0	0	0	0.243
5	0	0	0	0.222
4	0	0	0	0.301
3	7	21	63	0.301
2	6	12	24	0.301
1	1	1	1	0.176
0	1	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.301	15	34	88	0.275

USE EITHER NEGATIVES OR POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
-1.841	log(microF)
0.0144	microF
s (using negatives)	
0.3375	log(microF)
2.2	microF

H_{50} (using positives)	
-1.815	log(microF)
0.0153	microF
s (using positives)	
0.3375	log(microF)
2.2	microF

Figure B27: H_{50} Calculations for Mix ID SS #29 – Fine Al-MnO

Calculation of 50% impact initiation level from Bruceton data

Modified Bureau of Mines (MBOM) Impact Sensitivity Test

Sample: **SS #29**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	**0**	**30**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.050 log(cm)
112.2 cm
s (using negatives)
0.0047 log(cm)
1.0 cm

H_{50} (using positives)
#NAME? log(cm)
#NAME? cm
s (using positives)
#DIV/0! log(cm)
#DIV/0! cm

Calculation of 50% friction initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #29**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	0	30
795.0	2.9	0	0
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
2	0	0	0	
1	0	0	0	0.094
0	30	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
3.000	30	0	0	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.094
FALSE	0	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
3.050	log(lbf)
1121.5	lbf
s (using negatives)	
0.0047	log(lbf)
1.0	lbf

H_{50} (using positives)	
#NAME?	log(lbf)
#NAME?	lbf
s (using positives)	
#DIV/0!	log(lbf)
#DIV/0!	lbf

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #29**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(micro F)	Frequency +	Frequency -
0.750	-0.1	4	0
0.350	-0.5	3	1
0.200	-0.7	4	2
0.120	-0.9	1	3
0.060	-1.2	4	0
0.030	-1.5	1	3
0.015	-1.8	1	2
0.010	-2.0	0	1
0.0050	-2.3	0	0
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	18	12

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
7	0	0	0	
6	1	6	36	0.331
5	2	10	50	0.243
4	3	12	48	0.222
3	0	0	0	0.301
2	3	6	12	0.301
1	2	2	2	0.301
0	1	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.000	12	36	148	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
6	4	24	144	
5	3	15	75	0.331
4	4	16	64	0.243
3	1	3	9	0.222
2	4	8	16	0.301
1	1	1	1	0.301
0	1	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-1.824	18	67	309	0.275

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-1.038 log(microF)
0.0917 microF
s (using negatives)
1.4975 log(microF)
31.4 microF

H_{50} (using positives)
-0.938 log(microF)
0.1 microF
s (using positives)
1.4879 log(microF)
30.8 microF

Figure B28: H_{50} Calculations for Mix ID SS #30 – Fine Al-NiO

Calculation of 50% impact initiation level from Bruceton data

Modified Bureau of Mines (MBOM) Impact Sensitivity Test

Sample: **SS #30**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height (cm)	log(cm)	Frequency +	Frequency -
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	**0**	**30**

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.050 log(cm)
112.2 cm
s (using negatives)
0.0047 log(cm)
1.0 cm

H_{50} (using positives)
#NAME? log(cm)
#NAME? cm
s (using positives)
#DIV/0! log(cm)
#DIV/0! cm

Calculation of 50% friction initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #30**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	1	28
795.0	2.9	0	1
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	**1**	**29**
		51.0	
		0.0000	

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
3	0	0	0	
2	0	0	0	0.094
1	28	28	28	0.107
0	1	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.900	29	28	28	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
2	0	0	0	
1	0	0	0	0.094
0	1	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
3.000	1	0	0	0.100

H_{50} (using negatives)
3.046 log(lbf)
1112.5 lbf
s (using negatives)
0.0101 log(lbf)
1.0 lbf

H_{50} (using positives)
2.950 log(lbf)
891.7 lbf
s (using positives)
0.0047 log(lbf)
1.0 lbf

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #30**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance		Frequency	
(microF)	log(microF)	+	-
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	0	0
0.030	-1.5	0	0
0.015	-1.8	1	0
0.010	-2.0	1	0
0.0050	-2.3	1	0
0.0025	-2.6	1	0
0.0012	-2.9	1	0
0.0007	-3.2	1	0
0.0003	-3.5	2	0
0.0002	-3.7	21	1
0.0000	0	0	0
	SUM	29	1

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
13	0	0	0	
12	0	0	0	0.331
11	0	0	0	0.243
10	0	0	0	0.222
9	0	0	0	0.301
8	0	0	0	0.301
7	0	0	0	0.301
6	0	0	0	0.176
5	0	0	0	0.301
4	0	0	0	0.301
3	0	0	0	0.319
2	0	0	0	0.234
1	0	0	0	0.368
0	1	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-3.699	1	0	0	0.275

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
13	0	0	0	
12	0	0	0	0.331
11	0	0	0	0.243
10	0	0	0	0.222
9	0	0	0	0.301
8	0	0	0	0.301
7	1	7	49	0.301
6	1	6	36	0.176
5	1	5	25	0.301
4	1	4	16	0.301
3	1	3	9	0.319
2	1	2	4	0.234
1	2	2	2	0.368
0	21	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-3.699	29	29	141	0.275

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
-3.562	log(microF)
0.0003	microF
s (using negatives)	
0.0129	log(microF)
1.0	microF

H_{50} (using positives)	
-3.562	log(microF)
0.0003	microF
s (using positives)	
1.7330	log(microF)
54.1	microF

Figure B29: H_{50} Calculations for Mix ID SS #31 – Fine Al-Sb_2O_3

Calculation of 50% impact initiation level from Bruceton data

Modified Bureau of Mines (MBOM) Impact Sensitivity Test

Sample: **SS #31**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	**0**	**30**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.050 log(cm)
112.2 cm
s (using negatives)
0.0047 log(cm)
1.0 cm

H_{50} (using positives)
#NAME? log(cm)
#NAME? cm
s (using positives)
#DIV/0! log(cm)
#DIV/0! cm

Calculation of 50% friction initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #31**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	6	2
795.0	2.9	5	5
635.0	2.8	3	4
505.0	2.7	2	2
400.0	2.6	0	1
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	16	14

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
6	0	0	0	
5	0	0	0	0.094
4	2	8	32	0.107
3	5	15	45	0.100
2	4	8	16	0.098
1	2	2	2	0.099
0	1	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.602	14	33	95	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
5	0	0	0	
4	0	0	0	0.094
3	6	18	54	0.107
2	5	10	20	0.100
1	3	3	3	0.098
0	2	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.703	16	31	77	0.100

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.887 log(lbf)
770.2 lbf
s (using negatives)
0.2031 log(lbf)
1.6 lbf

H_{50} (using positives)
2.846 log(lbf)
702.2 lbf
s (using positives)
0.1755 log(lbf)
1.5 lbf

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #31**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	1	0
0.350	-0.5	2	0
0.200	-0.7	2	1
0.120	-0.9	6	1
0.060	-1.2	6	5
0.030	-1.5	0	5
0.015	-1.8	0	1
0.010	-2.0	0	0
0.0050	-2.3	0	0
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	**17**	**13**

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
6	0	0	0	
5	0	0	0	0.331
4	1	4	16	0.243
3	1	3	9	0.222
2	5	10	20	0.301
1	5	5	5	0.301
0	1	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-1.824	13	22	50	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
4	1	4	16	
3	2	6	18	0.331
2	2	4	8	0.243
1	6	6	6	0.222
0	6	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-1.222	17	20	48	0.275

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-1.221 log(microF)
0.0601 microF
s (using negatives)
0.4504 log(microF)
2.8 microF

H_{50} (using positives)
-1.036 log(microF)
0.1 microF
s (using positives)
0.6540 log(microF)
4.5 microF

Figure B30: H_{50} Calculations for Mix ID SS #33 – Fine Al-SiO_2

Calculation of 50% impact initiation level from Bruceton data

Modified Bureau of Mines (MBOM) Impact Sensitivity Test

Sample: **SS #33**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.050 log(cm)
112.2 cm
s (using negatives)
0.0047 log(cm)
1.0 cm

H_{50} (using positives)
#NAME? log(cm)
#NAME? cm
s (using positives)
#DIV/0! log(cm)
#DIV/0! cm

Calculation of 50% friction initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #33**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	0	30
795.0	2.9	0	0
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	**0**	**30**

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
2	0	0	0	
1	0	0	0	0.094
0	30	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
3.000	30	0	0	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.094
FALSE	0	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
3.050	log(lbf)
1121.5	lbf
s (using negatives)	
0.0047	log(lbf)
1.0	lbf

H_{50} (using positives)	
#NAME?	log(lbf)
#NAME?	lbf
s (using positives)	
#DIV/0!	log(lbf)
#DIV/0!	lbf

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #33**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(micro F)	Frequency +	Frequency -
0.750	-0.1	1	0
0.350	-0.5	1	0
0.200	-0.7	1	0
0.120	-0.9	3	0
0.060	-1.2	5	2
0.030	-1.5	5	4
0.015	-1.8	1	6
0.010	-2.0	0	1
0.0050	-2.3	0	0
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	17	13

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
7	0	0	0	
6	0	0	0	0.331
5	0	0	0	0.243
4	0	0	0	0.222
3	2	6	18	0.301
2	4	8	16	0.301
1	6	6	6	0.301
0	1	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.000	13	20	40	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
6	1	6	36	
5	1	5	25	0.331
4	1	4	16	0.243
3	3	9	27	0.222
2	5	10	20	0.301
1	5	5	5	0.301
0	1	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-1.824	17	39	129	0.275

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-1.440 log(microF)
0.0363 microF
s (using negatives)
0.3292 log(microF)
2.1 microF

H_{50} (using positives)
-1.331 log(microF)
0.0 microF
s (using positives)
1.0485 log(microF)
11.2 microF

Figure B31: H_{50} Calculations for Mix ID SS #34 – Fine Al-SnO

Calculation of 50% impact initiation level from Bruceton data

Modified Bureau of Mines (MBOM) Impact Sensitivity Test

Sample: **SS #34**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	**0**	**30**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.050 log(cm)
112.2 cm
s (using negatives)
0.0047 log(cm)
1.0 cm

H_{50} (using positives)
#NAME? log(cm)
#NAME? cm
s (using positives)
#DIV/0! log(cm)
#DIV/0! cm

Calculation of 50% friction initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #34**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	Force log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	7	10
795.0	2.9	3	7
635.0	2.8	0	3
505.0	2.7	0	0
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	**10**	**20**

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
4	0	0	0	
3	0	0	0	0.094
2	10	20	40	0.107
1	7	7	7	0.100
0	3	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.803	20	27	47	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
3	0	0	0	
2	0	0	0	0.094
1	7	7	7	0.107
0	3	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.900	10	7	7	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.987	log(lbf)
970.5	lbf
s (using negatives)	
0.0898	log(lbf)
1.2	lbf

H_{50} (using positives)	
2.920	log(lbf)
832.3	lbf
s (using positives)	
0.0386	log(lbf)
1.1	lbf

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #34**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	1	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	1	0
0.030	-1.5	2	0
0.015	-1.8	7	2
0.010	-2.0	5	7
0.0050	-2.3	0	5
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	16	14

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
8	0	0	0	
7	0	0	0	0.331
6	0	0	0	0.243
5	0	0	0	0.222
4	0	0	0	0.301
3	0	0	0	0.301
2	2	4	8	0.301
1	7	7	7	0.176
0	5	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.301	14	11	15	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
7	1	7	49	
6	0	0	0	0.331
5	0	0	0	0.243
4	0	0	0	0.222
3	1	3	9	0.301
2	2	4	8	0.301
1	7	7	7	0.301
0	5	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.000	16	21	73	0.275

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-1.948 log(microF)
0.0113 microF
s (using negatives)
0.2152 log(microF)
1.6 microF

H_{50} (using positives)
-1.777 log(microF)
0.0 microF
s (using positives)
1.2777 log(microF)
19.0 microF

Figure B32: H_{50} Calculations for Mix ID SS #35 – Fine Al-ZnO

Calculation of 50% impact initiation level from Bruceton data

Modified Bureau of Mines (MBOM) Impact Sensitivity Test

Sample: **SS #35**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	**0**	**30**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.050 log(cm)
112.2 cm
s (using negatives)
0.0047 log(cm)
1.0 cm

H_{50} (using positives)
#NAME? log(cm)
#NAME? cm
s (using positives)
#DIV/0! log(cm)
#DIV/0! cm

Calculation of 50% friction initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #35**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force		Frequency	
(lbf)	log(lbf)	+	-
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	0	30
795.0	2.9	0	0
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
2	0	0	0	
1	0	0	0	0.094
0	30	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	N_S	A	B	d
3.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.094
FALSE	0	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	N_S	A	B	d
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
3.050	log(lbf)
1121.5	lbf
s (using negatives)	
0.0047	log(lbf)
1.0	lbf

H_{50} (using positives)	
#NAME?	log(lbf)
#NAME?	lbf
s (using positives)	
#DIV/0!	log(lbf)
#DIV/0!	lbf

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #35**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance		Frequency	
(microF)	log(microF)	+	-
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	1	0
0.060	-1.2	10	1
0.030	-1.5	1	11
0.015	-1.8	1	2
0.010	-2.0	0	1
0.0050	-2.3	0	1
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	1
	SUM	**13**	**17**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
14	0	0	0	
13	0	0	0	0.331
12	0	0	0	0.243
11	0	0	0	0.222
10	1	10	100	0.301
9	11	99	891	0.301
8	2	16	128	0.301
7	1	7	49	0.176
6	1	6	36	0.301
5	0	0	0	0.301
4	0	0	0	0.319
3	0	0	0	0.234
2	0	0	0	0.368
1	0	0	0	0.176
0	1	0	0	
c	**N_S**	**A**	**B**	**d**
0.000	17	138	1204	0.275

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
6	0	0	0	
5	0	0	0	0.331
4	0	0	0	0.243
3	1	3	9	0.222
2	10	20	40	0.301
1	1	1	1	0.301
0	1	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-1.824	13	24	50	0.275

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.369 log(microF)
234.0 microF
s (using negatives)
2.2074 log(microF)
161.2 microF

H_{50} (using positives)
-1.454 log(microF)
0.0352 microF
s (using positives)
0.2079 log(microF)
1.6 microF

Figure B33: H_{50} Calculations for Mix ID SS #36 – Fine Al-ZrO_2

Calculation of 50% impact initiation level from Bruceton data

Modified Bureau of Mines (MBOM) Impact Sensitivity Test

Sample: **SS #36**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height (cm)	log(cm)	Frequency +	Frequency -
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	**0**	**30**

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.050 log(cm)
112.2 cm
s (using negatives)
0.0047 log(cm)
1.0 cm

H_{50} (using positives)
#NAME? log(cm)
#NAME? cm
s (using positives)
#DIV/0! log(cm)
#DIV/0! cm

Calculation of 50% friction initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #36**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force		Frequency	
(lbf)	log(lbf)	+	-
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	0	30
795.0	2.9	0	0
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	$i^2(-)\cdot n(-)$	Interval
2	0	0	0	
1	0	0	0	0.094
0	30	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	N_S	A	B	d
3.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	$i^2(+)\cdot n(+)$	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.094
FALSE	0	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	N_S	A	B	d
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
3.050 log(lbf)
1121.5 lbf
s (using negatives)
0.0047 log(lbf)
1.0 lbf

H_{50} (using positives)
#NAME? log(lbf)
#NAME? lbf
s (using positives)
#DIV/0! log(lbf)
#DIV/0! lbf

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #36**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance		Frequency	
(microF)	log(micro F)	+	-
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	0	0
0.030	-1.5	4	0
0.015	-1.8	9	4
0.010	-2.0	3	8
0.0050	-2.3	0	2
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	16	14

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
8	0	0	0	
7	0	0	0	0.331
6	0	0	0	0.243
5	0	0	0	0.222
4	0	0	0	0.301
3	0	0	0	0.301
2	4	8	16	0.301
1	8	8	8	0.176
0	2	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	N_S	A	B	d
-2.301	14	16	24	0.275

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
7	0	0	0	
6	0	0	0	0.331
5	0	0	0	0.243
4	0	0	0	0.222
3	0	0	0	0.301
2	4	8	16	0.301
1	9	9	9	0.301
0	3	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	N_S	A	B	d
-2.000	16	17	25	0.275

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
-1.849	log(microF)
0.0141	microF
s (using negatives)	
0.1947	log(microF)
1.6	microF

H_{50} (using positives)	
-1.845	log(microF)
0.0	microF
s (using positives)	
0.2060	log(microF)
1.6	microF

Figure B34: H_{50} Calculations for Mix ID SS #37 – Fine Mg-Al_2O_3

Calculation of 50% impact initiation level from Bruceton data

Modified Bureau of Mines (MBOM) Impact Sensitivity Test

Sample: **SS #37**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	**0**	**30**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#NAME?	log(cm)
#NAME?	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Calculation of 50% friction initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #37**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	1	28
795.0	2.9	0	1
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	**1**	**29**

CALCULATIONS USING NEGATIVES				
i	**n(-)**	**i(-)·n(-)**	**i^2(-)·n(-)**	**Interval**
3	0	0	0	
2	0	0	0	0.094
1	28	28	28	0.107
0	1	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.900	29	28	28	0.100

CALCULATIONS USING POSITIVES				
i(+)	**n(+)**	**i(+)·n(+)**	**i^2(+)·n(+)**	**Interval**
2	0	0	0	
1	0	0	0	0.094
0	1	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
3.000	1	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
3.046 log(lbf)
1112.5 lbf
s (using negatives)
0.0101 log(lbf)
1.0 lbf

H_{50} (using positives)
2.950 log(lbf)
891.7 lbf
s (using positives)
0.0047 log(lbf)
1.0 lbf

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #37**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(micro F)	Frequency +	Frequency -
0.750	-0.1	1	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	1	0
0.060	-1.2	1	0
0.030	-1.5	5	0
0.015	-1.8	7	5
0.010	-2.0	2	6
0.0050	-2.3	0	2
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	**17**	**13**

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
8	0	0	0	
7	0	0	0	0.331
6	0	0	0	0.243
5	0	0	0	0.222
4	0	0	0	0.301
3	0	0	0	0.301
2	5	10	20	0.301
1	6	6	6	0.176
0	2	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.301	13	16	26	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
7	1	7	49	
6	0	0	0	0.331
5	0	0	0	0.243
4	1	4	16	0.222
3	1	3	9	0.301
2	5	10	20	0.301
1	7	7	7	0.301
0	2	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.000	17	31	101	0.275

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-1.825 log(microF)
0.0150 microF
s (using negatives)
0.2290 log(microF)
1.7 microF

H_{50} (using positives)
-1.636 log(microF)
0.0 microF
s (using positives)
1.1780 log(microF)
15.1 microF

Figure B35: H_{50} Calculations for Mix ID SS #38 – Fine Mg-CrO_3

Calculation of 50% impact initiation level from Bruceton data

Modified Bureau of Mines (MBOM) Impact Sensitivity Test

Sample: **SS #38**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	0
79.4	1.9	1	0
63.1	1.8	2	1
50.1	1.7	5	3
39.8	1.6	4	6
31.6	1.5	0	5
25.1	1.4	0	1
20.0	1.3	0	1
15.8	1.2	0	1
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	12	18

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
8	0	0	0	
7	0	0	0	0.100
6	1	6	36	0.100
5	3	15	75	0.100
4	6	24	96	0.100
3	5	15	45	0.100
2	1	2	4	0.100
1	1	1	1	0.099
0	1	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
1.199	18	63	257	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
4	0	0	0	
3	1	3	9	0.100
2	2	4	8	0.100
1	5	5	5	0.100
0	4	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
1.600	12	12	22	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
1.597 log(cm)
39.6 cm
s (using negatives)
0.3321 log(cm)
2.1 cm

H_{50} (using positives)
1.650 log(cm)
44.6 cm
s (using positives)
0.1392 log(cm)
1.4 cm

Calculation of 50% friction initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #38**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	Force log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	0	30
795.0	2.9	0	0
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	**0**	**30**

CALCULATIONS USING NEGATIVES				
i	**n(-)**	**i(-)·n(-)**	**i²(-)·n(-)**	**Interval**
2	0	0	0	
1	0	0	0	0.094
0	30	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
3.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	**n(+)**	**i(+)·n(+)**	**i²(+)·n(+)**	**Interval**
FALSE	0	0	0	
FALSE	0	0	0	0.094
FALSE	0	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
3.050	log(lbf)
1121.5	lbf
s (using negatives)	
0.0047	log(lbf)
1.0	lbf

H_{50} (using positives)	
#NAME?	log(lbf)
#NAME?	lbf
s (using positives)	
#DIV/0!	log(lbf)
#DIV/0!	lbf

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #38**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance		Frequency	
(microF)	log(microF)	+	-
0.750	-0.1	0	29
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	0	0
0.030	-1.5	0	0
0.015	-1.8	0	0
0.010	-2.0	1	0
0.0050	-2.3	0	0
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	1	29

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	29	0	0	
FALSE	0	0	0	0.331
FALSE	0	0	0	0.243
FALSE	0	0	0	0.222
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	N_S	A	B	d
-0.125	29	0	0	0.275

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
7	0	0	0	
6	0	0	0	0.331
5	0	0	0	0.243
4	0	0	0	0.222
3	0	0	0	0.301
2	0	0	0	0.301
1	0	0	0	0.301
0	1	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	N_S	A	B	d
-2.000	1	0	0	0.275

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
0.013 log(microF)
1.0 microF
s (using negatives)
0.0129 log(microF)
1.0 microF

H_{50} (using positives)
-2.137 log(microF)
0.0 microF
s (using positives)
0.0129 log(microF)
1.0 microF

Figure B36: H_{50} Calculations for Mix ID SS #39 – Fine Mg-Bi_2O_3

Calculation of 50% impact initiation level from Bruceton data

Modified Bureau of Mines (MBOM) Impact Sensitivity Test

Sample: **SS #39**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	4	7
79.4	1.9	2	3
63.1	1.8	4	1
50.1	1.7	1	3
39.8	1.6	2	0
31.6	1.5	1	1
25.1	1.4	0	1
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	14	16

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
6	7	42	252	
5	3	15	75	0.100
4	1	4	16	0.100
3	3	9	27	0.100
2	0	0	0	0.100
1	1	1	1	0.100
0	1	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
1.400	16	71	371	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
5	4	20	100	
4	2	8	32	0.100
3	4	12	36	0.100
2	1	2	4	0.100
1	2	2	2	0.100
0	1	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
1.500	14	44	174	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
1.892 log(cm)
77.9 cm
s (using negatives)
0.5691 log(cm)
3.7 cm

H_{50} (using positives)
1.763 log(cm)
58.0 cm
s (using positives)
0.4165 log(cm)
2.6 cm

Calculation of 50% friction initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS # 39**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force		Frequency	
(lbf)	log(lbf)	+	-
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	12	7
795.0	2.9	2	7
635.0	2.8	0	2
505.0	2.7	0	0
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	**14**	**16**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
4	0	0	0	
3	0	0	0	0.094
2	7	14	28	0.107
1	7	7	7	0.100
0	2	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.803	16	21	35	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
3	0	0	0	
2	0	0	0	0.094
1	12	12	12	0.107
0	2	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.900	14	12	12	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.983	log(lbf)
962.2	lbf
s (using negatives)	
0.0797	log(lbf)
1.2	lbf

H_{50} (using positives)	
2.936	log(lbf)
862.8	lbf
s (using positives)	
0.0244	log(lbf)
1.1	lbf

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #39**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance		Frequency	
(microF)	log(micro F)	+	-
0.750	-0.1	2	11
0.350	-0.5	1	2
0.200	-0.7	4	2
0.120	-0.9	1	5
0.060	-1.2	0	1
0.030	-1.5	0	0
0.015	-1.8	0	1
0.010	-2.0	0	0
0.0050	-2.3	0	0
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	8	22

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
6	11	66	396	
5	2	10	50	0.331
4	2	8	32	0.243
3	5	15	45	0.222
2	1	2	4	0.301
1	0	0	0	0.301
0	1	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	N_S	A	B	d
-1.824	22	101	527	0.275

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
3	2	6	18	
2	1	2	4	0.331
1	4	4	4	0.243
0	1	0	0	0.222
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	N_S	A	B	d
-0.921	8	12	26	0.275

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-0.424 log(microF)
0.4 microF
s (using negatives)
1.2948 log(microF)
19.7 microF

H_{50} (using positives)
-0.646 log(microF)
0.2260 microF
s (using positives)
0.4583 log(microF)
2.9 microF

Figure B37: H_{50} Calculations for Mix ID SS #40 – Fine Mg-Co_3O_4

Calculation of 50% impact initiation level from Bruceton data

Modified Bureau of Mines (MBOM) Impact Sensitivity Test

Sample: **SS #40**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height (cm)	log(cm)	Frequency +	Frequency -
100	2.0	2	26
79.4	1.9	0	2
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	2	28

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
1	26	26	26	
0	2	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
1.900	28	26	26	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
0	2	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.000	2	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.042 log(cm)
110.2 cm
s (using negatives)
0.0154 log(cm)
1.0 cm

H_{50} (using positives)
1.950 log(cm)
89.2 cm
s (using positives)
0.0047 log(cm)
1.0 cm

Calculation of 50% friction initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS # 40**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	2	26
795.0	2.9	0	2
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	2	28

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
3	0	0	0	
2	0	0	0	0.094
1	26	26	26	0.107
0	2	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.900	28	26	26	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
2	0	0	0	
1	0	0	0	0.094
0	2	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
3.000	2	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
3.043 log(lbf)
1103.2 lbf
s (using negatives)
0.0154 log(lbf)
1.0 lbf

H_{50} (using positives)
2.950 log(lbf)
891.7 lbf
s (using positives)
0.0047 log(lbf)
1.0 lbf

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #40**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	3	17
0.350	-0.5	3	3
0.200	-0.7	0	3
0.120	-0.9	0	0
0.060	-1.2	0	0
0.030	-1.5	0	0
0.015	-1.8	0	1
0.010	-2.0	0	0
0.0050	-2.3	0	0
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	**6**	**24**

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
6	17	102	612	
5	3	15	75	0.331
4	3	12	48	0.243
3	0	0	0	0.222
2	0	0	0	0.301
1	0	0	0	0.301
0	1	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-1.824	24	129	735	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
1	3	3	3	
0	3	0	0	0.331
FALSE	0	0	0	0.243
FALSE	0	0	0	0.222
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-0.456	6	3	3	0.275

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-0.209 log(microF)
0.6 microF
s (using negatives)
0.7854 log(microF)
6.1 microF

H_{50} (using positives)
-0.456 log(microF)
0.350 microF
s (using positives)
0.1243 log(microF)
1.3 microF

Figure B38: H_{50} Calculations for Mix ID SS #41 – Fine Mg-Cr_2O_3

Calculation of 50% impact initiation level from Bruceton data

Modified Bureau of Mines (MBOM) Impact Sensitivity Test

Sample: **SS #41**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.050 log(cm)
112.2 cm
s (using negatives)
0.0047 log(cm)
1.0 cm

H_{50} (using positives)
#NAME? log(cm)
#NAME? cm
s (using positives)
#DIV/0! log(cm)
#DIV/0! cm

Calculation of 50% friction initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #41**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	Force log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	1	28
795.0	2.9	0	1
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	**1**	**29**

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
3	0	0	0	
2	0	0	0	0.094
1	28	28	28	0.107
0	1	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.900	29	28	28	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
2	0	0	0	
1	0	0	0	0.094
0	1	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
3.000	1	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
3.046	log(lbf)
1112.5	lbf
s (using negatives)	
0.0101	log(lbf)
1.0	lbf

H_{50} (using positives)	
2.950	log(lbf)
891.7	lbf
s (using positives)	
0.0047	log(lbf)
1.0	lbf

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #41**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance		Frequency	
(microF)	log(micro F)	+	-
0.750	-0.1	1	0
0.350	-0.5	0	0
0.200	-0.7	2	0
0.120	-0.9	2	2
0.060	-1.2	4	1
0.030	-1.5	3	3
0.015	-1.8	1	4
0.010	-2.0	3	1
0.0050	-2.3	0	3
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	16	14

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	$i^2(-)\cdot n(-)$	Interval
8	0	0	0	
7	0	0	0	0.331
6	0	0	0	0.243
5	2	10	50	0.222
4	1	4	16	0.301
3	3	9	27	0.301
2	4	8	16	0.301
1	1	1	1	0.176
0	3	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	N_S	A	B	d
-2.301	14	32	110	0.275

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	$i^2(+)\cdot n(+)$	Interval
7	1	7	49	
6	0	0	0	0.331
5	2	10	50	0.243
4	2	8	32	0.222
3	4	12	36	0.301
2	3	6	12	0.301
1	1	1	1	0.301
0	3	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	N_S	A	B	d
-2.000	16	44	180	0.275

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-1.535 log(microF)
0.0292 microF
s (using negatives)
1.1854 log(microF)
15.3 microF

H_{50} (using positives)
-1.381 log(microF)
0.0416 microF
s (using positives)
1.6553 log(microF)
45.2 microF

Figure B39: H_{50} Calculations for Mix ID SS #42 – Fine $Mg\text{-}MoO_3$

Calculation of 50% impact initiation level from Bruceton data

Modified Bureau of Mines (MBOM) Impact Sensitivity Test

Sample: **SS #42**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.050 log(cm)
112.2 cm
s (using negatives)
0.0047 log(cm)
1.0 cm

H_{50} (using positives)
#NAME? log(cm)
#NAME? cm
s (using positives)
#DIV/0! log(cm)
#DIV/0! cm

Calculation of 50% friction initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #42**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	5	18
795.0	2.9	2	3
635.0	2.8	0	2
505.0	2.7	0	0
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	7	23

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
4	0	0	0	
3	0	0	0	0.094
2	18	36	72	0.107
1	3	3	3	0.100
0	2	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.803	23	39	75	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
3	0	0	0	
2	0	0	0	0.094
1	5	5	5	0.107
0	2	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.900	7	5	5	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
3.021	log(lbf)
1050.6	lbf
s (using negatives)	
0.0669	log(lbf)
1.2	lbf

H_{50} (using positives)	
2.922	log(lbf)
835.0	lbf
s (using positives)	
0.0376	log(lbf)
1.1	lbf

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #42**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(micro F)	Frequency +	Frequency -
0.750	-0.1	1	0
0.350	-0.5	2	0
0.200	-0.7	3	1
0.120	-0.9	2	2
0.060	-1.2	6	2
0.030	-1.5	2	6
0.015	-1.8	0	3
0.010	-2.0	0	0
0.0050	-2.3	0	0
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	**16**	**14**

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
6	0	0	0	
5	0	0	0	0.331
4	1	4	16	0.243
3	2	6	18	0.222
2	2	4	8	0.301
1	6	6	6	0.301
0	3	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-1.824	14	20	48	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
5	1	5	25	
4	2	8	32	0.331
3	3	9	27	0.243
2	2	4	8	0.222
1	6	6	6	0.301
0	2	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-1.523	16	32	98	0.275

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-1.294 log(microF)
0.0509 microF
s (using negatives)
0.6310 log(microF)
4.3 microF

H_{50} (using positives)
-1.110 log(microF)
0.1 microF
s (using positives)
0.9593 log(microF)
9.1 microF

Figure B40: H_{50} Calculations for Mix ID SS #43 – Fine Mg-SiO_2

Calculation of 50% impact initiation level from Bruceton data

Modified Bureau of Mines (MBOM) Impact Sensitivity Test

Sample: **SS #43**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.050 log(cm)
112.2 cm
s (using negatives)
0.0047 log(cm)
1.0 cm

H_{50} (using positives)
#NAME? log(cm)
#NAME? cm
s (using positives)
#DIV/0! log(cm)
#DIV/0! cm

Calculation of 50% friction initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #43**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force		Frequency	
(lbf)	log(lbf)	+	-
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	0	30
795.0	2.9	0	0
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
2	0	0	0	
1	0	0	0	0.094
0	30	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	N_S	A	B	d
3.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.094
FALSE	0	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	N_S	A	B	d
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
3.050 log(lbf)
1121.5 lbf
s (using negatives)
0.0047 log(lbf)
1.0 lbf

H_{50} (using positives)
#NAME? log(lbf)
#NAME? lbf
s (using positives)
#DIV/0! log(lbf)
#DIV/0! lbf

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #43**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance		Frequency	
(microF)	log(micro F)	+	-
0.750	-0.1	1	0
0.350	-0.5	3	0
0.200	-0.7	2	2
0.120	-0.9	1	1
0.060	-1.2	6	1
0.030	-1.5	3	6
0.015	-1.8	0	4
0.010	-2.0	0	0
0.0050	-2.3	0	0
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	**16**	**14**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
6	0	0	0	
5	0	0	0	0.331
4	2	8	32	0.243
3	1	3	9	0.222
2	1	2	4	0.301
1	6	6	6	0.301
0	4	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-1.824	14	19	51	0.275

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
5	1	5	25	
4	3	12	48	0.331
3	2	6	18	0.243
2	1	2	4	0.222
1	6	6	6	0.301
0	3	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-1.523	16	31	101	0.275

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-1.313 log(microF)
0.0486 microF
s (using negatives)
0.8151 log(microF)
6.5 microF

H_{50} (using positives)
-1.128 log(microF)
0.1 microF
s (using positives)
1.1525 log(microF)
14.2 microF

Figure B41: H_{50} Calculations for Mix ID SS #44 – Fine $Mg\text{-}SnO_2$

Calculation of 50% impact initiation level from Bruceton data

Modified Bureau of Mines (MBOM) Impact Sensitivity Test

Sample: **SS #44**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.050 log(cm)
112.2 cm
s (using negatives)
0.0047 log(cm)
1.0 cm

H_{50} (using positives)
#NAME? log(cm)
#NAME? cm
s (using positives)
#DIV/0! log(cm)
#DIV/0! cm

Calculation of 50% friction initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #44**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	Force log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	0	30
795.0	2.9	0	0
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
2	0	0	0	
1	0	0	0	0.094
0	30	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	N_S	A	B	d
3.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.094
FALSE	0	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	N_S	A	B	d
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
3.050	log(lbf)
1121.5	lbf
s (using negatives)	
0.0047	log(lbf)
1.0	lbf

H_{50} (using positives)	
#NAME?	log(lbf)
#NAME?	lbf
s (using positives)	
#DIV/0!	log(lbf)
#DIV/0!	lbf

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: SS #44

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(micro F)	Frequency +	Frequency -
0.750	-0.1	3	0
0.350	-0.5	6	2
0.200	-0.7	3	5
0.120	-0.9	2	2
0.060	-1.2	3	1
0.030	-1.5	0	2
0.015	-1.8	0	1
0.010	-2.0	0	0
0.0050	-2.3	0	0
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	17	13

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
6	0	0	0	
5	2	10	50	0.331
4	5	20	80	0.243
3	2	6	18	0.222
2	1	2	4	0.301
1	2	2	2	0.301
0	1	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-1.824	13	40	154	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
4	3	12	48	
3	6	18	54	0.331
2	3	6	12	0.243
1	2	2	2	0.222
0	3	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-1.222	17	38	116	0.275

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-0.841 log(microF)
0.1444 microF
s (using negatives)
1.0723 log(microF)
11.8 microF

H_{50} (using positives)
-0.745 log(microF)
0.2 microF
s (using positives)
0.8266 log(microF)
6.7 microF

Figure B42: H_{50} Calculations for Mix ID SS #45 – Fine Mg-WO_3

Calculation of 50% impact initiation level from Bruceton data

Modified Bureau of Mines (MBOM) Impact Sensitivity Test

Sample: **SS #45**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height (cm)	log(cm)	Frequency +	Frequency -
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.050 log(cm)
112.2 cm
s (using negatives)
0.0047 log(cm)
1.0 cm

H_{50} (using positives)
#NAME? log(cm)
#NAME? cm
s (using positives)
#DIV/0! log(cm)
#DIV/0! cm

Calculation of 50% friction initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #45**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	4	23
795.0	2.9	0	3
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	4	26

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
3	0	0	0	
2	0	0	0	0.094
1	23	23	23	0.107
0	3	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.900	26	23	23	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
2	0	0	0	
1	0	0	0	0.094
0	4	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
3.000	4	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
3.038 log(lbf)
1092.1 lbf
s (using negatives)
0.0211 log(lbf)
1.0 lbf

H_{50} (using positives)
2.950 log(lbf)
891.7 lbf
s (using positives)
0.0047 log(lbf)
1.0 lbf

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #45**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance		Frequency	
(microF)	log(micro F)	+	-
0.750	-0.1	1	0
0.350	-0.5	1	0
0.200	-0.7	1	0
0.120	-0.9	1	0
0.060	-1.2	11	0
0.030	-1.5	2	10
0.015	-1.8	1	2
0.010	-2.0	0	0
0.0050	-2.3	0	0
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	**18**	**12**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
6	0	0	0	
5	0	0	0	0.331
4	0	0	0	0.243
3	0	0	0	0.222
2	0	0	0	0.301
1	10	10	10	0.301
0	2	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-1.824	12	10	10	0.275

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
6	1	6	36	
5	1	5	25	0.331
4	1	4	16	0.243
3	1	3	9	0.222
2	11	22	44	0.301
1	2	2	2	0.301
0	1	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-1.824	18	42	132	0.275

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-1.457 log(microF)
0.0349 microF
s (using negatives)
0.0748 log(microF)
1.2 microF

H_{50} (using positives)
-1.320 log(microF)
0.0 microF
s (using positives)
0.8542 log(microF)
7.1 microF

Figure B43: H_{50} Calculations for Mix ID SS #46 – Fine Ti-Al_2O_3

Calculation of 50% impact initiation level from Bruceton data

Modified Bureau of Mines (MBOM) Impact Sensitivity Test

Sample: **SS #46**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.050 log(cm)
112.2 cm
s (using negatives)
0.0047 log(cm)
1.0 cm

H_{50} (using positives)
#NAME? log(cm)
#NAME? cm
s (using positives)
#DIV/0! log(cm)
#DIV/0! cm

Calculation of 50% friction initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #46**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	1	28
795.0	2.9	0	1
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	1	29

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
3	0	0	0	
2	0	0	0	0.094
1	28	28	28	0.107
0	1	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.900	29	28	28	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
2	0	0	0	
1	0	0	0	0.094
0	1	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
3.000	1	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
3.046	log(lbf)
1112.5	lbf
s (using negatives)	
0.0101	log(lbf)
1.0	lbf

H_{50} (using positives)	
2.950	log(lbf)
891.7	lbf
s (using positives)	
0.0047	log(lbf)
1.0	lbf

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #46**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(micro F)	Frequency +	Frequency -
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	0	0
0.030	-1.5	0	0
0.015	-1.8	1	0
0.010	-2.0	0	0
0.0050	-2.3	0	0
0.0025	-2.6	0	0
0.0012	-2.9	1	0
0.0007	-3.2	2	1
0.0003	-3.5	9	2
0.0002	-3.7	4	10
0.0000	0	0	0
	SUM	17	13

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
13	0	0	0	
12	0	0	0	0.331
11	0	0	0	0.243
10	0	0	0	0.222
9	0	0	0	0.301
8	0	0	0	0.301
7	0	0	0	0.301
6	0	0	0	0.176
5	0	0	0	0.301
4	0	0	0	0.301
3	0	0	0	0.319
2	1	2	4	0.234
1	2	2	2	0.368
0	10	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-3.699	13	4	6	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
13	0	0	0	
12	0	0	0	0.331
11	0	0	0	0.243
10	0	0	0	0.222
9	0	0	0	0.301
8	0	0	0	0.301
7	1	7	49	0.301
6	0	0	0	0.176
5	0	0	0	0.301
4	0	0	0	0.301
3	1	3	9	0.319
2	2	4	8	0.234
1	9	9	9	0.368
0	4	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-3.699	17	23	75	0.275

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-3.477 log(microF)
0.0003 microF
s (using negatives)
0.1763 log(microF)
1.5 microF

H_{50} (using positives)
-3.464 log(microF)
0.0 microF
s (using positives)
1.1626 log(microF)
14.5 microF

Figure B44: H_{50} Calculations for Mix ID SS #47 – Fine Ti-CrO_3

Calculation of 50% impact initiation level from Bruceton data

Modified Bureau of Mines (MBOM) Impact Sensitivity Test

Sample: **SS #47**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height (cm)	log(cm)	Frequency +	Frequency -
100	2.0	0	0
79.4	1.9	0	0
63.1	1.8	2	0
50.1	1.7	1	2
39.8	1.6	1	2
31.6	1.5	2	2
25.1	1.4	3	2
20.0	1.3	2	4
15.8	1.2	2	2
12.6	1.1	1	1
10.0	1.0	0	1
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	14	16

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
10	0	0	0	
9	0	0	0	0.100
8	0	0	0	0.100
7	2	14	98	0.100
6	2	12	72	0.100
5	2	10	50	0.100
4	2	8	32	0.100
3	4	12	36	0.099
2	2	4	8	0.102
1	1	1	1	0.098
0	1	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
1.000	16	61	297	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
9	0	0	0	
8	0	0	0	0.100
7	2	14	98	0.100
6	1	6	36	0.100
5	1	5	25	0.100
4	2	8	32	0.100
3	3	9	27	0.100
2	2	4	8	0.099
1	2	2	2	0.102
0	1	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
1.100	14	48	228	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
1.430 log(cm)
26.9 cm
s (using negatives)
0.6549 log(cm)
4.5 cm

H_{50} (using positives)
1.392 log(cm)
24.7 cm
s (using positives)
0.7361 log(cm)
5.4 cm

Calculation of 50% friction initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #47**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	1	1
795.0	2.9	1	0
635.0	2.8	5	0
505.0	2.7	3	4
400.0	2.6	5	2
320.0	2.5	2	4
255.0	2.4	0	2
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	17	13

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
8	0	0	0	
7	0	0	0	0.094
6	1	6	36	0.107
5	0	0	0	0.100
4	0	0	0	0.098
3	4	12	36	0.099
2	2	4	8	0.101
1	4	4	4	0.097
0	2	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	N_S	A	B	d
2.407	13	26	84	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
7	0	0	0	
6	0	0	0	0.094
5	1	5	25	0.107
4	1	4	16	0.100
3	5	15	45	0.098
2	3	6	12	0.099
1	5	5	5	0.101
0	2	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	N_S	A	B	d
2.505	17	35	103	0.100

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.656	log(lbf)
452.4	lbf
s (using negatives)	
0.4018	log(lbf)
2.5	lbf

H_{50} (using positives)	
2.660	log(lbf)
457.5	lbf
s (using positives)	
0.2983	log(lbf)
2.0	lbf

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #47**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.
where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$
where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	-
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	0	0
0.030	-1.5	0	0
0.015	-1.8	1	0
0.010	-2.0	0	0
0.0050	-2.3	2	0
0.0025	-2.6	6	2
0.0012	-2.9	4	5
0.0007	-3.2	2	4
0.0003	-3.5	1	1
0.0002	-3.7	1	1
0.0000	0	0	0
	SUM	17	13

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
13	0	0	0	
12	0	0	0	0.331
11	0	0	0	0.243
10	0	0	0	0.222
9	0	0	0	0.301
8	0	0	0	0.301
7	0	0	0	0.301
6	0	0	0	0.176
5	0	0	0	0.301
4	2	8	32	0.301
3	5	15	45	0.319
2	4	8	16	0.234
1	1	1	1	0.368
0	1	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-3.699	13	32	94	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
13	0	0	0	
12	0	0	0	0.331
11	0	0	0	0.243
10	0	0	0	0.222
9	0	0	0	0.301
8	0	0	0	0.301
7	1	7	49	0.301
6	0	0	0	0.176
5	2	10	50	0.301
4	6	24	96	0.301
3	4	12	36	0.319
2	2	4	8	0.234
1	1	1	1	0.368
0	1	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-3.699	17	58	240	0.275

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-2.885 log(microF)
0.0013 microF
s (using negatives)
0.5347 log(microF)
3.4 microF

H_{50} (using positives)
-2.898 log(microF)
0.0 microF
s (using positives)
1.1163 log(microF)
13.1 microF

Figure B45: H_{50} Calculations for Mix ID SS #48 – Fine Ti-Bi_2O_3

Calculation of 50% impact initiation level from Bruceton data

Modified Bureau of Mines (MBOM) Impact Sensitivity Test

Sample: **SS #48**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height (cm)	log(cm)	Frequency +	Frequency -
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	**0**	**30**

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#NAME?	0	0	0	0.100

E POSITIVES

ations are performed using
gatives, whichever has the
equal, either may be used.

H_{50} (using negatives)
2.050 log(cm)
112.2 cm
s (using negatives)
0.0047 log(cm)
1.0 cm

H_{50} (using positives)
#NAME? log(cm)
#NAME? cm
s (using positives)
#DIV/0! log(cm)
#DIV/0! cm

Calculation of 50% friction initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #48**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force		Frequency	
(lbf)	log(lbf)	+	-
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	7	16
795.0	2.9	1	6
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	8	22

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
3	0	0	0	
2	0	0	0	0.094
1	16	16	16	0.107
0	6	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	N_S	A	B	d
2.900	22	16	16	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
3	0	0	0	
2	0	0	0	0.094
1	7	7	7	0.107
0	1	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	N_S	A	B	d
2.900	8	7	7	0.100

E POSITIVES

ıtions are performed using
gatives, whichever has the
equal, either may be used.

H_{50} (using negatives)
3.023 log(lbf)
1053.4 lbf
s (using negatives)
0.0367 log(lbf)
1.1 lbf

H_{50} (using positives)
2.938 log(lbf)
866.4 lbf
s (using positives)
0.0223 log(lbf)
1.1 lbf

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #48**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.
where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$
where $B = \Sigma i^2 \cdot n_i$

Capacitance		Frequency	
(microF)	log(microF)	+	-
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	0	0
0.030	-1.5	0	0
0.015	-1.8	1	0
0.010	-2.0	1	0
0.0050	-2.3	3	1
0.0025	-2.6	4	3
0.0012	-2.9	5	4
0.0007	-3.2	1	4
0.0003	-3.5	0	1
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	**15**	**13**

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
12	0	0	0	
11	0	0	0	0.331
10	0	0	0	0.243
9	0	0	0	0.222
8	0	0	0	0.301
7	0	0	0	0.301
6	0	0	0	0.301
5	0	0	0	0.176
4	1	4	16	0.301
3	3	9	27	0.301
2	4	8	16	0.319
1	4	4	4	0.234
0	1	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-3.523	13	25	63	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
11	0	0	0	
10	0	0	0	0.331
9	0	0	0	0.243
8	0	0	0	0.222
7	0	0	0	0.301
6	0	0	0	0.301
5	1	5	25	0.301
4	1	4	16	0.176
3	3	9	27	0.301
2	4	8	16	0.301
1	5	5	5	0.319
0	1	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-3.155	15	31	89	0.275

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-2.857 log(microF)
0.0014 microF
s (using negatives)
0.5242 log(microF)
3.3 microF

H_{50} (using positives)
-2.724 log(microF)
0.0 microF
s (using positives)
0.7532 log(microF)
5.7 microF

Figure B46: H_{50} Calculations for Mix ID SS #49 – Fine Ti-Co_3O_4

Calculation of 50% impact initiation level from Bruceton data

Modified Bureau of Mines (MBOM) Impact Sensitivity Test

Sample: **SS #49**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height (cm)	log(cm)	Frequency +	Frequency -
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.050 log(cm)
112.2 cm
s (using negatives)
0.0047 log(cm)
1.0 cm

H_{50} (using positives)
#NAME? log(cm)
#NAME? cm
s (using positives)
#DIV/0! log(cm)
#DIV/0! cm

Calculation of 50% friction initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS # 49**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force		Frequency	
(lbf)	log(lbf)	+	-
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	0	0
795.0	2.9	0	0
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	1	0
64.0	1.8	1	1
51.0	1.7	26	1
0.0000	0	0	0
	SUM	28	2

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
15	0	0	0	
14	0	0	0	0.094
13	0	0	0	0.107
12	0	0	0	0.100
11	0	0	0	0.098
10	0	0	0	0.099
9	0	0	0	0.101
8	0	0	0	0.097
7	0	0	0	0.099
6	0	0	0	0.106
5	0	0	0	0.097
4	0	0	0	0.100
3	0	0	0	0.104
2	0	0	0	0.097
1	1	1	1	0.097
0	1	0	0	0.099
FALSE	0	0	0	
c	N_S	A	B	d
1.708	2	1	1	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
15	0	0	0	
14	0	0	0	0.094
13	0	0	0	0.107
12	0	0	0	0.100
11	0	0	0	0.098
10	0	0	0	0.099
9	0	0	0	0.101
8	0	0	0	0.097
7	0	0	0	0.099
6	0	0	0	0.106
5	0	0	0	0.097
4	0	0	0	0.100
3	0	0	0	0.104
2	1	2	4	0.097
1	1	1	1	0.097
0	26	0	0	0.099
FALSE	0	0	0	0.000
c	N_S	A	B	d
1.708	28	3	5	0.100

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
1.807 log(lbf)
64.1 lbf
s (using negatives)
0.0450 log(lbf)
1.1 lbf

H_{50} (using positives)
1.668 log(lbf)
46.6 lbf
s (using positives)
0.0316 log(lbf)
1.1 lbf

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #49**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance		Frequency	
(microF)	log(microF)	+	-
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	0	0
0.030	-1.5	0	0
0.015	-1.8	1	0
0.010	-2.0	0	0
0.0050	-2.3	0	0
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	1	0
0.0003	-3.5	6	2
0.0002	-3.7	14	6
0.0000	0	0	0
	SUM	**22**	**8**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
13	0	0	0	
12	0	0	0	0.331
11	0	0	0	0.243
10	0	0	0	0.222
9	0	0	0	0.301
8	0	0	0	0.301
7	0	0	0	0.301
6	0	0	0	0.176
5	0	0	0	0.301
4	0	0	0	0.301
3	0	0	0	0.319
2	0	0	0	0.234
1	2	2	2	0.368
0	6	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-3.699	8	2	2	0.275

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
13	0	0	0	
12	0	0	0	0.331
11	0	0	0	0.243
10	0	0	0	0.222
9	0	0	0	0.301
8	0	0	0	0.301
7	1	7	49	0.301
6	0	0	0	0.176
5	0	0	0	0.301
4	0	0	0	0.301
3	0	0	0	0.319
2	1	2	4	0.234
1	6	6	6	0.368
0	14	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-3.699	22	15	59	0.275

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-3.493 log(microF)
0.0 microF
s (using negatives)
0.0964 log(microF)
1.2 microF

H_{50} (using positives)
-3.649 log(microF)
0.0 microF
s (using positives)
1.0003 log(microF)
10.0 microF

Figure B47: H_{50} Calculations for Mix ID SS #50 – Fine Ti-Cr_2O_3

Calculation of 50% impact initiation level from Bruceton data

Modified Bureau of Mines (MBOM) Impact Sensitivity Test

Sample: **SS #50**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#NAME?	log(cm)
#NAME?	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Calculation of 50% friction initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: SS #50

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	Force log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	1	28
795.0	2.9	0	1
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	1	29

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
3	0	0	0	
2	0	0	0	0.094
1	28	28	28	0.107
0	1	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.900	29	28	28	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
2	0	0	0	
1	0	0	0	0.094
0	1	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
3.000	1	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
3.046	log(lbf)
1112.5	lbf
s (using negatives)	
0.0101	log(lbf)
1.0	lbf

H_{50} (using positives)	
2.950	log(lbf)
891.7	lbf
s (using positives)	
0.0047	log(lbf)
1.0	lbf

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #50**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(micro F)	Frequency +	Frequency -
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	0	0
0.030	-1.5	0	0
0.015	-1.8	1	0
0.010	-2.0	7	0
0.0050	-2.3	5	7
0.0025	-2.6	0	6
0.0012	-2.9	1	0
0.0007	-3.2	1	0
0.0003	-3.5	1	0
0.0002	-3.7	1	0
0.0000	0	0	0
	SUM	**17**	**13**

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
9	0	0	0	
8	0	0	0	0.331
7	0	0	0	0.243
6	0	0	0	0.222
5	0	0	0	0.301
4	0	0	0	0.301
3	0	0	0	0.301
2	0	0	0	0.176
1	7	7	7	0.301
0	6	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.602	13	7	7	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
13	0	0	0	
12	0	0	0	0.331
11	0	0	0	0.243
10	0	0	0	0.222
9	0	0	0	0.301
8	0	0	0	0.301
7	1	7	49	0.301
6	7	42	252	0.176
5	5	25	125	0.301
4	0	0	0	0.301
3	1	3	9	0.319
2	1	2	4	0.234
1	1	1	1	0.368
0	1	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-3.699	17	80	440	0.275

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-2.317 log(microF)
0.0048 microF
s (using negatives)
0.1236 log(microF)
1.3 microF

H_{50} (using positives)
-2.543 log(microF)
0.0 microF
s (using positives)
1.6773 log(microF)
47.6 microF

Figure B48: H_{50} Calculations for Mix ID SS #51 – Fine Ti-Cu_2O

Calculation of 50% impact initiation level from Bruceton data

Modified Bureau of Mines (MBOM) Impact Sensitivity Test

Sample: **SS #51**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height (cm)	log(cm)	Frequency +	Frequency -
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	**0**	**30**

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.050 log(cm)
112.2 cm
s (using negatives)
0.0047 log(cm)
1.0 cm

H_{50} (using positives)
#NAME? log(cm)
#NAME? cm
s (using positives)
#DIV/0! log(cm)
#DIV/0! cm

Calculation of 50% friction initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #51**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force		Frequency	
(lbf)	log(lbf)	+	-
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	5	20
795.0	2.9	0	5
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	5	25

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
3	0	0	0	
2	0	0	0	0.094
1	20	20	20	0.107
0	5	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	N_S	A	B	d
2.900	25	20	20	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
2	0	0	0	
1	0	0	0	0.094
0	5	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	N_S	A	B	d
3.000	5	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
3.030 log(lbf)
1071.1 lbf
s (using negatives)
0.0305 log(lbf)
1.1 lbf

H_{50} (using positives)
2.950 log(lbf)
891.7 lbf
s (using positives)
0.0047 log(lbf)
1.0 lbf

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #51**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	0	0
0.030	-1.5	0	0
0.015	-1.8	1	0
0.010	-2.0	0	0
0.0050	-2.3	0	0
0.0025	-2.6	2	1
0.0012	-2.9	7	3
0.0007	-3.2	3	8
0.0003	-3.5	0	4
0.0002	-3.7	0	1
0.0000	0	0	0
	SUM	13	17

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
13	0	0	0	
12	0	0	0	0.331
11	0	0	0	0.243
10	0	0	0	0.222
9	0	0	0	0.301
8	0	0	0	0.301
7	0	0	0	0.301
6	0	0	0	0.176
5	0	0	0	0.301
4	1	4	16	0.301
3	3	9	27	0.319
2	8	16	32	0.234
1	4	4	4	0.368
0	1	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-3.699	17	33	79	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
11	0	0	0	
10	0	0	0	0.331
9	0	0	0	0.243
8	0	0	0	0.222
7	0	0	0	0.301
6	0	0	0	0.301
5	1	5	25	0.301
4	0	0	0	0.176
3	0	0	0	0.301
2	2	4	8	0.301
1	7	7	7	0.319
0	3	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-3.155	13	16	40	0.275

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-3.028 log(microF)
0.0 microF
s (using negatives)
0.4044 log(microF)
2.5 microF

H_{50} (using positives)
-2.954 log(microF)
0.0011 microF
s (using positives)
0.7087 log(microF)
5.1 microF

Figure B49: H_{50} Calculations for Mix ID SS #52 – Fine Ti-MoO_3

Modified Bureau of Mines (MBOM) Impact Sensitivity Test

Sample: **SS #52**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height (cm)	Drop Height log(cm)	Frequency +	Frequency -
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.050 log(cm)
112.2 cm

s (using negatives)
0.0047 log(cm)
1.0 cm

H_{50} (using positives)
#NAME? log(cm)
#NAME? cm

s (using positives)
#DIV/0! log(cm)
#DIV/0! cm

Calculation of 50% friction initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #52**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force		Frequency	
(lbf)	log(lbf)	+	-
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	0	0
795.0	2.9	0	0
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	1	0
320.0	2.5	1	1
255.0	2.4	6	1
200.0	2.3	3	6
160.0	2.2	0	4
127.0	2.1	1	1
100.0	2.0	0	2
80.0	1.9	0	1
64.0	1.8	0	1
51.0	1.7	0	1
0.0000	0	0	0
	SUM	12	18

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
15	0	0	0	
14	0	0	0	0.094
13	0	0	0	0.107
12	0	0	0	0.100
11	0	0	0	0.098
10	0	0	0	0.099
9	0	0	0	0.101
8	1	8	64	0.097
7	1	7	49	0.099
6	6	36	216	0.106
5	4	20	100	0.097
4	1	4	16	0.100
3	2	6	18	0.104
2	1	2	4	0.097
1	1	1	1	0.097
0	1	0	0	0.099
FALSE	0	0	0	
c	N_S	A	B	d
1.708	18	84	468	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
11	0	0	0	
10	0	0	0	0.094
9	0	0	0	0.107
8	0	0	0	0.100
7	0	0	0	0.098
6	0	0	0	0.099
5	1	5	25	0.101
4	1	4	16	0.097
3	6	18	54	0.099
2	3	6	12	0.106
1	0	0	0	0.097
0	1	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	N_S	A	B	d
2.104	12	33	107	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.222	log(lbf)
166.8	lbf
s (using negatives)	
0.6859	log(lbf)
4.9	lbf

H_{50} (using positives)	
2.328	log(lbf)
212.8	lbf
s (using positives)	
0.2232	log(lbf)
1.7	lbf

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #52**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	0	0
0.030	-1.5	0	0
0.015	-1.8	1	0
0.010	-2.0	0	0
0.0050	-2.3	0	0
0.0025	-2.6	0	0
0.0012	-2.9	1	0
0.0007	-3.2	5	2
0.0003	-3.5	7	6
0.0002	-3.7	0	8
0.0000	0	0	0
	SUM	14	16

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
13	0	0	0	
12	0	0	0	0.331
11	0	0	0	0.243
10	0	0	0	0.222
9	0	0	0	0.301
8	0	0	0	0.301
7	0	0	0	0.301
6	0	0	0	0.176
5	0	0	0	0.301
4	0	0	0	0.301
3	0	0	0	0.319
2	2	4	8	0.234
1	6	6	6	0.368
0	8	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-3.699	16	10	14	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
12	0	0	0	
11	0	0	0	0.331
10	0	0	0	0.243
9	0	0	0	0.222
8	0	0	0	0.301
7	0	0	0	0.301
6	1	6	36	0.301
5	0	0	0	0.176
4	0	0	0	0.301
3	0	0	0	0.301
2	1	2	4	0.319
1	5	5	5	0.234
0	7	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-3.523	14	13	45	0.275

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
-3.390	log(microF)
0.0	microF
s (using negatives)	
0.2286	log(microF)
1.7	microF

H_{50} (using positives)	
-3.405	log(microF)
0.0004	microF
s (using positives)	
1.0605	log(microF)
11.5	microF

Figure B50: H_{50} Calculations for Mix ID SS #53 – Fine Ti-SiO_2

Calculation of 50% impact initiation level from Bruceton data

Modified Bureau of Mines (MBOM) Impact Sensitivity Test

Sample: **SS #53**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height (cm)	log(cm)	Frequency +	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	**0**	**30**

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#NAME?	0	0	0	0.100

E POSITIVES

ations are performed using
gatives, whichever has the
equal, either may be used.

H_{50} (using negatives)
2.050 log(cm)
112.2 cm
s (using negatives)
0.0047 log(cm)
1.0 cm

H_{50} (using positives)
#NAME? log(cm)
#NAME? cm
s (using positives)
#DIV/0! log(cm)
#DIV/0! cm

Calculation of 50% friction initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #53**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	Force log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	0	30
795.0	2.9	0	0
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	**0**	**30**

CALCULATIONS USING NEGATIVES				
i	**n(-)**	**i(-)·n(-)**	**i^2(-)·n(-)**	**Interval**
2	0	0	0	
1	0	0	0	0.094
0	30	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
3.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	**n(+)**	**i(+)·n(+)**	**i^2(+)·n(+)**	**Interval**
FALSE	0	0	0	
FALSE	0	0	0	0.094
FALSE	0	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#NAME?	0	0	0	0.100

E POSITIVES

ations are performed using
gatives, whichever has the
equal, either may be used.

H_{50} (using negatives)	
3.050	log(lbf)
1121.5	lbf
s (using negatives)	
0.0047	log(lbf)
1.0	lbf

H_{50} (using positives)	
#NAME?	log(lbf)
#NAME?	lbf
s (using positives)	
#DIV/0!	log(lbf)
#DIV/0!	lbf

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #53**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance		Frequency	
(microF)	log(micro F)	+	-
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	0	0
0.030	-1.5	0	0
0.015	-1.8	1	0
0.010	-2.0	0	0
0.0050	-2.3	0	0
0.0025	-2.6	0	0
0.0012	-2.9	7	0
0.0007	-3.2	3	8
0.0003	-3.5	3	4
0.0002	-3.7	0	4
0.0000	0	0	0
	SUM	**14**	**16**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
13	0	0	0	
12	0	0	0	0.331
11	0	0	0	0.243
10	0	0	0	0.222
9	0	0	0	0.301
8	0	0	0	0.301
7	0	0	0	0.301
6	0	0	0	0.176
5	0	0	0	0.301
4	0	0	0	0.301
3	0	0	0	0.319
2	8	16	32	0.234
1	4	4	4	0.368
0	4	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-3.699	16	20	36	0.275

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
12	0	0	0	
11	0	0	0	0.331
10	0	0	0	0.243
9	0	0	0	0.222
8	0	0	0	0.301
7	0	0	0	0.301
6	1	6	36	0.301
5	0	0	0	0.176
4	0	0	0	0.301
3	0	0	0	0.301
2	7	14	28	0.319
1	3	3	3	0.234
0	3	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-3.523	14	23	67	0.275

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-3.218 log(microF)
0.0 microF
s (using negatives)
0.3191 log(microF)
2.1 microF

H_{50} (using positives)
-3.209 log(microF)
0.0006 microF
s (using positives)
0.9423 log(microF)
8.8 microF

Figure B51: H_{50} Calculations for Mix ID SS #54 – Fine Ti-SnO_2

Calculation of 50% impact initiation level from Bruceton data

Modified Bureau of Mines (MBOM) Impact Sensitivity Test

Sample: **SS #54**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	**0**	**30**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.050 log(cm)
112.2 cm
s (using negatives)
0.0047 log(cm)
1.0 cm

H_{50} (using positives)
#NAME? log(cm)
#NAME? cm
s (using positives)
#DIV/0! log(cm)
#DIV/0! cm

Calculation of 50% friction initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #54**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force		Frequency	
(lbf)	log(lbf)	+	-
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	3	14
795.0	2.9	3	3
635.0	2.8	2	3
505.0	2.7	0	2
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	8	22

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
5	0	0	0	
4	0	0	0	0.094
3	14	42	126	0.107
2	3	6	12	0.100
1	3	3	3	0.098
0	2	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	N_S	A	B	d
2.703	22	51	141	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
4	0	0	0	
3	0	0	0	0.094
2	3	6	12	0.107
1	3	3	3	0.100
0	2	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	N_S	A	B	d
2.803	8	9	15	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.984 log(lbf)
963.7 lbf
s (using negatives)
0.1717 log(lbf)
1.5 lbf

H_{50} (using positives)
2.865 log(lbf)
732.9 lbf
s (using positives)
0.1030 log(lbf)
1.3 lbf

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #54**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	0	0
0.030	-1.5	0	0
0.015	-1.8	1	0
0.010	-2.0	0	0
0.0050	-2.3	0	0
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	4	0
0.0002	-3.7	11	4
0.0000	0		
	SUM	16	4

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
13	0	0	0	
12	0	0	0	0.331
11	0	0	0	0.243
10	0	0	0	0.222
9	0	0	0	0.301
8	0	0	0	0.301
7	0	0	0	0.301
6	0	0	0	0.176
5	0	0	0	0.301
4	0	0	0	0.301
3	0	0	0	0.319
2	0	0	0	0.234
1	0	0	0	0.368
0	4	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-3.699	4	0	0	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
13	0	0	0	
12	0	0	0	0.331
11	0	0	0	0.243
10	0	0	0	0.222
9	0	0	0	0.301
8	0	0	0	0.301
7	1	7	49	0.301
6	0	0	0	0.176
5	0	0	0	0.301
4	0	0	0	0.301
3	0	0	0	0.319
2	0	0	0	0.234
1	4	4	4	0.368
0	11	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-3.699	16	11	53	0.275

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-3.562 log(microF)
0.0 microF

s (using negatives)
0.0129 log(microF)
1.0 microF

H_{50} (using positives)
-3.647 log(microF)
0.0 microF

s (using positives)
1.2777 log(microF)
19.0 microF

Figure B52: H_{50} Calculations for Mix ID SS #55 – Fine Ti-WO_3

Calculation of 50% impact initiation level from Bruceton data

Modified Bureau of Mines (MBOM) Impact Sensitivity Test

Sample: **SS #55**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
#NAME?	0	0	0	0.100

E POSITIVES

ıtions are performed using
gatives, whichever has the
equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#NAME?	log(cm)
#NAME?	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Calculation of 50% friction initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #55**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	9	3
795.0	2.9	4	8
635.0	2.8	2	3
505.0	2.7	0	1
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	15	15

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
5	0	0	0	
4	0	0	0	0.094
3	3	9	27	0.107
2	8	16	32	0.100
1	3	3	3	0.098
0	1	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.703	15	28	62	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
4	0	0	0	
3	0	0	0	0.094
2	9	18	36	0.107
1	4	4	4	0.100
0	2	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.803	15	22	40	0.100

EGATIVES OR POSITIVES

ations are performed using
gatives, whichever has the
equal, either may be used.

H_{50} (using negatives)
2.939 log(lbf)
868.9 lbf
s (using negatives)
0.1094 log(lbf)
1.3 lbf

H_{50} (using positives)
2.899 log(lbf)
792.6 lbf
s (using positives)
0.0879 log(lbf)
1.2 lbf

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #55**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance		Frequency	
(microF)	log(microF)	+	-
0.750	-0.1	1	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	1	0
0.060	-1.2	0	0
0.030	-1.5	0	0
0.015	-1.8	1	0
0.010	-2.0	0	0
0.0050	-2.3	0	0
0.0025	-2.6	1	0
0.0012	-2.9	1	0
0.0007	-3.2	1	0
0.0003	-3.5	1	0
0.0002	-3.7	23	0
0.0000	0	0	0
	SUM	30	0

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.331
FALSE	0	0	0	0.243
FALSE	0	0	0	0.222
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	N_S	A	B	d
#NAME?	0	0	0	0.275

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
13	1	13	169	
12	0	0	0	0.331
11	0	0	0	0.243
10	1	10	100	0.222
9	0	0	0	0.301
8	0	0	0	0.301
7	1	7	49	0.301
6	0	0	0	0.176
5	0	0	0	0.301
4	1	4	16	0.301
3	1	3	9	0.319
2	1	2	4	0.234
1	1	1	1	0.368
0	23	0	0	0.176
FALSE	0	0	0	
c	N_S	A	B	d
-3.699	30	40	348	0.275

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
#NAME?	log(microF)
#NAME?	microF
s (using negatives)	
#DIV/0!	log(microF)
#DIV/0!	microF

H_{50} (using positives)	
-3.470	log(microF)
0.0	microF
s (using positives)	
4.3875	log(microF)
24407.9	microF

Figure B53: H_{50} Calculations Mix ID SS #56 – Fine Mg & Al-MoO_3 & CuO

Calculation of 50% impact initiation level from Bruceton data

Modified Bureau of Mines (MBOM) Impact Sensitivity Test

Sample: **SS #56**

$H_{50} = c + d\ (A/N_S \pm 0.5)$

NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height			Frequency	
(cm)	log(cm)		+	-
100	2.0		3	24
79.4	1.9		0	3
63.1	1.8		0	0
50.1	1.7		0	0
39.8	1.6		0	0
31.6	1.5		0	0
25.1	1.4		0	0
20.0	1.3		0	0
15.8	1.2		0	0
12.6	1.1		0	0
10.0	1.0		0	0
7.9	0.9		0	0
6.3	0.8		0	0
5.0	0.7		0	0
4.0	0.6		0	0
3.2	0.5		0	0
0.0000	0	0.000	0	0
	SUM		**3**	**27**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
1	24	24	24	
0	3	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
1.900	27	24	24	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
0	3	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.000	3	0	0	0.100

E POSITIVES

ıtions are performed using
gatives, whichever has the
equal, either may be used.

H_{50} (using negatives)
2.038 log(cm)
109.2 cm
s (using negatives)
0.0206 log(cm)
1.0 cm

H_{50} (using positives)
1.950 log(cm)
89.2 cm
s (using positives)
0.0047 log(cm)
1.0 cm

Calculation of 50% friction initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #56**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force			Frequency	
(lbf)	log(lbf)		+	-
1590	3.2		0	0
1280.0	3.1		0	0
1000.0	3.0		2	0
795.0	2.9		7	1
635.0	2.8		5	8
505.0	2.7		1	5
400.0	2.6		0	1
320.0	2.5		0	0
255.0	2.4		0	0
200.0	2.3		0	0
160.0	2.2		0	0
127.0	2.1		0	0
100.0	2.0		0	0
80.0	1.9		0	0
64.0	1.8		0	0
51.0	1.7		0	0
0.0000	0	0.000	0	0
	SUM		**15**	**15**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
6	0	0	0	
5	0	0	0	0.094
4	0	0	0	0.107
3	1	3	9	0.100
2	8	16	32	0.098
1	5	5	5	0.099
0	1	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	N_S	A	B	d
2.602	15	24	46	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
5	0	0	0	
4	0	0	0	0.094
3	2	6	18	0.107
2	7	14	28	0.100
1	5	5	5	0.098
0	1	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	N_S	A	B	d
2.703	15	25	51	0.100

EGATIVES OR POSITIVES

ıtions are performed using
gatives, whichever has the
equal, either may be used.

H_{50} (using negatives)	
2.811	log(lbf)
647.4	lbf
s (using negatives)	
0.0864	log(lbf)
1.2	lbf

H_{50} (using positives)	
2.819	log(lbf)
659.9	lbf
s (using positives)	
0.1051	log(lbf)
1.3	lbf

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: SS #56

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance			Frequency	
(microF)	log(microF)		+	-
0.750	-0.1		0	0
0.350	-0.5		0	0
0.200	-0.7		0	0
0.120	-0.9		0	0
0.060	-1.2		0	0
0.030	-1.5		0	0
0.015	-1.8		0	0
0.010	-2.0		2	0
0.0050	-2.3		4	1
0.0025	-2.6		7	3
0.0012	-2.9		1	7
0.0007	-3.2		1	1
0.0003	-3.5		1	1
0.0002	-3.7		0	1
0.0000	0	0.000	0	0
	SUM		**16**	**14**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
13	0	0	0	
12	0	0	0	0.331
11	0	0	0	0.243
10	0	0	0	0.222
9	0	0	0	0.301
8	0	0	0	0.301
7	0	0	0	0.301
6	0	0	0	0.176
5	1	5	25	0.301
4	3	12	48	0.301
3	7	21	63	0.319
2	1	2	4	0.234
1	1	1	1	0.368
0	1	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-3.699	14	41	141	0.275

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
12	0	0	0	
11	0	0	0	0.331
10	0	0	0	0.243
9	0	0	0	0.222
8	0	0	0	0.301
7	0	0	0	0.301
6	0	0	0	0.301
5	2	10	50	0.176
4	4	16	64	0.301
3	7	21	63	0.301
2	1	2	4	0.319
1	1	1	1	0.234
0	1	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-3.523	16	50	182	0.275

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-2.756 log(microF)
0.0018 microF
s (using negatives)
0.6787 log(microF)
4.8 microF

H_{50} (using positives)
-2.801 log(microF)
0.0 microF
s (using positives)
0.7297 log(microF)
5.4 microF

APPENDIX C
– DSC Plots

Figure C1: High-Temp DSC Plot for Mix ID LS #1 Trial 1: Fine Al-Fe_2O_3

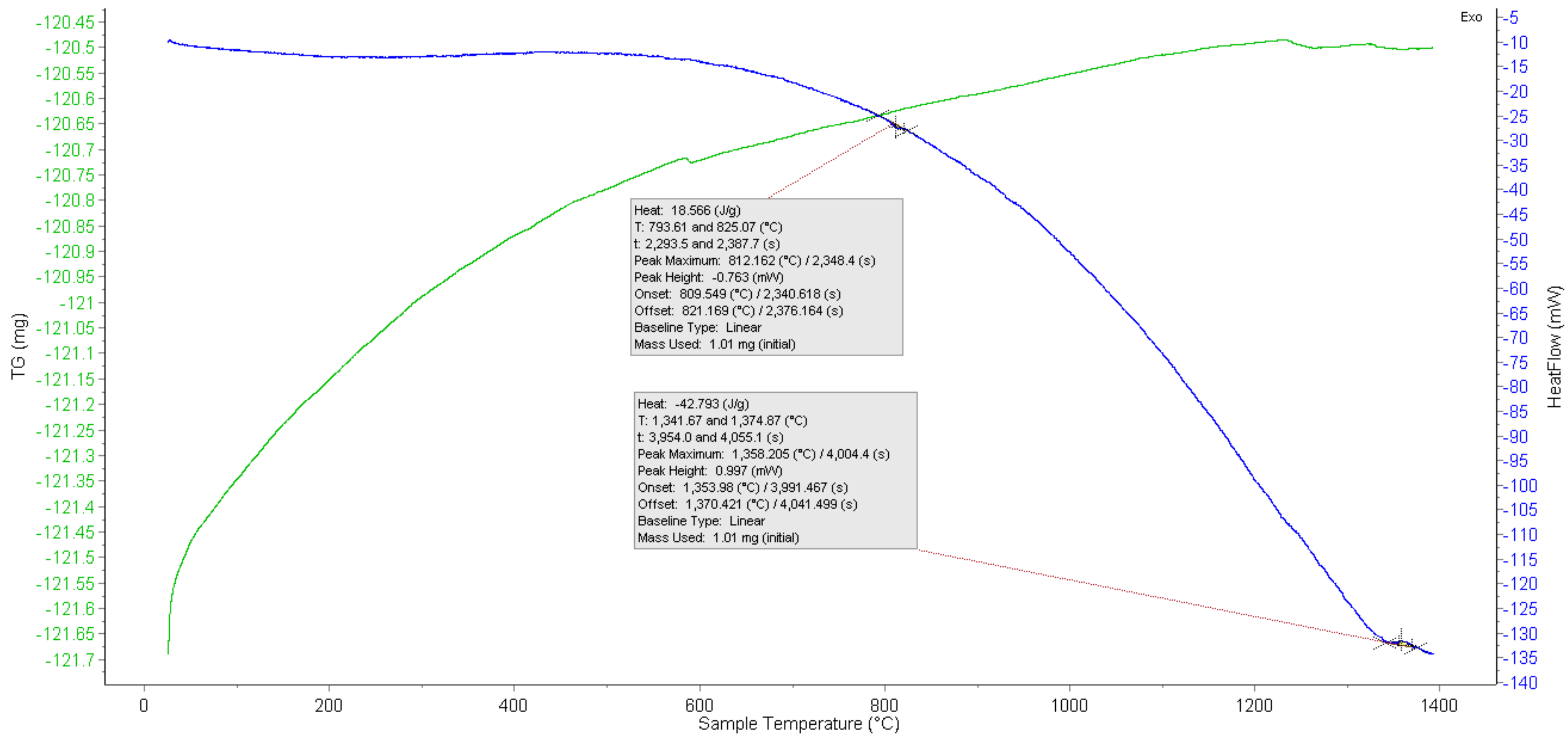


Figure C2: High-Temp DSC Plot for Mix ID LS #1 Trial 2: Fine Al-Fe_2O_3

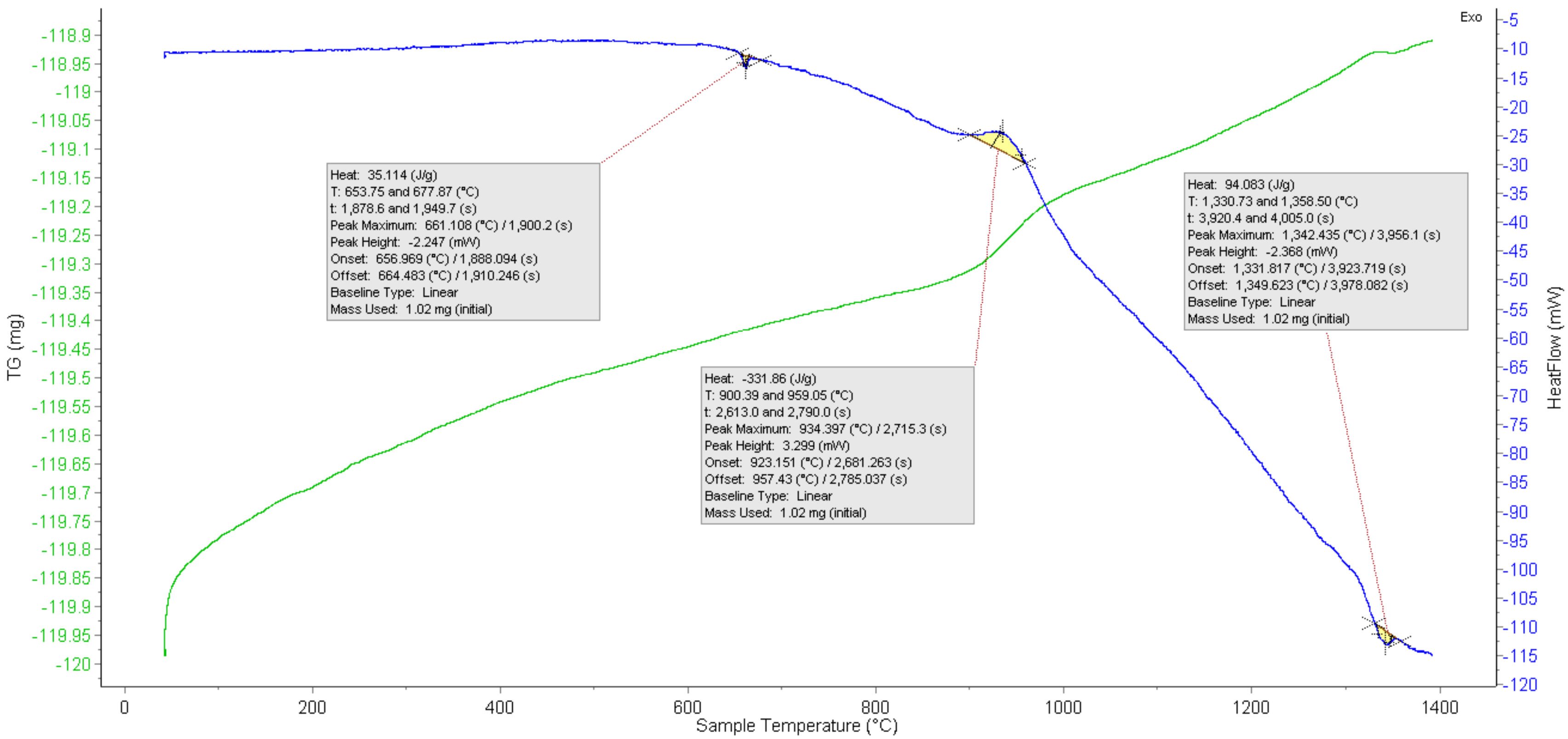


Figure C3: High-Temp DSC Plot for Mix ID LS #2 Trial 1: Coarse Al-Fe_2O_3 Thermite A

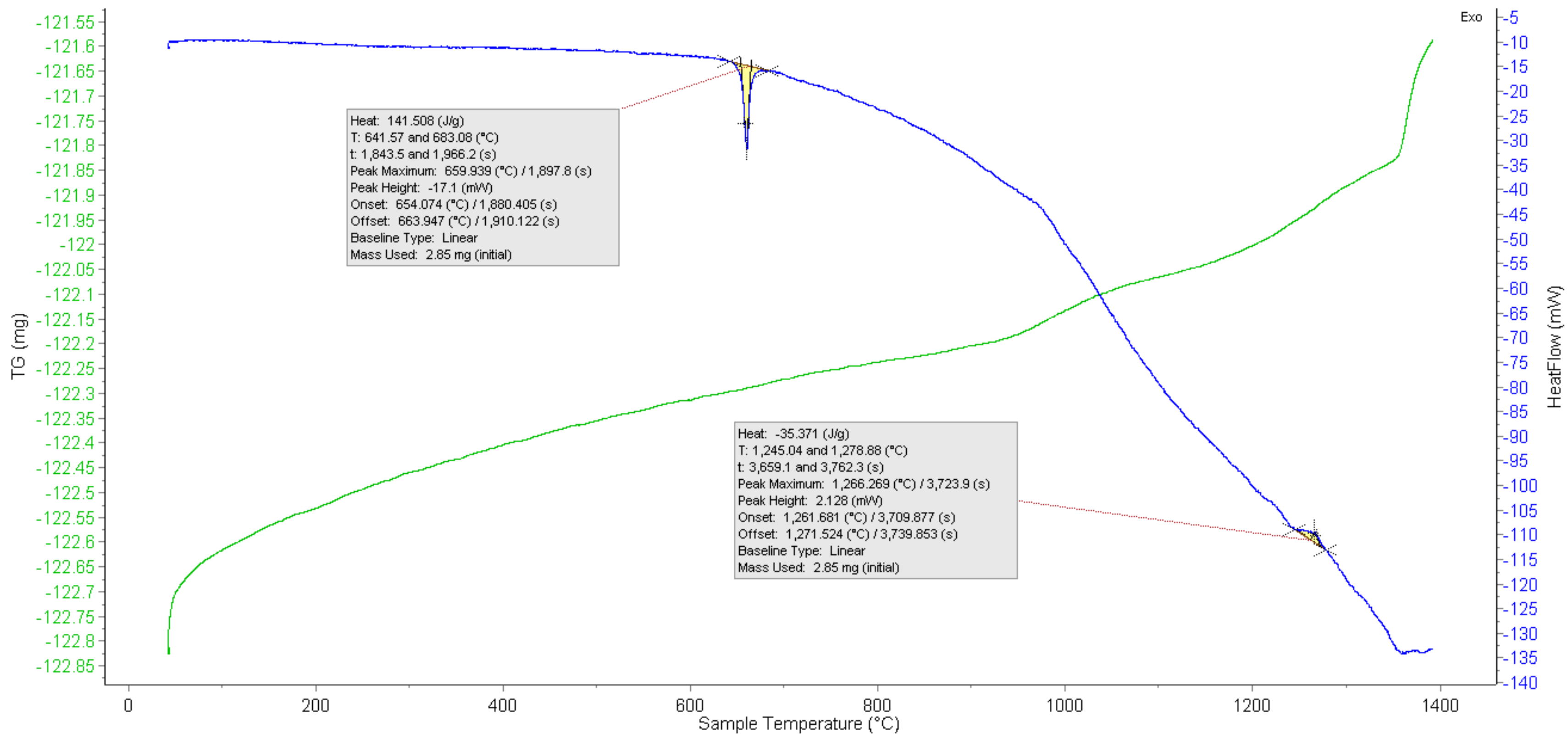


Figure C4: High-Temp DSC Plot for Mix ID LS #2 Trial 2: Coarse Al-Fe_2O_3 Thermite A

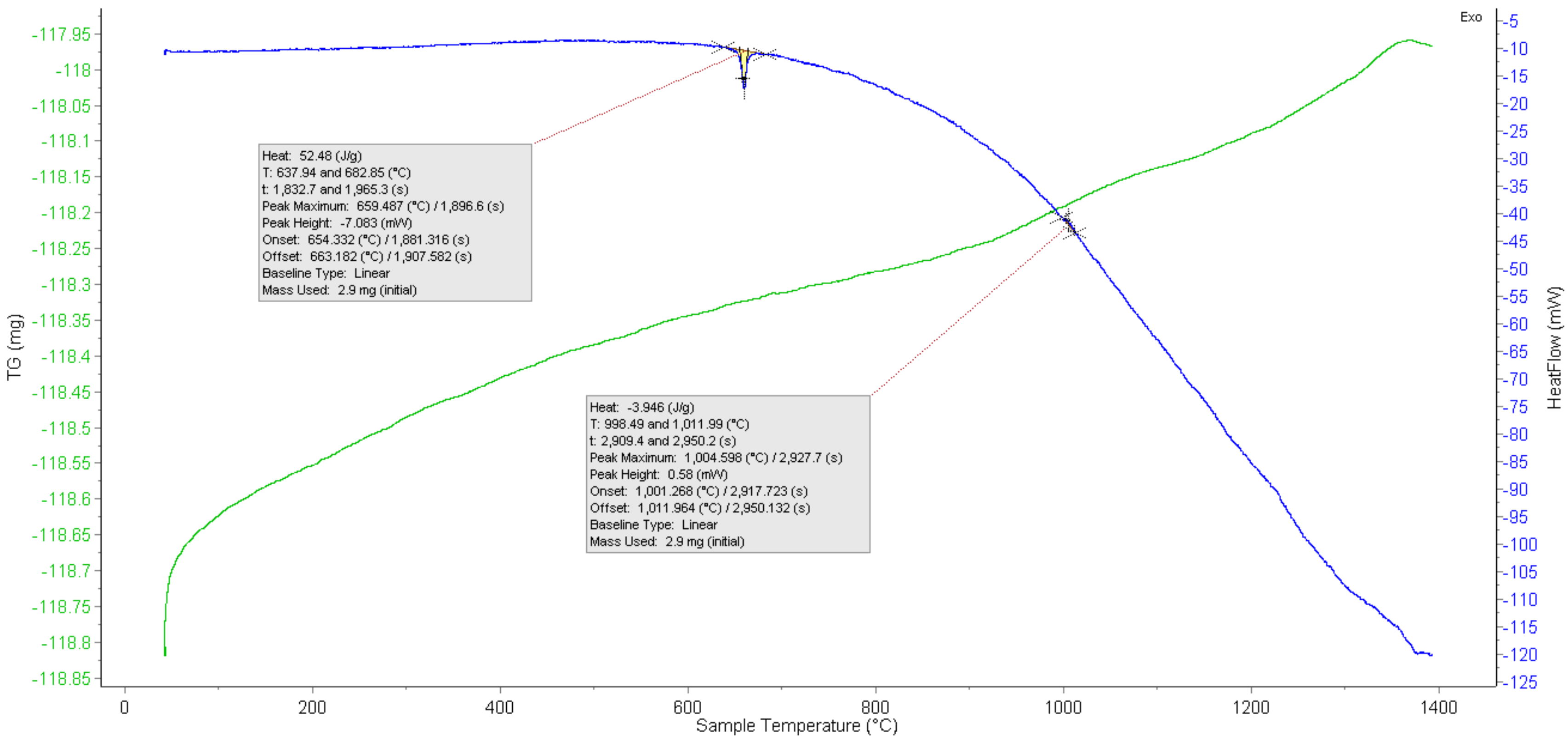


Figure C5: High-Temp DSC Plot for Mix ID LS #3 Trial 1: Coarse Al-Fe_2O_3 Thermite B

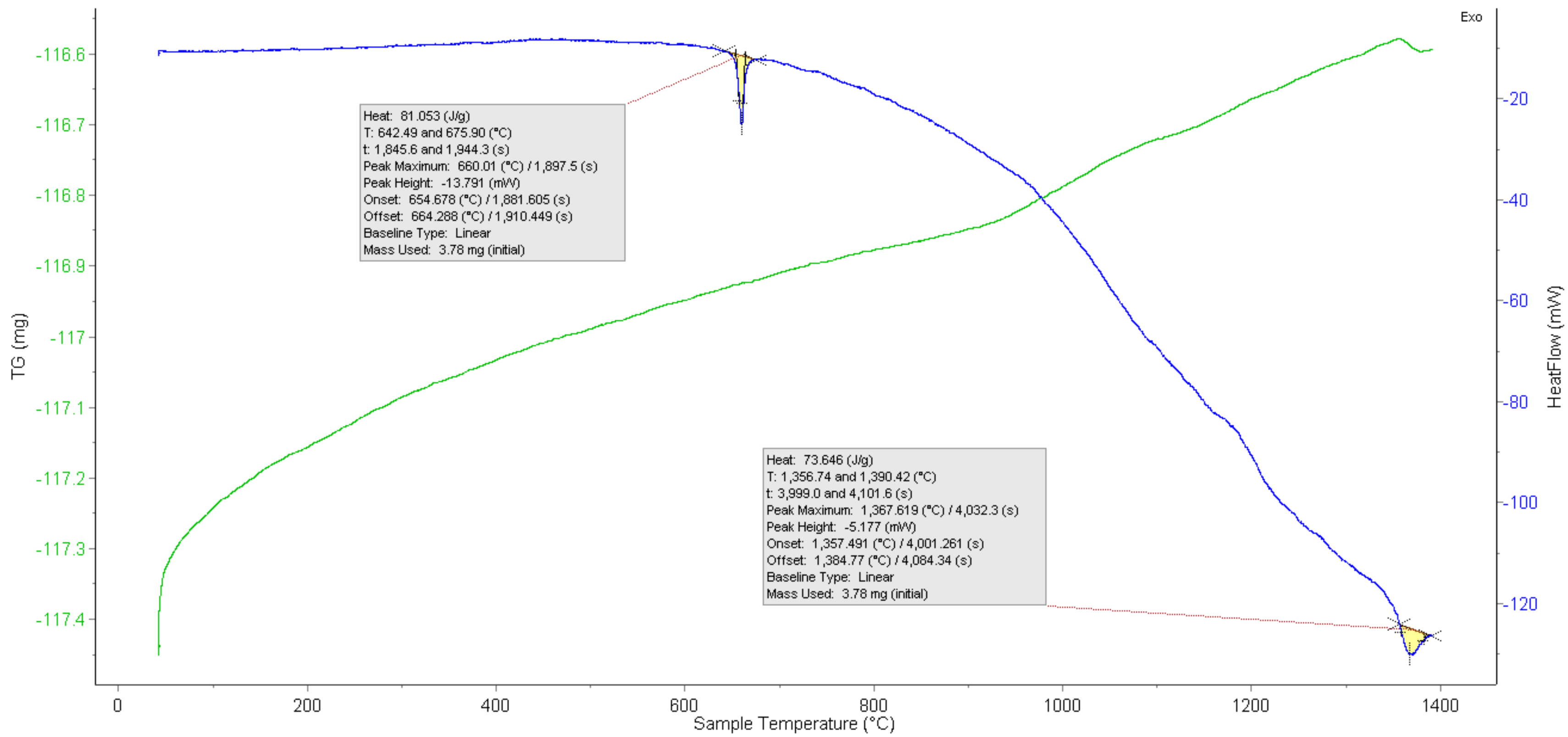


Figure C6: High-Temp DSC Plot for Mix ID LS #3 Trial 2: Coarse Al-Fe_2O_3 Thermite B

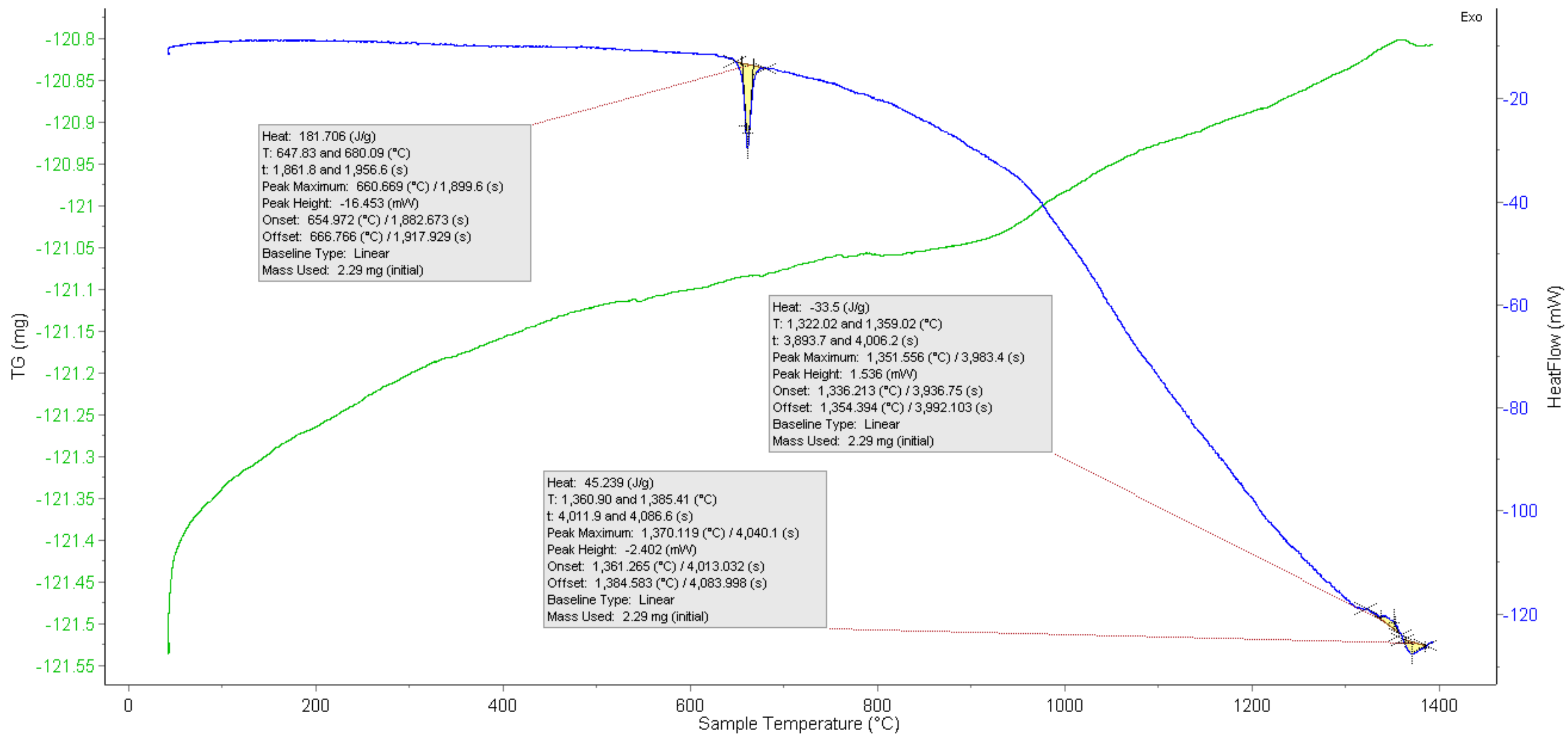


Figure C7: High-Temp DSC Plot for Mix ID LS #4 Trial 1: Fine Al-CuO

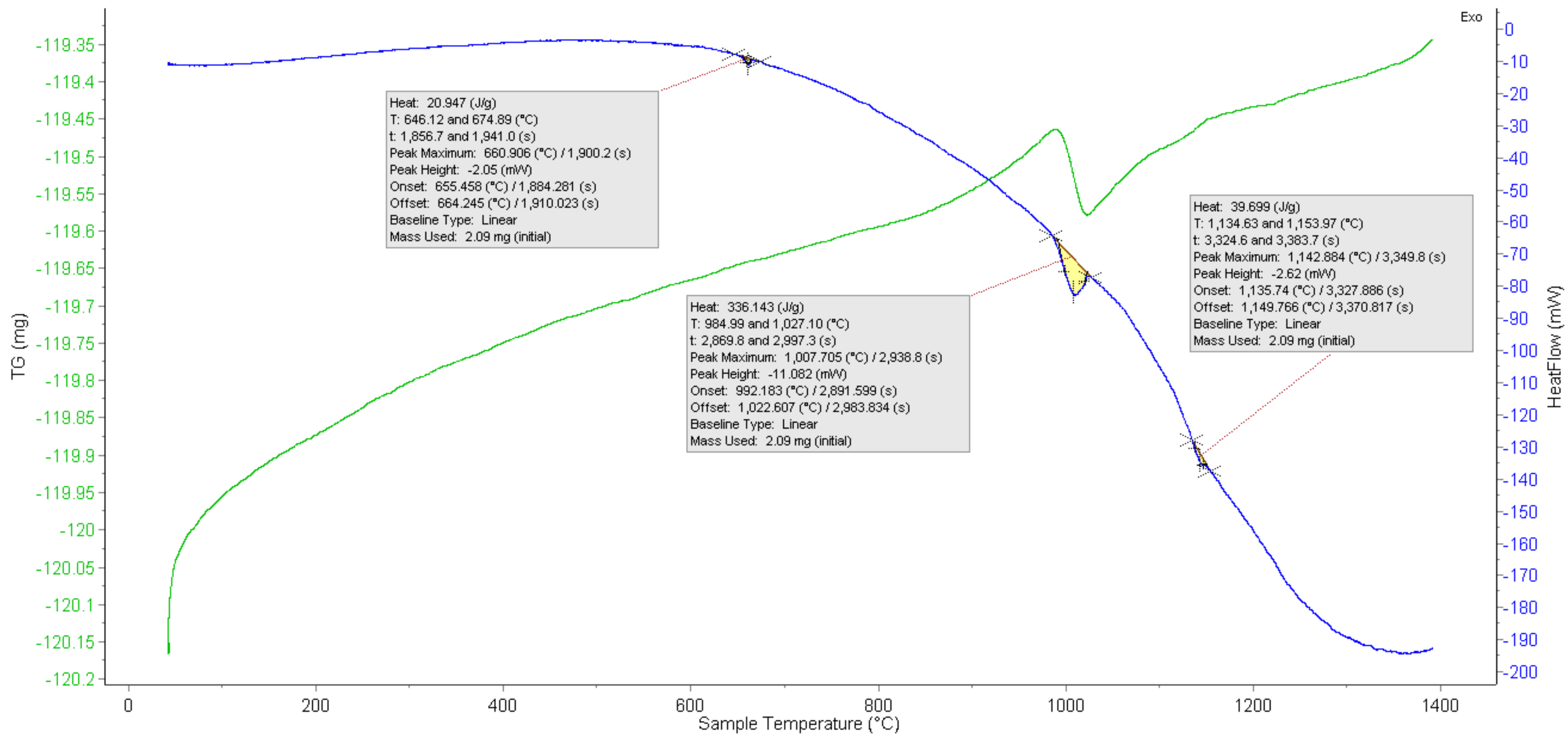


Figure C8: High-Temp DSC Plot for Mix ID LS #4 Trial 2: Fine Al-CuO

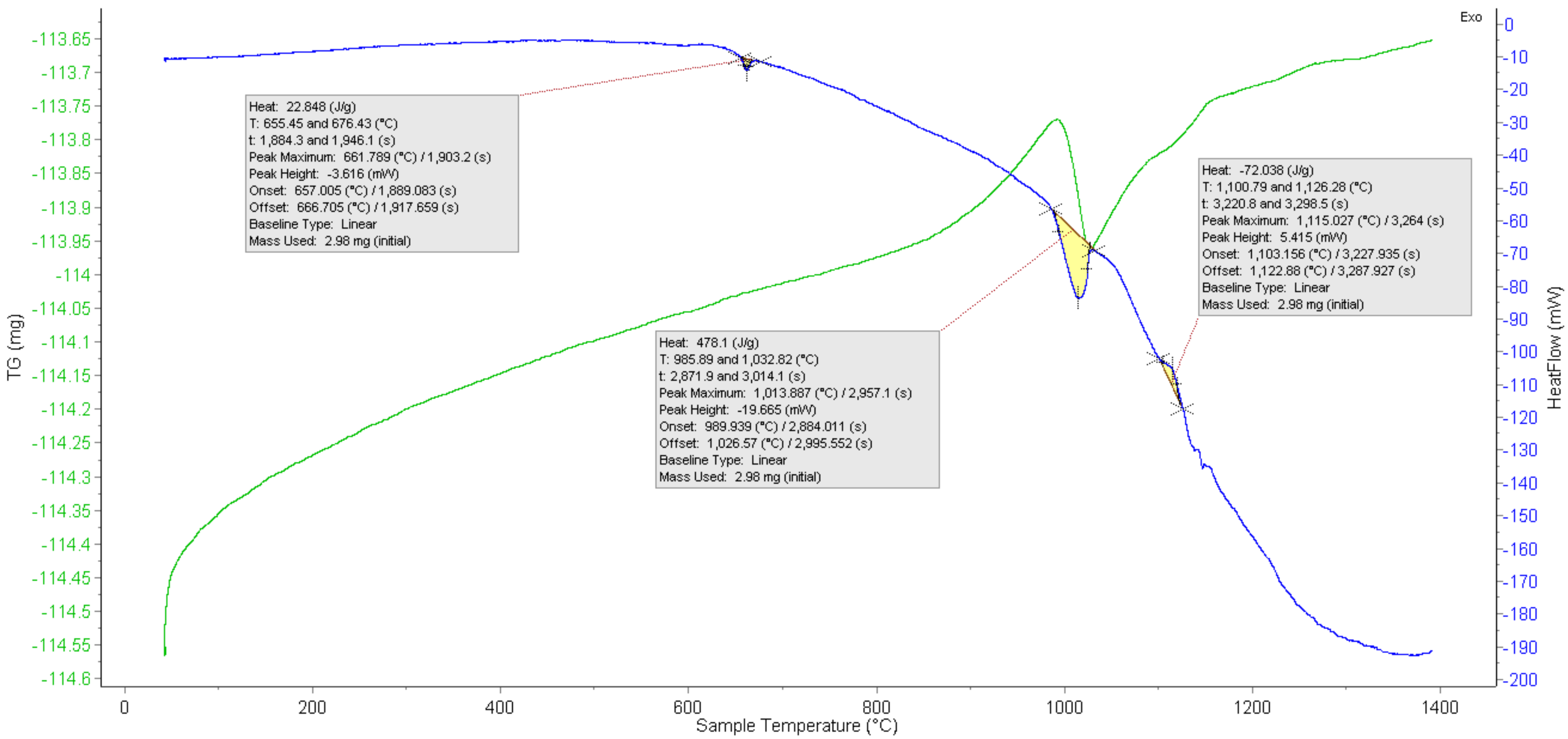


Figure C9: High-Temp DSC Plot for Mix ID LS #5 Trial 1: Medium Al-CuO

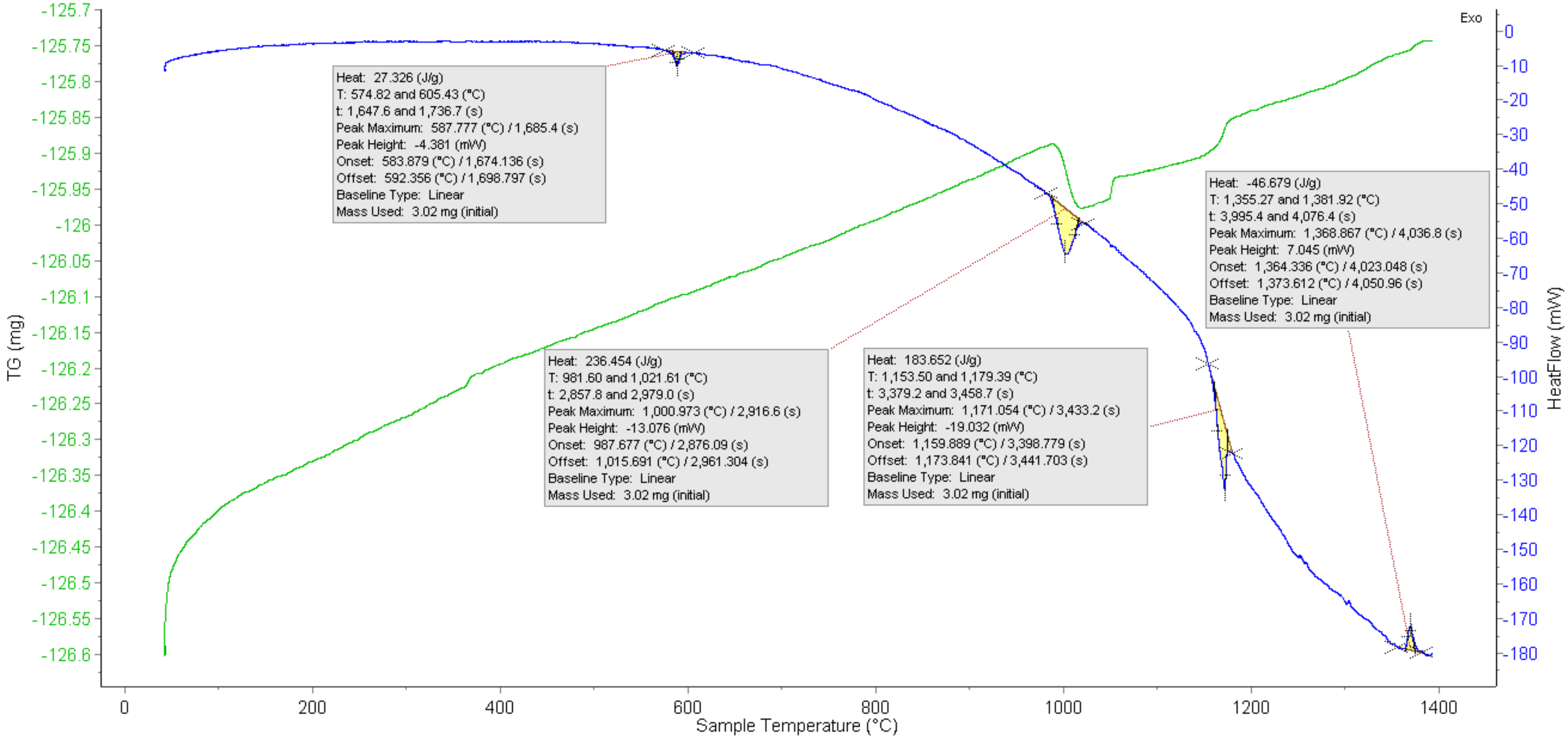


Figure C10: High-Temp DSC Plot for Mix ID LS #5 Trial 2: Medium Al-CuO

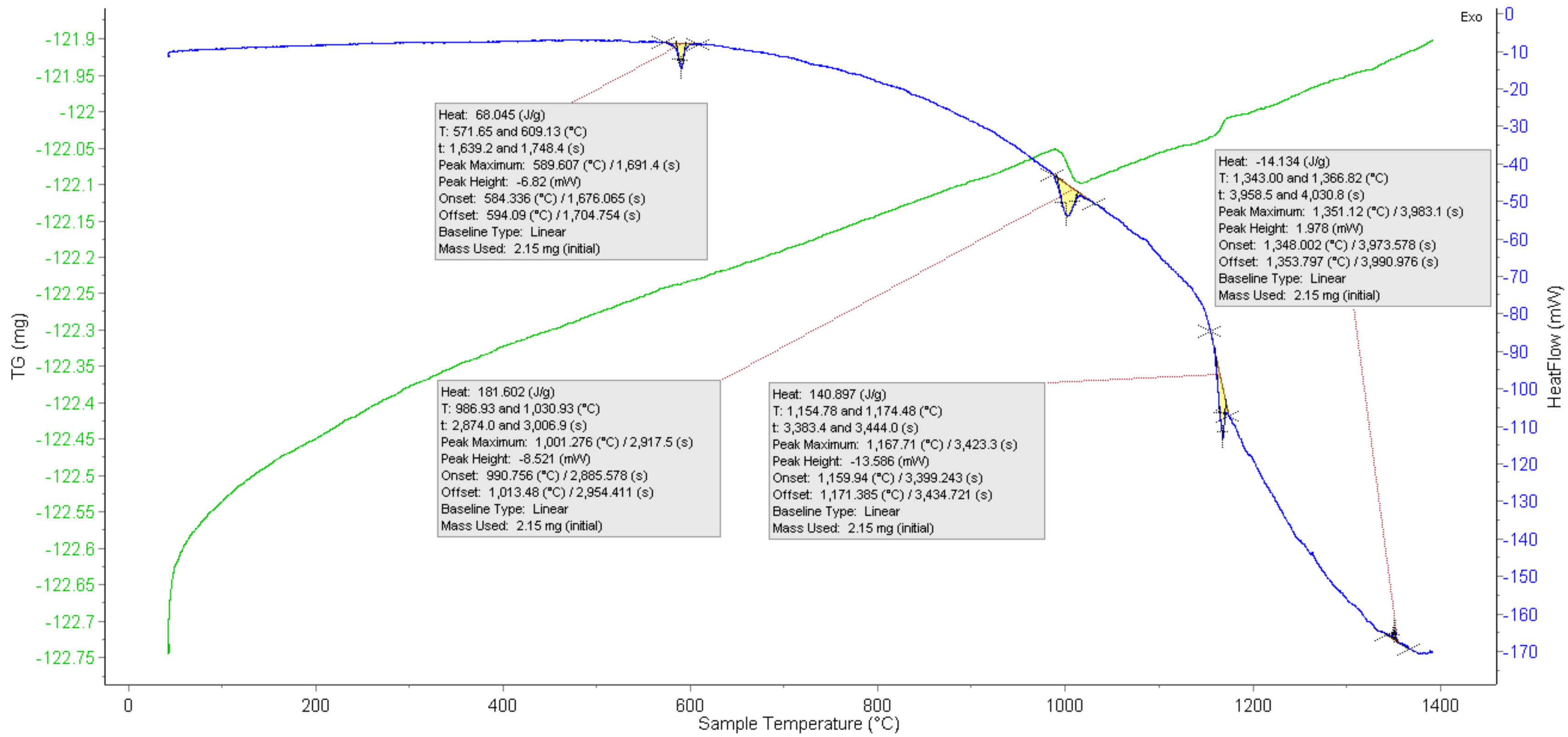


Figure C11: High-Temp DSC Plot for Mix ID LS #6 Trial 1: Fine Al-Ni_2O_3

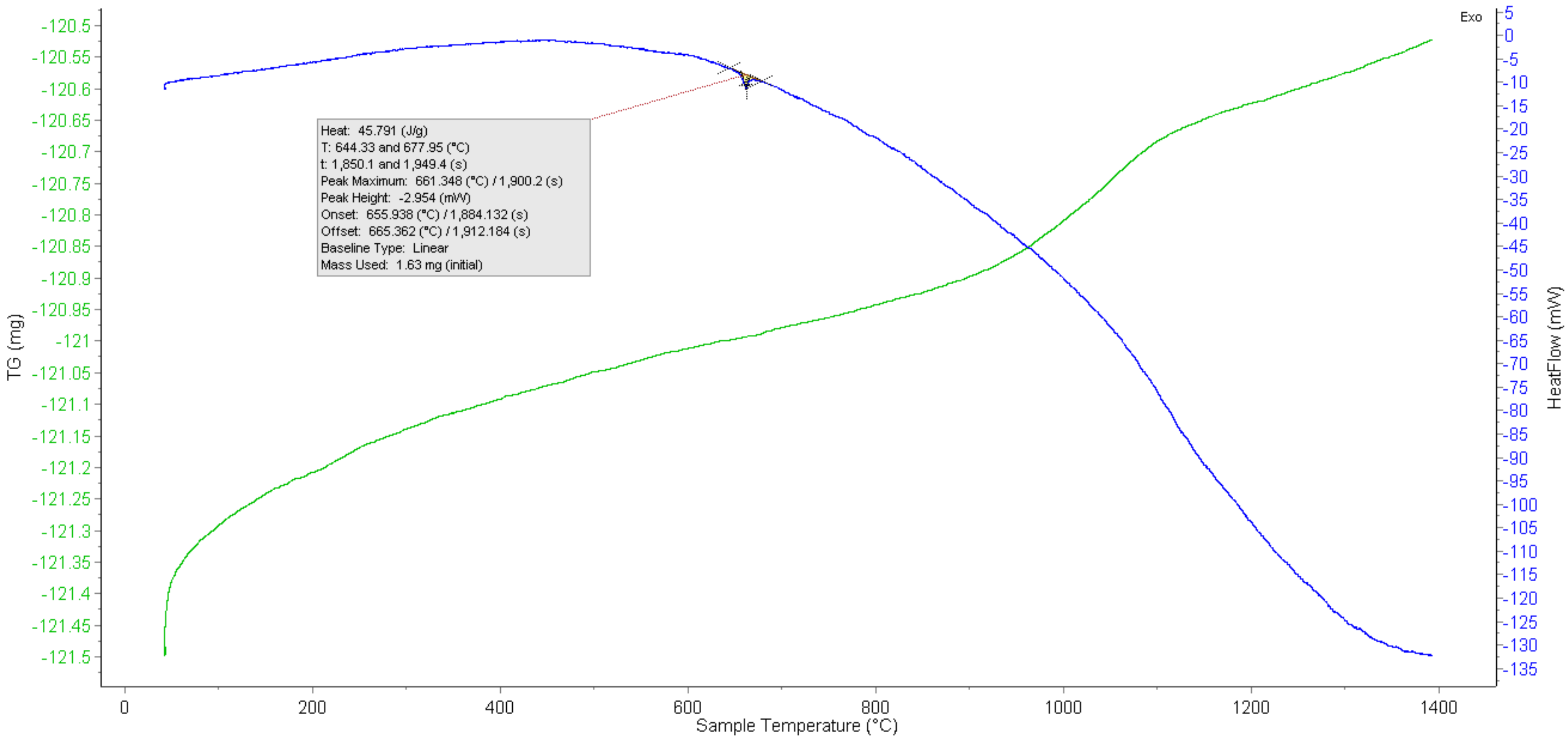


Figure C12: High-Temp DSC Plot for Mix ID LS #6 Trial 2: Fine Al-Ni_2O_3

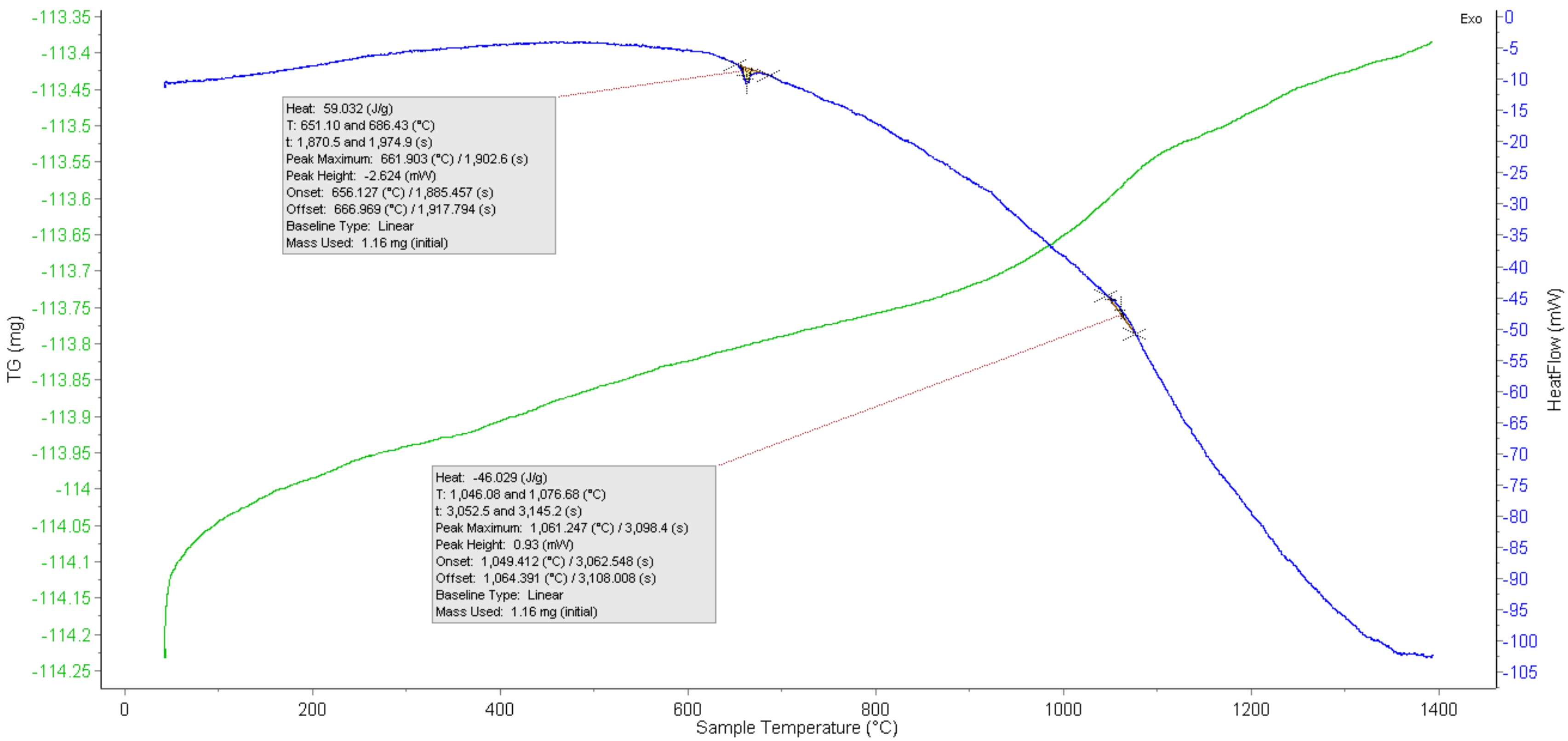


Figure C13: High-Temp DSC Plot for Mix ID LS #7 Trial 1: Fine Al-MnO_2

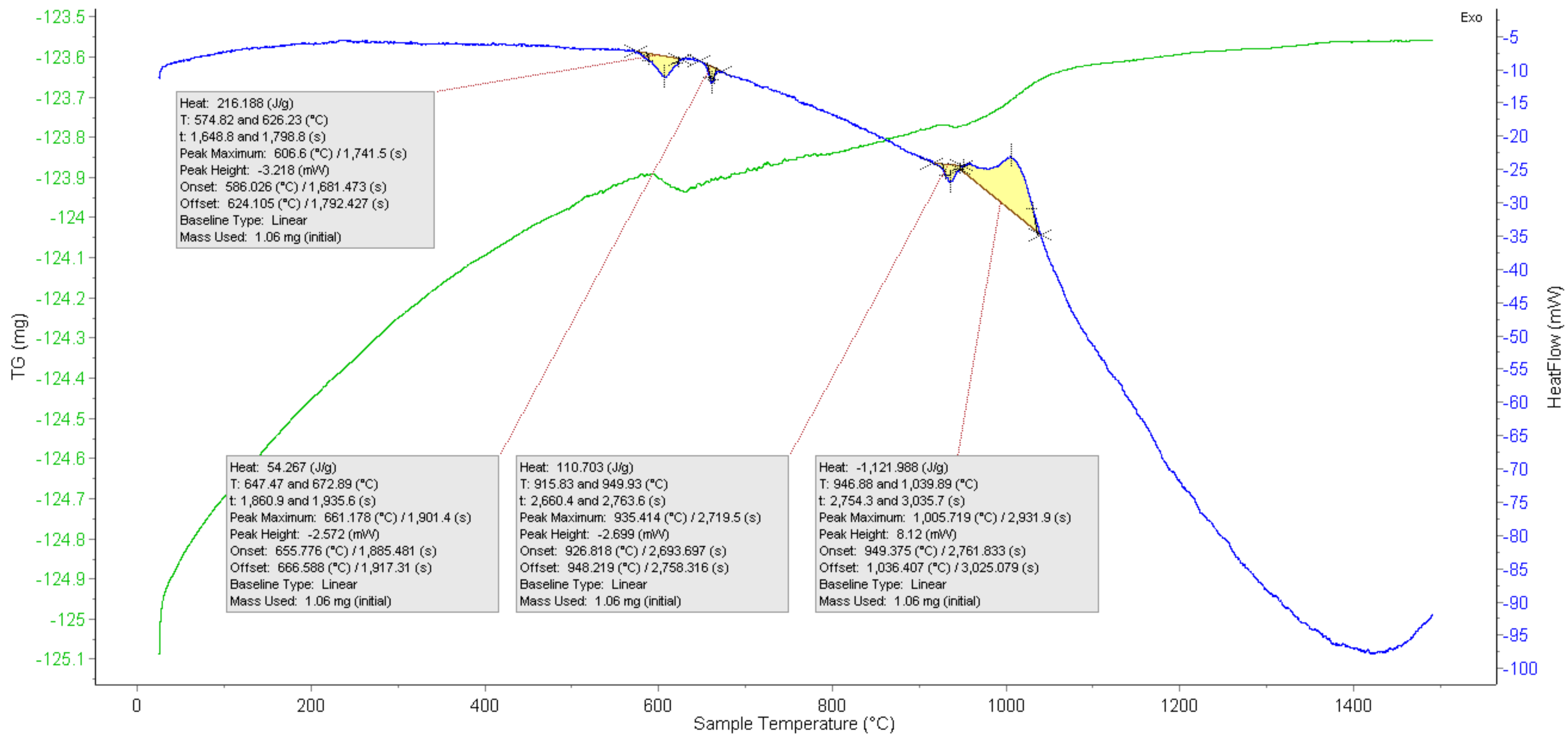


Figure C14: High-Temp DSC Plot for Mix ID LS #7 Trial 2: Fine Al-MnO_2

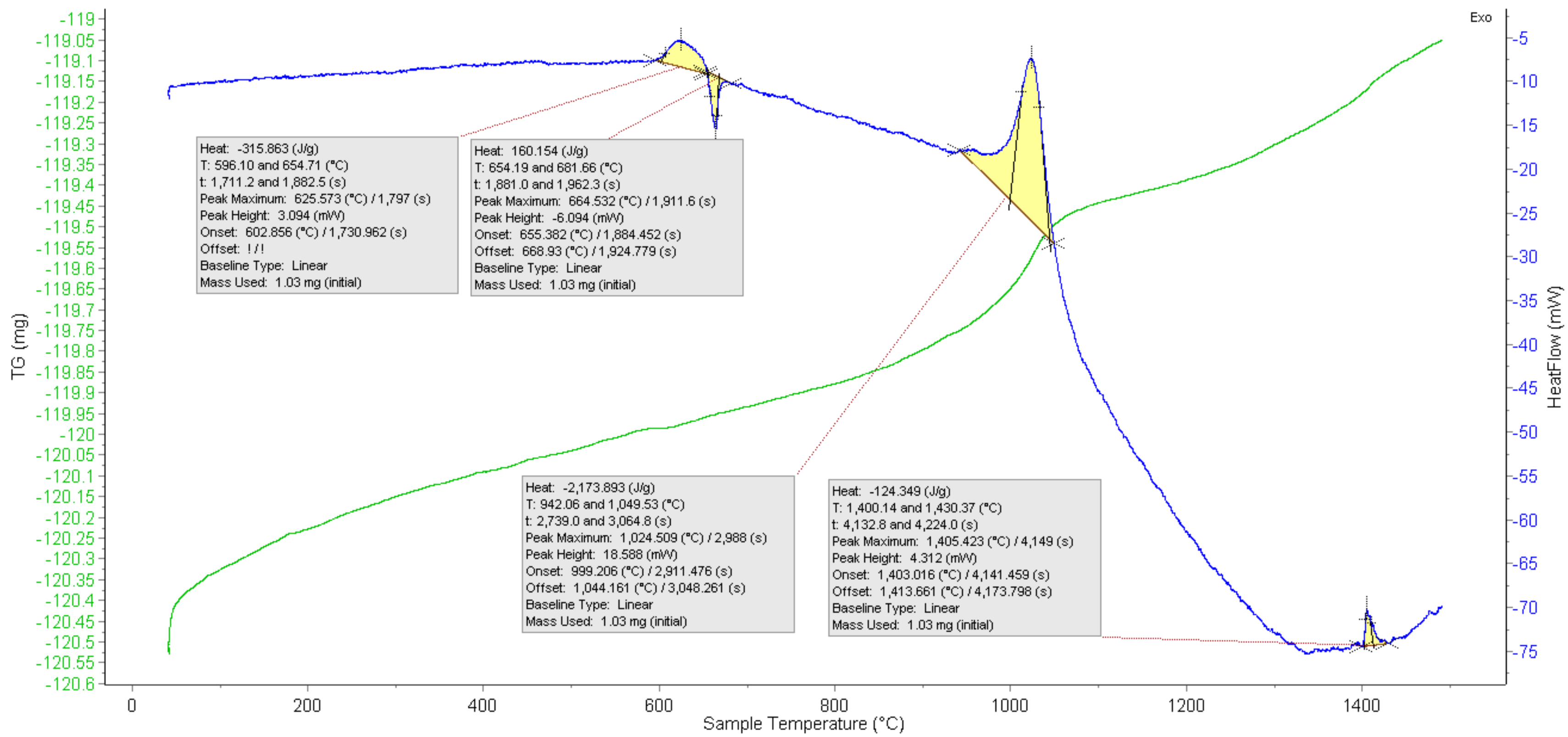


Figure C15: High-Temp DSC Plot for Mix ID LS #8 Trial 1: Fine Mg&Al-MoO_3&CuO

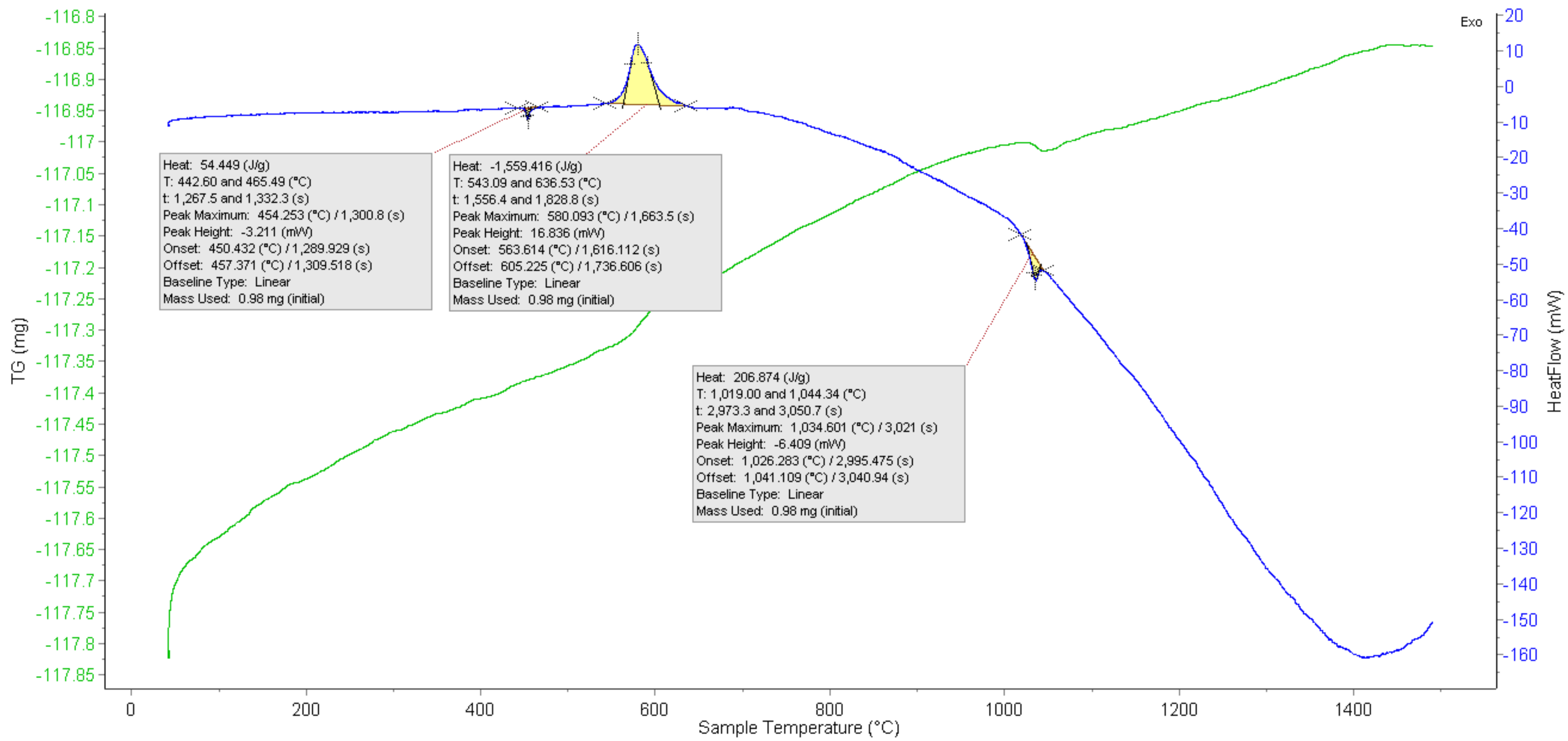


Figure C16: High-Temp DSC Plot for Mix ID LS #8 Trial 2: Fine Mg&Al-MoO_3&CuO

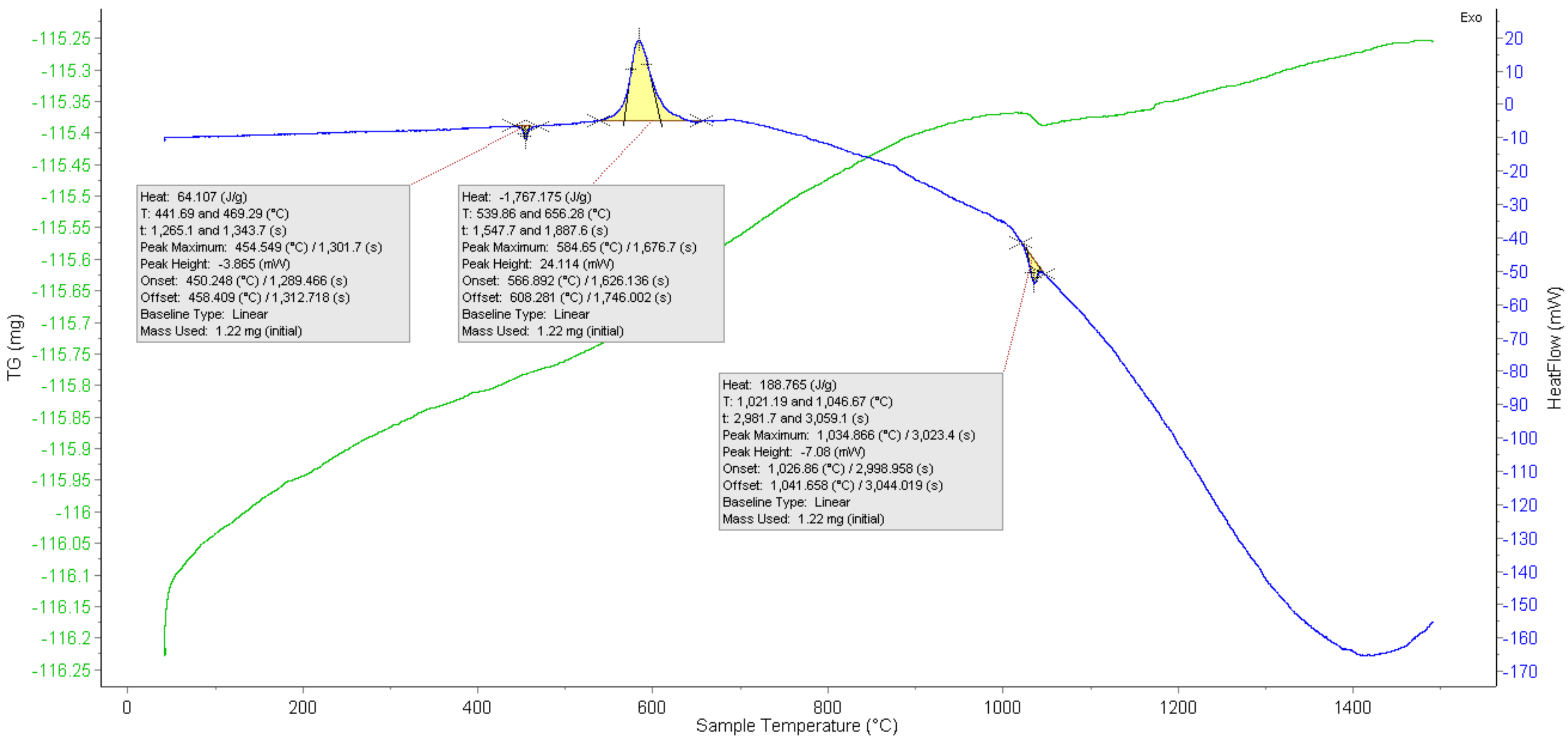


Figure C17: High-Temp DSC Plot for Mix ID SS #1 Trial 1: Fine Mg-B_2O_3

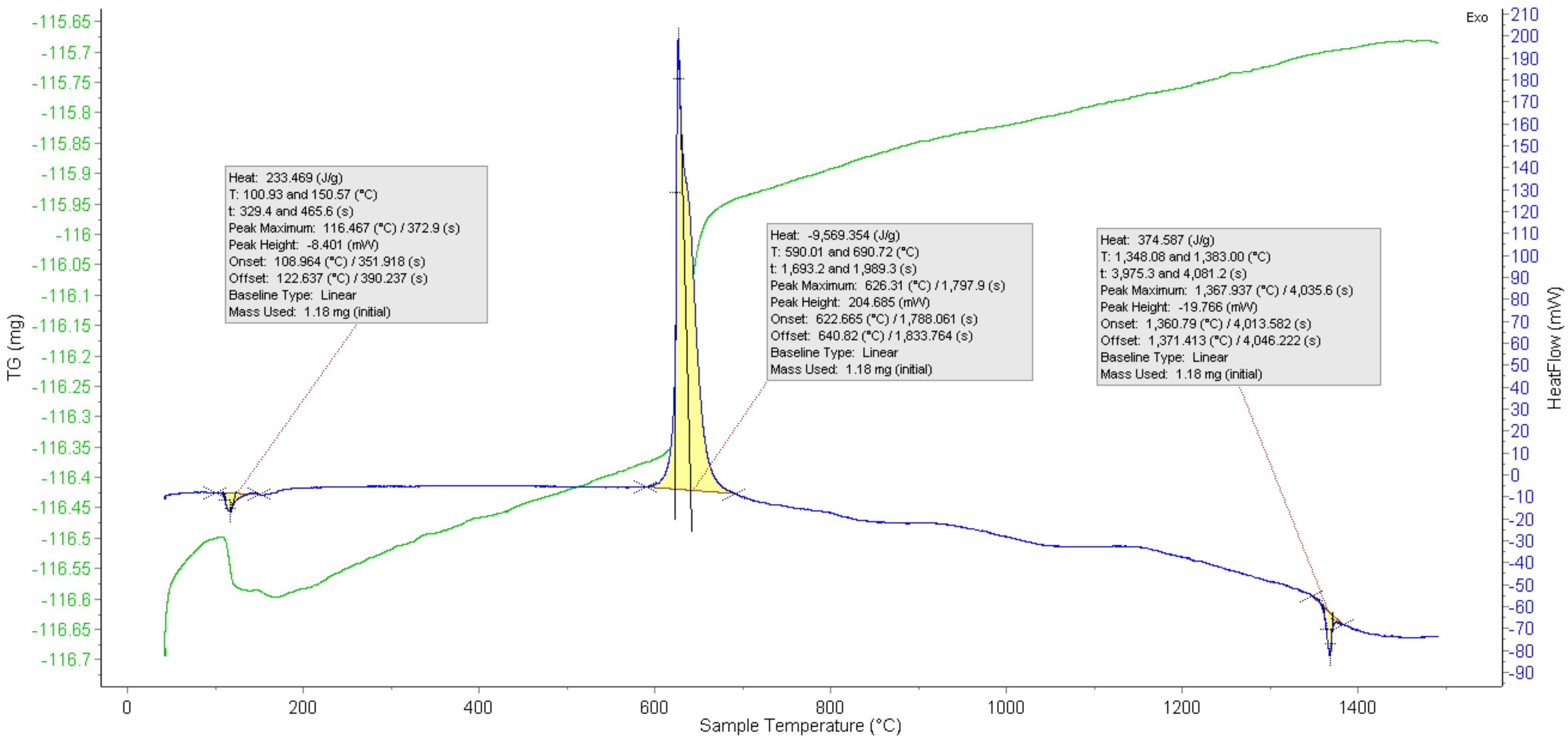


Figure C18: High-Temp DSC Plot for Mix ID SS #1 Trial 2: Fine Mg-B_2O_3

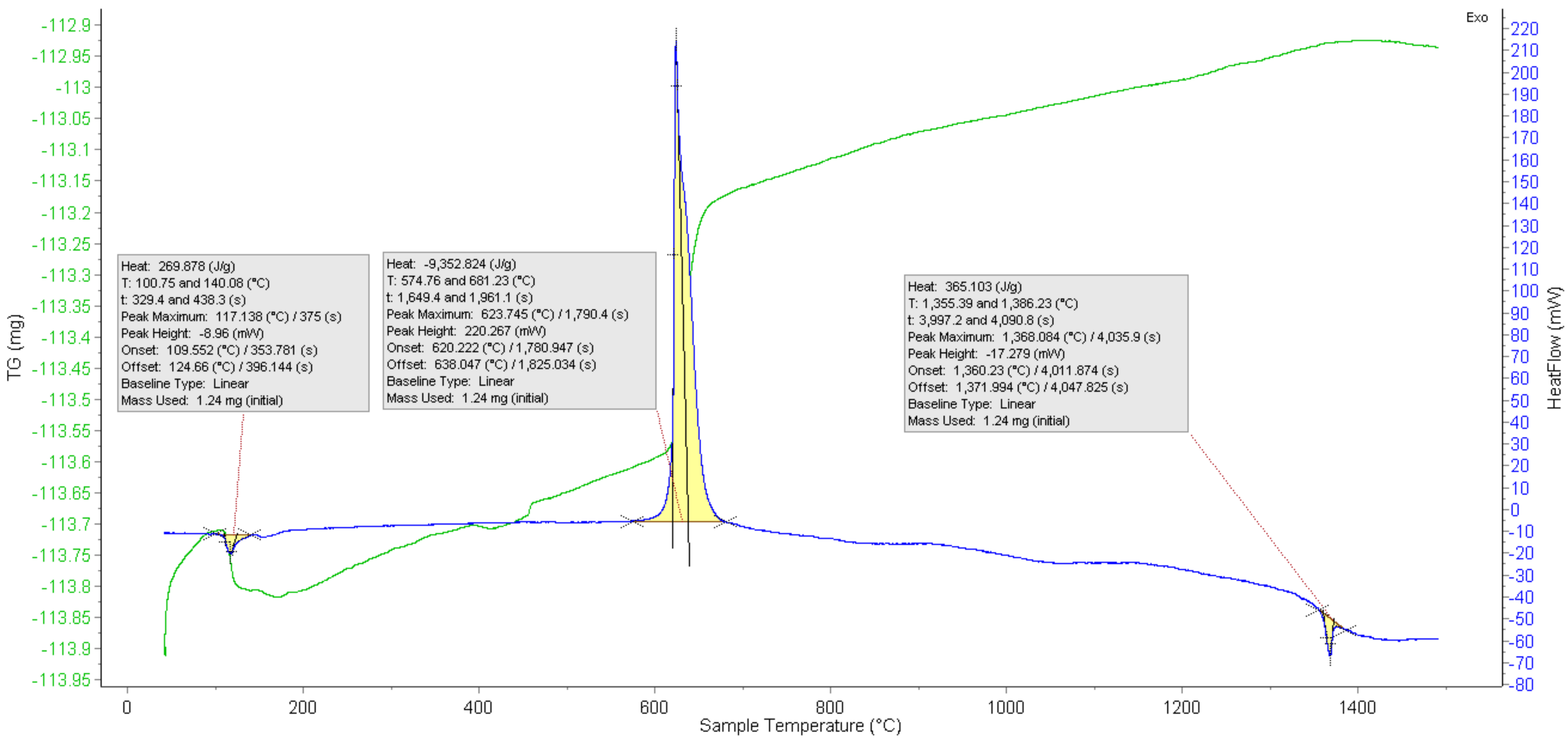


Figure C19: High-Temp DSC Plot for Mix ID SS #2B Trial 1: Ti-B_2O_3

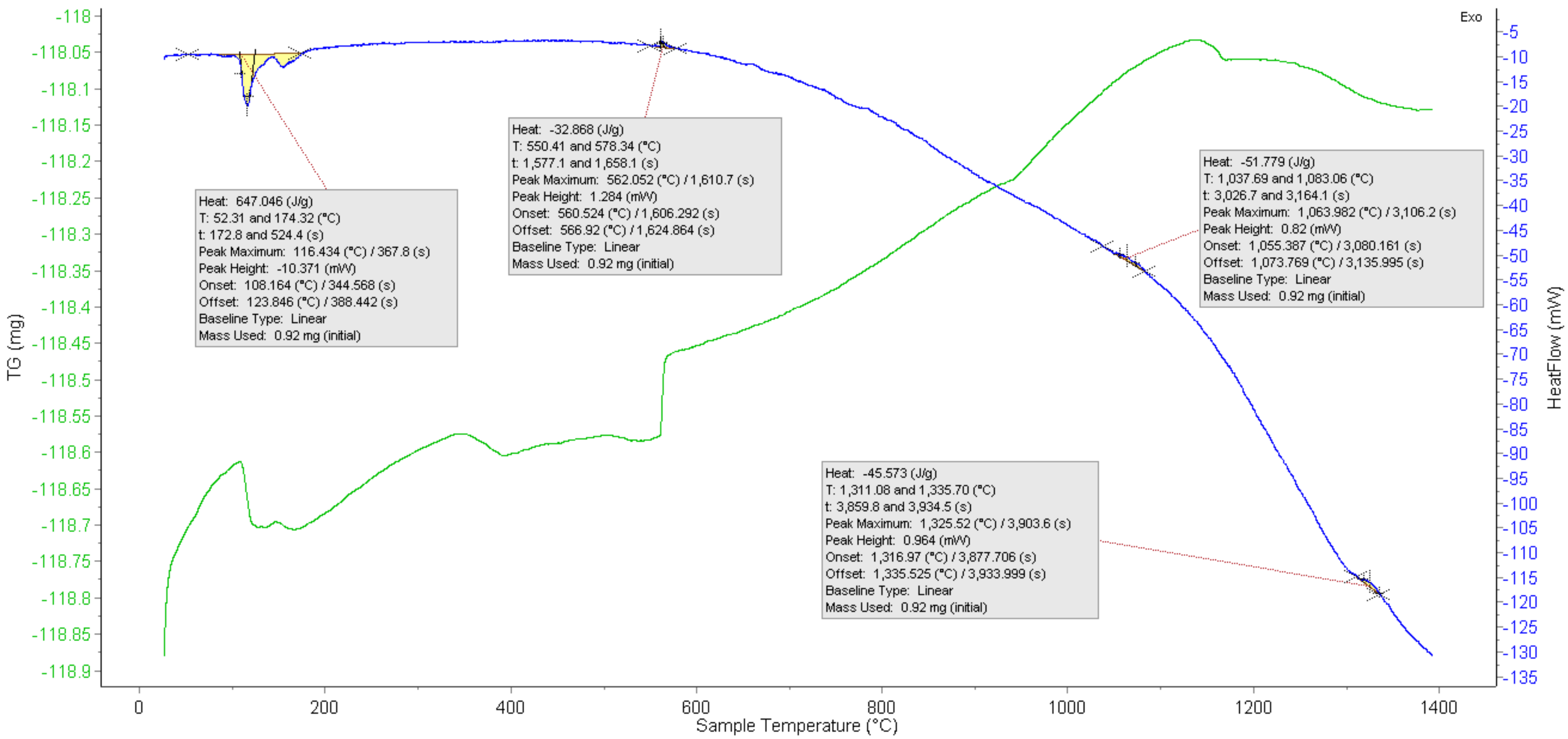


Figure C20: High-Temp DSC Plot for Mix ID SS #2B Trial 2: Ti-B_2O_3

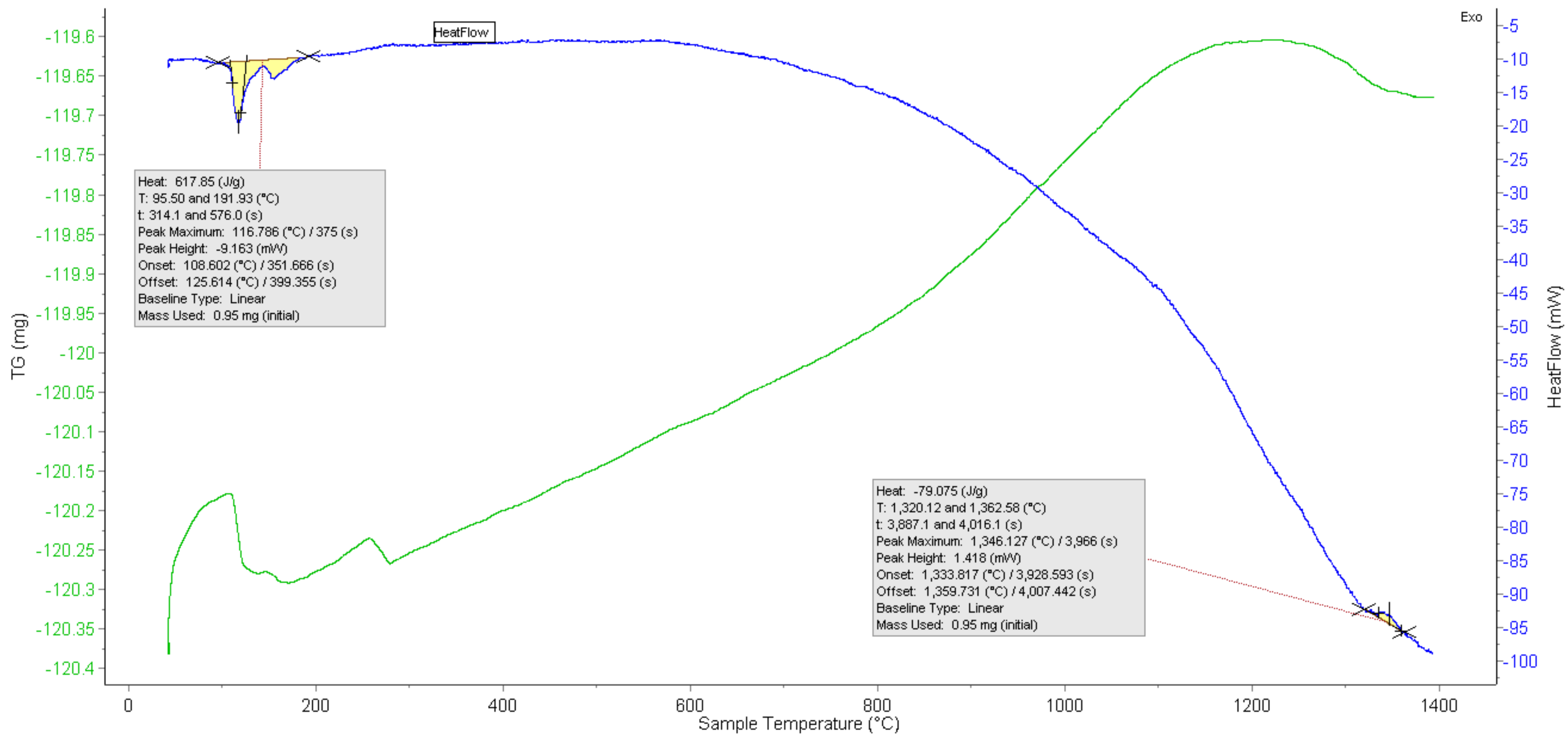


Figure C21: High-Temp DSC Plot for Mix ID SS #3B Trial 1: Fine Ti-MnO_2

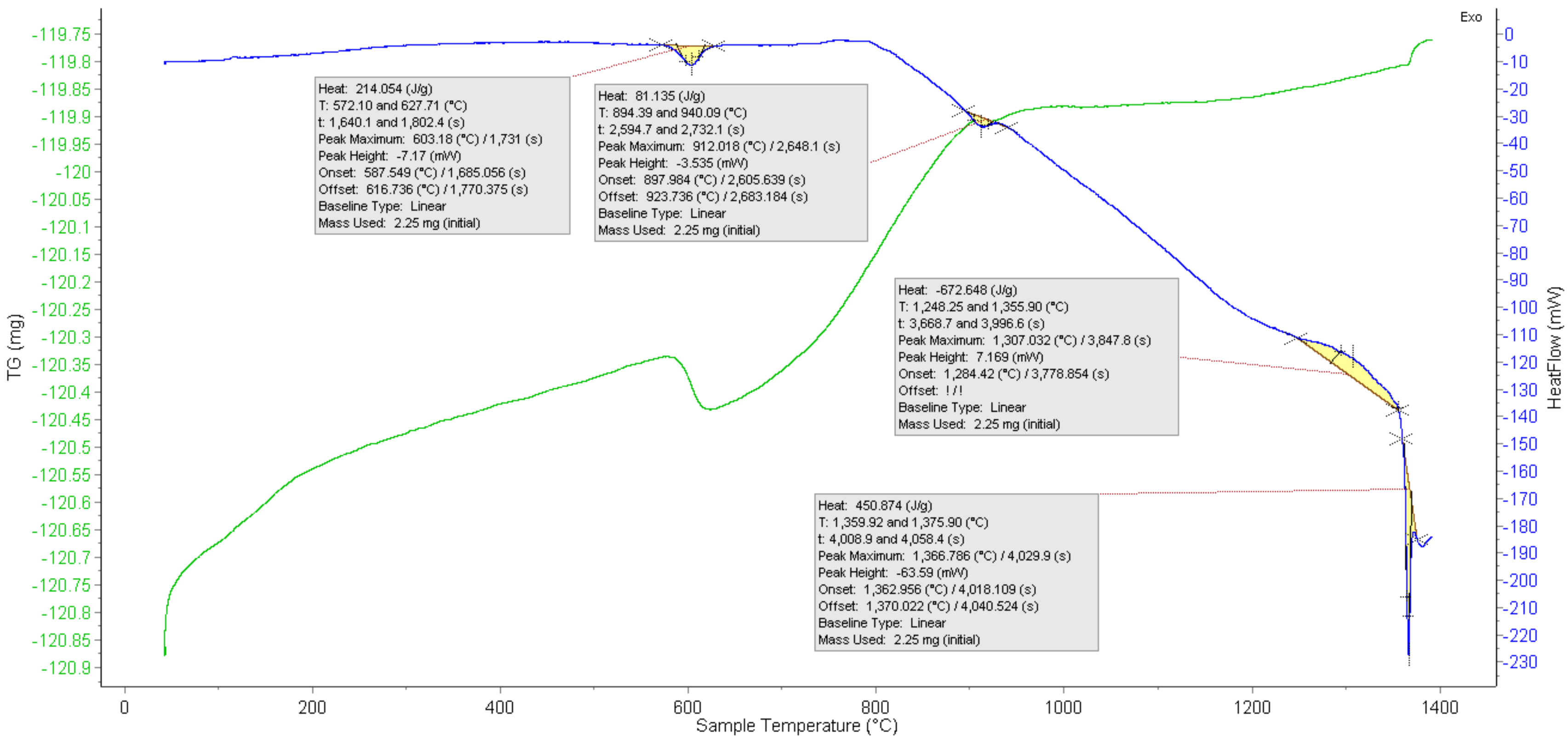


Figure C22: High-Temp DSC Plot for Mix ID SS #3B Trial 2: Fine Ti-MnO_2

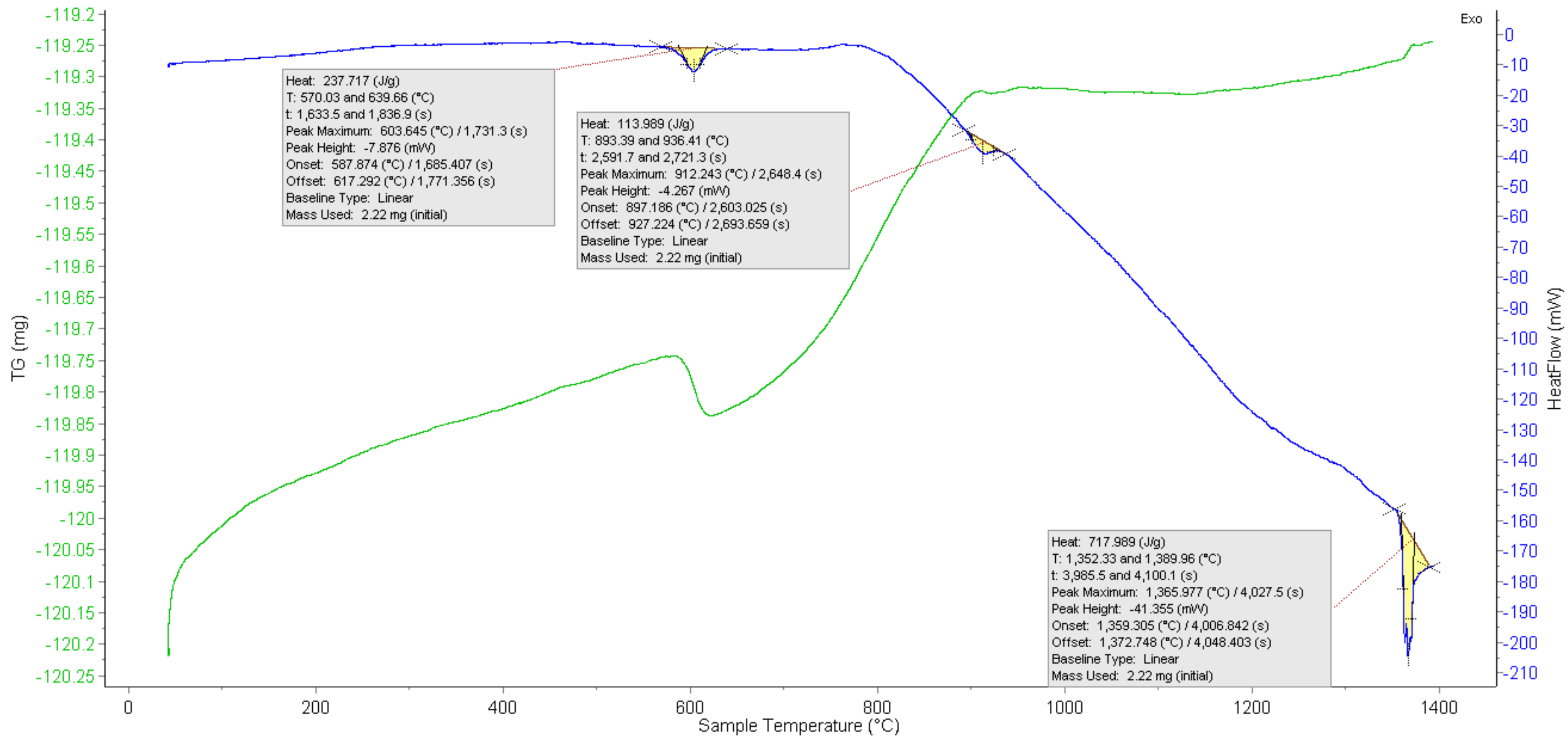


Figure C23: High-Temp DSC Plot for Mix ID SS #4 Trial 1: Fine Mg-MnO_2

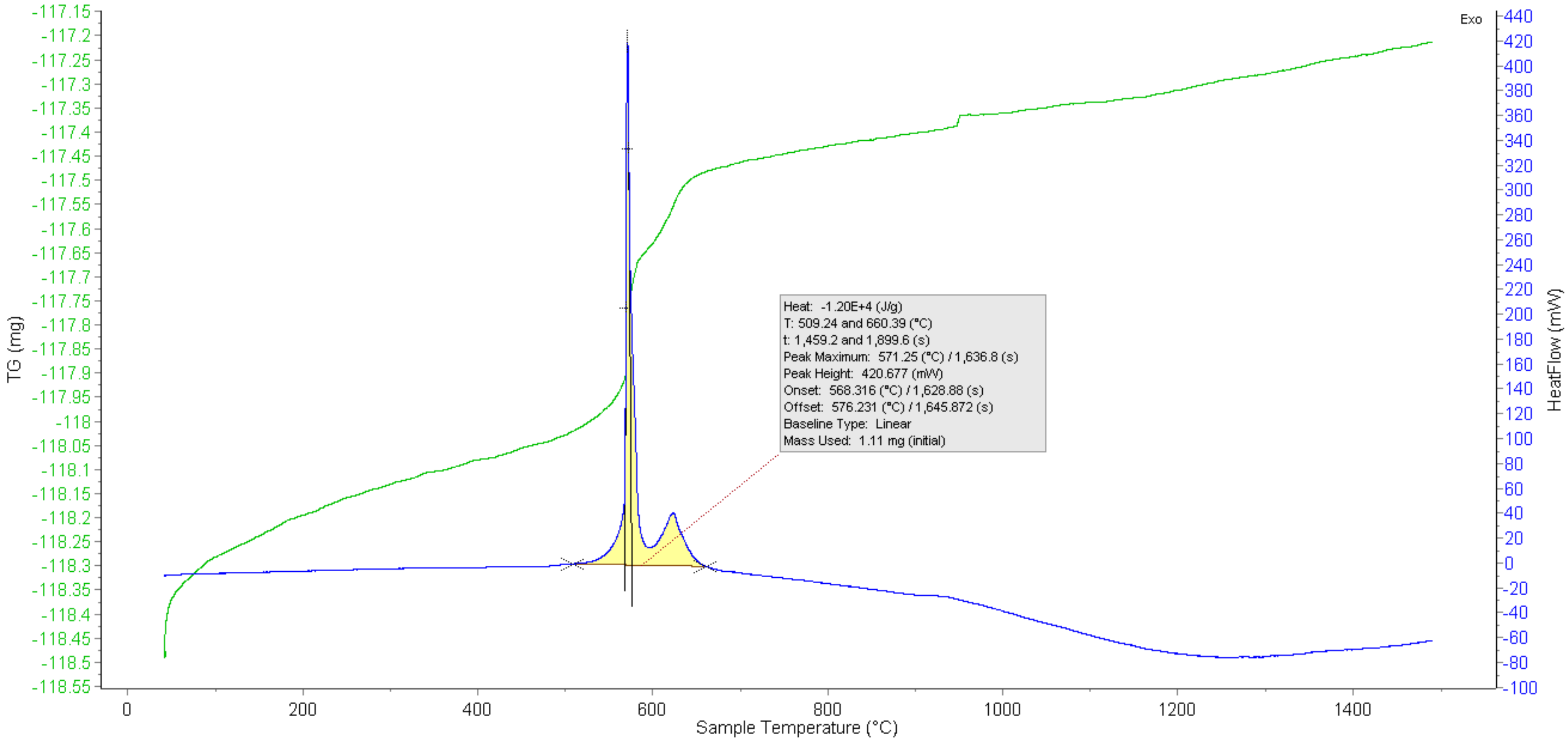


Figure C24: High-Temp DSC Plot for Mix ID SS #4 Trial 2: Fine Mg-MnO_2

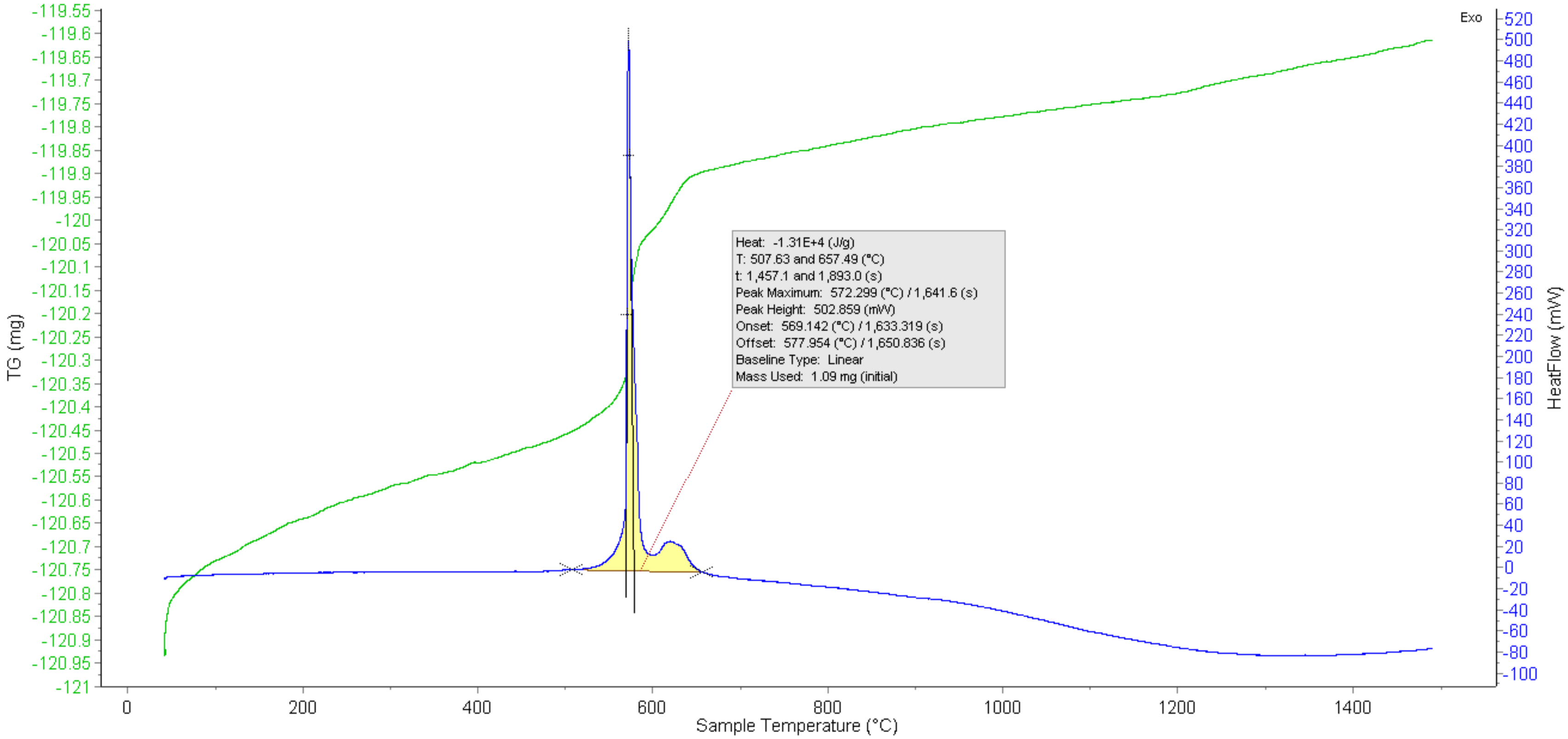


Figure C25: High-Temp DSC Plot for Mix ID SS #6B Trial 1: Fine Ti-Fe_2O_3

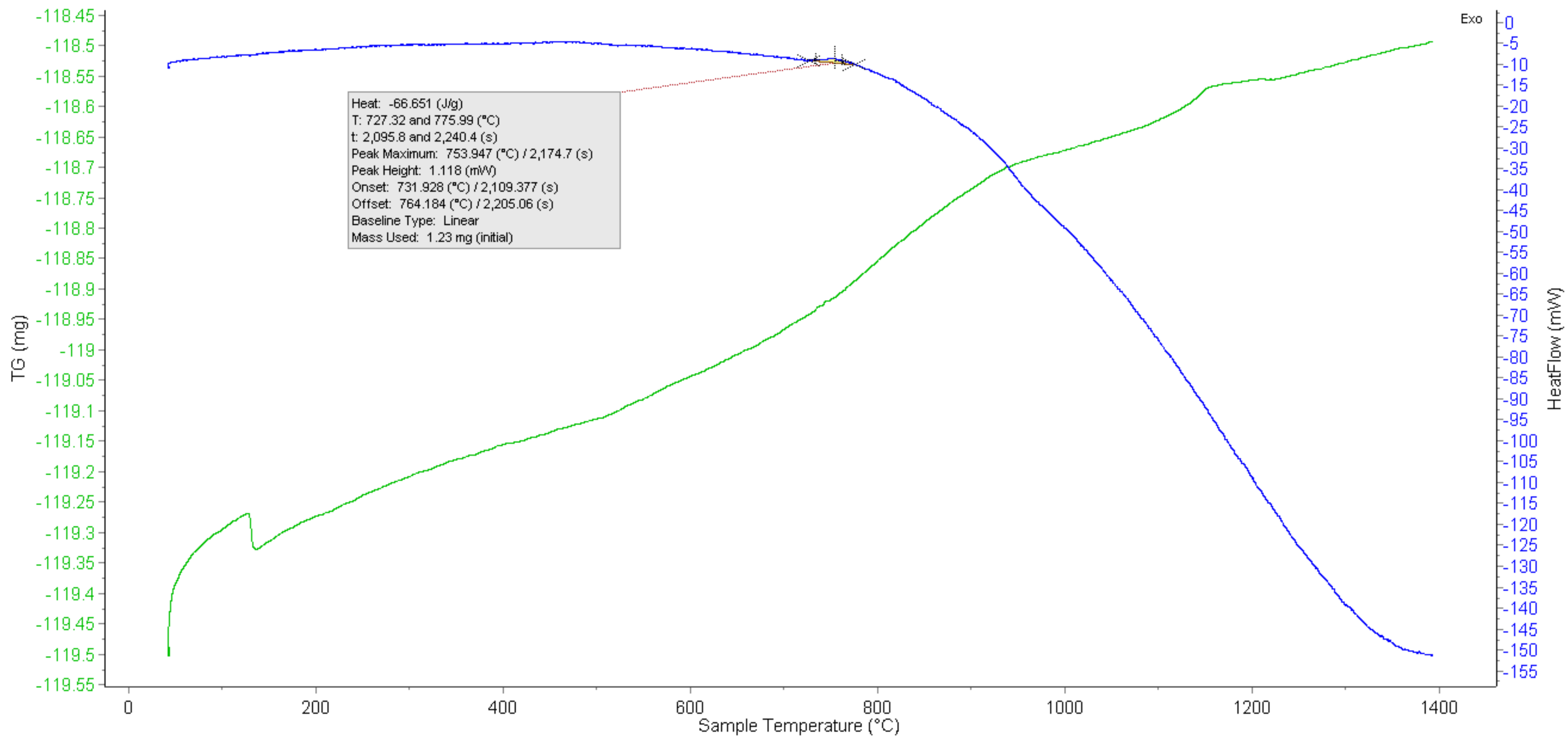


Figure C26: High-Temp DSC Plot for Mix ID SS #6B Trial 2: Fine Ti-Fe_2O_3

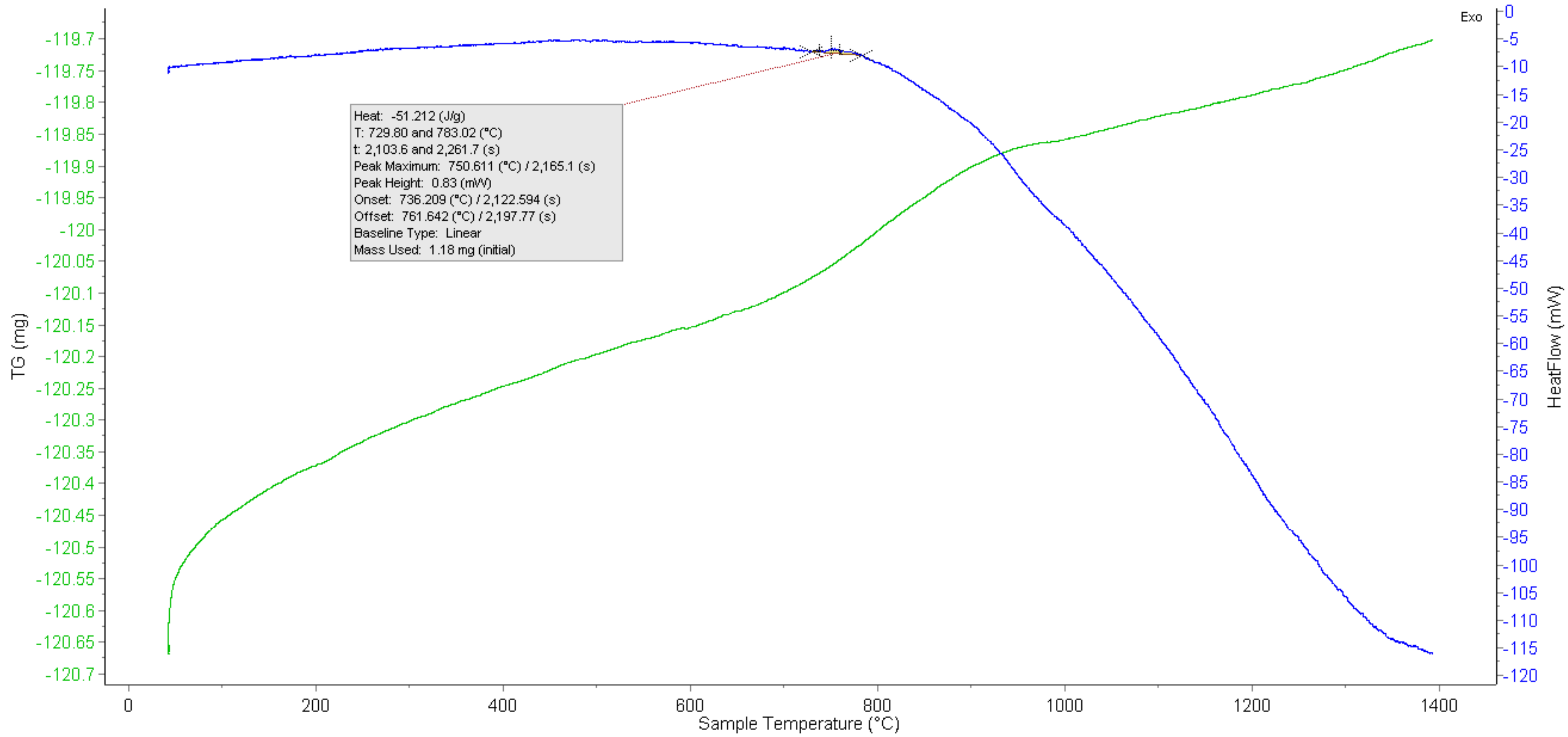


Figure C27: High-Temp DSC Plot for Mix ID SS #7B Trial 1: Fine Ti-CuO

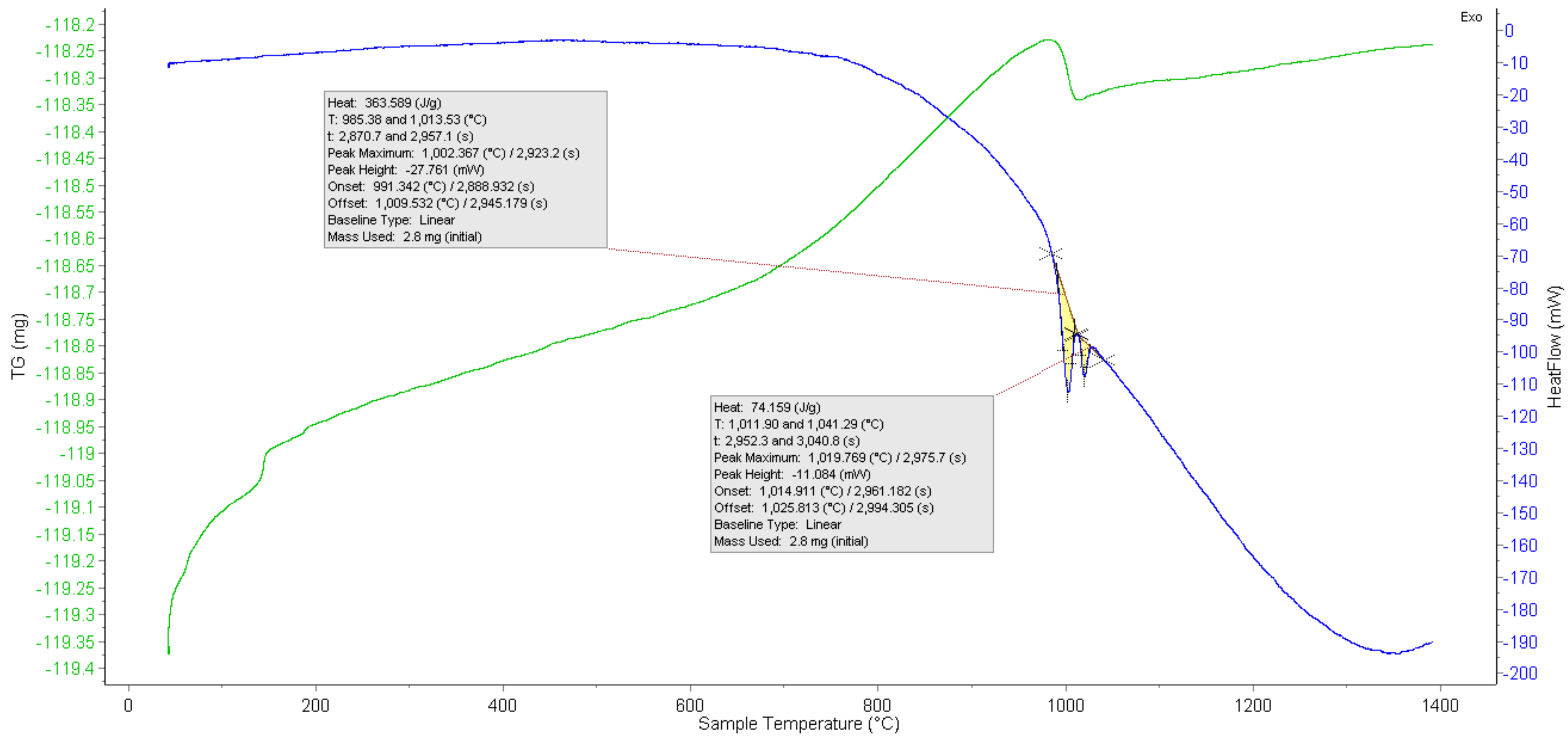


Figure C28: High-Temp DSC Plot for Mix ID SS #7B Trial 2: Fine Ti-CuO

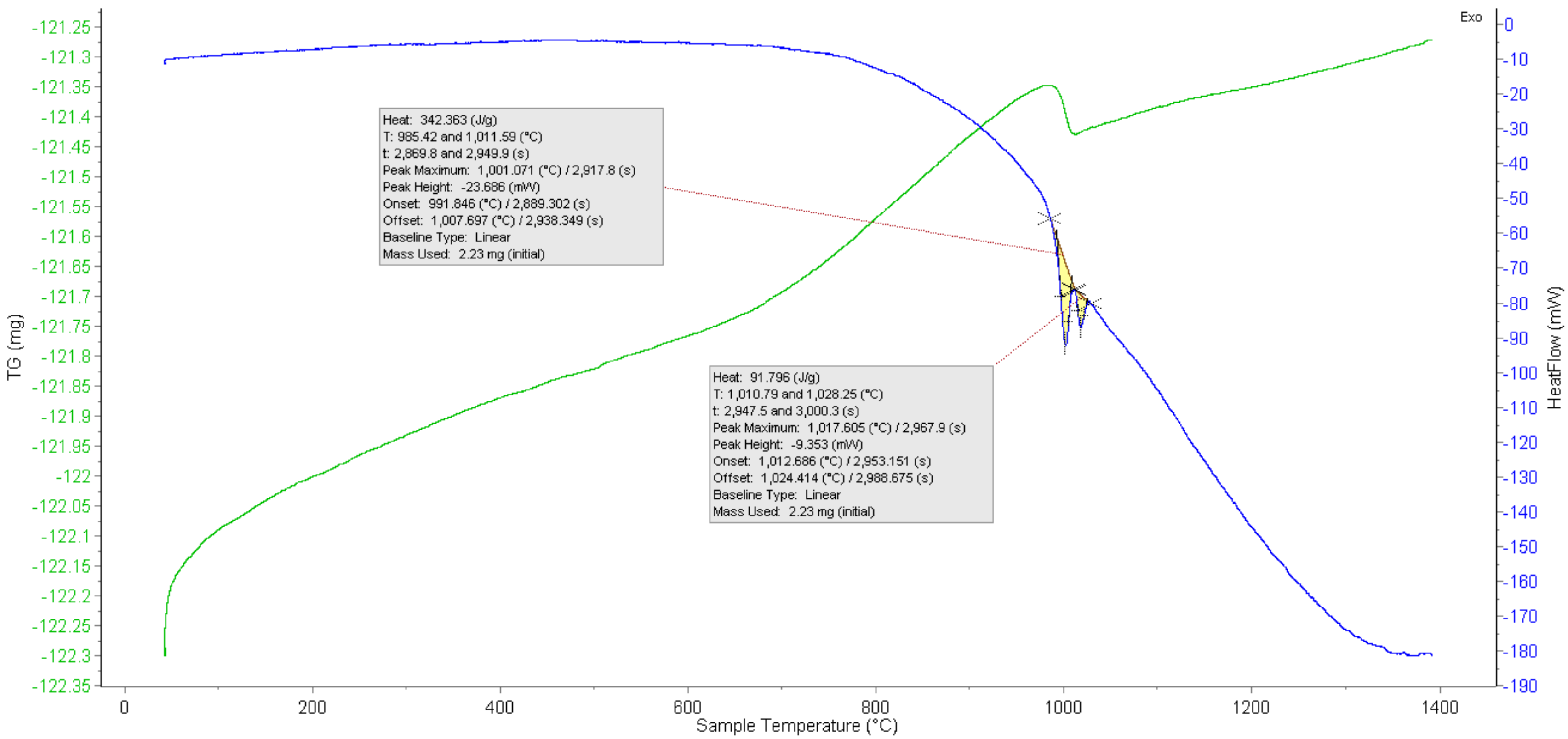


Figure C29: High-Temp DSC Plot for Mix ID SS #9 Trial 1: Fine Al-MoO_3

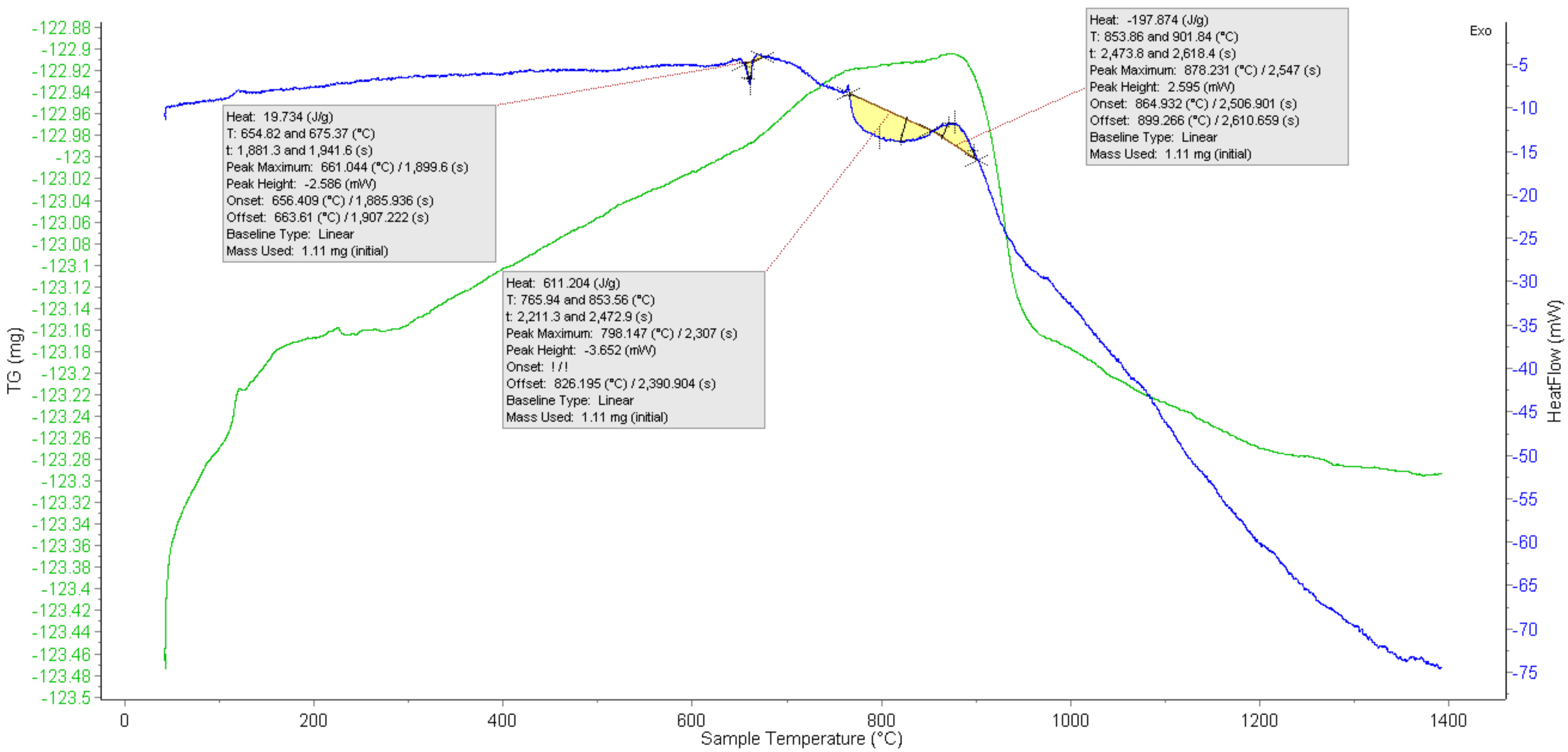


Figure C30: High-Temp DSC Plot for Mix ID SS #9 Trial 2: Fine Al-MoO_3

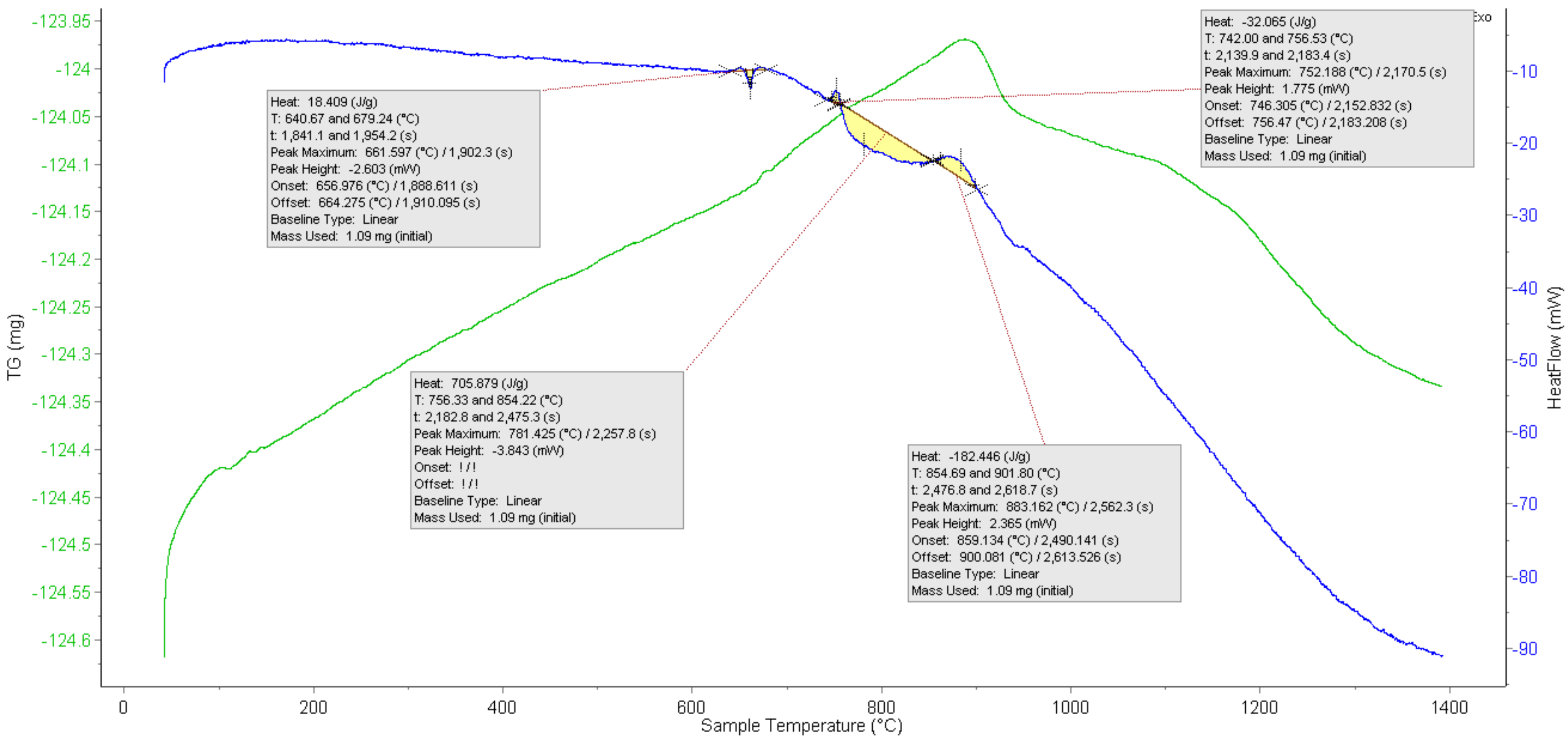


Figure C31: High-Temp DSC Plot for Mix ID SS #10 Trial 1: Fine Mg-Fe_2O_3

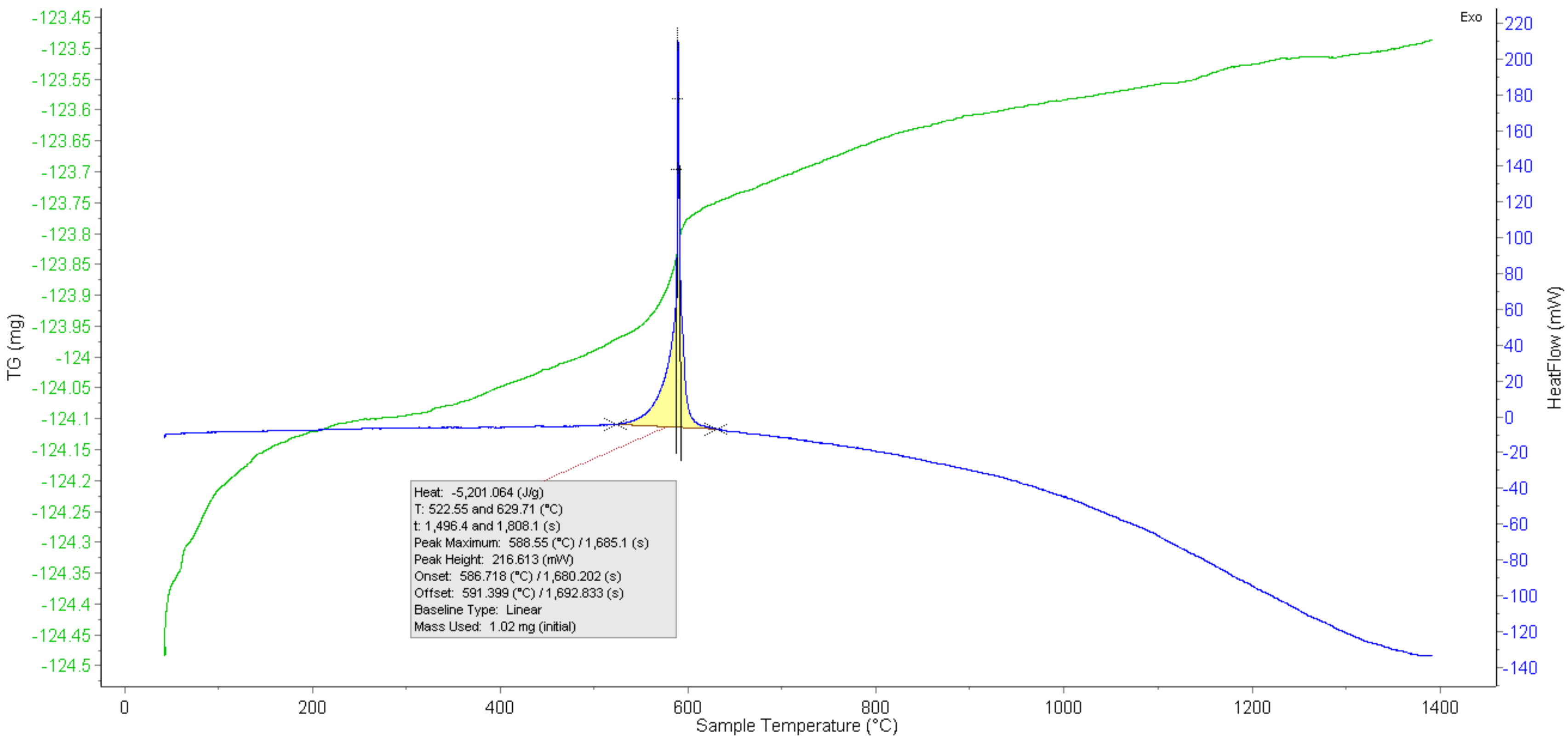


Figure C32: High-Temp DSC Plot for Mix ID SS #10 Trial 2: Fine Mg-Fe_2O_3

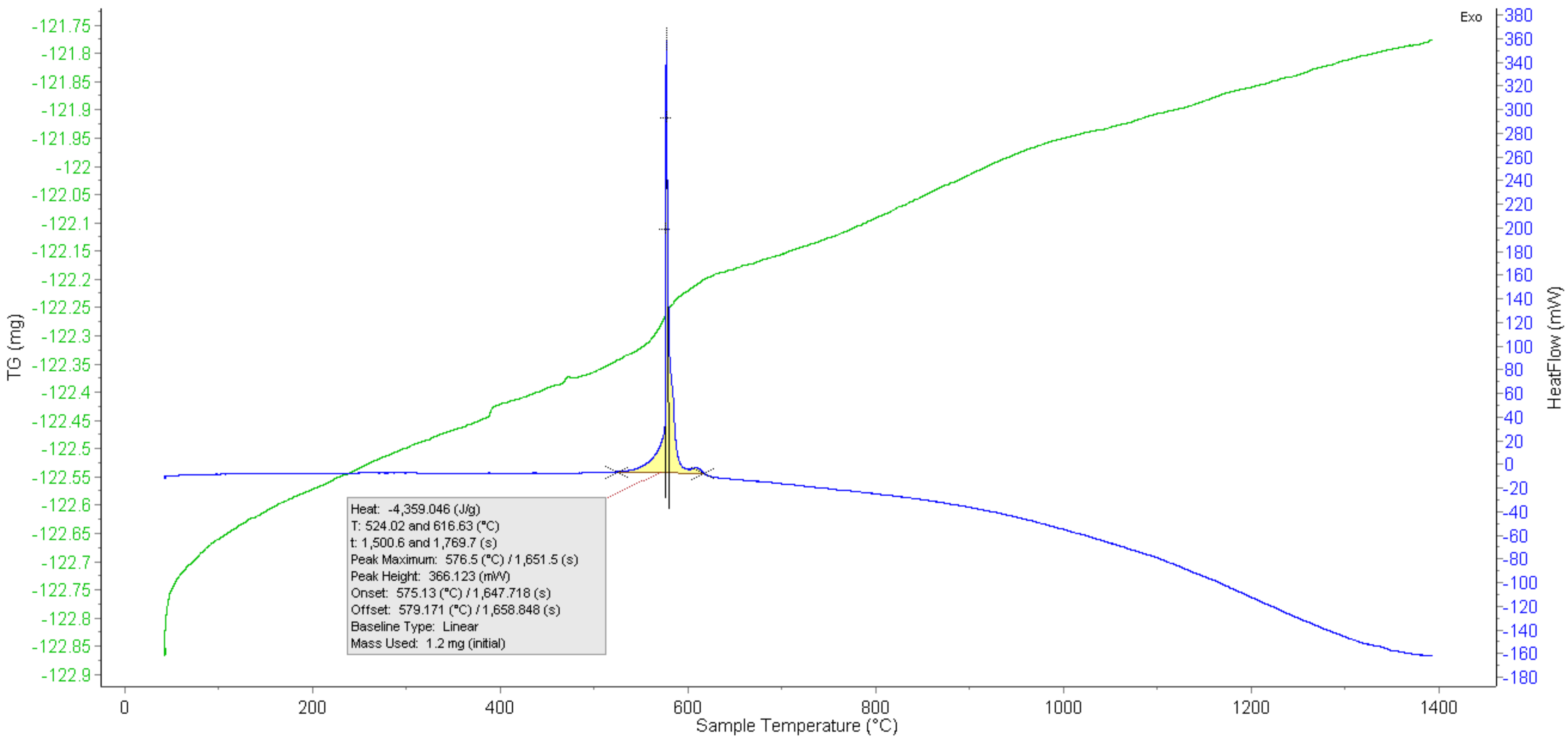


Figure C33: High-Temp DSC Plot for Mix ID SS #11 Trial 1: Fine Mg-CuO

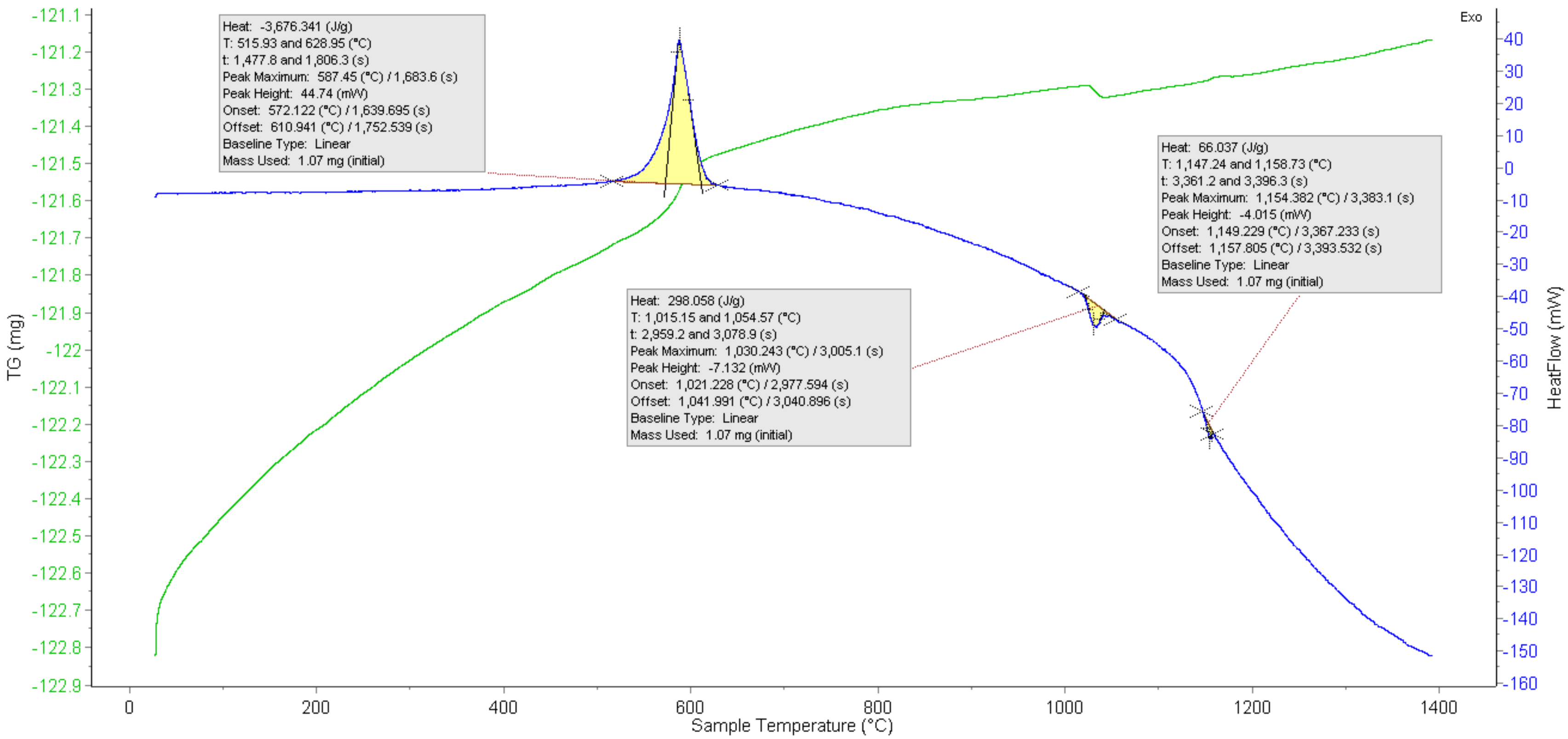


Figure C34: High-Temp DSC Plot for Mix ID SS #11 Trial 2: Fine Mg-CuO

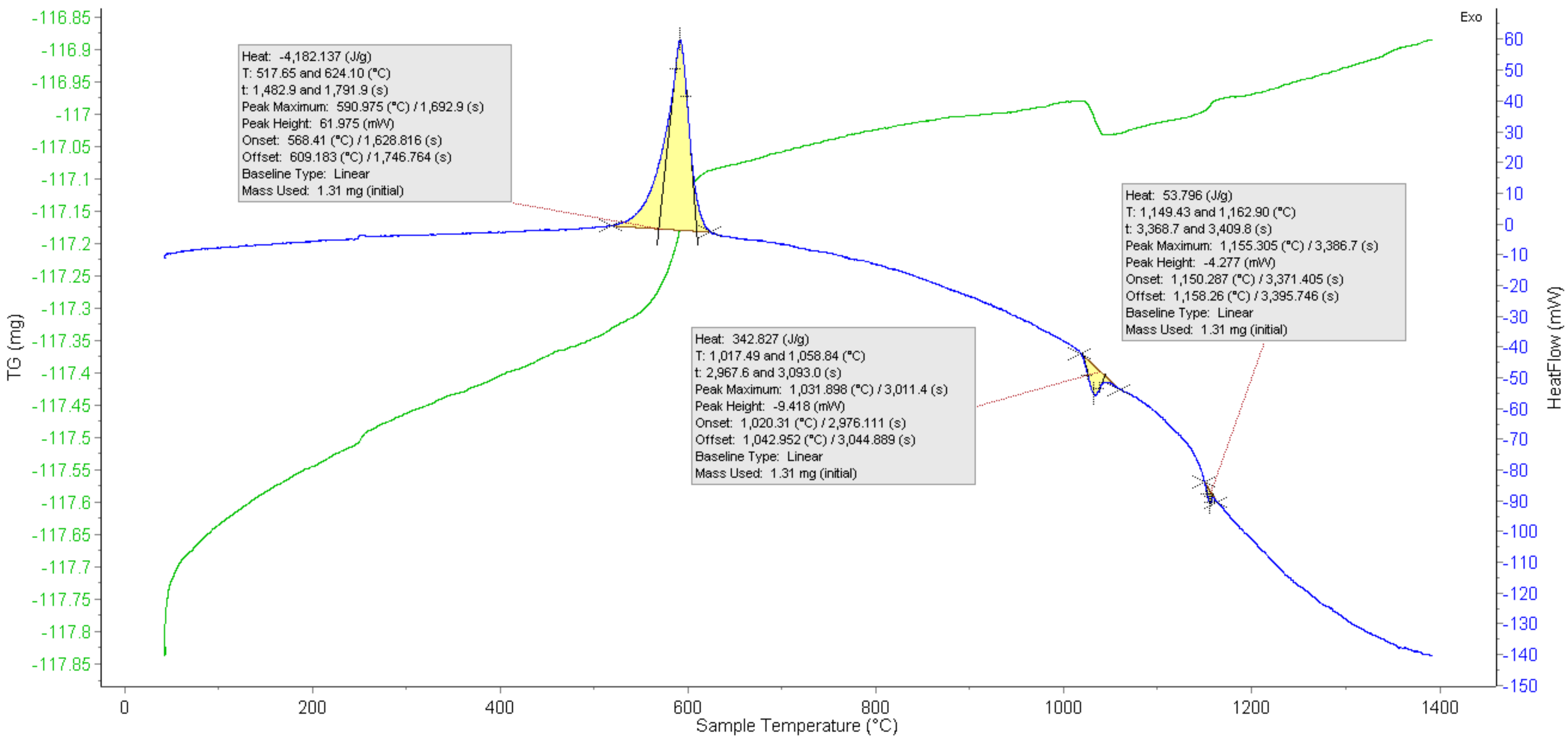


Figure C35: High-Temp DSC Plot for Mix ID SS #12 Trial 1: Fine Al-Co_3O_4

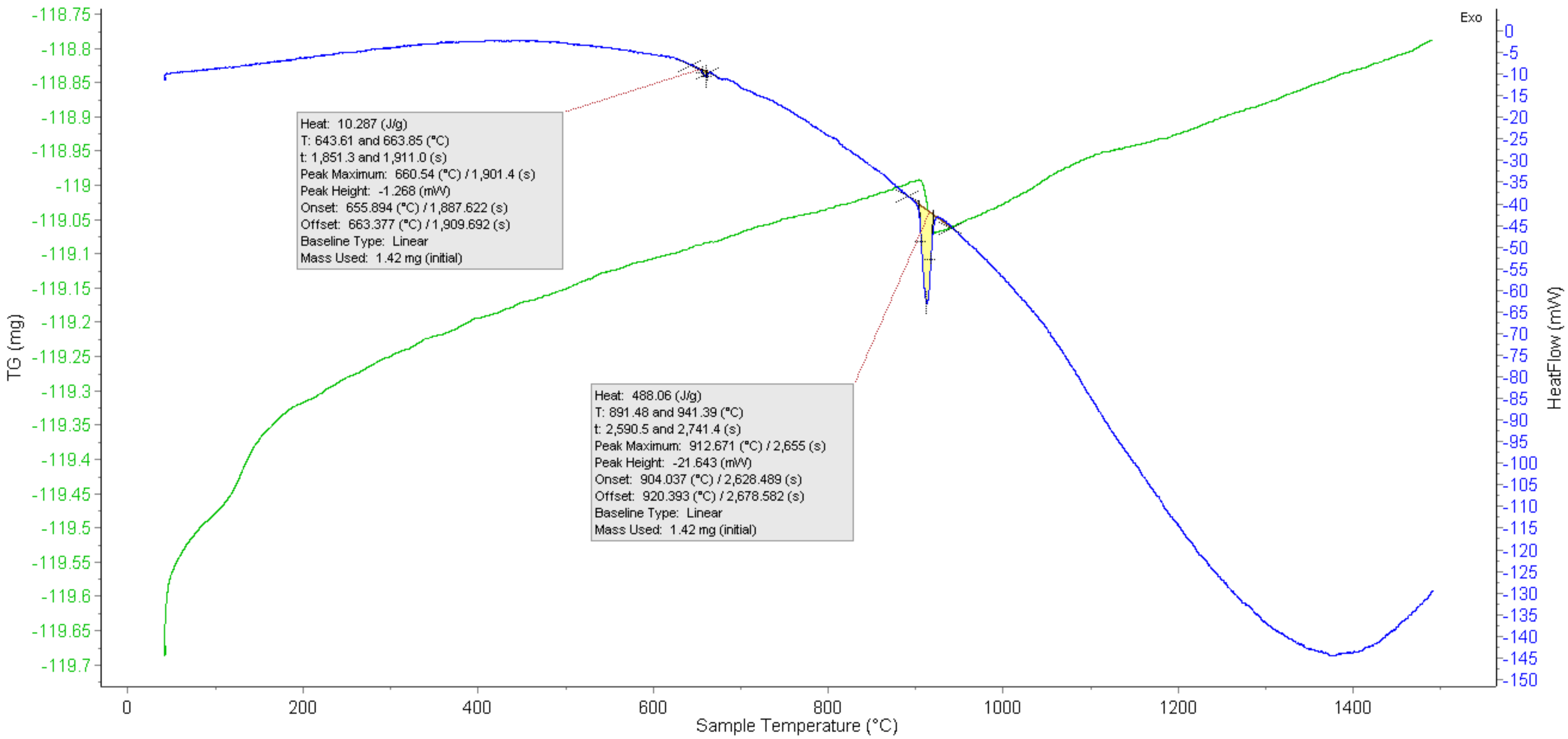


Figure C36: High-Temp DSC Plot for Mix ID SS #12 Trial 2: Fine Al-Co_3O_4

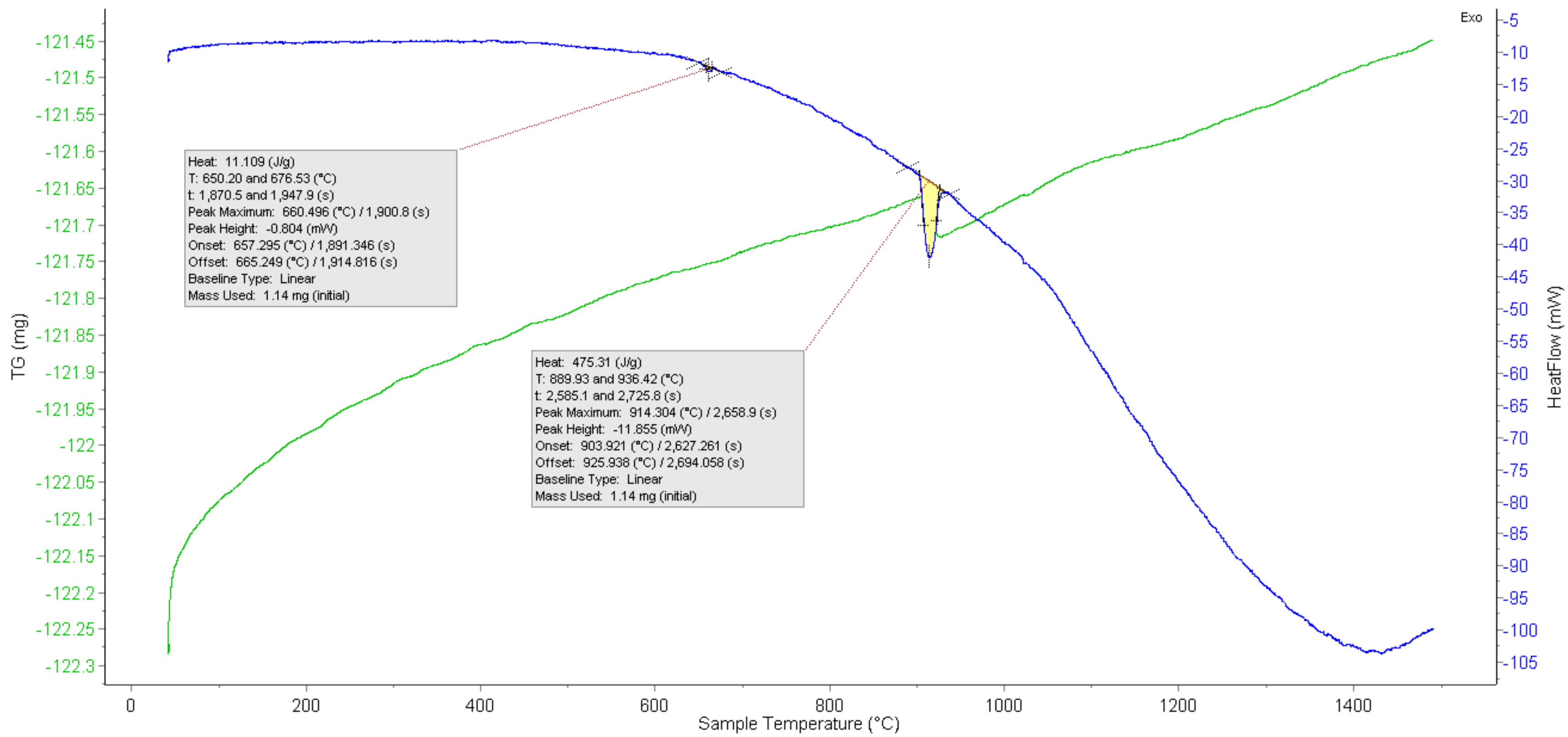


Figure C37: High-Temp DSC Plot for Mix ID SS #18 Trial 1: Fine Al-WO_3

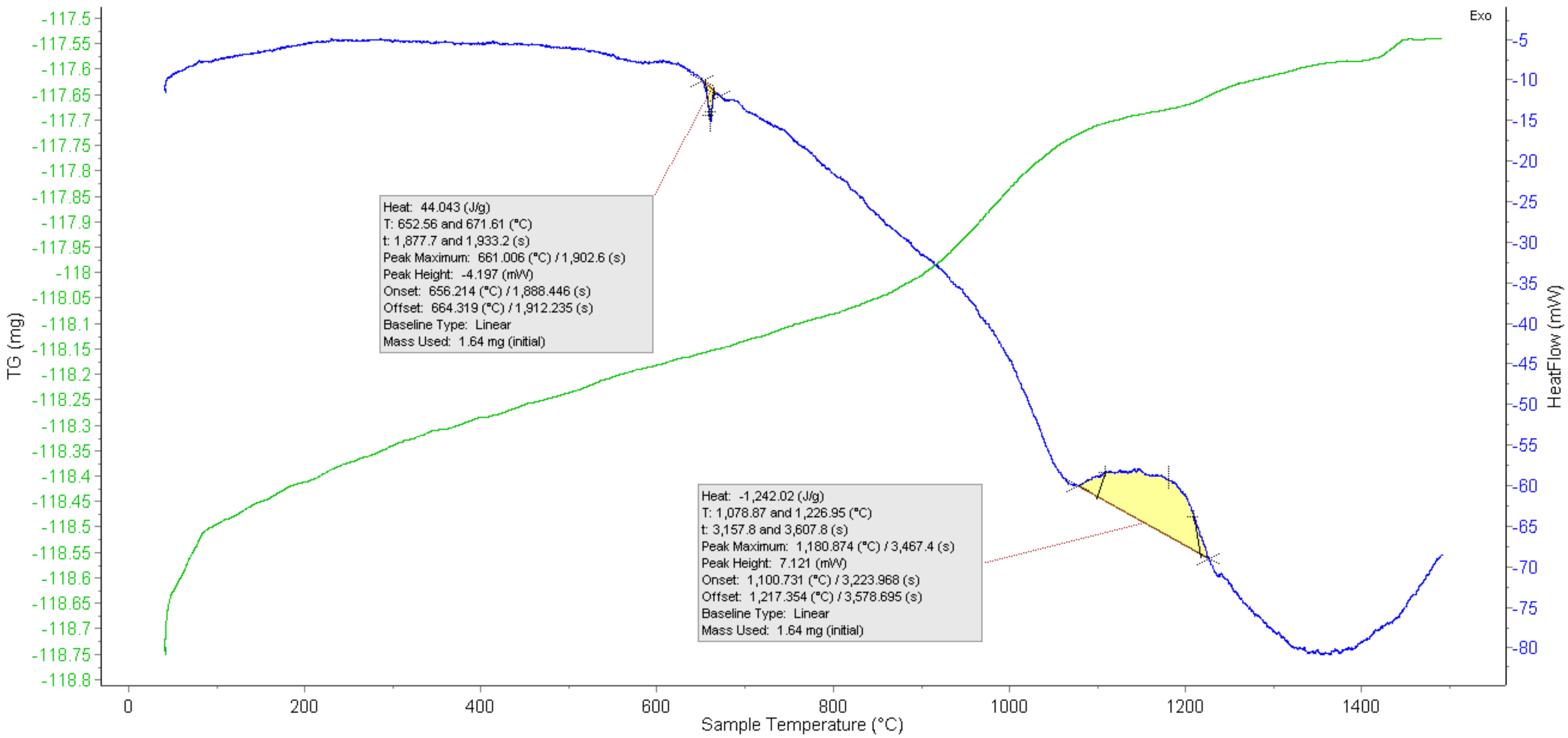


Figure C38: High-Temp DSC Plot for Mix ID SS #18 Trial 2: Fine Al-WO_3

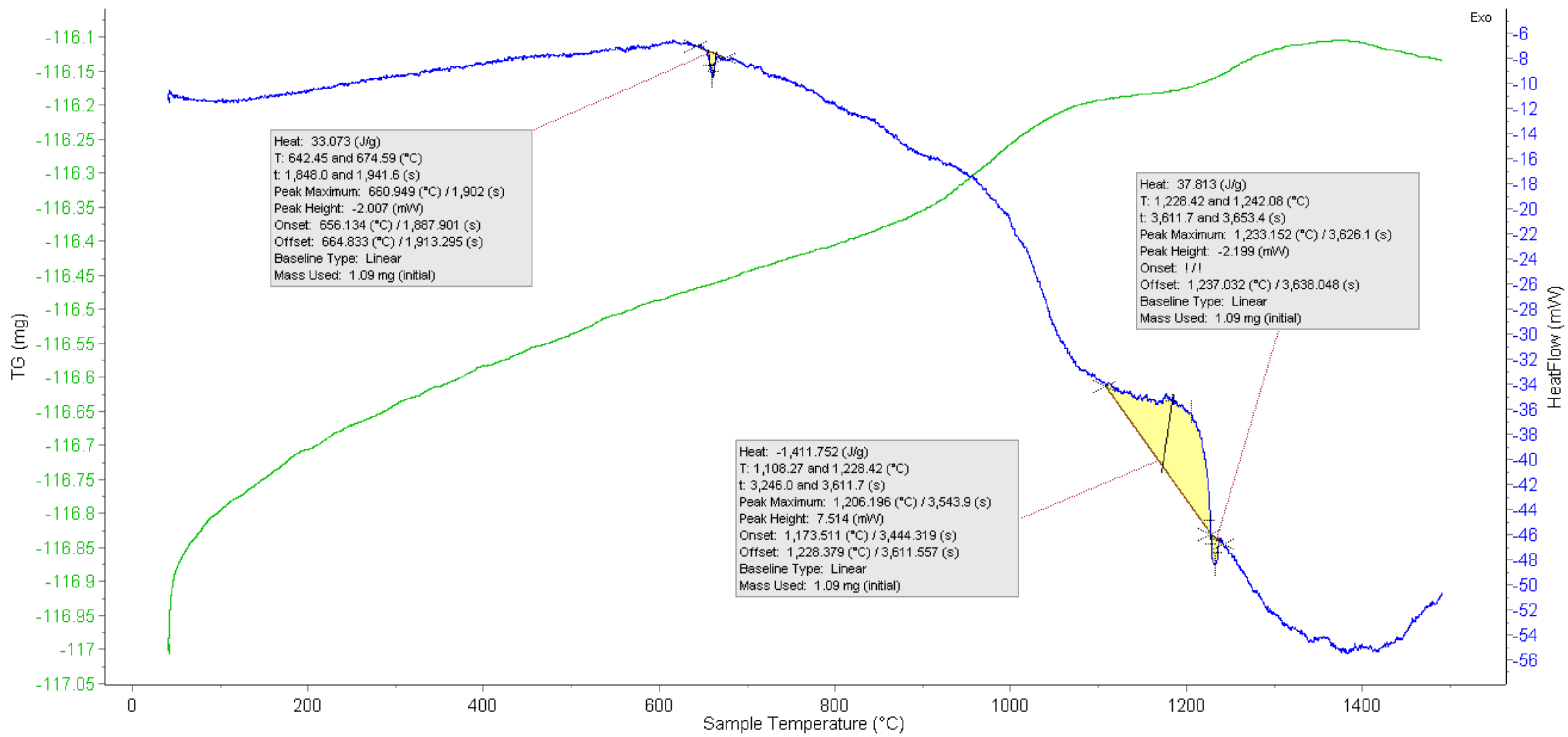


Figure C39: High-Temp DSC Plot for Mix ID SS #19 Trial 1: Fine Al-SnO_2

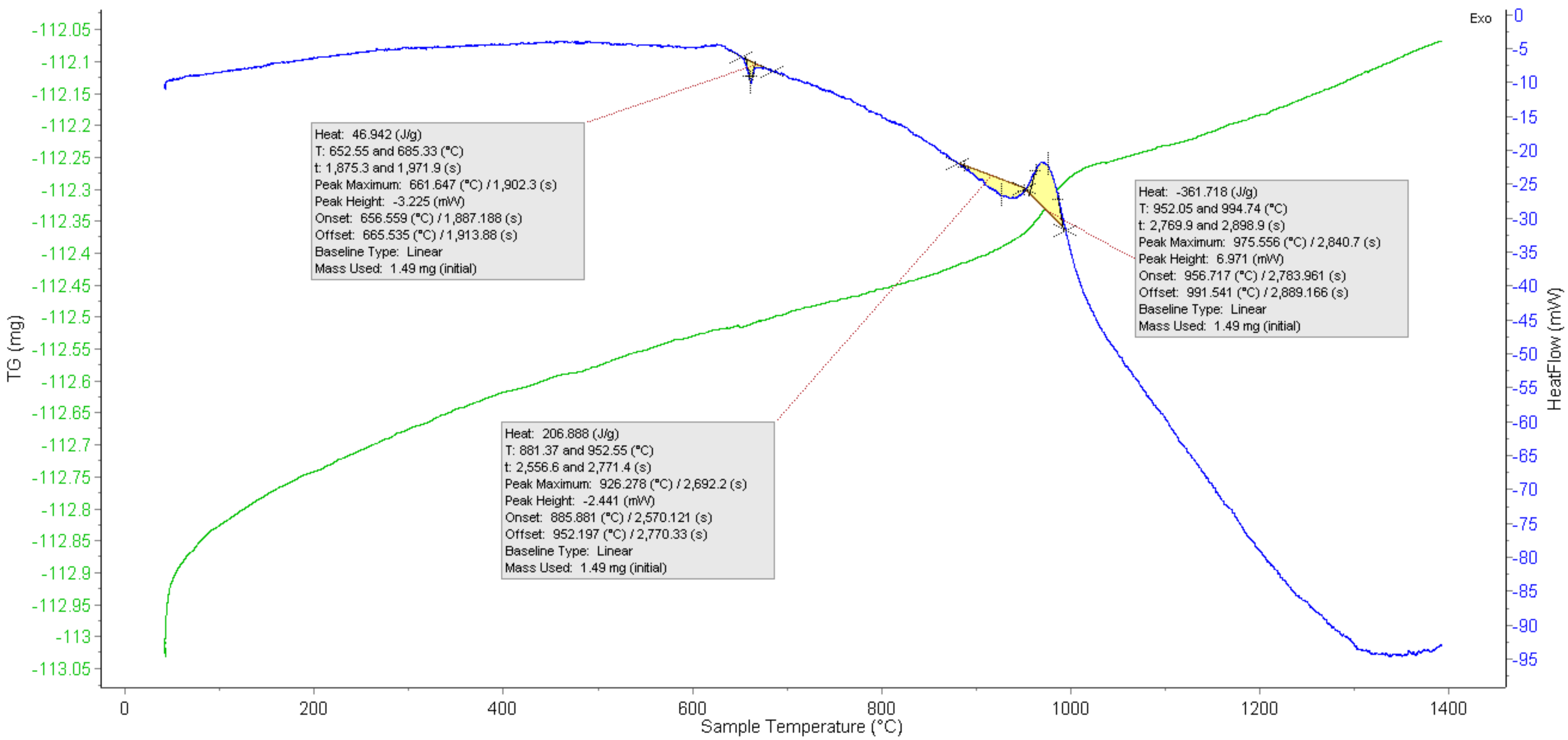


Figure C40: High-Temp DSC Plot for Mix ID SS #19 Trial 2: Fine Al-SnO_2

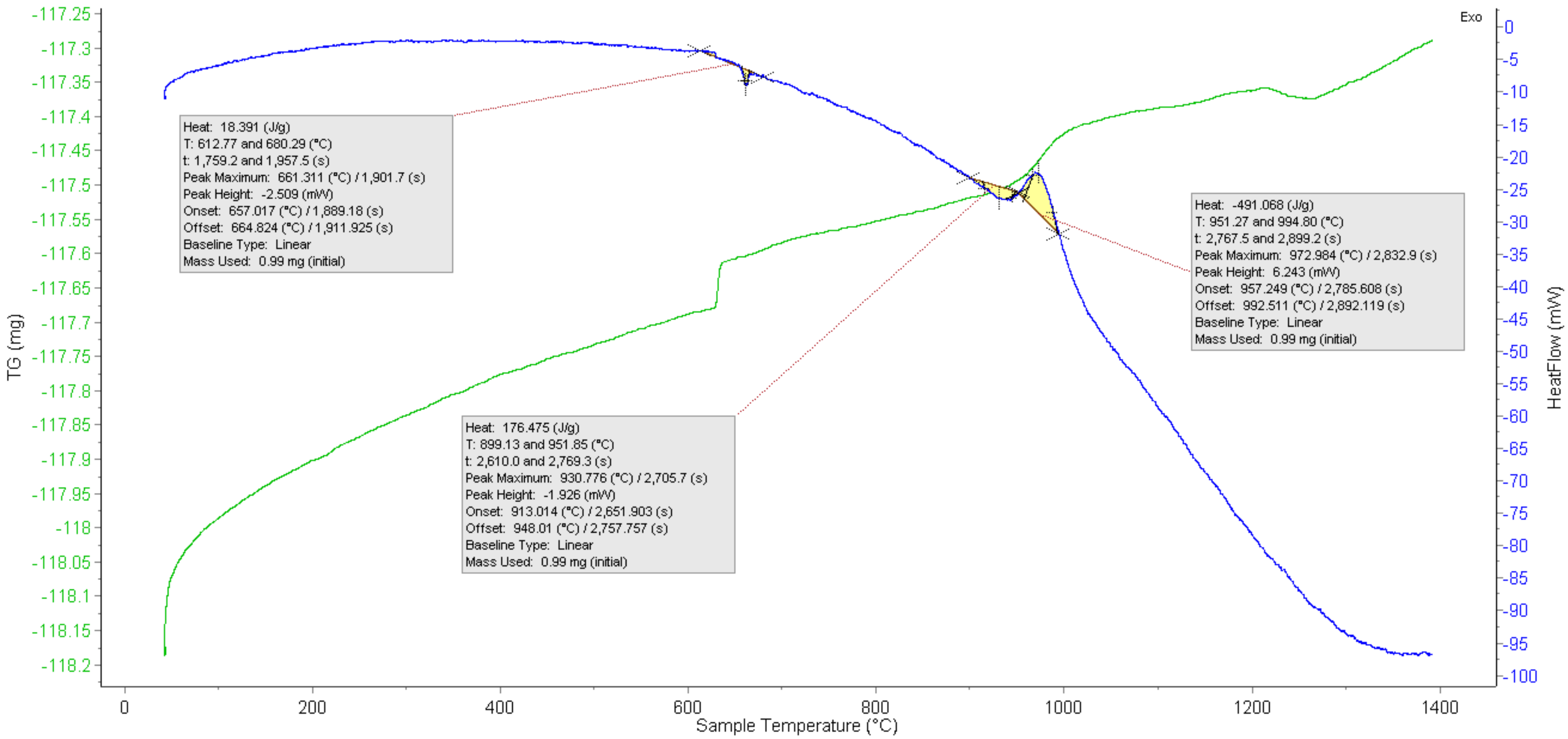


Figure C41: High-Temp DSC Plot for Mix ID SS #21 Trial 1: Fine Al-Cr_2O_3

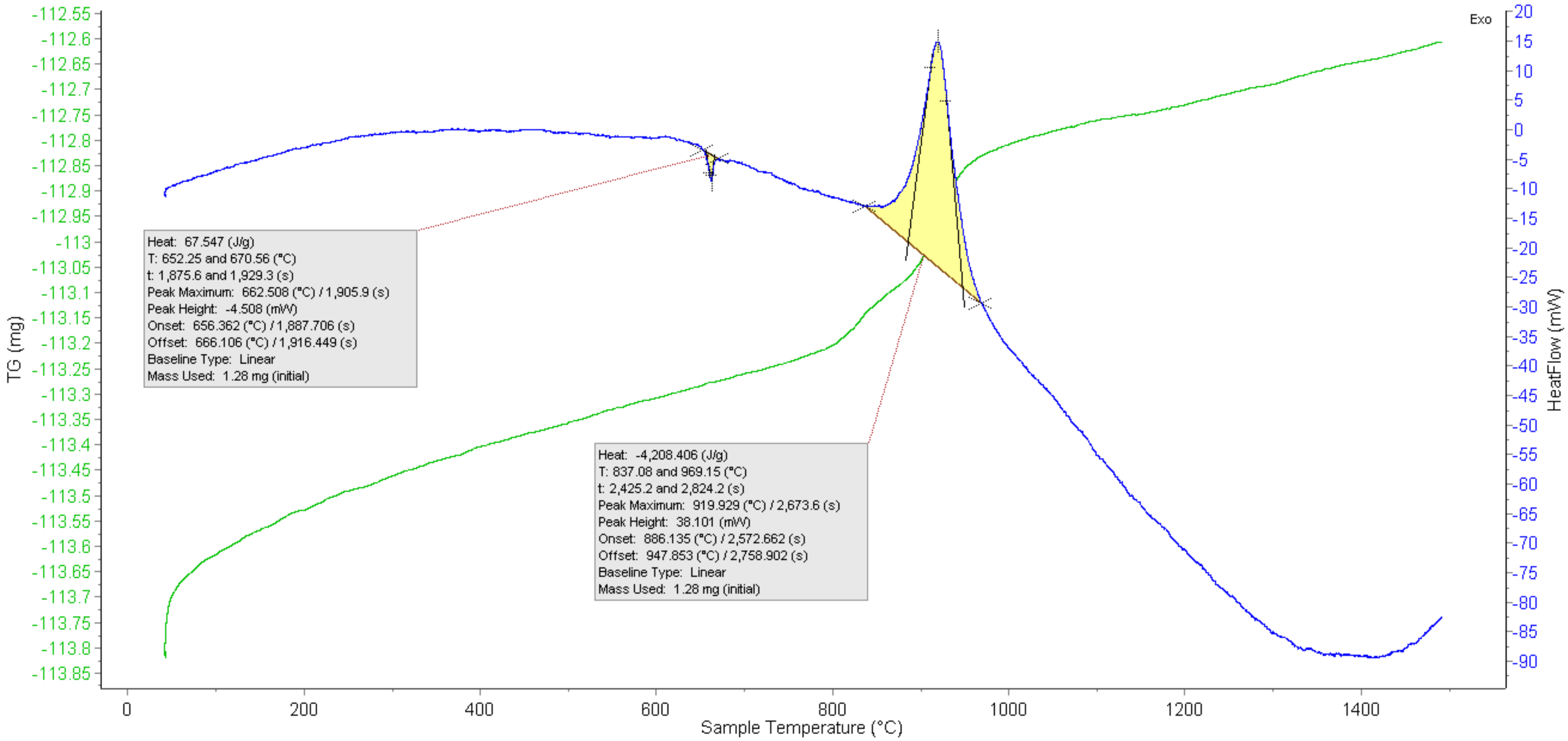


Figure C42: High-Temp DSC Plot for Mix ID SS #21 Trial 2: Fine Al-Cr_2O_3

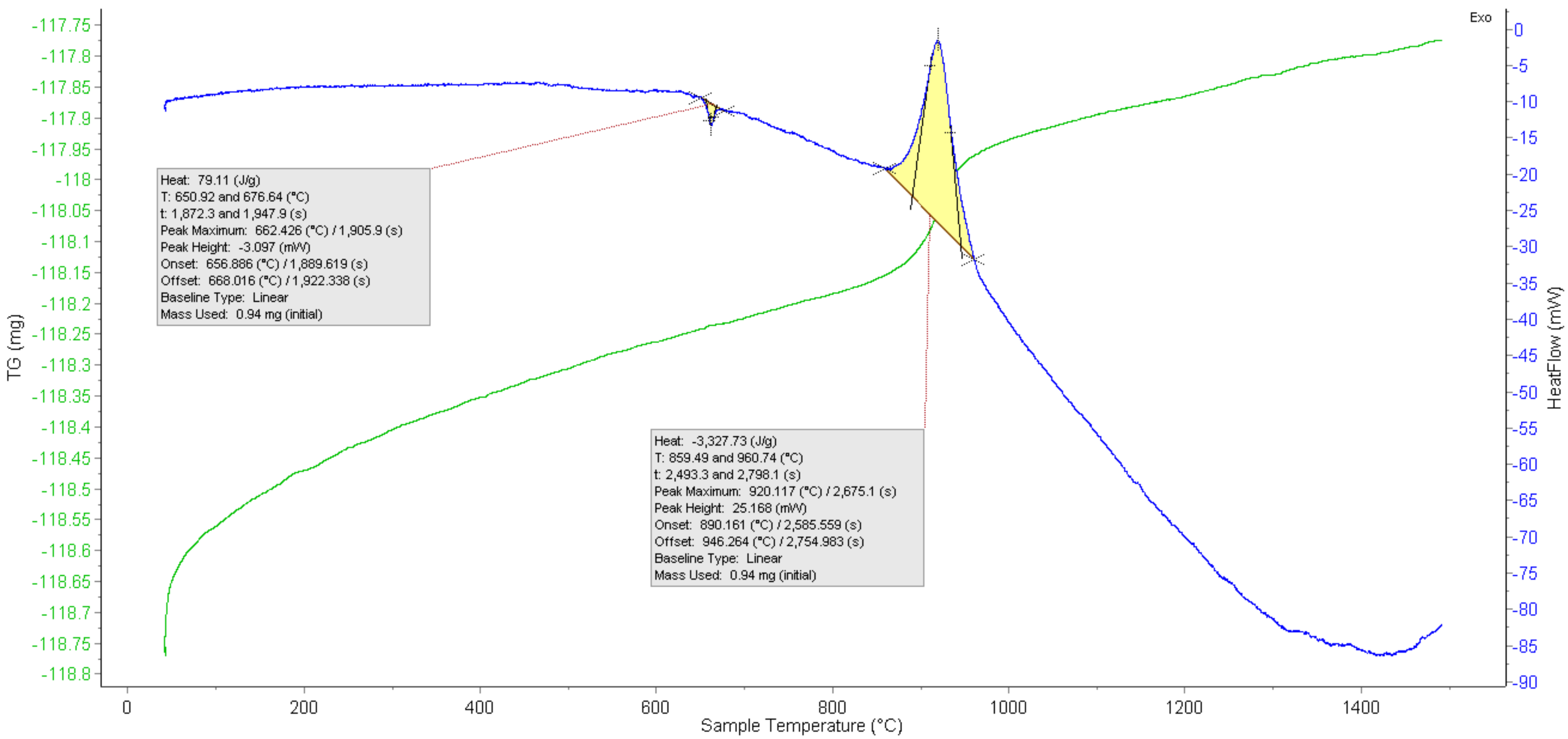


Figure C43: High-Temp DSC Plot for Mix ID SS #24 Trial 1: Fine Al-Bi_2O_3

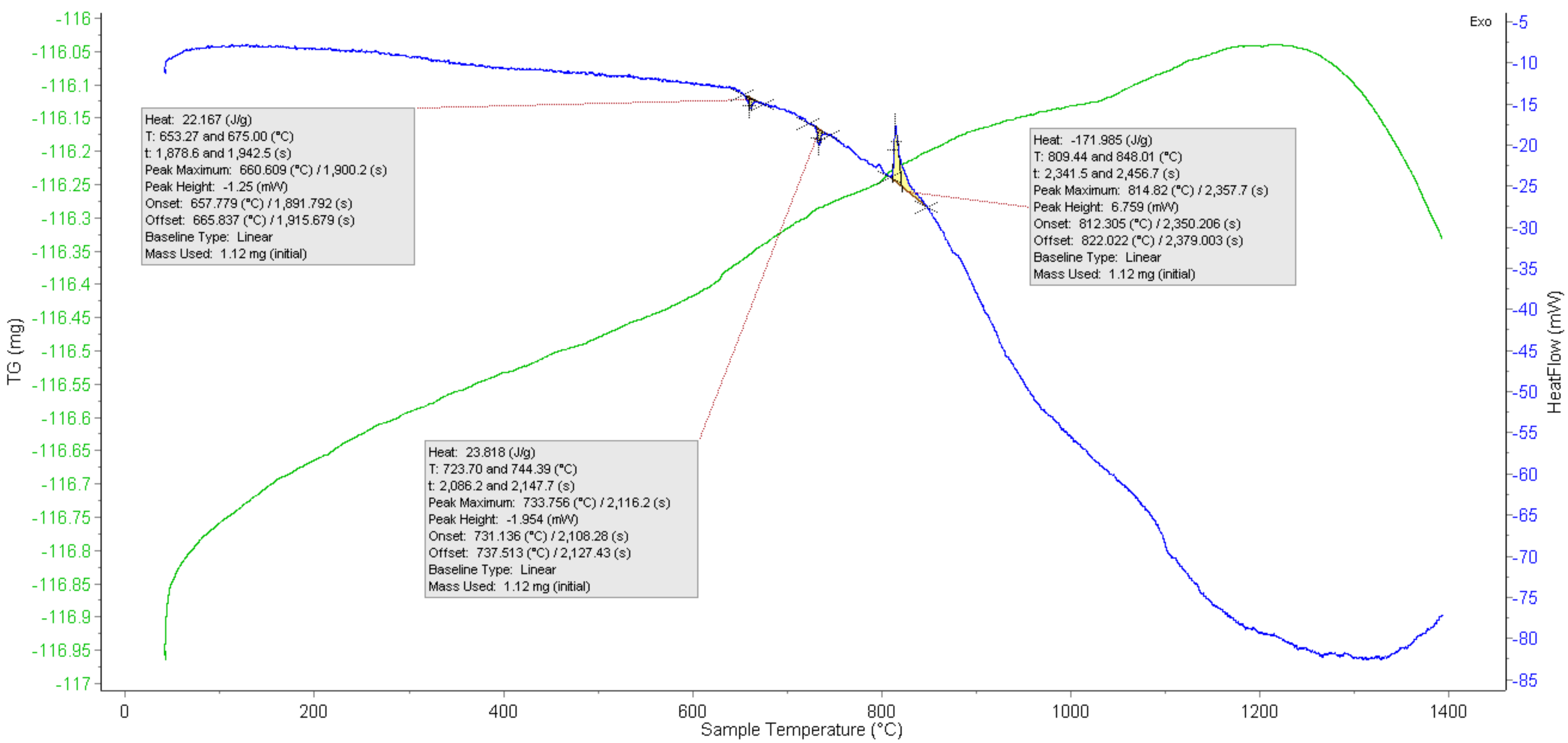


Figure C44: High-Temp DSC Plot for Mix ID SS #24 Trial 2: Fine Al-Bi_2O_3

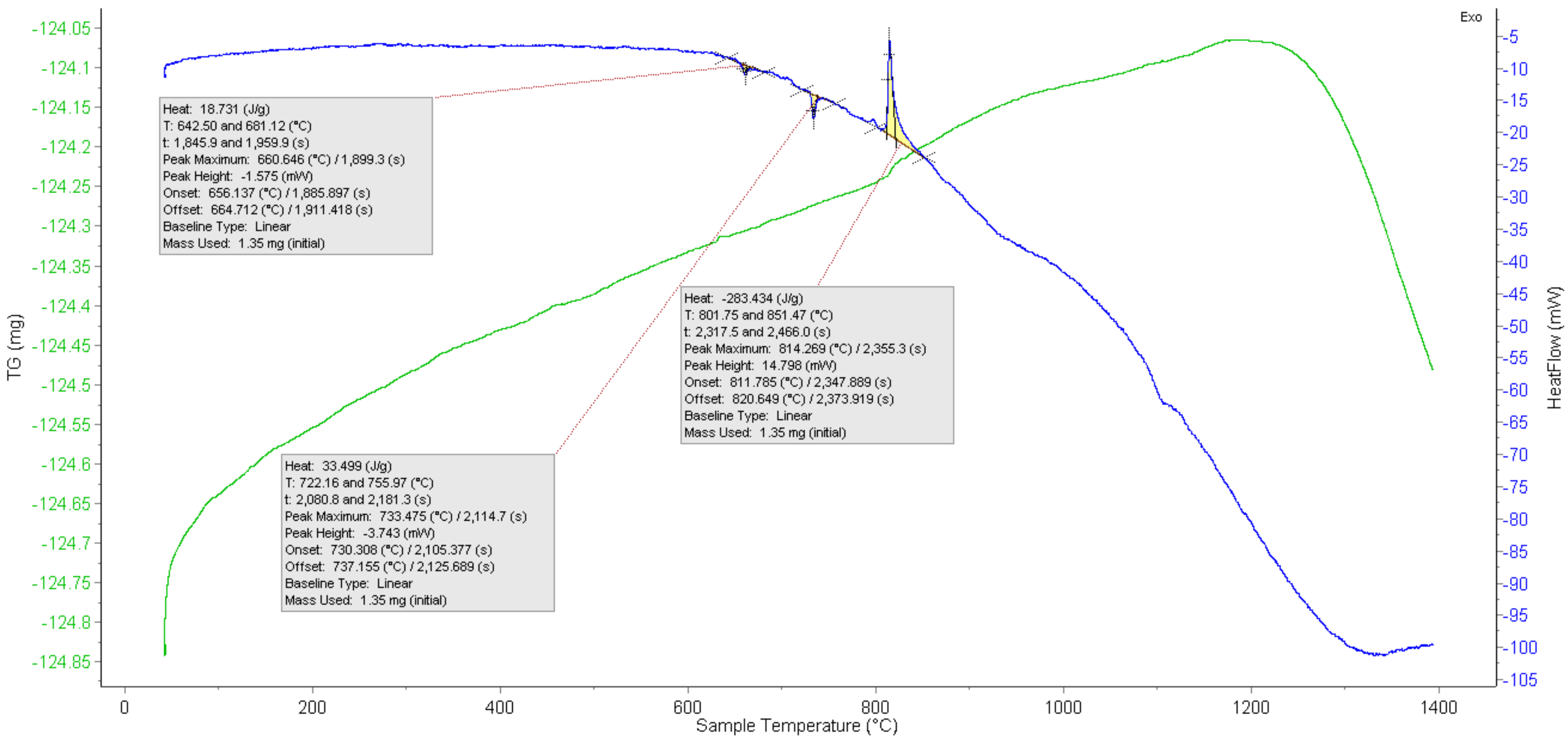


Figure C45: High-Temp DSC Plot for Mix ID SS #25 Trial 1: Fine Al-TiO_2

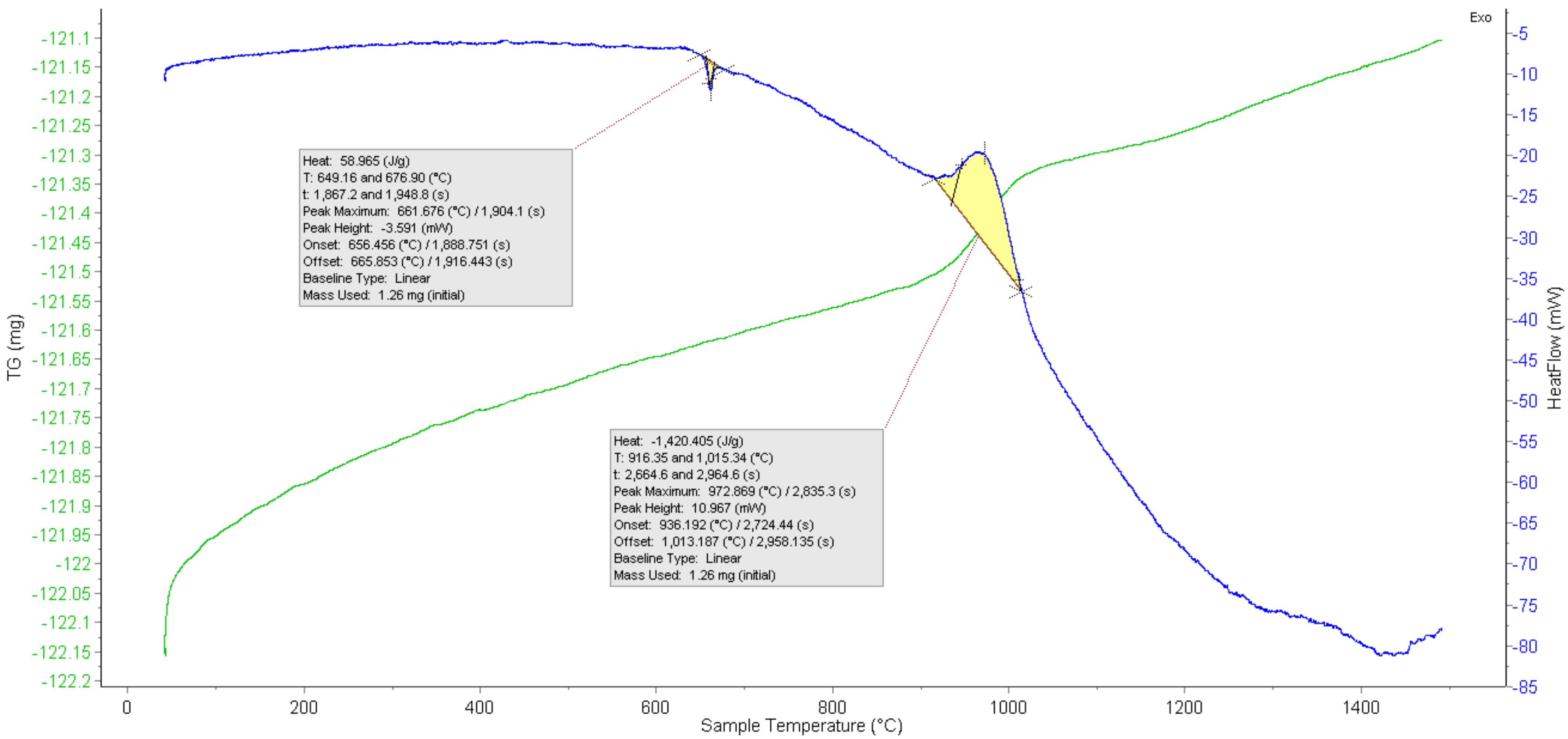


Figure C46: High-Temp DSC Plot for Mix ID SS #25 Trial 2: Fine Al-TiO_2

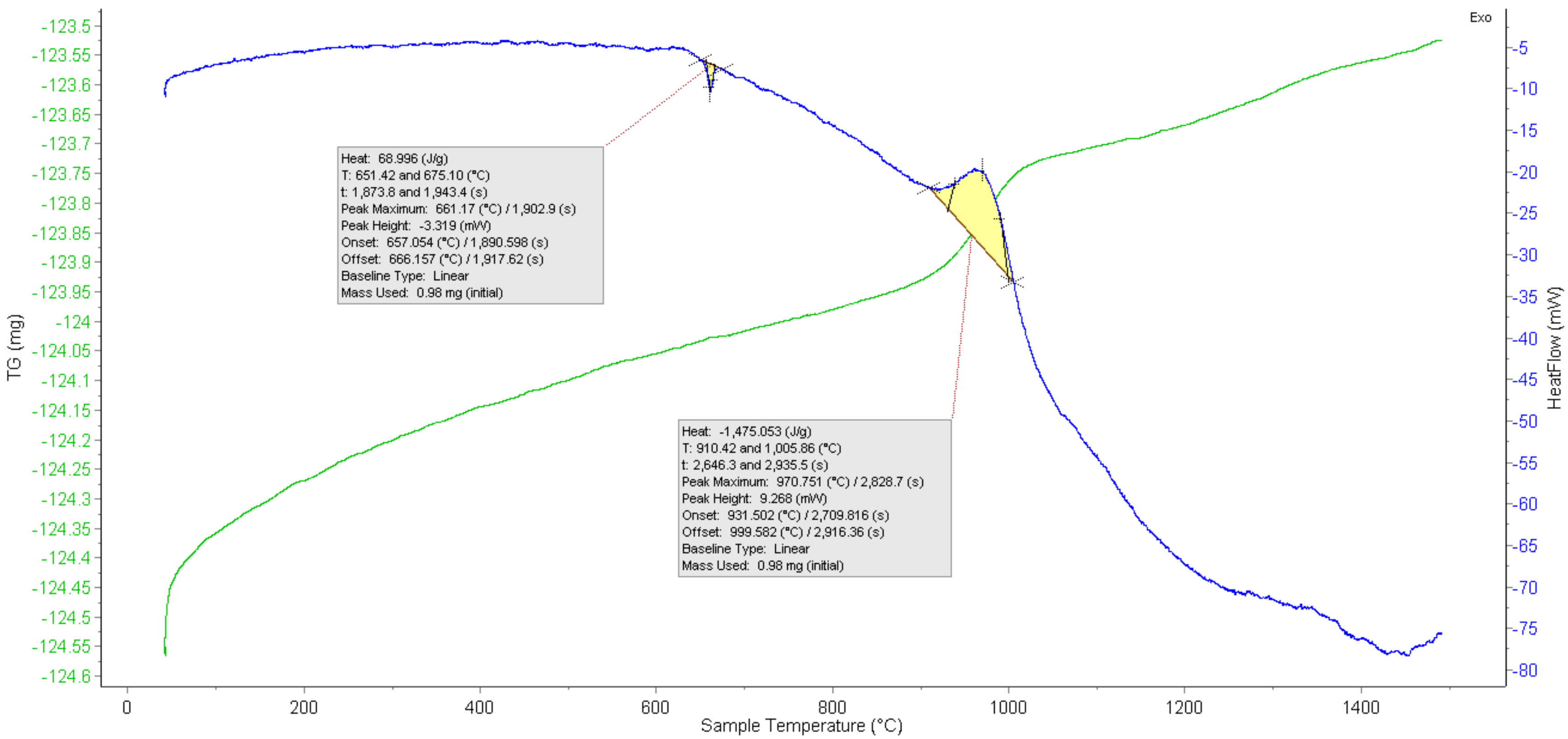


Figure C47: High-Temp DSC Plot for Mix ID SS #26 Trial 1: Fine Al-CrO_3

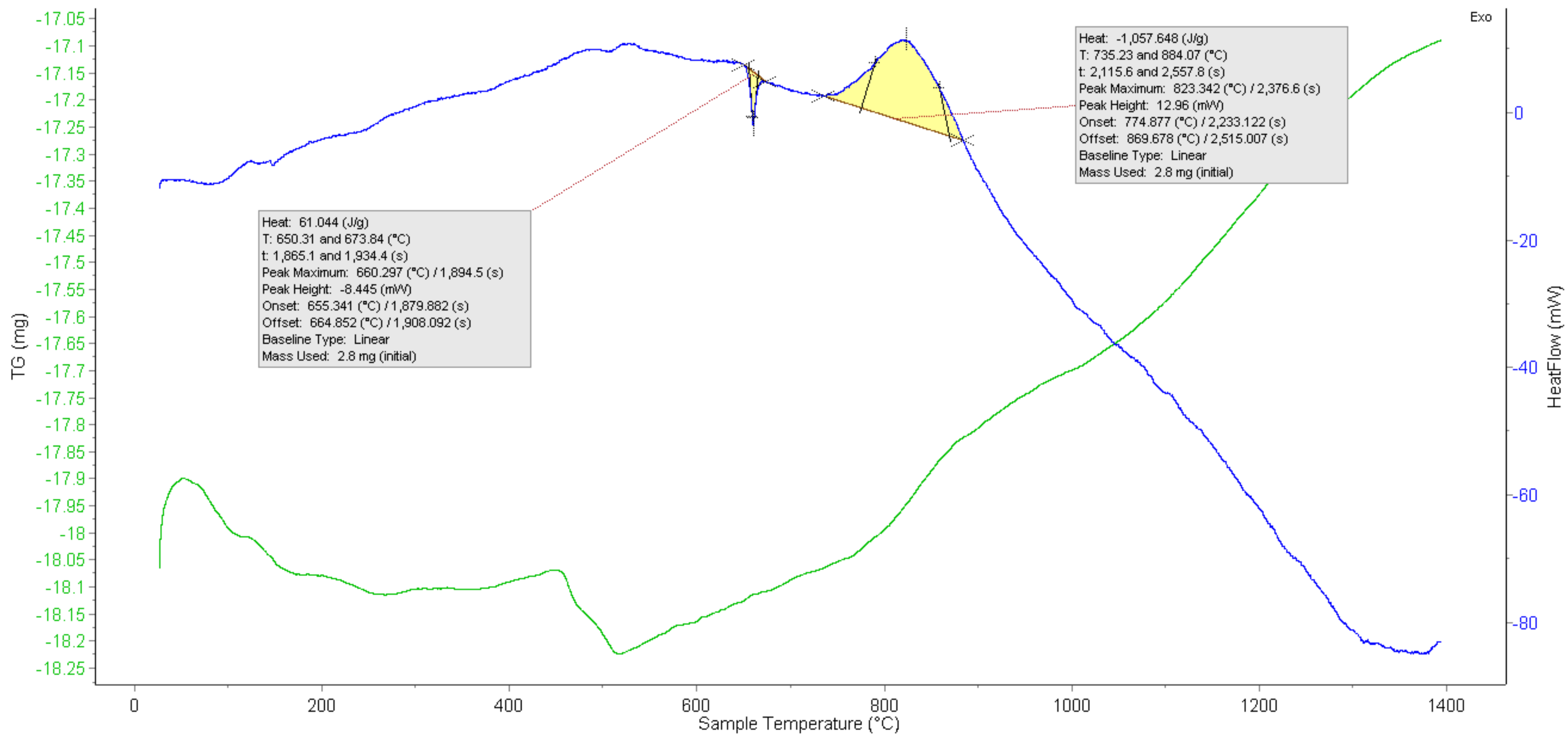


Figure C48: High-Temp DSC Plot for Mix ID SS #26 Trial 2: Fine Al-CrO_3

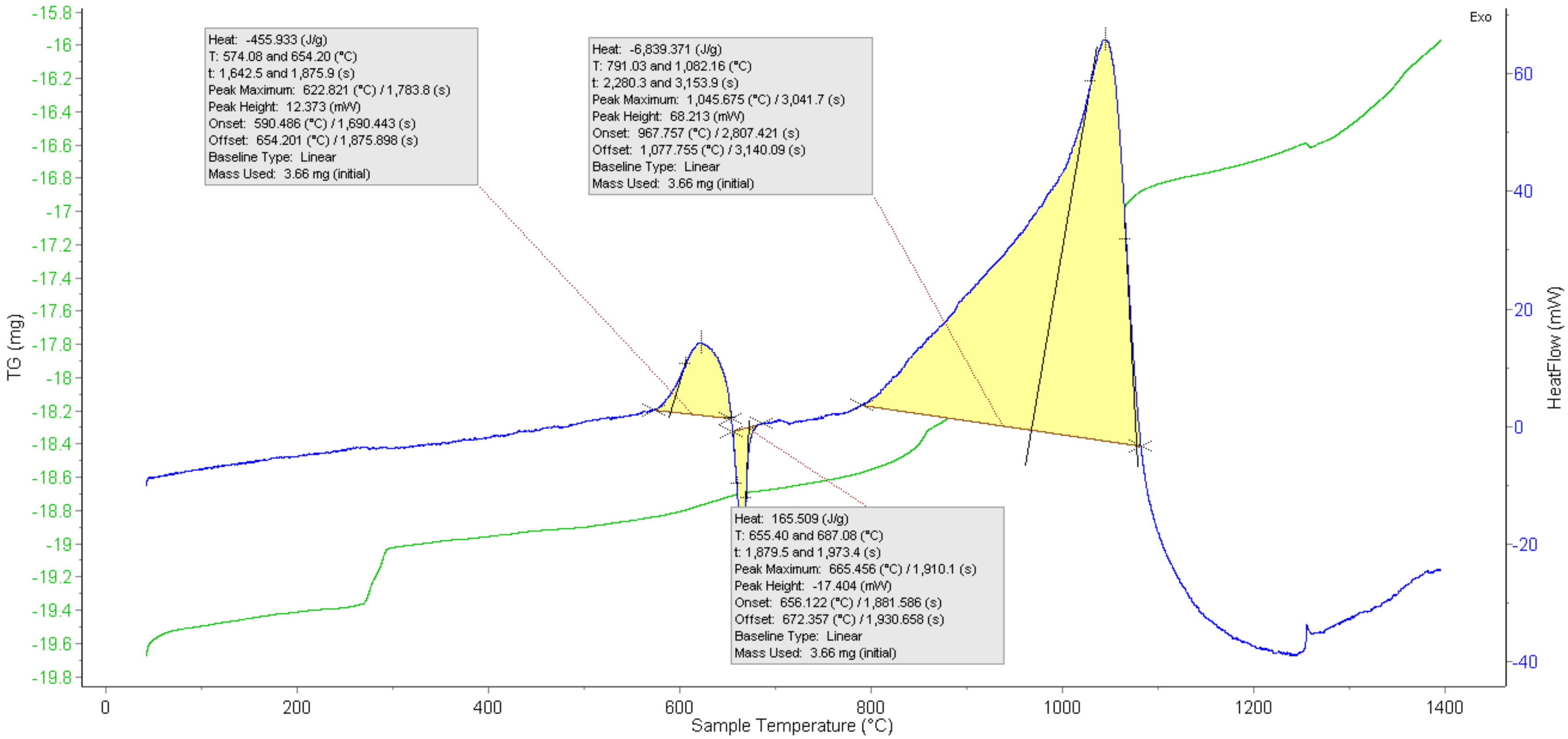


Figure C49: High-Temp DSC Plot for Mix ID SS #27 Trial 1: Fine Al-Fe_3O_4

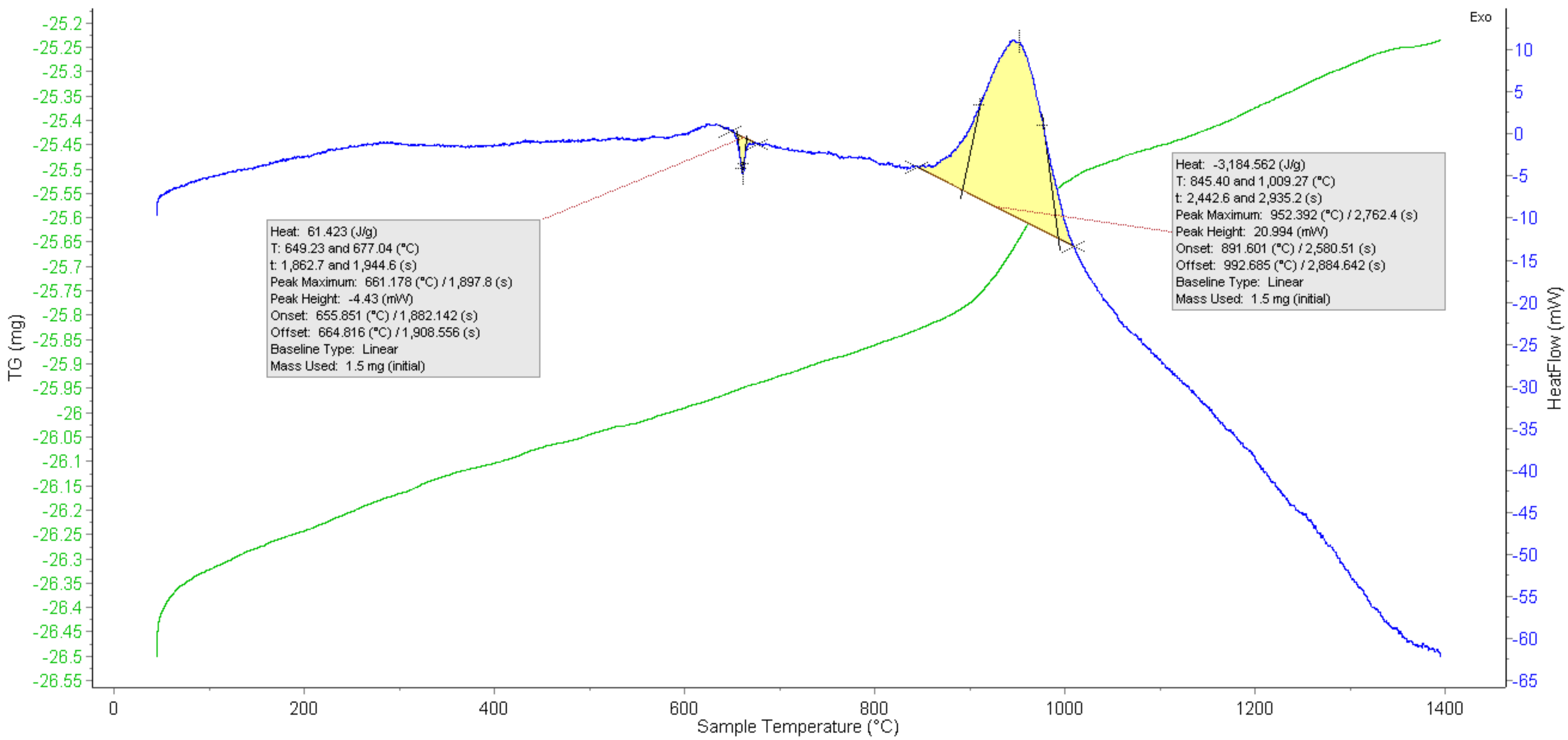


Figure C50: High-Temp DSC Plot for Mix ID SS #27 Trial 2: Fine Al-Fe_3O_4

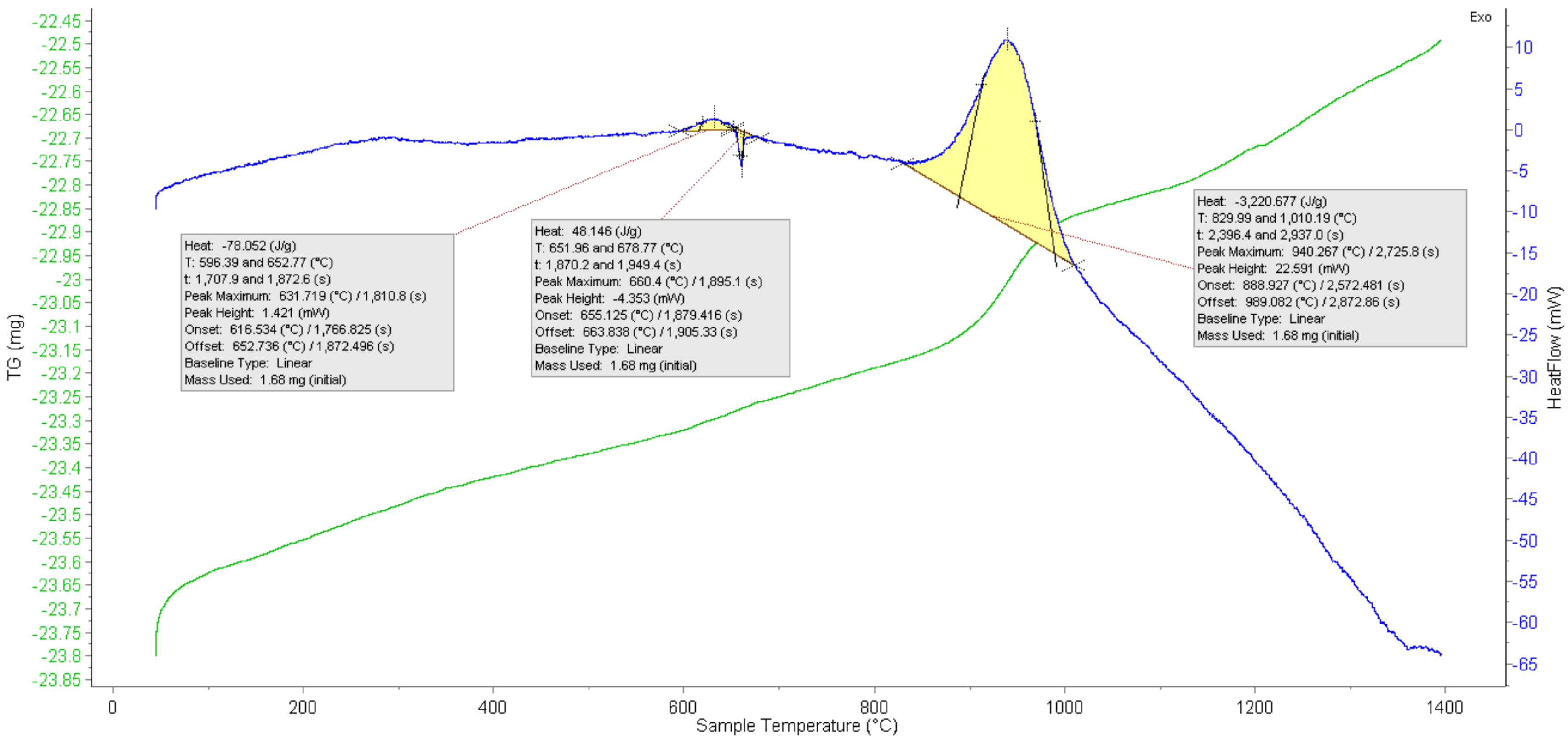


Figure C51: High-Temp DSC Plot for Mix ID SS #28 Trial 1: Fine Al-Mn_2O_3

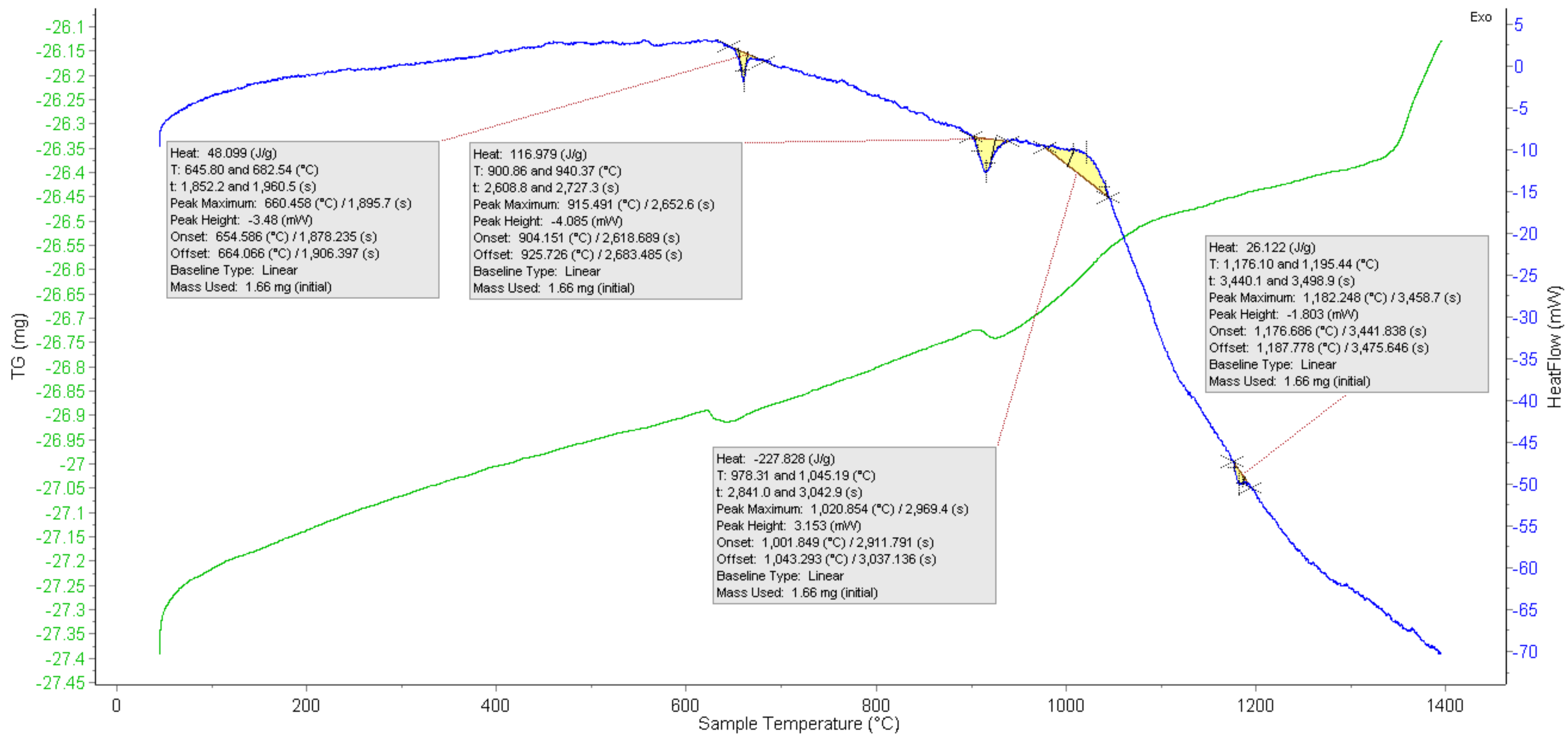


Figure C52: High-Temp DSC Plot for Mix ID SS #28 Trial 2: Fine Al-Mn_2O_3

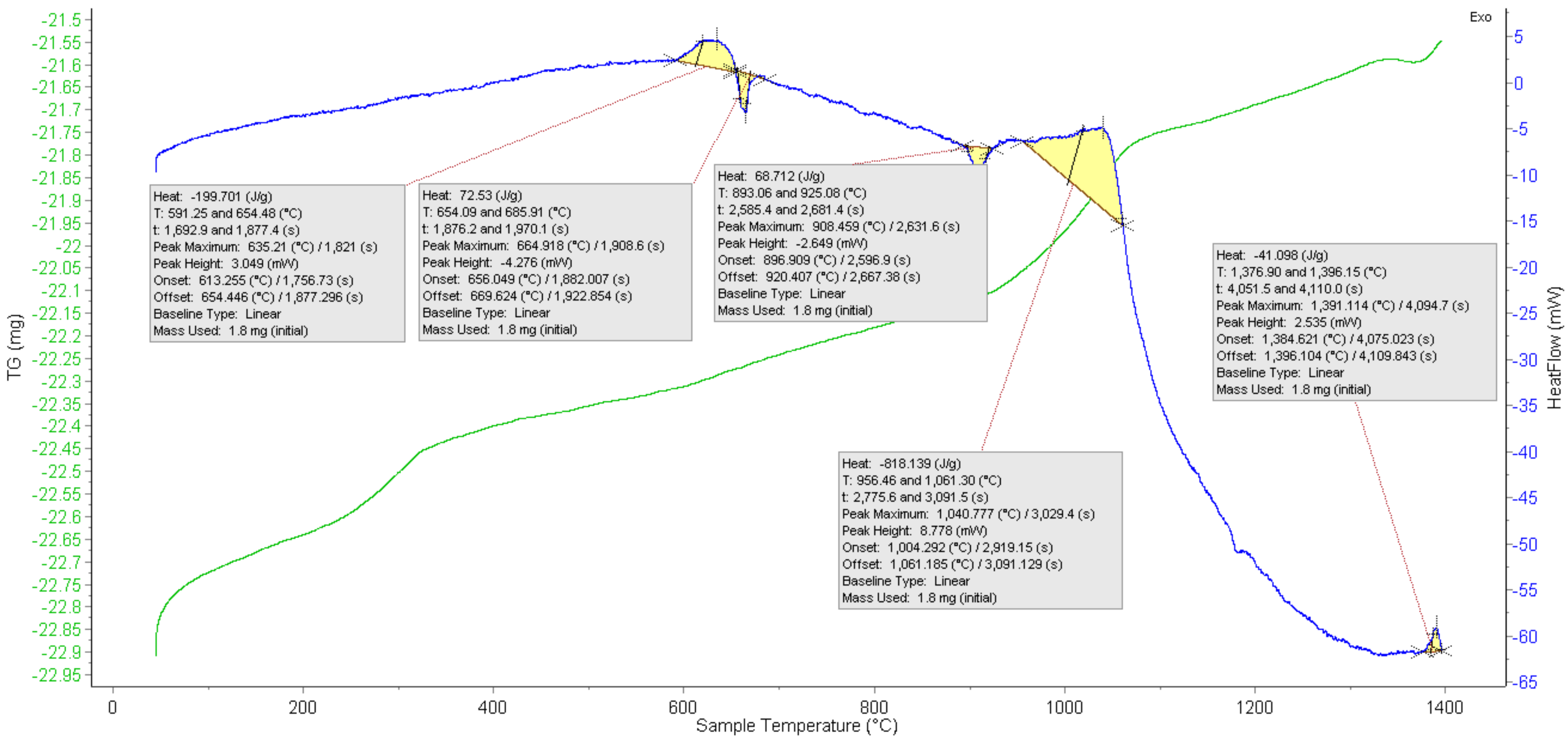


Figure C53: High-Temp DSC Plot for Mix ID SS #29 Trial 1: Fine Al-MnO

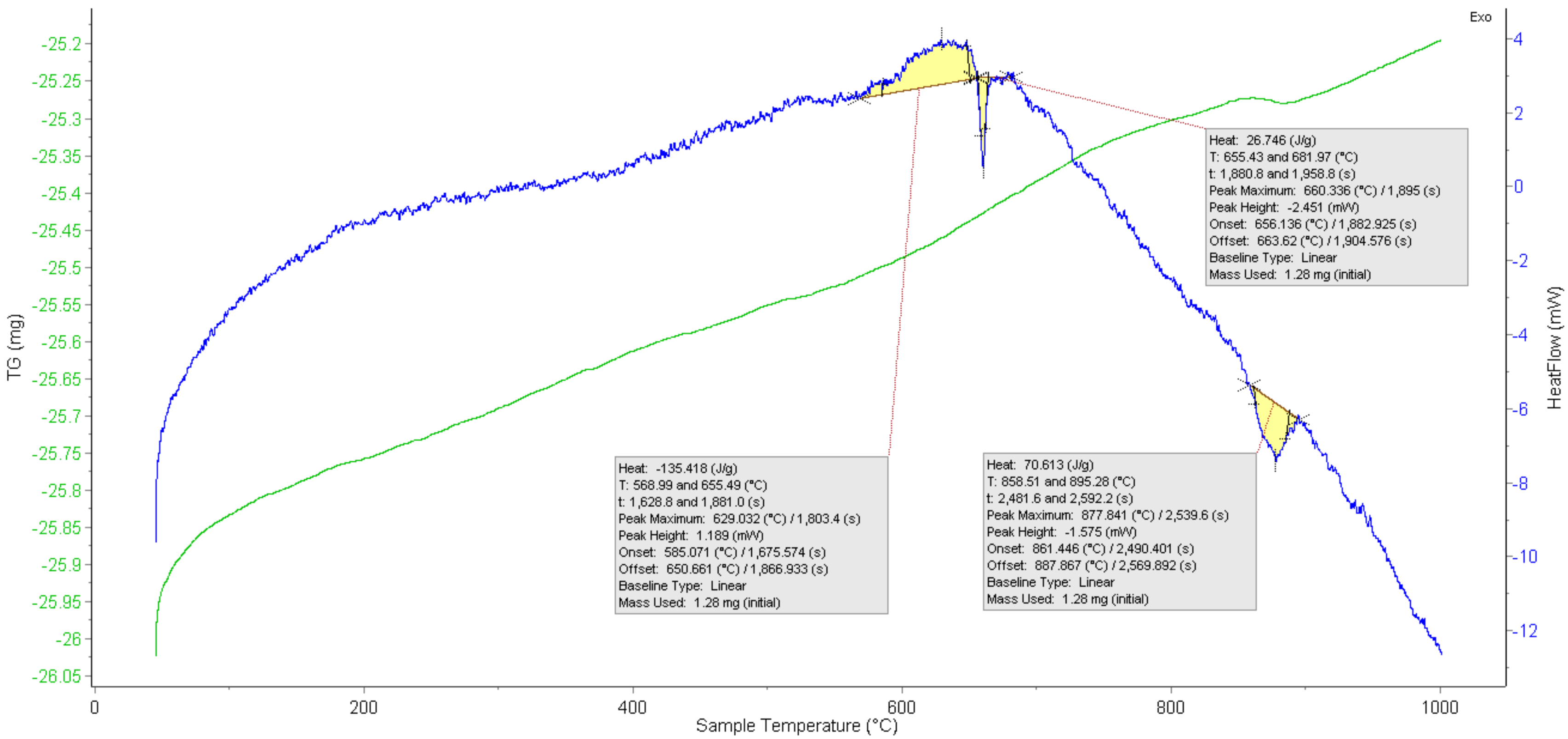


Figure C54: High-Temp DSC Plot for Mix ID SS #29 Trial 2: Fine Al-MnO

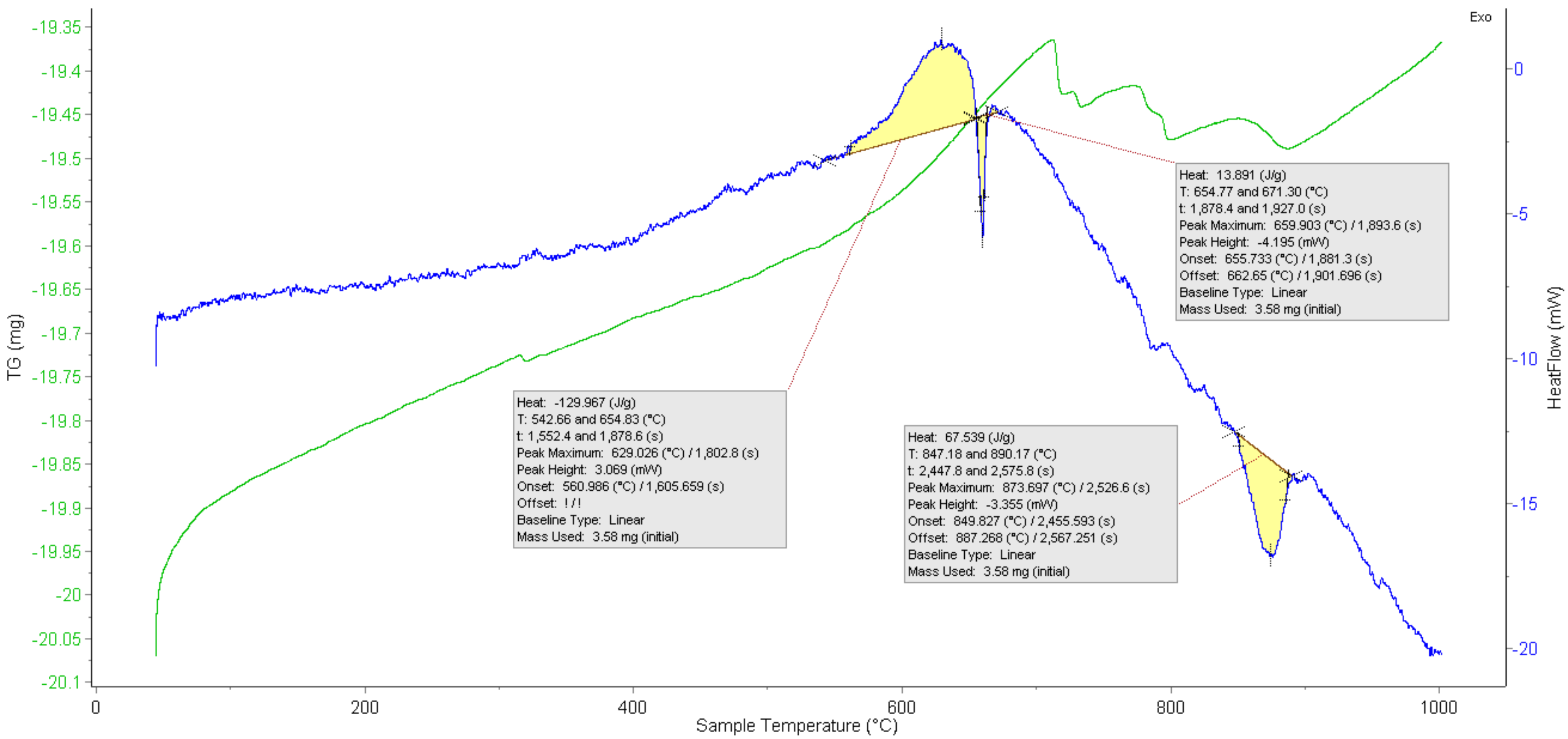


Figure C55: High-Temp DSC Plot for Mix ID SS #30 Trial 1: Fine Al-NiO

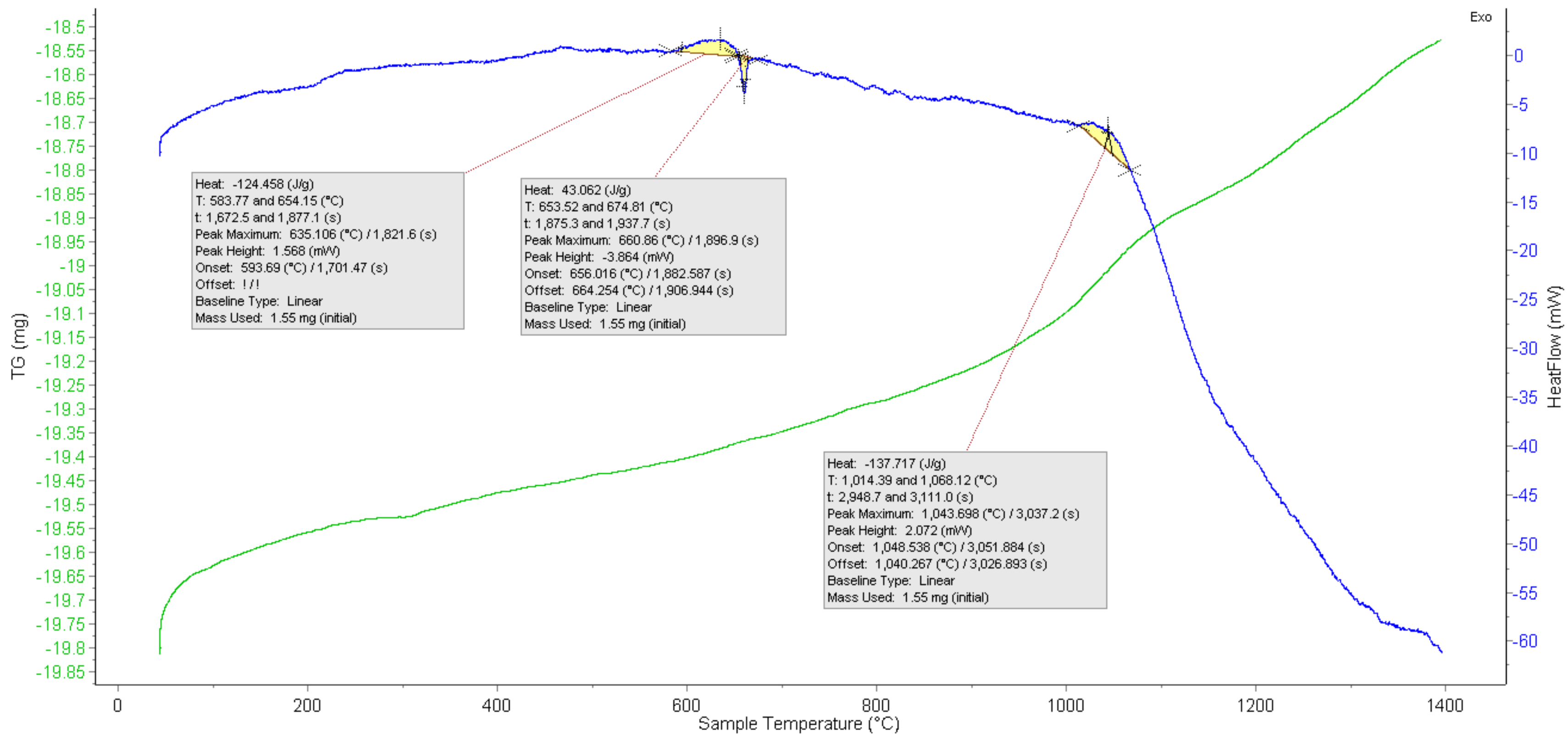


Figure C56: High-Temp DSC Plot for Mix ID SS #30 Trial 2: Fine Al-NiO

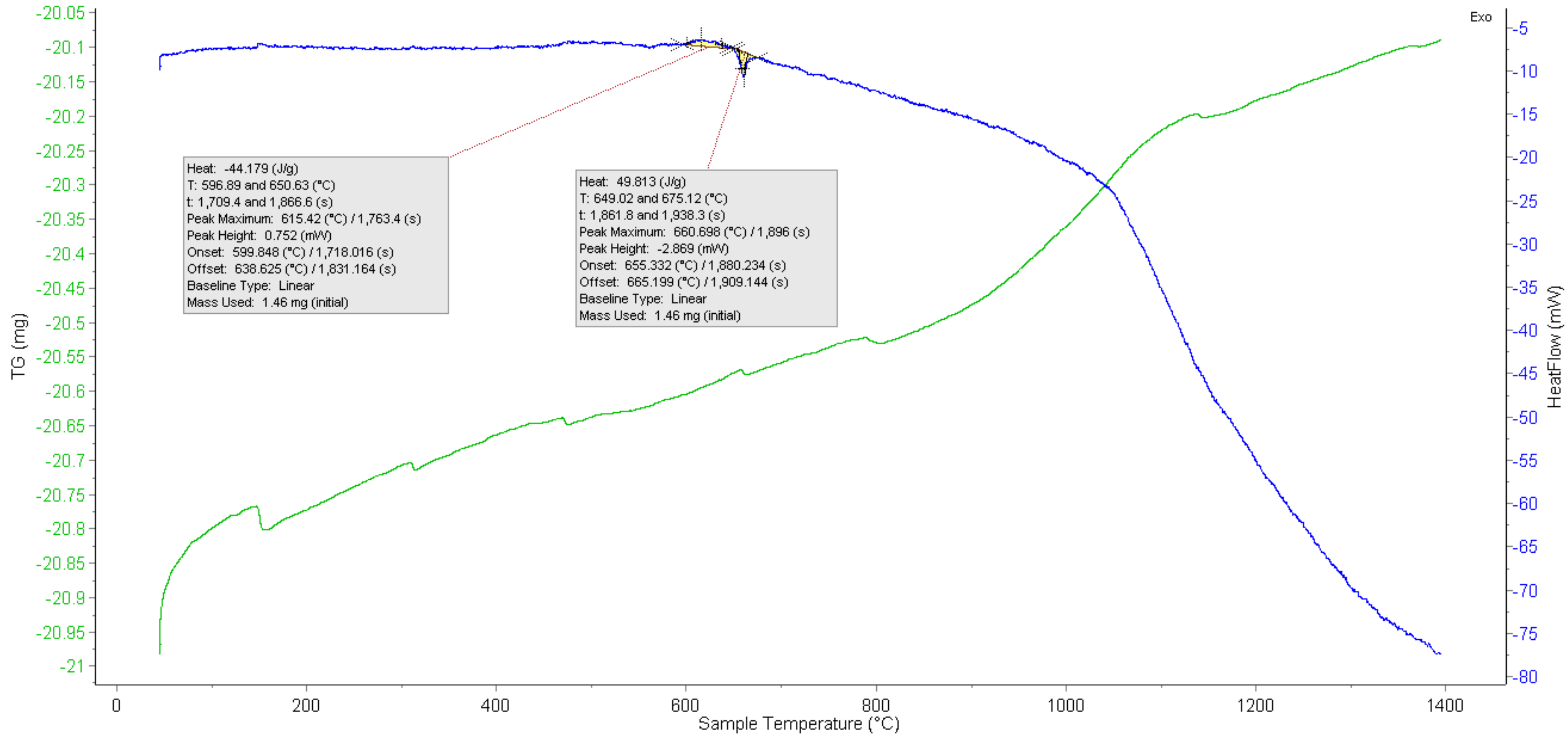


Figure C57: High-Temp DSC Plot for Mix ID SS #31 Trial 1: Fine Al-Sb_2O_3

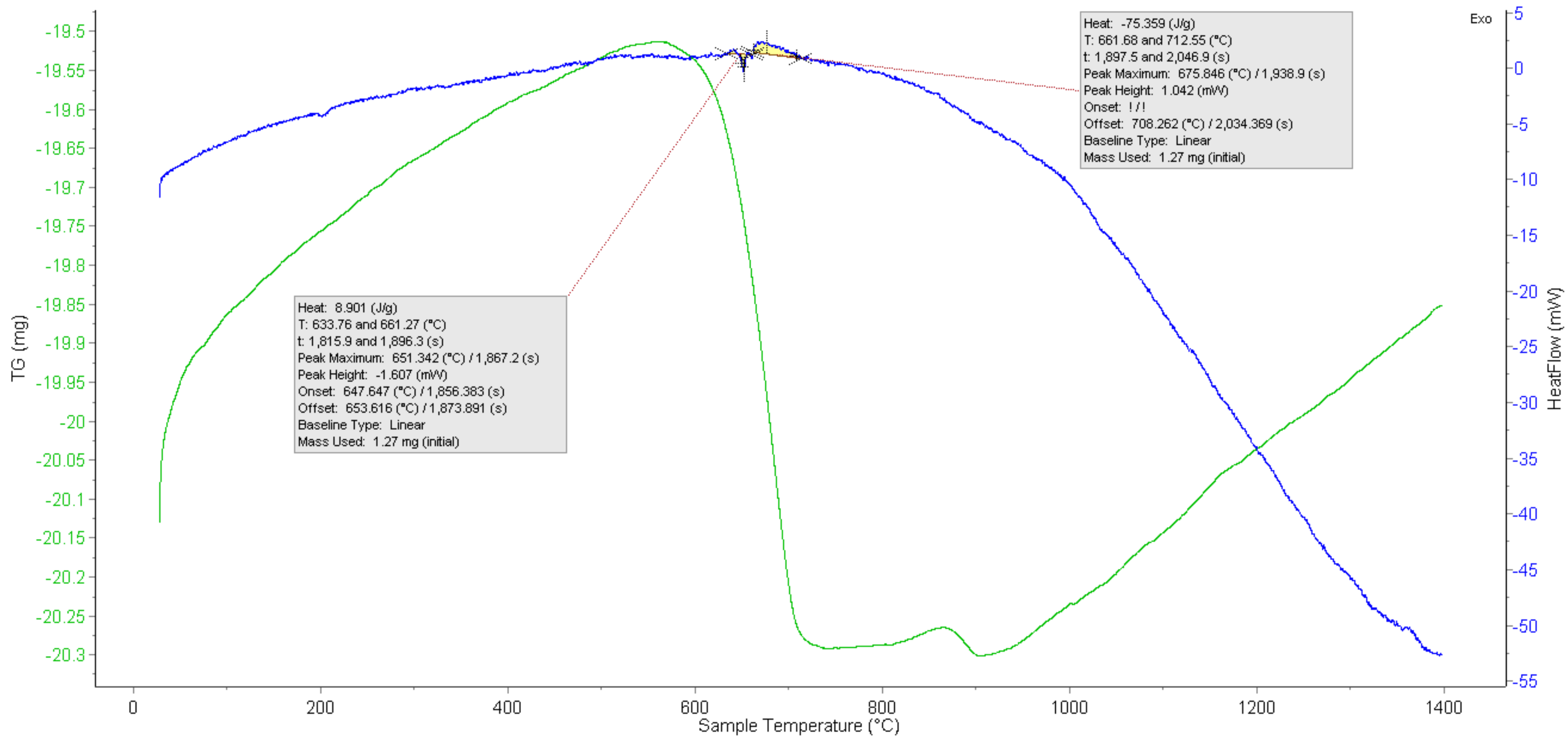


Figure C58: High-Temp DSC Plot for Mix ID SS #31 Trial 2: Fine Al-Sb_2O_3

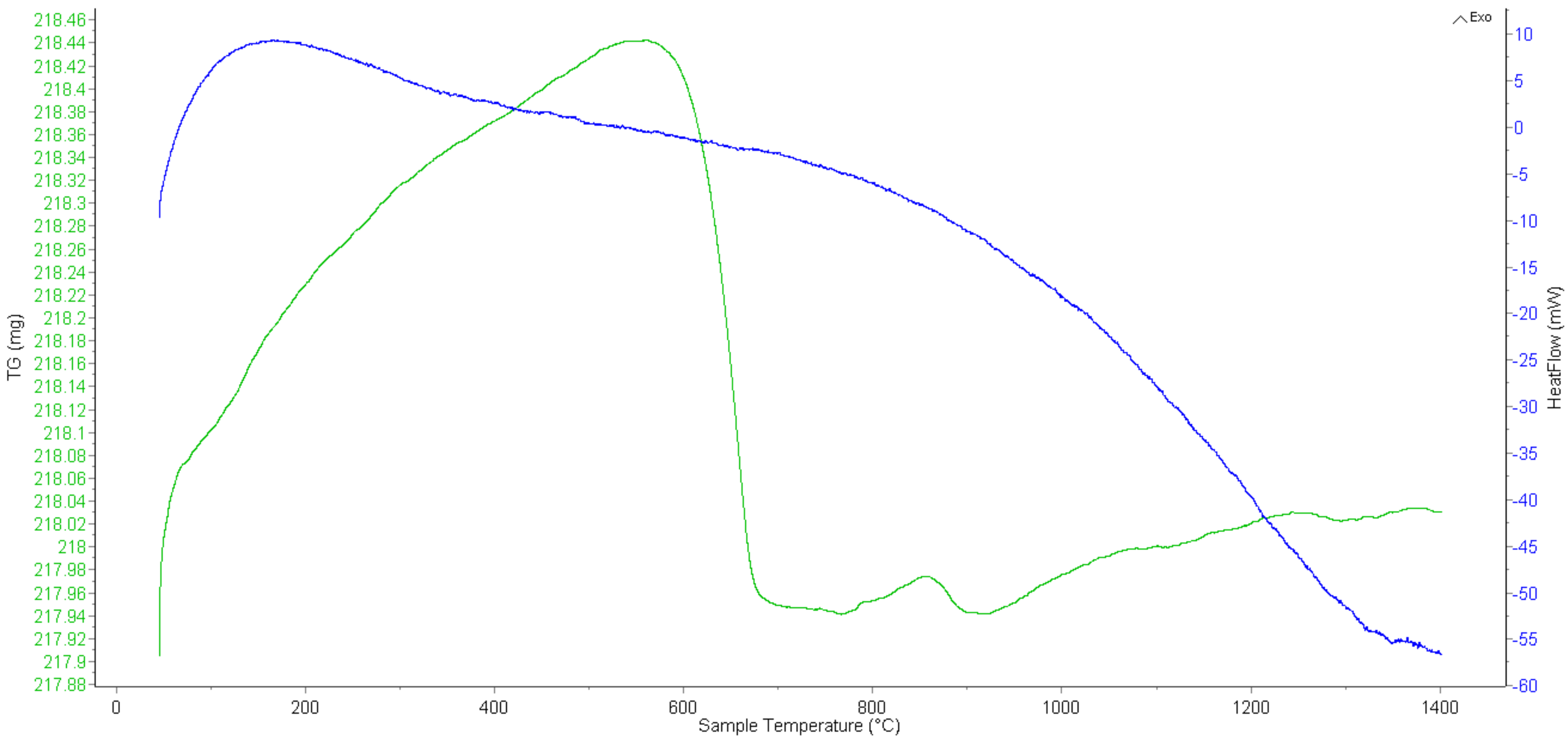


Figure C59: High-Temp DSC Plot for Mix ID SS #33 Trial 1: Fine Al-SiO_2

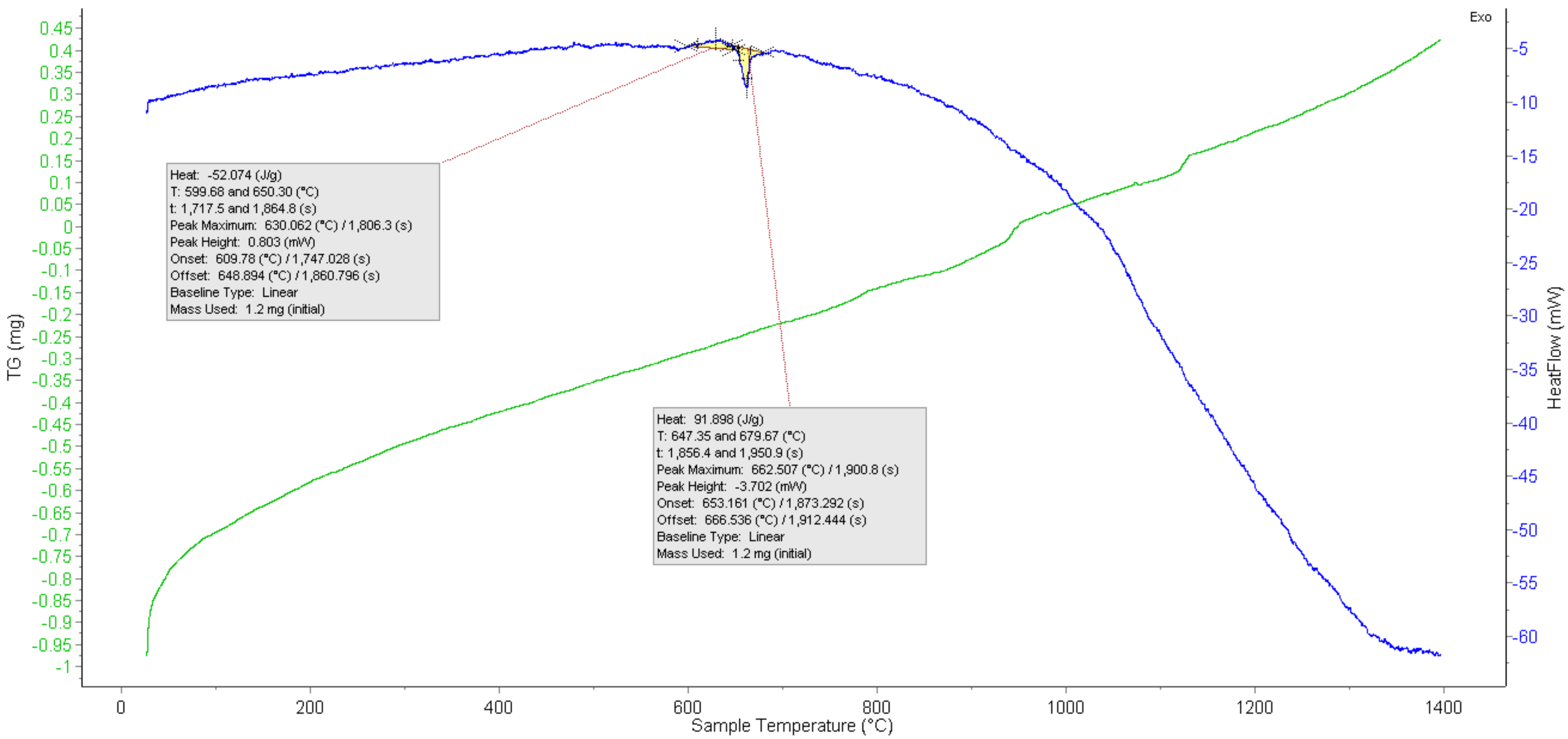


Figure C60: High-Temp DSC Plot for Mix ID SS #33 Trial 2: Fine Al-SiO_2

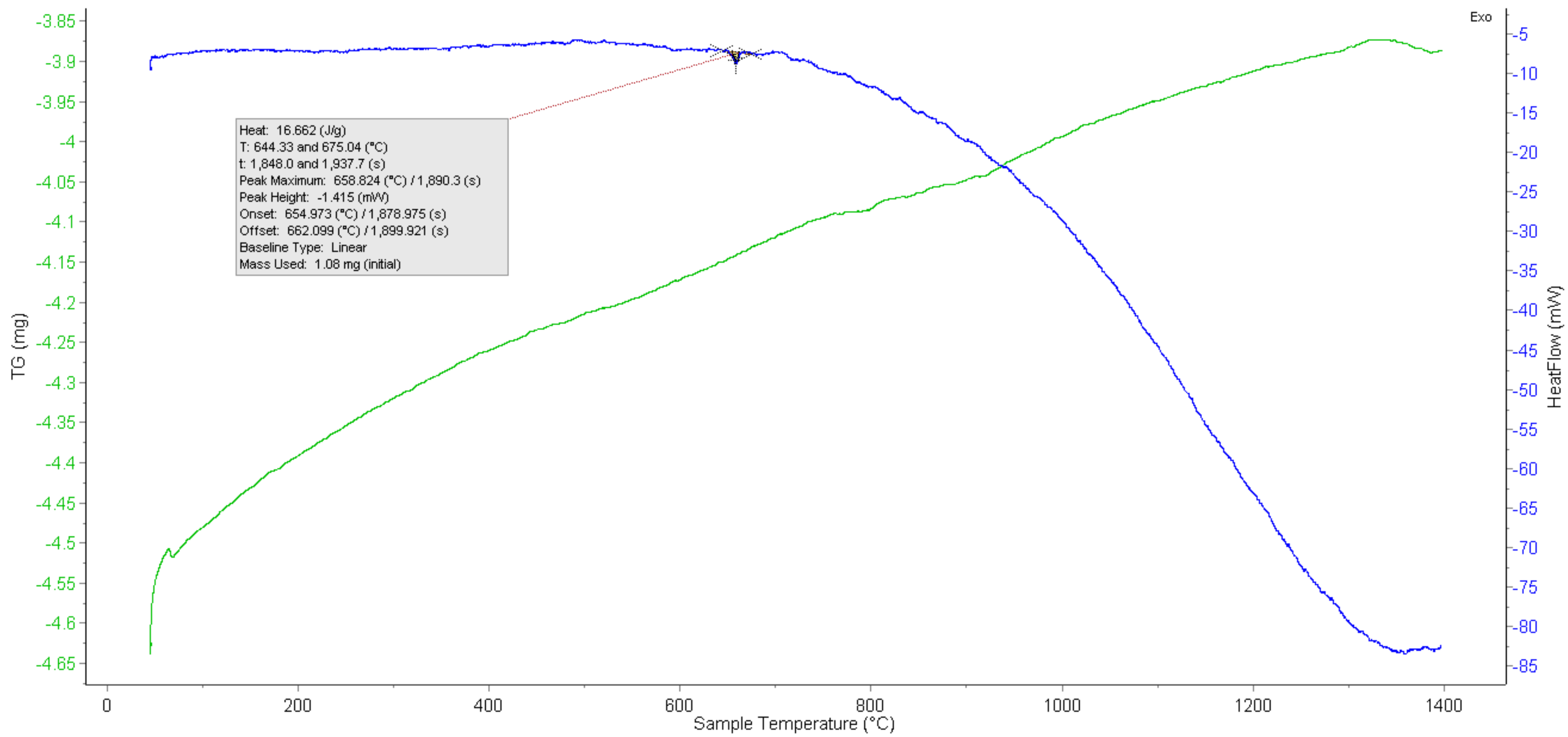


Figure C61: High-Temp DSC Plot for Mix ID SS #34 Trial 1: Fine Al-SnO

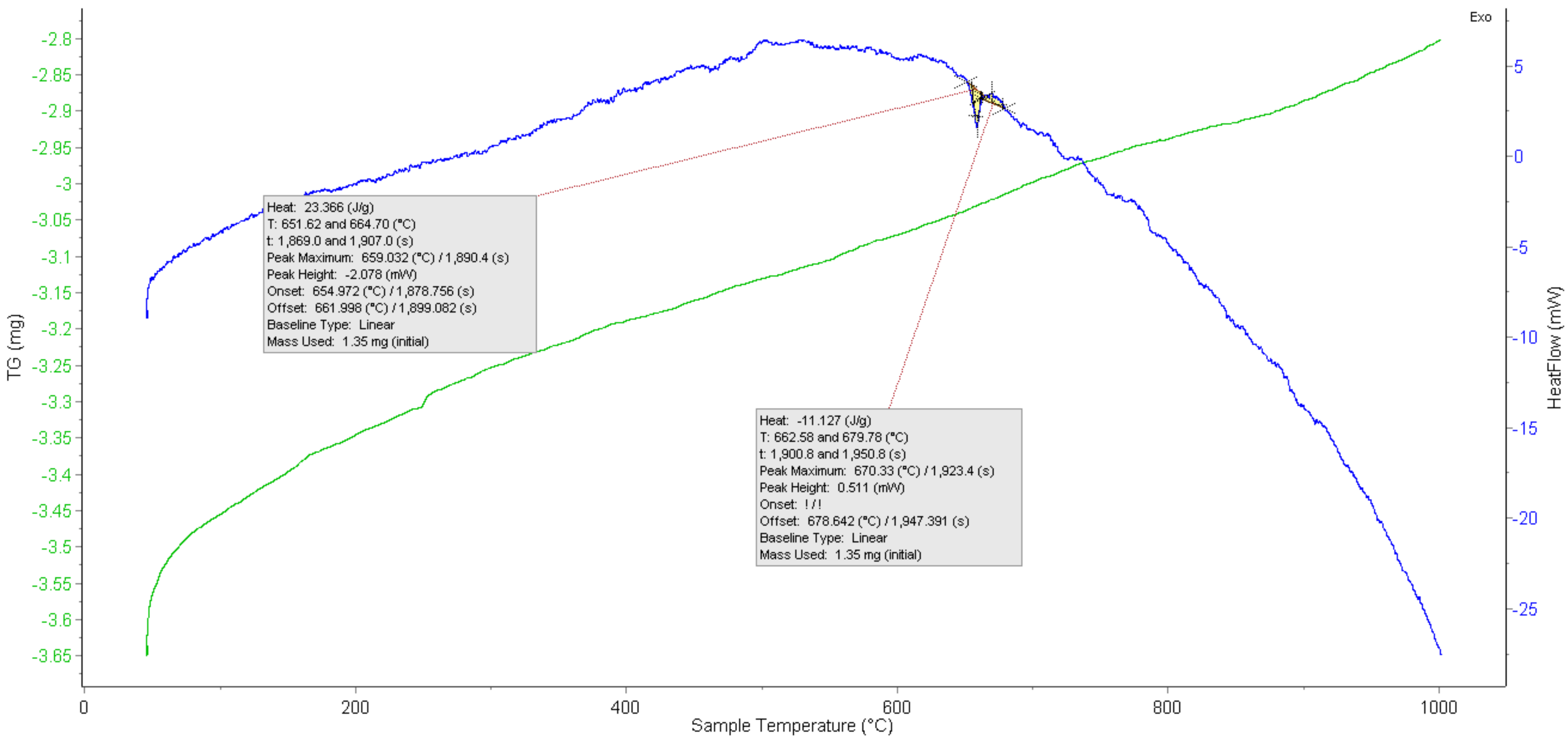


Figure C62: High-Temp DSC Plot for Mix ID SS #34 Trial 2: Fine Al-SnO

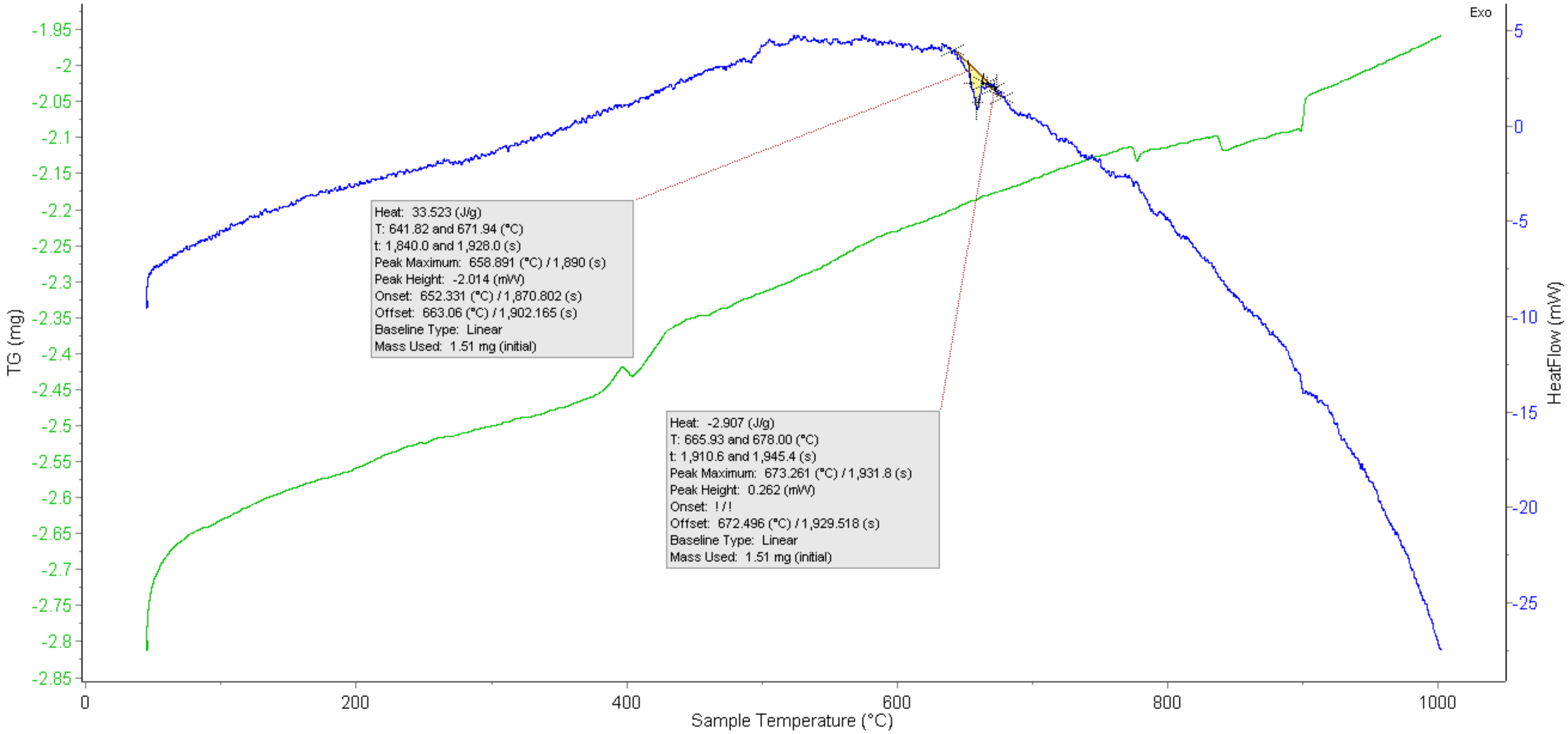


Figure C63: High-Temp DSC Plot for Mix ID SS #35 Trial 1: Fine Al-ZnO

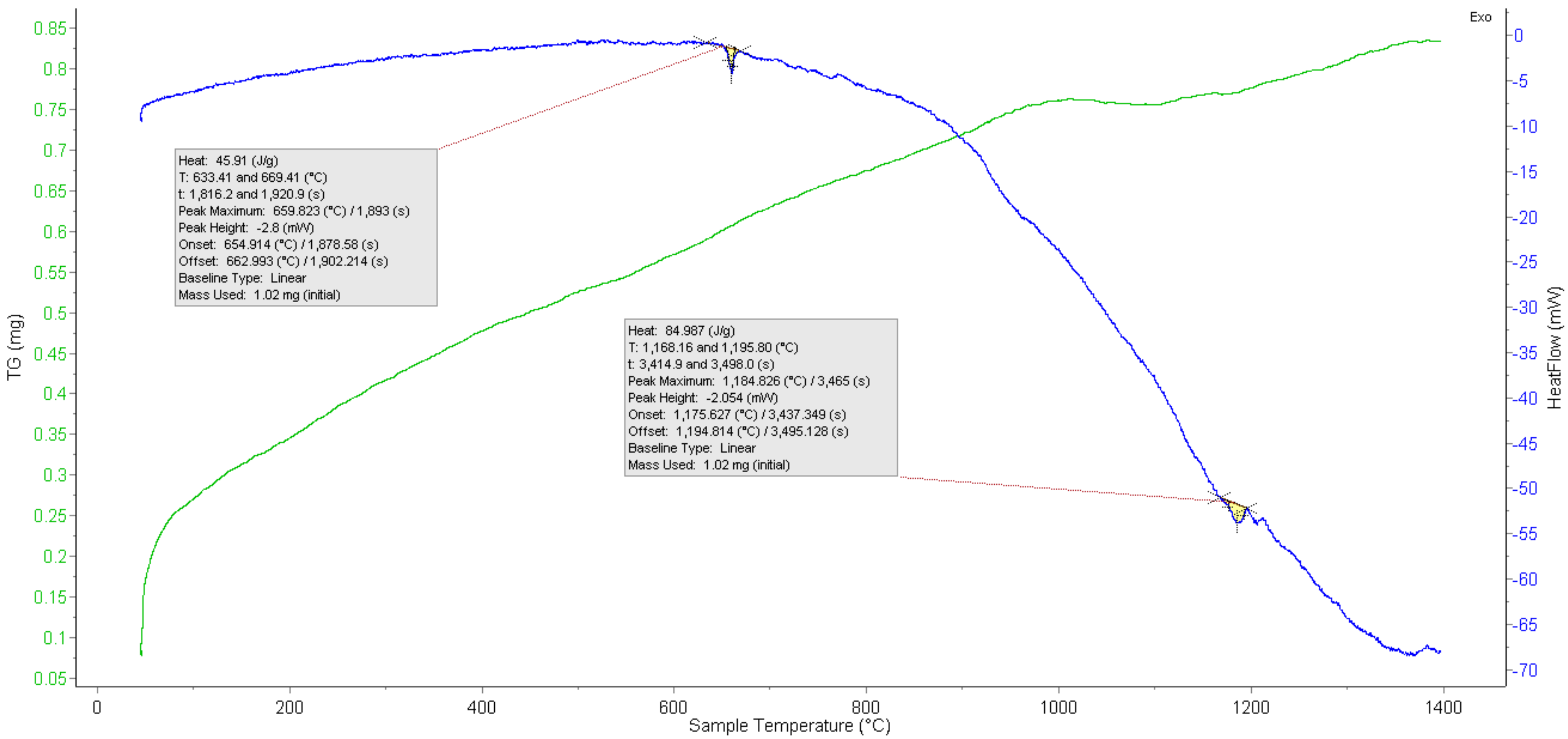


Figure C64: High-Temp DSC Plot for Mix ID SS #35 Trial 2: Fine Al-ZnO

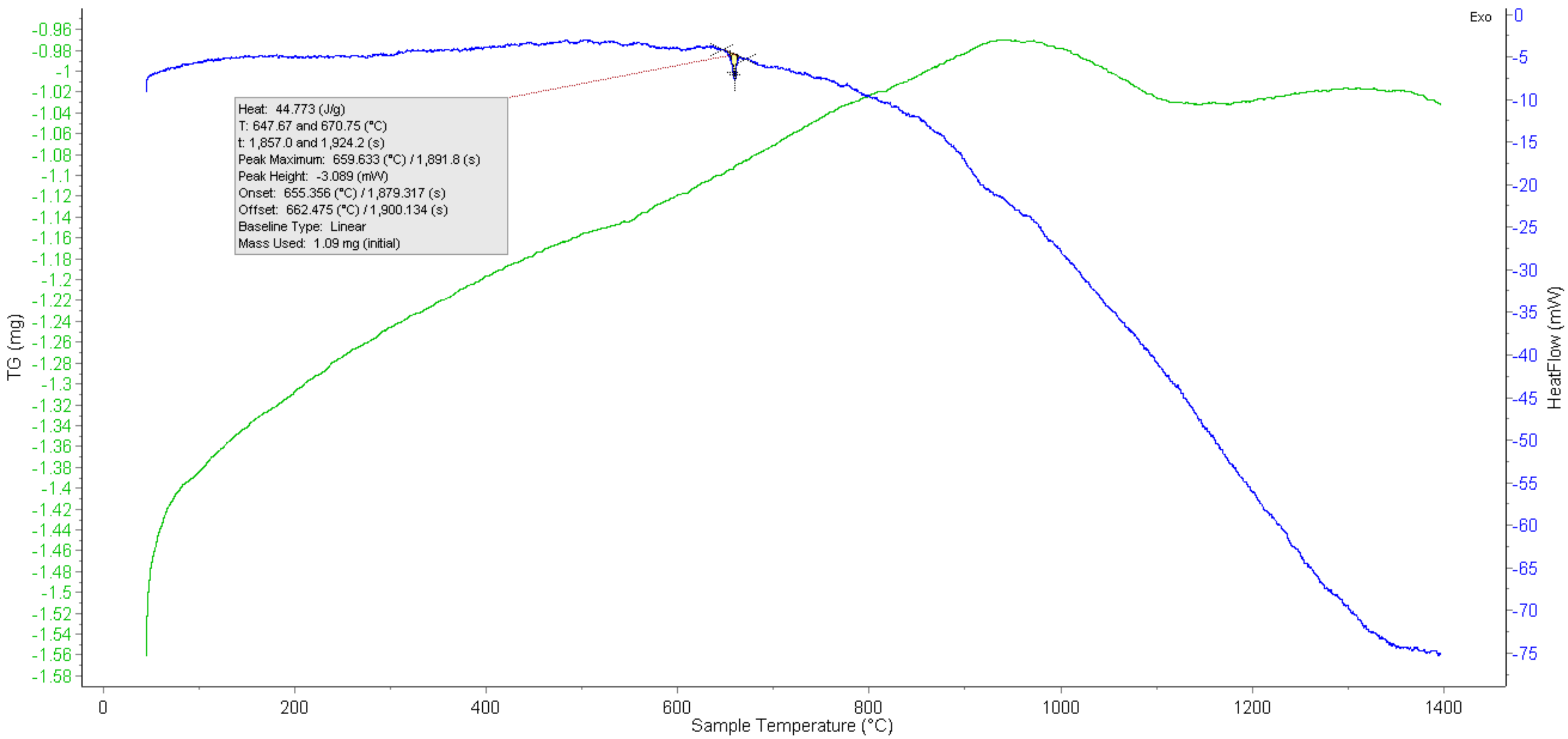


Figure C65: High-Temp DSC Plot for Mix ID SS #36 Trial 1: Fine Al-ZrO_2

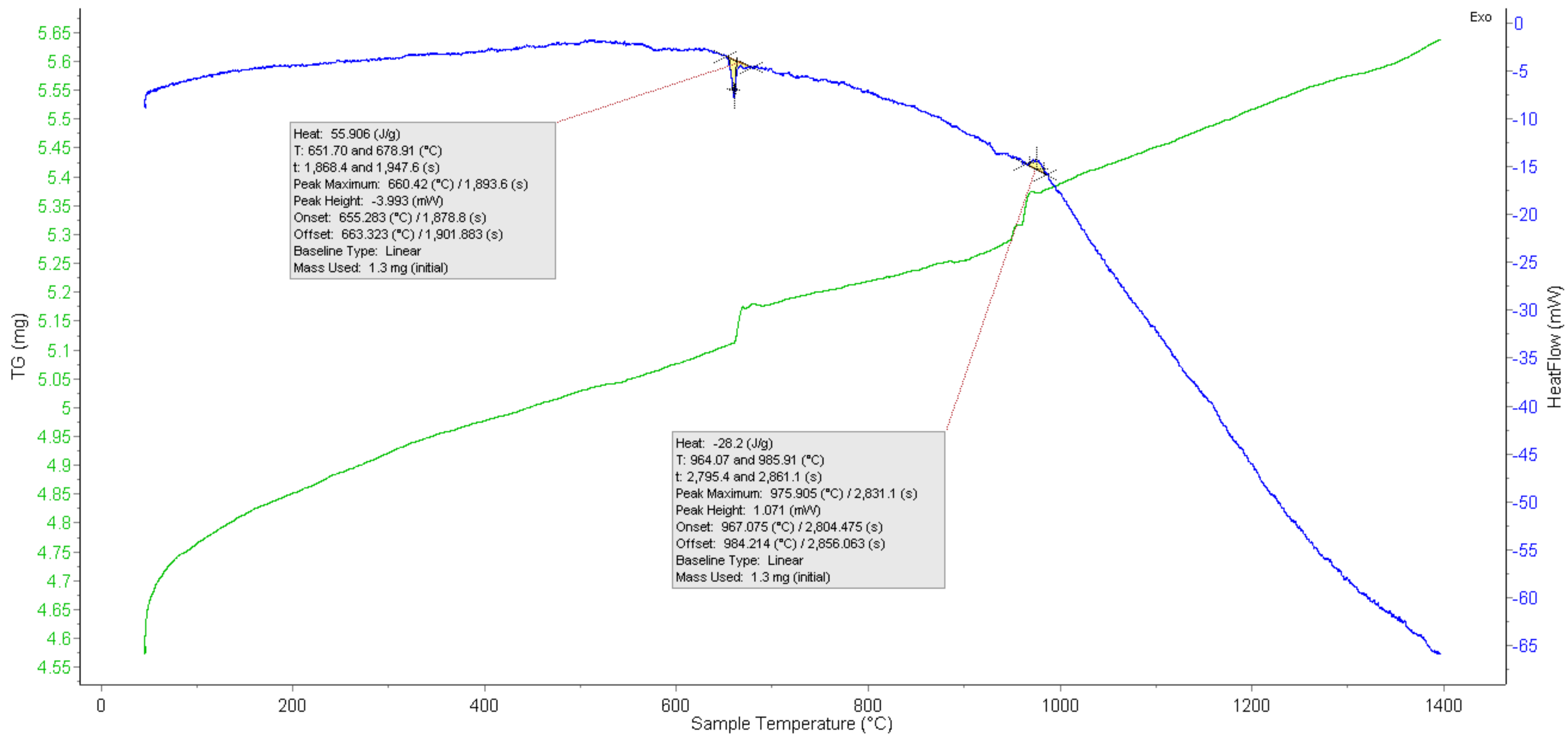


Figure C66: High-Temp DSC Plot for Mix ID SS #36 T2: Fine Al-ZrO_2

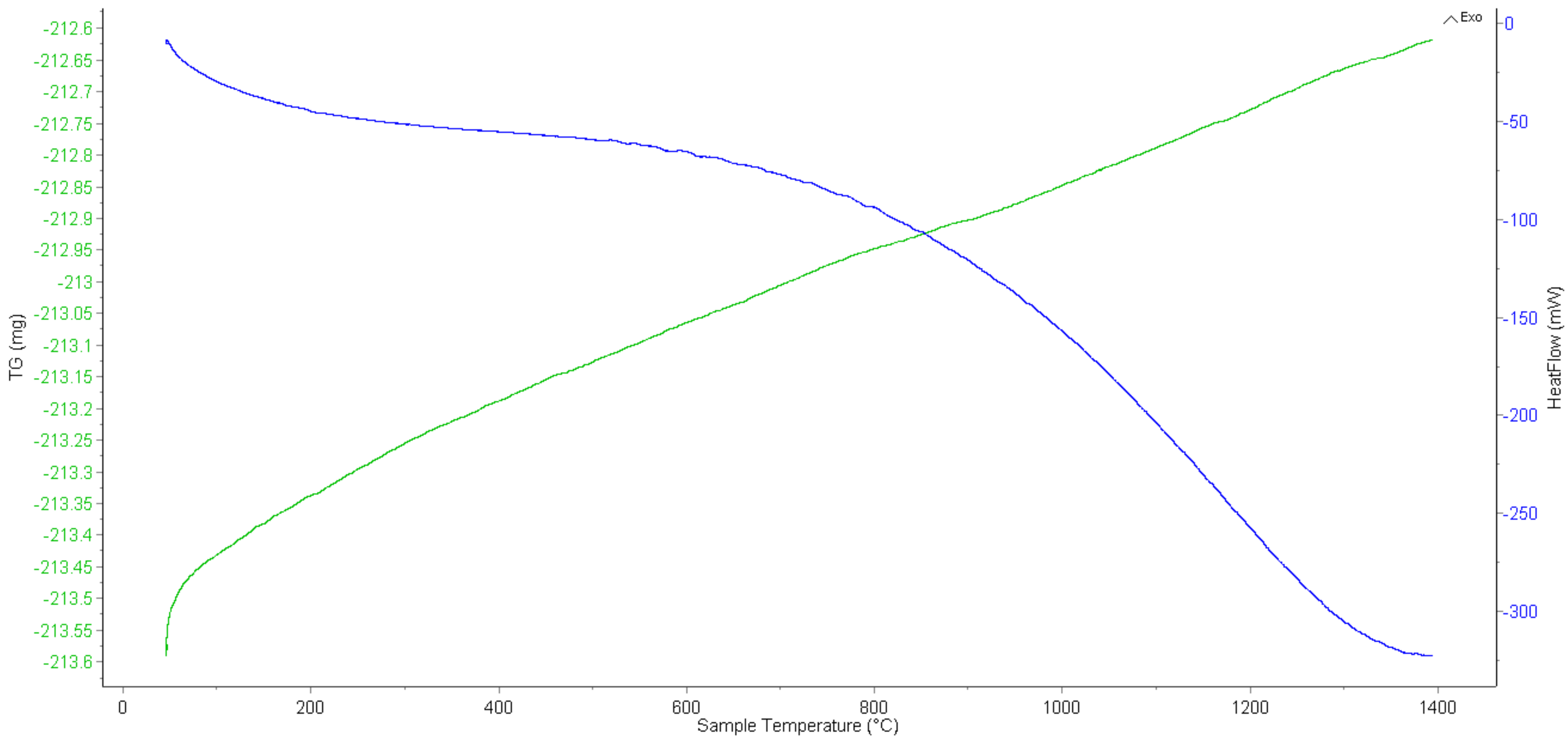


Figure C67: High-Temp DSC Plot for Mix ID SS #37 Trial 1: Fine Mg-Al_2O_3

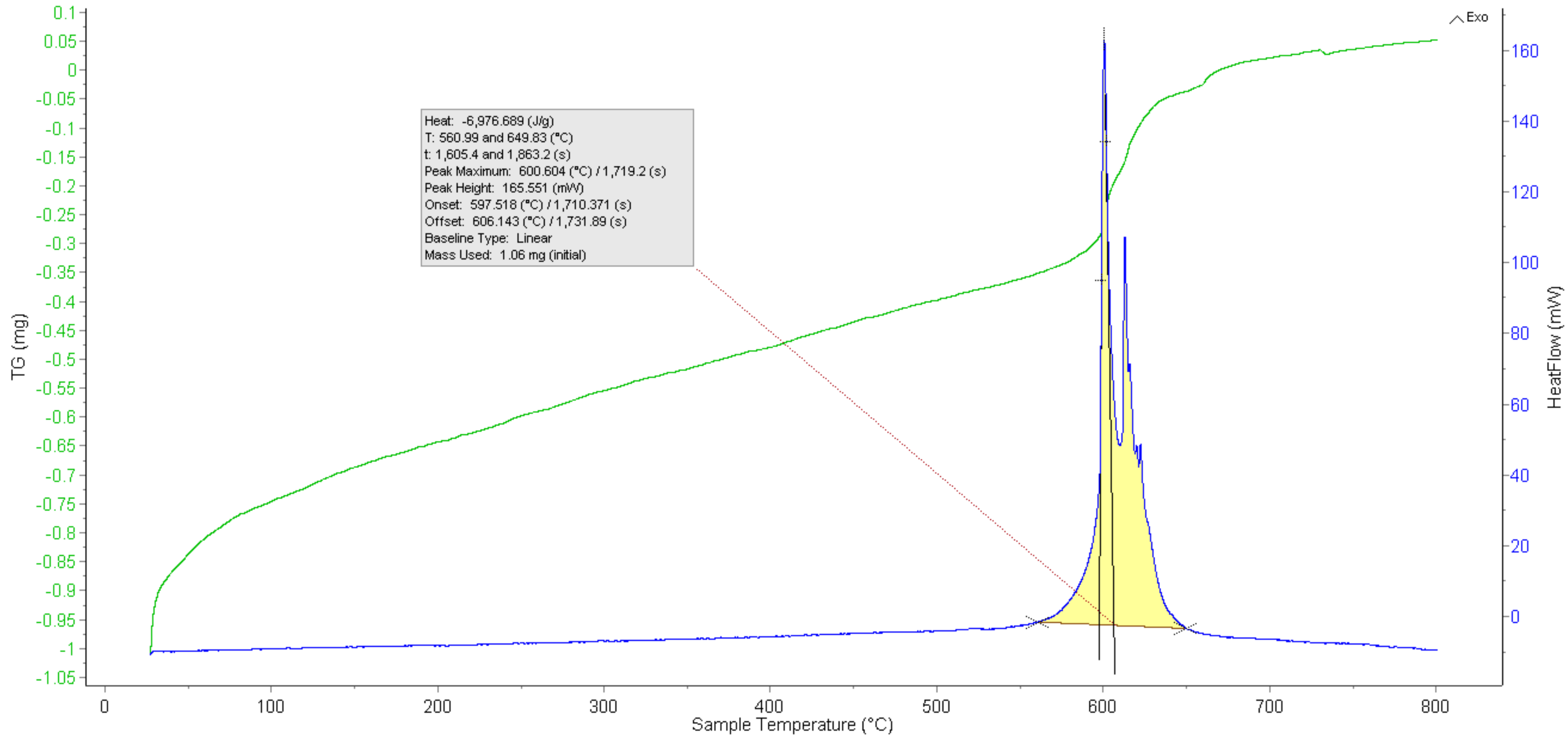


Figure C68: High-Temp DSC Plot for Mix ID SS #37 Trial 2: Fine Mg-Al_2O_3

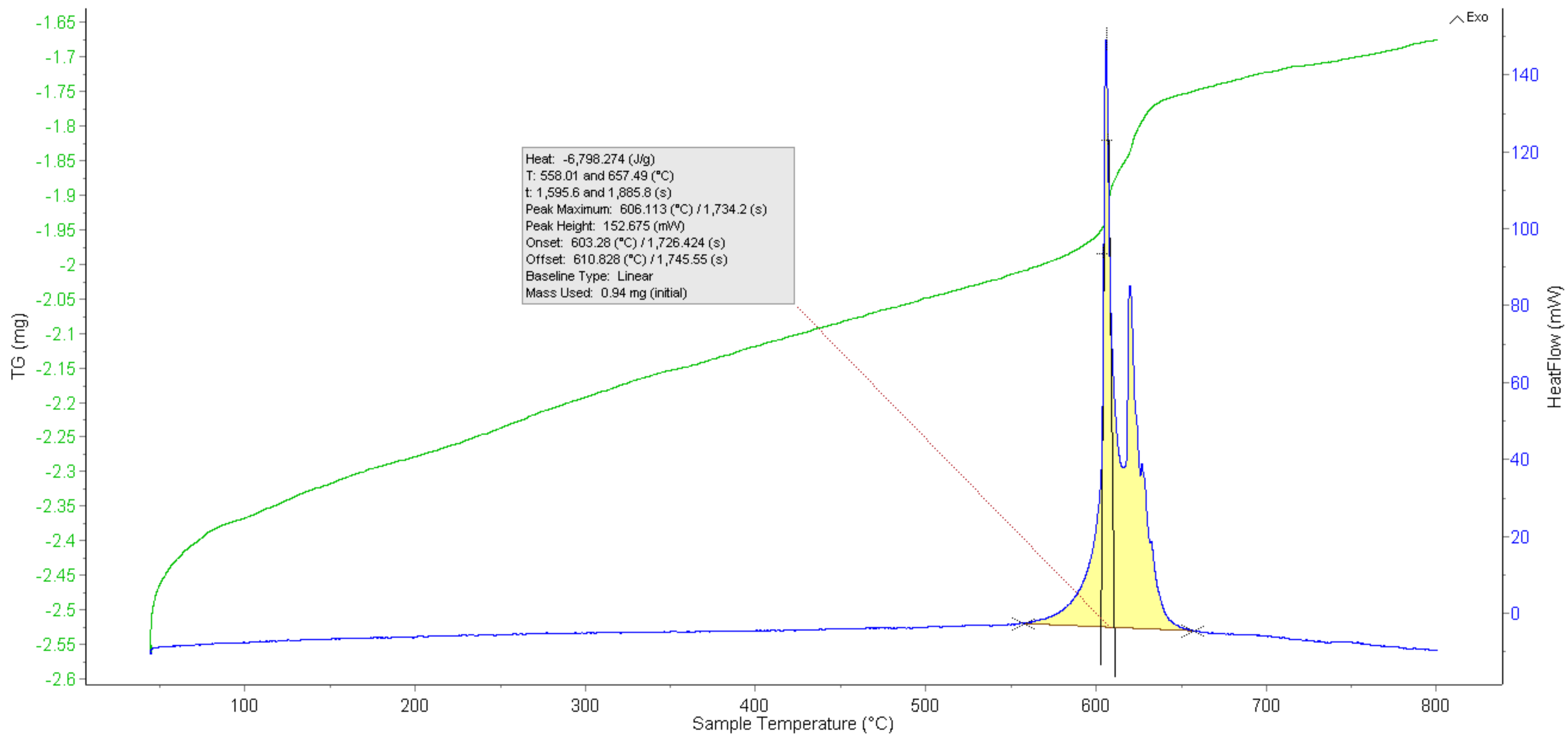


Figure C69: High-Temp DSC Plot for Mix ID SS #38 Trial 1: Fine Mg-CrO_3

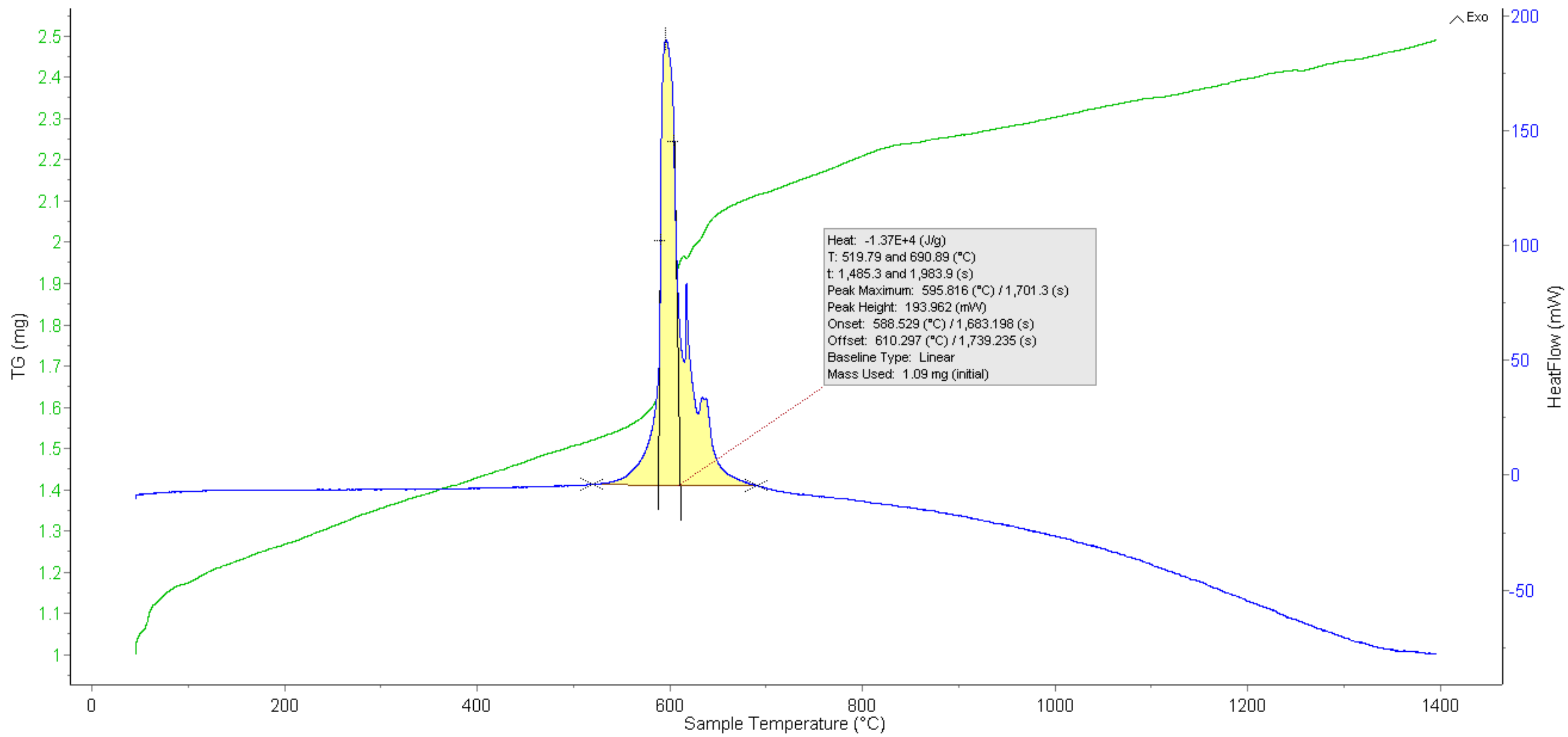


Figure C70: High-Temp DSC Plot for Mix ID SS #38 Trial 2: Fine Mg-CrO_3

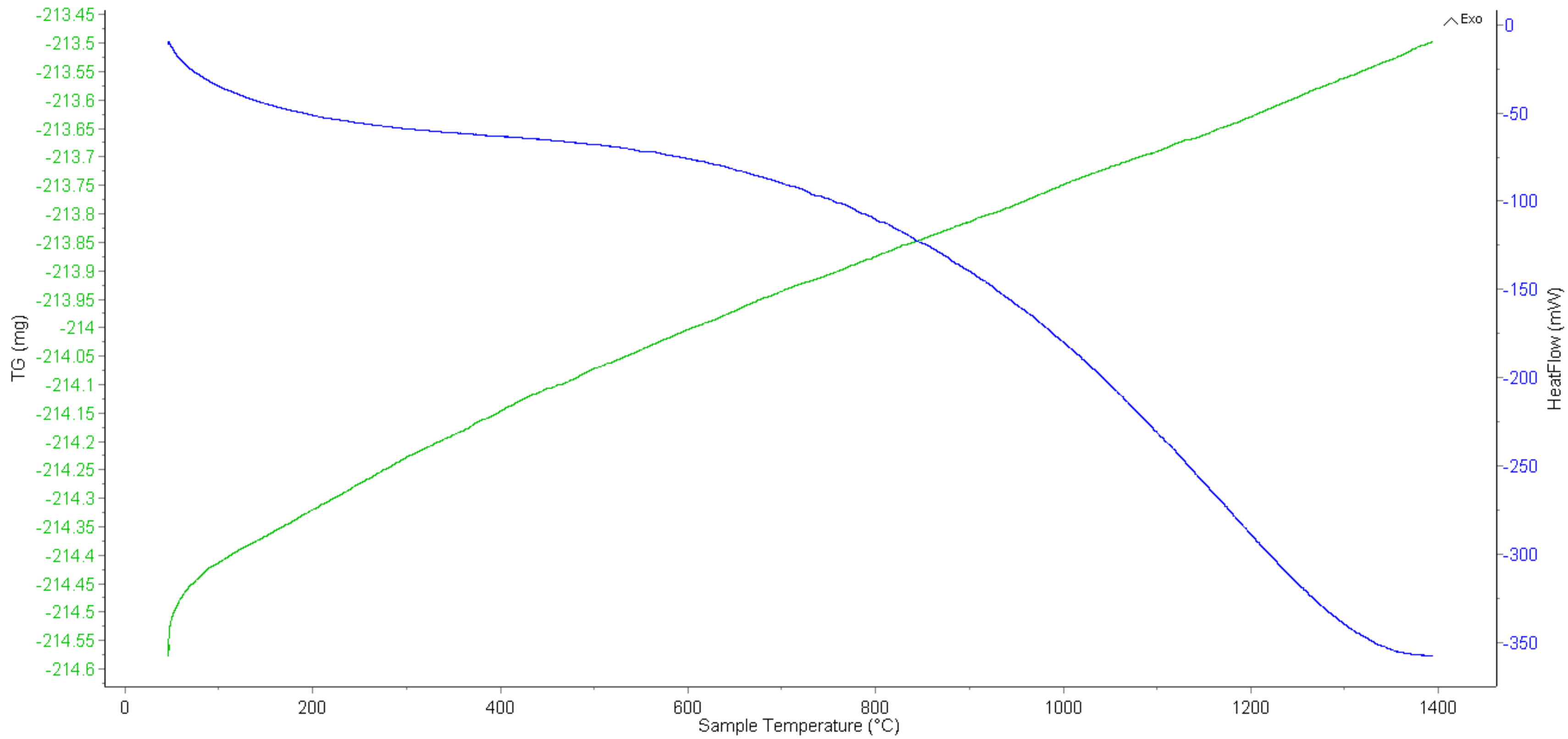


Figure C71: High-Temp DSC Plot for Mix ID SS #39 Trial 1: Fine Mg-Bi_2O_3

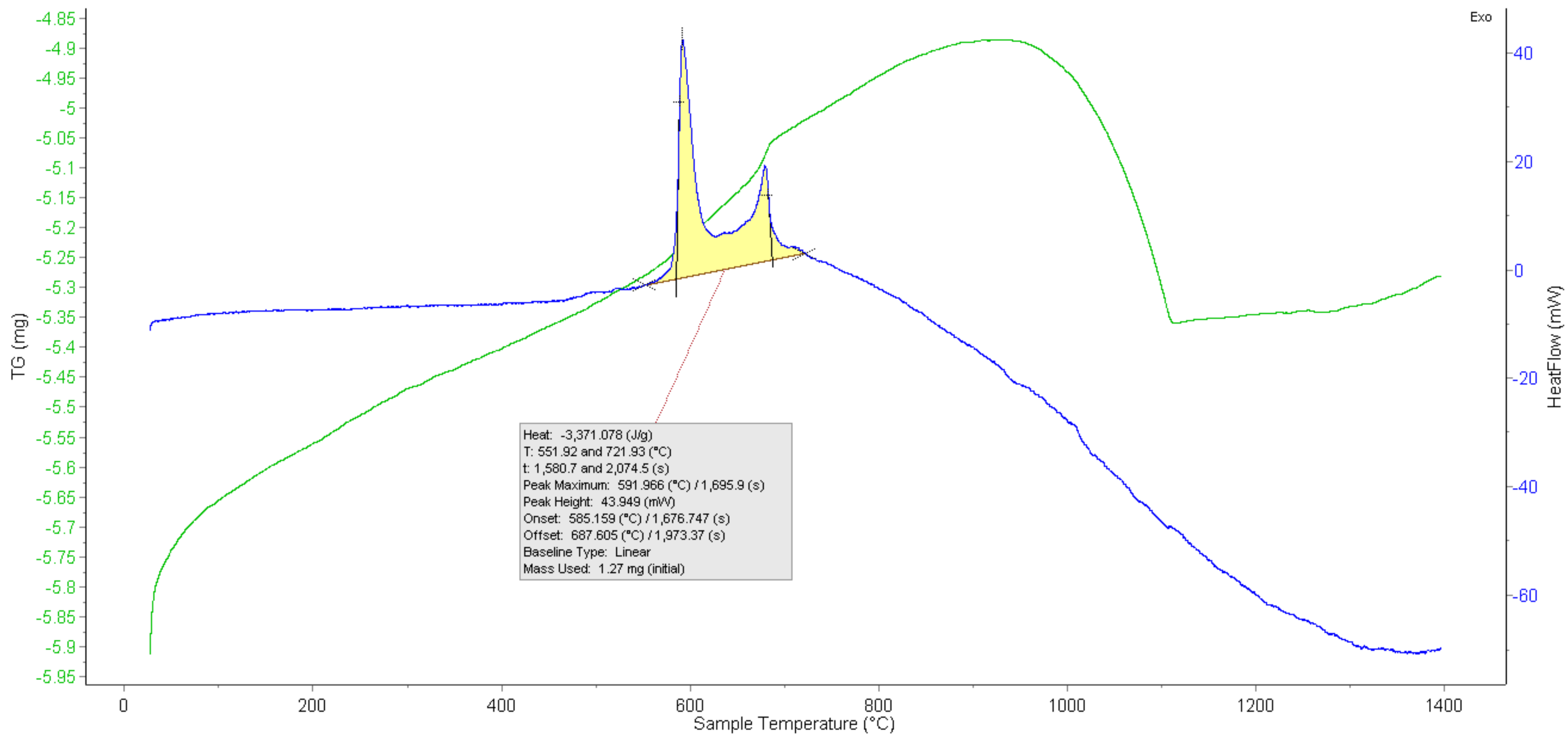


Figure C72: High-Temp DSC Plot for Mix ID SS #39 Trial 2: Fine Mg-Bi_2O_3

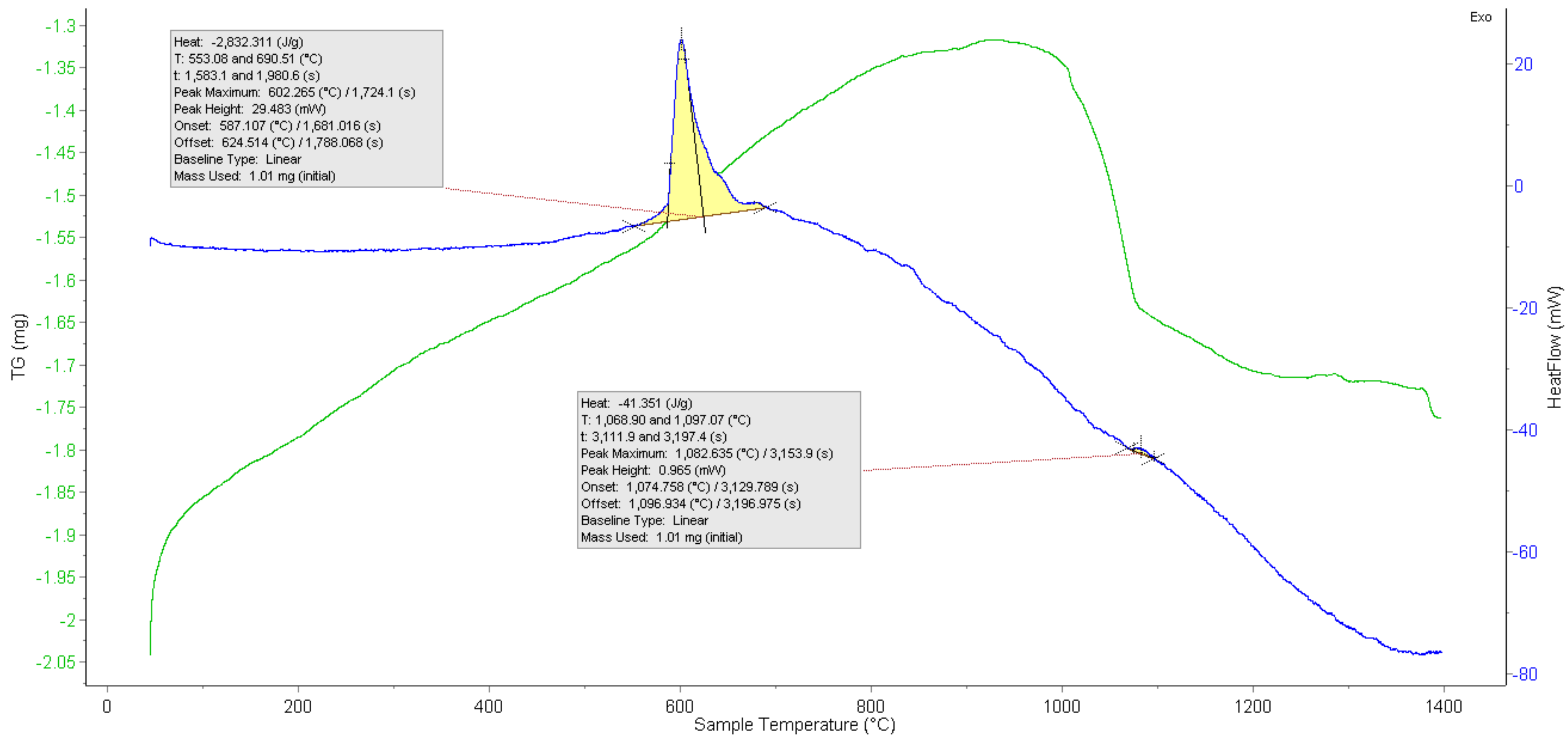


Figure C73: High-Temp DSC Plot for Mix ID SS #40 Trial 1: Fine Mg-Co_3O_4

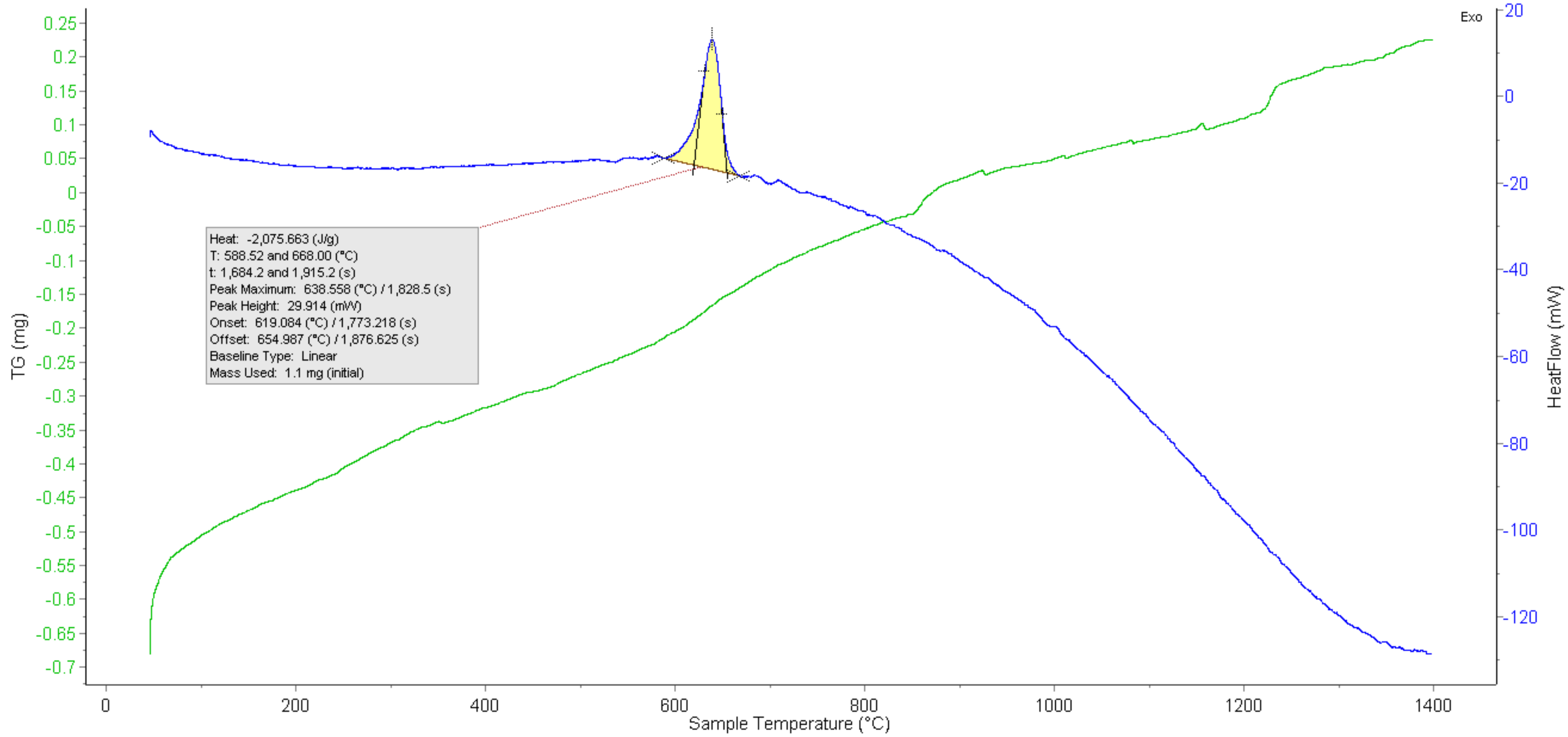


Figure C74: High-Temp DSC Plot for Mix ID SS #40 Trial 2: Fine Mg-Co_3O_4

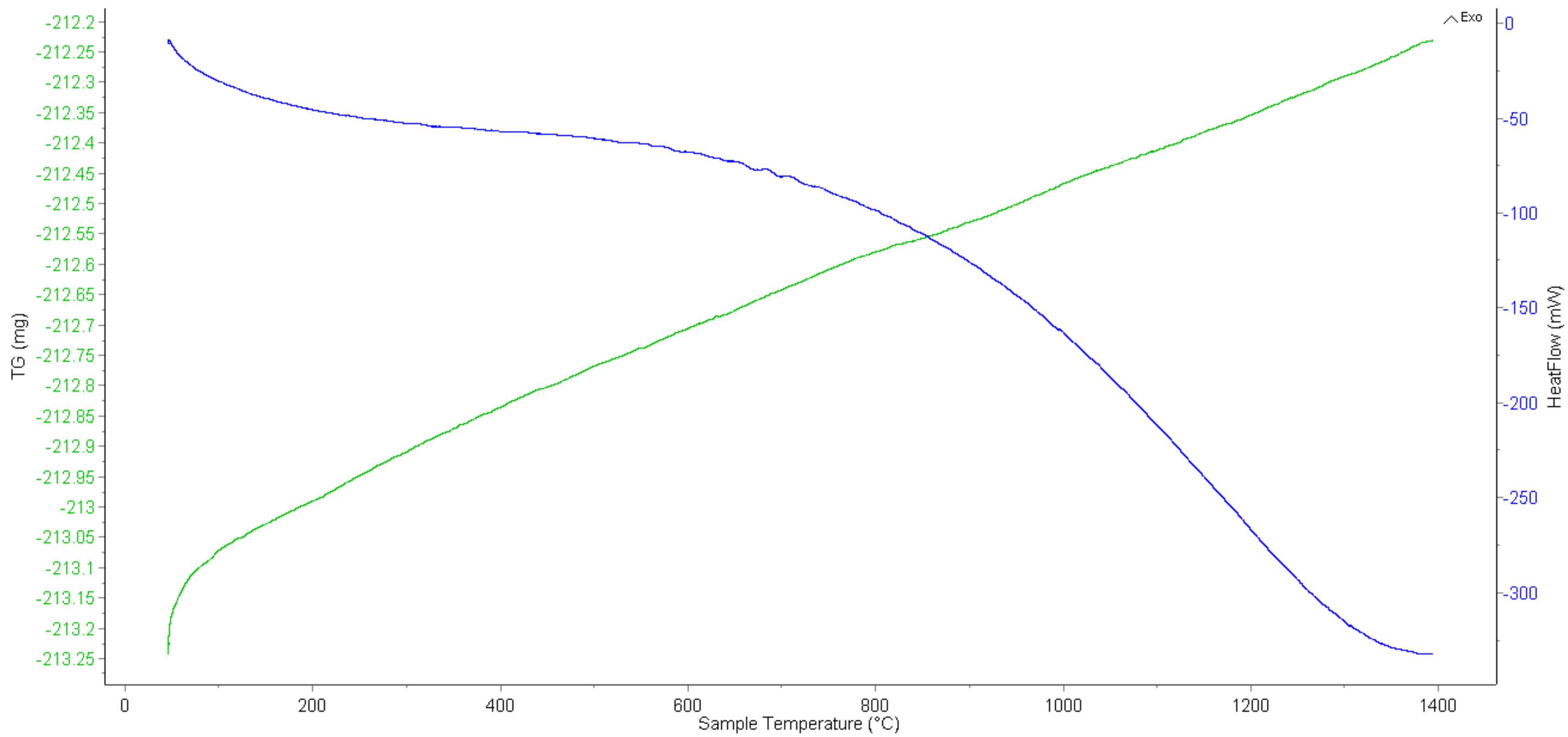


Figure C75: High-Temp DSC Plot for Mix ID SS #41 Trial 1: Fine Mg-Cr_2O_3

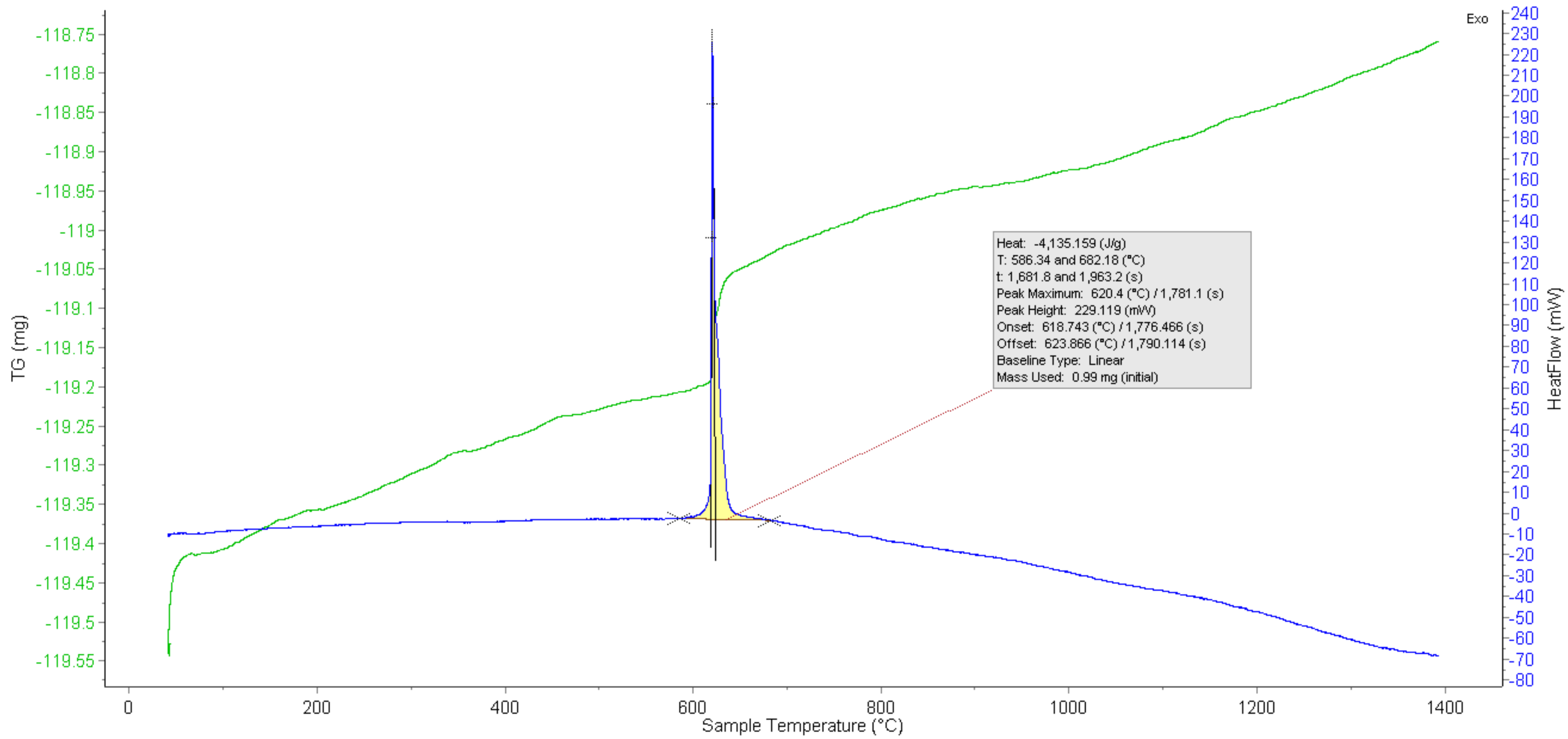


Figure C76: High-Temp DSC Plot for Mix ID SS #41 Trial 2: Fine Mg-Cr_2O_3

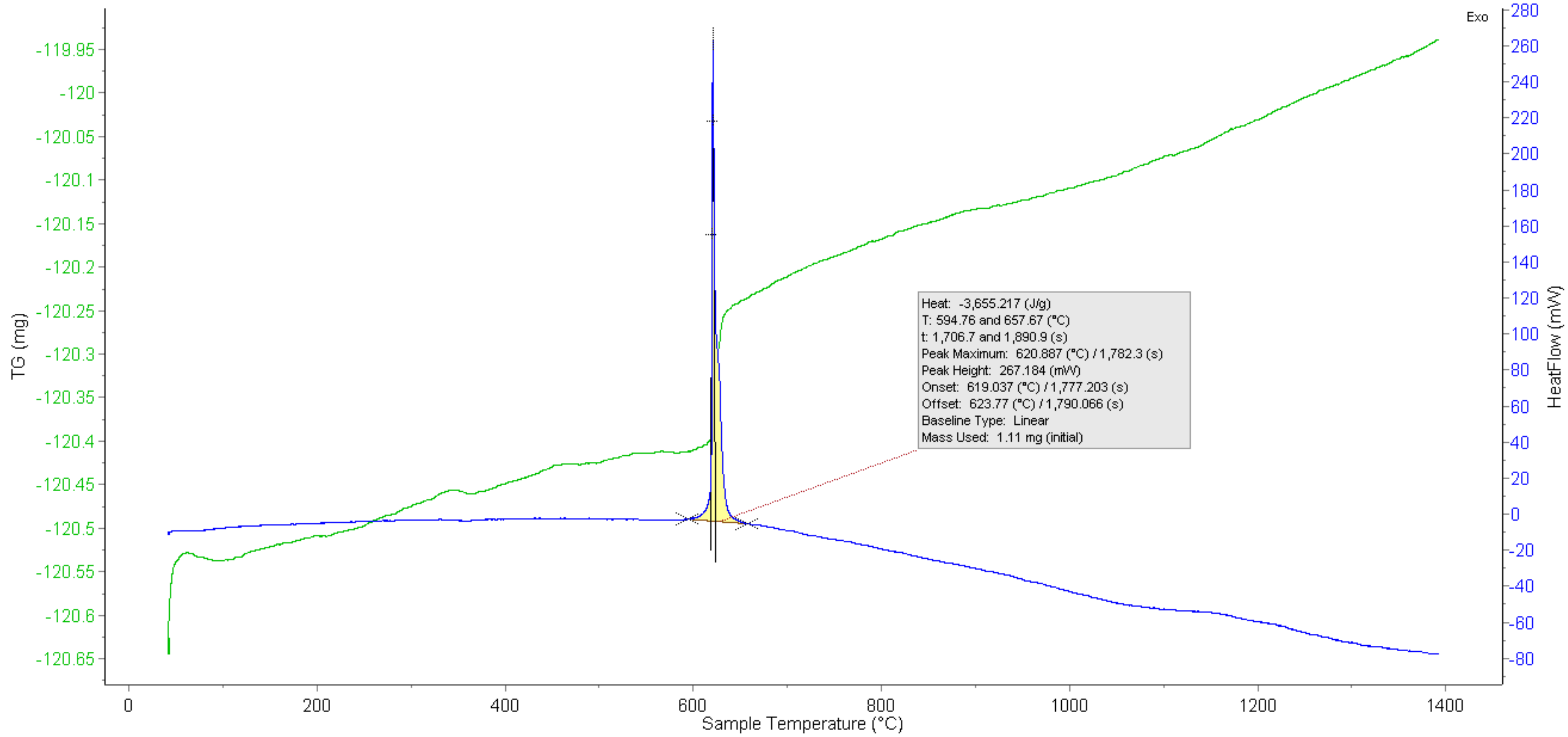


Figure C77: High-Temp DSC Plot for Mix ID SS #42 Trial 1: Fine Mg-MoO_3

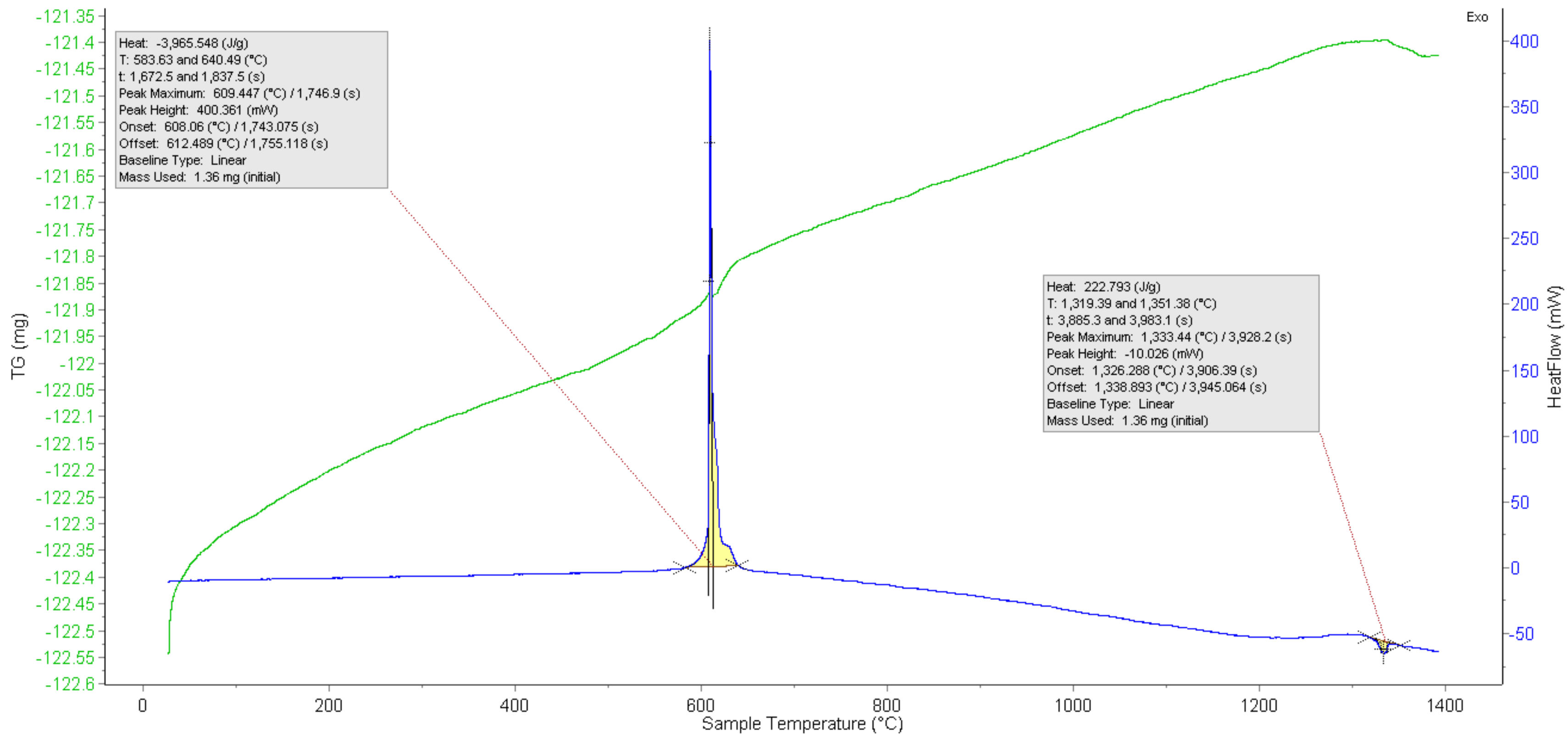


Figure C78: High-Temp DSC Plot for Mix ID SS #42 Trial 2: Fine Mg-MoO$_3$

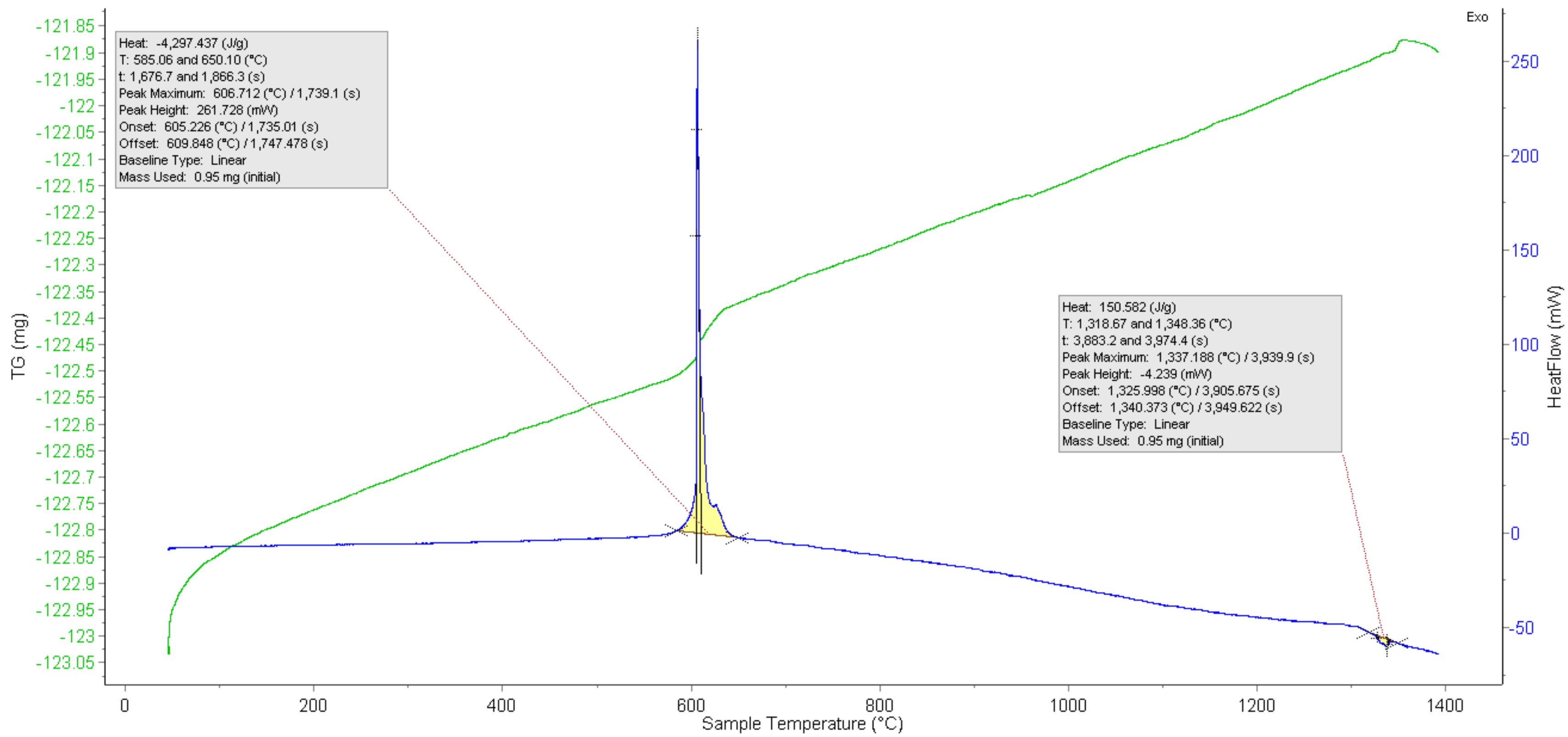


Figure C79: High-Temp DSC Plot for Mix ID SS #43 Trial 1: Fine Mg-SiO_2

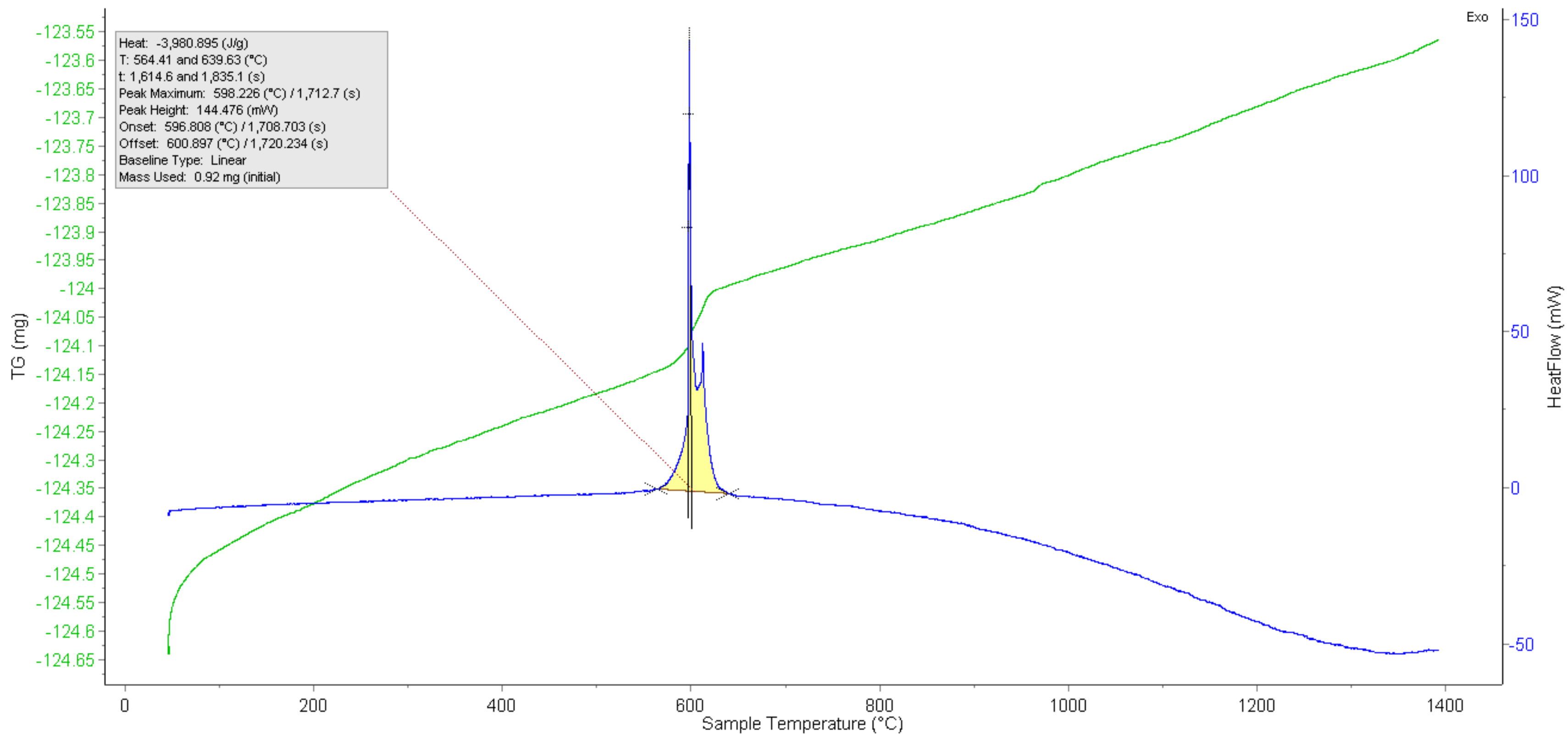


Figure C80: High-Temp DSC Plot for Mix ID SS #43 Trial 2: Fine Mg-SiO_2

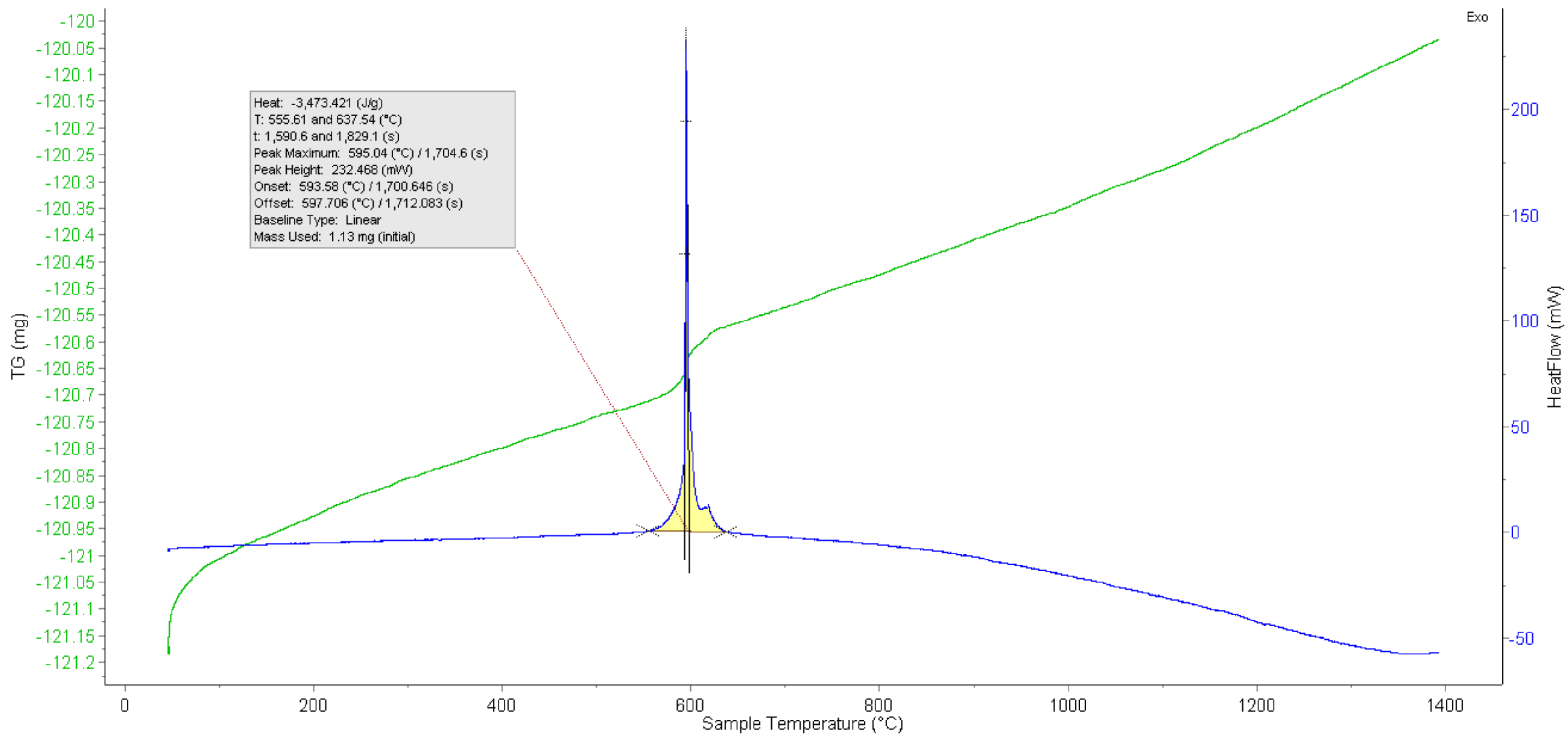


Figure C81: High-Temp DSC Plot for Mix ID SS #44 Trial 1: Fine Mg-SnO_2

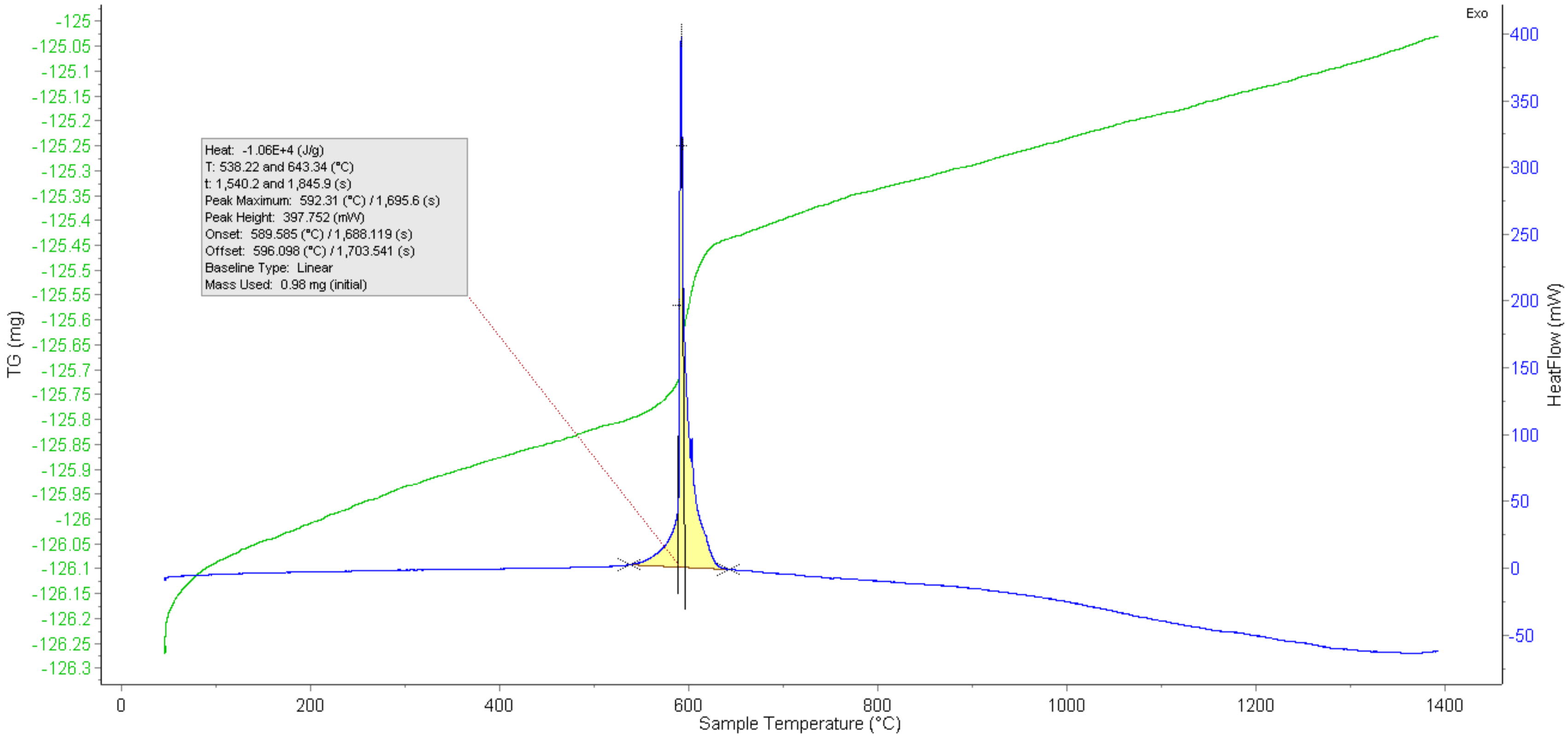


Figure C82: High-Temp DSC Plot for Mix ID SS #44 Trial 2: Fine Mg-SnO_2

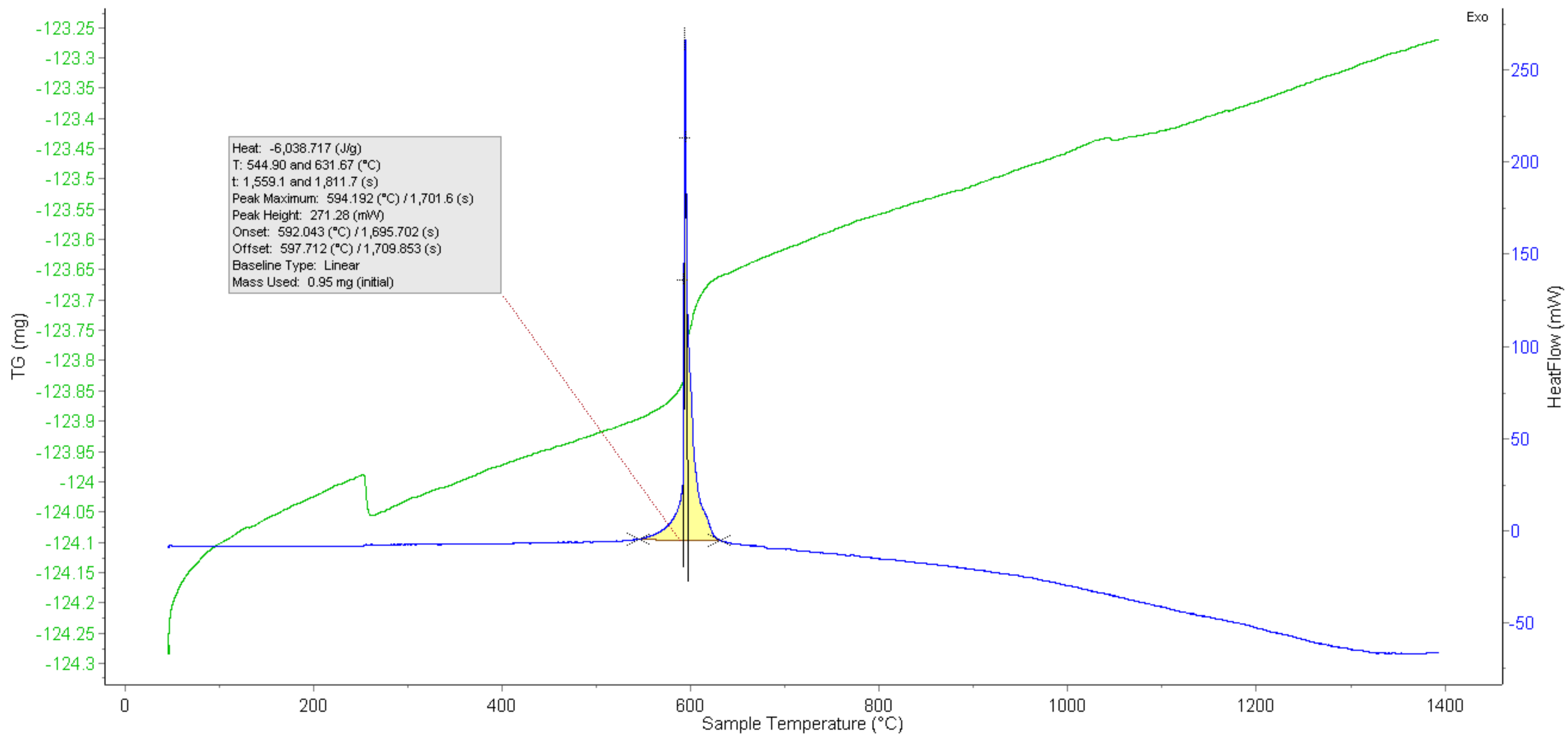


Figure C83: High-Temp DSC Plot for Mix ID SS #45 Trial 1: Fine Mg-WO_3

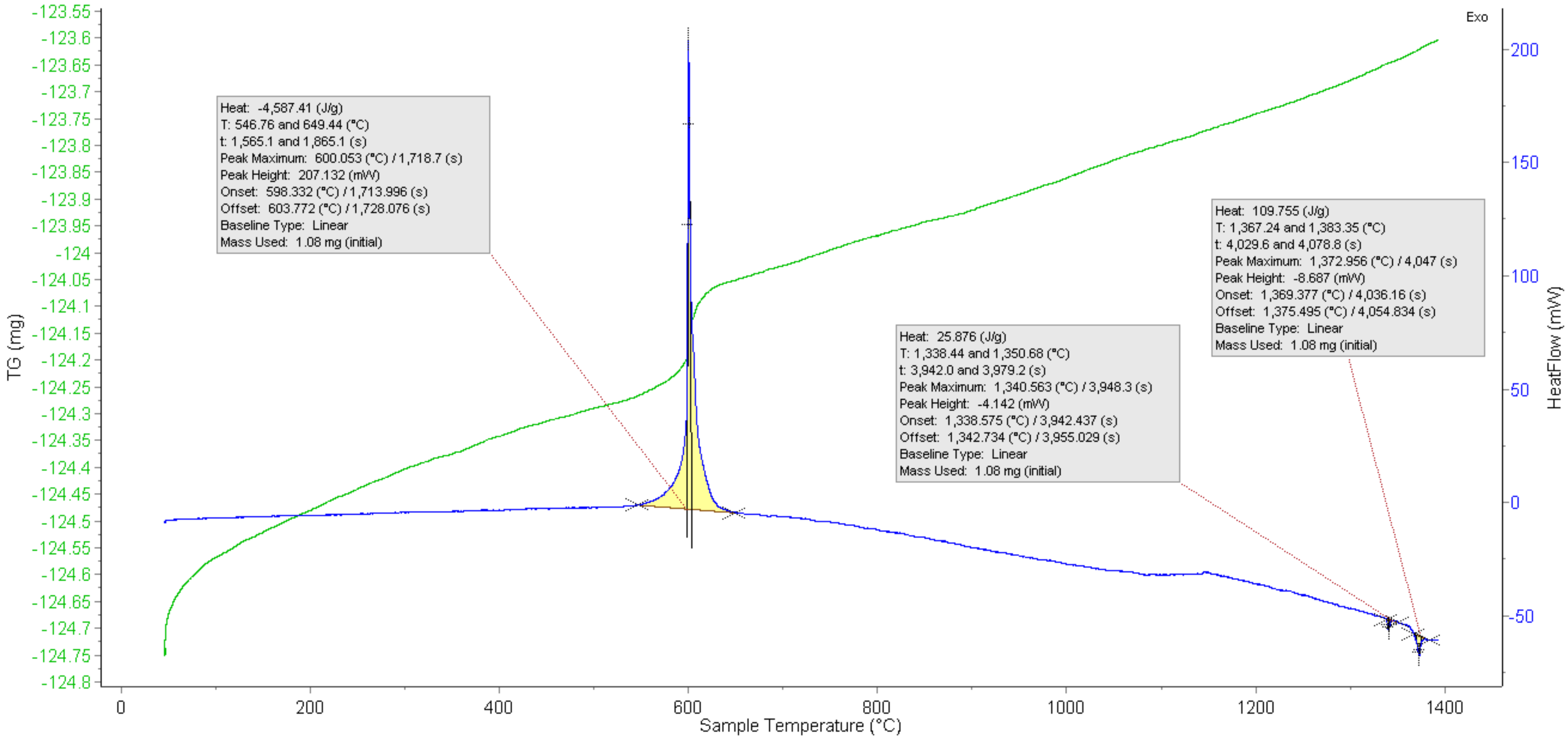


Figure C84: High-Temp DSC Plot for Mix ID SS #45 Trial 2: Fine Mg-WO_3

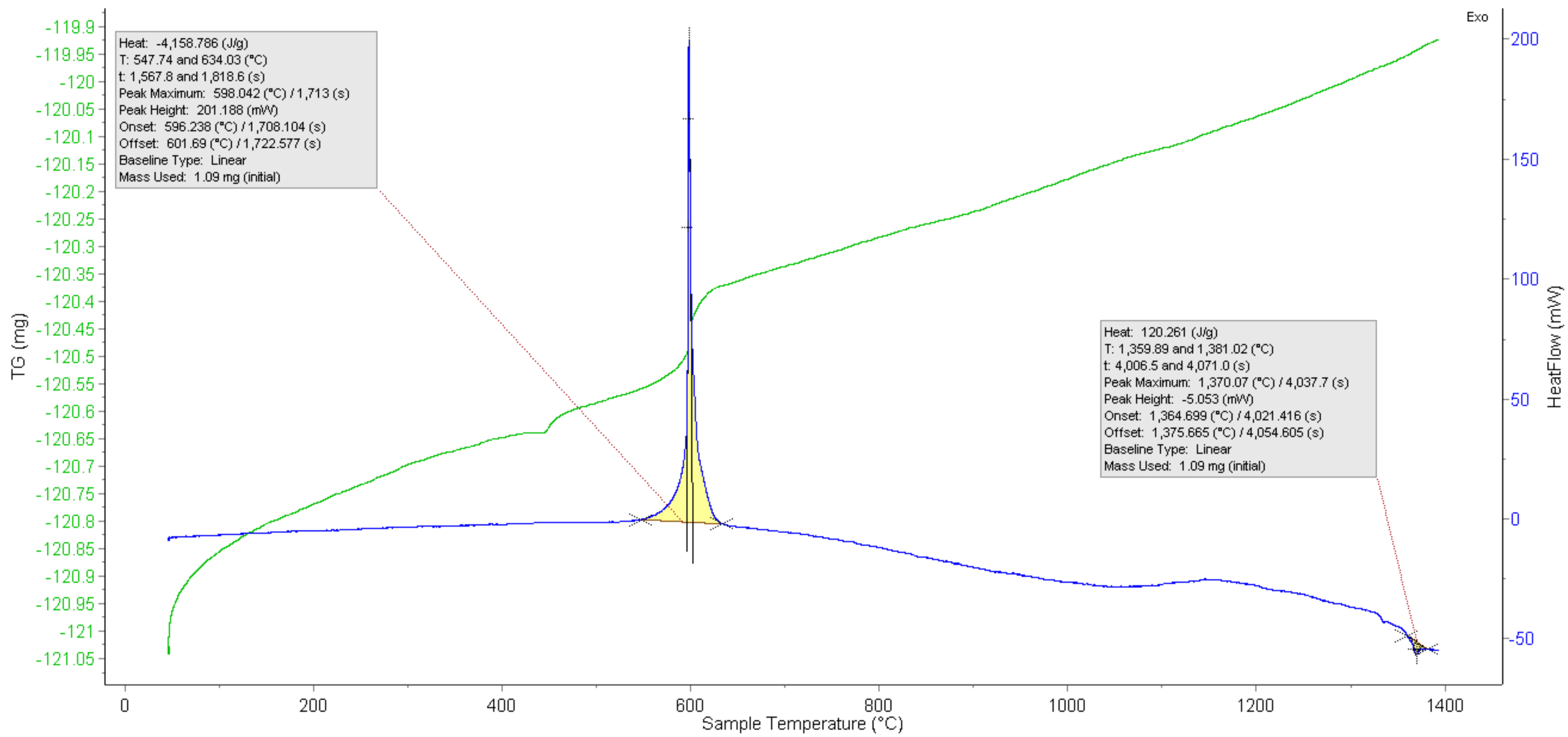


Figure C85: High-Temp DSC Plot for Mix ID SS #46 Trial 1: Fine Ti-Al_2O_3

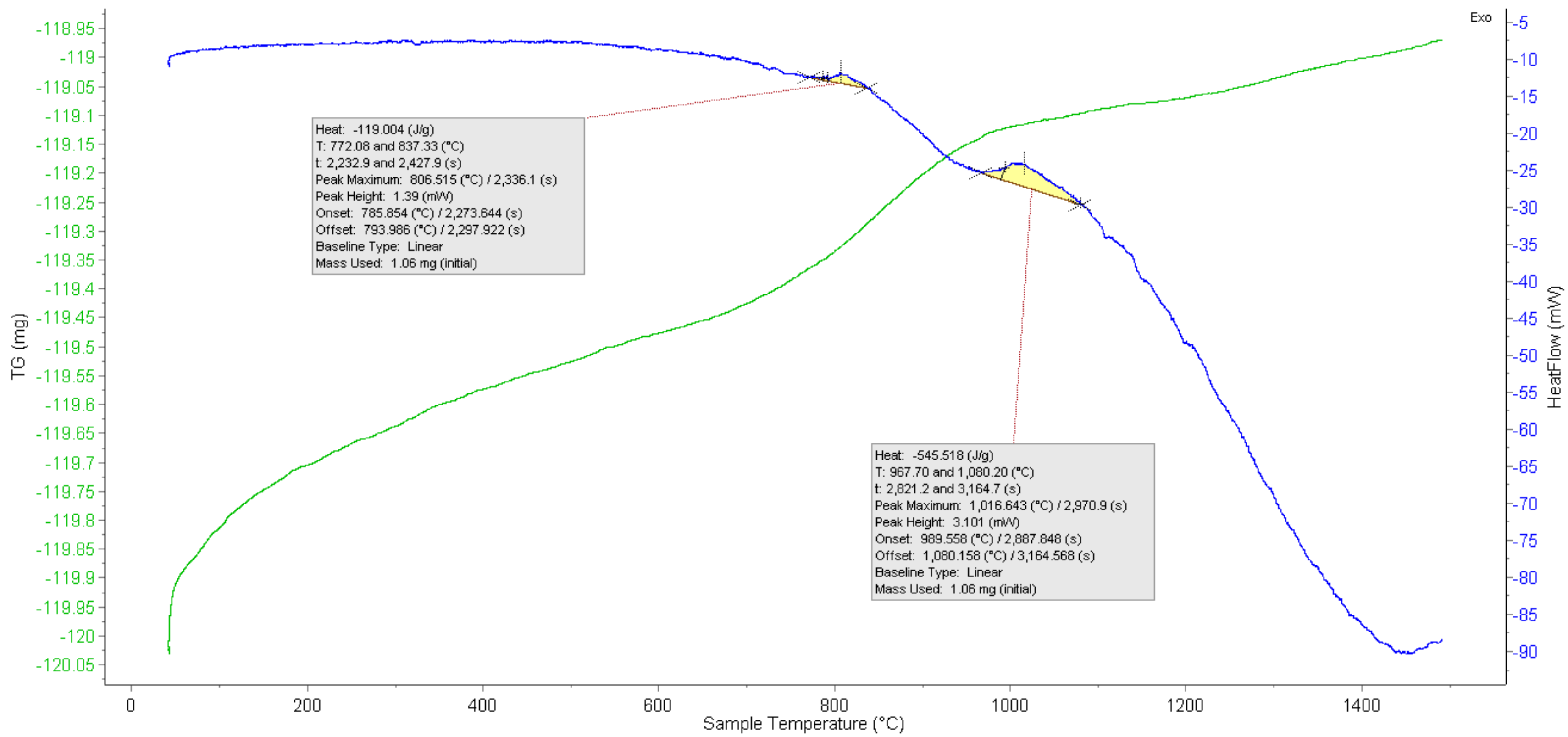


Figure C86: High-Temp DSC Plot for Mix ID SS #46 Trial 2: Fine Ti-Al_2O_3

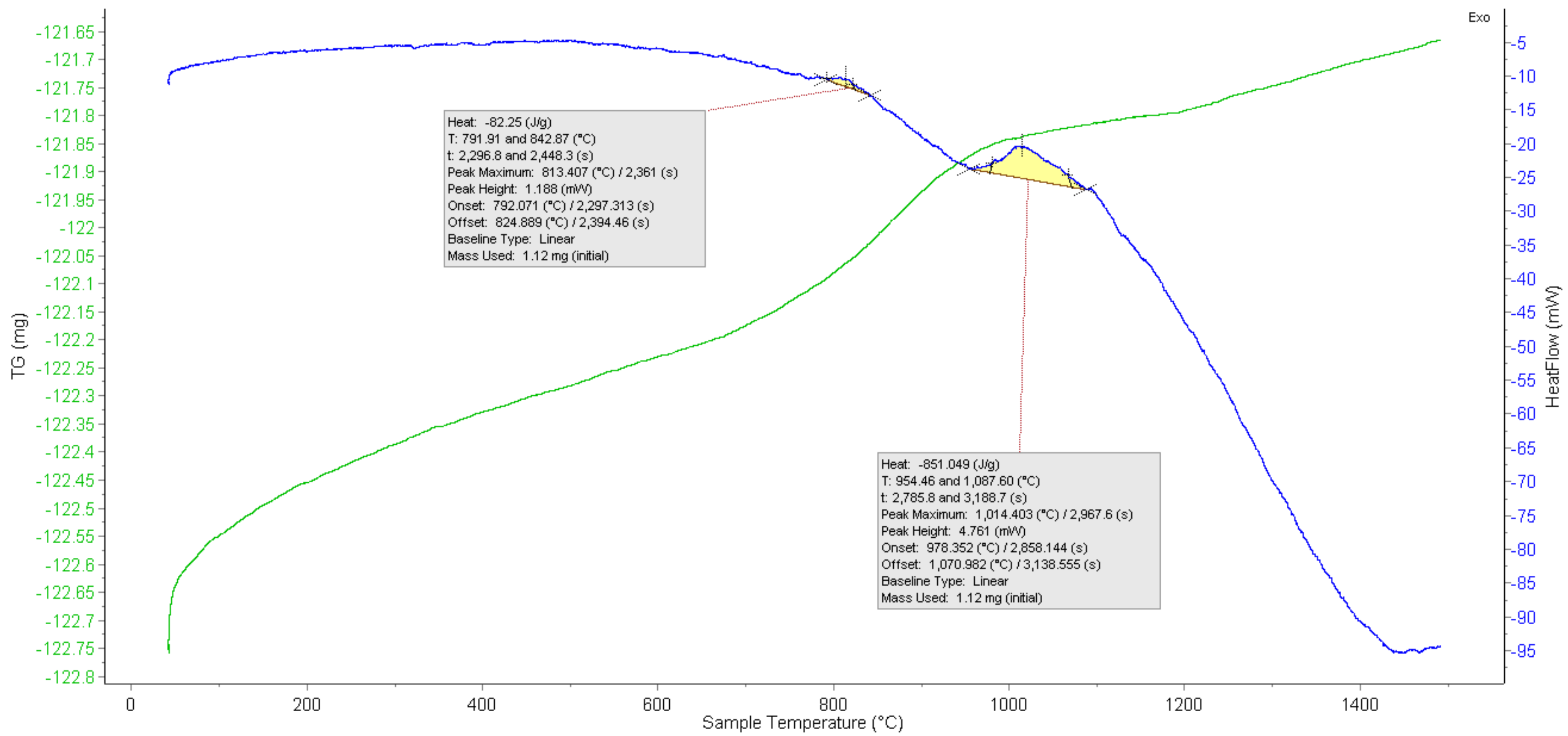


Figure C87: High-Temp DSC Plot for Mix ID SS #47 Trial 1: Fine Ti-CrO_3

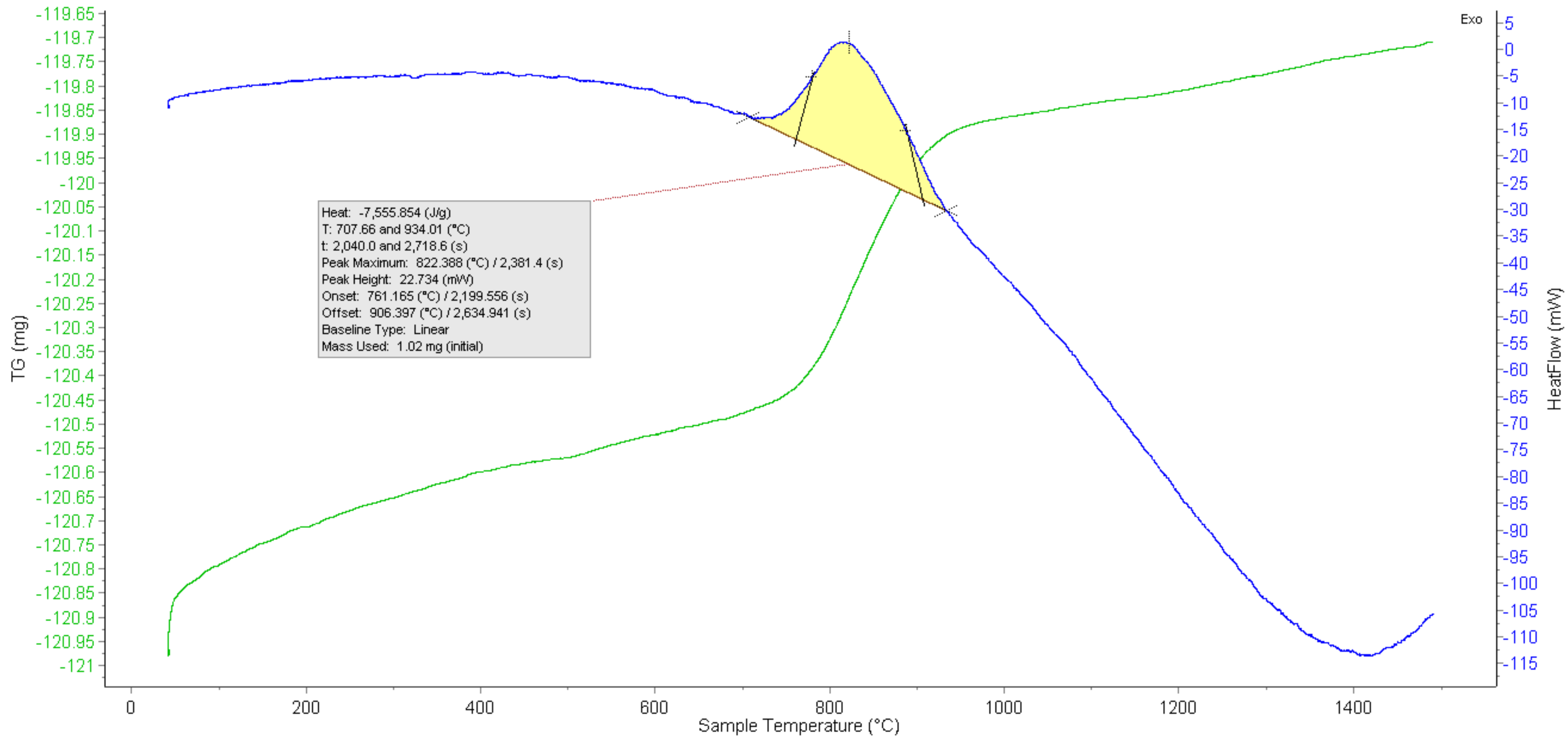


Figure C88: High-Temp DSC Plot for Mix ID SS #47 Trial 2: Fine Ti-CrO_3

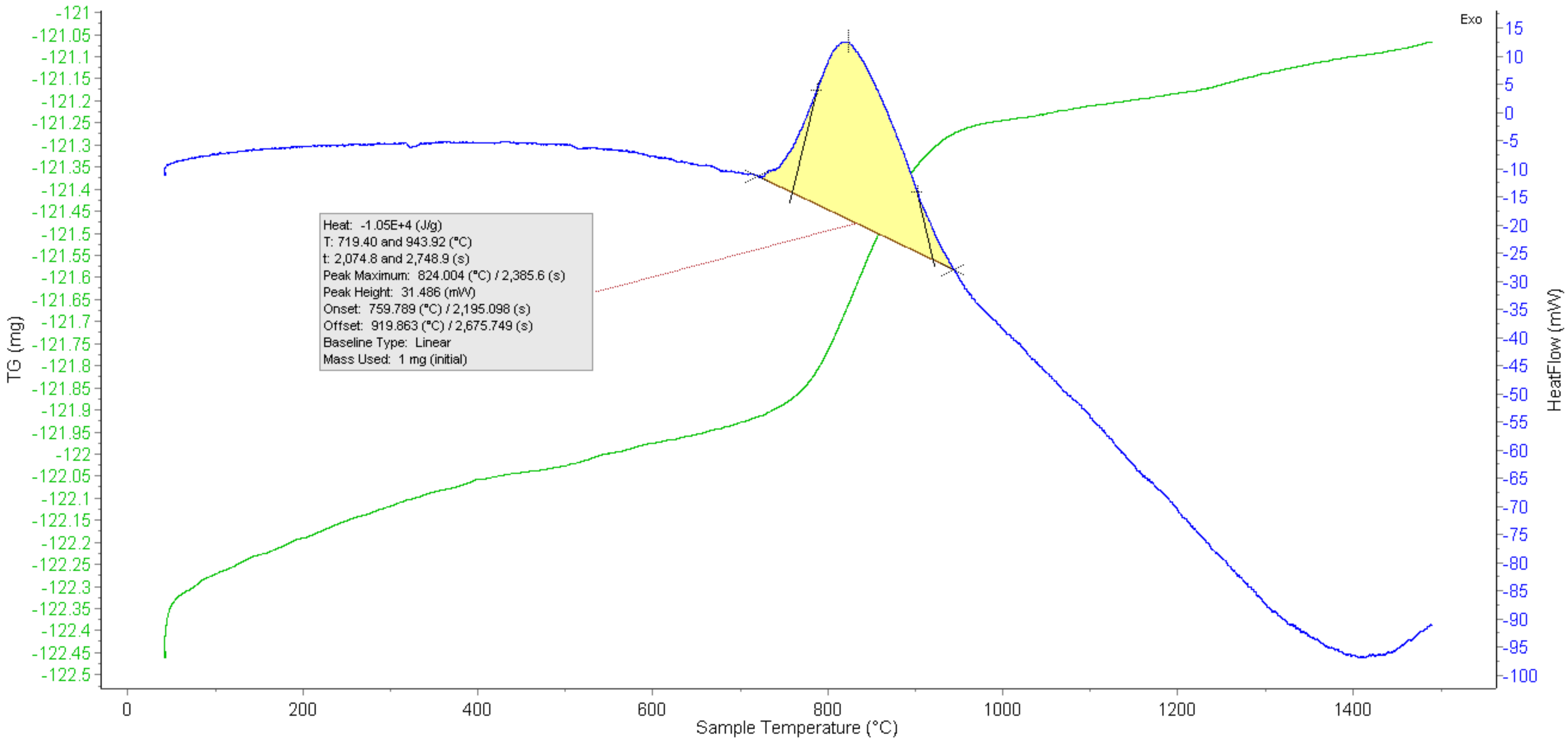


Figure C89: High-Temp DSC Plot for Mix ID SS #48 Trial 1: Fine Ti-Bi_2O_3

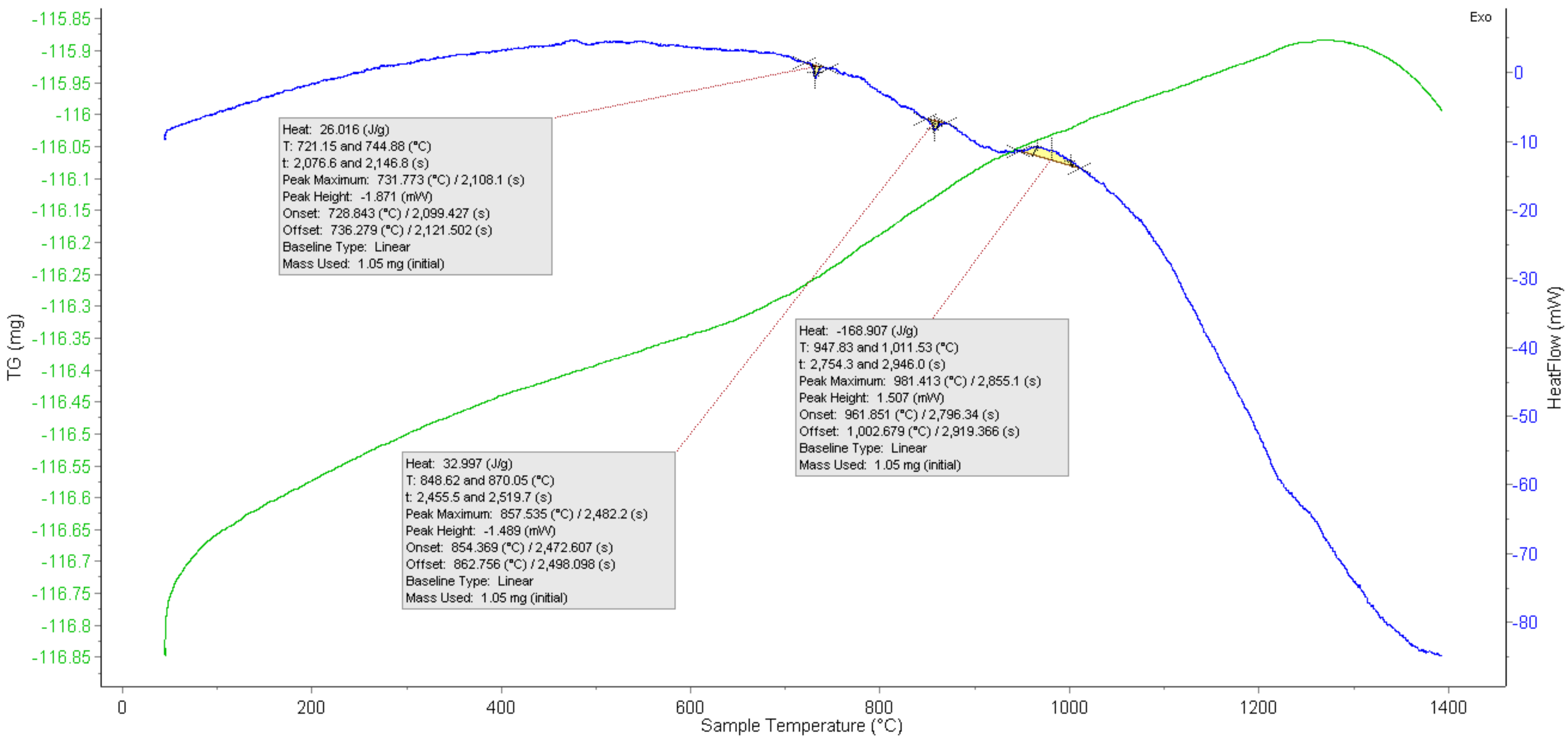


Figure C90: High-Temp DSC Plot for Mix ID SS #48 Trial 2: Fine Ti-Bi_2O_3

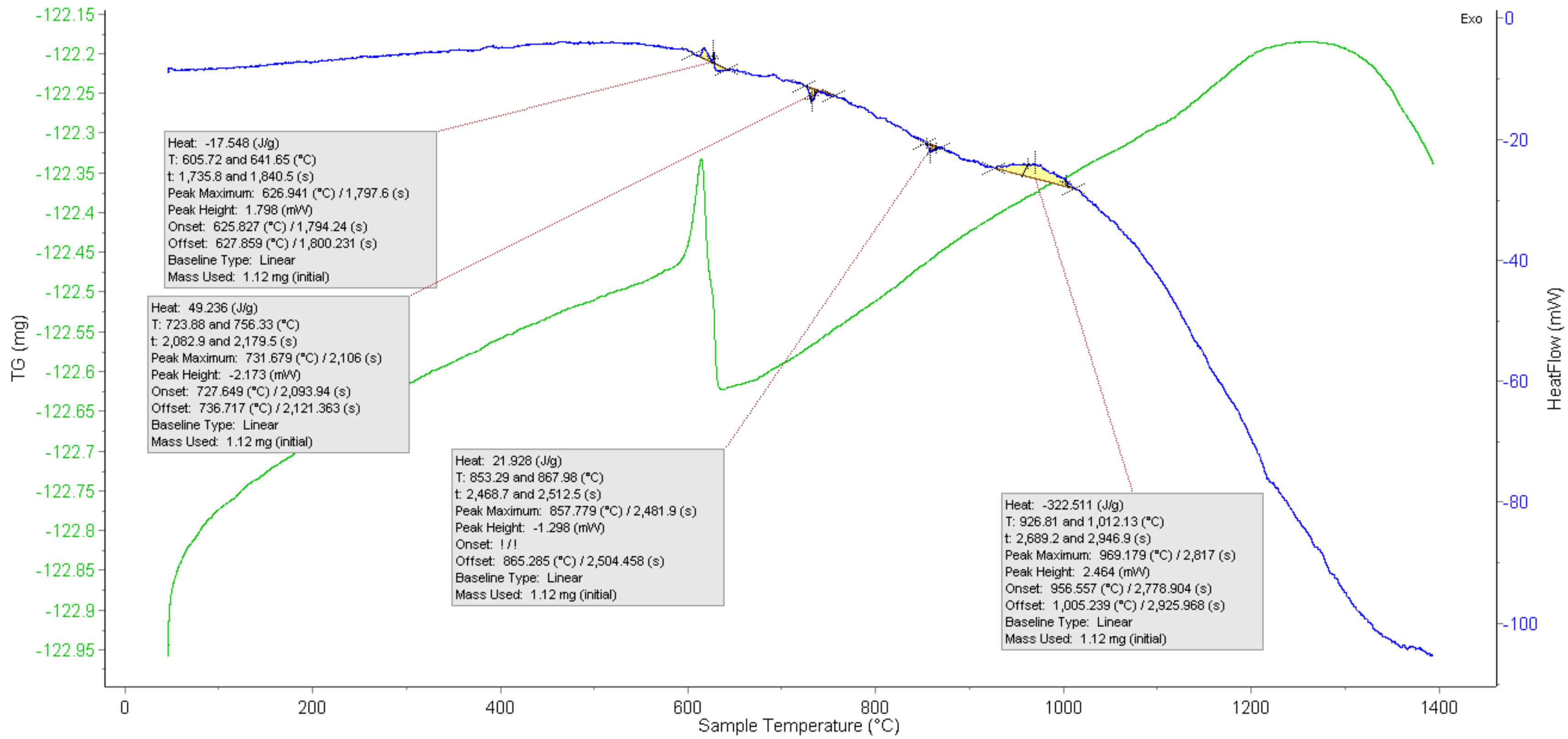


Figure C91: High-Temp DSC Plot for Mix ID SS #49 Trial 1: Fine Ti-Co_3O_4

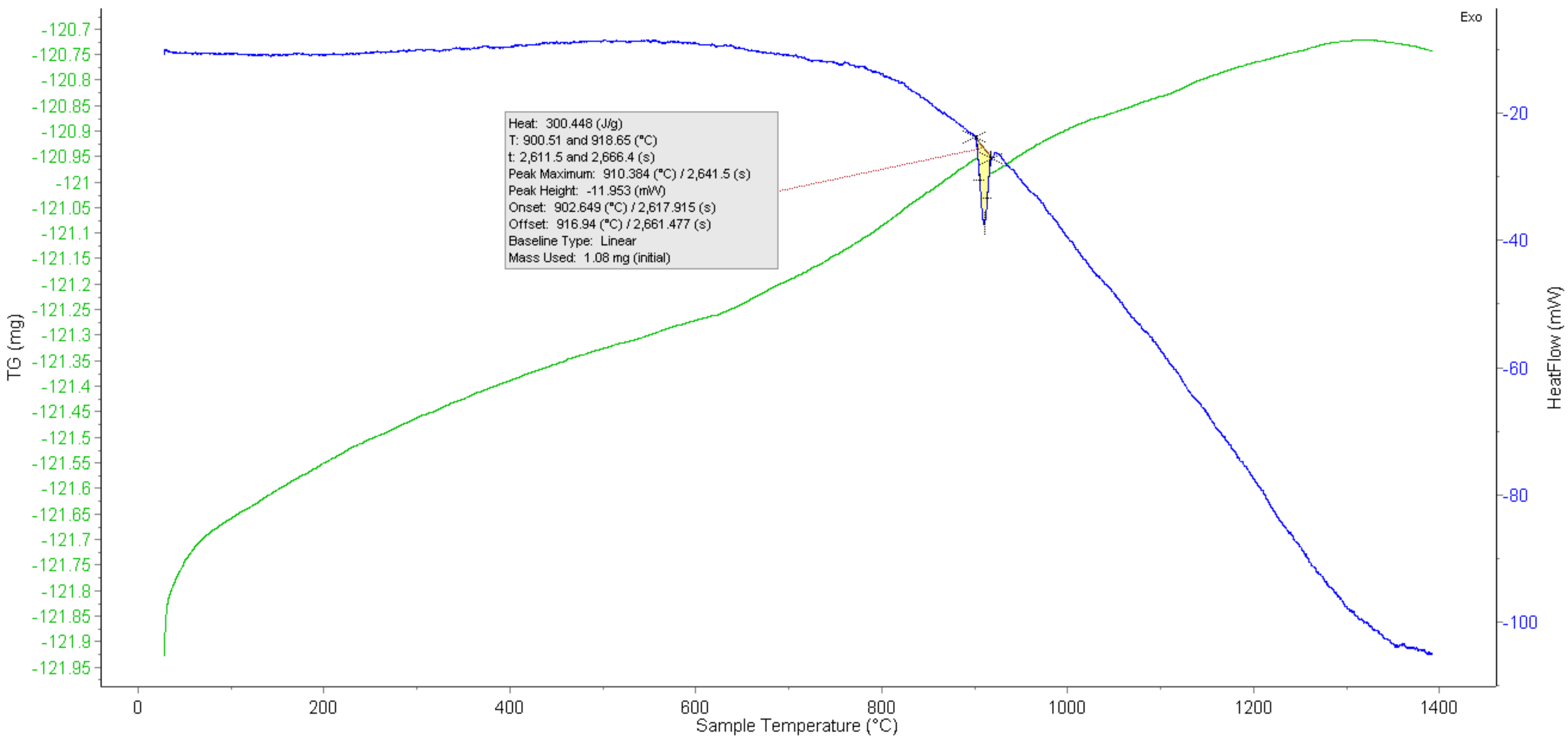


Figure C92: High-Temp DSC Plot for Mix ID SS #49 Trial 2: Fine Ti-Co_3O_4

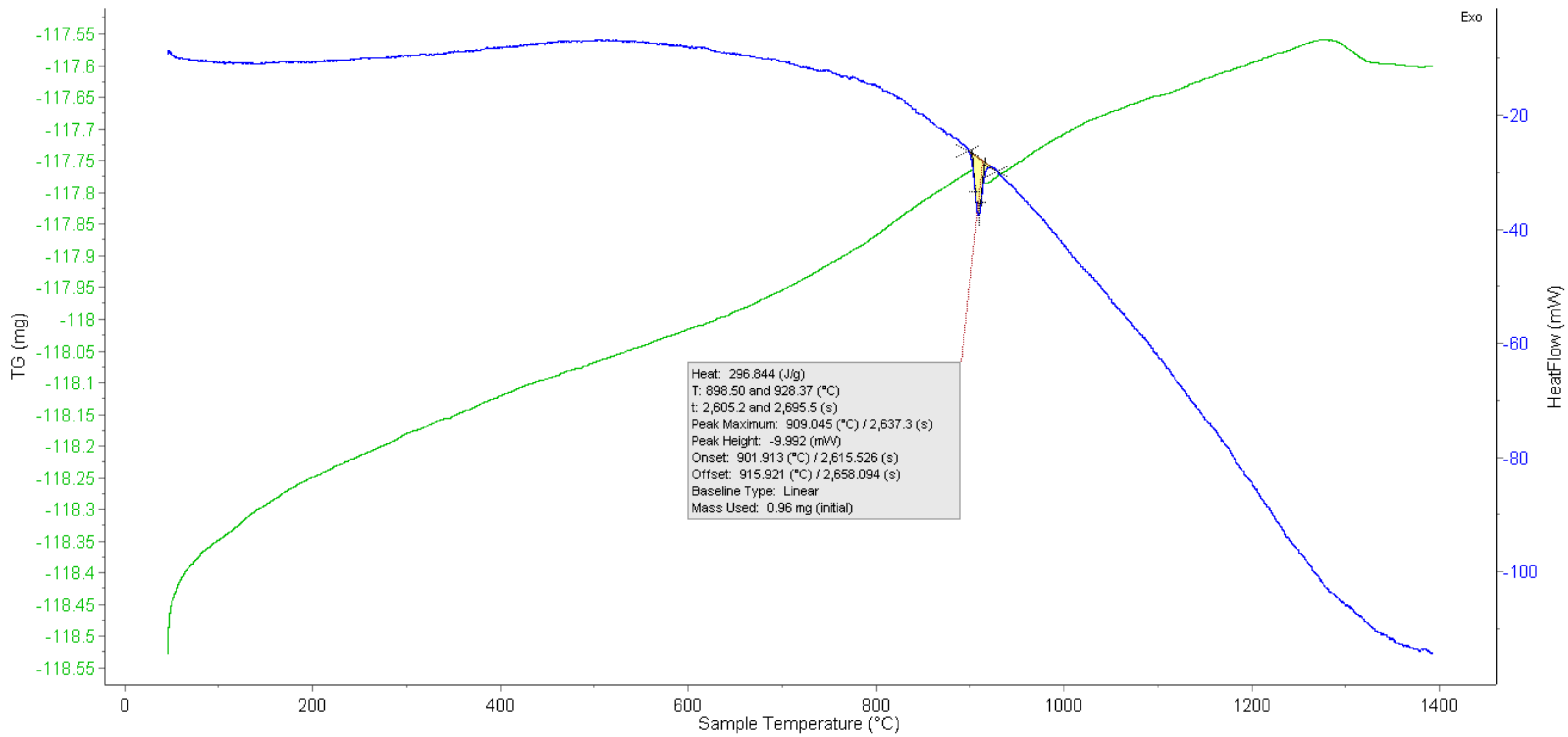


Figure C93: High-Temp DSC Plot for Mix ID SS #50 Trial 1: Fine Ti-Cr_2O_3

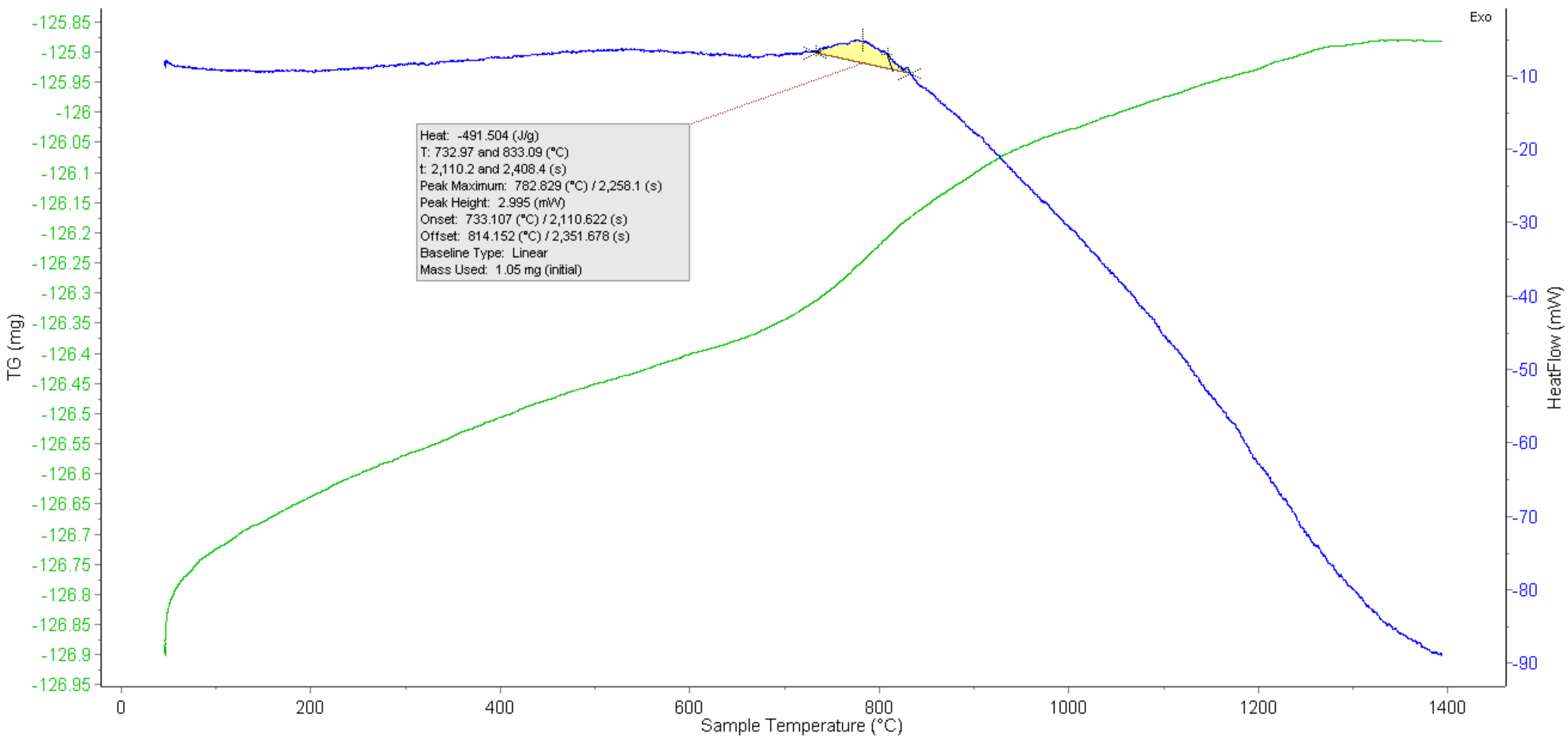


Figure C94: High-Temp DSC Plot for Mix ID SS #50 Trial 2: Fine Ti-Cr_2O_3

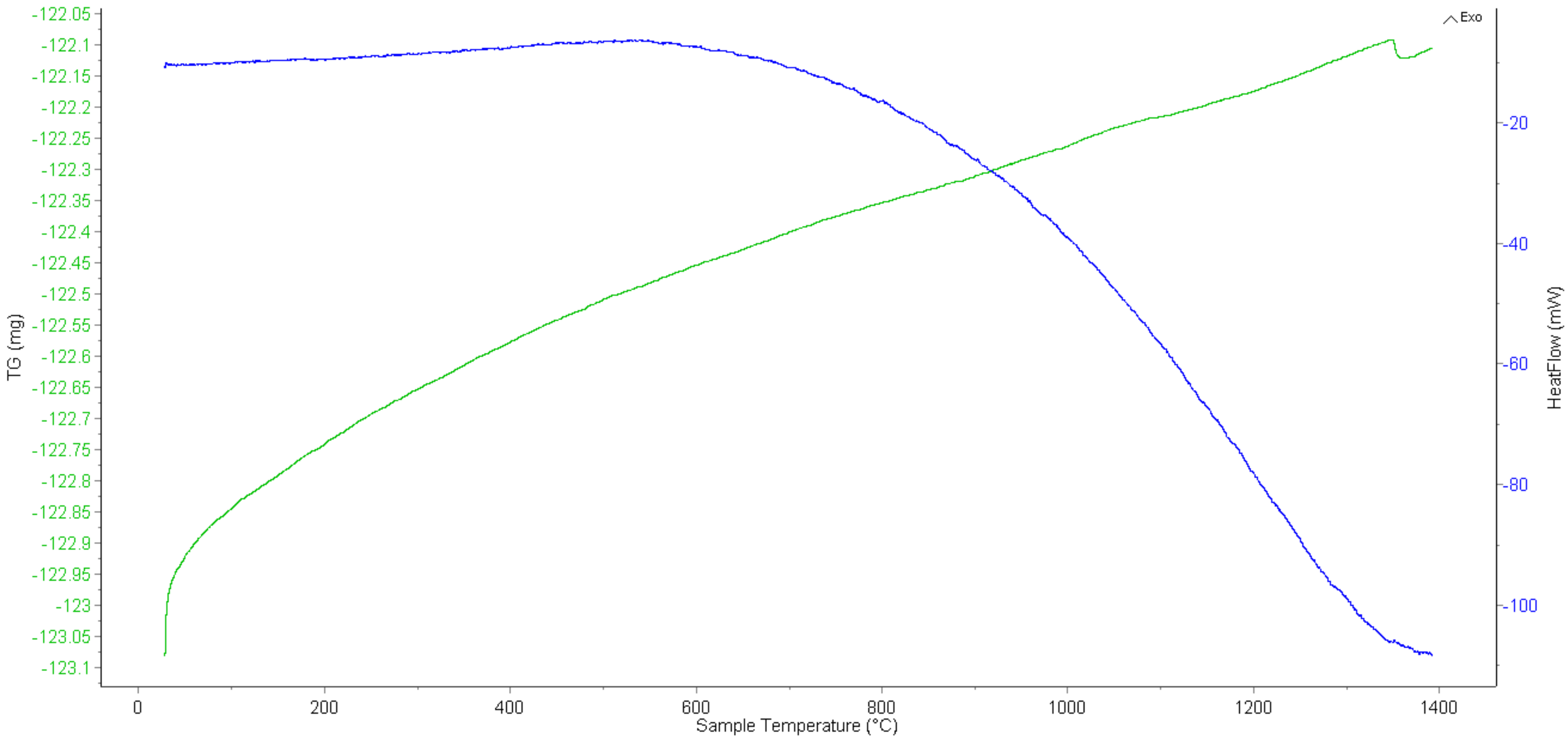


Figure C95: High-Temp DSC Plot for Mix ID SS #51 Trial 1: Fine Ti-Cu_2O

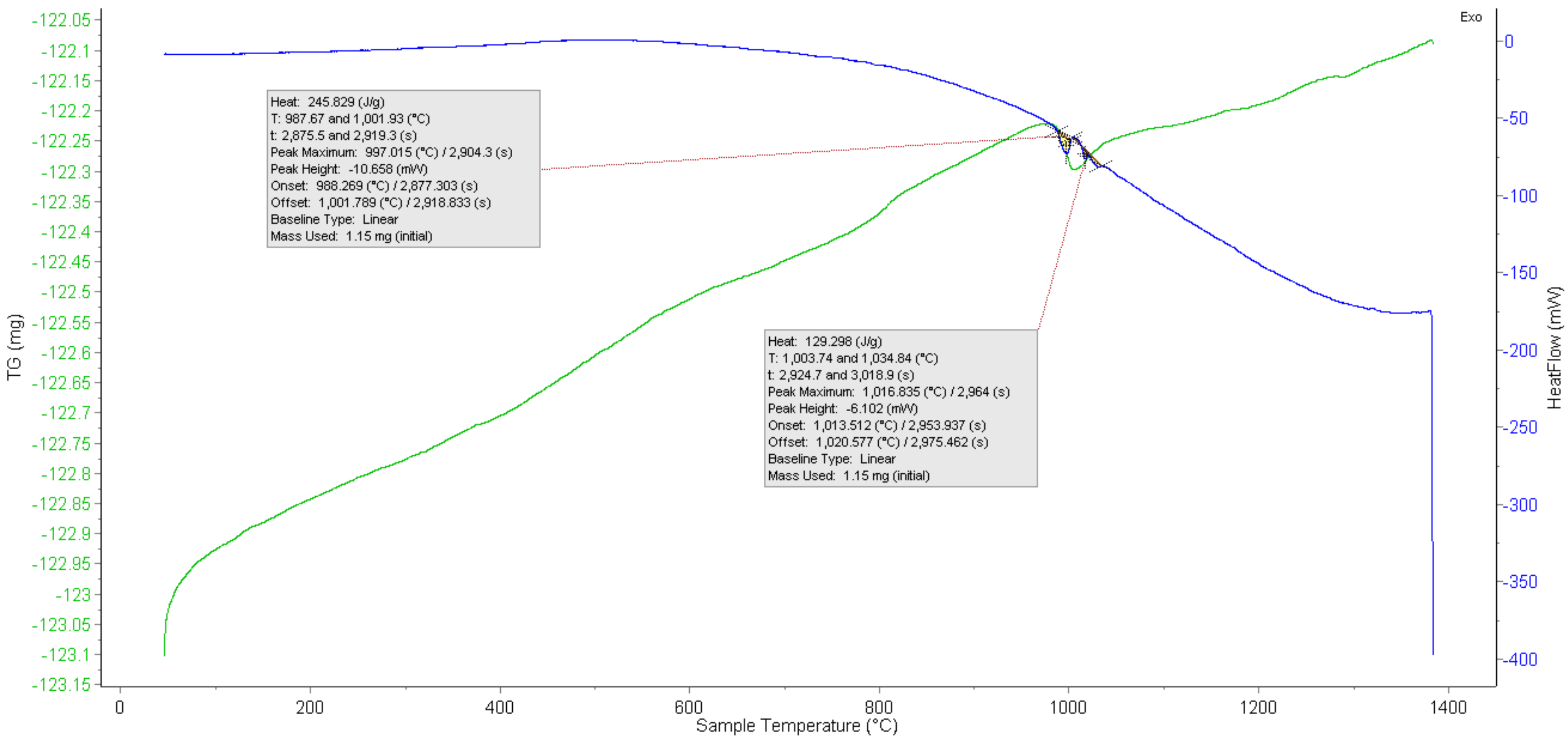


Figure C96: High-Temp DSC Plot for Mix ID SS #51 Trial 2: Fine Ti-Cu_2O

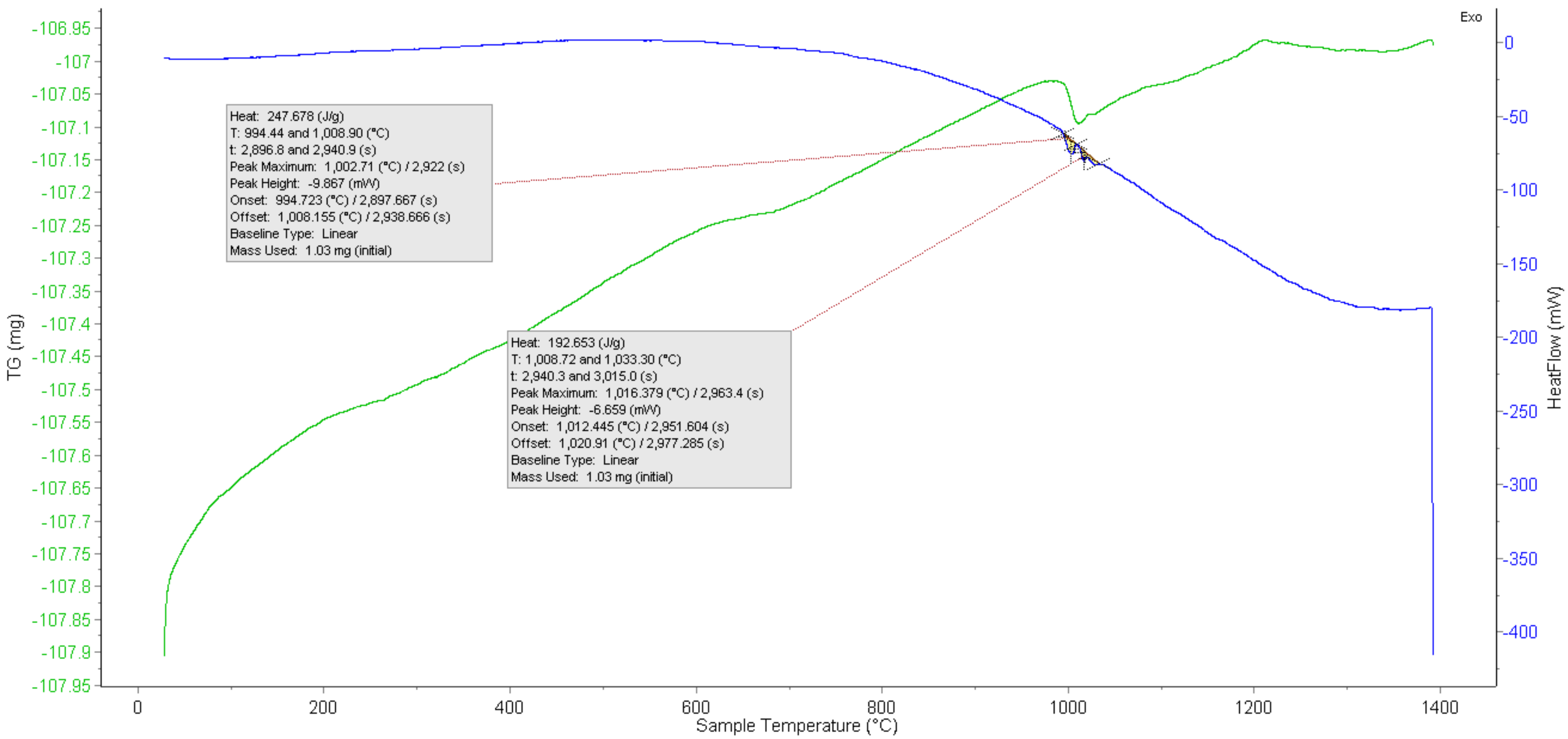


Figure C97: High-Temp DSC Plot for Mix ID SS #52 Trial 1: Fine Ti-MoO3

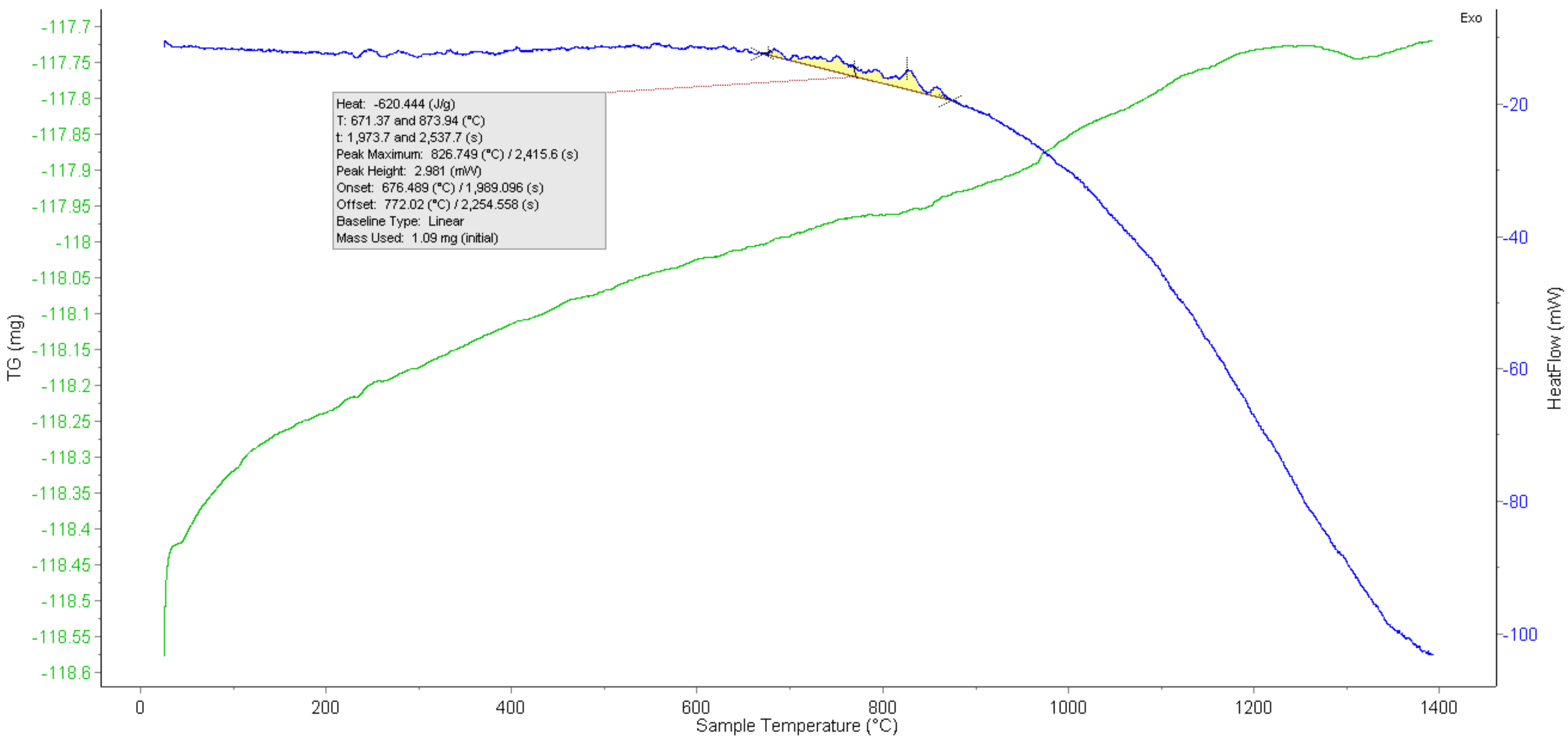


Figure C98: High-Temp DSC Plot for Mix ID SS #52 Trial 2: Fine Ti-MoO_3

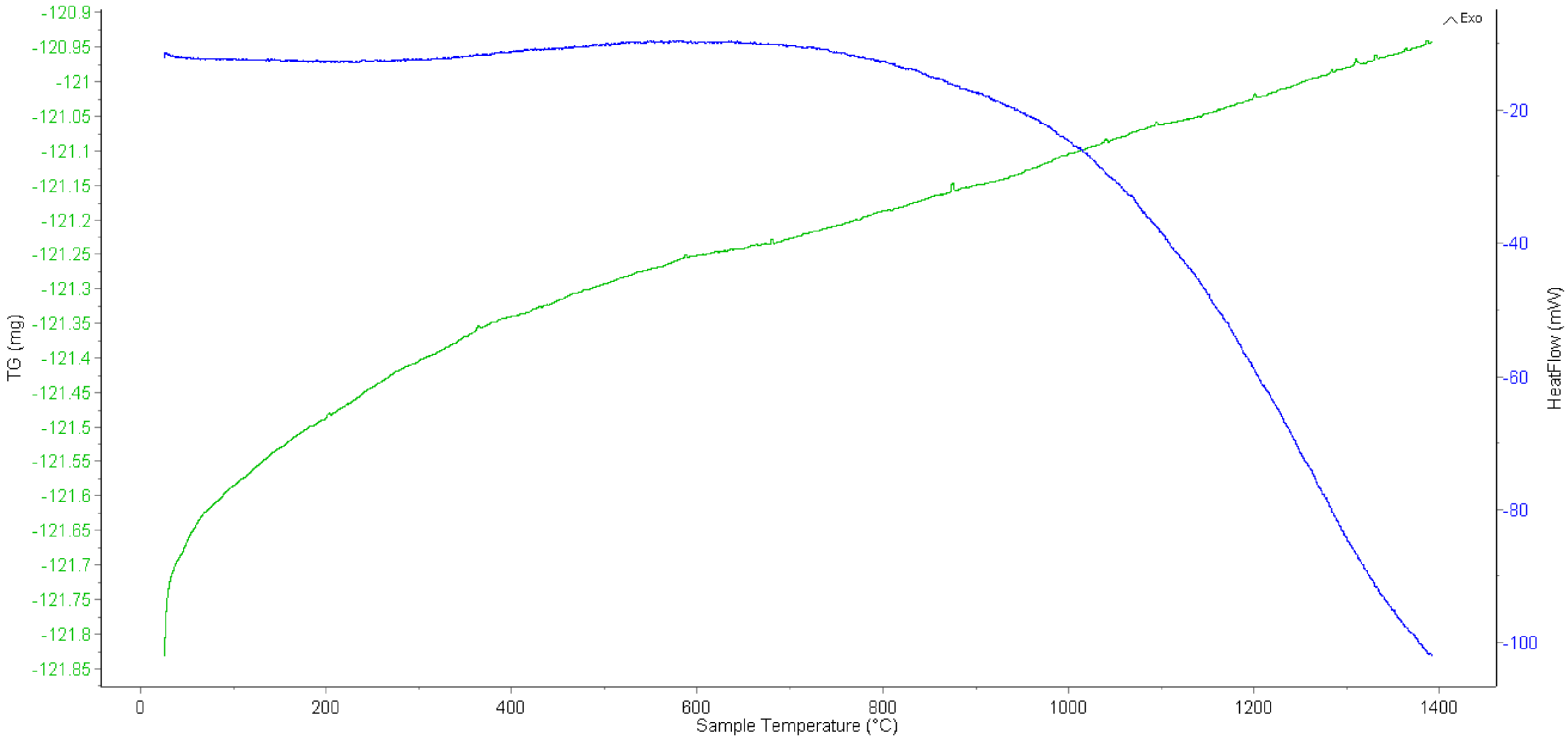


Figure C99: High-Temp DSC Plot for Mix ID SS #53 Trial 1: Fine Ti-SiO_2

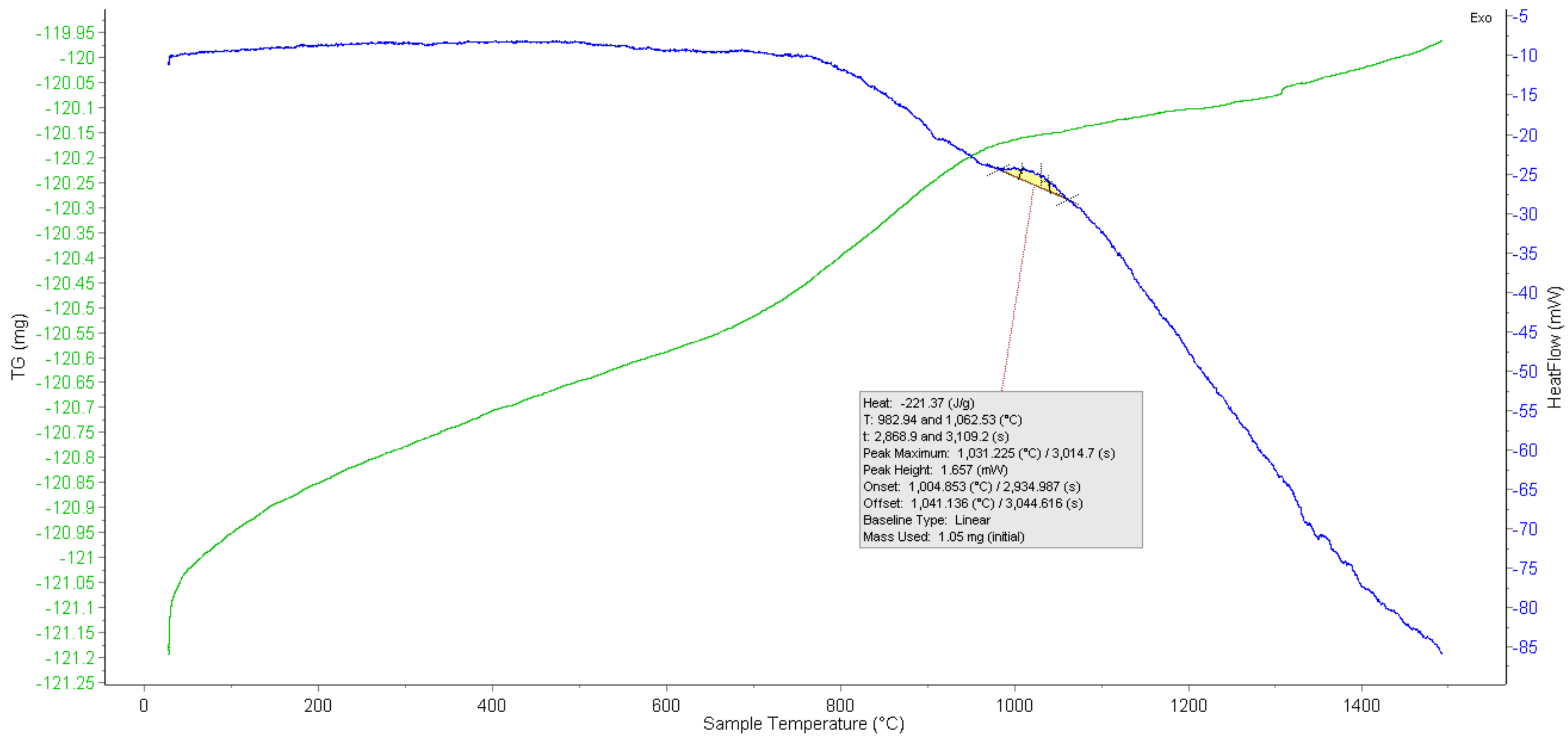


Figure C100: High-Temp DSC Plot for Mix ID SS #53 Trial 2: Fine Ti-SiO_2

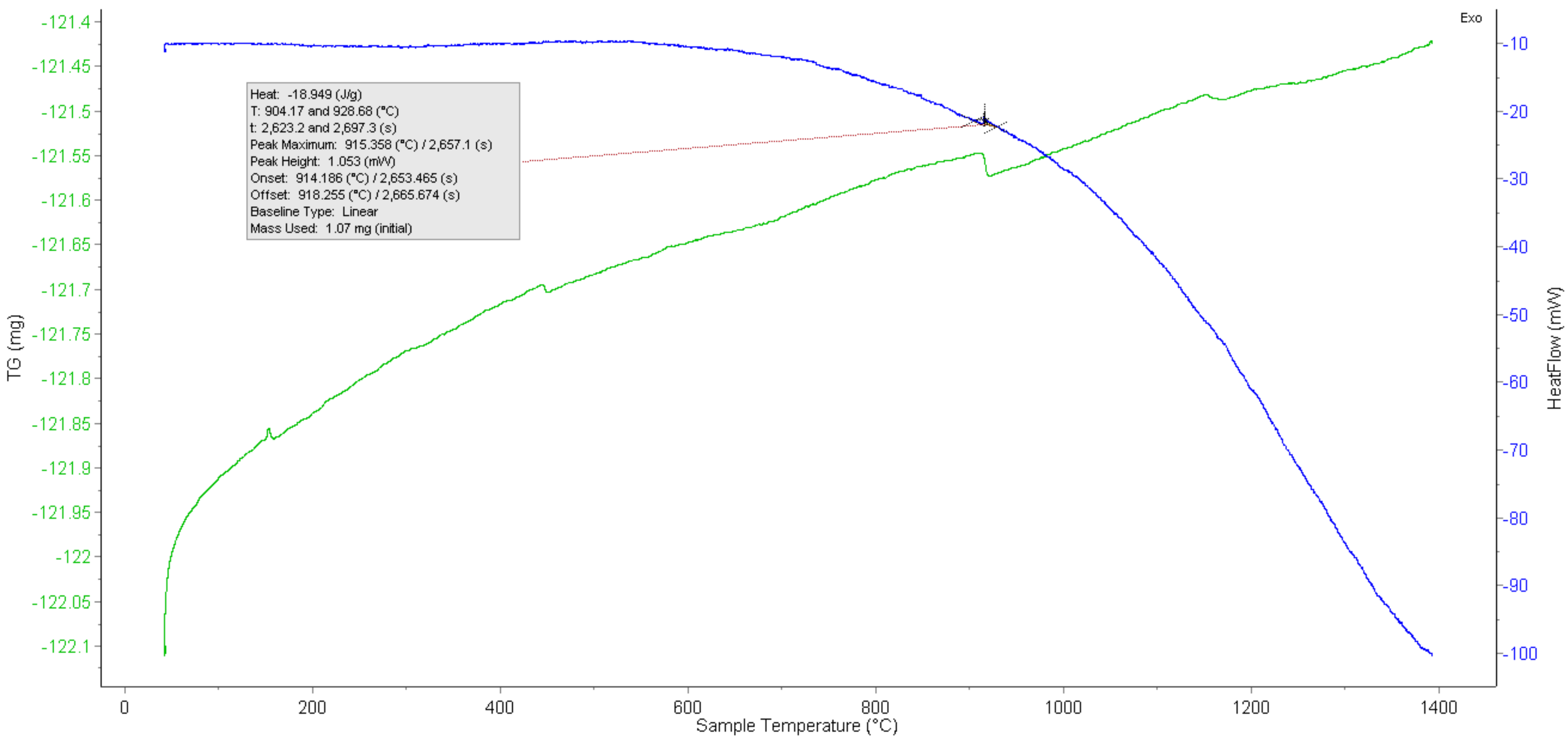


Figure C101: High-Temp DSC Plot for Mix ID SS #54 Trial 1: Fine Ti-SnO_2

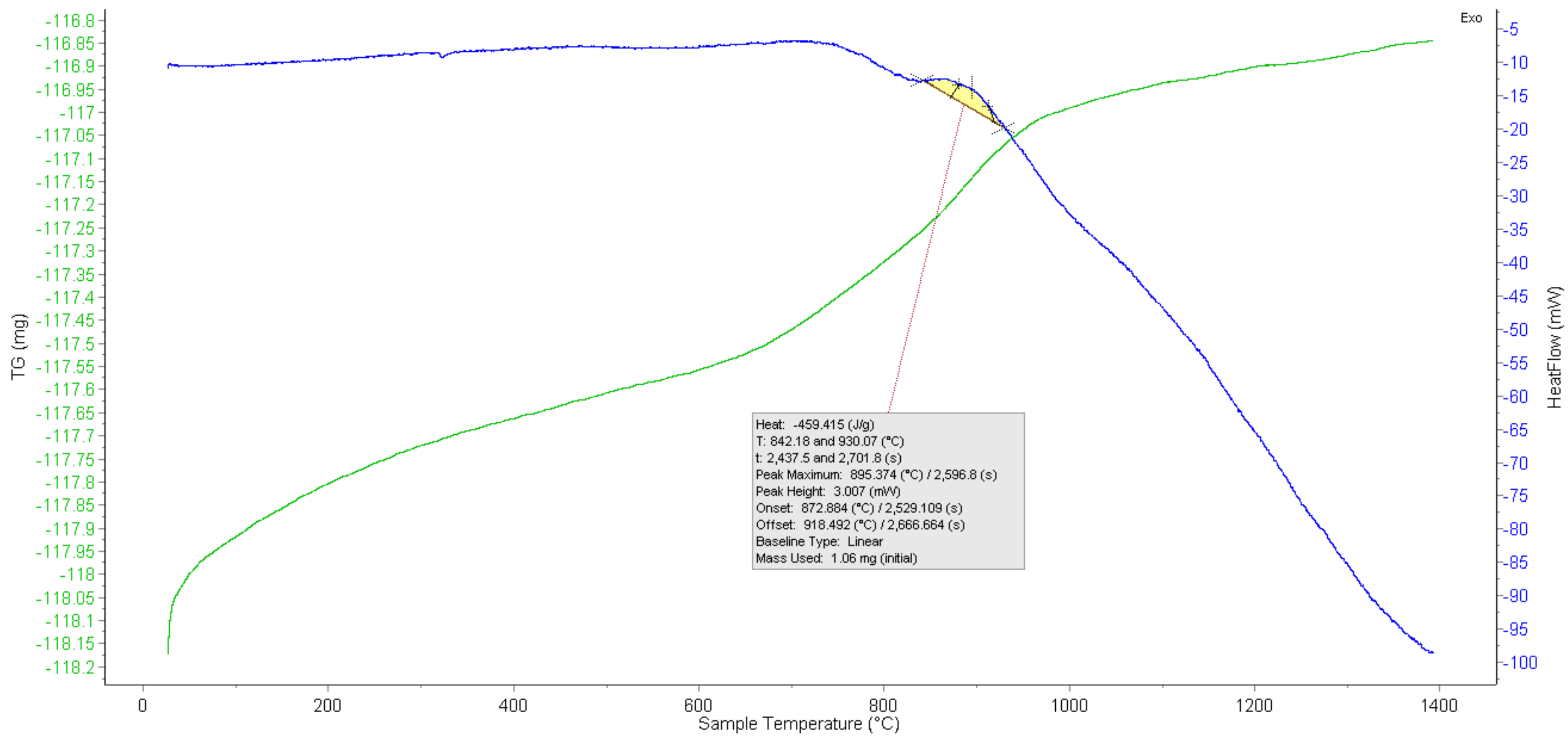


Figure C102: High-Temp DSC Plot for Mix ID SS #54 Fine Ti-SnO_2

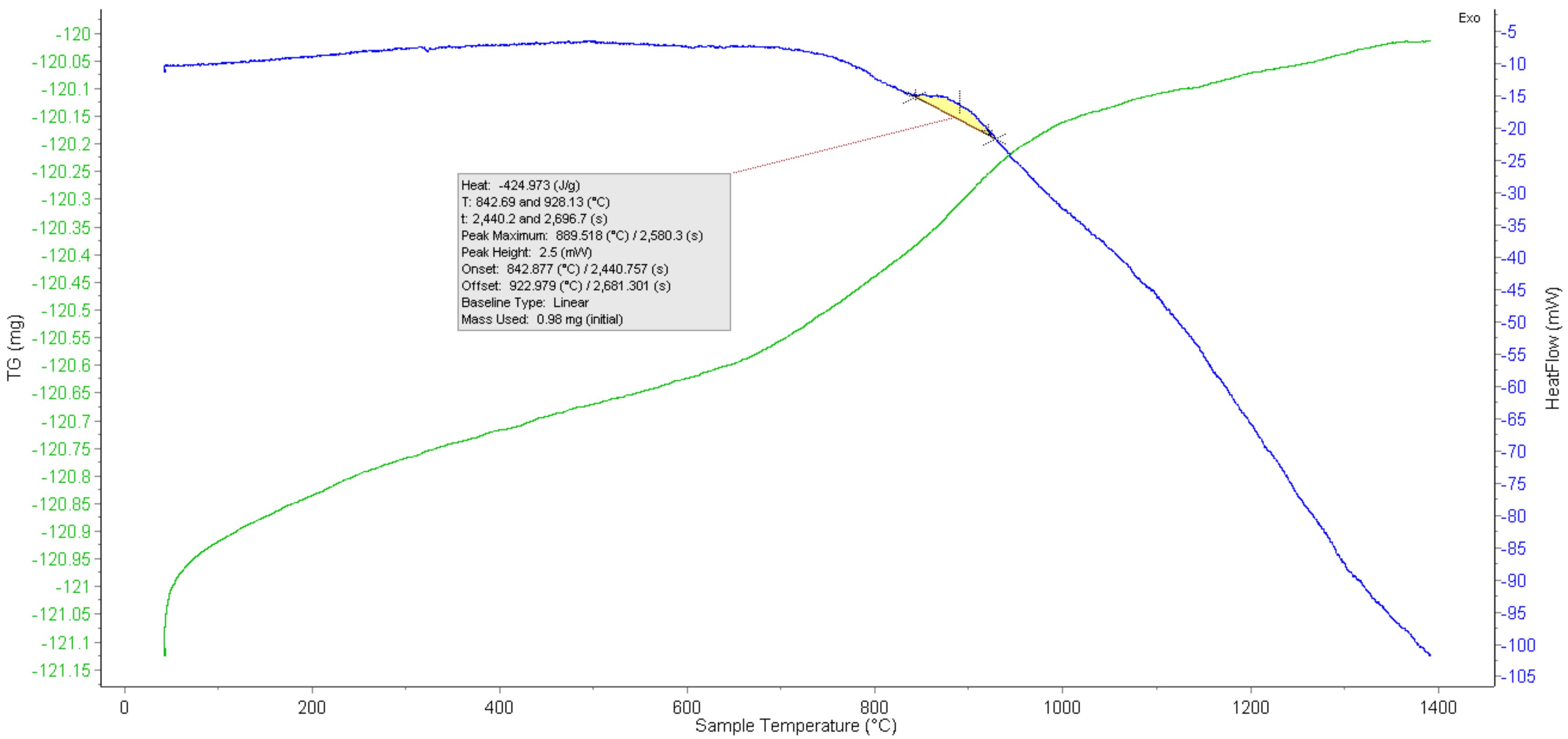


Figure C103: High-Temp DSC Plot for Mix ID SS #55 Trial 1: Fine Ti-WO_3

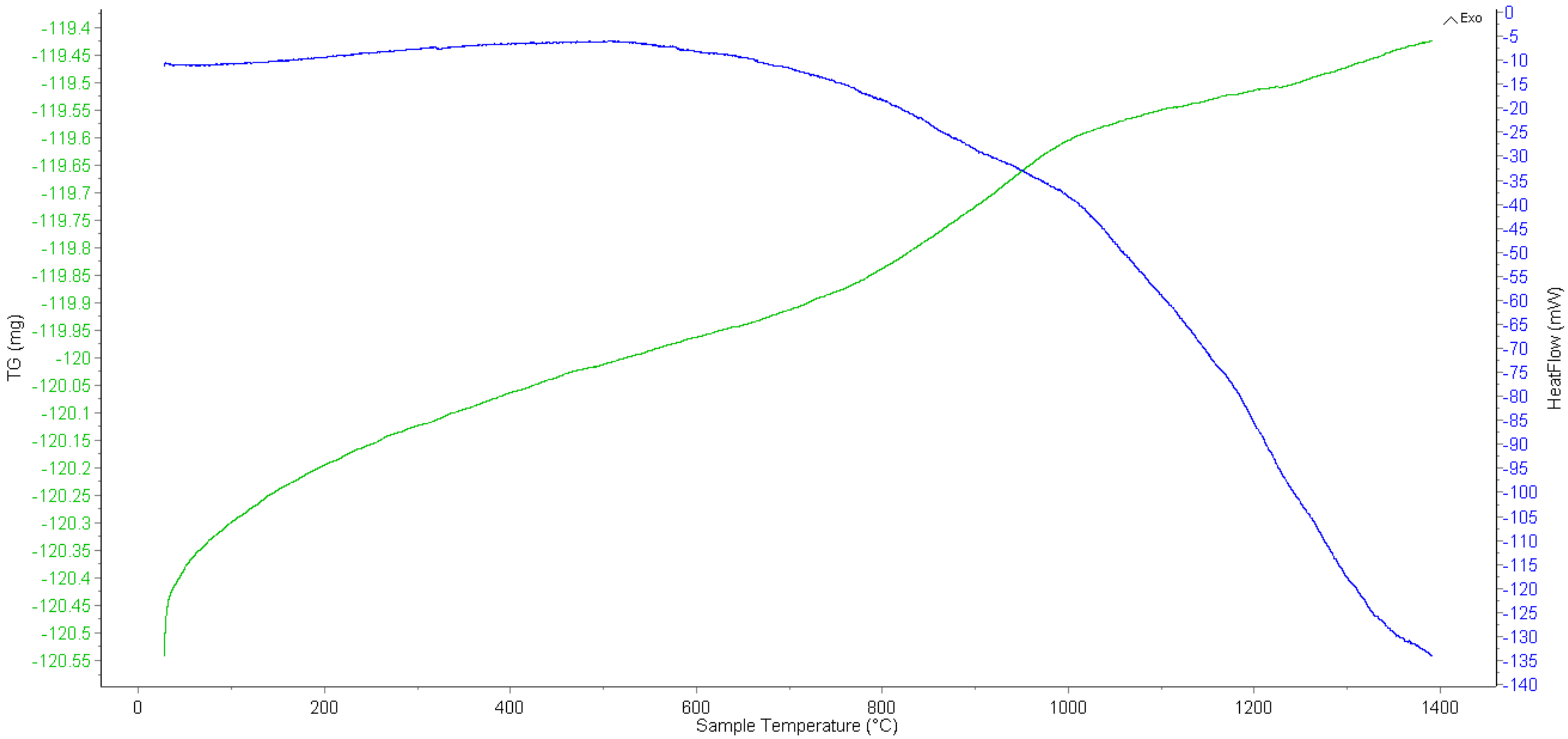


Figure C104: High-Temp DSC Plot for Mix ID SS #55 Trial 2: Fine Ti-WO_3

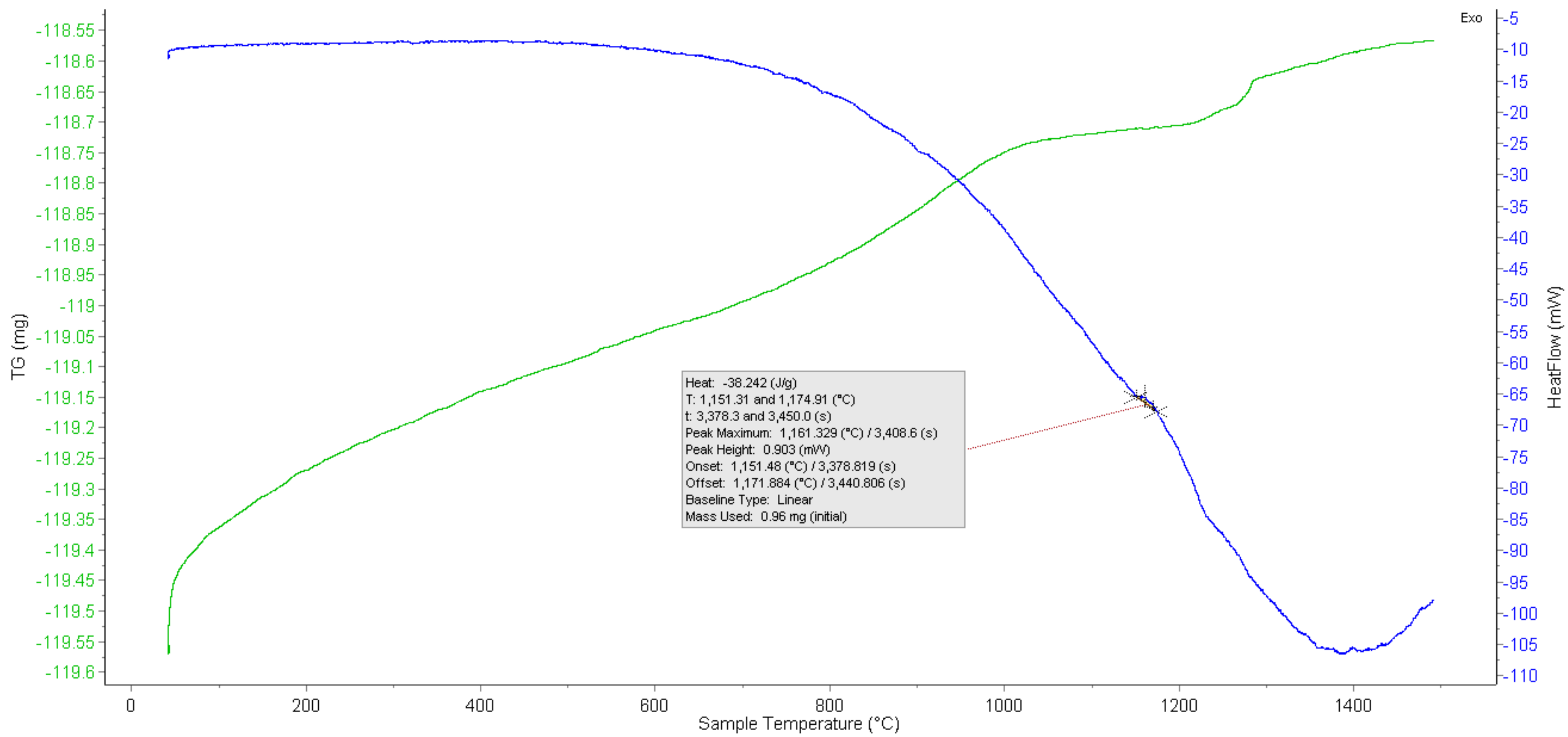


Figure C105: High-Temp DSC Plot for Mix ID SS #56 Trial 1: Fine Mg & Al-MoO_3 & CuO

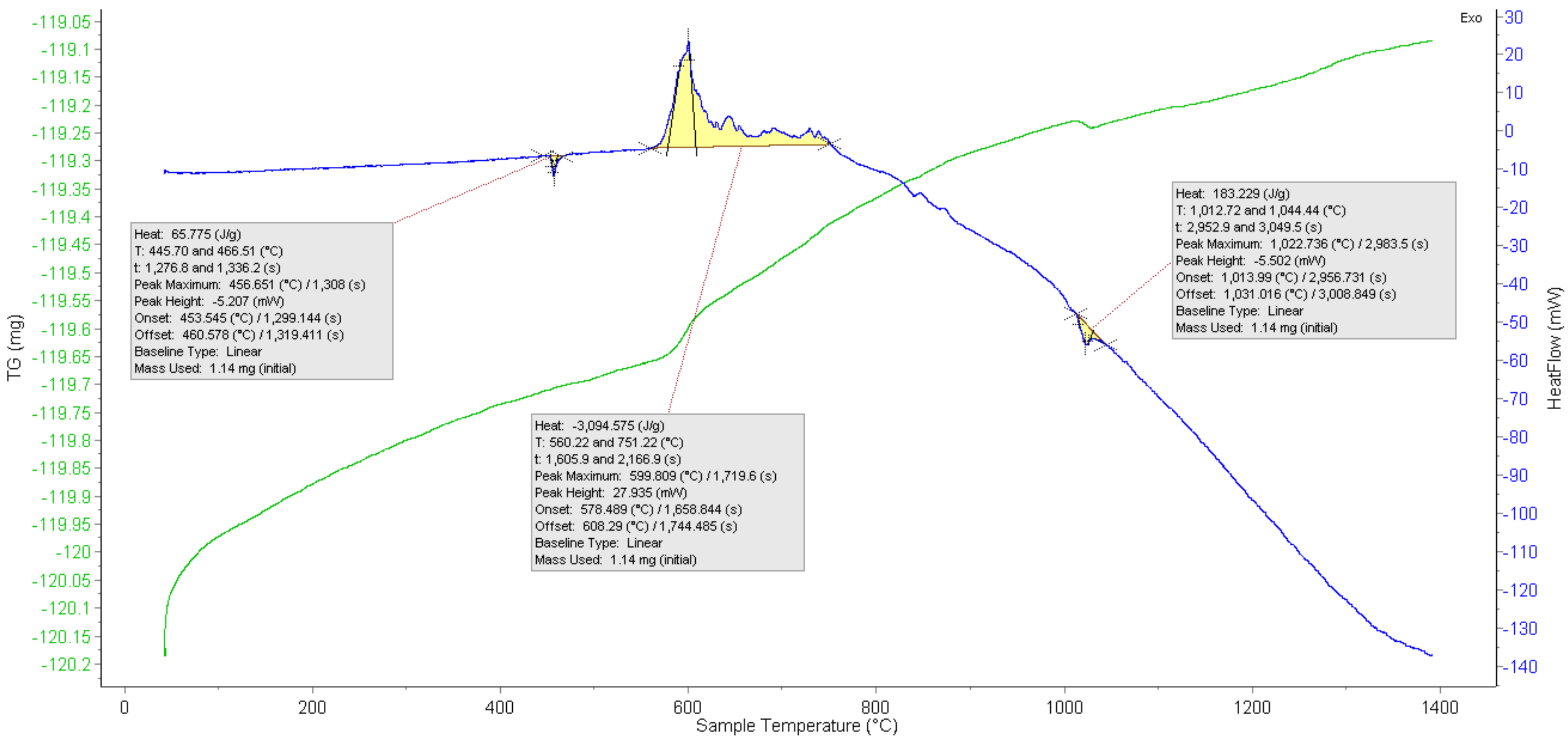
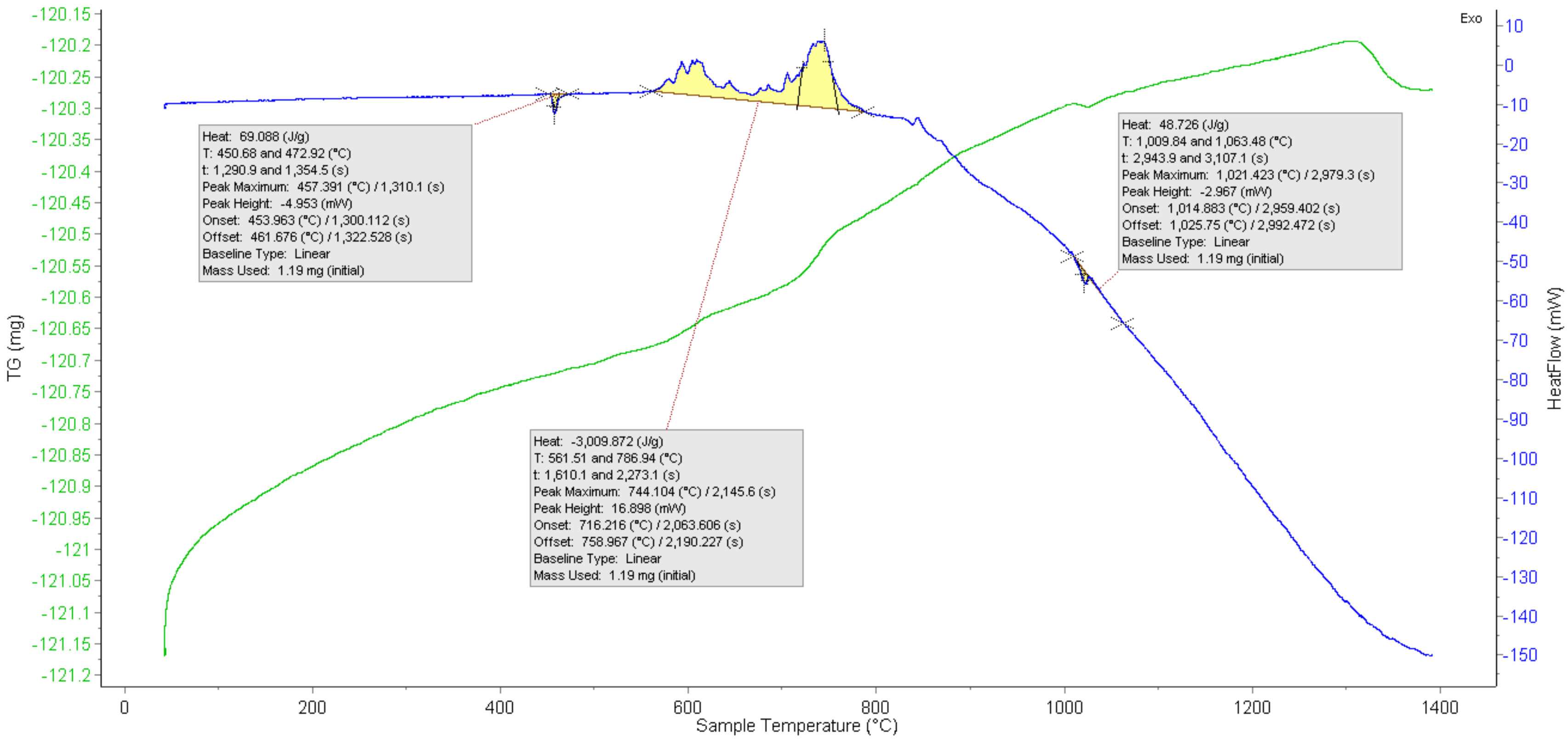


Figure C106: High-Temp DSC Plot for Mix ID SS #56 Trial 2: Fine Mg & Al-MoO3 & CuO



APPENDIX D
– Product Certifications

Figure D1: Product Certification for Al Metal Powder

ATLANTIC EQUIPMENT ENGINEERS
HIGH PURITY METALS AND COMPOUNDS

Certificate of Analysis
ALUMINUM METAL POWDER
AL-100

1.1 General

SOLD TO	PURCHASE ORDER #	SHIP DATE	DOCUMENT NUMBER
SAFETY MANAGEMENT SERVICES for COMMANDER TOOELE ARMY DEPOT	1526	9 MAR 2021	2101018
CATALOG NUMBER	LOT NUMBER	QUANTITY	CAS NUMBER
AL-100	2002510-6	173 LBS	7429-90-5

2.1 Chemical Analysis (in percentage (%) unless otherwise stated)

Al	Ti	Si	Fe
99.9%	<0.06	<0.10	<0.20

3.1 Screen Analysis (percent passing) / Other

Size	D 10	D 50	D 90
1-5 microns	1.6 microns	3.6 microns	9 microns

4.1 Notes

5.1 Statement

Shelf life is indefinite when material is stored in a tightly sealed container in a cool, dry place.

The above analysis is carried out as part of our internal quality control testing and is based upon our analysis methods.

We do not assume any warranty, liability, or risk based on such findings. Our quality is warranted within the scope of our general sales conditions.

Please refer to SDS for material handling instructions.

Very Truly Yours,

M. Gerald, QA

24 Industrial Ave, Upper Saddle River, NJ 07458 Tel: 201.828.9400 Fax: 201.387.0291
On the web at: www.micronmetals.com Email: info@micronmetals.com

Page 1 of 1

Figure D2: Product Certification for Al_2O_3

ATLANTIC EQUIPMENT ENGINEERS
HIGH PURITY METALS AND COMPOUNDS

Certificate of Analysis

ALUMINUM OXIDE, FUSED
AL 604

1.1 General

SOLD TO	PURCHASE ORDER #	SHIP DATE	DOCUMENT NUMBER
SAFETY MANAGEMENT SERVICES for COMMANDER TOOELE ARMY DEPOT	1526	9 MAR 2021	2101018
CATALOG NUMBER	LOT NUMBER	QUANTITY	CAS NUMBER
AL 604	1912511	1 LB	1344 28 1

2.1 Chemical Analysis (in percentage (%) unless otherwise stated)

Al2O3	
99.9%	

3.1 Screen Analysis (percent passing) / Other

Size	Bulk density
-200+325 mesh	1.510 g/cm3

4.1 Notes

5.1 Statement

The above analysis is carried out as part of our internal quality control testing and is based upon our analysis methods.

We do not assume any warranty, liability, or risk based on such findings. Our quality is warranted within the scope of our general sales conditions.

Please refer to SDS for material handling instructions.

Very Truly Yours,

M. Gerald, QA

24 Industrial Ave, Upper Saddle River, NJ 07458 Tel: 201.828.9400 Fax: 201.387.0291
On the web at: www.micronmetals.com Email: info@micronmetals.com

Figure D3: Product Certification for Co_3O_4

ATLANTIC EQUIPMENT ENGINEERS
HIGH PURITY METALS AND COMPOUNDS

Certificate of Analysis
COBALT OXIDE POWDER
CO 601

1.1 General

SOLD TO	PURCHASE ORDER #	SHIP DATE	DOCUMENT NUMBER
SAFETY MANAGEMENT SERVICES for COMMANDER TOOELE ARMY DEPOT	1526	9 MAR 2021	2101018
CATALOG NUMBER	LOT NUMBER	QUANTITY	CAS NUMBER
CO 601	2006516	1 LB	1309-06-1

2.1 Chemical Analysis (in percentage (%) unless otherwise stated)

Co	Ni	Fe	Ca	Cu	Pb
73.09	0.0007	0.0014	0.0029	0.0003	0.0005

3.1 Screen Analysis (percent passing) / Other

Size	D 50
-400 mesh	4.13 microns

4.1 Notes

5.1 Statement

The above analysis is carried out as part of our internal quality control testing and is based upon our analysis methods.

We do not assume any warranty, liability, or risk based on such findings. Our quality is warranted within the scope of our general sales conditions.

Please refer to SDS for material handling instructions.

Very Truly Yours,

M. Gerald, QA

24 Industrial Ave, Upper Saddle River, NJ 07458 Tel: 201.828.9400 Fax: 201.387.0291
On the web at: www.micronmetals.com Email: info@micronmetals.com

Page 1 of 1

Figure D4: Product Certification for Cr_2O_3

ATLANTIC EQUIPMENT ENGINEERS
HIGH PURITY METALS AND COMPOUNDS

Certificate of Analysis

CHROMIUM OXIDE, GREEN
CR-601

1.1 General

SOLD TO	PURCHASE ORDER #	SHIP DATE	DOCUMENT NUMBER
SAFETY MANAGEMENT SERVICES for COMMANDER TOOELE ARMY DEPOT	1526	9 MAR 2021	2101018
CATALOG NUMBER	LOT NUMBER	QUANTITY	CAS NUMBER
CR-601	2011518	1 LB	1308-38-9

2.1 Chemical Analysis (in percentage (%) unless otherwise stated)

Cr2O3	Water Soluble Substances	Moisture	pH
99.6% min	0.38	0.06	5.0

3.1 Screen Analysis (percent passing) / Other

Size	
1-5 microns	

4.1 Notes

5.1 Statement

The above analysis is carried out as part of our internal quality control testing and is based upon our analysis methods.

We do not assume any warranty, liability, or risk based on such findings. Our quality is warranted within the scope of our general sales conditions.

Please refer to SDS for material handling instructions.

Very Truly Yours,

M. Gerald, QA

24 Industrial Ave, Upper Saddle River, NJ 07458 Tel: 201.828.9400 Fax: 201.387.0291
On the web at: www.micronmetals.com Email: info@micronmetals.com

Page 1 of 1

Figure D5: Product Certification for CuO

ATLANTIC EQUIPMENT ENGINEERS
HIGH PURITY METALS AND COMPOUNDS

Certificate of Analysis
CUPRIC OXIDE
CU-602

1.1 General

SOLD TO	PURCHASE ORDER #	SHIP DATE	DOCUMENT NUMBER
SAFETY MANAGEMENT SERVICES for COMMANDER TOOELE ARMY DEPOT	1526	9 MAR 2021	2101018
CATALOG NUMBER	LOT NUMBER	QUANTITY	CAS NUMBER
CU-602	2102518	548 LBS	1317-38-0

2.1 Chemical Analysis (in percentage (%) unless otherwise stated)

Cu	CuO	Cu2O	Zn	Fe	Ca	Mg
75	94	3	0.3	0.02	0.01	0.002
Mn	Pb	Cd	As	Sb	Moisture	
0.001	0.05	0.01	0.01	0.01	0.2	

3.1 Screen Analysis (percent passing) / Other

Size	Specific Gravity	-325 mesh	Loose Bulk Density
1-5 microns	6.7 g/cc	99.9	80 lbs / ft³

4.1 Notes

5.1 Statement

The above analysis is carried out as part of our internal quality control testing and is based upon our analysis methods.

We do not assume any warranty, liability, or risk based on such findings. Our quality is warranted within the scope of our general sales conditions.

Please refer to SDS for material handling instructions.

Very Truly Yours,

M. Gerald, QA

24 Industrial Ave, Upper Saddle River, NJ 07458 Tel: 201.828.9400 Fax: 201.387.0291
On the web at: www.micronmetals.com Email: info@micronmetals.com

Page 1 of 1

Figure D6: Product Certification for Fe_2O_3

ATLANTIC EQUIPMENT ENGINEERS
HIGH PURITY METALS AND COMPOUNDS

Certificate of Analysis
RED IRON OXIDE POWDER
FE-601

1.1 General

SOLD TO	PURCHASE ORDER #	SHIP DATE	DOCUMENT NUMBER
SAFETY MANAGEMENT SERVICES for COMMANDER TOOELE ARMY DEPOT	1526	9 MAR 2021	2101018
CATALOG NUMBER	LOT NUMBER	QUANTITY	CAS NUMBER
FE-601	2102517-RD	282 LBS	1309-37-1

2.1 Chemical Analysis (in percentage (%) unless otherwise stated)

Tint strength	Moisture	Water soluble
100.4	0.60	0.10
Fe2O3	pH	
99 min	6.1	

3.1 Screen Analysis (percent passing) / Other

Size	+325 mesh
1-5 microns	0.012

4.1 Notes

5.1 Statement

The above analysis is carried out as part of our internal quality control testing and is based upon our analysis methods.

We do not assume any warranty, liability, or risk based on such findings. Our quality is warranted within the scope of our general sales conditions.

Please refer to SDS for material handling instructions.

Very Truly Yours,

M. Gerald, QA

24 Industrial Ave, Upper Saddle River, NJ 07458 Tel: 201.828.9400 Fax: 201.387.0291
On the web at: www.micronmetals.com Email: info@micronmetals.com

Figure D7: Product Certification for Fe_3O_4

ATLANTIC EQUIPMENT ENGINEERS
HIGH PURITY METALS AND COMPOUNDS

Certificate of Analysis
BLACK IRON OXIDE
FE-602

1.1 General

SOLD TO	PURCHASE ORDER #	SHIP DATE	DOCUMENT NUMBER
SAFETY MANAGEMENT SERVICES for COMMANDER TOOELE ARMY DEPOT	1526	9 MAR 2021	2101018
CATALOG NUMBER	LOT NUMBER	QUANTITY	CAS NUMBER
FE-602	2009517	1 LB	1317-61-6

2.1 Chemical Analysis (in percentage (%) unless otherwise stated)

Tint Strength	pH	FeO	Moisture
97.6	8.91	23.4	0.39
Water soluble Salts		Fe2O3	
0.18		99.9	

3.1 Screen Analysis (percent passing) / Other

Size	+325 mesh
1-5 microns	0.009

4.1 Notes

Very fine, black powder, manufactured in the USA.

5.1 Statement

The above analysis is carried out as part of our internal quality control testing and is based upon our analysis methods.

We do not assume any warranty, liability, or risk based on such findings. Our quality is warranted within the scope of our general sales conditions.

Please refer to SDS for material handling instructions.

Very Truly Yours,

M. Gerald, QA

24 Industrial Ave, Upper Saddle River, NJ 07458 Tel: 201.828.9400 Fax: 201.387.0291
On the web at: www.micronmetals.com Email: info@micronmetals.com

Figure D8: Product Certification for Sb_2O_3

ATLANTIC EQUIPMENT ENGINEERS
HIGH PURITY METALS AND COMPOUNDS

Certificate of Analysis

Antimony Trioxide Powder
AN 601

1.1 General

SOLD TO	PURCHASE ORDER #	SHIP DATE	DOCUMENT NUMBER
SAFETY MANAGEMENT SERVICES for COMMANDER TOOELE ARMY DEPOT	1526	9 MAR 2021	2101018
CATALOG NUMBER	LOT NUMBER	QUANTITY	CAS NUMBER
AN 601	1605516	1 LB	1309 64 4

2.1 Chemical Analysis (in percentage (%) unless otherwise stated)

Sb2O3	As	Pb	Fe	Free Moisture
99.81	0.03	0.03	0.001	<0.10

3.1 Screen Analysis (percent passing) / Other

Size	APS
1-5 microns	1.06 microns

4.1 Notes

5.1 Statement

The above analysis is carried out as part of our internal quality control testing and is based upon our analysis methods.

We do not assume any warranty, liability, or risk based on such findings. Our quality is warranted within the scope of our general sales conditions.

Please refer to SDS for material handling instructions.

Very Truly Yours,

M. Gerald, QA

24 Industrial Ave, Upper Saddle River, NJ 07458 Tel: 201.828.9400 Fax: 201.387.0291
On the web at: www.micronmetals.com Email: info@micronmetals.com

Page 1 of 1

Figure D9: Product Certification for SnO

ATLANTIC EQUIPMENT ENGINEERS
HIGH PURITY METALS AND COMPOUNDS

24 Industrial Avenue, P.O. Box 181, Upper Saddle River, NJ 07458
TEL: (201) 828-9400 • FAX: (201) 387-0291

Certificate of Analysis

SOLD TO:	SAFETY MANAGEMENT SERVICES for COMMANDER TOOELE ARMY DEPOT
CUSTOMER PO:	1526
SHIP DATE:	9 MAR 2021
CATALOG NUMBER:	SN-610
LOT #:	1703541
ITEM NAME:	STANNOUS OXIDE, BLACK TIN OXIDE, SnO
CAS NUMBER:	21651-19-4
DOCUMENT:	2101018
QUANTITY:	2 LBS

CHEMICAL ANALYSIS

STANNOUS TIN	86.8
COLOR	BLUE BLACK POWDER
APPEARANCE	FREE FLOWING
SPECIFIC GRAVITY:	6.50

SCREEN ANALYSIS

Average Particle Size: -100 MESH

The above analysis is carried out as part of our internal quality control testing and is based upon our analysis methods.

We do not assume any warranty, liability, or risk based on such findings. Our quality is warranted within the scope of our general sales conditions.

Very Truly Yours,

M. GERALD, QA

Figure D10: Product Certification for Ti Metal Powder

ATLANTIC EQUIPMENT ENGINEERS
HIGH PURITY METALS AND COMPOUNDS

Certificate of Analysis

TITANIUM METAL POWDER
TI 101

1.1 General

SOLD TO	PURCHASE ORDER #	SHIP DATE	DOCUMENT NUMBER
SAFETY MANAGEMENT SERVICES for COMMANDER TOOELE ARMY DEPOT	1526	9 MAR 2021	2101018
CATALOG NUMBER	LOT NUMBER	QUANTITY	CAS NUMBER
TI 101	2012519	7 LBS	7440-32-6

2.1 Chemical Analysis (in percentage (%) unless otherwise stated)

Al	Cl	Cr	Fe	H	Mg	Mn
0.007	<0.025	0.004	0.028	0.51	<0.010	<0.005
Mo	Zr	Na	Ni	O	P	Pb & Cd
<0.005	<0.01	<0.001	0.006	0.91	<0.010	<0.002
Si	Sn	V	Ti			
0.007	<0.010	<0.005	99.8% min			

3.1 Screen Analysis (percent passing) / Other

Size	
< 20 microns	

4.1 Notes
99.8% min metals basis

5.1 Statement

The above analysis is carried out as part of our internal quality control testing and is based upon our analysis methods.

We do not assume any warranty, liability, or risk based on such findings. Our quality is warranted within the scope of our general sales conditions.

Please refer to SDS for material handling instructions.

Very Truly Yours,

M. Gerald, QA

24 Industrial Ave, Upper Saddle River, NJ 07458 Tel: 201.828.9400 Fax: 201.387.0291
On the web at: www.micronmetals.com Email: info@micronmetals.com

Page 1 of 1

Figure D11: Product Certification for WO_3

ATLANTIC EQUIPMENT ENGINEERS
HIGH PURITY METALS AND COMPOUNDS

Certificate of Analysis

TUNGSTEN TRIOXIDE POWDER
WP-602

1.1 General

SOLD TO	PURCHASE ORDER #	SHIP DATE	DOCUMENT NUMBER
SAFETY MANAGEMENT SERVICES for COMMANDER TOOELE ARMY DEPOT	1526	9 MAR 2021	2101018
CATALOG NUMBER	LOT NUMBER	QUANTITY	CAS NUMBER
WP-602	1710527	1 LB	1314-35-8

2.1 Chemical Analysis (in percentage (%) unless otherwise stated)

Al	As	B	Ca	Cd	Co	Cr
<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cu	Fe	K	Mg	Mn	Mo	Na
<0.001	0.003	<0.001	<0.001	<0.001	<0.001	<0.001
Ni	P	Pb	Sb	Si	Sn	Ta
<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ti	V	Zn	WO3			
<0.001	<0.001	<0.001	99.99			

3.1 Screen Analysis (percent passing) / Other

Size	FSSS
-325 mesh	25.20 microns

4.1 Notes

5.1 Statement

The above analysis is carried out as part of our internal quality control testing and is based upon our analysis methods.

We do not assume any warranty, liability, or risk based on such findings. Our quality is warranted within the scope of our general sales conditions.

Please refer to SDS for material handling instructions.

Very Truly Yours,

M. Gerald, QA

24 Industrial Ave, Upper Saddle River, NJ 07458 Tel: 201.828.9400 Fax: 201.828.9414
On the web at: www.micronmetals.com Email: info@micronmetals.com

Page 1 of 1

Figure D12: Product Certification for ZnO_2

ATLANTIC EQUIPMENT ENGINEERS
HIGH PURITY METALS AND COMPOUNDS

Certificate of Analysis
ZINC OXIDE POWDER
ZN-601

1.1 General

SOLD TO	PURCHASE ORDER #	SHIP DATE	DOCUMENT NUMBER
SAFETY MANAGEMENT SERVICES for COMMANDER TOOELE ARMY DEPOT	1526	9 MAR 2021	2101018
CATALOG NUMBER	LOT NUMBER	QUANTITY	CAS NUMBER
ZN-601	1906513	1 LB	1314-13-2

2.1 Chemical Analysis (in percentage (%) unless otherwise stated)

Pb	Cd	Fe	As	LOI
0.0015	0.0001	0.0002	<0.0001	0.19

3.1 Screen Analysis (percent passing) / Other

Size	-325 mesh	Surface area
1-5 microns	99.9997	5.34 m^2/g

4.1 Notes

5.1 Statement

The above analysis is carried out as part of our internal quality control testing and is based upon our analysis methods.

We do not assume any warranty, liability, or risk based on such findings. Our quality is warranted within the scope of our general sales conditions.

Please refer to SDS for material handling instructions.

Very Truly Yours,

M. Gerald, QA

24 Industrial Ave, Upper Saddle River, NJ 07458 Tel: 201.828.9400 Fax: 201.387.0291
On the web at: www.micronmetals.com Email: info@micronmetals.com

Figure D13: Product Certification for MnO_2

AMERICAN ELEMENTS

World's Leading Manufacturer of Rare Earth and Advanced Material Products

A MERELEX CORPORATION • 10884 WEYBURN AVE. LOS ANGELES, CA 90024
TEL. 310-208-0551 • FAX 310-208-0351 • E-MAIL: customerservice@americanelements.com

CERTIFICATE OF COMPLIANCE

99+% (metals basis) Manganese Oxide Powder

MnO2

Product Code: MN-OX-021M-P.5UM

CAS #: 1313-13-9

LOT #: 1441516447-410

American Elements certifies that the materials listed below and shipped on 4/8/2021 meets the purity and dimensional requirements set forth in SMS Energetics, Inc. purchase order: DOT1-6265D.

99+% (metals basis) Manganese Oxide Powder
MnO2
APS: 5 um

AMERICAN ELEMENTS

By

AEC FORM 102CA REV. APP. 2/3/99

Figure D14: Product Certification for Ni_2O_3

AMERICAN ELEMENTS

World's Leading Manufacturer of Rare Earth and Advanced Material Products

A MERELEX CORPORATION • 10884 WEYBURN AVE. LOS ANGELES, CA 90024
TEL. 310-208-0551 • FAX 310-208-0351 • E-MAIL: customerservice@americanelements.com

CERTIFICATE OF COMPLIANCE

99+% (metals basis) Nickel Oxide Powder

Ni2O3

Product Code: NI-OX-021M-P.5UM

CAS #: 1314-06-3

LOT #: 1471516447-407

American Elements certifies that the materials listed below and shipped on 4/8/2021 meets the purity and dimensional requirements set forth in SMS Energetics, Inc. purchase order: DOT1-6265D.

99+% (metals basis) Nickel Oxide Powder
Ni2O3
APS: 5 um

AMERICAN ELEMENTS

By

AEC FORM 102:CA REV. APP. 2/3/99

Figure D15: Product Certification for Bi_2O_3

SANTECH Changsha Santech Materials Co.,Ltd.
长沙盛特新材料有限公司

Address: B-22 Bldg, Jinke Yida Industry Creation Town, No. 77 of East Sixth Road, Economic Development Zone, Changsha, Hunan, 410001, China

地　址：中国湖南省长沙市经济技术开发区东六路 77 号长沙科技新城 B22 栋 Web: www.santechchem.com

Certificate of Analysis / 产品质检单

Customer(客户): ____________________ Analyst(检验员): ____________________

Item 项目	Purity 纯度	Specs 规格	Total 批量	Lot NO. 批号	Structure 结构
Bi2O3	99.9% up	Powder	100 KGS	CS200512	Tetragonal crystal structure(α type)

Chemical Composition 化学成分（max %）

Element 元素	Test Result 实测值	Element 元素	Test Result 实测值	Element 元素	Test Result 实测值
Li	0.0001%	Si	0.0001%	Ni	0.0001%
Na	0.0001%	As	0.0001%	Cu	0.0001%
K	0.0001%	Cd	0.0001%	Pb	0.0003%
Ca	0.0002%	Fe	0.0003%	Ag	0.0003%
Mg	0.0003%	Sn	0.0001%	Sb	0.0001%
Al	0.0005%	Cr	0.0001%		

氯化物 Chloride Radical	0.0006%
硫酸根 Sulfate Radical	0.0008%
烧失量 Loss on Ignition	0.2%
硝酸不溶物 Insoluble Matter in Nitric Acid	0.0044%

Conclusion of Analysis(检验结论): Product's purity is 99.9% 产品纯度为 99.9%

产品检验章

Figure D16: Product Certification for B_2O_3

SIGMA-ALDRICH

3050 Spruce Street, Saint Louis, MO 63103 USA
Email USA: techserv@sial.com Outside USA: eurtechserv@sial.com

Certificate of Analysis

Product Name:	BORIC ANHYDRIDE granulated, >= 98.0 % T
Product Number:	11615
Batch Number:	BCCB3599
Brand:	Sigma-Aldrich
CAS Number:	1303-86-2
Formula:	B_2O_3
Formula Weight:	69.62
Quality Release Date:	02 APR 2019
Recommended Retest Date:	DEC 2022

TEST	SPECIFICATION	RESULT
APPEARANCE (COLOR)	COLORLESS OR WHITE	WHITE
APPEARANCE (FORM)	POWDER OR CRYSTALS	CRYSTALS
TITRATION (T) NAOH 1M	98.0 - 102.0 %	98.8 %
LOSS ON IGNITION	≤ 3.0 %	0.8900000 %
METAL TRACE ANALYSIS (ICP)	CORRESPONDS TO REQUIREMENTS	PASSED
IRON (ICP)	≤ 300 MG/KG	< 300 MG/KG

Dr. R. Schwenninger

Dr. Reinhold Schwenninger
Quality Assurance
Buchs, Switzerland

Figure D17: Product Certification for CrO_3

Sigma-Aldrich.

3050 Spruce Street, Saint Louis, MO 63103, USA
Website: www.sigmaaldrich.com
Email USA: techserv@sial.com
Outside USA: eurtechserv@sial.com

Certificate of Analysis

Product Name:
Chromium(VI) oxide - ReagentPlus®, 99.9% trace metals basis

CrO_3

Product Number:	**232653**
Batch Number:	**MKCM7142**
Brand:	SIGALD
CAS Number:	1333-82-0
MDL Number:	MFCD00010952
Formula:	CrO3
Formula Weight:	99.99 g/mol
Quality Release Date:	30 JUN 2020

Test	Specification	Result
Appearance (Color)	Red to Purple	Dark Red
Appearance (Form)	Powder or Flakes	Flakes
Titration by Na2S2O3 % Chromium	51.2 - 52.7 %	51.6 %
ICP Major Analysis Confirms Chromium Component	Confirmed	Confirmed
Purity 99.9% Based On Trace Metals Analysis	Conforms	Conforms
Trace Metal Analysis	≤ 1500.0 ppm	100.6 ppm
Silver (Ag)		5.4 ppm
Barium (Ba)		0.1 ppm
Bismuth (Bi)		6.7 ppm
Iron (Fe)		9.4 ppm
Magnesium (Mg)		0.7 ppm
Manganese (Mn)		0.1 ppm
Sodium (Na)		59.4 ppm
Titanium (Ti)		1.9 ppm
Vanadium (V)		12.0 ppm
Zinc (Zn)		4.8 ppm

Michael Grady, Manager
Quality Control

Version Number: 1 Page 1 of 2

Figure D18: Product Certification for Cu_2O

SIGMA-ALDRICH

sigma-aldrich.com

3050 Spruce Street, Saint Louis, MO 63103, USA
Website: www.sigmaaldrich.com
Email USA: techserv@sial.com
Outside USA: eurtechserv@sial.com

Certificate of Analysis

Product Name:
Copper(I) oxide – powder, ≤7 µm, 97%

Product Number:	208825
Batch Number:	MKCK4597
Brand:	SIGALD
CAS Number:	1317-39-1
MDL Number:	MFCD00010974
Formula:	Cu2O
Formula Weight:	143.09 g/mol
Quality Release Date:	02 JUL 2019

Cu_2O

Test	Specification	Result
Appearance (Color)	Red to Brown	Brown-Red
Appearance (Form)	Powder	Powder
X-Ray Diffraction	Conforms to Structure	Conforms
Complexometric EDTA % Cu	85.6 - 91.8 %	87.0 %
Size	≤ 7.00 micron	3.92 micron

Michael Grady, Manager
Quality Control
Milwaukee, WI US

Sigma-Aldrich warrants, that at the time of the quality release or subsequent retest date this product conformed to the information contained in this publication. The current Specification sheet may be available at Sigma-Aldrich.com. For further inquiries, please contact Technical Service. Purchaser must determine the suitability of the product for its particular use. See reverse side of invoice or packing slip for additional terms and conditions of sale.

Version Number: 1

Page 1 of 1

Figure D19: Product Certification for Mg Metal Powder

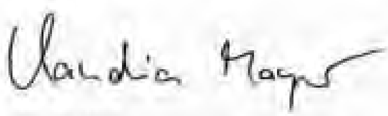
SIGMA-ALDRICH

3050 Spruce Street, Saint Louis, MO 63103, USA
Email USA: techserv@sial.com Outside USA: eurtechserv@sial.com

Certificate of Analysis

Product Name:	MAGNESIUM powder, >= 99 %
Product Number:	13112
Batch Number:	STBH6715
Brand:	Aldrich
CAS Number:	7439-95-4
Formula:	Mg
Formula Weight:	24.31
Quality Release Date:	09 JUL 2018
Recommended Retest Date:	DEC 2021

TEST	SPECIFICATION	RESULT
APPEARANCE (COLOR)	WHITE TO GREY	LIGHT GREY
APPEARANCE (FORM)	POWDER	POWDER
ASSAY	≥ 99 %	100.7 %
INSOLUBLE MATTER	≤ 0.05 % (INSOLUBLE IN HCL)	< 0.05 %
IRON	≤ 0.05 %	< 0.05 %



Claudia Mayer
Manager Quality Control
Steinheim, Germany

Figure D20: Product Certification for Mn_2O_3

9/29/21, 2:09 PM Sigma-Aldrich

MilliporeSigma

Type in Product Names, Product Numbers, or CAS Numbers to see suggestions.

Certificate of Analysis

Sigma-Aldrich

Product Name:	Manganese(III) oxide
Product Description:	-325 mesh, 99%
Product Brand:	Sigma-Aldrich
Product Number:	377457
Molecular Weight:	157.87
Molecular Formula:	Mn_2O_3
CAS Number:	1317-34-6

TEST	SPECIFICATION	LOT MKBB4082 RESULTS
Appearance (Color):	Black	Black
Appearance (Form):	Powder	Powder
Titration by KMNO4: % Mn:	68.6 - 70.6 %	69.9 %
X-Ray Diffraction:	Conforms to Structure	Conforms
Size: -325 Mesh:	Conforms	Conforms
Specification Date::		MAY 2009

Barbara Rajzer, Supervisor
Quality Control
Milwaukee, Wisconsin USA

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https://www.sigmaaldrich.com/US/en/coa/ALDRICH/377457/MKBB4082 1/2

Figure D21: Product Certification for MnO

SIGMA-ALDRICH

sigma-aldrich.com

3050 Spruce Street, Saint Louis, MO 63103, USA
Website: www.sigmaaldrich.com
Email USA: techserv@sial.com
Outside USA: eurtechserv@sial.com

Certificate of Analysis

Product Name:
Manganese(II) oxide - powder, -60 mesh, 99%

Product Number:	377201
Batch Number:	MKCL5330
Brand:	ALDRICH
CAS Number:	1344-43-0
MDL Number:	MFCD00016226
Formula:	MnO
Formula Weight:	70.94 g/mol
Quality Release Date:	16 DEC 2019

MnO

Test	Specification	Result
Appearance (Color) Green	Conforms to Requirements	Green
Appearance (Form)	Powder	Powder
Complexometric EDTA % Mn	76.2 - 78.6 %	77.0 %
X-Ray Diffraction	Conforms to Structure	Conforms
Size -60 Mesh	Conforms	Conforms

Michael Grady, Manager
Quality Control
Milwaukee, WI US

Sigma-Aldrich warrants, that at the time of the quality release or subsequent retest date this product conformed to the information contained in this publication. The current Specification sheet may be available at Sigma-Aldrich.com. For further inquiries, please contact Technical Service. Purchaser must determine the suitability of the product for its particular use. See reverse side of invoice or packing slip for additional terms and conditions of sale.

Version Number: 1 Page 1 of 1

Figure D22: Product Certification for NiO

Sigma-Aldrich.

3050 Spruce Street, Saint Louis, MO 63103, USA
Website: www.sigmaaldrich.com
Email USA: techserv@sial.com
Outside USA: eurtechserv@sial.com

Certificate of Analysis

Product Name:
Nickel(II) oxide - green, −325 mesh, 99%

Product Number:	399523
Batch Number:	MKCN2758
Brand:	ALDRICH
CAS Number:	1313-99-1
MDL Number:	MFCD00011145
Formula:	NiO
Formula Weight:	74.69 g/mol
Quality Release Date:	11 DEC 2020

NiO

Test	Specification	Result
Appearance (Color)	Green to Very Dark Green and Green-Brown and Brown-Green	Green
Appearance (Form)	Powder	Powder
X-Ray Diffraction	Conforms to Structure	Conforms
Nickel	77.4 - 79.8 %	77.9 %
Particle Size -325 Mesh	Confirmed	Confirmed

Michael Grady, Manager
Quality Control
Milwaukee, WI US

Version Number: 1 Page 1 of 1

Figure D23: Product Certification for SiO_2

SIGMA-ALDRICH

sigma-aldrich.com

3050 Spruce Street, Saint Louis, MO 63103, USA
Website: www.sigmaaldrich.com
Email USA: techserv@sial.com
Outside USA: eurtechserv@sial.com

Certificate of Analysis

Product Name:
Diatomaceous earth - powder, suitable for most filtrations

SiO_2

Product Number: D3877
Batch Number: SLCF8512
Brand: SIGALD
CAS Number: 91053-39-3
MDL Number: MFCD00132803
Formula Weight: 1,495 g/mol
Quality Release Date: 12 MAR 2020
Recommended Retest Date: MAR 2025

Test	Specification	Result
Appearance (Color)	Faint Brown to Light Brown to Light Orange	Light Brown-Orange
Appearance (Form)	Powder	Powder

Brian Dulle, Supervisor
Quality Assurance
St. Louis, Missouri US

Sigma-Aldrich warrants, that at the time of the quality release or subsequent retest date this product conformed to the information contained in this publication. The current Specification sheet may be available at Sigma-Aldrich.com. For further inquiries, please contact Technical Service. Purchaser must determine the suitability of the product for its particular use. See reverse side of invoice or packing slip for additional terms and conditions of sale.

Version Number: 1

Page 1 of 1

Figure D24: Product Certification for SnO_2

SIGMA-ALDRICH

sigma-aldrich.com

3050 Spruce Street, Saint Louis, MO 63103, USA
Website: www.sigmaaldrich.com
Email USA: techserv@sial.com
Outside USA: eurtechserv@sial.com

Certificate of Analysis

Product Name:
Tin(IV) oxide - -325 mesh, 99.9% trace metals basis

SnO_2

Product Number:	**244651**
Batch Number:	**MKBX0592V**
Brand:	ALDRICH
CAS Number:	18282-10-5
MDL Number:	MFCD00011244
Formula:	O2Sn
Formula Weight:	150.71 g/mol
Quality Release Date:	16 DEC 2015

Test	Specification	Result
Appearance (Color) Off-White to Grey	Conforms to Requirements	Light Grey
Appearance (Form)	Powder	Powder
X-Ray Diffraction	Conforms to Structure	Conforms
Loss on Ignition 1 Hour at 1000 Degrees Celsius	≤ 0.5 %	0.1 %
ICP Major Analysis Confirms Tin Component	Confirmed	Conforms
Purity 99.9% Based On Trace Metals Analysis	Conforms	Conforms
Trace Metal Analysis	≤ 1000.0 ppm	579.0 ppm
Silver (Ag)		9.0 ppm
Aluminum (Al)		4.4 ppm
Arsenic (As)		4.5 ppm
Bismuth (Bi)		16.0 ppm
Calcium (Ca)		35.0 ppm
Chromium (Cr)		2.2 ppm
Copper (Cu)		15.0 ppm
Iron (Fe)		120.0 ppm
Potassium (K)		2.0 ppm
Magnesium (Mg)		24.0 ppm
Manganese (Mn)		0.7 ppm
Sodium (Na)		11.0 ppm
Nickel (Ni)		1.9 ppm

Sigma-Aldrich warrants, that at the time of the quality release or subsequent retest date this product conformed to the information contained in this publication. The current Specification sheet may be available at Sigma-Aldrich.com. For further inquiries, please contact Technical Service. Purchaser must determine the suitability of the product for its particular use. See reverse side of invoice or packing slip for additional terms and conditions of sale.

Version Number: 1 Page 1 of 2

Figure D25: Product Certification for ZrO_2

SIGMA-ALDRICH

3050 Spruce Street, Saint Louis, MO 63103 USA
Email USA: techserv@sial.com Outside USA: eurtechserv@sial.com

Certificate of Analysis

Product Name:	Zirconium(IV) oxide powder, 5μm, 99 % trace metals
Product Number:	230693
Batch Number:	BCCC2320
Brand:	Aldrich
CAS Number:	1314-23-4
Formula:	ZrO_2
Formula Weight:	123.22
Quality Release Date:	16 OCT 2019

TEST	SPECIFICATION	RESULT
APPEARANCE (COLOR)	WHITE	WHITE
APPEARANCE (FORM)	POWDER	POWDER
PARTICLE SIZE	< 5 MICRON AVERAGE PARTICLE SIZE	0.60 MICRON AVERAGE PARTICLE SIZE
LOSS ON IGNITION	≤ 1.5 %	0.2 %
ICP ANALYSIS	CONFIRMS ZIRCONIUM COMPONENT	CORRESPONDS
METAL TRACE ANALYSIS (ICP)	≥ 99 % AS DEFINED BY DETERMINATION OF TRACE METALLIC IMPURITIES	> 99 % AS DEFINED BY DETERMINATION OF TRACE METALLIC IMPURITIES
VARIOUS GUARANTEE LABEL TRACES (ICP-OES)	≤ 2.0 % HAFNIUM	1.7 % HAFNIUM

Dr. Reinhold Schwenninger
Quality Assurance
Buchs, Switzerland

Figure D26: Product Certification for MoO_3

STANFORD
ADVANCED MATERIALS

Stanford Advanced Materials
23661 Birtcher Dr. Lake Forest, CA 92630, USA
Tel: (949) 407-8904 Fax: (949) 812-6690

Certificate of Analysis

Product Name:	Molybdenum Trioxide (MoO3) Powder
Purity:	≥99.5%
Particle Size:	-325mesh
Lot Number:	OC210201-12629-1
Date:	2/1/21

Purity (wt%)	99.5
C (wt%)	0.05
H (wt%)	0.02
O (wt%)	0.01
N (wt%)	0.01
Mg (wt%)	0.01
Al (wt%)	0.01
Si (wt%)	0.02
Ca (wt%)	0.01
Ti (wt%)	0.01
Fe (wt%)	0.08
Ni (wt%)	0.01
Cu (wt%)	0.02
Sn (wt%)	0.01
W (wt%)	0.03
Pb (wt%)	0.01

Stanford Advanced Materials

TEST REPORT

Sensitivity of Fine, Medium, and Coarse Exploding Thermite Iterations

DOT Contract # 693JK320C000005

U.S. Department of Transportation
Pipeline and Hazardous Materials Safety Administration
(PHMSA)

Attention: PHH-20
Hazardous Materials Technology
1200 New Jersey Avenue, SE
E21-317
Washington, DC 20590

Troy A. Gardner, PE, CSP
Jackson Zarbock

February 17, 2022
SMS-6265c-R1, Rev 0

1847 West 9000 South, Suite 205 • West Jordan, Utah 84088 • 801-567-0456 • www.smsenergetics.com

Test Report

Sensitivity of Fine, Medium, and Coarse Exploding Thermite Iterations

February 17, 2022
SMS-6265c-R1, Rev 0

Troy A. Gardner, PE, CSP
Testing & Classifications Manager
Safety Management Services, Inc.

Jackson D. Zarbock
Project Engineer

TABLE OF CONTENTS

TABLES

FIGURES

PHOTOS

1.0 STATEMENT OF WORK

DOT Contract # 693JK320C000005 with Safety Management Services, Inc. (SMS) of West Jordan, Utah defines that for Task 3, "Explosion Potential for Exploding Thermites of Coarser Particle Size", SMS shall:

1) Order and receive fine, medium, and coarse metal and metal oxides of the eight exploding thermites.
2) Mix small-scale thermite mixes for each of the exploding thermites in the following combinations:
    1) medium metal with fine metal oxide,
    2) fine metal with medium metal oxide,
    3) medium metal with medium metal oxide,
    4) coarse metal with fine metal oxide,
    5) fine metal with coarse metal oxide, and
    6) coarse metal with coarse metal oxide.
3) Perform impact sensitivity, friction sensitivity, ESD sensitivity, and hotwire sensitivity tests.
4) Perform high-temperature DSC in duplicate on each small-scale thermite mix.
5) Provide the COR with a test report and video(s).

2.0 SUMMARY AND CONCLUSIONS

In cooperation with the U.S. Department of Transportation (DOT) Pipeline and Hazardous Materials Safety Administration (PHMSA), SMS has proposed, procured, and mixed fine, medium, and coarse iterations for the following eight exploding thermite mixtures:

1. Large-Scale Mix ID #7 – Al-MnO_2 Thermite
2. Large-Scale Mix ID #8 – Mg & Al – MoO_3 & CuO Thermite
3. Small-Scale Mix ID #3B – Ti-MnO_2 Thermite
4. Small-Scale Mix ID #4 – Mg-MnO_2 Thermite
5. Small-Scale Mix ID #9 – Al-MoO_3 Thermite
6. Small-Scale Mix ID #19 – Al-SnO_2 Thermite
7. Small-Scale Mix ID #24 – Al-Bi_2O_3 Thermite
8. Small-Scale Mix ID #48 – Ti-Bi_2O_3 Thermite

SMS performed impact, friction, electrostatic discharge (ESD), high-temperature Differential Scanning Calorimetry (DSC) and hotwire sensitivity tests on nine unique particle size combinations of exploding thermites as documented in this test report (fine metal with fine, medium and coarse metal oxides; medium metal with fine, medium and coarse* metal oxides, coarse metal with fine, medium* and coarse metal oxides), with combinations designated with an asterisk as additional combinations prepared by SMS for a more thorough/complete evaluation. Varying the particle size did not significantly increase or decrease the impact sensitivity of the tested thermites; it did have a more significant effect upon the friction sensitivity, increasing or decreasing its sensitivity. Larger particles were generally less sensitive to ESD.

High-temperature DSC of the various particle size combinations of a specific metal/metal-oxide thermite yielded similar thermograms but with various differences (such as different onsets of reaction for endotherms or exotherms, different reaction types/severities, different heat output), even though the same thermite formulation was being tested. Four of the eight exploding thermites exhibited sudden, sharp exothermic activity consistent with that of a fast-reacting (exploding) thermite; there was no indication of an explosion hazard in the thermograms of the other four thermites.

Thermites with larger particle sizes tended to be less susceptible to explosion by hotwire. A test video of the hotwire explosion screening test (SMS-6265c-V1) is being sent to the attention of the Contracting Officer's Representative (COR).

3.0 ACKNOWLEDGEMENTS

Mixing of fine thermites was performed by Greg J. Dohm, Jordan D. Dzubak, Derek J. Holmstead, and Derek M. Sutton and Jackson D. Zarbock. Sensitivity testing of thermites was performed by Collin L. Boren, Jackson D. Zarbock, Derek J. Holmstead and Derek M. Sutton. High-temperature Differential Scanning Calorimetry (DSC) was performed by Jordan D. Dzubak and Derek M. Sutton.

4.0 BACKGROUND

Historically, industry has offered traditional thermite formulations (containing only metal and metal oxides) for transport in Class 4 as flammable or water-reactive solids. The reaction produces a burst of heat, high temperature, and molten metal for various uses including joining steel railroad ties or copper transmission lines, metal refining, disabling munitions, etc. Traditional thermite formulations pass the UN Manual of Tests and Criteria, Appendix 6 "Screening Procedures" for substances which may have explosive properties as they do not contain any of the chemical groups listed in Table A6.1 that are associated with explosive properties. NOTE: The Appendix 6 Screening Procedures cannot be used for substances manufactured with the view to producing a practical explosive or pyrotechnic effect.

Newer "exotic" thermite formulations include those with additives such as plastics, oxidizers, nano materials, explosives, etc. to confer special compositions or actions upon use. Thermite research was needed to identify families of new and existing thermite compositions and to determine their hazards in transport and to transport vehicles.

Safety Management Services, Inc. (SMS) was contracted to perform research on thermite formulations in cooperation with Southwest Research Institute (SwRI) and the U.S. Department of Transportation (DOT) Pipeline and Hazardous Materials Safety Administration (PHMSA). This effort is considered to be Phase I of thermite testing (DOT Contract # DTPH5616D00001). During Phase I, eight thermites for large-scale testing and fifteen thermite formulations were selected for small-scale testing. It was discovered that thermite mixtures exhibited hazards from ranging from rapid reactions that were consistent with 1.3G materials to exploding when ignited in unconfined 5-gram quantities, similar to 1.1G flash powders.

These findings prompted the request for SMS to perform additional testing to further research the energetic properties of thermite and develop the technical basis to base policies and decision on thermite-based products. This additional testing is considered Phase II of thermite testing. During Task 2 of Phase II, 30 additional thermite mixtures were selected and tested for friction, impact, and electrostatic discharge sensitivity, auto-ignition temperature via high-temperature differential scanning calorimeter (DSC), and hotwire explosion screening test. Six additional thermite mixtures transitioned to explosion in unconfined 5-gram quantities. Of the fine thermite mixtures testing during Phase I and Phase II, the following were found to exhibit 1.1G hazards:

Phase I

- LS #7 Al-MnO_2
- LS #8 Mg & Al-MoO_3 & CuO
- SS #3B Ti-MnO2
- SS #4 Mg-MnO_2
- SS #9 Al MoO3
- SS #19 Al-SnO_2
- SS #24 Al-Bi_2O_3

Phase II

- SS #27 Al-Fe_3O_4
- SS #30 Al-NiO
- SS #38 Mg-CrO_3
- SS #47 Ti-CrO_3
- SS #48 Ti-Bi_2O_3
- SS #56 Mg & Al-MoO_3 & CuO

To assess the influence of particle size on the sensitivity and reactivity of exploding thermites, fine, medium, and coarse iterations of eight exploding thermites were mixed and tested. The seven exploding thermites from Phase I and Fine SS #48 Ti-Bi_2O_3 were selected. Fine SS #48 was chosen above the other Phase II exploding thermites based on the violence of the response exhibited during the hotwire explosion screening test (see SMS-6265b-V1). Fine, medium, and coarse metals and metal oxides for each of the eight thermites were procured and mixed in the following combinations.

1. Fine metal, medium metal oxide
2. Fine metal, coarse metal oxide
3. Medium metal, fine metal oxide
4. Medium metal, medium metal oxide
5. Medium metal, coarse metal oxide
6. Coarse metal, fine metal oxide
7. Coarse metal, medium metal oxide
8. Coarse metal, fine metal oxide

5.0 DESCRIPTION OF THERMITE TEST SAMPLES

5.1 General

The metal and metal oxide for each thermite were procured in fine, medium and coarse product types, as detailed in the following sections. A parametric study was performed on combination of the various product types to determine the effect of particle size upon the explosibility of the thermite:

- Fine metal and fine metal oxide.
- Fine metal and medium metal oxide.
- Fine metal and coarse metal oxide.
- Medium metal and fine metal oxide.
- Medium metal and medium metal oxide.
- Medium metal and coarse metal oxide.
- Coarse metal and fine metal oxide.
- Coarse metal and medium metal oxide.
- Coarse metal and coarse metal oxide.

5.2 Al-MnO_2 Thermite – Large-Scale Mix ID #7 (SMS mixed)

SMS procured and mixed the raw ingredients for all iterations of this thermite. The composition of each fine, medium coarse iteration by mass was 29.27% aluminum (Al) and 70.73% manganese(IV) oxide (MnO_2). This thermite was a dark gray powder when fully mixed.

The aluminum (Al) powder was procured in the following three product types:

- Fine: 1 - 5 microns in size and 3N (99.9%) pure.
- Medium: 50 - 70 microns in size and 99.5% pure.
- Coarse: 150 - 200 microns in size and 99.5% pure.

The manganese(IV) oxide (MnO_2) powder was procured in the following three product types:

- Fine: 1 - 5 microns in size and 2N (99%) purity.
- Medium: 50 - 70 microns in diameter and 2N (99%) pure.
- Coarse: 150 - 200 microns in diameter and 2N (99%) pure.

Photo 1: Large-Scale Mix ID #7 Thermite with Fine Al and MnO_2 as Fine (left), Medium (center), Coarse (right)

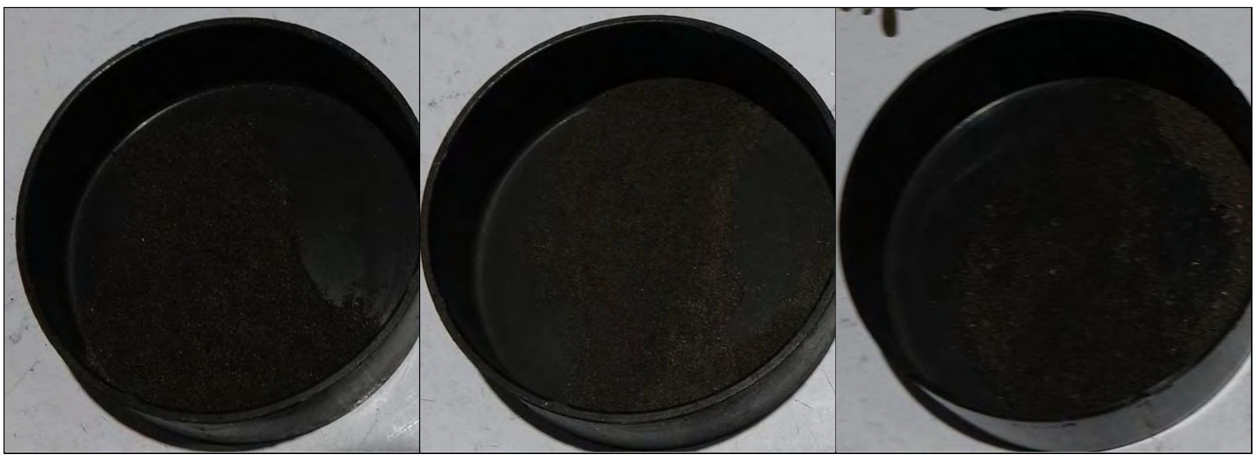


Photo 2: Large-Scale Mix ID #7 Thermite with Medium Al and MnO_2 as Fine (left), Medium (center), Coarse (right)

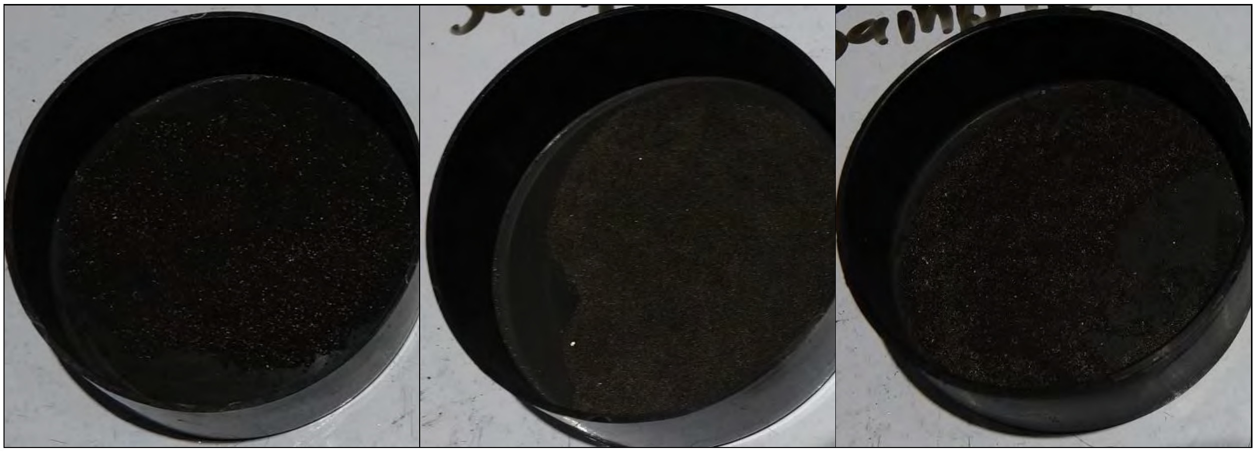


Photo 3: Large-Scale Mix ID #7 Thermite with Coarse Al and MnO_2 as Fine (left), Medium (center), Coarse (right)

5.3 Mg & Al – MoO_3 & CuO Thermite – Large-Scale Mix ID #8 (SMS mixed)

SMS procured and mixed the raw ingredients for all iterations of this thermite. The composition of this thermite by mass was 25% magnalium (magnesium-aluminum), 34% molybdenum trioxide (MoO_3), and 41% copper(II)/cupric oxide (CuO). This thermite was a dark gray powder with white and silver flecks when fully mixed.

The magnalium powder was 50% magnesium, 50% aluminum by weight and procured in the following three product types:

- Fine: 1 - 5 micron in size (-325 mesh)
- Medium: 75 - 175 micron in size (80 - 200 mesh).
- Coarse: 250 - 600 micron in size (30 - 60 mesh).

The molybdenum trioxide (MoO_3) powder was in the following three product types:

- Fine: 1 - 5 micron in size (-325 mesh) and 99.5% pure.
- Medium: Pellets (99.5% pure) ground to a powder using a mortar and pestle and screened by SMS using a 100-mesh sieve (<150 micron).
- Coarse: 1 - 3 mm diameter pellets and 99.5% pure (as procured).

The copper(II)/cupric oxide (CuO) powder was procured in the following three product types:

- Fine: 1 - 5 microns in size and 3N (99.9%) purity.
- Medium: 75 microns in diameter and 99.8% pure.
- Coarse: 150 microns in size and 99.8% pure.

Photo 4: Large-Scale Mix ID #8 Thermite with Fine Mg & Al and MoO_3 & CuO as Fine (left), Medium (center), Coarse (right)

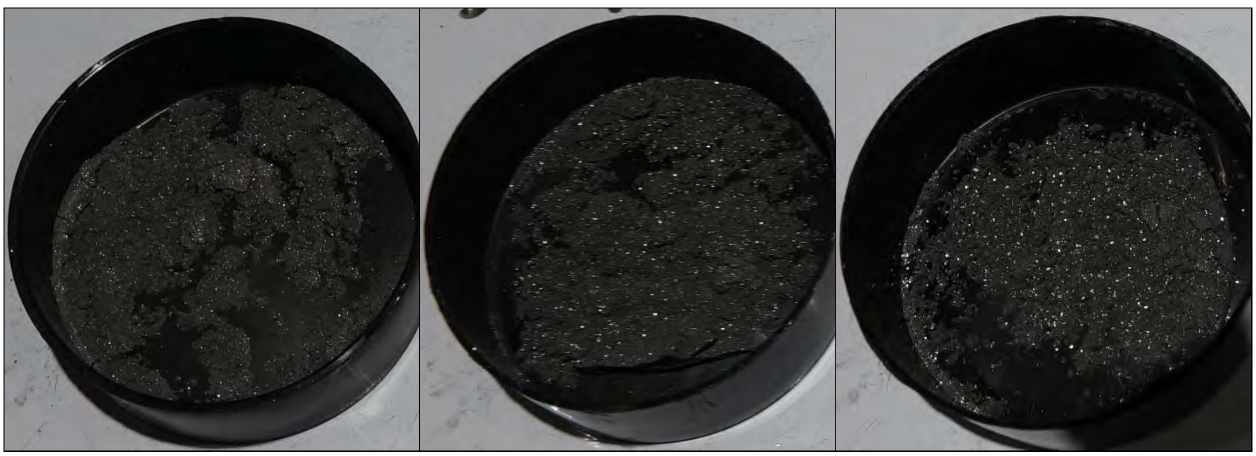


Photo 5: Large-Scale Mix ID #8 Thermite with Medium Mg & Al and MoO_3 & CuO as Fine (left), Medium (center), Coarse (right)

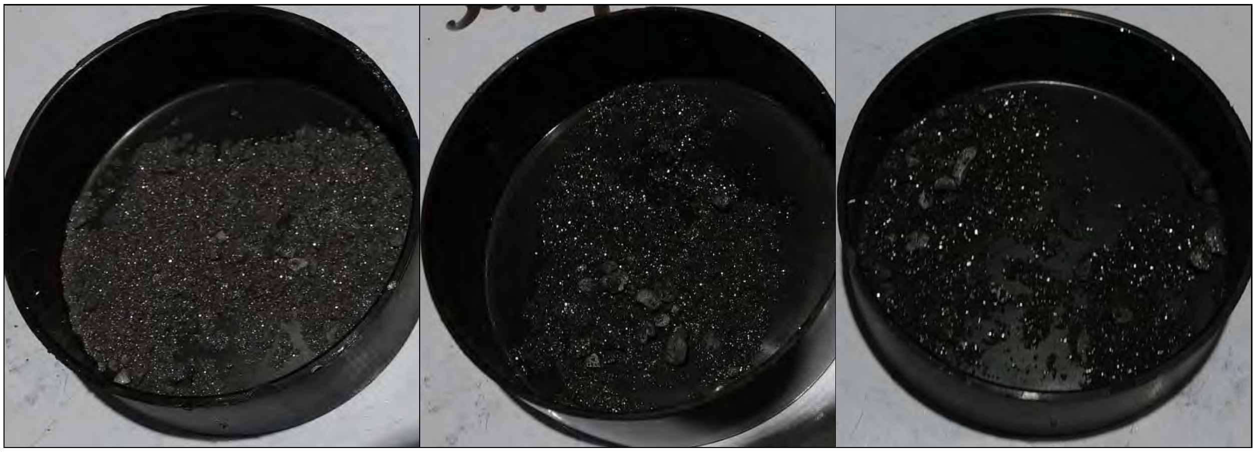


Photo 6: Large-Scale Mix ID #8 Thermite with Coarse Mg & Al and MoO_3 & CuO as Fine (left), Medium (center), Coarse (right)

5.4 Ti-MnO_2 Thermite – Small-Scale Mix ID #3B (SMS mixed)

SMS procured and mixed the raw ingredients for all iterations of this thermite. The composition of this thermite by mass was 35.51% titanium (Ti) and 64.49% manganese(IV) oxide (MnO_2). This thermite was a dark gray powder when fully mixed.

The titanium (Ti) powder was procured in the following three product types:

- Fine: 20 microns maximum in size and 3N (99.9%) pure.
- Medium: 50 - 70 microns in size and 99.5% pure.
- Coarse: 150 - 200 microns in size and 99.5% pure.

The manganese(IV) oxide (MnO_2) powder was procured in the following three product types:

- Fine: 1 - 5 microns in size and 2N (99%) purity.
- Medium: 50 - 70 microns in diameter and 2N (99%) pure.
- Coarse: 150 - 200 microns in diameter and 2N (99%) pure.

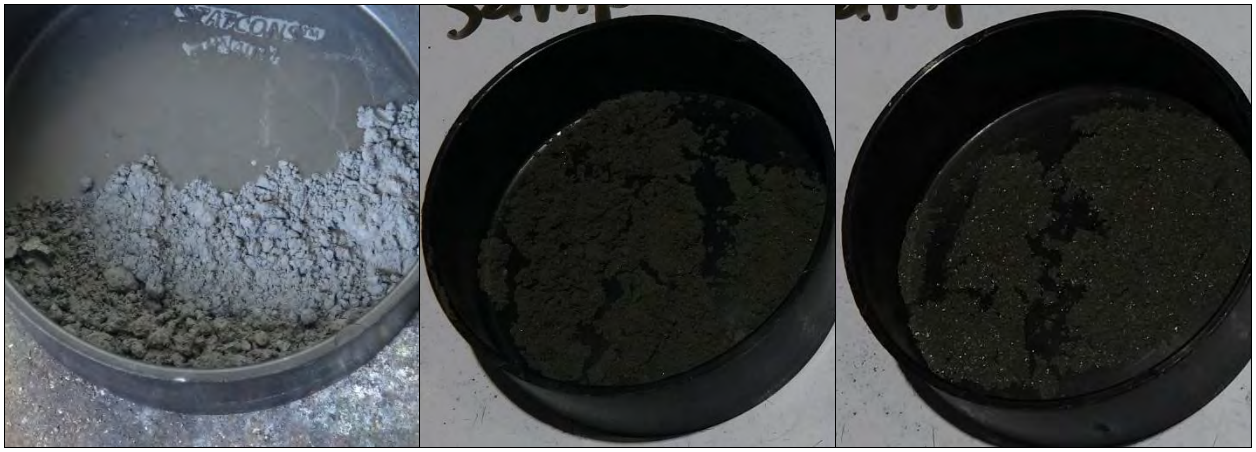


Photo 7: Small-Scale Mix ID #3B Thermite with Fine Ti and MnO_2 as Fine (left), Medium (center), Coarse (right)

Photo 8: Small-Scale Mix ID #3B Thermite with Medium Ti and MnO_2 as Fine (left), Medium (center), Coarse (right)

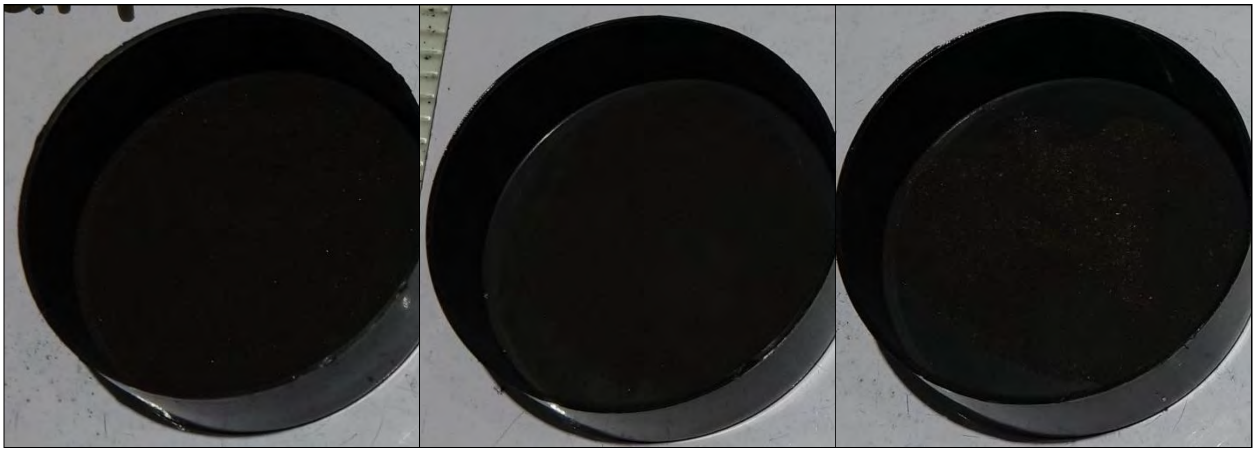


Photo 9: Small-Scale Mix ID #3B Thermite with Coarse Ti and MnO_2 as Fine (left), Medium (center), Coarse (right)

5.5 Mg-MnO_2 Thermite – Small-Scale Mix ID #4 (SMS mixed)

SMS procured and mixed the raw ingredients for all iterations of this thermite. The composition of this thermite by mass was 35.86% magnesium (Mg) and 64.14% manganese(IV) oxide (MnO_2). This thermite was a gray powder when fully mixed.

The magnesium (Mg) powder was procured in the following three product types:

- Fine: fine powder (size to be determined), 99% pure.
- Medium: 0.06 - 0.3 mm in size and 99% pure.
- Coarse: 0.1mm maximum in size and 99% pure.

The manganese(IV) oxide (MnO_2) powder was procured in the following three product types:

- Fine: 1 - 5 microns in size and 2N (99%) purity.
- Medium: 50 - 70 microns in diameter and 2N (99%) pure.
- Coarse: 150 - 200 microns in diameter and 2N (99%) pure.

Photo 10: Scale-Scale Mix ID #4 Thermite with Fine Mg and MnO_2 as Fine (left), Medium (center), Coarse (right)

Photo 11: Scale-Scale Mix ID #4 Thermite with Medium Mg and MnO_2 as Fine (left), Medium (center), Coarse (right)

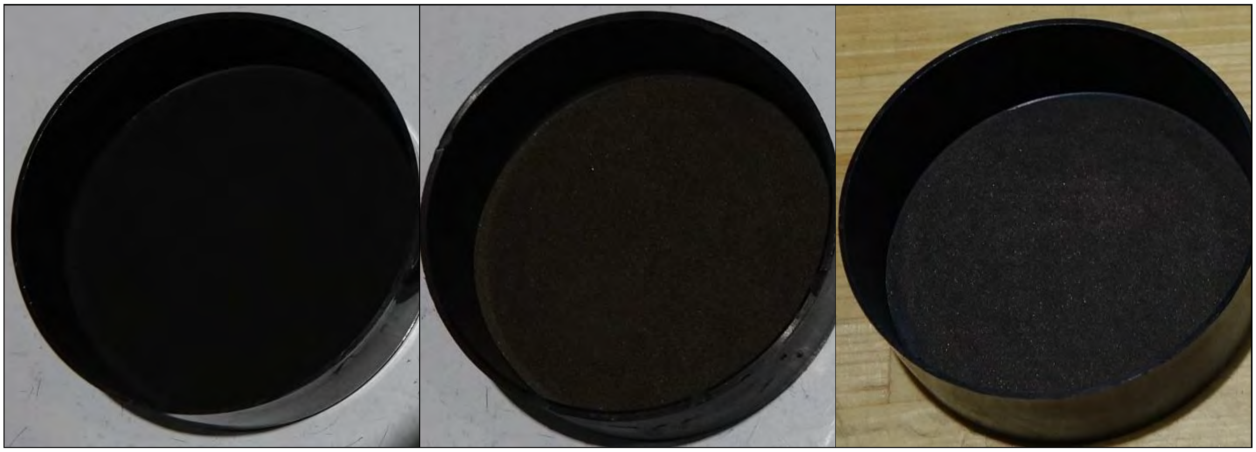


Photo 12: Scale-Scale Mix ID #4 Thermite with Coarse Mg and MnO_2 as Fine (left), Medium (center), Coarse (right)

5.6 Al-MoO_3 Thermite – Small-Scale Mix ID #9 (SMS mixed)

SMS procured and mixed the raw ingredients for all iterations of this thermite. The composition of this thermite by mass was 27.27% aluminum (Al) and 72.73% molybdenum trioxide (MoO_3). This thermite was a light gray powder when fully mixed.

The aluminum (Al) powder was procured in the following three product types:

- Fine: 1 - 5 microns in size and 3N (99.9%) pure.
- Medium: 50 - 70 microns in size and 99.5% pure.
- Coarse: 150 - 200 microns in size and 99.5% pure.

The molybdenum trioxide (MoO_3) powder was in the following three product types:

- Fine: 1 - 5 micron in size (-325 mesh) and 99.5% pure.
- Medium: Pellets (99.5% pure) ground to a powder using a mortar and pestle and screened by SMS using a 100-mesh sieve (<150 micron).
- Coarse: 1 - 3 mm diameter pellets and 99.5% pure (as procured).

Photo 13: Small-Scale Mix ID #9 Thermite with Fine Al and MoO_3 as Fine (left), Medium (center), Coarse (right)

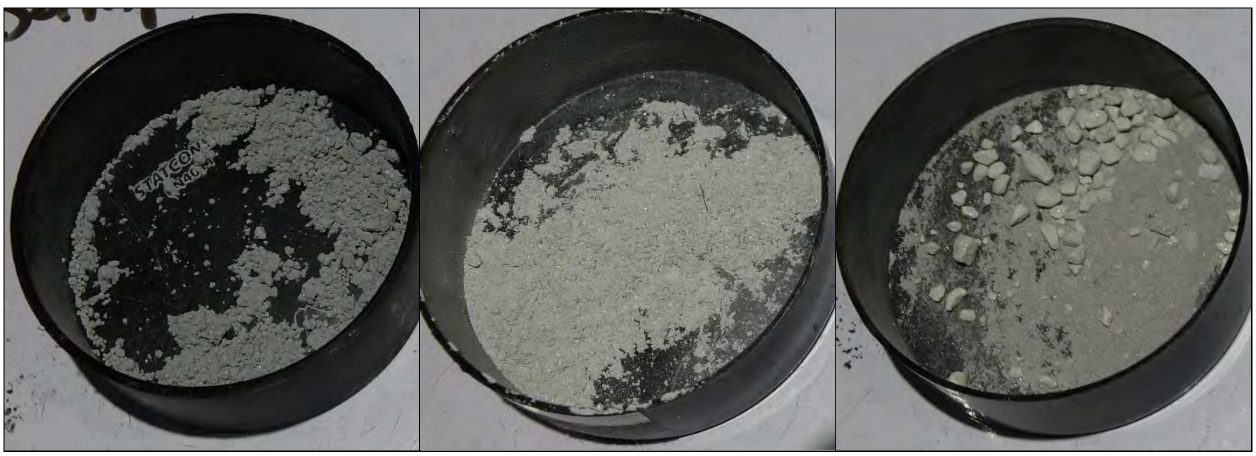


Photo 14: Small-Scale Mix ID #9 Thermite with Medium Al and MoO_3 as Fine (left), Medium (center), Coarse (right)

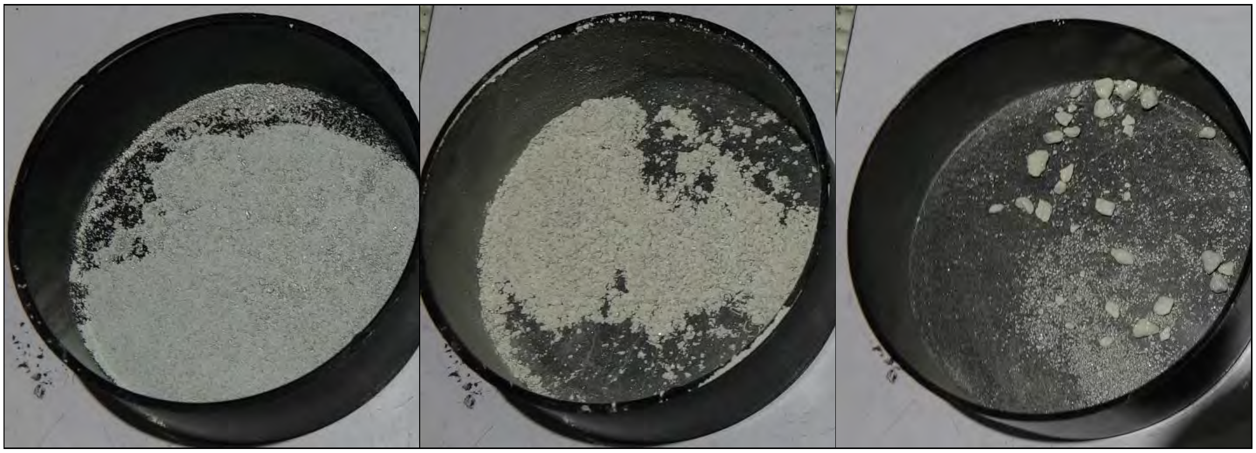


Photo 15: Small-Scale Mix ID #9 Thermite with Coarse Al and MoO_3 as Fine (left), Medium (center), Coarse (right)

5.7 Al-SnO_2 Thermite – Small-Scale Mix ID #19 (SMS mixed)

SMS procured and mixed the raw ingredients for all iterations of this thermite. The composition of this thermite by mass was 19.27% aluminum (Al) and 80.73% tin(IV) oxide (SnO_2). This thermite was a fine off-white powder when fully mixed.

The aluminum (Al) powder was procured in the following three product types:

- Fine: 1 - 5 microns in size and 3N (99.9%) pure.
- Medium: 50 - 70 microns in size and 99.5% pure.
- Coarse: 150 - 200 microns in size and 99.5% pure.

The tin(IV) oxide (SnO_2) powder was procured in the following three product types:

- Fine: 1 - 5 microns in size and 3N (99.9%) purity.
- Medium: 115 micron (-125 mesh) maximum size and 2N (99%) pure.
- Coarse: 250 micron (-60 mesh) maximum size and 5N (99.999%) pure.

Photo 16: Small-Scale Mix ID #19 Thermite with Fine Al and SnO_2 as Fine (left), Medium (center), Coarse (right)

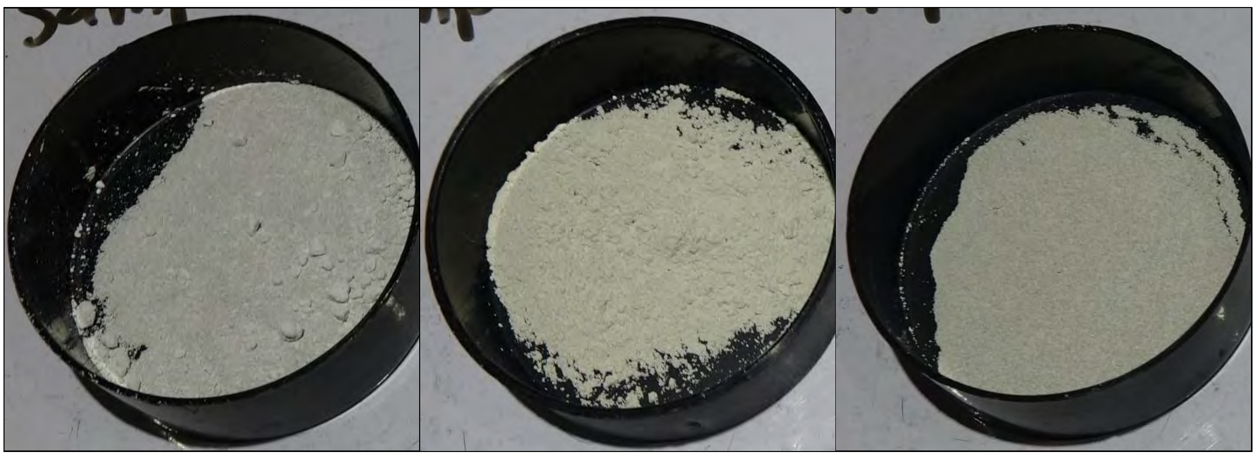


Photo 17: Small-Scale Mix ID #19 Thermite with Medium Al and SnO_2 as Fine (left), Medium (center), Coarse (right)

Photo 18: Small-Scale Mix ID #19 Thermite with Coarse Al and SnO_2 as Fine (left), Medium (center), Coarse (right)

5.8 Al-Bi_2O_3 Thermite – Small-Scale Mix ID #24 (SMS mixed)

SMS procured and mixed the raw ingredients for all iterations of this thermite. The composition of each fine, medium coarse iteration by mass was 10.38% aluminum (Al) and 89.62% bismuth oxide (Bi_2O_3). This thermite was a yellowish-gray powder when fully mixed.

The aluminum (Al) powder was procured in the following three product types:

- Fine: 1 - 5 microns in size and 3N (99.9%) pure.
- Medium: 50 - 70 microns in size and 99.5% pure.
- Coarse: 150 - 200 microns in size and 99.5% pure.

The bismuth oxide (Bi_2O_3) powder was procured in the following three product types:

- Fine: 1 - 5 microns in size and 3N (99.9%) purity.
- Medium: 5 - 10 microns in size and 3N (99.9%) pure.
- Coarse: 10 - 20 microns in size and 3N (99.9%) pure.

Photo 19: Small-Scale Mix ID #24 Thermite with Fine Al and Bi_2O_3 as Fine (left), Medium (center), Coarse (right)

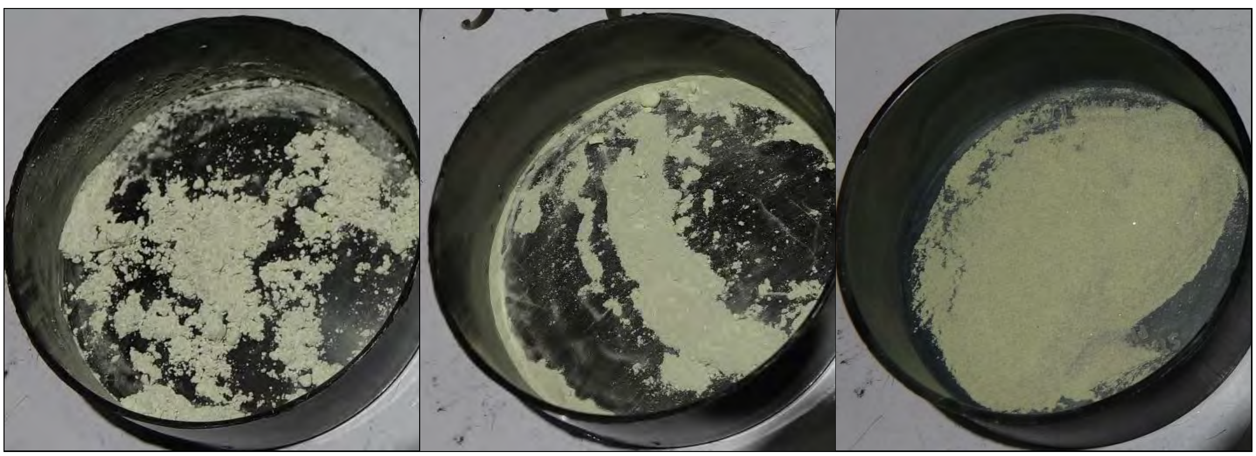


Photo 20: Small-Scale Mix ID #24 Thermite with Medium Al and Bi_2O_3 as Fine (left), Medium (center), Coarse (right)

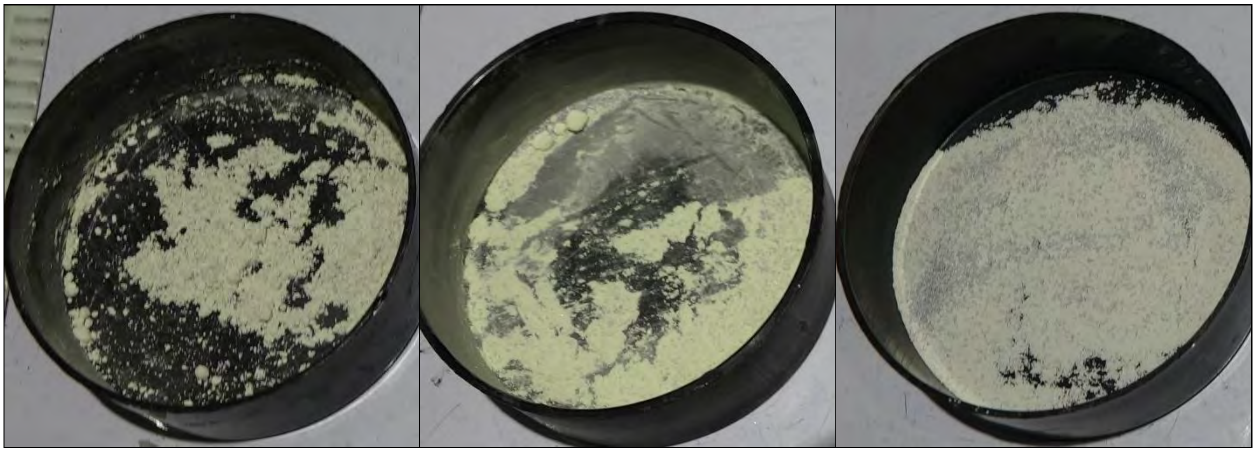


Photo 21: Small-Scale Mix ID #24 Thermite with Coarse Al and Bi_2O_3 as Fine (left), Medium (center), Coarse (right)

5.9 Ti-Bi_2O_3 Thermite – Small-Scale Mix ID #48 (SMS Mixed)

SMS procured and mixed the raw ingredients for all iterations of this thermite. The composition of this thermite by mass was 13.35% titanium (Ti) and 86.65% bismuth trioxide (Bi_2O_3). This thermite was a yellowish-gray powder when fully mixed.

The titanium (Ti) powder was procured in the following three product types:

- Fine: 20 microns maximum in size and 3N (99.9%) pure.
- Medium: 50 - 70 microns in size and 99.5% pure.
- Coarse: 150 - 200 microns in size and 99.5% pure.

The bismuth oxide (Bi_2O_3) powder was procured in the following three product types:

- Fine: 1 - 5 microns in size and 3N (99.9%) purity.
- Medium: 5 - 10 microns in size and 3N (99.9%) pure.
- Coarse: 10 - 20 microns in size and 3N (99.9%) pure.

Photo 22: Small-Scale Mix ID #48 Thermite with Fine Ti and Bi_2O_3 as Fine (left), Medium (center), Coarse (right)

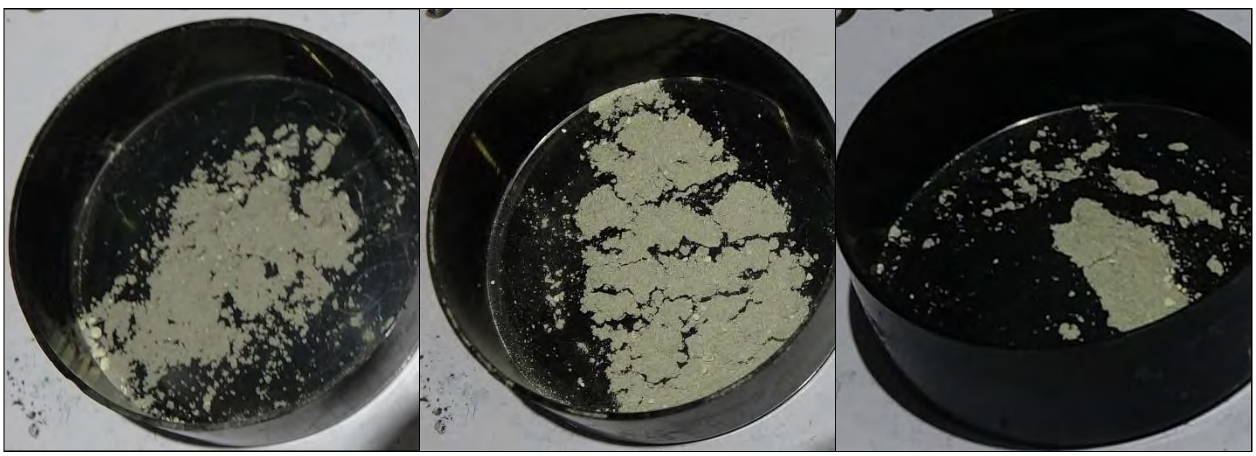


Photo 23: Small-Scale Mix ID #48 Thermite with Medium Ti and Bi_2O_3 as Fine (left), Medium (center), Coarse (right)

Photo 24: Small-Scale Mix ID #48 Thermite with Coarse Ti and Bi_2O_3 as Fine (left), Medium (center), Coarse (right)

6.0 TEST DESCRIPTIONS AND RESULTS

6.1 <u>Modified Bureau of Mines (MBOM) Impact Sensitivity Testing</u>

6.1.1 Test Description

The MBOM Impact Test is used to measure the sensitiveness of a substance to drop-weight impact and to determine if the substance is too dangerous to transport in the form tested.

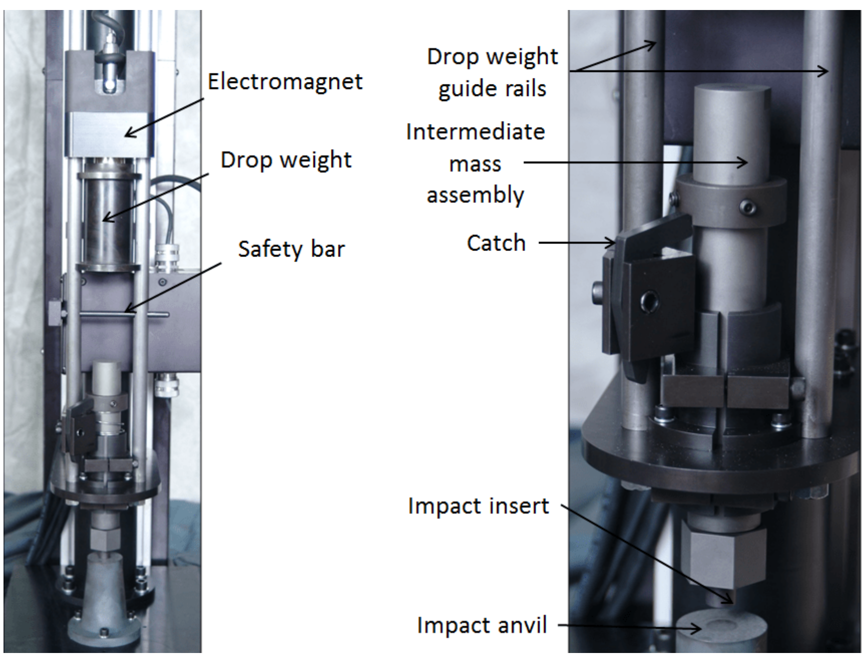


Figure 1: Modified Bureau of Mines (MBOM) Impact Apparatus

For solids, a 10-mg sample is loaded onto the impact anvil. The intermediate mass is slowly lowered onto the anvil until the sample is impinged between the anvil and impact insert. A 2.5-kg drop weight is raised to the desired drop height and released. The drop weight strikes the intermediate mass and delivers an impact stimulus to the sample. The catch prevents multiple impacts from occurring.

Observations are made on whether an "explosion" occurs as evidenced by flame or audible report (smoke excluded). Thermite mixtures were analyzed via a 30-shot Bruceton Method as described in Appendix 2 of the UN Manual of Tests and Criteria to determine the Bruceton 50% Point of Ignition. If a negative result was observed at the maximum height of the apparatus (100 cm) at any point during testing, the sample was tested again at the maximum height. If an explosion occurred at the minimum height of the apparatus (3.2 cm), the sample was tested again at the minimum height. For thermite mixtures that did not exhibit any explosions at the maximum height for all 30 shots, the Bruceton 50% Point is shown as ≥100 cm. For samples that exhibited multiple explosions at the minimum height, the Bruceton 50% point is shown as <3.2 cm.

6.1.2 Test Results

Impact sensitivity testing was performed on the large-scale (LS) and small-scale (SS) thermite test samples. The laboratory data sheets are provided in the Appendix along with the calculations for the 50% initiation level (H_{50}) and standard deviation(s). The test results are summarized in the following table.

Table 1: Summary of MBOM Impact Sensitivity Test Results (cm)

LS #7 Al-MnO_2

		Metal		
		F	M	C
Metal Oxide	F	>100	>100	>100
	M	>100	>100	>100
	C	>100	>100	>100

SS #9 Al-MoO_3

		Metal		
		F	M	C
Metal Oxide	F	>100	>100	89.2
	M	>100	>100	>100
	C	>100	89.2	89.2

LS #8 Mg & Al – MoO_3 & CuO

		Metal		
		F	M	C
Metal Oxide	F	>100	>100	66.7
	M	89.2	89.2	89.2
	C	>100	89.2	89.2

SS #19 Al-SnO_2

		Metal		
		F	M	C
Metal Oxide	F	>100	>100	>100
	M	>100	>100	>100
	C	>100	>100	>100

		Metal		
		F	M	C
Metal Oxide	F	>100	>100	>100
	M	>100	>100	>100
	C	>100	>100	>100

SS #3B Ti-MnO_2

		Metal		
		F	M	C
Metal Oxide	F	>100	>100	>100
	M	89.2	>100	>100
	C	>100	70.8	89.2

SS #24 Al-Bi_2O_3

		Metal		
		F	M	C
Metal Oxide	F	>100	>100	>100
	M	>100	>100	>100
	C	>100	>100	>100

SS #4 Mg-MnO_2

		Metal		
		F	M	C
Metal Oxide	F	>100	>100	>100
	M	>100	>100	>100
	C	>100	>100	>100

SS #48 Ti-Bi_2O_3

6.1.3 Assessment of Test Results

The majority of thermite iterations tested were extremely insensitive to impact stimulus, with Bruceton 50% Points greater than 100 cm. No thermite samples exhibited an impact 50% Point less than 50 cm. Varying particle size did not significantly increase or decrease the impact sensitivity of the tested thermites.

6.2 ABL Friction Sensitivity Testing

6.2.1 Test Description

This test is used to measure the sensitiveness of the substance to frictional stimuli and to determine if the substance is too dangerous to transport in the form tested.

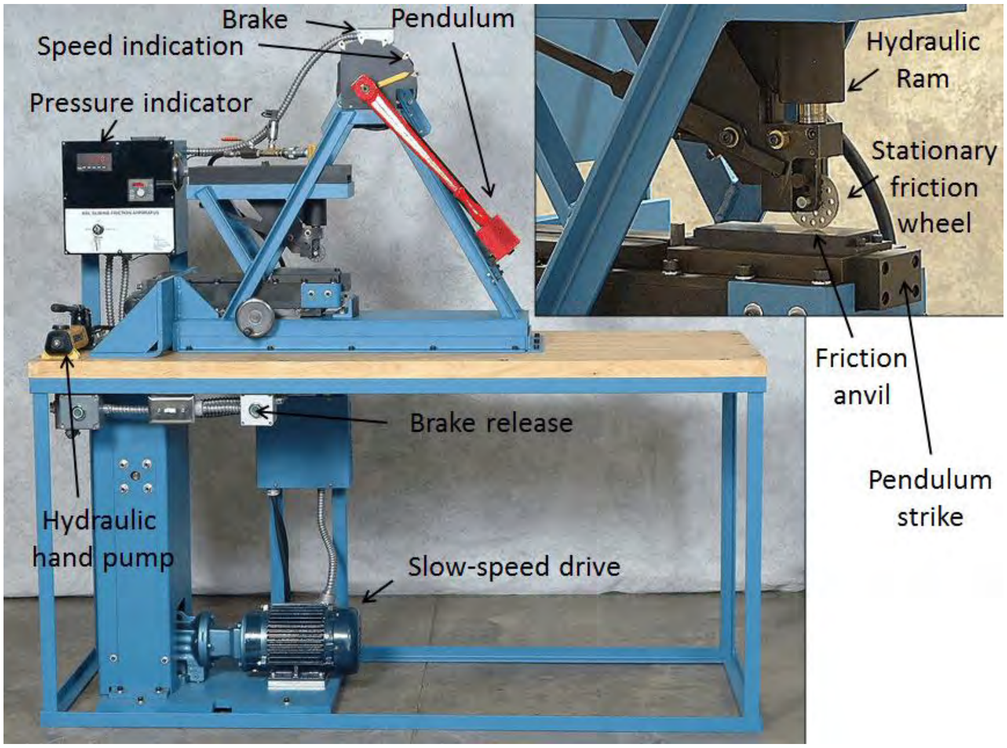


Figure 2: ABL Friction Sensitivity Apparatus

A 10-mg sample is placed on the friction anvil, and the stationary friction wheel is lowered via the hydraulic ram until the sample is impinged between the anvil and the wheel at a desired pressure. The friction anvil is then either struck by the pendulum or dragged by the slow-speed drive at a desired speed so that it travels one inch. The combination of pressure supplied by the stationary wheel and lateral movement of the anvil delivers a frictional stimulus to the sample. Each thermite sample test was conducted at a speed of 3 ft/sec. Initially, the maximum force used during testing was 1280 lb_f. However, repeated testing at this force was causing excessive damage to the machine. As such, the maximum force used during testing was reduced to 1000 lb_f.

Observations are made on whether an "explosion" occurs as evidenced by an audible report, crackling, sparking, or flame. Thermite mixtures were analyzed via a 30-shot Bruceton Method as described in Appendix 2 of the UN Manual of Tests and Criteria to determine the Bruceton 50% Point of Ignition.

If a negative result was observed at the maximum force of the apparatus (1000 - 1280 lb_f) at any point during testing, the sample was tested again at the maximum force. If an explosion occurred at the minimum pressure of the apparatus (51 lb_f), the sample was tested again at the minimum force. For thermite mixtures that did not exhibit any explosions at the maximum force for all 30 shots, the Bruceton 50% Point is shown as ≥1280 lb_f or ≥1000 lb_f. For samples that exhibited multiple explosions at the minimum height, the Bruceton 50% point is shown as <51 lb_f.

6.2.2 Test Results

Friction sensitivity testing was performed on the large-scale (LS) and small-scale (SS) thermite test samples. The laboratory data sheets are provided in the Appendix along with the calculations for the 50% initiation level (H_{50}) and standard deviation (s). The test results are summarized in the following table.

Table 2: Summary of ABL Friction Test Results (lbf at 3 feet per second)

LS #7 Al-MnO_2

Metal Oxide \ Metal	F	M	C
F	475	>1000	>1000
M	745.6	401.4	169.9
C	754.2	>1000	247.6

SS #9 Al-MoO_3

Metal Oxide \ Metal	F	M	C
F	<51	<51	577.1
M	<51	90.5	273.6
C	488.3	768.7	612.4

LS #8 Mg & Al – MoO_3 & CuO

Metal Oxide \ Metal	F	M	C
F	331	836.1	862.8
M	567.7	770.2	862.8
C	858.2	491.0	891.7

SS #19 Al-SnO_2

Metal Oxide \ Metal	F	M	C
F	>1280	728.7	597.6
M	891.7	808.1	847.3
C	826.0	774.2	467.2

SS #3B Ti-MnO_2

Metal Oxide \ Metal	F	M	C
F	<51	521.0	506.4
M	80.7	<51	<51
C	<51	<51	<51

SS #24 Al-Bi_2O_3

Metal Oxide \ Metal	F	M	C
F	1071	891.7	841.9
M	891.7	891.7	653.8
C	>1000	712.1	698.8

SS #4 Mg-MnO_2

Metal Oxide \ Metal	F	M	C
F	>1280	>1000	>1000
M	891.7	891.7	891.7
C	>1000	891.7	795.0

SS #48 Ti-Bi_2O_3

Metal Oxide \ Metal	F	M	C
F	866	421.4	817.2
M	891.7	768.7	891.7
C	862.8	858.2	891.7

6.2.3 Assessment of Test Results

The friction sensitivity of the thermite samples varied significantly, with the majority being relatively insensitive (e.g., Bruceton 50% Point >800 lb_f). The relative sensitivity of the iterations for each sample tended to be uniform (e.g., fine thermite mixtures that were found to be relatively sensitive to friction were also found to be sensitive when particle size was varied). Sensitivity results varied greatly for SS #3B and SS #9.

6.3 ABL Electrostatic Discharge (ESD) Sensitivity Testing

6.3.1 Test Description

This test is used to measure the sensitiveness of the substance to electrostatic discharge and to assess how the substance may response to static discharge that may result from in-process conditions.

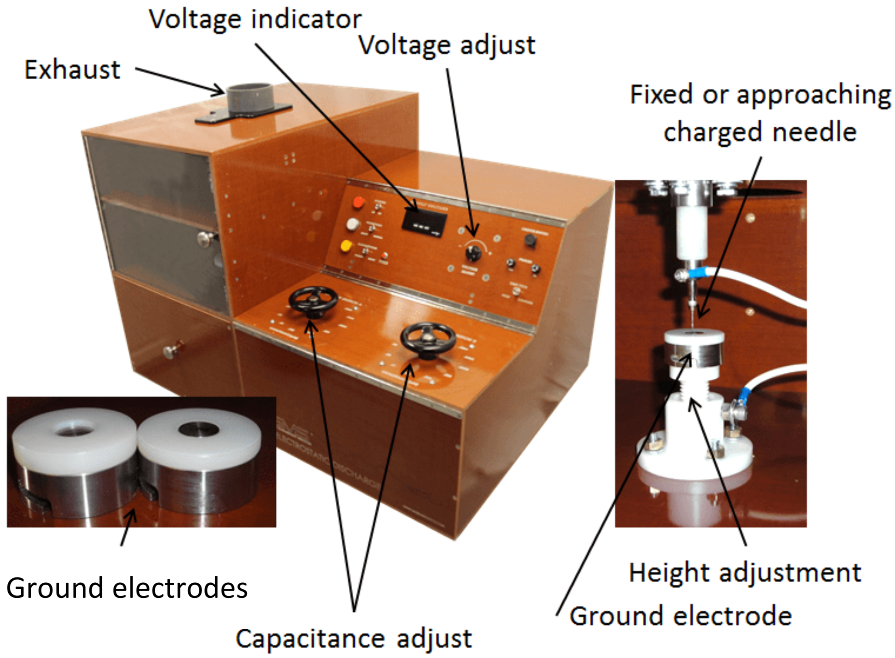


Figure 3: ABL Friction Sensitivity Apparatus

A 10-mg sample is placed on a ground electrode and placed on the ground post inside the ESD machine underneath the charged needle. The total energy discharged from the needle to the ground electrode is determined by the following equation:

$$E = \frac{1}{2}CV^2$$

Where E is the total energy discharged, C is the capacitance of the system, and V is the voltage difference between the grounding electrode and needle. All thermite samples were tested at a voltage of 5000 VDC. The discharge energy is varied by selecting the desired capacitance. After the capacitance is selected, the capacitor is charged to 5000 VDC. The needle is then lower via hydraulic press until the electrostatic discharge arcs from the needle to the ground electrode, delivering ESD stimulus to the substance.

Because the light intensity emitted from ignited thermites can be hazardous, a high-speed camera and GoDetect ESD™ were used to determine whether an explosion occurred. GoDetect ESD™ is a software developed by Safety Management Services that uses image-based machine learning to determine the severity of a given reaction. Images of the test are collected via high-speed camera and the reaction severity is calculated using an image-based machine learning algorithm. Thermite mixtures were analyzed via a 30-shot Bruceton Method as described in Appendix 2 of the UN Manual of Tests and Criteria to determine the Bruceton 50% Point of Ignition.

6.3.2 Test Results

ESD sensitivity testing was performed on the large-scale (LS) and small-scale (SS) thermite test samples. The laboratory data sheets are provided in the Appendix along with the calculations for the 50% initiation level (H_{50}) and standard deviation (s). The H_{50} calculations are summarized in the following table.

Table 3: Summary of ABL ESD Test Results (µF)

		Metal		
		F	M	C
Metal Oxide	F	0.0005	0.0618	0.1709
	M	0.0124	0.0236	0.0448
	C	0.0141	0.0234	0.3094

LS #7 Al-MnO_2

		Metal		
		F	M	C
Metal Oxide	F	0.0073	0.0741	0.3531
	M	0.0133	0.0711	0.3234
	C	0.0617	0.3262	0.5465

SS #9 Al-MoO_3

		Metal		
		F	M	C
Metal Oxide	F	0.1596	0.0189	0.0194
	M	0.0094	0.0153	0.0277
	C	0.0189	0.0314	0.0197

LS #8 Mg & Al – MoO_3 & CuO

		Metal		
		F	M	C
Metal Oxide	F	0.0099	0.0049	0.0019
	M	0.0247	0.0172	0.3972
	C	0.1137	0.3357	0.4322

SS #19 Al-SnO_2

		Metal		
		F	M	C
Metal	F	<0.0002	0.0796	0.0174

		Metal		
		F	M	C
Met	F	0.0246	0.0250	0.0391

	M	0.0563	0.0296	0.0184
	C	0.0388	0.0855	0.1460

SS #3B Ti-MnO_2

	M	0.0012	0.0037	0.0310
	C	0.0046	0.0132	0.0214

SS #24 Al-Bi_2O_3

		Metal		
		F	M	C
Metal Oxide	F	0.0023	0.0189	0.0197
	M	0.0283	0.0122	0.0109
	C	0.0214	0.0047	0.0070

SS #4 Mg-MnO_2

		Metal		
		F	M	C
Metal Oxide	F	0.0014	<0.0002	<0.0002
	M	0.0007	0.0009	0.0007
	C	0.0011	0.0007	0.0016

SS #48 Ti-Bi_2O_3

6.3.3 Assessment of Test Results

GoDetect ESD™ detects reactions at the threshold of ignition with a high degree of sensitivity, resulting in ESD sensitivity levels that represent small consumption of the sample. Based on the high-speed video and GoDetect ESD™ algorithm, reactions were detected at low ESD levels for most of the thermites with larger particles being less ESD sensitive than smaller particles.

6.4 <u>Hotwire Explosion Screening Test</u>

6.4.1 Test Description

This test was performed to screen for thermite mixtures that would explode when exposed to high temperature. Each end of a 105-mm long, 18-gauge 80/20 nickel/chromium (ni-chrome) resistance heating wire (Type A) was attached to electrodes suspended just above an insulating clay-based firebrick. A 5-gram test sample was poured over the heating wire, as shown in photo. The resistance heating wire could achieve a maximum test temperature of 1200°C. All thermite samples were tested at 10 volts and 21 amps. The test was conducted for two minutes, until the sample was consumed, or the ni-chrome wire degraded and did not conduct. Two trials were performed for each thermite material. Test results were determined visually.

It was determined that each thermite mixture could be placed into one of five categories. Each thermite iteration was assigned a number based on the type of reaction:

1. Explosion – the entire thermite sample was consumed with an audible report
2. Fast Reaction – the entire thermite sample was consumed in less than one second, but no audible report was detected.
3. Moderate Reaction – the entire sample was consumed between one to thirty seconds.
4. Slow Reaction – the entire sample was consumed in greater than thirty seconds, or a reaction was detected but the entire sample was not consumed before two minutes.
5. Negligible Reaction – no reaction was detected

Photo 25: Test Sample Loaded onto Hotwire Auto-ignition Temperature Apparatus

6.4.2 Test Results

The test results are summarized in the following table with numbers corresponding to the definitions listed in the preceding section. Observations on the nature of the reaction were recorded for all samples. Samples were assessed on total burn time, reaction violence, and presence of an audible report.

Table 4: Summary of Hotwire Explosion Screening Test Results

		Metal		
		F	M	C
Metal Oxide	F	1	1	5
	M	1	2	5
	C	3	2	5

LS #7 Al-MnO_2

		Metal		
		F	M	C
Metal Oxide	F	1	5	5
	M	1	5	5
	C	3	5	5

SS #9 Al-MoO_3

		Metal		
		F	M	C
Metal Oxide	F	1	1	2
	M	1	2	2
	C	1	1	2

LS #8 Mg & Al – MoO_3 & CuO

		Metal		
		F	M	C
Metal Oxide	F	1	5	1
	M	5	5	5
	C	5	5	5

SS #19 Al-SnO_2

SS #3B Ti-MnO_2

Metal Oxide		Metal F	Metal M	Metal C
	F	1	2	2
	M	3	3	2
	C	2	2	2

SS #24 Al-Bi_2O_3

Metal Oxide		Metal F	Metal M	Metal C
	F	1	1	4
	M	1	1	4
	C	1	1	4

SS #4 Mg-MnO_2

Metal Oxide		Metal F	Metal M	Metal C
	F	1	2	3
	M	1	1	1
	C	3	1	1

SS #48 Ti-Bi_2O_3

Metal Oxide		Metal F	Metal M	Metal C
	F	1	2	2
	M	1	2	2
	C	1	2	2

6.4.3 Assessment of Test Results

The reactions exhibited by the thermite iterations ranged from explosion when unconfined and in small quantities, to no visible reaction. Once a reaction category was assigned to each thermite sample, reaction category designations were averaged across all samples to assess the influence of particle size on reaction violence. Table 5 shows the average reaction category for each iteration across all samples.

Table 5: Average Reaction Category Designation Observed Across All Samples

Metal Oxide		Metal F	Metal M	Metal C
	F	1.0	2.4	3.0
	M	1.8	2.6	3.3
	C	2.4	2.4	3.3

From this analysis, it can be seen that as metal and metal oxide particle size is reduced, reaction violence increases. The reaction violence appears to be more heavily influenced by metal particle size than metal oxide particle size (i.e., larger metal particles appear to reduce the reaction violence more than larger metal oxide particles do).

6.5 High-Temperature Differential Scanning Calorimeter (DSC) Testing

6.5.1 Test Description

This test is used to evaluate the behavior of energetic materials when subjected to a temperature rise. Characteristics displayed on the thermograms can be used to monitor samples in comparison to controls and to examine whether changes that may affect stability have occurred in a sample. Results provide onset temperature and peak maxima for any endothermic or exothermic event.

An instrument employing heat flow DSC was utilized. The test specimen and a thermally-inert reference material are loaded into separate crucibles. The crucibles are placed in the test chamber in separate holders. As the presence of air may critically affect the measured decomposition energy, the atmosphere in the test chamber is continuously purged with an inert atmosphere (oxygen deficient). The specimen and reference material are simultaneously heated at a controlled rate over a specified temperature range.

Thermocouples near the sample containers detect differences between the temperatures of the crucibles. The difference between these two temperatures is correlated to heat flow. A record of the change in heat flow is plotted against the furnace temperature or time. When the sample undergoes a transition involving a change of enthalpy, that change is indicated by a departure from the initially established baseline of the heat flow record.

For the self-heating test, the minimum temperature for exotherm onset and the ignition temperature are reported.

6.5.2 Test Configuration

The DSC instrument is a Themys One+ DSC using a nitrogen purge gas flow rate of 7 L/min at ambient pressure. After each completed test, the test chamber was cooled by a Julabo FL1703 chiller. The sample is contained in a SETARAM 100 µL alumina crucible. The test specimens were heated from 30°C to 1400°C using a heating rate of 20°C/min. The testing was not conducted at an elevated pressure. The reference material was selected as an empty crucible.

The instrument was calibrated the week of September 3, 2021, to generate temperature correction coefficients and a sensitivity coefficient to convert the heat flow in terms of energy by measurement of the melting points and heats of fusion of three standard reference materials (indium, bismuth, and tin) at two different heating rates (5 and 10°C/min) per the apparatus manufacturer’s recommendations. The calibration trials were performed using the same type of crucible, purge gas, and flow rates specified above. The results of the calibration to determine the Temperature Correction Coefficients are as follows:

Table 6: September 3, 2021: Temperature Correction Coefficients

Material	Melt (°C)	Melt Measured (°C)	
		5°C/min	10°C/min
Indium	156.59	153.22	152.72
Tin	231.94	228.30	230.64

Lead	327.50	322.36	322.58
Zinc	419.60	415.60	415.52
Aluminum	660.30	654.67	658.29
Silver	961.80	952.50	953.05
Gold	1064.20	1058.00	1059.01

Based on these values, the constants for the temperature correction coefficients for the SETARAM 100 µL alumina crucible were determined to be:

$$C = B_0 + B_1T + B_2R$$

Where: C = Correction (°C)
T = Temperature (°C)
R = Heating rate (K/min)
B_0 = -3.9898
B_1 = -4.363 x 10^{-3}
B_2 = 2.0546 x 10^{-1}

The results of the calibration to determine the Sensitivity Coefficients are as follows:

Table 7: September Calibration: Sensitivity Coefficients

Material	Enthalpy (J/g)	Enthalpy Measured (J/g·K)	
		Sensitivity	Delta
Indium	28.5	0.2940	-0.00091
Tin	60.2	0.2870	0.00242
Lead	23	0.2797	-0.00182
Aluminum	401	0.2864	0.00052
Silver	104.8	0.2474	-0.00039
Gold	64.5	0.2258	0.00019

Based on these values, the manufacturer's default Sensitivity Coefficients were the best fit to convert the heat flow:

$$S = A0 + A1 \cdot T + A2 \cdot T^2 + A3 \cdot T^3 + A4 \cdot T^4$$

Where: S = Sensitivity (µV/mW)
T = Temperature (°C)
$A0$ = 3.5095 x 10^{-1}
$A1$ = -5.7595 x 10^{-4}
$A2$ = 1.6236 x 10^{-6}

$A3$ = -1.759942 x 10^{-9}
$A4$ = 5.9925 x 10^{-13}

Test specimens were weighed using a calibrated Sartorius CPA225D balance with a weighing capacity of 100 grams and a sensitivity of ±10 µg.

6.5.3 Test Results

The test results are summarized in the following table. The DSC thermograms for each trial are provided in the Appendix. A nominal sample size of 1 milligram was utilized for each trial.

Table 8: Summary of High-Temperature DSC Test Results

Sample ID	Metal	Metal Oxide	Reaction Onset Temperature (°C)		Observations
			Trial 1	Trial 2	
Al-MnO_2 Thermite – Large-Scale Mix ID #7 (SMS mixed)					
LS #7	Fine	Fine	N/E	999	Small exotherm and mass change around 600 and 1400°C (Trial 2); small/moderate exotherm around 950°C.
LS #7	Fine	Medium	N/E	N/E	Small exotherm around 1400°C (Trial 2).
LS #7	Fine	Coarse	N/E	N/E	Small exotherm around 1500°C.
LS #7	Medium	Fine	1357	1363	Moderate, wide exotherm at 1400°C.
LS #7	Medium	Medium	N/E	N/E	No exotherms.
LS #7	Medium	Coarse	1413	1411	Moderate exotherm around 1400°C.
LS #7	Coarse	Fine	1409	1371	Moderate exotherm around 1400°C.
LS #7	Coarse	Medium	N/E	N/E	Small exotherm around 1400°C for Trial 1; absent from Trial 2.
LS #7	Coarse	Coarse	1410	N/E	Moderate exotherm around 1400°C; smaller in Trial 2. Small endotherm around 650°C.
Mg & Al – MoO_3 & CuO Thermite – Large-Scale Mix ID #8 (SMS mixed)					
LS #8	Fine	Fine	N/E	N/E	Small exotherm and mass change around 560°C; small endotherms around 450°C and 1050°C.
LS #8	Fine	Medium	790	762	Tall, sharp exotherm around 800°C with smaller exotherms around 650 and 950°C.
LS #8	Fine	Coarse	845	N/E	Tall, sharp exotherm around 850°C in Trial 1; no exotherms for Trial 2
LS #8	Medium	Fine	N/E	N/E	Small exotherms around 600°C for both trials and 800°C for Trial 1.

Sample ID	Metal	Metal Oxide	Reaction Onset Temperature (°C)		Observations
			Trial 1	Trial 2	
LS #8	Medium	Medium	N/E	N/E	No exotherms for Trial 1; small exotherms at 850 and 1100°C for Trial 2.
LS #8	Medium	Coarse	N/E	867	Small exotherm at 1100°C for Trial 1; tall, sharp exotherm around 900°C with smaller exotherms around 750 and 1000°C.
LS #8	Coarse	Fine	732	728	Sharp, double exotherms around 670°C.
LS #8	Coarse	Medium	683	676	Tall, sharp exotherm around 680°C; smaller exotherm around 850°C.
LS #8	Coarse	Coarse	N/E	826	Small exotherm at 600°C; tall, sharp exotherm around 830°C for Trial 2.
Ti-MnO_2 Thermite – Small-Scale Mix ID #3B (SMS mixed)					
SS #3B	Fine	Fine	N/E	N/E	No significant exotherms in Trials 1 and 2
SS #3B	Fine	Medium	N/E	N/E	No exotherms.
SS #3B	Fine	Coarse	N/E	N/E	No exotherms.
SS #3B	Medium	Fine	N/E	N/E	Small, wide exotherm around 1350°C.
SS #3B	Medium	Medium	N/E	N/E	Small, wide exotherm around 1350°C in Trial 1.
SS #3B	Medium	Coarse	N/E	N/E	No exotherms.
SS #3B	Coarse	Fine	N/E	N/E	No exotherms.
SS #3B	Coarse	Medium	N/E	N/E	Small, wide exotherm around 1350°C in Trial 1.
SS #3B	Coarse	Coarse	N/E	N/E	Small, wide exotherm around 800°C.
Mg-MnO_2 Thermite – Small-Scale Mix ID #4 (SMS mixed)					
SS #4	Fine	Fine	568	569	Tall, sharp exotherm around 570°C.
SS #4	Fine	Medium	627	614	Tall, sharp exotherm around 600°C; small exotherm in Trial 1 and medium, wide exotherm in Trial 2 around 1100°C.
SS #4	Fine	Coarse	625	636	Tall, sharp exotherm around 600°C and small to moderate, wide exotherm around 1150°C with mass change.
SS #4	Medium	Fine	635	630	Tall, sharp exotherm around 600°C and moderate, wide exotherm around 1300°C.

Sample ID	Metal	Metal Oxide	Reaction Onset Temperature (°C)		Observations
			Trial 1	Trial 2	
SS #4	Medium	Medium	620	617	Tall, sharp exotherm around 600°C and moderate, wide exotherms around 1100 and 1300°C.
SS #4	Medium	Coarse	611	618	Tall exotherm around 600°C and tall, wide exotherm around 1000°C.
SS #4	Coarse	Fine	N/E	N/E	Small, wide exotherm around 1500°C for Trial 2.
SS #4	Coarse	Medium	N/E	620	No exotherms for Trial 1; tall, sharp exotherm around 600°C for Trial 1 with moderate, wide exotherm around 1050°C.
SS #4	Coarse	Coarse	N/E	623	No exotherms for Trial 1; tall, sharp exotherm around 600°C for Trial 1 with moderate, wide exotherm around 1050°C.
Al-MoO_3 Thermite – Small-Scale Mix ID #9 (SMS mixed)					
SS #9	Fine	Fine	N/E	N/E	Small exotherm at 855°C.
SS #9	Fine	Medium	N/E	N/E	Small exotherm at 1100°C.
SS #9	Fine	Coarse	1176	1300	Sharp, intermittent exotherms at 1100°C.
SS #9	Medium	Fine	N/E	N/E	No exotherms.
SS #9	Medium	Medium	1113	1126	Small exotherm at 792°C; sharp, intermittent exotherms around 1100°C.
SS #9	Medium	Coarse	1394	1191, 1268	Sharp, intermittent exotherms around 1200 - 1400°C.
SS #9	Coarse	Fine	961	916	Tall, wide exotherm at 960°C with smaller peaks around 1100 - 1250°C.
SS #9	Coarse	Medium	1203	1258	Tall, sharp exotherm near 1200°C for Trial 1 followed by small intermittent peaks around 1250 - 1450°C.
SS #9	Coarse	Coarse	1373	1304	Multiple strong peaks around 1300°C.
Al-SnO_2 Thermite – Small-Scale Mix ID #19 (SMS mixed)					
SS #19	Fine	Fine	N/E	N/E	Small exotherm around 950°C.
SS #19	Fine	Medium	N/E	N/E	No visible exotherms.
SS #19	Fine	Coarse	N/E	N/E	Multiple small exotherms around 1100 - 1400°C for Trial 1; no exotherms for Trial 2.
SS #19	Medium	Fine	1361	1370	Tall and wide exotherm around 1350°C.

Sample ID	Metal	Metal Oxide	Reaction Onset Temperature (°C)		Observations
			Trial 1	Trial 2	
SS #19	Medium	Medium	1319	1356	Tall and wide exotherm around 1350°C.
SS #19	Medium	Coarse	1406	1359	Tall and wide exotherm around 1350°C.
SS #19	Coarse	Fine	1461	1505	Tall and wide exotherm around 1350°C.
SS #19	Coarse	Medium	1229	1499	Moderate, wide exotherm around 1200°C for Trial 1 and 1500°C for Trial 2.
SS #19	Coarse	Coarse	1333	1405	Sharp, intermittent exotherms (crackling) around 1300 - 1500°C.
Al-Bi_2O_3 Thermite – Small-Scale Mix ID #24 (SMS mixed)					
SS #24	Fine	Fine	N/E	N/E	Small exotherm around 800°C.
SS #24	Fine	Medium	N/E	N/E	No exotherms for Trial 1; small exotherms around 800°C and multiple small exotherms around 1450°C for Trial 2.
SS #24	Fine	Coarse	N/E	N/E	No exotherms for Trial 1; multiple small exotherms around 1450°C for Trial 2.
SS #24	Medium	Fine	1499	N/E	For Trial 1, a tall, sharp exotherm around 1500°C followed by multiple small, sharp exotherms; small exotherm around 800°C for Trial 2 followed by a small, wide exotherm around 1000°C.
SS #24	Medium	Medium	1404	1354	Tall, sharp exotherm around 1400°C for Trial 1; small exotherms around 1350°C for Trial 2.
SS #24	Medium	Coarse	N/E	1450	Small exotherms around 750°C for Trial 1; tall, sharp exotherm around 1450°C for Trial 2.
SS #24	Coarse	Fine	N/E	N/E	Small exotherm around 800°C and small, wide exotherm around 900°C.
SS #24	Coarse	Medium	N/E	N/E	No significant exotherms.
SS #24	Coarse	Coarse	N/E	1449	No exotherms for Trial 1; multiple small exotherms around 1400°C for Trial 2.
Ti-Bi_2O_3 Thermite – Small-Scale Mix ID #48 (SMS Mixed)					
SS #48	Fine	Fine	N/E	N/E	Small, wide exotherm around 930°C.
SS #48	Fine	Medium	N/E	N/E	Moderate, wide exotherm around 1000°C; small exotherm around 820°C for Trial 2.

Sample ID	Metal	Metal Oxide	Reaction Onset Temperature (°C)		Observations
			Trial 1	Trial 2	
SS #48	Fine	Coarse	N/E	N/E	Small, sharp exotherm around 820°C; small exotherm around 1000°C for Trial 1.
SS #48	Medium	Fine	N/E	N/E	Small exotherm around 820°C for Trial 1 and sharp for Trial 2; moderate, wide exotherm around 1000°C for Trial 1.
SS #48	Medium	Medium	N/E	N/E	Small exotherm around 820°C.
SS #48	Medium	Coarse	N/E	N/E	Small, sharp exotherm around 820°C.
SS #48	Coarse	Fine	N/E	N/E	Small exotherm around 820°C; small exotherm around 1000°C for Trial 1.
SS #48	Coarse	Medium	N/E	N/E	Small exotherm around 820°C; small exotherm around 1000°C for Trial 1.
SS #48	Coarse	Coarse	N/E	N/E	Small, sharp exotherm around 820°C.

*n/e - No evidence of a significant exotherm for test sample.

6.5.4 Assessment of Test Results

The Al-MnO_2 Thermite – Large-Scale Mix ID #7 (SMS mixed) DSC thermograms were consistent with each other with the following characteristic features: small endotherm around 650°C followed by a large, gradual endotherm with a minima around 1400°C. There was also often a small inflection in the heat flow and mass around 700°C and a moderate exotherm around the minima of the endotherm for larger particle sizes. The thermograms for the fine/fine, fine/medium and medium/fine combinations of the metal/metal-oxide thermite did not exhibit sudden, sharp exothermic activity that would be consistent with that of a fast-reacting thermite as observed in the hotwire explosion screening trials.

The Mg & Al – MoO_3 & CuO Thermite – Large-Scale Mix ID #8 (SMS mixed) DSC thermograms were fairly consistent with each other with the following characteristic features: small endotherm around 450°C followed by a large, gradual endotherm that was more pronounced after 1150°C; exotherms around 650 and 850°C. The thermograms for the fine/medium, fine/coarse, medium/coarse, coarse/medium and coarse/coarse combinations of the metal/metal-oxide thermite exhibited sudden, sharp exothermic activity consistent with that of the hotwire explosion screening test results.

The Ti-MnO_2 Thermite – Small-Scale Mix ID #3B (SMS mixed) DSC thermograms were comparable with each other but did not show any significant exothermic activity.

The Mg-MnO_2 Thermite – Small-Scale Mix ID #4 (SMS mixed) DSC thermograms were consistent with each other. The exothermic activity was very consistent with that obtained in the hotwire explosion screening trials; each exhibited sudden, sharp exothermic activity that would be consistent with that of a fast-reacting thermite except for the coarse/fine combination of the metal/metal-oxide thermite that also resulted in no evidence of a significant exotherm.

The Al-MoO_3 Thermite – Small-Scale Mix ID #9 (SMS mixed) DSC thermograms were consistent with each other with the following characteristic features: small endotherm around 650°C and sharp, erratic exothermic behavior around 1100 - 1400°C that is consistent with that of a violent, non-propagating reaction (e.g., crackling / intermittent consumption).

The Al-SnO_2 Thermite – Small-Scale Mix ID #19 (SMS mixed) DSC thermograms were consistent with each other with the following characteristic features: small endotherm around 650°C followed by a large, gradual endotherm with a minima around 1400°C. There was also often a moderate, wide exotherm around the minima of the endotherm for larger particle sizes. The thermograms for the fine/fine and coarse/fine combinations of the metal/metal-oxide thermite did not exhibit sudden, sharp exothermic activity that would be consistent with that of a fast-reacting thermite as observed in the hotwire explosion screening trials.

The Al-Bi_2O_3 Thermite – Small-Scale Mix ID #24 (SMS mixed) DSC thermograms were consistent with each other with the following characteristic features: small endotherms around 600 and 650°C followed by a large, gradual endotherm with a minima around 1400°C. In the hotwire explosion screening tests, an explosion result was obtained for each of the fine and medium metal combinations with fine, medium or coarse metal oxide. Similarly, for the DSC trials none of coarse metal combinations resulted in sudden, sharp exothermic activity that would be consistent with that of a fast-reacting thermite. Conversely, each of the medium metal combinations did demonstrate sudden, sharp exothermic activity; the fine metal combinations did not.

The Ti-Bi_2O_3 Thermite – Small-Scale Mix ID #48 (SMS Mixed) DSC thermograms were consistent with each other with the following characteristic features: small endotherm around 720°C followed by a large, gradual endotherm with a minima around 1400°C. In the hotwire explosion screening tests, rapid reactions were obtained for each of the metal/metal-oxide thermite combinations of various particle sizes. Conversely, none of the DSC trials resulted in sudden, sharp exothermic activity.

The following thermites did not exhibit DSC results with sudden, sharp exothermic activity that would be consistent with that of a fast-reacting (i.e., exploding) thermite:

- Al-MnO_2 Thermite – Large-Scale Mix ID #7 (SMS mixed)
- Ti-MnO_2 Thermite – Small-Scale Mix ID #3B (SMS mixed)
- Al-SnO_2 Thermite – Small-Scale Mix ID #19 (SMS mixed)
- Ti-Bi_2O_3 Thermite – Small-Scale Mix ID #48 (SMS Mixed)

The absence of a sudden reaction for these thermites in the DSC test could be due to an absence of critical mass (i.e., smaller quantities may not be susceptible to deflagration-to-detonation transition), the difference in the heating rates (i.e., low heat transfer from indirect convective heating by DSC furnace versus high heat transfer through direct conductive heating by hotwire), the probability of transition, the composition of the 1-mg sample, the distribution of the pile or other possible variables in the test methodologies and/or configurations.

APPENDIX A
– Laboratory Data Sheets

Figure A1: Laboratory Data Sheets for Mix ID LS #7 - Fine Al - Medium MnO_2

Material: LS #7 (fine, medium) **Operator:** DMS
Date: 10/16/2021 **Relative Humidity:** 40% **Temperature:** 65°F **Project:** DOT1-6265c

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F		
Level	100																															0	30

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: LS #7 (fine, medium) **Operator:** JDZ
Date: 11/24/2021 **Relative Humidity:** 20% **Temperature:** 70°F **Project:** DOT1-6265c

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI							S																										
Level	0.060 [0.75]						Z																									1	0
RSI		S				F		S						S														S		S			
Level	0.030 [0.38]	Z						Z						Z														Z		Z		5	1
RSI			S		F				S		S		F		S												F		F		F		
Level	0.015 [0.19]		Z						Z		Z				Z																	4	5
RSI				F						F		F				S						S				F							
Level	0.010 [0.13]															Z						Z										2	4
RSI																	S		S		F		S		F								
Level	0.0050 [0.063]																Z		Z				Z									3	2
RSI																		F		F				F									
Level	0.0025 [0.031]																															0	3

Material: LS #7 (fine, medium) **Operator:** DJH
Date: 19/19/21 **Relative Humidity:** 41% **Temperature:** 66°F **Project:** DOT1-6265c

ABL Friction	lbf (3ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	S				F	F	F	F	F	F	S						F	F	F	F	F		
Level	1000										Z										Z											2	20
RSI												S		F								S				F							
Level	795											Z										Z										2	2
RSI													F										S		F								
Level	635																						Z									1	2
RSI																								F									
Level	505																															0	1

Number indicates amount
of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction

F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace
M = Smoke
Z = Spark
A = Flame
B = Flash
X = Sample Consumed
L = Loud Report or Explosion
H = Hardware Damage
P = Pop or Small Explosion
HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A2: Laboratory Data Sheets for Mix ID LS #7 - Fine Al - Coarse MnO_2

Material: LS #7 (fine, coarse) **Operator:** DMS
Date: 10/16/2021 **Relative Humidity:** 39% **Temperature:** 65°F **Project:** DOT1-6265c

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F		
Level	100																															0	30

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: LS #7 (fine, coarse) **Operator:** JDZ
Date: 11/24/2021 **Relative Humidity:** 23% **Temperature:** 70°F **Project:** DOT1-6265c

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI																															S		
Level	0.120 [1.50]																														Z	1	0
RSI						S																				S		S		F			
Level	0.060 [0.75]					Z																				Z		Z				3	1
RSI			S		F		S																		F		F		F				
Level	0.030 [0.38]		Z				Z																									2	4
RSI		F		F				S														S		F									
Level	0.015 [0.19]							Z														Z										2	3
RSI									S								S		S		F		F										
Level	0.010 [0.13]								Z								Z		Z													3	2
RSI										S		S		S		F		F		F													
Level	0.0050 [0.063]									Z		Z		Z																		3	3
RSI											F		F		F																		
Level	0.0025 [0.031]																															0	3

Material: LS #7 (fine, coarse) **Operator:** DJH
Date: **Relative Humidity:** **Temperature:** °F **Project:** DOT1-6265c

ABL Friction	lbf (3ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI			F	F	S		F	F	F	F	F	F	F	F	S								F	F	F	S							
Level	1000				Z										Z											Z						3	13
RSI						F										S				S		F					S		S		F		
Level	795															Z				Z							Z		Z			4	3
RSI																	S		F		F							F		F			
Level	635																Z															1	4
RSI																		F															
Level	505																															0	1
RSI		F																															
Level	400																															0	1

Number indicates amount
of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace X = Sample Consumed
M = Smoke L = Loud Report or Explosion
Z = Spark H = Hardware Damage
A = Flame P = Pop or Small Explosion
B = Flash HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A3: Laboratory Data Sheets for Mix ID LS #7 – Medium Al - Fine MnO_2

Material: LS #7 (medium, fine) **Operator:** DMS
Date: 10/17/2021 **Relative Humidity:** 39% **Temperature:** 65°F **Project:** DOT1-6265c

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F		
Level	100																															0	30

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: LS #7 (medium, fine) **Operator:** JDZ
Date: 11/24/2021 **Relative Humidity:** 20% **Temperature:** 70°F **Project:** DOT1-6265c

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI								S		S																							
Level	0.200 [2.50]							Z		Z																						2	0
RSI							F		F		S				S		S						S						S		S		
Level	0.120 [1.50]										Z				M		M						Z						Z		Z	6	2
RSI				S		F						S		F		F		S		S		F		S				F		F			
Level	0.060 [0.75]			Z								Z						Z		Z				Z								5	6
RSI			F		F								F						F		F				S		F						
Level	0.030 [0.38]																								Z							1	6
RSI		F																								F							
Level	0.015 [0.19]																															0	2

Material: LS #7 (medium, fine) **Operator:** DJH
Date: 10/19/2021 **Relative Humidity:** 41% **Temperature:** 67°F **Project:** DOT1-6265c

ABL Friction	lbf (3ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F		
Level	1000																															0	30

Number indicates amount of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace
M = Smoke
Z = Spark
A = Flame
B = Flash
X = Sample Consumed
L = Loud Report or Explosion
H = Hardware Damage
P = Pop or Small Explosion
HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A4: Laboratory Data Sheets for Mix ID LS #7 – Medium Al - Medium MnO_2

Material: LS #7 (medium, medium) **Operator:** DMS
Date: 10/17/2021 **Relative Humidity:** 41% **Temperature:** 67°F **Project:** DOT1-6265c

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F		
Level	100																															0	30

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: LS #7 (medium, medium) **Operator:** JDZ
Date: 11/24/2021 **Relative Humidity:** 20% **Temperature:** 70°F **Project:** DOT1-6265c

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI																															S		
Level	0.200 [2.50]																														Z	1	0
RSI																														F			
Level	0.120 [1.50]																															0	1
RSI			S						S												S		S						F				
Level	0.060 [0.75]		Z						Z												Z		Z									4	1
RSI		F		S				F		S		S						S		F		F		S				F					
Level	0.030 [0.38]			Z						Z		Z						Z						Z								5	5
RSI					S		F				F		S		S		F		F						S		F						
Level	0.015 [0.19]				Z								Z		Z										Z							4	5
RSI						F								F		F										F							
Level	0.010 [0.13]																															0	4

Material: LS #7 (medium, medium) **Operator:** DJH
Date: 10/20/2021 **Relative Humidity:** 28% **Temperature:** 70°F **Project:** DOT1-6265c

ABL Friction	lbf (3ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		S																															
Level	1000	Z																														1	0
RSI																											S						
Level	795																										Z					1	0
RSI			S																							F		S					
Level	635		Z																									Z				2	1
RSI					S		S		S																F				S				
Level	505				Z		Z		Z																				Z			4	1
RSI				F		F		F		S						S						S		F						S			
Level	400									Z						Z						Z								Z		4	4
RSI											S		S		F		S		S		F		F								F		
Level	320										Z		Z				Z		Z													4	4
RSI												F		F				F		F													
Level	255																															0	4

Number indicates amount of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace
M = Smoke
Z = Spark
A = Flame
B = Flash
X = Sample Consumed
L = Loud Report or Explosion
H = Hardware Damage
P = Pop or Small Explosion
HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A5: Laboratory Data Sheets for Mix ID LS #7 – Medium Al - Coarse MnO_2

Material: LS #7 (medium, coarse) **Operator:** DMS
Date: 10/17/2021 **Relative Humidity:** 30% **Temperature:** 67°F **Project:** DOT1-6265c

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F		
Level	100																															0	30

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: LS #7 (medium, coarse) **Operator:** JDZ
Date: 11/24/2021 **Relative Humidity:** 20% **Temperature:** 70°F **Project:** DOT1-6265c

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI														S				S															
Level	0.120 [1.50]													P				P														2	0
RSI													F		S		F		S		S												
Level	0.060 [0.75]														Z				Z		Z											3	2
RSI		S				S				S		F				F				F		S						S		S			
Level	0.030 [0.38]	Z				Z				Z												Z						Z		Z		6	3
RSI			S		F		S		F		F												S		S		F		F		F		
Level	0.015 [0.19]		Z				Z																Z		Z							4	6
RSI				F				F																F		F							
Level	0.010 [0.13]																															0	4

Material: LS #7 (medium, coarse) **Operator:** DJH
Date: 10/20/2021 **Relative Humidity:** 31% **Temperature:** 65°F **Project:** DOT1-6265c

ABL Friction	lbf (3ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		S																															
Level	1000	Z																														1	0
RSI					S		S																										
Level	795				Z		Z																									2	0
RSI				F		F		S						S																			
Level	635							Z						Z																		2	2
RSI									S		S		F		S														S				
Level	505								Z		Z				Z														Z			4	1
RSI			F							F		F				S										S		F		S			
Level	400															Z										Z				Z		3	4
RSI																	S				S		S		F		F				S		
Level	320																Z				Z		Z								Z	4	2
RSI																		S		F		F		F									
Level	255																	Z														1	3
RSI																			F														
Level	200																															0	1

Number indicates amount of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)

S = Go or Reaction

F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace X = Sample Consumed
M = Smoke L = Loud Report or Explosion
Z = Spark H = Hardware Damage
A = Flame P = Pop or Small Explosion
B = Flash HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A6: Laboratory Data Sheets for Mix ID LS #7 – Coarse Al - Fine MnO_2

Material: LS #7 (coarse, fine) **Operator:** DMS
Date: 10/17/2021 **Relative Humidity:** 29% **Temperature:** 66°F **Project:** DOT1-6265c

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F		
Level	100																															0	30

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: LS #7 (coarse, fine) **Operator:** JDZ
Date: 11/24/2021 **Relative Humidity:** 20% **Temperature:** 70°F **Project:** DOT1-6265c

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI																											S				S		
Level	0.750 [9.38]																										Z				Z	2	0
RSI																S						S		S		F		S		F			
Level	0.350 [4.38]															Z						P		P				P				4	2
RSI											S				F		S		S		F		F		F				F				
Level	0.200 [2.50]										Z						Z		Z													3	5
RSI				S						F		S		F				F		F													
Level	0.120 [1.50]			Z								Z																				2	4
RSI			F		S		S		F				F																				
Level	0.060 [0.75]				Z		Z																									2	3
RSI		F				F		F																									
Level	0.030 [0.38]																															0	3

Material: LS #7 (coarse, fine) **Operator:** DJH
Date: 10/19/2021 **Relative Humidity:** 40% **Temperature:** 65°F **Project:** DOT1-6265c

ABL Friction	lbf (3ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F		
Level	1000																															0	30

Number indicates amount
of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction

F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace X = Sample Consumed
M = Smoke L = Loud Report or Explosion
Z = Spark H = Hardware Damage
A = Flame P = Pop or Small Explosion
B = Flash HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Material: LS #7 (medium, coarse) **Operator:** DMS
Date: 10/17/2021 **Relative Humidity:** 30% **Temperature:** 67°F **Project:** DOT1-6265c

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F		
Level	100																															0	30

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: LS #7 (medium, coarse) **Operator:** JDZ
Date: 11/24/2021 **Relative Humidity:** 20% **Temperature:** 70°F **Project:** DOT1-6265c

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI														S				S															
Level	0.120 [1.50]													P				P														2	0
RSI													F		S		F		S		S												
Level	0.060 [0.75]														Z				Z		Z											3	2
RSI		S				S				S		F				F				F		S						S		S			
Level	0.030 [0.38]	Z				Z				Z												Z						Z		Z		6	3
RSI			S		F		S		F		F												S		S		F		F		F		
Level	0.015 [0.19]		Z				Z																Z		Z							4	6
RSI				F				F																F		F							
Level	0.010 [0.13]																															0	4

Material: LS #7 (medium, coarse) **Operator:** DJH
Date: 10/20/2021 **Relative Humidity:** 31% **Temperature:** 65°F **Project:** DOT1-6265c

ABL Friction	lbf (3ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		S																															
Level	1000	Z																														1	0
RSI					S		S																										
Level	795				Z		Z																									2	0
RSI				F		F		S						S																			
Level	635							Z						Z																		2	2
RSI									S		S		F		S														S				
Level	505								Z		Z				Z														Z			4	1
RSI			F							F		F				S										S		F		S			
Level	400															Z										Z				Z		3	4
RSI																	S				S		S		F		F				S		
Level	320																Z				Z		Z								Z	4	2
RSI																		S		F		F		F									
Level	255																	Z														1	3
RSI																			F														
Level	200																															0	1

Number indicates amount
<u>of sample consumption</u>
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)

S = Go or Reaction

F = No-Go or No Reaction

<u>Reaction Severity Index (RSI)</u>
T = Flame Trace X = Sample Consumed
M = Smoke L = Loud Report or Explosion
Z = Spark H = Hardware Damage
A = Flame P = Pop or Small Explosion
B = Flash HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A7: Laboratory Data Sheets for Mix ID LS #7 – Coarse Al - Medium MnO_2

Material: LS #7 (coarse, medium) **Operator:** DMS
Date: 10/16/2021 **Relative Humidity:** 40% **Temperature:** 66°F **Project:** DOT1-6265c

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F		
Level	100																															0	30

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: LS #7 (coarse, medium) **Operator:** JDZ
Date: 11/24/2021 **Relative Humidity:** 20% **Temperature:** 70°F **Project:** DOT1-6265c

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI																												S					
Level	0.200 [2.50]																											Z				1	0
RSI																							S				F		S		S		
Level	0.120 [1.50]																						Z						Z		Z	3	1
RSI		S		S						S		S				S		S		S		F		S		F				F			
Level	0.060 [0.75]	Z		Z						Z		Z				Z		Z		Z				Z								8	3
RSI			F		S		S		F		F		S		F		F		F		F				F								
Level	0.030 [0.38]				Z		Z						Z																			3	8
RSI						F		F						F																			
Level	0.015 [0.19]																															0	3

Material: LS #7 (coarse, medium) **Operator:** DJH
Date: 10/20/2021 **Relative Humidity:** 29% **Temperature:** 68°F **Project:** DOT1-6265c

ABL Friction	lbf (3ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	S																														
Level	1000		A																													1	1
RSI				S																													
Level	795			Z																												1	0
RSI																																	
Level	635																															0	0
RSI					S																												
Level	505				Z																											1	0
RSI																																	
Level	400																															0	0
RSI						S																									S		
Level	320					Z																									Z	2	0
RSI								S																				S		F			
Level	255							Z																				Z				2	1
RSI							F		S																		F		F				
Level	200								Z																							1	3
RSI										S												S				F							
Level	160									Z												Z										2	1
RSI											S						S		S		F		S		F								
Level	127										Z						Z		Z				Z									4	2
RSI												S		S		F		F		F				F									
Level	100											Z		Z																		2	4
RSI													F		F																		
Level	80																															0	2

Number indicates amount
<u>of sample consumption</u>
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace X = Sample Consumed
M = Smoke L = Loud Report or Explosion
Z = Spark H = Hardware Damage
A = Flame P = Pop or Small Explosion
B = Flash HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A8: Laboratory Data Sheets for Mix ID LS #7 – Coarse Al - Coarse MnO2

Material: LS #7 (coarse, coarse) **Operator:** DMS
Date: 10/16/2021 **Relative Humidity:** 41% **Temperature:** 66°F **Project:** DOT1-6265c

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F		
Level	100																															0	30

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: LS #7 (coarse, coarse) **Operator:** JDZ
Date: 11/24/2021 **Relative Humidity:** 20% **Temperature:** 70°F **Project:** DOT1-6265c

ABL ESD	μF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI												F	S		F	F	F	S		S		S								S			
Level	0.750 [9.38]												Z					Z		Z		Z								Z		5	4
RSI							S		S		F			F					F		F		S		S				F		F		
Level	0.350 [4.38]						Z		P														Z		Z							4	6
RSI						F		F		F														F		S		F					
Level	0.200 [2.50]																									Z						1	5
RSI					F																						F						
Level	0.120 [1.50]																															0	2
RSI		S		F																													
Level	0.060 [0.75]	Z																														1	1
RSI			F																														
Level	0.030 [0.38]																															0	1

Material: LS #7 (coarse, coarse) **Operator:** DJH
Date: 10/19/2021 **Relative Humidity:** 40% **Temperature:** 68°F **Project:** DOT1-6265c

ABL Friction	lbf (3ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	S																														
Level	1000		Z																													1	1
RSI				S																													
Level	795			Z																												1	0
RSI					S		S		S																								
Level	635				Z		Z		Z																							3	0
RSI						F		F		S																							
Level	505									Z																						1	2
RSI											S						S																
Level	400										Z						Z															2	0
RSI												S		S		F		S															
Level	320											Z		Z				Z														3	1
RSI													F		F				S														
Level	255																		Z													1	2
RSI																				S													
Level	200																			Z												1	0
RSI																					S								S				
Level	160																				Z								Z			2	0
RSI																						S		S		S		F		S			
Level	127																					Z		Z		Z				Z		4	1
RSI																							F		F		F				F		
Level	100																															0	4

Number indicates amount
of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace X = Sample Consumed
M = Smoke L = Loud Report or Explosion
Z = Spark H = Hardware Damage
A = Flame P = Pop or Small Explosion
B = Flash HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A9: Laboratory Data Sheets for Mix ID LS #8 – Fine Mg & Al - Medium MoO_3 & CuO

Material: LS #8 (fine, medium) **Operator:** DMS
Date: 10/17/2021 **Relative Humidity:** 35% **Temperature:** 64°F **Project:** DOT1-6265c

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	S		F	F	F	F	F	F	F	F	F	F	F	F	F	F	1	28
Level	100															Z																	
RSI																	F															0	1
Level	79.4																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: LS #8 (fine, medium) **Operator:** JDZ
Date: 11/24/2021 **Relative Humidity:** 20% **Temperature:** 69°F **Project:** DOT1-6265c

ABL ESD	μF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		S		S		S		S		S						S						S		S		S		S				10	0
Level	0.015 [0.19]	Z		Z		Z		Z		Z						Z						Z		Z		Z		Z					
RSI			F		F		F		F		S		S		F		S				F		F		F		F		S		F	4	10
Level	0.010 [0.13]										Z		Z				Z												Z				
RSI												F		F				S		F										F		1	4
Level	0.0050 [0.063]																	Z															
RSI																			F													0	1
Level	0.0025 [0.031]																																

Material: LS #8 (fine, medium) **Operator:** DJH
Date: 10/20/2021 **Relative Humidity:** 33% **Temperature:** 65°F **Project:** DOT1-6265c

ABL Friction	lbf (3ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI			S																					F	S							2	1
Level	1000		Z																						Z								
RSI				S											S		S						F			S						4	1
Level	795			Z											Z		Z									Z							
RSI					S									F		F		S		S		F					S		S			5	3
Level	635				Z													Z		Z							Z		Z				
RSI							S						F						F		F							F		S		2	4
Level	505						Z																							Z			
RSI		F				F		S		S		F																			F	2	4
Level	400							Z		Z																							
RSI									F		F																					0	2
Level	320																																

Number indicates amount
of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace X = Sample Consumed
M = Smoke L = Loud Report or Explosion
Z = Spark H = Hardware Damage
A = Flame P = Pop or Small Explosion
B = Flash HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A10: Laboratory Data Sheets for Mix ID LS #8 – Fine Mg & Al - Coarse MoO_3 & CuO

Material: LS #8 (fine, coarse) **Operator:** DMS
Date: 10/17/2021 **Relative Humidity:** 34% **Temperature:** 64°F **Project:** DOT1-6265c

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: LS #8 (fine, coarse) **Operator:** JDZ
Date: 11/24/2021 **Relative Humidity:** 20% **Temperature:** 69°F **Project:** DOT1-6265c

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI				S		S																										2	0
Level	0.060 [0.75]			Z		Z																											
RSI			F		F		S		S														S		S		S		S		S	7	2
Level	0.030 [0.38]						Z		Z														Z		Z		Z		Z		Z		
RSI		F						F		S		S		S				S				F		F		F		F		F		4	7
Level	0.015 [0.19]									Z		Z		Z				Z															
RSI											F		F		S		F		S		F											2	4
Level	0.010 [0.13]														Z				Z														
RSI																F				F												0	2
Level	0.0050 [0.063]																																

Material: LS #8 (fine, coarse) **Operator:** DJH
Date: 10/20/2021 **Relative Humidity:** 35% **Temperature:** 64°F **Project:** DOT1-6265c

ABL Friction	lbf (3ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI			F	F	F	S		F	F	F	F	F	F	S		F	S				F	F	S		S		F	F	F	F	F	5	17
Level	1000					Z								Z			Z						Z		Z								
RSI							F								F			S		F				F		F						1	5
Level	795																	Z															
RSI																			F													0	1
Level	635																																
RSI																																0	0
Level	505																																
RSI		F																														0	1
Level	400																																

Number indicates amount
of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace X = Sample Consumed
M = Smoke L = Loud Report or Explosion
Z = Spark H = Hardware Damage
A = Flame P = Pop or Small Explosion
B = Flash HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A11: Laboratory Data Sheets for Mix ID LS #8 – Medium Mg & Al - Fine MoO_3 & CuO

Material: LS #8 (medium, fine) **Operator:** DMS
Date: 10/17/2021 **Relative Humidity:** 34% **Temperature:** 64°F **Project:** DOT1-6265c

MBOM Impact	**cm**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**+**	**-**
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: LS #8 (medium, fine) **Operator:** JDZ
Date: 11/24/2021 **Relative Humidity:** 20% **Temperature:** 70°F **Project:** DOT1-6265c

ABL ESD	**µF [J] @ 5000V**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**+**	**-**
RSI				S				S		S				S		S																5	0
Level	0.060 [0.75]			Z				Z		Z				Z		Z																	
RSI			F		S		F		F		S		F		F		S															3	5
Level	0.030 [0.38]				Z						Z						Z																
RSI		F				F						F						S		S		S		S		S		S		S		7	3
Level	0.015 [0.19]																	Z		Z		Z		Z		Z		Z		Z			
RSI																			F		F		F		F		F		F		F	0	7
Level	0.010 [0.13]																																

Material: LS #8 (medium, fine) **Operator:** DJH
Date: 10/20/2021 **Relative Humidity:** **Temperature:** 64°F **Project:** DOT1-6265c

ABL Friction	**lbf (3ft/sec)**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**+**	**-**
RSI			F	S		F	S		S		S		F	S		F	F	F	S						F	S		F	S		F	8	9
Level	1000			Z			Z		Z		Z			Z					B							Z			Z				
RSI					F			F		F		F			F					S				F			F			F		1	8
Level	795																			Z													
RSI																					S		F									1	1
Level	635																				Z												
RSI		F																				F										0	2
Level	505																																

Number indicates amount
<u>of sample consumption</u>
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

<u>Reaction Severity Index (RSI)</u>
T = Flame Trace
M = Smoke
Z = Spark
A = Flame
B = Flash
X = Sample Consumed
L = Loud Report or Explosion
H = Hardware Damage
P = Pop or Small Explosion
HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A12: Laboratory Data Sheets for Mix ID LS #8 – Medium Mg & Al - Medium MoO_3 & CuO

Material: LS #8 (medium, medium) **Operator:** DMS
Date: 10/17/2021 **Relative Humidity:** 35% **Temperature:** 64°F **Project:** DOT1-6265c

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	S		F	F	F	F	F	F	F	F	F	F	F	F	F	F	1	28
Level	100															Z																	
RSI																	F															0	1
Level	79.4																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: LS #8 (medium, medium) **Operator:** JDZ
Date: 11/24/2021 **Relative Humidity:** 20% **Temperature:** 70°F **Project:** DOT1-6265c

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI																												S				1	0
Level	0.060 [0.75]																											Z					
RSI									S				S		S										S		F		S			5	1
Level	0.030 [0.38]								Z				Z		Z										Z				Z				
RSI		S						F		S		F		F		S				S		S		F		F				S		6	5
Level	0.015 [0.19]	Z								Z						Z				Z		Z								Z			
RSI			S		S		F				F						S		F		F		F								F	3	6
Level	0.010 [0.13]		Z		Z												Z																
RSI				F		F												F														0	3
Level	0.0050 [0.063]																																

Material: LS #8 (medium, medium) **Operator:** DJH
Date: 10/20/2021 **Relative Humidity:** 33% **Temperature:** 64°F **Project:** DOT1-6265c

ABL Friction	lbf (3ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI			S		S																											2	0
Level	1000		Z		Z																												
RSI				F		S														S												2	1
Level	795					Z														Z													
RSI							S						S		S		S		F		S		S									6	1
Level	635						Z						Z		Z		Z				Z		Z										
RSI								S		S		F		F		F		F				F		S								3	5
Level	505							Z		Z														Z									
RSI		F							F		F														S						F	1	4
Level	400																								Z								
RSI																										S		S		F		2	1
Level	320																									Z		Z					
RSI																											F		F			0	2
Level	255																																

Number indicates amount
<u>of sample consumption</u>
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

<u>Reaction Severity Index (RSI)</u>
T = Flame Trace X = Sample Consumed
M = Smoke L = Loud Report or Explosion
Z = Spark H = Hardware Damage
A = Flame P = Pop or Small Explosion
B = Flash HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A13: Laboratory Data Sheets for Mix ID LS #8 – Medium Mg & Al - Coarse MoO_3 & CuO

Material: LS #8 (medium, coarse) **Operator:** DMS
Date: 10/17/2021 **Relative Humidity:** 72% **Temperature:** 65°F **Project:** DOT1-6265c

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	S		F	F	F	F	F	F	F	F	F	S		F	F	F	2	26
Level	100															Z											Z						
RSI																	F											F				0	2
Level	79.4																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: LS #8 (medium, coarse) **Operator:** JDZ
Date: 11/24/2021 **Relative Humidity:** 20% **Temperature:** 70°F **Project:** DOT1-6265c

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI																						S										1	0
Level	0.200 [2.50]																					Z											
RSI																	S				F		S									2	1
Level	0.120 [1.50]																Z						Z										
RSI						S		S						S		F		S		F				S								5	2
Level	0.060 [0.75]					Z		Z						Z				Z						Z									
RSI					F		F		S		S		F		F				F						S				S		S	5	5
Level	0.030 [0.38]								Z		Z														Z				Z		Z		
RSI		S		F						F		F														S		F		F		2	5
Level	0.015 [0.19]	Z																								Z							
RSI			F																								F					0	2
Level	0.010 [0.13]																																

Material: LS #8 (medium, coarse) **Operator:** DJH
Date: 10/20/2021 **Relative Humidity:** 34% **Temperature:** 64°F **Project:** DOT1-6265c

ABL Friction	lbf (3ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		S						S		S		F	F	F	F	F	S		F	F	S		F	F	S		F	F	F	F	F	6	14
Level	1000	Z						Z		Z							Z				Z				Z								
RSI					S		F		F		F							F				F				F						1	6
Level	795				Z																												
RSI				F		F																										0	2
Level	635																																
RSI																																0	0
Level	505																																
RSI			F																													0	1
Level	400																																

Number indicates amount of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace
M = Smoke
Z = Spark
A = Flame
B = Flash
X = Sample Consumed
L = Loud Report or Explosion
H = Hardware Damage
P = Pop or Small Explosion
HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A14: Laboratory Data Sheets for Mix ID LS #8 – Coarse Mg & Al - Fine MoO_3 & CuO

Material: LS #8 (coarse, fine) **Operator:** DMS
Date: 10/17/2021 **Relative Humidity:** 35% **Temperature:** 64°F **Project:** DOT1-6265c

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	S		S		F	S		F	F	F	F	S									4	15
Level	100											Z		Z			Z						Z										
RSI													F		F			F						S								1	3
Level	79.4																							Z									
RSI																									S						F	1	1
Level	63.1																								Z								
RSI																										S				F		1	1
Level	50.1																									Z							
RSI																											S		F			1	1
Level	39.8																										Z						
RSI																												F				0	1
Level	31.6																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: LS #8 (coarse, fine) **Operator:** JDZ
Date: 11/24/2021 **Relative Humidity:** 20% **Temperature:** 70°F **Project:** DOT1-6265c

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI																					S				S							2	0
Level	0.060 [0.75]																				Z				Z								
RSI		S		S		S						S		S						F		S		F		S						7	2
Level	0.030 [0.38]	Z		Z		Z						Z		Z								Z				Z							
RSI			F		F		S		S		F		F		S		S		F				F				S				S	6	6
Level	0.015 [0.19]						Z		Z						Z		Z										Z				Z		
RSI								F		F						F		F										S		F		1	5
Level	0.010 [0.13]																											Z					
RSI																													F			0	1
Level	0.0050 [0.063]																																

Material: LS #8 (coarse, fine) **Operator:** DJH
Date: 10/20/2021 **Relative Humidity:** 33% **Temperature:** 65°F **Project:** DOT1-6265c

ABL Friction	lbf (3ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	S		S		S		S		S		S				S		S				S		S		S		S		F	12	2
Level	1000		Z		Z		Z		Z		Z		Z				Z		Z				Z		Z		Z		Z				
RSI				F		F		F		F		F		S		F		F		S		F		F		F		F		F		2	12
Level	795													Z						Z													
RSI															F						F											0	2
Level	635																																

Number indicates amount
<u>of sample consumption</u>
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace
M = Smoke
Z = Spark
A = Flame
B = Flash
X = Sample Consumed
L = Loud Report or Explosion
H = Hardware Damage
P = Pop or Small Explosion
HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A15: Laboratory Data Sheets for Mix ID LS #8 – Coarse Mg & Al - Medium MoO_3 & CuO

Material: LS #8 (coarse, medium) **Operator:** DMS
Date: 10/17/2021 **Relative Humidity:** 33% **Temperature:** 64°F **Project:** DOT1-6265c

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	S		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	1	28
Level	100								Z																								
RSI										F																						0	1
Level	79.4																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: LS #8 (coarse, medium) **Operator:** JDZ
Date: 11/24/2021 **Relative Humidity:** 20% **Temperature:** 70°F **Project:** DOT1-6265c

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI			S								S		S		S		S		S								S		S		S	9	0
Level	0.060 [0.75]		Z								Z		Z		Z		Z		Z								Z		Z		Z		
RSI		F		S						F		F		F		F		F		S		S		S		F		F		F		4	9
Level	0.030 [0.38]			Z																Z		Z		Z									
RSI					S		S		F												F		F		F							2	4
Level	0.015 [0.19]				Z		Z																										
RSI						F		F																								0	2
Level	0.010 [0.13]																																

Material: LS #8 (coarse, medium) **Operator:** DJH
Date: 10/20/2021 **Relative Humidity:** 34% **Temperature:** 64°F **Project:** DOT1-6265c

ABL Friction	lbf (3ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI			F	S		S																S				S		S				5	1
Level	1000			Z		Z																Z				Z		Z					
RSI					F		S												S		F		S		F		F		S		F	4	5
Level	795						Z												Z				B						Z				
RSI								S		S				S		S		F		F				F						F		4	4
Level	635							Z		B				Z		Z																	
RSI									F		S		F		F		F															1	4
Level	505										Z																						
RSI		F										F																				0	2
Level	400																																

Number indicates amount of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace
M = Smoke
Z = Spark
A = Flame
B = Flash
X = Sample Consumed
L = Loud Report or Explosion
H = Hardware Damage
P = Pop or Small Explosion
HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A16: Laboratory Data Sheets for Mix ID LS #8 – Coarse Mg & Al - Coarse MoO_3 & CuO

Material: LS #8 (coarse, coarse) **Operator:** DMS
Date: 10/17/2021 **Relative Humidity:** 30% **Temperature:** 66°F **Project:** DOT1-6265c

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	S		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	S	2	27
Level	100											Z																			Z		
RSI													F																			0	1
Level	79.4																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: LS #8 (coarse, coarse) **Operator:** JDZ
Date: 11/24/2021 **Relative Humidity:** 20% **Temperature:** 70°F **Project:** DOT1-6265c

ABL ESD	μF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI																						S		S		S		S		S		5	0
Level	0.060 [0.75]																					Z		Z		Z		Z		Z			
RSI			S		S				S								S				F		F		F		F		F		F	4	6
Level	0.030 [0.38]		Z		Z				Z								Z																
RSI		F		F		S		F		S		S		S		F		S		F												5	5
Level	0.015 [0.19]					Z				Z		Z		Z				Z															
RSI							F				F		F		F				F													0	5
Level	0.010 [0.13]																																

Material: LS #8 (coarse, coarse) **Operator:** DJH
Date: 10/20/2021 **Relative Humidity:** 33% **Temperature:** 64°F **Project:** DOT1-6265c

ABL Friction	lbf (3ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		S				S		S		S		F	F	F	F	S		F	F	S		F	F	F	F	F	F	S		F	F	7	14
Level	1000	Z				Z		Z		Z						Z				Z								Z					
RSI					F		F		F		F						F				F								F			0	7
Level	795																																
RSI				F																												0	1
Level	635																																
RSI																																0	0
Level	505																																
RSI			F																													0	1
Level	400																																

Number indicates amount
of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace
M = Smoke
Z = Spark
A = Flame
B = Flash
X = Sample Consumed
L = Loud Report or Explosion
H = Hardware Damage
P = Pop or Small Explosion
HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A17: Laboratory Data Sheets for Mix ID SS #3B – Fine Ti - Medium MnO_2

Material: SS #3B (fine, medium) **Operator:** DMS
Date: 10/7/2021 **Relative Humidity:** 42% **Temperature:** 67°F **Project:** DOT1-6265c

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: SS #3B (fine, medium) **Operator:** JDZ
Date: 11/23/2021 **Relative Humidity:** 25% **Temperature:** 70°F **Project:** DOT1-6265c

ABL ESD	μF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI																						S		S						S		3	0
Level	0.350 [4.38]																					P		Z						P			
RSI																			S		F		F		S				F		S	3	3
Level	0.200 [2.50]																		Z						Z						Z		
RSI																		F		F						S		F				1	3
Level	0.120 [1.50]																									Z							
RSI																	F										F					0	2
Level	0.060 [0.75]																																
RSI														S		F																1	1
Level	0.030 [0.38]													Z																			
RSI			S						S		S		F		F																	3	2
Level	0.015 [0.19]		Z						Z		Z																						
RSI		F		S		S		F		F		F																				2	4
Level	0.010 [0.13]			Z		Z																											
RSI					F		F																									0	2
Level	0.0050 [0.063]																																

Material: SS #3B (fine, medium) **Operator:** DJH
Date: 10/7/2021 **Relative Humidity:** 42% **Temperature:** 67°F **Project:** DOT1-6265c

ABL Friction	lbf (3ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		S																														1	0
Level	400	Z																															
RSI																																0	0
Level	320																																
RSI																																0	0
Level	255																																
RSI			S																													1	0
Level	200		Z																														
RSI																																0	0
Level	160																																
RSI					S																											1	0
Level	127				Z																												
RSI				F		S																										1	1
Level	100					Z																											
RSI							S																									1	0
Level	80						Z																										
RSI								S			S																					2	0
Level	64							Z			Z																						
RSI									S	F		S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	21	1
Level	51								Z			Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z		

Number indicates amount
<u>of sample consumption</u>
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

<u>Reaction Severity Index (RSI)</u>
T = Flame Trace
M = Smoke
Z = Spark
A = Flame
B = Flash
X = Sample Consumed
L = Loud Report or Explosion
H = Hardware Damage
P = Pop or Small Explosion
HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A18: Laboratory Data Sheets for Mix ID SS #3B – Fine Ti - Coarse MnO_2

Material: SS #3B (fine, coarse) **Operator:** DMS
Date: 10/7/2021 **Relative Humidity:** 47% **Temperature:** 69°F **Project:** DOT1-6265c

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: SS #3B (fine, coarse) **Operator:** JDZ
Date: 11/23/2021 **Relative Humidity:** 25% **Temperature:** 71°F **Project:** DOT1-6265c

ABL ESD	μF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI													S		S														S		F	3	1
Level	0.200 [2.50]												Z		Z														Z				
RSI												F		F		S										S		F		F		2	4
Level	0.120 [1.50]															Z										Z							
RSI			S								F						S		S						F		F					3	3
Level	0.060 [0.75]		Z														Z		Z														
RSI		F		S						F								F		S				F								2	4
Level	0.030 [0.38]			Z																Z													
RSI					S		S		F												S		F									3	2
Level	0.015 [0.19]				Z		Z														Z												
RSI						F		F														F										0	3
Level	0.010 [0.13]																																

Material: SS #3B (fine, coarse) **Operator:** DJH
Date: 10/7/2021 **Relative Humidity:** 42% **Temperature:** 67°F **Project:** DOT1-6265c

ABL Friction	lbf (3ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		S																														1	0
Level	400	Z																															
RSI																																0	0
Level	320																																
RSI																																0	0
Level	255																																
RSI			S																													1	0
Level	200		Z																														
RSI																																0	0
Level	160																																
RSI																																0	0
Level	127																																
RSI				S																												1	0
Level	100			Z																													
RSI																																0	0
Level	80																																
RSI					S																					S				S		3	0
Level	64				Z																					Z				Z			
RSI						S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	F		S	S	F		S	22	2
Level	51					Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z			Z	Z			Z		

Number indicates amount <u>of sample consumption</u>
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

<u>Reaction Severity Index (RSI)</u>
T = Flame Trace
M = Smoke
Z = Spark
A = Flame
B = Flash
X = Sample Consumed
L = Loud Report or Explosion
H = Hardware Damage
P = Pop or Small Explosion
HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A19: Laboratory Data Sheets for Mix ID SS #3B – Medium Ti - Fine MnO_2

Material: SS #3B (medium, fine) **Operator:** DMS
Date: 10/7/2021 **Relative Humidity:** 50% **Temperature:** 69°F **Project:** DOT1-6265c

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: SS #3B (medium, fine) **Operator:** JDZ
Date: 11/23/2021 **Relative Humidity:** 26% **Temperature:** 70°F **Project:** DOT1-6265c

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI																			S		F	F	F	F	S		F	F	F	S		3	7
Level	0.750 [9.38]																		M						M					Z			
RSI																S		F		F						F					F	1	4
Level	0.350 [4.38]															Z																	
RSI															F		F															0	2
Level	0.200 [2.50]																																
RSI										S				F																		1	1
Level	0.120 [1.50]									Z																							
RSI									F		S		F																			1	2
Level	0.060 [0.75]										Z																						
RSI		S				S		F				F																				2	2
Level	0.030 [0.38]	Z				Z																											
RSI			S		F		F																									1	2
Level	0.015 [0.19]		Z																														
RSI				F																												0	1
Level	0.010 [0.13]																																

Material: SS #3B (medium, fine) **Operator:** DJH
Date: 10/7/2021 **Relative Humidity:** **Temperature:** °F **Project:** DOT1-6265c

ABL Friction	lbf (3ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI			S								S																					2	0
Level	1000		Z								Z																						
RSI				S		S		S		F		S																				4	1
Level	795			Z		Z		Z				Z																					
RSI					F		F		F				S		S										S		S					4	3
Level	635												Z		Z										Z		Z						
RSI														F		S								F		F		S		S		3	3
Level	505															Z												Z		Z			
RSI		F															S		S				F						F		S	3	3
Level	400																Z		Z												Z		
RSI																		F		S		F										1	2
Level	320																			Z													
RSI																					F											0	1
Level	255																																

Number indicates amount
<u>of sample consumption</u>
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction

F = No-Go or No Reaction

<u>Reaction Severity Index (RSI)</u>
T = Flame Trace X = Sample Consumed
M = Smoke L = Loud Report or Explosion
Z = Spark H = Hardware Damage
A = Flame P = Pop or Small Explosion
B = Flash HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A20: Laboratory Data Sheets for Mix ID SS #3B – Medium Ti - Medium MnO_2

Material: SS #3B (medium, medium) **Operator:** DMS
Date: 10/7/2021 **Relative Humidity:** 44% **Temperature:** 67°F **Project:** DOT1-6265c

MBOM Impact	**cm**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**+**	**-**
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: SS #3B (medium, medium) **Operator:** JDZ
Date: 11/23/2021 **Relative Humidity:** 28% **Temperature:** 70°F **Project:** DOT1-6265c

ABL ESD	**µF [J] @ 5000V**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**+**	**-**
RSI								S																								1	0
Level	0.120 [1.50]							Z																									
RSI			S		S		F		S		S								S		S											6	1
Level	0.060 [0.75]		Z		Z				Z		Z								Z		Z												
RSI		F		F		F				F		S						F		F		S				S						3	6
Level	0.030 [0.38]											Z										Z				Z							
RSI													S		S		F						S		F		S		S		S	6	2
Level	0.015 [0.19]												Z		Z								Z				Z		Z		Z		
RSI														F		F								F				F		F		0	5
Level	0.010 [0.13]																																

Material: SS #3B (medium, medium) **Operator:** DJH
Date: 10/7/2021 **Relative Humidity:** 42% **Temperature:** 67°F **Project:** DOT1-6265c

ABL Friction	**lbf (3ft/sec)**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**+**	**-**
RSI		S																														1	0
Level	400	Z																															
RSI																																0	0
Level	320																																
RSI																																0	0
Level	255																																
RSI			S																													1	0
Level	200		Z																														
RSI																																0	0
Level	160																																
RSI																																0	0
Level	127																																
RSI				S																												1	0
Level	100			Z																													
RSI																																0	0
Level	80																																
RSI					S																											1	0
Level	64				Z																												
RSI						S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	26	0
Level	51					Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z		

Number indicates amount of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction

F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace X = Sample Consumed
M = Smoke L = Loud Report or Explosion
Z = Spark H = Hardware Damage
A = Flame P = Pop or Small Explosion
B = Flash HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A21: Laboratory Data Sheets for Mix ID SS #3B – Medium Ti - Coarse MnO_2

Material: SS #3B (medium, coarse) **Operator:** DMS
Date: 10/7/2021 **Relative Humidity:** 50% **Temperature:** 69°F **Project:** DOT1-6265c

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: SS #3B (medium, coarse) **Operator:** JDZ
Date: 11/23/2021 **Relative Humidity:** 29% **Temperature:** 70°F **Project:** DOT1-6265c

ABL ESD	μF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI											F																					0	1
Level	0.750 [9.38]																																
RSI										F		S		S						S												3	1
Level	0.350 [4.38]											Z		Z						M													
RSI							S		F				F		S				F		S											3	3
Level	0.200 [2.50]						Z								Z						Z												
RSI						F		F								S		F				S										2	3
Level	0.120 [1.50]															Z						Z											
RSI			S		F												F						S				S				F	3	3
Level	0.060 [0.75]		Z																				Z				Z						
RSI		F		F																				S		F		S		F		2	4
Level	0.030 [0.38]																							Z				Z					
RSI																									F				F			0	2
Level	0.015 [0.19]																																

Material: SS #3B (medium, coarse) **Operator:** DJH
Date: 10/7/2021 **Relative Humidity:** 45% **Temperature:** 67°F **Project:** DOT1-6265c

ABL Friction	lbf (3ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		S																														1	0
Level	400	Z																															
RSI			S																													1	0
Level	320		Z																														
RSI				S																												1	0
Level	255			Z																													
RSI																																0	0
Level	200																																
RSI																																0	0
Level	160																																
RSI																																0	0
Level	127																																
RSI					S																											1	0
Level	100				Z																												
RSI						S																										1	0
Level	80					Z																											
RSI							S																									1	0
Level	64						Z																										
RSI								S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	24	0
Level	51							Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z		

Number indicates amount of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace
M = Smoke
Z = Spark
A = Flame
B = Flash
X = Sample Consumed
L = Loud Report or Explosion
H = Hardware Damage
P = Pop or Small Explosion
HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A22: Laboratory Data Sheets for Mix ID SS #3B – Coarse Ti - Fine MnO_2

Material: SS #3B (coarse, fine) **Operator:** DMS
Date: 10/7/2021 **Relative Humidity:** 49% **Temperature:** 68°F **Project:** DOT1-6265c

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: SS #3B (coarse, fine) **Operator:** JDZ
Date: **Relative Humidity:** % **Temperature:** °F **Project:** DOT1-6265c

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI													S																			1	0
Level	0.120 [1.50]												Z																				
RSI												F		S																		1	1
Level	0.060 [0.75]													Z																			
RSI			S		S				S		F				S						S										S	6	1
Level	0.030 [0.38]		Z		Z				Z						Z						Z										Z		
RSI		F		F		S		F		F						S		S		F		S		S		S		S		F		7	6
Level	0.015 [0.19]					Z										Z		Z				Z		Z		Z		Z					
RSI							F										F		F				F		F		F		F			0	7
Level	0.010 [0.13]																																

Material: SS #3B (coarse, fine) **Operator:** DJH
Date: 10/7/2021 **Relative Humidity:** 48% **Temperature:** 69°F **Project:** DOT1-6265c

ABL Friction	lbf (3ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI																										S						1	0
Level	1000																									Z							
RSI			S																						F		S					2	1
Level	795		Z																								Z						
RSI				S								S		S								S		F				S				5	1
Level	635			Z								Z		Z								Z						Z					
RSI					S				S		F		F		S				S		F		F						S		S	6	4
Level	505				Z				Z						Z				Z										Z		Z		
RSI		F				S		F		F						S		F		F										F		2	6
Level	400					Z										Z																	
RSI							F										F															0	2
Level	320																																

Number indicates amount
<u>of sample consumption</u>
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

<u>Reaction Severity Index (RSI)</u>
T = Flame Trace
M = Smoke
Z = Spark
A = Flame
B = Flash
X = Sample Consumed
L = Loud Report or Explosion
H = Hardware Damage
P = Pop or Small Explosion
HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A23: Laboratory Data Sheets for Mix ID SS #3B – Coarse Ti - Medium MnO_2

Material: SS #3B (coarse, medium) **Operator:** DMS
Date: 10/7/2021 **Relative Humidity:** 44% **Temperature:** 67°F **Project:** DOT1-6265c

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: SS #3B (coarse, medium) **Operator:** JDZ
Date: 11/23/2021 **Relative Humidity:** 31% **Temperature:** 70°F **Project:** DOT1-6265c

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI									S																		S				F	2	1
Level	0.060 [0.75]								Z																		Z						
RSI				S				F		S																F		S		F		3	3
Level	0.030 [0.38]			Z						Z																		Z					
RSI			F		S		F				S		S		S		S		S				S		F				F			7	4
Level	0.015 [0.19]				Z						Z		Z		Z		Z		Z				Z										
RSI		F				F						F		F		F		F		S		F		F								1	8
Level	0.010 [0.13]																			Z													
RSI																					F											0	1
Level	0.0050 [0.063]																																

Material: SS #3B (coarse, medium) **Operator:** DJH
Date: 10/7/2021 **Relative Humidity:** 44% **Temperature:** 67°F **Project:** DOT1-6265c

ABL Friction	lbf (3ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		S																														1	0
Level	400	Z																															
RSI																																0	0
Level	320																																
RSI																																0	0
Level	255																																
RSI			S																													1	0
Level	200		Z																														
RSI																																0	0
Level	160																																
RSI																																0	0
Level	127																																
RSI				S																												1	0
Level	100			Z																													
RSI																																0	0
Level	80																																
RSI					S																							S				2	0
Level	64				Z																							Z					
RSI						S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	F		S	S	S	24	1
Level	51					Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z			Z	Z	Z		

Number indicates amount <u>of sample consumption</u>
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

<u>Reaction Severity Index (RSI)</u>
T = Flame Trace X = Sample Consumed
M = Smoke L = Loud Report or Explosion
Z = Spark H = Hardware Damage
A = Flame P = Pop or Small Explosion
B = Flash HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A24: Laboratory Data Sheets for Mix ID SS #3B – Coarse Ti - Coarse MnO_2

Material: SS #3B (coarse, coarse) **Operator:** DMS
Date: 9/21/2021 **Relative Humidity:** 25% **Temperature:** 71°F **Project:** DOT1-6265c

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: SS #3B (coarse, coarse) **Operator:** JDZ
Date: 11/23/2021 **Relative Humidity:** 31% **Temperature:** 70°F **Project:** DOT1-6265c

ABL ESD	μF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI																				S												1	0
Level	0.750 [9.38]																			P													
RSI									S				S		S				F		S		S									5	1
Level	0.350 [4.38]								P				P		Z						P		P										
RSI								F		S		F		F		S		F				F		S		S						4	5
Level	0.200 [2.50]									Z						P								M		Z							
RSI							F				F						F								F		S		S		F	2	5
Level	0.120 [1.50]																										Z		Z				
RSI		S				F																						F		F		1	3
Level	0.060 [0.75]	Z																															
RSI			S		F																											1	1
Level	0.030 [0.38]		Z																														
RSI				F																												0	1
Level	0.015 [0.19]																																

Material: SS #3B (coarse, coarse) **Operator:** DJH
Date: 10/7/2021 **Relative Humidity:** 49% **Temperature:** 69°F **Project:** DOT1-6265c

ABL Friction	lbf (3ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		S																														1	0
Level	1000	Z																															
RSI			S																													1	0
Level	795		Z																														
RSI				S																												1	0
Level	635			Z																													
RSI																																0	0
Level	505																																
RSI																																0	0
Level	400																																
RSI					S																											1	0
Level	320				Z																												
RSI																																0	0
Level	255																																
RSI																																0	0
Level	200																																
RSI						S																										1	0
Level	160					Z																											
RSI							S																									1	0
Level	127						Z																										
RSI								S																								1	0
Level	100							Z																									
RSI									S																							1	0
Level	80								Z																								
RSI										S											S											2	0
Level	64									Z											Z												
RSI											S	S	S	S	S	S	S	S	S	F		S	S	S	S	S	S	S	S	S	S	19	1
Level	51										Z	Z	Z	Z	Z	Z	Z	Z	Z			Z	Z	Z	Z	Z	Z	Z	Z	Z	Z		

Number indicates amount
of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace X = Sample Consumed
M = Smoke L = Loud Report or Explosion
Z = Spark H = Hardware Damage
A = Flame P = Pop or Small Explosion
B = Flash HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A25: Laboratory Data Sheets for Mix ID SS #4 – Fine Mg - Medium MnO_2

Material: SS #4 (fine, medium) **Operator:** DMS
Date: 10/7/2021 **Relative Humidity:** 41% **Temperature:** 66°F **Project:** DOT1-6265c

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: SS #4 (fine, medium) **Operator:** JDZ
Date: 11/23/2021 **Relative Humidity:** 20% **Temperature:** 70°F **Project:** DOT1-6265c

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI																			S													1	0
Level	0.200 [2.50]																		Z														
RSI								S		S								F		S												3	1
Level	0.120 [1.50]							Z		Z										Z													
RSI					S		F		F		S		S				F				S											4	3
Level	0.060 [0.75]				Z						Z		Z								Z												
RSI				F		F						F		S		F						S										2	4
Level	0.030 [0.38]													Z								Z											
RSI			F												F								S		S						S	3	2
Level	0.015 [0.19]																						Z		Z						Z		
RSI		F																						F		S				F		1	3
Level	0.010 [0.13]																									Z							
RSI																											S		F			1	1
Level	0.0050 [0.063]																										Z						
RSI																												F				0	1
Level	0.0025 [0.031]																																

Material: SS #4 (fine, medium) **Operator:** DJH
Date: **Relative Humidity:** **Temperature:** °F **Project:** DOT1-6265c

ABL Friction	lbf (3ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		S		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	S		2	26
Level	1000	Z																												Z			
RSI			F																												F	0	2
Level	795																																

Number indicates amount of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace
M = Smoke
Z = Spark
A = Flame
B = Flash
X = Sample Consumed
L = Loud Report or Explosion
H = Hardware Damage
P = Pop or Small Explosion
HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A26: Laboratory Data Sheets for Mix ID SS #4 – Fine Mg - Coarse MnO_2

Material: SS #4 (fine, coarse) **Operator:** DMS
Date: 10/12/2021 **Relative Humidity:** 36% **Temperature:** 66°F **Project:** DOT1-6265c

MBOM Impact	**cm**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**+**	**-**
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: SS #4 (fine, coarse) **Operator:** JDZ
Date: 11/23/2021 **Relative Humidity:** 20% **Temperature:** 69°F **Project:** DOT1-6265c

ABL ESD	**µF [J] @ 5000V**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**+**	**-**
RSI							S																									1	0
Level	0.120 [1.50]						Z																										
RSI						F		S												S										S		3	1
Level	0.060 [0.75]							Z												Z										Z			
RSI					F				S						S				F		S								F		S	4	3
Level	0.030 [0.38]								Z						Z						Z										Z		
RSI		S		F						S		S		F		S		F				S				S		F				6	4
Level	0.015 [0.19]	Z								Z		Z				Z						Z				Z							
RSI			F								F		F				F						S		F		F					1	6
Level	0.010 [0.13]																						Z										
RSI																								F								0	1
Level	0.0050 [0.063]																																

Material: SS #4 (fine, coarse) **Operator:** DJH
Date: 10/12/2021 **Relative Humidity:** 36% **Temperature:** °66F **Project:** DOT1-6265c

ABL Friction	**lbf (3ft/sec)**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**+**	**-**
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	1000																																

Number indicates amount <u>of sample consumption</u>
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

<u>Reaction Severity Index (RSI)</u>
T = Flame Trace X = Sample Consumed
M = Smoke L = Loud Report or Explosion
Z = Spark H = Hardware Damage
A = Flame P = Pop or Small Explosion
B = Flash HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A27: Laboratory Data Sheets for Mix ID SS #4 – Medium Mg - Fine MnO_2

Material: SS #4 (medium, fine) **Operator:** DMS
Date: 10/12/2021 **Relative Humidity:** 37% **Temperature:** 64°F **Project:** DOT1-6265c

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: SS #4 (medium, fine) **Operator:** JDZ
Date: 11/23/2021 **Relative Humidity:** 20% **Temperature:** 70°F **Project:** DOT1-6265c

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI					S										S																	2	0
Level	0.060 [0.75]				Z										Z																		
RSI				F		S								F		S		S				S		S						S		6	2
Level	0.030 [0.38]					Z										Z		Z				Z		Z						Z			
RSI			F				S		S		S		F				F		S		F		F		S				F		S	6	6
Level	0.015 [0.19]						Z		Z		Z								Z						Z						Z		
RSI		F						F		F		F								F						S		F				1	6
Level	0.010 [0.13]																									Z							
RSI																											F					0	1
Level	0.0050 [0.063]																																

Material: SS #4 (medium, fine) **Operator:** DJH
Date: 10/12/2021 **Relative Humidity:** 35% **Temperature:** 66°F **Project:** DOT1-6265c

ABL Friction	lbf (3ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI			F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	29
Level	1000																																
RSI																																0	0
Level	795																																
RSI																																0	0
Level	635																																
RSI																																0	0
Level	505																																
RSI		F																														0	1
Level	400																																

Number indicates amount <u>of sample consumption</u>
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

<u>Reaction Severity Index (RSI)</u>
T = Flame Trace X = Sample Consumed
M = Smoke L = Loud Report or Explosion
Z = Spark H = Hardware Damage
A = Flame P = Pop or Small Explosion
B = Flash HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A28: Laboratory Data Sheets for Mix ID SS #4 – Medium Mg - Medium MnO_2

Material: SS #4 (medium, medium) **Operator:** DMS
Date: 10/12/2021 **Relative Humidity:** 36% **Temperature:** 66°F **Project:** DOT1-6265c

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: SS #4 (medium, medium) **Operator:** JDZ
Date: 11/23/2021 **Relative Humidity:** 20% **Temperature:** 70°F **Project:** DOT1-6265c

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI				S				S										S														3	0
Level	0.030 [0.38]			Z				Z										Z															
RSI			F		S		F		S		S		S		S		F		S		S		S				S					9	3
Level	0.015 [0.19]				Z				Z		Z		Z		Z				Z		Z		Z				Z						
RSI		F				F				F		F		F		F				F		F		S		F		S				2	9
Level	0.010 [0.13]																							Z				Z					
RSI																									F				S		S	2	1
Level	0.0050 [0.063]																												Z		Z		
RSI																														F		0	1
Level	0.0025 [0.031]																																

Material: SS #4 (medium, medium) **Operator:** DJH
Date: 10/12/2021 **Relative Humidity:** 36% **Temperature:** 66°F **Project:** DOT1-6265c

ABL Friction	lbf (3ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI			F	F	F	F	F	F	S		F	F	S		F	F	S		F	F	F	F	F	F	F	F	F	F	F	F	F	3	23
Level	1000								Z				Z				Z																
RSI										F				F				F														0	3
Level	795																																
RSI																																0	0
Level	635																																
RSI																																0	0
Level	505																																
RSI		F																														0	1
Level	400																																

Number indicates amount
of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace X = Sample Consumed
M = Smoke L = Loud Report or Explosion
Z = Spark H = Hardware Damage
A = Flame P = Pop or Small Explosion
B = Flash HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A29: Laboratory Data Sheets for Mix ID SS #4 – Medium Mg - Coarse MnO_2

Material: SS #4 (medium, coarse) **Operator:** DMS
Date: 10/12/2021 **Relative Humidity:** 36% **Temperature:** 66°F **Project:** DOT1-6265c

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: SS #4 (medium, coarse) **Operator:** JDZ
Date: 11/23/2021 **Relative Humidity:** 20% **Temperature:** 70°F **Project:** DOT1-6265c

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI											S																					1	0
Level	0.015 [0.19]										Z																						
RSI		S				S		S		F		S		S						S						S		S		S		9	1
Level	0.010 [0.13]	Z				Z		Z				Z		Z						Z						Z		Z		Z			
RSI			S		F		F		F				F		S		S		F		S				F		F		F		S	5	8
Level	0.0050 [0.063]		Z												Z		Z				Z										Z		
RSI				F												F		F				S		F								1	4
Level	0.0025 [0.031]																					Z											
RSI																							F									0	1
Level	0.0012 [0.015]																																
RSI																																0	0
Level	0.0007 [0.0088]																																
RSI																																0	0
Level	0.0003 [0.0038]																																
RSI																																0	0
Level	0.0002 [0.0025]																																

Material: SS #4 (medium, coarse) **Operator:** DJH
Date: 10/12/2021 **Relative Humidity:** 36% **Temperature:** 66°F **Project:** DOT1-6265c

ABL Friction	lbf (3ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI			F	F	F	F	F	F	F	F	S		F	F	F	F	F	F	F	F	F	F	S		F	F	F	F	F	F	F	2	25
Level	1000										Z												Z										
RSI												F												F								0	2
Level	795																																
RSI																																0	0
Level	635																																
RSI																																0	0
Level	505																																
RSI		F																														0	1
Level	400																																

Number indicates amount
of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction

F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace X = Sample Consumed
M = Smoke L = Loud Report or Explosion
Z = Spark H = Hardware Damage
A = Flame P = Pop or Small Explosion
B = Flash HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A30: Laboratory Data Sheets for Mix ID SS #4 – Coarse Mg - Fine MnO_2

Material: SS #4 (coarse, fine) **Operator:** DMS
Date: 10/7/2021 **Relative Humidity:** 41% **Temperature:** 66°F **Project:** DOT1-6265c

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: SS #4 (coarse, fine) **Operator:** JDZ
Date: 11/23/2021 **Relative Humidity:** 23% **Temperature:** 70°F **Project:** DOT1-6265c

ABL ESD	μF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI																							S		S						S	3	0
Level	0.060 [0.75]																						Z		Z						Z		
RSI						S		S		S		S		S						S		F		F		S				F		7	3
Level	0.030 [0.38]					Z		Z		Z		Z		Z						Z						Z							
RSI			S		F		F		F		F		F		S		S		F		F						S		F			4	8
Level	0.015 [0.19]		Z												Z		Z										Z						
RSI		F		F												F		F										F				0	5
Level	0.010 [0.13]																																

Material: SS #4 (coarse, fine) **Operator:** DJH
Date: 10/12/2021 **Relative Humidity:** 37% **Temperature:** 62°F **Project:** DOT1-6265c

ABL Friction	lbf (3ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI			F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	29
Level	1000																																
RSI																																0	0
Level	795																																
RSI																																0	0
Level	635																																
RSI																																0	0
Level	505																																
RSI		F																														0	1
Level	400																																

Number indicates amount of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace X = Sample Consumed
M = Smoke L = Loud Report or Explosion
Z = Spark H = Hardware Damage
A = Flame P = Pop or Small Explosion
B = Flash HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A31: Laboratory Data Sheets for Mix ID SS #4 – Coarse Mg - Medium MnO_2

Material: SS #4 (coarse, medium) **Operator:** DMS
Date: 10/7/2021 **Relative Humidity:** 41% **Temperature:** 67°F **Project:** DOT1-6265c

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: SS #4 (coarse, medium) **Operator:** JDZ
Date: 11/23/2021 **Relative Humidity:** 24% **Temperature:** 70°F **Project:** DOT1-6265c

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI																															S	1	0
Level	0.060 [0.75]																														Z		
RSI										S																				F		1	1
Level	0.030 [0.38]									Z																							
RSI					S		S		F		S																S		F			4	2
Level	0.015 [0.19]				Z		Z				Z																Z						
RSI		S		F		F		F				S		S		S		S		S		S		S		F		F				8	5
Level	0.010 [0.13]	Z										Z		Z		Z		Z		Z		Z		Z									
RSI			F										F		F		F		F		F		F		F							0	8
Level	0.0050 [0.063]																																

Material: SS #4 (coarse, medium) **Operator:** DJH
Date: 10/7/2021 **Relative Humidity:** 41% **Temperature:** 66°F **Project:** DOT1-6265c

ABL Friction	lbf (3ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI			F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	S		S		F	F	F	F	F	F	S	3	24
Level	1000																				Z		Z								Z		
RSI																						F		F								0	2
Level	795																																
RSI																																0	0
Level	635																																
RSI																																0	0
Level	505																																
RSI		F																														0	1
Level	400																																

Number indicates amount
of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace X = Sample Consumed
M = Smoke L = Loud Report or Explosion
Z = Spark H = Hardware Damage
A = Flame P = Pop or Small Explosion
B = Flash HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A32: Laboratory Data Sheets for Mix ID SS #4 – Coarse Mg - Coarse MnO_2

Material: SS #4 (coarse, coarse) **Operator:** DMS
Date: 10/12/2021 **Relative Humidity:** 25% **Temperature:** 66°F **Project:** DOT1-6265c

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: SS #4 (coarse, coarse) **Operator:** JDZ
Date: 11/23/2021 **Relative Humidity:** 25% **Temperature:** 70°F **Project:** DOT1-6265c

ABL ESD	μF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI			S						S												S		S								S	5	0
Level	0.015 [0.19]		Z						Z												Z		Z								Z		
RSI		F		S		S		F		S				S		S		S		F		F		S						F		7	5
Level	0.010 [0.13]			Z		Z				Z				Z		Z		Z						Z									
RSI					F		F				S		F		F		F		F						S		S		F			3	7
Level	0.0050 [0.063]										Z														Z		Z						
RSI												F														F		F				0	3
Level	0.0025 [0.031]																																

Material: SS #4 (coarse, coarse) **Operator:** DJH
Date: 10/12/2021 **Relative Humidity:** 36% **Temperature:** 66°F **Project:** DOT1-6265c

ABL Friction	lbf (3ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	S		S						F	F	F	F	F	F	2	22
Level	1000																	Z		Z													
RSI																			F		S		S		F							2	2
Level	795																				Z		Z										
RSI																						F		F								0	2
Level	635																																

Number indicates amount
of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction

F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace X = Sample Consumed
M = Smoke L = Loud Report or Explosion
Z = Spark H = Hardware Damage
A = Flame P = Pop or Small Explosion
B = Flash HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A33: Laboratory Data Sheets for Mix ID SS #9 – Fine Al - Medium MoO_3

Material: SS #9 (fine, medium) **Operator:** DMS
Date: 10/12/2021 **Relative Humidity:** 36% **Temperature:** 66°F **Project:** DOT1-6265c

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: SS #9 (fine, medium) **Operator:** JDZ
Date: 11/22/2021 **Relative Humidity:** 25% **Temperature:** 70°F **Project:** DOT1-6265c

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI													S																			1	0
Level	0.200 [2.50]												ZA																				
RSI												F		S																		1	1
Level	0.120 [1.50]													ZA																			
RSI											F				S		S															2	1
Level	0.060 [0.75]														ZA		Z																
RSI		S								F						F		S														2	2
Level	0.030 [0.38]	Z																Z															
RSI			S		S		S		F										S				S									5	1
Level	0.015 [0.19]		Z		Z		Z												Z				ZA										
RSI				F		F		F												S		F		S								2	4
Level	0.010 [0.13]																			Z				ZA									
RSI																					F				S		S					2	1
Level	0.0050 [0.063]																								ZA		ZA						
RSI																										F		S				1	1
Level	0.0025 [0.031]																											ZA					
RSI																													S		F	1	1
Level	0.0012 [0.015]																												Z				
RSI																														F		0	1
Level	0.0007 [0.0088]																																

Material: SS #9 (fine, medium) **Operator:** DJH
Date: 10/12/2021 **Relative Humidity:** 36% **Temperature:** 66°F **Project:** DOT1-6265c

ABL Friction	lbf (3ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		S																														1	0
Level	400	Z																															
RSI																																0	0
Level	320																																
RSI																																0	0
Level	255																																
RSI			S																													1	0
Level	200		Z																														
RSI																																0	0
Level	160																																
RSI																																0	0
Level	127																																
RSI				S																												1	0
Level	100			B																													
RSI					S																						S					2	0
Level	80				B																						B						
RSI						S									S					S						F		S				4	1
Level	64					Z									Z					Z								B					
RSI							S	S	S	S	S	S	S	F		S	S	S	F		S	S	S	S	F				S	S	S	17	3
Level	51						Z	Z	B	Z	Z	Z	Z			B	B	B			Z	B	B	B					B	B	B		

Number indicates amount of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace
M = Smoke
Z = Spark
A = Flame
B = Flash
X = Sample Consumed
L = Loud Report or Explosion
H = Hardware Damage
P = Pop or Small Explosion
HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A34: Laboratory Data Sheets for Mix ID SS #9 – Fine Al - Coarse MoO_3

Material: SS #9 (fine, coarse) **Operator:** DMS
Date: 10/19/2021 **Relative Humidity:** 33% **Temperature:** 69°F **Project:** DOT1-6265c

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: SS #9 (fine, coarse) **Operator:** JDZ
Date: 11/22/2021 **Relative Humidity:** 25% **Temperature:** 70°F **Project:** DOT1-6265c

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI																	S															1	0
Level	0.750 [9.38]																Z																
RSI																F		S														1	1
Level	0.350 [4.38]																	SZ															
RSI									S		S		S		F				S													4	1
Level	0.200 [2.50]								Z		Z		Z						AZS														
RSI								F		F		F		F						S						S						2	4
Level	0.120 [1.50]																			ZA						ZA							
RSI					S		F														S				F		S					3	2
Level	0.060 [0.75]				Z																ZA						ZA						
RSI				F		F																S		F				S				2	3
Level	0.030 [0.38]																					ZA						ZA					
RSI			F																				F						S		S	2	2
Level	0.015 [0.19]																												ZA		ZA		
RSI		F																												F		0	2
Level	0.010 [0.13]																																

Material: SS #9 (fine, coarse) **Operator:** DJH
Date: 10/19/2021 **Relative Humidity:** 33% **Temperature:** 68°F **Project:** DOT1-6265c

ABL Friction	lbf (3ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI														S																		1	0
Level	635													Z																			
RSI													F		S		S															2	1
Level	505														Z		Z																
RSI		S						S				F				F		S		S												4	2
Level	400	Z						Z										Z		Z													
RSI					S		F		S		F								F		S						S				S	5	3
Level	320				Z				Z												Z						Z				Z		
RSI				F		F				F												S				F		S		F		2	5
Level	255																					Z						Z					
RSI			F																				S		F				F			1	3
Level	200																						Z										
RSI																								F								0	1
Level	160																																

Number indicates amount
of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction

F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace X = Sample Consumed
M = Smoke L = Loud Report or Explosion
Z = Spark H = Hardware Damage
A = Flame P = Pop or Small Explosion
B = Flash HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A35: Laboratory Data Sheets for Mix ID SS #9 – Medium Al - Fine MoO_3

Material: SS #9 (medium, fine) **Operator:** DMS
Date: 10/12/2021 **Relative Humidity:** 35% **Temperature:** 66°F **Project:** DOT1-6265c

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: SS #9 (medium, fine) **Operator:** JDZ
Date: 11/22/2021 **Relative Humidity:** 25% **Temperature:** 70°F **Project:** DOT1-6265c

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI							S								S																S	3	0
Level	0.200 [2.50]						Z								Z																Z		
RSI						F		S						F		S		S				S				S		S		F		6	3
Level	0.120 [1.50]							Z								Z		Z				Z				Z		Z					
RSI					F				S		S		F				F		S		F		S		F		F		F			4	7
Level	0.060 [0.75]								Z		Z								Z				Z										
RSI				F						F		F								F				F								0	5
Level	0.030 [0.38]																																
RSI			F																													0	1
Level	0.015 [0.19]																																
RSI		F																														0	1
Level	0.010 [0.13]																																

Material: SS #9 (medium, fine) **Operator:** DJH
Date: 10/19/2021 **Relative Humidity:** 33% **Temperature:** 70°F **Project:** DOT1-6265c

ABL Friction	lbf (3ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		S																														1	0
Level	400	Z																															
RSI																																0	0
Level	320																																
RSI																																0	0
Level	255																																
RSI			S																													1	0
Level	200		Z																														
RSI																																0	0
Level	160																																
RSI																																0	0
Level	127																																
RSI				S																												1	0
Level	100			Z																													
RSI																					S											1	0
Level	80																				Z												
RSI					S		S						S		S					F		S		S					S			7	1
Level	64				Z		Z						Z		B							Z		Z					B				
RSI						F		S	S	S	S	F		F		S	S	S	F				F		S	S	S	F		S	S	12	6
Level	51							B	Z	Z	Z					Z	B	Z							Z	Z	Z			Z	Z		

Number indicates amount
of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace X = Sample Consumed
M = Smoke L = Loud Report or Explosion
Z = Spark H = Hardware Damage
A = Flame P = Pop or Small Explosion
B = Flash HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A36: Laboratory Data Sheets for Mix ID SS #9 – Medium Al - Medium MoO_3

Material: SS #9 (medium, medium) **Operator:** DMS
Date: 10/12/2021 **Relative Humidity:** 36% **Temperature:** 66°F **Project:** DOT1-6265c

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: SS #9 (medium, medium) **Operator:** JDZ
Date: 11/22/2021 **Relative Humidity:** 25% **Temperature:** 70°F **Project:** DOT1-6265c

ABL ESD	μF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI																										S						1	0
Level	0.350 [4.38]																									ZP							
RSI																									F		S					1	1
Level	0.200 [2.50]																										ZA						
RSI						S						S				S		S						F				S				5	1
Level	0.120 [1.50]					Z						Z				Z		Z										ZA					
RSI					F		S		S		F		S		F		F		S		S		F						S		F	6	6
Level	0.060 [0.75]						Z		Z				Z						Z		Z								Z				
RSI				F				F		F				F						F		F								F		0	7
Level	0.030 [0.38]																																
RSI			F																													0	1
Level	0.015 [0.19]																																
RSI		F																														0	1
Level	0.010 [0.13]																																

Material: SS #9 (medium, medium) **Operator:** DJH
Date: 10/12/2021 **Relative Humidity:** 36% **Temperature:** 66°F **Project:** DOT1-6265c

ABL Friction	lbf (3ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		S																														1	0
Level	400	Z																															
RSI																																0	0
Level	320																																
RSI																																0	0
Level	255																																
RSI			S				S																									2	0
Level	200		Z				Z																										
RSI						F		S																								1	1
Level	160							Z																									
RSI					F				S																							1	1
Level	127								Z																								
RSI				F						S		S																			F	2	2
Level	100									Z		Z																					
RSI											F		S						S		S									F		3	2
Level	80												Z						Z		Z												
RSI														S				F		F		S							F			2	3
Level	64													Z								Z											
RSI															S	S	F						S	S	S	S	S	F				7	2
Level	51														Z	Z							Z	Z	Z	Z	Z						

Number indicates amount of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace X = Sample Consumed
M = Smoke L = Loud Report or Explosion
Z = Spark H = Hardware Damage
A = Flame P = Pop or Small Explosion
B = Flash HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A37: Laboratory Data Sheets for Mix ID SS #9 – Medium Al - Coarse MoO_3

Material: SS #9 (medium, coarse) **Operator:** DMS
Date: 10/12/2021 **Relative Humidity:** 351% **Temperature:** 66°F **Project:** DOT1-6265c

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	S		F	F	F	F	F	F	F	F	F	1	28
Level	100																				Z												
RSI																						F										0	1
Level	79.4																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: SS #9 (medium, coarse) **Operator:** JDZ
Date: 11/22/2021 **Relative Humidity:** 23% **Temperature:** 70°F **Project:** DOT1-6265c

ABL ESD	μF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI										S								S		S		F	F	F	F	F	S					4	5
Level	0.750 [9.38]									Z								ZM		ZM							Z						
RSI					S		S		F		S				S		F		F		F							S		S		6	4
Level	0.350 [4.38]				Z		Z				Z				Z													Z		Z			
RSI				F		F		F				S		F		F													F		F	1	7
Level	0.200 [2.50]											Z																					
RSI			F										F																			0	2
Level	0.120 [1.50]																																
RSI		F																														0	1
Level	0.060 [0.75]																																

Material: SS #9 (medium, coarse) **Operator:** DJH
Date: 10/12/2021 **Relative Humidity:** 35% **Temperature:** 66°F **Project:** DOT1-6265c

ABL Friction	lbf (3ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI																												S				1	0
Level	1000																											Z					
RSI																											F		S		F	1	2
Level	795																												Z				
RSI														S				S						S		F				F		3	2
Level	635													Z				Z						Z									
RSI									S				F		S		F		S				F		F							3	4
Level	505								Z						Z				Z														
RSI		S				S		F		S		F				F				S		F										4	4
Level	400	Z				Z				Z										Z													
RSI					F		F				F										F											0	4
Level	320																																
RSI				F																												0	1
Level	255																																
RSI			F																													0	1
Level	200																																

Number indicates amount
<u>of sample consumption</u>
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

<u>Reaction Severity Index (RSI)</u>
T = Flame Trace X = Sample Consumed
M = Smoke L = Loud Report or Explosion
Z = Spark H = Hardware Damage
A = Flame P = Pop or Small Explosion
B = Flash HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A38: Laboratory Data Sheets for Mix ID SS #9 – Coarse Al - Fine MoO_3

Material: SS #9 (coarse, fine) **Operator:** DMS
Date: 10/12/2021 **Relative Humidity:** 35% **Temperature:** 66°F **Project:** DOT1-6265c

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	S		F	F	F	F	F	F	F	F	F	F	1	28
Level	100																			Z													
RSI																					F											0	1
Level	79.4																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: SS #9 (coarse, fine) **Operator:** JDZ
Date: 11/22/2021 **Relative Humidity:** 23% **Temperature:** 70°F **Project:** DOT1-6265c

ABL ESD	μF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI								S		S				S		F	F	S						S		S		F	F	F	F	6	6
Level	0.750 [9.38]							Z		Z				Z				Z						Z		Z							
RSI							F		F		S		F		F				S		S		F		F		F					3	7
Level	0.350 [4.38]										ZA								Z		Z												
RSI						F						F								F		F										0	4
Level	0.200 [2.50]																																
RSI					F																											0	1
Level	0.120 [1.50]																																
RSI		S		F																												1	1
Level	0.060 [0.75]	Z																															
RSI			F																													0	1
Level	0.030 [0.38]																																

Material: SS #9 (coarse, fine) **Operator:** DJH
Date: 10/12/2021 **Relative Humidity:** 35% **Temperature:** 66°F **Project:** DOT1-6265c

ABL Friction	lbf (3ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI																	S															1	0
Level	795																Z																
RSI																F		S														1	1
Level	635																	Z															
RSI													S		F				S		S											3	1
Level	505												Z						Z		Z												
RSI		S										F		F						F		S		S		S				S		5	3
Level	400	Z																				Z		Z		Z				Z			
RSI									S		F												F		F		S		F		F	2	5
Level	320								Z																		Z						
RSI				S				F		F																		F				1	3
Level	255			Z																													
RSI			F		S		F																									1	2
Level	200				Z																												
RSI						F																										0	1
Level	160																																

Number indicates amount <u>of sample consumption</u>
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction

F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace X = Sample Consumed
M = Smoke L = Loud Report or Explosion
Z = Spark H = Hardware Damage
A = Flame P = Pop or Small Explosion
B = Flash HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A39: Laboratory Data Sheets for Mix ID SS #9 – Coarse Al - Medium MoO_3

Material: SS #9 (coarse, medium) **Operator:** DMS
Date: 10/19/2021 **Relative Humidity:** 33% **Temperature:** 68°F **Project:** DOT1-6265c

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: SS #9 (coarse, medium) **Operator:** JDZ
Date: 11/22/2021 **Relative Humidity:** 20% **Temperature:** 70°F **Project:** DOT1-6265c

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI										F	S								F	S		F	F	F	F	F	F	F	S		F	3	10
Level	0.750 [9.38]										Z									ZM									Z				
RSI					S		S		F			S		S		S		F			F									F		5	4
Level	0.350 [4.38]				Z		ZM					M		Z		Z																	
RSI				F		F		F					F		F		F															0	6
Level	0.200 [2.50]																																
RSI			F																													0	1
Level	0.120 [1.50]																																
RSI		F																														0	1
Level	0.060 [0.75]																																

Material: SS #9 (coarse, medium) **Operator:** DJH
Date: 10/19/2021 **Relative Humidity:** 34% **Temperature:** 68°F **Project:** DOT1-6265c

ABL Friction	lbf (3ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		S								S								S												S		4	0
Level	400	Z								Z								Z												Z			
RSI									F		S				S		F		S				S				S		F		S	6	3
Level	320										Z				Z				Z				Z				Z				Z		
RSI				S				F				S		F		F				S		F		S		F		F				4	6
Level	255			Z								Z								Z				Z									
RSI			F		S		F						F								F				F							1	5
Level	200				Z																												
RSI						F																										0	1
Level	160																																

Number indicates amount
of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction

F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace X = Sample Consumed
M = Smoke L = Loud Report or Explosion
Z = Spark H = Hardware Damage
A = Flame P = Pop or Small Explosion
B = Flash HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A40: Laboratory Data Sheets for Mix ID SS #9 – Coarse Al - Coarse MoO_3

Material: SS #9 (coarse, coarse) **Operator:** DMS
Date: 10/12/2021 **Relative Humidity:** 35% **Temperature:** 66°F **Project:** DOT1-6265c

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	S		F	F	F	F	F	F	F	F	F	F	1	28
Level	100																			Z													
RSI																					F											0	1
Level	79.4																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: SS #9 (coarse, coarse) **Operator:** JDZ
Date: 11/22/2021 **Relative Humidity:** 20% **Temperature:** 70°F **Project:** DOT1-6265c

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI				F	S		F	F	F	F	F	F	S		F	F	F	F	F	F	F	F	F	F	F	F	F	F	S		S	4	21
Level	0.750 [9.38]				Z								Z																Z		Z		
RSI			F			F								F																F		0	4
Level	0.350 [4.38]																																
RSI		F																														0	1
Level	0.200 [2.50]																																

Material: SS #9 (coarse, coarse) **Operator:** DJH
Date: 10/12/2021 **Relative Humidity:** 36% **Temperature:** 66°F **Project:** DOT1-6265c

ABL Friction	lbf (3ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI			F	F	F	F	F	F	S				S								S											3	6
Level	1000								Z				Z								Z												
RSI										S		F		S		S		S		F		S										5	2
Level	795									Z				Z		Z		Z				Z											
RSI											F				F		F		F				S									1	4
Level	635																						Z										
RSI																								S		S		S		S		4	0
Level	505																							Z		Z		Z		Z			
RSI		F																							F		F		F		S	1	4
Level	400																														Z		

Number indicates amount of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace X = Sample Consumed
M = Smoke L = Loud Report or Explosion
Z = Spark H = Hardware Damage
A = Flame P = Pop or Small Explosion
B = Flash HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A41: Laboratory Data Sheets for Mix ID SS #19 – Fine Al - Medium SnO_2

Material: SS #19 (fine, medium) **Operator:** DMS
Date: 10/17/2021 **Relative Humidity:** 35% **Temperature:** 68°F **Project:** DOT1-6265c

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: SS #19 (fine, medium) **Operator:** JDZ
Date: 11/15/2021 **Relative Humidity:** 32% **Temperature:** 71°F **Project:** DOT1-6265c

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI							S						S		S										S		S					5	0
Level	0.060 [0.75]						Z						Z		Z										Z		Z						
RSI				S		F		S				F		F		S								F		F		S				4	5
Level	0.030 [0.38]			Z				Z								Z												Z					
RSI			F		F				S		F						S		S				F						S		F	4	5
Level	0.015 [0.19]								Z								Z		Z										Z				
RSI		F								F								F		S		F								F		1	5
Level	0.010 [0.13]																			Z													
RSI																					F											0	1
Level	0.0050 [0.063]																																

Material: SS #19 (fine, medium) **Operator:** DJH
Date: 10/20/2021 **Relative Humidity:** 35% **Temperature:** 66°F **Project:** DOT1-6265c

ABL Friction	lbf (3ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI			F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	S		1	27
Level	1000																													Z			
RSI																															F	0	1
Level	795																																
RSI																																0	0
Level	635																																
RSI																																0	0
Level	505																																
RSI		F																														0	1
Level	400																																

Number indicates amount <u>of sample consumption</u>
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace X = Sample Consumed
M = Smoke L = Loud Report or Explosion
Z = Spark H = Hardware Damage
A = Flame P = Pop or Small Explosion
B = Flash HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A42: Laboratory Data Sheets for Mix ID SS #19 – Fine Al - Coarse SnO_2

Material: SS #19 (fine, coarse) **Operator:** DMS
Date: 10/17/2021 **Relative Humidity:** 34% **Temperature:** 65°F **Project:** DOT1-6265c

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: SS #19 (fine, coarse) **Operator:**
Date: **Relative Humidity:** % **Temperature:** °F **Project:** DOT1-6265c

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI																	F	F	F	F	S		F	S								2	5
Level	0.750 [9.38]																				Z			Z									
RSI																F						F			S		S		S		S	4	2
Level	0.350 [4.38]																								Z		Z		Z		Z		
RSI															F											F		F		F		0	4
Level	0.200 [2.50]																																
RSI												S		F																		1	1
Level	0.120 [1.50]											Z																					
RSI											F		F																			0	2
Level	0.060 [0.75]																																
RSI			F	S				S		F																						2	2
Level	0.030 [0.38]			Z				Z																									
RSI					S		F		F																							1	2
Level	0.015 [0.19]				Z																												
RSI		F				F																										0	2
Level	0.010 [0.13]																																

Material: SS #19 (fine, coarse) **Operator:** DJH
Date: 10/20/2021 **Relative Humidity:** 35% **Temperature:** 66°F **Project:** DOT1-6265c

ABL Friction	lbf (3ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	S		F	F	F	F	F	F	S				F	F	F	F	F	F	F	F	F	F	F	F	F	2	24
Level	1000						Z								Z																		
RSI								F								S		F														1	2
Level	795															Z																	
RSI																	F															0	1
Level	635																																

Number indicates amount
of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace X = Sample Consumed
M = Smoke L = Loud Report or Explosion
Z = Spark H = Hardware Damage
A = Flame P = Pop or Small Explosion
B = Flash HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A43: Laboratory Data Sheets for Mix ID SS #19 – Medium Al - Fine SnO_2

Material: SS #19 (medium, fine) **Operator:** DMS
Date: 10/17/2021 **Relative Humidity:** 25% **Temperature:** 67°F **Project:** DOT1-6265c

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: SS #19 (medium, fine) **Operator:** JDZ
Date: 11/15/2021 **Relative Humidity:** 29% **Temperature:** 70°F **Project:** DOT1-6265c

ABL ESD	μF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI				S								S		S																		3	0
Level	0.030 [0.38]			Z								Z		Z																			
RSI			F		S				S		F		F		S																	3	3
Level	0.015 [0.19]				Z				Z						Z																		
RSI		F				S		F		F						S																2	3
Level	0.010 [0.13]					Z										Z																	
RSI							F										S		S													2	1
Level	0.0050 [0.063]																Z		Z														
RSI																		F		S		S		S		S		S		S		6	1
Level	0.0025 [0.031]																			Z		Z		Z		Z		Z		Z			
RSI																					F		F		F		F		F		F	0	6
Level	0.0012 [0.015]																																

Material: SS #19 (medium, fine) **Operator:** DJH
Date: 10/20/2021 **Relative Humidity:** **Temperature:** 67°F **Project:** DOT1-6265c

ABL Friction	lbf (3ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	S						S		S				F	F	F	F	F	F	F	F	S								F	4	10
Level	1000		Z						Z		Z												Z										
RSI				S				F		F		S		F										S						F		3	4
Level	795			Z								Z												Z									
RSI					S		F						F												S		S		F			3	3
Level	635				Z																				Z		Z						
RSI						F																				F		F				0	3
Level	505																																

Number indicates amount
of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace
M = Smoke
Z = Spark
A = Flame
B = Flash
X = Sample Consumed
L = Loud Report or Explosion
H = Hardware Damage
P = Pop or Small Explosion
HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A44: Laboratory Data Sheets for Mix ID SS #19 – Medium Al - Medium SnO_2

Material: SS #19 (medium, medium) **Operator:** DMS
Date: 10/17/2021 **Relative Humidity:** 35% **Temperature:** 66°F **Project:** DOT1-6265c

MBOM Impact	**cm**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**+**	**-**
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: SS #19 (medium, medium) **Operator:** JDZ
Date: 11/15/2021 **Relative Humidity:** 31% **Temperature:** 71°F **Project:** DOT1-6265c

ABL ESD	**µF [J] @ 5000V**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**+**	**-**
RSI						S				S				S		S								S						S		6	0
Level	0.030 [0.38]					Z				Z				Z		Z								Z						Z			
RSI			S		F		S		F		S		F		F		S				S		F		S		S		F		F	7	7
Level	0.015 [0.19]		Z				Z				Z						Z				Z				Z		Z						
RSI		F		F				F				F						S		F		F				F		F				1	8
Level	0.010 [0.13]																	Z															
RSI																			F													0	1
Level	0.0050 [0.063]																																

Material: SS #19 (medium, medium) **Operator:** DJH
Date: 10/20/2021 **Relative Humidity:** 35% **Temperature:** 65°F **Project:** DOT1-6265c

ABL Friction	**lbf (3ft/sec)**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**+**	**-**
RSI		F	F	F	S				F	S		F	F	F	F	F	F	F	F	F	F	S						S		F	F	4	16
Level	1000				Z					Z												Z						Z					
RSI						S		F			F												S		S		F		F			3	4
Level	795					Z																	Z		Z								
RSI							F																	F		F						0	3
Level	635																																

Number indicates amount
<u>of sample consumption</u>
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction

F = No-Go or No Reaction

<u>Reaction Severity Index (RSI)</u>
T = Flame Trace X = Sample Consumed
M = Smoke L = Loud Report or Explosion
Z = Spark H = Hardware Damage
A = Flame P = Pop or Small Explosion
B = Flash HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A45: Laboratory Data Sheets for Mix ID SS #19 – Medium Al - Coarse SnO_2

Material: SS #19 (medium, coarse) **Operator:** DMS
Date: 10/17/2021 **Relative Humidity:** 35% **Temperature:** 66°F **Project:** DOT1-6265c

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: SS #19 (medium, coarse) **Operator:** JDZ
Date: 11/22/2021 **Relative Humidity:** 24% **Temperature:** 70°F **Project:** DOT1-6265c

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI										F	S		F	S		F	F	F	S								S		F	F	F	4	8
Level	0.750 [9.38]										Z			Z					Z								Z						
RSI									F			F			F					S				S		F		F				2	5
Level	0.350 [4.38]																			Z				Z									
RSI								F													S		F		F							1	3
Level	0.200 [2.50]																				Z												
RSI					S		F															F										1	2
Level	0.120 [1.50]				Z																												
RSI				F		F																										0	2
Level	0.060 [0.75]																																
RSI			F																													0	1
Level	0.030 [0.38]																																
RSI		F																														0	1
Level	0.015 [0.19]																																

Material: SS #19 (medium, coarse) **Operator:** DJH
Date: 10/20/2021 **Relative Humidity:** 35% **Temperature:** 67°F **Project:** DOT1-6265c

ABL Friction	lbf (3ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	S		S		F	F	F	S						S				S										5	6
Level	1000				Z		Z					Z						Z				Z											
RSI						F		F					S		S		F		S		F		S		S		S		S		S	8	4
Level	795												Z		Z				Z				Z		Z		Z		Z		Z		
RSI														F		F				F				F		F		F		F		0	7
Level	635																																

Number indicates amount
<u>of sample consumption</u>
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace X = Sample Consumed
M = Smoke L = Loud Report or Explosion
Z = Spark H = Hardware Damage
A = Flame P = Pop or Small Explosion
B = Flash HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A46: Laboratory Data Sheets for Mix ID SS #19 – Coarse Al - Fine SnO_2

Material: SS #19 (coarse, fine) **Operator:** DMS
Date: 10/17/2021 **Relative Humidity:** 35% **Temperature:** 68°F **Project:** DOT1-6265c

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: SS #19 (coarse, fine) **Operator:** JDZ
Date: 11/15/2021 **Relative Humidity:** 30% **Temperature:** 71°F **Project:** DOT1-6265c

ABL ESD	μF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI			S																													1	0
Level	0.015 [0.19]		Z																														
RSI		F		S																S		S						S				4	1
Level	0.010 [0.13]			Z																Z		Z						Z					
RSI					S		S				S						S		F		F		S		S		F		S		F	7	4
Level	0.0050 [0.063]				Z		Z				Z						Z						Z		Z				Z				
RSI						F		S		F		S		S		F		F						F		F				F		3	7
Level	0.0025 [0.031]							Z				Z		Z																			
RSI									F				F		F																	0	3
Level	0.0012 [0.015]																																

Material: SS #19 (coarse, fine) **Operator:** DJH
Date: 10/20/2021 **Relative Humidity:** 34% **Temperature:** 66°F **Project:** DOT1-6265c

ABL Friction	lbf (3ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	S																											1	3
Level	1000				B																												
RSI						S		S																S		S						4	0
Level	795					B		B																Z		B							
RSI							F		S				S										F		F		S					3	3
Level	635								B				Z														Z						
RSI										S		F		S		S				S		F						S				5	2
Level	505									B				Z		Z				Z								B					
RSI											F				F		S		F		F								S			2	4
Level	400																B												Z				
RSI																		F												S		1	1
Level	320																													Z			
RSI																															F	0	1
Level	255																																

Number indicates amount of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace
M = Smoke
Z = Spark
A = Flame
B = Flash
X = Sample Consumed
L = Loud Report or Explosion
H = Hardware Damage
P = Pop or Small Explosion
HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A47: Laboratory Data Sheets for Mix ID SS #19 – Coarse Al - Medium SnO_2

Material: SS #19 (coarse, medium) **Operator:** DMS
Date: 10/17/2021 **Relative Humidity:** 35% **Temperature:** 67°F **Project:** DOT1-6265c

MBOM Impact	**cm**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**+**	**-**
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: SS #19 (coarse, medium) **Operator:** JDZ
Date: 11/22/2021 **Relative Humidity:** 24% **Temperature:** 70°F **Project:** DOT1-6265c

ABL ESD	**µF [J] @ 5000V**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**+**	**-**
RSI				S						F	S		S		F	F	F	F	F	S		S		S				S		F	F	7	8
Level	0.750 [9.38]			Z							Z		Z							Z		Z		Z				Z					
RSI			F		S		S		F			F		F							F		F		S		F		F			3	8
Level	0.350 [4.38]				Z		Z																		Z								
RSI		F				F		F																		F						0	4
Level	0.200 [2.50]																																

Material: SS #19 (coarse, medium) **Operator:** DJH
Date: 10/20/2021 **Relative Humidity:** 35% **Temperature:** 68°F **Project:** DOT1-6265c

ABL Friction	**lbf (3ft/sec)**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**+**	**-**
RSI		F	S		F	F	S		S		F	F	S		F	F	S				F	F	S				F	F	F	S		7	12
Level	1000		Z				Z		Z				Z				Z						Z							Z			
RSI				F				F		F				F				S		F				S		F					F	2	7
Level	795																	Z						Z									
RSI																			F						F							0	2
Level	635																																

Number indicates amount
of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction

F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace X = Sample Consumed
M = Smoke L = Loud Report or Explosion
Z = Spark H = Hardware Damage
A = Flame P = Pop or Small Explosion
B = Flash HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A48: Laboratory Data Sheets for Mix ID SS #19 – Coarse Al - Coarse SnO_2

Material: SS #19 (coarse, coarse) **Operator:** DMS
Date: 10/17/2021 **Relative Humidity:** 33% **Temperature:** 67°F **Project:** DOT1-6265c

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: SS #19 (coarse, coarse) **Operator:** JDZ
Date: 11/22/2021 **Relative Humidity:** 24% **Temperature:** 71°F **Project:** DOT1-6265c

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	S		F	F	F	F	F	F	S		F	F	S		F	F	S		F	S				F	F	F	F	5	18
Level	0.750 [9.38]				Z								Z				Z				Z			Z									
RSI						F								F				F				F			S		F					1	5
Level	0.350 [4.38]																								Z								
RSI																										F						0	1
Level	0.200 [2.50]																																

Material: SS #19 (coarse, coarse) **Operator:** DJH
Date: 10/17/2021 **Relative Humidity:** 35% **Temperature:** 66°F **Project:** DOT1-6265c

ABL Friction	lbf (3ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		S																								S		S		S		4	0
Level	1000	Z																								Z		Z		Z			
RSI																									F		F		F		S	1	3
Level	795																														Z		
RSI				S																				F								1	1
Level	635			Z																													
RSI			F		S				S												S		F									3	2
Level	505				Z				Z												Z												
RSI						S		F		S								S		F		F										3	3
Level	400					Z				Z								Z															
RSI							F				S		S				F		F													2	3
Level	320										Z		Z																				
RSI												F		S		F																1	2
Level	255													Z																			
RSI															F																	0	1
Level	200																																

Number indicates amount of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace
M = Smoke
Z = Spark
A = Flame
B = Flash
X = Sample Consumed
L = Loud Report or Explosion
H = Hardware Damage
P = Pop or Small Explosion
HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A49: Laboratory Data Sheets for Mix ID SS #24 – Fine Al - Medium Bi_2O_3

Material: SS #24 (fine, medium) **Operator:** DMS
Date: 10/16/2021 **Relative Humidity:** 35% **Temperature:** 66°F **Project:** DOT1-6265c

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	S		F	F	F	F	1	28
Level	100																									Z							
RSI																											F					0	1
Level	79.4																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: SS #24 (fine, medium) **Operator:** JDZ
Date: 11/9/2021 **Relative Humidity:** 36% **Temperature:** 67°F **Project:** DOT1-6265c

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		S																														1	0
Level	0.030 [0.38]	Z																															
RSI			S																													1	0
Level	0.015 [0.19]		Z																														
RSI				S																												1	0
Level	0.010 [0.13]			Z																													
RSI					S																		S									2	0
Level	0.0050 [0.063]				Z																		Z										
RSI						S		S		S		S		S						S		F		S								7	1
Level	0.0025 [0.031]					Z		Z		Z		Z		Z						Z				Z									
RSI							F		F		F		F		S				F		F				S							2	6
Level	0.0012 [0.015]														Z										Z								
RSI																S		F								S					F	2	2
Level	0.0007 [0.0088]															Z										Z							
RSI																	F										S			F		1	2
Level	0.0003 [0.0038]																										Z						
RSI																												S	F			1	1
Level	0.0002 [0.0025]																											Z					

Material: SS #24 (fine, medium) **Operator:** DJH
Date: 10/19/2021 **Relative Humidity:** 36% **Temperature:** 65°F **Project:** DOT1-6265c

ABL Friction	lbf (3ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI			S		F	F	F	F	F	F	F	F	F	F	F	F	F	S		S		F	F	F	F	S		F	F	F	F	4	21
Level	1000		Z															Z		Z						Z							
RSI				F															F		F						F					0	4
Level	795																																
RSI																																0	0
Level	635																																
RSI																																0	0
Level	505																																
RSI		F																														0	1
Level	400																																

Number indicates amount
of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction

F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace X = Sample Consumed
M = Smoke L = Loud Report or Explosion
Z = Spark H = Hardware Damage
A = Flame P = Pop or Small Explosion
B = Flash HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A50: Laboratory Data Sheets for Mix ID SS #24 – Fine Al - Coarse Bi_2O_3

Material: SS #24 (fine, coarse) **Operator:** DMS
Date: 10/16/2021 **Relative Humidity:** 37% **Temperature:** 65°F **Project:** DOT1-6265c

MBOM Impact	**cm**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**+**	**-**
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: SS #24 (fine, coarse) **Operator:** JDZ
Date: 11/15/2021 **Relative Humidity:** 25% **Temperature:** 70°F **Project:** DOT1-6265c

ABL ESD	**µF [J] @ 5000V**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**+**	**-**
RSI			S		S																				S							3	0
Level	0.015 [0.19]		Z		Z																				A								
RSI		F		F		S		S		S		S												F		S						5	3
Level	0.010 [0.13]					Z		Z		Z		Z														Z							
RSI							F		F		F		S				S				S		F				S					4	4
Level	0.0050 [0.063]												Z				Z				Z						Z						
RSI														S		F		S		F		F						S				3	3
Level	0.0025 [0.031]													Z				Z										Z					
RSI															F				F										S		S	2	2
Level	0.0012 [0.015]																												Z		Z		
RSI																														F		0	1
Level	0.0007 [0.0088]																																

Material: SS #24 (fine, coarse) **Operator:** DJH
Date: 10/18/2021 **Relative Humidity:** 39% **Temperature:** 65°F **Project:** DOT1-6265c

ABL Friction	**lbf (3ft/sec)**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**+**	**-**
RSI			F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	29
Level	1000																																
RSI																																0	0
Level	795																																
RSI		F																														0	1
Level	635																																

Number indicates amount
of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace
M = Smoke
Z = Spark
A = Flame
B = Flash
X = Sample Consumed
L = Loud Report or Explosion
H = Hardware Damage
P = Pop or Small Explosion
HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A51: Laboratory Data Sheets for Mix ID SS #24 – Medium Al - Fine Bi_2O_3

Material: SS #24 (medium, fine) **Operator:** DMS
Date: 10/16/2021 **Relative Humidity:** 37% **Temperature:** 65°F **Project:** DOT1-6265c

MBOM Impact	F	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: SS #24 (medium, fine) **Operator:** JDZ
Date: 11/9/2021 **Relative Humidity:** 35% **Temperature:** 69°F **Project:** DOT1-6265c

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI											S						S		S				S								S	5	0
Level	0.060 [0.75]										Z						Z		Z				Z								Z		
RSI						S		S		F		S				F		F		S		F		S		S		S		F		7	5
Level	0.030 [0.38]					Z		Z				Z								Z				Z		Z		Z					
RSI					F		F		F				S		F						F				F		F		F			1	8
Level	0.015 [0.19]												Z																				
RSI				F										F																		0	2
Level	0.010 [0.13]																																
RSI			F																													0	1
Level	0.0050 [0.063]																																
RSI		F																														0	1
Level	0.0025 [0.031]																																

Material: SS #24 (medium, fine) **Operator:** DJH
Date: 10/19/2021 **Relative Humidity:** 40% **Temperature:** 65°F **Project:** DOT1-6265c

ABL Friction	lbf (3ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		S					F	F	F	F	F	F	F	F	F	F	S		F	F	F	F	F	F	S		F	F	S		F	4	19
Level	1000	Z															Z								Z				Z				
RSI						F												F								F				F		0	4
Level	795																																
RSI					F																											0	1
Level	635																																
RSI				F																												0	1
Level	505																																
RSI			F																													0	1
Level	400																																

Number indicates amount
of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace X = Sample Consumed
M = Smoke L = Loud Report or Explosion
Z = Spark H = Hardware Damage
A = Flame P = Pop or Small Explosion
B = Flash HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A52: Laboratory Data Sheets for Mix ID SS #24 – Medium Al - Medium Bi_2O_3

Material: SS #24 (medium, medium) **Operator:** DMS
Date: 10/16/2021 **Relative Humidity:** 34% **Temperature:** 67°F **Project:** DOT1-6265c

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: SS #24 (medium, medium) **Operator:** JDZ
Date: 11/15/2021 **Relative Humidity:** 25% **Temperature:** 70°F **Project:** DOT1-6265c

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI											S																					1	0
Level	0.030 [0.38]										Z																						
RSI						S				F		S																				2	1
Level	0.015 [0.19]					Z						Z																					
RSI			S		F		S		F				S																			3	2
Level	0.010 [0.13]		Z				Z						Z																				
RSI		F		F				F						S						S						S						3	3
Level	0.0050 [0.063]													Z						Z						Z							
RSI															S		S		F		S		S		F		S		S		F	6	3
Level	0.0025 [0.031]														Z		Z				Z		Z				Z		Z				
RSI																F		F				F		F				F		F		0	6
Level	0.0012 [0.015]																																

Material: SS #24 (medium, medium) **Operator:** DJH
Date: 10/19/2021 **Relative Humidity:** 35% **Temperature:** 66°F **Project:** DOT1-6265c

ABL Friction	lbf (3ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI			S		F	F	F	S		F	F	F	F	F	S		F	F	F	F	F	F	F	F	F	S		F	F	S		5	19
Level	1000		Z					Z							Z											Z				Z			
RSI				F					F							F											F				F	0	5
Level	795																																
RSI																																0	0
Level	635																																
RSI																																0	0
Level	505																																
RSI		F																														0	1
Level	400																																

Number indicates amount
of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace X = Sample Consumed
M = Smoke L = Loud Report or Explosion
Z = Spark H = Hardware Damage
A = Flame P = Pop or Small Explosion
B = Flash HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A53: Laboratory Data Sheets for Mix ID SS #24 – Medium Al - Coarse Bi_2O_3

Material: SS #24 (medium, coarse) **Operator:** DMS
Date: 10/16/2021 **Relative Humidity:** 36% **Temperature:** 65°F **Project:** DOT1-6265c

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		S						F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	1	24
Level	100	Z																															
RSI			S				F																									1	1
Level	79.4		Z																														
RSI				S		F																										1	1
Level	63.1			Z																													
RSI					F																											0	1
Level	50.1																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: SS #24 (medium, coarse) **Operator:** JDZ
Date: 11/15/2021 **Relative Humidity:** 26% **Temperature:** 70°F **Project:** DOT1-6265c

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI									S																		S					2	0
Level	0.060 [0.75]								Z																		Z						
RSI								F		S								S								F		S		S		4	2
Level	0.030 [0.38]									Z								Z										Z		Z			
RSI							F				S				S		S		S						F				F		F	4	4
Level	0.015 [0.19]										Z				Z		Z		Z														
RSI		S		S		F						S		F		F				S				F								4	4
Level	0.010 [0.13]	Z		Z								Z								Z													
RSI			F		F								F								S		F									1	4
Level	0.0050 [0.063]																				Z												
RSI																						F										0	1
Level	0.0025 [0.031]																																

Material: SS #24 (medium, coarse) **Operator:** DJH
Date: 10/19/2021 **Relative Humidity:** 38% **Temperature:** 65°F **Project:** DOT1-6265c

ABL Friction	lbf (3ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		S								F	S		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	2	20
Level	1000	Z									Z																						
RSI			S						F			F																				1	2
Level	795		Z																														
RSI				S		S		F																								2	1
Level	635			Z		Z																											
RSI					F		F																									0	2
Level	505																																

Number indicates amount
of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction

F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace X = Sample Consumed
M = Smoke L = Loud Report or Explosion
Z = Spark H = Hardware Damage
A = Flame P = Pop or Small Explosion
B = Flash HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A54: Laboratory Data Sheets for Mix ID SS #24 – Coarse Al - Fine Bi_2O_3

Material: SS #24 (coarse, fine) **Operator:** DMS
Date: 10/16/2021 **Relative Humidity:** 37% **Temperature:** 65°F **Project:** DOT1-6265c

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: SS #24 (coarse, fine) **Operator:** JDZ
Date: 11/9/2021 **Relative Humidity:** 35% **Temperature:** 69°F **Project:** DOT1-6265c

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI															S								S									2	0
Level	0.120 [1.50]														Z								Z										
RSI						S						S		F		S						F		S		S		S		S		7	2
Level	0.060 [0.75]					Z						Z				Z								Z		Z		Z		Z			
RSI					F		S				F		F				S		S		F				F		F		F		F	3	8
Level	0.030 [0.38]						Z										Z		Z														
RSI				F				F		F								F		F												0	5
Level	0.015 [0.19]																																
RSI			F						F																							0	2
Level	0.010 [0.13]																																
RSI		F																														0	1
Level	0.0050 [0.063]																																

Material: SS #24 (coarse, fine) **Operator:** DJH
Date: 10/19/2021 **Relative Humidity:** 37% **Temperature:** 65°F **Project:** DOT1-6265c

ABL Friction	lbf (3ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI										F	F	F	F	F	S		F	F	F	F	F	F	S				F	F	F	S		3	14
Level	1000														Z								Z							Z			
RSI									F							F								S		F					F	1	4
Level	795																							Z									
RSI								F																	F							0	2
Level	635																																
RSI							F																									0	1
Level	505																																
RSI		F				F																										0	2
Level	400																																
RSI					F																											0	1
Level	320																																
RSI				F																												0	1
Level	255																																
RSI			F																													0	1
Level	200																																

Number indicates amount
of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction

F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace
M = Smoke
Z = Spark
A = Flame
B = Flash
X = Sample Consumed
L = Loud Report or Explosion
H = Hardware Damage
P = Pop or Small Explosion
HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A55: Laboratory Data Sheets for Mix ID SS #24 – Coarse Al - Medium Bi_2O_3

Material: SS #24 (coarse, medium) **Operator:** DMS
Date: 10/16/2021 **Relative Humidity:** 38% **Temperature:** 65°F **Project:** DOT1-6265c

MBOM Impact	cm	1	2	3	4	5	6	7	(	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30
Level	100																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: SS #24 (coarse, medium) **Operator:** JDZ
Date: 11/15/2021 **Relative Humidity:** 25% **Temperature:** 70°F **Project:** DOT1-6265c

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI															S		S															2	0
Level	0.120 [1.50]														Z		Z																
RSI										S				F		F		S		S						S						4	2
Level	0.060 [0.75]									Z								Z		Z						Z							
RSI									F		S		F						F		S		S		F		S		S		S	6	4
Level	0.030 [0.38]										Z										Z		Z				Z		Z		Z		
RSI								F				F										F		F				F		F		0	6
Level	0.015 [0.19]																																
RSI			S		S		F																									2	1
Level	0.010 [0.13]		Z		Z																												
RSI		F		F		F																										0	3
Level	0.0050 [0.063]																																

Material: SS #24 (coarse, medium) **Operator:** DJH
Date: 10/19/2021 **Relative Humidity:** 39% **Temperature:** 65°F **Project:** DOT1-6265c

ABL Friction	lbf (3ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI				F	S								F	S				F	F	S		S										4	4
Level	1000				Z									Z						Z		Z											
RSI						S						F			S		F				F		S		S						S	5	3
Level	795					Z									Z								Z		Z						Z		
RSI							S				F					F								F		S				F		2	4
Level	635						Z																			Z							
RSI								S		F																	S		F			2	2
Level	505							Z																			Z						
RSI		S							F																			F				1	2
Level	400	Z																															
RSI			F																													0	1
Level	320																																

Number indicates amount
of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace
M = Smoke
Z = Spark
A = Flame
B = Flash
X = Sample Consumed
L = Loud Report or Explosion
H = Hardware Damage
P = Pop or Small Explosion
HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A56: Laboratory Data Sheets for Mix ID SS #24 – Coarse Al - Coarse Bi_2O_3

Material: SS #24 (coarse, coarse) **Operator:** DMS
Date: 10/19/2021 **Relative Humidity:** 34% **Temperature:** 68°F **Project:** DOT1-6265c

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	S		F	F	F	F	F	F	F	F	F	F	1	28
Level	100																			Z													
RSI																					F											0	1
Level	79.4																																

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: SS #24 (coarse, coarse) **Operator:** JDZ
Date: 11/15/2021 **Relative Humidity:** 26% **Temperature:** 70°F **Project:** DOT1-6265c

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI														S																		1	0
Level	0.120 [1.50]													Z																			
RSI					S		S		S		S		F		S																	5	1
Level	0.060 [0.75]				Z		Z		Z		Z				Z																		
RSI				F		F		F		F		F				S										S						2	5
Level	0.030 [0.38]															Z										Z							
RSI			F														S								F		S		S		S	4	2
Level	0.015 [0.19]																Z										Z		Z		Z		
RSI		F																S		S		S		F				F		F		3	4
Level	0.010 [0.13]																	Z		Z		Z											
RSI																			F		F		F									0	3
Level	0.0050 [0.063]																																

Material: SS #24 (coarse, coarse) **Operator:** DJH
Date: 10/19/2021 **Relative Humidity:** 34% **Temperature:** 67°F **Project:** DOT1-6265c

ABL Friction	lbf (3ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI			S											F	F	F	F	S		F	F	F	S		S		S					5	7
Level	1000		Z															Z					Z		Z		Z						
RSI							S						F						F					F		F		S				2	4
Level	795						Z																					Z					
RSI				S		F		S		S		F																	S			4	2
Level	635			Z				Z		Z																			Z				
RSI					F				F		F																			S		1	3
Level	505																													Z			
RSI		F																													F	0	2
Level	400																																

Number indicates amount of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace
M = Smoke
Z = Spark
A = Flame
B = Flash
X = Sample Consumed
L = Loud Report or Explosion
H = Hardware Damage
P = Pop or Small Explosion
HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A57: Laboratory Data Sheets for Mix ID SS #48 – Fine Ti - Medium Bi_2O_3

Material: SS #48 (fine, medium) **Operator:** CLB
Date: 11/10/2021 **Relative Humidity:** 34% **Temperature:** 70°F **Project:** DOT1-6265c

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F		
Level	100																															0	30

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: SS #48 (fine, medium) **Operator:** JDZ
Date: 11/9/2021 **Relative Humidity:** 34% **Temperature:** 73°F **Project:** DOT1-6265c

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI								S																		S							
Level	0.0050 [0.063]							Z																		Z						2	0
RSI							F		S		S														F		S		S				
Level	0.0025 [0.031]								Z		Z																Z		Z			4	2
RSI						F				F		S												F				F		S			
Level	0.0012 [0.015]											Z																		Z		2	4
RSI					F								S				S		S		S		F								S		
Level	0.0007 [0.0088]												Z				Z		Z		Z										Z	5	2
RSI		S		F										S		F		F		F		F											
Level	0.0003 [0.0038]	Z												Z																		2	5
RSI			F												F																		
Level	0.0002 [0.0025]																															0	2

Material: SS #48 (fine, medium) **Operator:** JDZ
Date: 10/ **Relative Humidity:** **Temperature:** °F **Project:** DOT1-6265c

ABL Friction	lbf (3ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		S					F	S		F	F	F	F	F	S		F	S		F	F	S		F	F	S		F	F	S			
Level	1000	ZXB						Z							Z			Z				XB				XB				XB		7	13
RSI						F			F							F			F				F				F				F		
Level	795																															0	7
RSI					F																												
Level	635																															0	1
RSI				F																													
Level	505																															0	1
RSI			F																														
Level	400																															0	1

Number indicates amount <u>of sample consumption</u>
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace
M = Smoke
Z = Spark
A = Flame
B = Flash
X = Sample Consumed
L = Loud Report or Explosion
H = Hardware Damage
P = Pop or Small Explosion
HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A58: Laboratory Data Sheets for Mix ID SS #48 – Fine Ti - Coarse Bi_2O_3

Material: SS #48 (fine, coarse) **Operator:** CLB
Date: 11/10/2021 **Relative Humidity:** 37% **Temperature:** 70°F **Project:** DOT1-6265c

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F		
Level	100																															0	30

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: SS #48 (fine, coarse) **Operator:** JDZ
Date: 11/9/2021 **Relative Humidity:** 34% **Temperature:** 73°F **Project:** DOT1-6265c

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI				S						S																							
Level	0.0050 [0.063]			Z						Z																						2	0
RSI			F		S		S		F		S										S		S				S						
Level	0.0025 [0.031]				Z		Z				Z										Z		Z				Z					6	2
RSI		F				F		F				S		S				S		F		F		S		F		S		S			
Level	0.0012 [0.015]											Z		Z				Z						Z				Z		Z		6	6
RSI													F		S		F		F						F				F		F		
Level	0.0007 [0.0088]														Z																	1	6
RSI																F																	
Level	0.0003 [0.0038]																															0	1

Material: SS #48 (fine, coarse) **Operator:** JDZ
Date: 11/9/2021 **Relative Humidity:** 34% **Temperature:** 69 °F **Project:** DOT1-6265c

ABL Friction	lbf (3ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	S		S		F	F	F	S		F	F	F	S		F	F	F	S		S					
Level	1000								Z		Z					XB					Z					XB		XB				6	16
RSI										F		F					F					F					F		S		F		
Level	795																												Z			1	6
RSI																														F			
Level	635																															0	1

Number indicates amount of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace
M = Smoke
Z = Spark
A = Flame
B = Flash
X = Sample Consumed
L = Loud Report or Explosion
H = Hardware Damage
P = Pop or Small Explosion
HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A59: Laboratory Data Sheets for Mix ID SS #48 – Medium Ti - Fine Bi_2O_3

Material: SS #48 (medium, fine) **Operator:** JDZ
Date: 10/28/2021 **Relative Humidity:** 44% **Temperature:** 64°F **Project:** DOT1-6265c

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F		
Level	100																															0	30

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: SS #48 (medium, fine) **Operator:** JDZ
Date: 11/9/2021 **Relative Humidity:** 34% **Temperature:** 73°F **Project:** DOT1-6265c

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		S																															
Level	0.010 [0.13]	ZX																														1	0
RSI																																	
Level	0.0050 [0.063]																															0	0
RSI			S																														
Level	0.0025 [0.031]		ZX																													1	0
RSI																																	
Level	0.0012 [0.015]																															0	0
RSI				S																													
Level	0.0007 [0.0088]			ZX																												1	0
RSI														S														S					
Level	0.0003 [0.0038]													ZMX														ZMX				2	0
RSI					S	S	S	S	S	S	S	S	F		S	S	S	S	S	S	S	S	S	S	S	S	F		S	S	F		
Level	0.0002 [0.0025]				ZX	ZX	ZX	ZMX	ZMX	ZMX	ZMX	ZMX			Z	ZMX	ZMX	ZMX	ZMX	Z	Z	Z	Z	ZMX	Z	Z			ZMX	ZMX		22	3

Material: SS #48 (medium, fine) **Operator:** CLB
Date: 10/28/2021 **Relative Humidity:** 40% **Temperature:** 64 °F **Project:** DOT1-6265c

ABL Friction	lbf (3ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI													F	F	F	F	F	F	S		S		F	F	F	F	F	F	F	F	F		
Level	1000																		Z		Z											2	15
RSI												F								F		F											
Level	795																															0	3
RSI											F																						
Level	635																															0	1
RSI										F																							
Level	505																															0	1
RSI									F																								
Level	400																															0	1
RSI						S		F																									
Level	320					Z																										1	1
RSI		S					F																										
Level	255	Z																														1	1
RSI					F																												
Level	200																															0	1
RSI																																	
Level	160																															0	0
RSI				F																													
Level	127																															0	1
RSI																																	
Level	100																															0	0
RSI																																	
Level	80																															0	0
RSI																																	
Level	64																															0	0
RSI			F																														
Level	51																															0	1

Number indicates amount of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace
M = Smoke
Z = Spark
A = Flame
B = Flash
X = Sample Consumed
L = Loud Report or Explosion
H = Hardware Damage
P = Pop or Small Explosion
HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A60: Laboratory Data Sheets for Mix ID SS #48 – Medium Ti - Medium Bi_2O_3

Material: SS #48 (medium, medium) **Operator:** JDZ
Date: 10/28/2021 **Relative Humidity:** 44% **Temperature:** 64°F **Project:** DOT1-6265c

MBOM Impact	**cm**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**+**	**-**
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F		
Level	100																															0	30

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: SS #48 (medium, medium) **Operator:** JDZ
Date: 11/9/2021 **Relative Humidity:** 34% **Temperature:** 73°F **Project:** DOT1-6265c

ABL ESD	**µF [J] @ 5000V**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**+**	**-**
RSI																										S							
Level	0.0050 [0.063]																									Z						1	0
RSI			S																S		S				F		S						
Level	0.0025 [0.031]		Z																Z		Z						Z					4	1
RSI		F		S		S						S				S		F		F		S		F				S		S			
Level	0.0012 [0.015]			Z		Z						Z				Z						Z						Z		Z		7	4
RSI					F		S		S		F		S		F		F						F						F		F		
Level	0.0007 [0.0088]						Z		Z				Z																			3	7
RSI								F		F				F																			
Level	0.0003 [0.0038]																															0	3

Material: SS #48 (medium, medium) **Operator:** JDZ
Date: 11/24/2021 **Relative Humidity:** 20% **Temperature:** 70 °F **Project:** DOT1-6265c

ABL Friction	**lbf (3ft/sec)**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**+**	**-**
RSI											F	F	S		F	F	F	F	S		S		F	F	S		S		F	F	F		
Level	1000												Z						Z		Z				Z		Z					5	11
RSI		S		S						F				F						F		F				F		F					
Level	795	Z		Z																												2	6
RSI			F		S		S		F																								
Level	635				Z		Z																									2	2
RSI						F		F																									
Level	505																															0	2

Number indicates amount
of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction

F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace X = Sample Consumed
M = Smoke L = Loud Report or Explosion
Z = Spark H = Hardware Damage
A = Flame P = Pop or Small Explosion
B = Flash HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A61: Laboratory Data Sheets for Mix ID SS #48 – Medium Ti - Coarse Bi_2O_3

Material: SS #48 (medium, coarse) **Operator:** CLB
Date: 11/10/2021 **Relative Humidity:** 33% **Temperature:** 68°F **Project:** DOT1-6265c

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F		
Level	100																															0	30

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: SS #48 (medium, coarse) **Operator:** JDZ
Date: 11/9/2021 **Relative Humidity:** 34% **Temperature:** 73°F **Project:** DOT1-6265c

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI																													S				
Level	0.0050 [0.063]																												Z			1	0
RSI																				S				S				F		S			
Level	0.0025 [0.031]																			Z				Z						Z		3	1
RSI		S																	F		S		F		S		F				F		
Level	0.0012 [0.015]	Z																			Z				Z							3	4
RSI			S				S				S							F				F				F							
Level	0.0007 [0.0088]		Z				Z				Z																					3	3
RSI				S		F		S		F		S		S			F																
Level	0.0003 [0.0038]			Z				Z				Z		Z																		4	3
RSI					F				F				F		S	F																	
Level	0.0002 [0.0025]														Z																	1	4

Material: SS #48 (medium, coarse) **Operator:** CLB
Date: 10/28/2021 **Relative Humidity:** 41% **Temperature:** 65 °F **Project:** DOT1-6265c

ABL Friction	lbf (3ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI			F	F	S				S		F	F	F	F	F	F	S		F	F	F	F	S		F	S		F	F	F	F		
Level	1000				Z				Z								Z						Z			Z						5	17
RSI						S		F		F								F						F			F						
Level	795					Z																										1	5
RSI							F																										
Level	635																															0	1
RSI																																	
Level	505																															0	0
RSI																																	
Level	400																															0	0
RSI																																	
Level	320																															0	0
RSI		F																															
Level	255																															0	1

Number indicates amount of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace
M = Smoke
Z = Spark
A = Flame
B = Flash
X = Sample Consumed
L = Loud Report or Explosion
H = Hardware Damage
P = Pop or Small Explosion
HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A62: Laboratory Data Sheets for Mix ID SS #48 – Coarse Ti – Fine Bi_2O_3

Material: SS #48 (coarse, fine) **Operator:** CLB
Date: 11/10/2021 **Relative Humidity:** 33% **Temperature:** 70°F **Project:** DOT1-6265c

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F		
Level	100																															0	30

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: SS #48 (coarse, fine) **Operator:** JDZ
Date: 11/9/2021 **Relative Humidity:** 34% **Temperature:** 73°F **Project:** DOT1-6265c

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		S															S																
Level	0.0003 [0.0038]	Z															Z															2	0
RSI			S	S	S	S	S	S	S	S	S	S	S	S	S	F		S	S	S	S	S	S	S	S	S	S	S	S	S	S		
Level	0.0002 [0.0025]		Z	ZM	ZMX	Z	Z	ZMX	ZMX	ZMX	ZMX	ZMX	Z	Z	Z			ZMX	ZMX	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	Z	ZMX	27	1

Material: SS #48 (coarse, fine) **Operator:** JDZ
Date: 11/24/2021 **Relative Humidity:** 23% **Temperature:** 70 °F **Project:** DOT1-6265c

ABL Friction	lbf (3ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		S		F	F	F	S		F	F	F	F	F	S		S		F	S		F	F	S		F	S							
Level	1000	Z					Z							Z		Z			Z				Z			Z						7	12
RSI			F					F							F		F			F				F			S				S		
Level	795																										Z				Z	2	6
RSI																												S		F			
Level	635																											Z				1	1
RSI																													F				
Level	505																															0	1

Number indicates amount
of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace X = Sample Consumed
M = Smoke L = Loud Report or Explosion
Z = Spark H = Hardware Damage
A = Flame P = Pop or Small Explosion
B = Flash HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A63: Laboratory Data Sheets for Mix ID SS #48 – Coarse Ti – Medium Bi_2O_3

Material: SS #48 (coarse, medium) **Operator:** JDZ
Date: 10/28/2021 **Relative Humidity:** 44% **Temperature:** 64°F **Project:** DOT1-6265c

MBOM Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F		
Level	100																															0	30

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: SS #48 (coarse, medium) **Operator:** JDZ
Date: 11/9/2021 **Relative Humidity:** 35% **Temperature:** 73°F **Project:** DOT1-6265c

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI																												S					
Level	0.0050 [0.063]																											Z				1	0
RSI																							S		S		F		S		F		
Level	0.0025 [0.031]																						Z		Z				Z			3	2
RSI		S		S				S		S										S		F		F		F				F			
Level	0.0012 [0.015]	Z		Z				Z		Z										Z												5	4
RSI			F		S		F		F		S				S				F		F												
Level	0.0007 [0.0088]				Z						Z				Z																	3	5
RSI						F						S		F		S		F															
Level	0.0003 [0.0038]											Z				Z																2	3
RSI													F				F																
Level	0.0002 [0.0025]																															0	2

Material: SS #48 (coarse, medium) **Operator:** CLB
Date: 11/23/2021 **Relative Humidity:** 25% **Temperature:** 70 °F **Project:** DOT1-6265c

ABL Friction	lbf (3ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI				S		F	S		F	F	F	F	F	F	F	F	S		F	F	F	F	F	F	F	S		S		F	S		
Level	1000			Z			Z										Z									Z		Z			Z	6	17
RSI					F			F										F									F		F				
Level	795																															0	5
RSI																																	
Level	635																															0	0
RSI																																	
Level	505																															0	0
RSI																																	
Level	400																															0	0
RSI			F																														
Level	320																															0	1
RSI		F																															
Level	255																															0	1

Number indicates amount of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace X = Sample Consumed
M = Smoke L = Loud Report or Explosion
Z = Spark H = Hardware Damage
A = Flame P = Pop or Small Explosion
B = Flash HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure A64: Laboratory Data Sheets for Mix ID SS #48 – Coarse Ti - Coarse Bi_2O_3

Material: SS #48 (coarse, coarse) **Operator:** JDZ
Date: 10/28/2021 **Relative Humidity:** 44% **Temperature:** 64°F **Project:** DOT1-6265c

MBOM Impact	**cm**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**+**	**-**
RSI		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F		
Level	100																															0	30

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: SS #48 (coarse, coarse) **Operator:** JDZ
Date: 11/9/2021 **Relative Humidity:** 36% **Temperature:** 73°F **Project:** DOT1-6265c

ABL ESD	**µF [J] @ 5000V**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**+**	**-**
RSI												S						S										S					
Level	0.0050 [0.063]											Z						Z										Z				3	0
RSI					S		S		S		F		S		S		F		S						S		F		S				
Level	0.0025 [0.031]				Z		Z		Z				Z		Z				Z						Z				Z			8	3
RSI		S		F		F		F		F				F		F				S		S		F		F				S			
Level	0.0012 [0.015]	Z																		Z		Z								Z		4	8
RSI			F																		F		F								F		
Level	0.0007 [0.0088]																															0	4

Material: SS #48 (coarse, coarse) **Operator:** JDZ
Date: 11/24/2021 **Relative Humidity:** 20% **Temperature:** 70 °F **Project:** DOT1-6265c

ABL Friction	**lbf (3ft/sec)**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**+**	**-**
RSI				S		S		F	S		F	F	F	F	F	F	F	F	F	S		F	F	S		S		F	F	S			
Level	1000			Z		Z			Z											Z				Z		Z				Z		7	14
RSI			F		F		F			F											F				F		F				F		
Level	795																															0	8
RSI		F																															
Level	635																															0	1

Number indicates amount of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction

F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace
M = Smoke
Z = Spark
A = Flame
B = Flash
X = Sample Consumed
L = Loud Report or Explosion
H = Hardware Damage
P = Pop or Small Explosion
HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

APPENDIX B
– Bruceton H_{50} Calculations

Figure B1: Bruceton Impact H_{50} Calculations for Mix ID LS #7 – Fine Al - Medium MnO_2

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity Test

Sample: **SS #19 (fine, medium)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#N/A	log(cm)
#N/A	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B2: Bruceton Impact H_{50} Calculations for Mix ID LS #7 – Fine Al - Coarse MnO_2

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity Test

Sample: **SS #19 (fine, coarse)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#N/A	log(cm)
#N/A	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B3: Bruceton Impact H_{50} Calculations for Mix ID LS #7 – Medium Al - Fine MnO_2

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity Test

Sample: **SS #19 (medium, fine)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#N/A	log(cm)
#N/A	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B4: Bruceton Impact H_{50} Calculations for Mix ID LS #7 – Medium Al - Medium MnO_2

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity Test

Sample: **SS #19 (medium, medium)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#N/A	log(cm)
#N/A	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B5: Bruceton Impact H_{50} Calculations for Mix ID LS #7 – Medium Al - Coarse MnO_2

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity Test

Sample: **SS #19 (medium, coarse)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height (cm)	Drop Height log(cm)	Frequency +	Frequency -
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#N/A	log(cm)
#N/A	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B6: Bruceton Impact H_{50} Calculations for Mix ID LS #7 – Coarse Al - Fine MnO_2

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity Test

Sample: **SS #19 (coarse, fine)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height (cm)	log(cm)	Frequency +	Frequency -
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#N/A	log(cm)
#N/A	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B7: Bruceton Impact H_{50} Calculations for Mix ID LS #7 – Coarse Al - Medium MnO_2

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity Test

Sample: **SS #19 (coarse, medium)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height (cm)	log(cm)	Frequency +	Frequency -
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#N/A	log(cm)
#N/A	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B8: Bruceton Impact H_{50} Calculations for Mix ID LS #7 – Coarse Al - Coarse MnO_2

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity Test

Sample: **SS #19 (coarse, coarse)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#N/A	log(cm)
#N/A	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B9: Bruceton Impact H_{50} Calculations for Mix ID LS #8 – Fine Mg & Al - Medium MoO_3 & CuO

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity Test

Sample: **LS #8 (fine, medium)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height (cm)	log(cm)	Frequency +	Frequency -
100	2.0	1	28
79.4	1.9	0	1
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	1	29

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
1	28	28	28	
0	1	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
1.900	29	28	28	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
0	1	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.000	1	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.046 log(cm)
111.1 cm
s (using negatives)
0.0101 log(cm)
1.0 cm

H_{50} (using positives)
1.950 log(cm)
89.2 cm
s (using positives)
0.0047 log(cm)
1.0 cm

Figure B10: Bruceton Impact H_{50} Calculations for Mix ID LS #8 – Fine Mg & Al - Coarse MoO_3 & CuO

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity Test

Sample: **LS #8 (fine, coarse)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#N/A	log(cm)
#N/A	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B11: Bruceton Impact H_{50} Calculations for Mix ID LS #8 – Medium Mg & Al - Fine MoO_3 & CuO

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity Test

Sample: **LS #8 (medium, fine)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.
where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$
where $B = \Sigma i^2 \cdot n_i$

Drop Height (cm)	log(cm)	Frequency +	Frequency -
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#N/A	log(cm)
#N/A	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B12: Bruceton Impact H_{50} Calculations for Mix ID LS #8 – Medium Mg & Al - Medium MoO_3 & CuO

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity Test

Sample: **LS #8 (medium, medium)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	1	28
79.4	1.9	0	1
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	**1**	**29**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
1	28	28	28	
0	1	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
1.900	29	28	28	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
0	1	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.000	1	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.046 log(cm)
111.1 cm
s (using negatives)
0.0101 log(cm)
1.0 cm

H_{50} (using positives)
1.950 log(cm)
89.2 cm
s (using positives)
0.0047 log(cm)
1.0 cm

Figure B13: Bruceton Impact H_{50} Calculations for Mix ID LS #8 – Medium Mg & Al - Coarse MoO_3 & CuO

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity Test

Sample: **LS #8 (medium, coarse)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height (cm)	log(cm)	Frequency +	Frequency -
100	2.0	2	26
79.4	1.9	0	2
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	2	28

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
1	26	26	26	
0	2	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
1.900	28	26	26	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
0	2	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.000	2	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.042 log(cm)
110.2 cm
s (using negatives)
0.0154 log(cm)
1.0 cm

H_{50} (using positives)
1.950 log(cm)
89.2 cm
s (using positives)
0.0047 log(cm)
1.0 cm

Figure B14: Bruceton Impact H_{50} Calculations for Mix ID LS #8 – Coarse Mg & Al - Fine MoO_3 & CuO

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity Test

Sample: **LS #8 (coarse, fine)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	4	15
79.4	1.9	1	3
63.1	1.8	1	1
50.1	1.7	1	1
39.8	1.6	1	1
31.6	1.5	0	1
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	**8**	**22**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
5	15	75	375	
4	3	12	48	0.100
3	1	3	9	0.100
2	1	2	4	0.100
1	1	1	1	0.100
0	1	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
1.500	22	93	437	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
4	4	16	64	
3	1	3	9	0.100
2	1	2	4	0.100
1	1	1	1	0.100
0	1	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
1.600	8	22	78	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
1.971 log(cm)
93.5 cm
s (using negatives)
0.3266 log(cm)
2.1 cm

H_{50} (using positives)
1.824 log(cm)
66.7 cm
s (using positives)
0.3578 log(cm)
2.3 cm

Figure B15: Bruceton Impact H_{50} Calculations for Mix ID LS #8 – Coarse Mg & Al - Medium MoO_3 & CuO

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity Test

Sample: **LS #8 (coarse, medium)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	1	28
79.4	1.9	0	1
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	1	29

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
1	28	28	28	
0	1	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
1.900	29	28	28	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
0	1	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
2.000	1	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.046 log(cm)
111.1 cm
s (using negatives)
0.0101 log(cm)
1.0 cm

H_{50} (using positives)
1.950 log(cm)
89.2 cm
s (using positives)
0.0047 log(cm)
1.0 cm

Figure B16: Bruceton Impact H_{50} Calculations for Mix ID LS #8 – Coarse Mg & Al - Coarse MoO_3 & CuO

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity Test

Sample: **LS #8 (coarse, coarse)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height (cm)	log(cm)	Frequency +	Frequency -
100	2.0	2	27
79.4	1.9	0	1
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	2	28

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
1	27	27	27	
0	1	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
1.900	28	27	27	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
0	2	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.000	2	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.046	log(cm)
111.1	cm
s (using negatives)	
0.0102	log(cm)
1.0	cm

H_{50} (using positives)	
1.950	log(cm)
89.2	cm
s (using positives)	
0.0047	log(cm)
1.0	cm

Figure B17: Bruceton Impact H_{50} Calculations for Mix ID SS #3B – Fine Ti - Medium MnO_2

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity Test

Sample: **SS #3B (fine, medium)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#N/A	log(cm)
#N/A	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B18: Bruceton Impact H_{50} Calculations for Mix ID SS #3B – Fine Ti - Coarse MnO_2

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity Test

Sample: **SS #3B (fine, coarse)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#N/A	log(cm)
#N/A	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B19: Bruceton Impact H_{50} Calculations for Mix ID SS #3B – Medium Ti - Fine MnO_2

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity Test

Sample: **SS #3B (medium, fine)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#N/A	log(cm)
#N/A	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B20: Bruceton Impact H_{50} Calculations for Mix ID SS #3B – Medium Ti - Medium MnO_2

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity Test

Sample: **SS#3B(medium, medium)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	**0**	**30**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#N/A	log(cm)
#N/A	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B21: Bruceton Impact H_{50} Calculations for Mix ID SS #3B – Medium Ti - Coarse MnO_2

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity Test

Sample: **SS #3B (medium, coarse)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#N/A	log(cm)
#N/A	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B22: Bruceton Impact H_{50} Calculations for Mix ID SS #3B – Coarse Ti - Fine MnO_2

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity Test

Sample: **SS #3B (coarse, fine)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#N/A	log(cm)
#N/A	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B23: Bruceton Impact H_{50} Calculations for Mix ID SS #3B – Coarse Ti - Medium MnO_2

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity Test

Sample: **SS #3B (coarse, medium)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#N/A	log(cm)
#N/A	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B24: Bruceton Impact H_{50} Calculations for Mix ID SS #3B – Coarse Ti - Coarse MnO_2

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity Test

Sample: **SS #3B (coarse, coarse)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height (cm)	log(cm)	Frequency +	Frequency -
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#N/A	log(cm)
#N/A	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B25: Bruceton Impact H_{50} Calculations for Mix ID SS #4 – Fine Mg - Medium MnO_2

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity Test

Sample: **SS #4 (fine, medium)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#N/A	log(cm)
#N/A	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B26: Bruceton Impact H_{50} Calculations for Mix ID SS #4 – Fine Mg - Coarse MnO_2

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity Test

Sample: **SS #4 (fine, coarse)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	**0**	**30**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#N/A	log(cm)
#N/A	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B27: Bruceton Impact H_{50} Calculations for Mix ID SS #4 – Medium Mg - Fine MnO_2

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity Test

Sample: **SS #4 (medium, fine)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#N/A	log(cm)
#N/A	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B28: Bruceton Impact H_{50} Calculations for Mix ID SS #4 – Medium Mg - Medium MnO_2

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity Test

Sample: **SS#4 (medium, medium)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#N/A	log(cm)
#N/A	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B29: Bruceton Impact H_{50} Calculations for Mix ID SS #4 – Medium Mg - Coarse MnO_2

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity Test

Sample: **SS #4 (medium, coarse)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#N/A	log(cm)
#N/A	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B30: Bruceton Impact H_{50} Calculations for Mix ID SS #4 – Coarse Mg - Fine MnO_2

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity Test

Sample: **SS #4 (coarse, fine)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	**0**	**30**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#N/A	log(cm)
#N/A	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B31: Bruceton Impact H_{50} Calculations for Mix ID SS #4 – Coarse Mg - Medium MnO_2

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity Test

Sample: **SS #4 (coarse, medium)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	**0**	**30**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#N/A	log(cm)
#N/A	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B32: Bruceton Impact H_{50} Calculations for Mix ID SS #4 – Coarse Mg - Coarse MnO_2

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity Test

Sample: **SS #4 (coarse, coarse)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height (cm)	Drop Height log(cm)	Frequency +	Frequency -
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#N/A	log(cm)
#N/A	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B33: Bruceton Impact H_{50} Calculations for Mix ID SS #9 – Fine Al - Medium MoO_3

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity

Sample: **SS #9 (fine, medium)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#N/A	log(cm)
#N/A	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B34: Bruceton Impact H_{50} Calculations for Mix ID SS #9 – Fine Al - Coarse MoO_3

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity

Sample: **SS #9 (fine, coarse)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height (cm)	log(cm)	Frequency +	Frequency -
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#N/A	log(cm)
#N/A	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B35: Bruceton Impact H_{50} Calculations for Mix ID SS #9 – Medium Al - Fine MoO_3

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity

Sample: **SS #9 (medium, fine)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#N/A	log(cm)
#N/A	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B36: Bruceton Impact H_{50} Calculations for Mix ID SS #9 – Medium Al - Medium MoO_3

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity

Sample: **SS #9 (medium, medium)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height (cm)	log(cm)	Frequency +	Frequency -
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#N/A	log(cm)
#N/A	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B37: Bruceton Impact H_{50} Calculations for Mix ID SS #9 – Medium Al - Coarse MoO_3

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity

Sample: **SS #9 (medium, coarse)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	1	28
79.4	1.9	0	1
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	1	29

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
1	28	28	28	
0	1	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
1.900	29	28	28	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
0	1	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
2.000	1	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.046 log(cm)
111.1 cm
s (using negatives)
0.0101 log(cm)
1.0 cm

H_{50} (using positives)
1.950 log(cm)
89.2 cm
s (using positives)
0.0047 log(cm)
1.0 cm

Figure B38: Bruceton Impact H_{50} Calculations for Mix ID SS #9 – Coarse Al - Fine MoO_3

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity

Sample: **SS #9 (coarse, fine)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height (cm)	log(cm)	Frequency +	Frequency -
100	2.0	1	28
79.4	1.9	0	1
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	1	29

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
1	28	28	28	
0	1	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
1.900	29	28	28	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
0	1	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.000	1	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.046 log(cm)
111.1 cm
s (using negatives)
0.0101 log(cm)
1.0 cm

H_{50} (using positives)
1.950 log(cm)
89.2 cm
s (using positives)
0.0047 log(cm)
1.0 cm

Figure B39: Bruceton Impact H_{50} Calculations for Mix ID SS #9 – Coarse Al - Medium MoO_3

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity

Sample: **SS #9 (coarse, medium)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.
where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$
where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#N/A	log(cm)
#N/A	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B40: Bruceton Impact H_{50} Calculations for Mix ID SS #9 – Coarse Al - Coarse MoO_3

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity

Sample: **SS #9 (coarse, coarse)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	1	28
79.4	1.9	0	1
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	1	29

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
1	28	28	28	
0	1	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
1.900	29	28	28	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
0	1	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
2.000	1	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.046 log(cm)
111.1 cm
s (using negatives)
0.0101 log(cm)
1.0 cm

H_{50} (using positives)
1.950 log(cm)
89.2 cm
s (using positives)
0.0047 log(cm)
1.0 cm

Figure B41: Bruceton Impact H_{50} Calculations for Mix ID SS #19 – Fine Al - Medium SnO_2

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity Test

Sample: **SS #19 (fine, medium)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#N/A	log(cm)
#N/A	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B42: Bruceton Impact H_{50} Calculations for Mix ID SS #19 – Fine Al - Coarse SnO_2

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity Test

Sample: **SS #19 (fine, coarse)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height (cm)	Drop Height log(cm)	Frequency +	Frequency -
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#N/A	log(cm)
#N/A	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B43: Bruceton Impact H_{50} Calculations for Mix ID SS #19 – Medium Al - Fine SnO_2

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity Test

Sample: **SS #19 (medium, fine)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#N/A	log(cm)
#N/A	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B44: Bruceton Impact H_{50} Calculations for Mix ID SS #19 – Medium Al - Medium SnO_2

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity Test

Sample: **SS #19 (medium, medium)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#N/A	log(cm)
#N/A	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B45: Bruceton Impact H_{50} Calculations for Mix ID SS #19 – Medium Al - Coarse SnO_2

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity Test

Sample: **SS #19 (medium, coarse)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#N/A	log(cm)
#N/A	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B46: Bruceton Impact H_{50} Calculations for Mix ID SS #19 – Coarse Al – Fine SnO_2

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity Test

Sample: **SS #19 (coarse, fine)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height (cm)	log(cm)	Frequency +	Frequency -
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#N/A	log(cm)
#N/A	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B47: Bruceton Impact H_{50} Calculations for Mix ID SS #19 – Coarse Al - Medium SnO_2

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity Test

Sample: **SS #19 (coarse, medium)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#N/A	log(cm)
#N/A	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B48: Bruceton Impact H_{50} Calculations for Mix ID SS #19 – Coarse Al - Coarse SnO_2

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity Test

Sample: **SS #19 (coarse, coarse)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	**0**	**30**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#N/A	log(cm)
#N/A	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B49: Bruceton Impact H_{50} Calculations for Mix ID SS #24 – Fine Al - Medium Bi_2O_3

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity Test

Sample: **SS #24 (fine, medium)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	1	28
79.4	1.9	0	1
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	**1**	**29**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
1	28	28	28	
0	1	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
1.900	29	28	28	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
0	1	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.000	1	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.046 log(cm)
111.1 cm
s (using negatives)
0.0101 log(cm)
1.0 cm

H_{50} (using positives)
1.950 log(cm)
89.2 cm
s (using positives)
0.0047 log(cm)
1.0 cm

Figure B50: Bruceton Impact H_{50} Calculations for Mix ID SS #24 – Fine Al - Coarse Bi_2O_3

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity Test

Sample: **SS #24 (fine, coarse)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#N/A	log(cm)
#N/A	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B51: Bruceton Impact H_{50} Calculations for Mix ID SS #24 – Medium Al - Fine Bi_2O_3

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity Test

Sample: **SS #24 (medium, fine)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height (cm)	log(cm)	Frequency +	Frequency -
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#N/A	log(cm)
#N/A	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B52: Bruceton Impact H_{50} Calculations for Mix ID SS #24 – Medium Al - Medium Bi_2O_3

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity Test

Sample: **SS #24 (medium, medium)**

H_{50} = c + d (A/N_S ± 0.5)   NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, A = Σi·n_i, and N_S = Σn_i

s = 1.62 d ((N_S B - A^2)/N_S^2 + 0.029)

where B = Σi^2·n_i

Drop Height (cm)	log(cm)	Frequency +	Frequency -
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#N/A	log(cm)
#N/A	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B53: Bruceton Impact H_{50} Calculations for Mix ID SS #24 – Medium Al - Coarse Bi_2O_3

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity Test

Sample: **SS #24 (medium, coarse)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i{\cdot}n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2{\cdot}n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	1	24
79.4	1.9	1	1
63.1	1.8	1	1
50.1	1.7	0	1
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	3	27

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
3	24	72	216	
2	1	2	4	0.100
1	1	1	1	0.100
0	1	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
1.700	27	75	221	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
2	1	2	4	
1	1	1	1	0.100
0	1	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
1.800	3	3	5	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.026 log(cm)
106.3 cm
s (using negatives)
0.0804 log(cm)
1.2 cm

H_{50} (using positives)
1.850 log(cm)
70.8 cm
s (using positives)
0.1123 log(cm)
1.3 cm

Figure B54: Bruceton Impact H_{50} Calculations for Mix ID SS #24 – Coarse Al - Fine Bi_2O_3

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity Test

Sample: **SS #24 (coarse, fine)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height (cm)	Drop Height log(cm)	Frequency +	Frequency -
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#N/A	log(cm)
#N/A	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B55: Bruceton Impact H_{50} Calculations for Mix ID SS #24 – Coarse Al - Medium Bi_2O_3

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity Test

Sample: **SS #24 (coarse, medium)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	**0**	**30**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#N/A	log(cm)
#N/A	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B56: Bruceton Impact H_{50} Calculations for Mix ID SS #24 – Coarse Al - Coarse Bi_2O_3

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity Test

Sample: **SS #24 (coarse, coarse)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height (cm)	log(cm)	Frequency +	Frequency -
100	2.0	1	28
79.4	1.9	0	1
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	1	29

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
1	28	28	28	
0	1	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
1.900	29	28	28	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
0	1	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.000	1	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.046	log(cm)
111.1	cm
s (using negatives)	
0.0101	log(cm)
1.0	cm

H_{50} (using positives)	
1.950	log(cm)
89.2	cm
s (using positives)	
0.0047	log(cm)
1.0	cm

Figure B57: Bruceton Impact H_{50} Calculations for Mix ID SS #48 – Fine Ti - Medium Bi_2O_3

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity Test

Sample: **SS #48 (fine, medium)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height (cm)	log(cm)	Frequency +	Frequency -
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#N/A	log(cm)
#N/A	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B58: Bruceton Impact H_{50} Calculations for Mix ID SS #48 – Fine Ti - Coarse Bi_2O_3

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity Test

Sample: **SS #48 (fine, coarse)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height (cm)	log(cm)	Frequency +	Frequency -
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#N/A	log(cm)
#N/A	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B59: Bruceton Impact H_{50} Calculations for Mix ID SS #48 – Medium Ti - Fine Bi_2O_3

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity Test

Sample: **SS #48 (medium, fine)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	**0**	**30**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#N/A	log(cm)
#N/A	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B60: Bruceton Impact H_{50} Calculations for Mix ID SS #48 – Medium Ti - Medium Bi_2O_3

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity Test

Sample: **SS #48 (medium, medium)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height (cm)	log(cm)	Frequency +	Frequency -
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#N/A	log(cm)
#N/A	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B61: Bruceton Impact H_{50} Calculations for Mix ID SS #48 – Medium Ti - Coarse Bi_2O_3

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity Test

Sample: **SS #48 (medium, coarse)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#N/A	log(cm)
#N/A	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B62: Bruceton Impact H_{50} Calculations for Mix ID SS #48 – Coarse Ti - Fine Bi_2O_3

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity Test

Sample: **SS #48 (coarse, fine)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height (cm)	Drop Height log(cm)	Frequency +	Frequency -
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	**0**	**30**

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#N/A	log(cm)
#N/A	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B63: Bruceton Impact H_{50} Calculations for Mix ID SS #48 – Coarse Ti - Medium Bi_2O_3

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity Test

Sample: **SS #48 (coarse, medium)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#N/A	log(cm)
#N/A	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B64: Bruceton Impact H_{50} Calculations for Mix ID SS #48 – Coarse Ti - Coarse Bi_2O_3

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity Test

Sample: **SS #48 (coarse, coarse)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
0.0000	0	0	0
	SUM	**0**	**30**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#N/A	log(cm)
#N/A	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B65: Bruceton Friction H_{50} Calculations for Mix ID LS #7 – Fine Al - Medium MnO_2

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **LS #7 (fine, medium)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	2	20
795.0	2.9	2	2
635.0	2.8	1	2
505.0	2.7	0	1
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	5	25

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
5	0	0	0	
4	0	0	0	0.094
3	20	60	180	0.107
2	2	4	8	0.100
1	2	2	2	0.098
0	1	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.703	25	66	190	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
4	0	0	0	
3	0	0	0	0.094
2	2	4	8	0.107
1	2	2	2	0.100
0	1	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.803	5	6	10	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
3.016	log(lbf)
1037.5	lbf
s (using negatives)	
0.1064	log(lbf)
1.3	lbf

H_{50} (using positives)	
2.872	log(lbf)
745.6	lbf
s (using positives)	
0.0950	log(lbf)
1.2	lbf

Figure B66: Bruceton Friction H_{50} Calculations for Mix ID LS #7 – Fine Al - Coarse MnO_2

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **LS #7 (fine, coarse)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	3	13
795.0	2.9	4	3
635.0	2.8	1	4
505.0	2.7	0	1
400.0	2.6	0	1
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	8	22

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
6	0	0	0	
5	0	0	0	0.094
4	13	52	208	0.107
3	3	9	27	0.100
2	4	8	16	0.098
1	1	1	1	0.099
0	1	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.602	22	70	252	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
4	0	0	0	
3	0	0	0	0.094
2	3	6	12	0.107
1	4	4	4	0.100
0	1	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.803	8	10	16	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.969	log(lbf)
930.5	lbf
s (using negatives)	
0.2193	log(lbf)
1.7	lbf

H_{50} (using positives)	
2.877	log(lbf)
754.2	lbf
s (using positives)	
0.0753	log(lbf)
1.2	lbf

Figure B67: Bruceton Friction H_{50} Calculations for Mix ID LS #7 – Medium Al - Fine MnO_2

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **LS #7 (medium, fine)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.
where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$
where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	0	30
795.0	2.9	0	0
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
2	0	0	0	
1	0	0	0	0.094
0	30	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
3.000	30	0	0	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.094
FALSE	0	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
3.050	log(lbf)
1121.5	lbf
s (using negatives)	
0.0047	log(lbf)
1.0	lbf

H_{50} (using positives)	
#N/A	log(lbf)
#N/A	lbf
s (using positives)	
#DIV/0!	log(lbf)
#DIV/0!	lbf

Figure B68: Bruceton Friction H_{50} Calculations for Mix ID LS #7 – Medium Al - Medium MnO_2

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **LS #7 (medium, medium)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	1	0
795.0	2.9	1	0
635.0	2.8	2	1
505.0	2.7	4	1
400.0	2.6	4	4
320.0	2.5	4	4
255.0	2.4	0	4
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	16	14

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
8	0	0	0	
7	0	0	0	0.094
6	0	0	0	0.107
5	0	0	0	0.100
4	1	4	16	0.098
3	1	3	9	0.099
2	4	8	16	0.101
1	4	4	4	0.097
0	4	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.407	14	19	45	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
7	0	0	0	
6	0	0	0	0.094
5	1	5	25	0.107
4	1	4	16	0.100
3	2	6	18	0.098
2	4	8	16	0.099
1	4	4	4	0.101
0	4	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.505	16	27	79	0.100

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.591 log(lbf)
390.4 lbf

s (using negatives)
0.2261 log(lbf)
1.7 lbf

H_{50} (using positives)
2.623 log(lbf)
420.2 lbf

s (using positives)
0.3418 log(lbf)
2.2 lbf

Figure B69: Bruceton Friction H_{50} Calculations for Mix ID LS #7 – Medium Al - Coarse MnO_2

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **LS #7 (medium, coarse)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	1	0
795.0	2.9	2	0
635.0	2.8	2	2
505.0	2.7	4	1
400.0	2.6	3	4
320.0	2.5	4	2
255.0	2.4	1	3
200.0	2.3	0	1
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	17	13

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
9	0	0	0	
8	0	0	0	0.094
7	0	0	0	0.107
6	0	0	0	0.100
5	2	10	50	0.098
4	1	4	16	0.099
3	4	12	36	0.101
2	2	4	8	0.097
1	3	3	3	0.099
0	1	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.301	13	33	113	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
8	0	0	0	
7	0	0	0	0.094
6	1	6	36	0.107
5	2	10	50	0.100
4	2	8	32	0.098
3	4	12	36	0.099
2	3	6	12	0.101
1	4	4	4	0.097
0	1	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.407	17	46	170	0.100

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.604	log(lbf)
401.4	lbf
s (using negatives)	
0.3674	log(lbf)
2.3	lbf

H_{50} (using positives)	
2.626	log(lbf)
422.9	lbf
s (using positives)	
0.4368	log(lbf)
2.7	lbf

Figure B70: Bruceton Friction H_{50} Calculations for Mix ID LS #7 – Coarse Al - Fine MnO_2

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **LS #7 (coarse, fine)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	0	30
795.0	2.9	0	0
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
2	0	0	0	
1	0	0	0	0.094
0	30	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
3.000	30	0	0	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.094
FALSE	0	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
3.050	log(lbf)
1121.5	lbf
s (using negatives)	
0.0047	log(lbf)
1.0	lbf

H_{50} (using positives)	
#N/A	log(lbf)
#N/A	lbf
s (using positives)	
#DIV/0!	log(lbf)
#DIV/0!	lbf

Figure B71: Bruceton Friction H_{50} Calculations for Mix ID LS #7 – Coarse Al - Medium MnO_2

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **LS #7 (coarse, medium)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	1	1
795.0	2.9	1	0
635.0	2.8	0	0
505.0	2.7	1	0
400.0	2.6	0	0
320.0	2.5	2	0
255.0	2.4	2	1
200.0	2.3	1	3
160.0	2.2	2	1
127.0	2.1	4	2
100.0	2.0	2	4
80.0	1.9	0	2
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	16	14

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
13	0	0	0	
12	0	0	0	0.094
11	1	11	121	0.107
10	0	0	0	0.100
9	0	0	0	0.098
8	0	0	0	0.099
7	0	0	0	0.101
6	0	0	0	0.097
5	1	5	25	0.099
4	3	12	48	0.106
3	1	3	9	0.097
2	2	4	8	0.100
1	4	4	4	0.104
0	2	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
1.903	14	39	215	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
12	0	0	0	
11	0	0	0	0.094
10	1	10	100	0.107
9	1	9	81	0.100
8	0	0	0	0.098
7	1	7	49	0.099
6	0	0	0	0.101
5	2	10	50	0.097
4	2	8	32	0.099
3	1	3	9	0.106
2	2	4	8	0.097
1	4	4	4	0.100
0	2	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.000	16	55	333	0.100

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.230 log(lbf)
169.9 lbf

s (using negatives)
1.2303 log(lbf)
17.0 lbf

H_{50} (using positives)
2.293 log(lbf)
196.1 lbf

s (using positives)
1.4560 log(lbf)
28.6 lbf

Figure B72: Bruceton Friction H_{50} Calculations for Mix ID LS #7 – Coarse Al - Coarse MnO_2

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **LS #7 (coarse, coarse)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	1	1
795.0	2.9	1	0
635.0	2.8	3	0
505.0	2.7	1	2
400.0	2.6	2	0
320.0	2.5	3	1
255.0	2.4	1	2
200.0	2.3	1	0
160.0	2.2	2	0
127.0	2.1	4	1
100.0	2.0	0	4
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	19	11

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
12	0	0	0	
11	0	0	0	0.094
10	1	10	100	0.107
9	0	0	0	0.100
8	0	0	0	0.098
7	2	14	98	0.099
6	0	0	0	0.101
5	1	5	25	0.097
4	2	8	32	0.099
3	0	0	0	0.106
2	0	0	0	0.097
1	1	1	1	0.100
0	4	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.000	11	38	256	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
11	0	0	0	
10	0	0	0	0.094
9	1	9	81	0.107
8	1	8	64	0.100
7	3	21	147	0.098
6	1	6	36	0.099
5	2	10	50	0.101
4	3	12	48	0.097
3	1	3	9	0.099
2	1	2	4	0.106
1	2	2	2	0.097
0	4	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.104	19	73	441	0.100

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.394 log(lbf)
247.6 lbf

s (using negatives)
1.8340 log(lbf)
68.2 lbf

H_{50} (using positives)
2.437 log(lbf)
273.3 lbf

s (using positives)
1.3677 log(lbf)
23.3 lbf

Figure B73: Bruceton Friction H_{50} Calculations for Mix ID LS #8 – Fine Mg & Al - Medium MoO_3 & CuO

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **LS #8 (fine, medium)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	2	1
795.0	2.9	4	1
635.0	2.8	5	3
505.0	2.7	2	4
400.0	2.6	2	4
320.0	2.5	0	2
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	15	15

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
7	0	0	0	
6	0	0	0	0.094
5	1	5	25	0.107
4	1	4	16	0.100
3	3	9	27	0.098
2	4	8	16	0.099
1	4	4	4	0.101
0	2	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.505	15	30	88	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
6	0	0	0	
5	0	0	0	0.094
4	2	8	32	0.107
3	4	12	36	0.100
2	5	10	20	0.098
1	2	2	2	0.099
0	2	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.602	15	32	90	0.100

USE EITHER NEGATIVES OR POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.754 log(lbf)
567.7 lbf

s (using negatives)
0.3058 log(lbf)
2.0 lbf

H_{50} (using positives)
2.765 log(lbf)
581.7 lbf

s (using positives)
0.2384 log(lbf)
1.7 lbf

Figure B74: Bruceton Friction H_{50} Calculations for Mix ID LS #8 – Fine Mg & Al - Coarse MoO_3 & CuO

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **LS #8 (fine, coarse)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	5	17
795.0	2.9	1	5
635.0	2.8	0	1
505.0	2.7	0	0
400.0	2.6	0	1
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	6	24

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
6	0	0	0	
5	0	0	0	0.094
4	17	68	272	0.107
3	5	15	45	0.100
2	1	2	4	0.098
1	0	0	0	0.099
0	1	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.602	24	85	321	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
3	0	0	0	
2	0	0	0	0.094
1	5	5	5	0.107
0	1	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.900	6	5	5	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
3.005	log(lbf)
1010.6	lbf
s (using negatives)	
0.1388	log(lbf)
1.4	lbf

H_{50} (using positives)	
2.934	log(lbf)
858.2	lbf
s (using positives)	
0.0271	log(lbf)
1.1	lbf

Figure B75: Bruceton Friction H_{50} Calculations for Mix ID LS #8 – Medium Mg & Al - Fine MoO_3 & CuO

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **LS #8 (medium, fine)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	8	9
795.0	2.9	1	8
635.0	2.8	1	1
505.0	2.7	0	2
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	10	20

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
5	0	0	0	
4	0	0	0	0.094
3	9	27	81	0.107
2	8	16	32	0.100
1	1	1	1	0.098
0	2	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.703	20	44	114	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
4	0	0	0	
3	0	0	0	0.094
2	8	16	32	0.107
1	1	1	1	0.100
0	1	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.803	10	17	33	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.972	log(lbf)
938.0	lbf
s (using negatives)	
0.1434	log(lbf)
1.4	lbf

H_{50} (using positives)	
2.922	log(lbf)
836.1	lbf
s (using positives)	
0.0708	log(lbf)
1.2	lbf

Figure B76: Bruceton Friction H_{50} Calculations for Mix ID LS #8 – Medium Mg & Al - Medium MoO_3 & CuO

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **LS #8 (medium, medium)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	2	0
795.0	2.9	2	1
635.0	2.8	6	1
505.0	2.7	3	5
400.0	2.6	1	4
320.0	2.5	2	1
255.0	2.4	0	2
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	16	14

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
8	0	0	0	
7	0	0	0	0.094
6	0	0	0	0.107
5	1	5	25	0.100
4	1	4	16	0.098
3	5	15	45	0.099
2	4	8	16	0.101
1	1	1	1	0.097
0	2	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.407	14	33	103	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
7	0	0	0	
6	0	0	0	0.094
5	2	10	50	0.107
4	2	8	32	0.100
3	6	18	54	0.098
2	3	6	12	0.099
1	1	1	1	0.101
0	2	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.505	16	43	149	0.100

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.691 log(lbf)
491.0 lbf
s (using negatives)
0.2952 log(lbf)
2.0 lbf

H_{50} (using positives)
2.723 log(lbf)
528.4 lbf
s (using positives)
0.3418 log(lbf)
2.2 lbf

Figure B77: Bruceton Friction H_{50} Calculations for Mix ID LS #8 – Medium Mg & Al - Coarse MoO_3 & CuO

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **LS #8 (medium, coarse)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i{\cdot}n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2{\cdot}n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	6	14
795.0	2.9	1	6
635.0	2.8	0	2
505.0	2.7	0	0
400.0	2.6	0	1
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	7	23

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
6	0	0	0	
5	0	0	0	0.094
4	14	56	224	0.107
3	6	18	54	0.100
2	2	4	8	0.098
1	0	0	0	0.099
0	1	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.602	23	78	286	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
3	0	0	0	
2	0	0	0	0.094
1	6	6	6	0.107
0	1	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.900	7	6	6	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.990 log(lbf)
976.3 lbf
s (using negatives)
0.1553 log(lbf)
1.4 lbf

H_{50} (using positives)
2.936 log(lbf)
862.8 lbf
s (using positives)
0.0244 log(lbf)
1.1 lbf

Figure B78: Bruceton Friction H_{50} Calculations for Mix ID LS #8 – Coarse Mg & Al - Fine MoO_3 & CuO

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **LS #8 (coarse, fine)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	12	2
795.0	2.9	2	12
635.0	2.8	0	2
505.0	2.7	0	0
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	14	16

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
4	0	0	0	
3	0	0	0	0.094
2	2	4	8	0.107
1	12	12	12	0.100
0	2	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.803	16	16	20	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
3	0	0	0	
2	0	0	0	0.094
1	12	12	12	0.107
0	2	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.900	14	12	12	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.952	log(lbf)
895.7	lbf
s (using negatives)	
0.0450	log(lbf)
1.1	lbf

H_{50} (using positives)	
2.936	log(lbf)
862.8	lbf
s (using positives)	
0.0244	log(lbf)
1.1	lbf

Figure B79: Bruceton Friction H_{50} Calculations for Mix ID LS #8 – Coarse Mg & Al - Medium MoO_3 & CuO

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **LS #8 (coarse, medium)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	5	1
795.0	2.9	4	5
635.0	2.8	4	4
505.0	2.7	1	4
400.0	2.6	0	2
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	14	16

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
6	0	0	0	
5	0	0	0	0.094
4	1	4	16	0.107
3	5	15	45	0.100
2	4	8	16	0.098
1	4	4	4	0.099
0	2	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.602	16	31	81	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
5	0	0	0	
4	0	0	0	0.094
3	5	15	45	0.107
2	4	8	16	0.100
1	4	4	4	0.098
0	1	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.703	14	27	65	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.845	log(lbf)
699.5	lbf
s (using negatives)	
0.2158	log(lbf)
1.6	lbf

H_{50} (using positives)	
2.846	log(lbf)
700.7	lbf
s (using positives)	
0.1537	log(lbf)
1.4	lbf

Figure B80: Bruceton Friction H_{50} Calculations for Mix ID LS #8 – Coarse Mg & Al - Coarse MoO_3 & CuO

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **LS #8 (coarse, coarse)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	7	14
795.0	2.9	0	7
635.0	2.8	0	1
505.0	2.7	0	0
400.0	2.6	0	1
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	7	23

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
6	0	0	0	
5	0	0	0	0.094
4	14	56	224	0.107
3	7	21	63	0.100
2	1	2	4	0.098
1	0	0	0	0.099
0	1	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.602	23	79	291	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
2	0	0	0	
1	0	0	0	0.094
0	7	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
3.000	7	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.994 log(lbf)
986.1 lbf

s (using negatives)
0.1425 log(lbf)
1.4 lbf

H_{50} (using positives)
2.950 log(lbf)
891.7 lbf

s (using positives)
0.0047 log(lbf)
1.0 lbf

Figure B81: Bruceton Friction H_{50} Calculations for Mix ID SS #3B – Fine Ti - Medium MnO_2

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #3B (fine, medium)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	0	0
795.0	2.9	0	0
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	1	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	1	0
160.0	2.2	0	0
127.0	2.1	1	0
100.0	2.0	1	1
80.0	1.9	1	0
64.0	1.8	2	0
51.0	1.7	21	1
0.0000	0	0	0
	SUM	28	2

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
15	0	0	0	
14	0	0	0	0.094
13	0	0	0	0.107
12	0	0	0	0.100
11	0	0	0	0.098
10	0	0	0	0.099
9	0	0	0	0.101
8	0	0	0	0.097
7	0	0	0	0.099
6	0	0	0	0.106
5	0	0	0	0.097
4	0	0	0	0.100
3	1	3	9	0.104
2	0	0	0	0.097
1	0	0	0	0.097
0	1	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
1.708	2	3	9	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
15	0	0	0	
14	0	0	0	0.094
13	0	0	0	0.107
12	0	0	0	0.100
11	0	0	0	0.098
10	0	0	0	0.099
9	1	9	81	0.101
8	0	0	0	0.097
7	0	0	0	0.099
6	1	6	36	0.106
5	0	0	0	0.097
4	1	4	16	0.100
3	1	3	9	0.104
2	1	2	4	0.097
1	2	2	2	0.097
0	21	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
1.708	28	26	148	0.100

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
1.907 log(lbf)
80.7 lbf
s (using negatives)
0.3677 log(lbf)
2.3 lbf

H_{50} (using positives)
1.750 log(lbf)
56.3 lbf
s (using positives)
0.7183 log(lbf)
5.2 lbf

Figure B82: Bruceton Friction H_{50} Calculations for Mix ID SS #3B – Fine Ti - Coarse MnO_2

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #3B (fine, coarse)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	0	0
795.0	2.9	0	0
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	1	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	1	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	1	0
80.0	1.9	0	0
64.0	1.8	3	0
51.0	1.7	22	2
0.0000	0	0	0
	SUM	28	2

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
15	0	0	0	
14	0	0	0	0.094
13	0	0	0	0.107
12	0	0	0	0.100
11	0	0	0	0.098
10	0	0	0	0.099
9	0	0	0	0.101
8	0	0	0	0.097
7	0	0	0	0.099
6	0	0	0	0.106
5	0	0	0	0.097
4	0	0	0	0.100
3	0	0	0	0.104
2	0	0	0	0.097
1	0	0	0	0.097
0	2	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
1.708	2	0	0	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
15	0	0	0	
14	0	0	0	0.094
13	0	0	0	0.107
12	0	0	0	0.100
11	0	0	0	0.098
10	0	0	0	0.099
9	1	9	81	0.101
8	0	0	0	0.097
7	0	0	0	0.099
6	1	6	36	0.106
5	0	0	0	0.097
4	0	0	0	0.100
3	1	3	9	0.104
2	0	0	0	0.097
1	3	3	3	0.097
0	22	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
1.708	28	21	129	0.100

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
1.757 log(lbf)
57.2 lbf
s (using negatives)
0.0047 log(lbf)
1.0 lbf

H_{50} (using positives)
1.732 log(lbf)
54.0 lbf
s (using positives)
0.6572 log(lbf)
4.5 lbf

Figure B83: Bruceton Friction H_{50} Calculations for Mix ID SS #3B – Medium Ti - Fine MnO_2

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #3B (medium, fine)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	2	0
795.0	2.9	4	1
635.0	2.8	4	3
505.0	2.7	3	3
400.0	2.6	3	3
320.0	2.5	1	2
255.0	2.4	0	1
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	17	13

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
8	0	0	0	
7	0	0	0	0.094
6	0	0	0	0.107
5	1	5	25	0.100
4	3	12	48	0.098
3	3	9	27	0.099
2	3	6	12	0.101
1	2	2	2	0.097
0	1	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.407	13	34	114	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
7	0	0	0	
6	0	0	0	0.094
5	2	10	50	0.107
4	4	16	64	0.100
3	4	12	36	0.098
2	3	6	12	0.099
1	3	3	3	0.101
0	1	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.505	17	47	165	0.100

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.717 log(lbf)
521.0 lbf

s (using negatives)
0.3159 log(lbf)
2.1 lbf

H_{50} (using positives)
2.731 log(lbf)
537.9 lbf

s (using positives)
0.3374 log(lbf)
2.2 lbf

Figure B84: Bruceton Friction H_{50} Calculations for Mix ID SS #3B – Medium Ti - Medium MnO_2

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS#3B(medium, medium)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	0	0
795.0	2.9	0	0
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	1	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	1	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	1	0
80.0	1.9	0	0
64.0	1.8	1	0
51.0	1.7	26	0
0.0000	0	0	0
	SUM	30	0

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.094
FALSE	0	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
#N/A	0	0	0	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
15	0	0	0	
14	0	0	0	0.094
13	0	0	0	0.107
12	0	0	0	0.100
11	0	0	0	0.098
10	0	0	0	0.099
9	1	9	81	0.101
8	0	0	0	0.097
7	0	0	0	0.099
6	1	6	36	0.106
5	0	0	0	0.097
4	0	0	0	0.100
3	1	3	9	0.104
2	0	0	0	0.097
1	1	1	1	0.097
0	26	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
1.708	30	19	127	0.100

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
#N/A	log(lbf)
#N/A	lbf
s (using negatives)	
#DIV/0!	log(lbf)
#DIV/0!	lbf

H_{50} (using positives)	
1.721	log(lbf)
52.6	lbf
s (using positives)	
0.6229	log(lbf)
4.2	lbf

Figure B85: Bruceton Friction H_{50} Calculations for Mix ID SS #3B – Medium Ti - Coarse MnO_2

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #3B (medium, coarse)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	0	0
795.0	2.9	0	0
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	1	0
320.0	2.5	1	0
255.0	2.4	1	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	1	0
80.0	1.9	1	0
64.0	1.8	1	0
51.0	1.7	24	0
0.0000	0	0	0
	SUM	30	0

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.094
FALSE	0	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
#N/A	0	0	0	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
15	0	0	0	
14	0	0	0	0.094
13	0	0	0	0.107
12	0	0	0	0.100
11	0	0	0	0.098
10	0	0	0	0.099
9	1	9	81	0.101
8	1	8	64	0.097
7	1	7	49	0.099
6	0	0	0	0.106
5	0	0	0	0.097
4	0	0	0	0.100
3	1	3	9	0.104
2	1	2	4	0.097
1	1	1	1	0.097
0	24	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
1.708	30	30	208	0.100

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
#N/A	log(lbf)
#N/A	lbf
s (using negatives)	
#DIV/0!	log(lbf)
#DIV/0!	lbf

H_{50} (using positives)	
1.757	log(lbf)
57.2	lbf
s (using positives)	
0.9619	log(lbf)
9.2	lbf

Figure B86: Bruceton Friction H_{50} Calculations for Mix ID SS #3B – Coarse Ti - Fine MnO_2

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #3B (coarse, fine)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	1	0
795.0	2.9	2	1
635.0	2.8	5	1
505.0	2.7	6	4
400.0	2.6	2	6
320.0	2.5	0	2
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	16	14

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
7	0	0	0	
6	0	0	0	0.094
5	0	0	0	0.107
4	1	4	16	0.100
3	1	3	9	0.098
2	4	8	16	0.099
1	6	6	6	0.101
0	2	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.505	14	21	47	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
6	0	0	0	
5	0	0	0	0.094
4	1	4	16	0.107
3	2	6	18	0.100
2	5	10	20	0.098
1	6	6	6	0.099
0	2	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.602	16	26	60	0.100

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.704 log(lbf)
506.2 lbf
s (using negatives)
0.1833 log(lbf)
1.5 lbf

H_{50} (using positives)
2.714 log(lbf)
517.7 lbf
s (using positives)
0.1837 log(lbf)
1.5 lbf

Figure B87: Bruceton Friction H_{50} Calculations for Mix ID SS #3B – Coarse Ti - Medium MnO_2

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #3B (coarse, medium)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	0	0
795.0	2.9	0	0
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	1	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	1	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	1	0
80.0	1.9	0	0
64.0	1.8	2	0
51.0	1.7	24	1
0.0000	0	0	0
	SUM	29	1

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
15	0	0	0	
14	0	0	0	0.094
13	0	0	0	0.107
12	0	0	0	0.100
11	0	0	0	0.098
10	0	0	0	0.099
9	0	0	0	0.101
8	0	0	0	0.097
7	0	0	0	0.099
6	0	0	0	0.106
5	0	0	0	0.097
4	0	0	0	0.100
3	0	0	0	0.104
2	0	0	0	0.097
1	0	0	0	0.097
0	1	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
1.708	1	0	0	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
15	0	0	0	
14	0	0	0	0.094
13	0	0	0	0.107
12	0	0	0	0.100
11	0	0	0	0.098
10	0	0	0	0.099
9	1	9	81	0.101
8	0	0	0	0.097
7	0	0	0	0.099
6	1	6	36	0.106
5	0	0	0	0.097
4	0	0	0	0.100
3	1	3	9	0.104
2	0	0	0	0.097
1	2	2	2	0.097
0	24	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
1.708	29	20	128	0.100

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
1.757	log(lbf)
57.2	lbf
s (using negatives)	
0.0047	log(lbf)
1.0	lbf

H_{50} (using positives)	
1.726	log(lbf)
53.3	lbf
s (using positives)	
0.6400	log(lbf)
4.4	lbf

Figure B88: Bruceton Friction H_{50} Calculations for Mix ID SS #3B – Coarse Ti - Coarse MnO_2

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #3B (coarse, coarse)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	1	0
795.0	2.9	1	0
635.0	2.8	1	0
505.0	2.7	0	0
400.0	2.6	0	0
320.0	2.5	1	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	1	0
127.0	2.1	1	0
100.0	2.0	1	0
80.0	1.9	1	0
64.0	1.8	2	0
51.0	1.7	19	1
0.0000	0	0	0
	SUM	29	1

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
15	0	0	0	
14	0	0	0	0.094
13	0	0	0	0.107
12	0	0	0	0.100
11	0	0	0	0.098
10	0	0	0	0.099
9	0	0	0	0.101
8	0	0	0	0.097
7	0	0	0	0.099
6	0	0	0	0.106
5	0	0	0	0.097
4	0	0	0	0.100
3	0	0	0	0.104
2	0	0	0	0.097
1	0	0	0	0.097
0	1	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
1.708	1	0	0	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
15	0	0	0	
14	0	0	0	0.094
13	1	13	169	0.107
12	1	12	144	0.100
11	1	11	121	0.098
10	0	0	0	0.099
9	0	0	0	0.101
8	1	8	64	0.097
7	0	0	0	0.099
6	0	0	0	0.106
5	1	5	25	0.097
4	1	4	16	0.100
3	1	3	9	0.104
2	1	2	4	0.097
1	2	2	2	0.097
0	19	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
1.708	29	60	554	0.100

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
1.757 log(lbf)
57.2 lbf

s (using negatives)
0.0047 log(lbf)
1.0 lbf

H_{50} (using positives)
1.864 log(lbf)
73.1 lbf

s (using positives)
2.3961 log(lbf)
248.9 lbf

Figure B89: Bruceton Friction H_{50} Calculations for Mix ID SS #4 – Fine Mg - Medium MnO_2

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #4 (fine, medium)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	2	26
795.0	2.9	0	2
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	2	28

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
3	0	0	0	
2	0	0	0	0.094
1	26	26	26	0.107
0	2	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.900	28	26	26	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
2	0	0	0	
1	0	0	0	0.094
0	2	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
3.000	2	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
3.043	log(lbf)
1103.2	lbf
s (using negatives)	
0.0154	log(lbf)
1.0	lbf

H_{50} (using positives)	
2.950	log(lbf)
891.7	lbf
s (using positives)	
0.0047	log(lbf)
1.0	lbf

Figure B90: Bruceton Friction H_{50} Calculations for Mix ID SS #4 – Fine Mg - Coarse MnO_2

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #4 (fine, coarse)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i{\cdot}n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2{\cdot}n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	0	30
795.0	2.9	0	0
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
2	0	0	0	
1	0	0	0	0.094
0	30	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
3.000	30	0	0	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.094
FALSE	0	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
3.050	log(lbf)
1121.5	lbf
s (using negatives)	
0.0047	log(lbf)
1.0	lbf

H_{50} (using positives)	
#N/A	log(lbf)
#N/A	lbf
s (using positives)	
#DIV/0!	log(lbf)
#DIV/0!	lbf

Figure B91: Bruceton Friction H_{50} Calculations for Mix ID SS #4 – Medium Mg - Fine MnO_2

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #4 (medium, fine)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	0	29
795.0	2.9	0	0
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	0	1
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
6	0	0	0	
5	0	0	0	0.094
4	29	116	464	0.107
3	0	0	0	0.100
2	0	0	0	0.098
1	0	0	0	0.099
0	1	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.602	30	116	464	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.094
FALSE	0	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
3.037	log(lbf)
1088.8	lbf
s (using negatives)	
0.0879	log(lbf)
1.2	lbf

H_{50} (using positives)	
#N/A	log(lbf)
#N/A	lbf
s (using positives)	
#DIV/0!	log(lbf)
#DIV/0!	lbf

Figure B92: Bruceton Friction H_{50} Calculations for Mix ID SS #4 – Medium Mg - Medium MnO_2

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS#4 (medium, medium)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	3	23
795.0	2.9	0	3
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	0	1
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	3	27

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
6	0	0	0	
5	0	0	0	0.094
4	23	92	368	0.107
3	3	9	27	0.100
2	0	0	0	0.098
1	0	0	0	0.099
0	1	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.602	27	101	395	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
2	0	0	0	
1	0	0	0	0.094
0	3	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
3.000	3	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
3.024 log(lbf)
1057.8 lbf

s (using negatives)
0.1074 log(lbf)
1.3 lbf

H_{50} (using positives)
2.950 log(lbf)
891.7 lbf

s (using positives)
0.0047 log(lbf)
1.0 lbf

Figure B93: Bruceton Friction H_{50} Calculations for Mix ID SS #4 – Medium Mg - Coarse MnO_2

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #4 (medium, coarse)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	2	25
795.0	2.9	0	2
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	0	1
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	2	28

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
6	0	0	0	
5	0	0	0	0.094
4	25	100	400	0.107
3	2	6	18	0.100
2	0	0	0	0.098
1	0	0	0	0.099
0	1	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.602	28	106	418	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
2	0	0	0	
1	0	0	0	0.094
0	2	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
3.000	2	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
3.029	log(lbf)
1068.7	lbf
s (using negatives)	
0.1010	log(lbf)
1.3	lbf

H_{50} (using positives)	
2.950	log(lbf)
891.7	lbf
s (using positives)	
0.0047	log(lbf)
1.0	lbf

Figure B94: Bruceton Friction H_{50} Calculations for Mix ID SS #4 – Coarse Mg - Fine MnO_2

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #4 (coarse, fine)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	0	29
795.0	2.9	0	0
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	0	1
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
6	0	0	0	
5	0	0	0	0.094
4	29	116	464	0.107
3	0	0	0	0.100
2	0	0	0	0.098
1	0	0	0	0.099
0	1	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.602	30	116	464	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.094
FALSE	0	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
3.037	log(lbf)
1088.8	lbf
s (using negatives)	
0.0879	log(lbf)
1.2	lbf

H_{50} (using positives)	
#N/A	log(lbf)
#N/A	lbf
s (using positives)	
#DIV/0!	log(lbf)
#DIV/0!	lbf

Figure B95: Bruceton Friction H_{50} Calculations for Mix ID SS #4 – Coarse Mg - Medium MnO_2

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #4 (coarse, medium)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	3	24
795.0	2.9	0	2
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	0	1
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	3	27

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
6	0	0	0	
5	0	0	0	0.094
4	24	96	384	0.107
3	2	6	18	0.100
2	0	0	0	0.098
1	0	0	0	0.099
0	1	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.602	27	102	402	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
2	0	0	0	
1	0	0	0	0.094
0	3	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
3.000	3	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
3.028	log(lbf)
1066.8	lbf
s (using negatives)	
0.1043	log(lbf)
1.3	lbf

H_{50} (using positives)	
2.950	log(lbf)
891.7	lbf
s (using positives)	
0.0047	log(lbf)
1.0	lbf

Figure B96: Bruceton Friction H_{50} Calculations for Mix ID SS #4 – Coarse Mg - Coarse MnO_2

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #4 (coarse, coarse)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	2	22
795.0	2.9	2	2
635.0	2.8	0	2
505.0	2.7	0	0
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	4	26

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
4	0	0	0	
3	0	0	0	0.094
2	22	44	88	0.107
1	2	2	2	0.100
0	2	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.803	26	46	90	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
3	0	0	0	
2	0	0	0	0.094
1	2	2	2	0.107
0	2	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.900	4	2	2	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
3.029 log(lbf)
1068.5 lbf

s (using negatives)
0.0581 log(lbf)
1.1 lbf

H_{50} (using positives)
2.900 log(lbf)
795.0 lbf

s (using positives)
0.0450 log(lbf)
1.1 lbf

Figure B97: Bruceton Friction H_{50} Calculations for Mix ID SS #9 – Fine Al - Medium MoO_3

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #9 (fine, medium)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	Force log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	0	0
795.0	2.9	0	0
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	1	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	1	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	1	0
80.0	1.9	2	0
64.0	1.8	4	1
51.0	1.7	17	3
0.0000	0	0	0
	SUM	26	4

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
15	0	0	0	
14	0	0	0	0.094
13	0	0	0	0.107
12	0	0	0	0.100
11	0	0	0	0.098
10	0	0	0	0.099
9	0	0	0	0.101
8	0	0	0	0.097
7	0	0	0	0.099
6	0	0	0	0.106
5	0	0	0	0.097
4	0	0	0	0.100
3	0	0	0	0.104
2	0	0	0	0.097
1	1	1	1	0.097
0	3	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
1.708	4	1	1	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
15	0	0	0	
14	0	0	0	0.094
13	0	0	0	0.107
12	0	0	0	0.100
11	0	0	0	0.098
10	0	0	0	0.099
9	1	9	81	0.101
8	0	0	0	0.097
7	0	0	0	0.099
6	1	6	36	0.106
5	0	0	0	0.097
4	0	0	0	0.100
3	1	3	9	0.104
2	2	4	8	0.097
1	4	4	4	0.097
0	17	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
1.708	26	26	138	0.100

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
1.782 log(lbf)
60.6 lbf

s (using negatives)
0.0349 log(lbf)
1.1 lbf

H_{50} (using positives)
1.757 log(lbf)
57.2 lbf

s (using positives)
0.6997 log(lbf)
5.0 lbf

Figure B98: Bruceton Friction H_{50} Calculations for Mix ID SS #9 – Fine Al - Coarse MoO_3

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #9 (fine, coarse)**

H_{50} = c + d (A/N_S ± 0.5)   NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, A = Σi·n_i, and N_S = Σn_i

s = 1.62 d ((N_S B - A^2)/N_S^2 + 0.029)

where B = Σi^2·n_i

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	1	0
795.0	2.9	2	1
635.0	2.8	4	2
505.0	2.7	5	3
400.0	2.6	2	5
320.0	2.5	1	3
255.0	2.4	0	1
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	15	15

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
8	0	0	0	
7	0	0	0	0.094
6	0	0	0	0.107
5	1	5	25	0.100
4	2	8	32	0.098
3	3	9	27	0.099
2	5	10	20	0.101
1	3	3	3	0.097
0	1	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.407	15	35	107	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
7	0	0	0	
6	0	0	0	0.094
5	1	5	25	0.107
4	2	8	32	0.100
3	4	12	36	0.098
2	5	10	20	0.099
1	2	2	2	0.101
0	1	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.505	15	37	115	0.100

USE EITHER NEGATIVES OR POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.689	log(lbf)
488.3	lbf
s (using negatives)	
0.2772	log(lbf)
1.9	lbf

H_{50} (using positives)	
2.701	log(lbf)
502.4	lbf
s (using positives)	
0.2599	log(lbf)
1.8	lbf

Figure B99: Bruceton Friction H_{50} Calculations for Mix ID SS #9 – Medium Al - Fine MoO_3

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #9 (medium, fine)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.
where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$
where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	0	0
795.0	2.9	0	0
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	1	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	1	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	1	0
80.0	1.9	1	0
64.0	1.8	7	1
51.0	1.7	12	6
0.0000	0	0	0
	SUM	23	7

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
15	0	0	0	
14	0	0	0	0.094
13	0	0	0	0.107
12	0	0	0	0.100
11	0	0	0	0.098
10	0	0	0	0.099
9	0	0	0	0.101
8	0	0	0	0.097
7	0	0	0	0.099
6	0	0	0	0.106
5	0	0	0	0.097
4	0	0	0	0.100
3	0	0	0	0.104
2	0	0	0	0.097
1	1	1	1	0.097
0	6	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
1.708	7	1	1	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
15	0	0	0	
14	0	0	0	0.094
13	0	0	0	0.107
12	0	0	0	0.100
11	0	0	0	0.098
10	0	0	0	0.099
9	1	9	81	0.101
8	0	0	0	0.097
7	0	0	0	0.099
6	1	6	36	0.106
5	0	0	0	0.097
4	0	0	0	0.100
3	1	3	9	0.104
2	1	2	4	0.097
1	7	7	7	0.097
0	12	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
1.708	23	27	137	0.100

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
1.772	log(lbf)
59.1	lbf
s (using negatives)	
0.0244	log(lbf)
1.1	lbf

H_{50} (using positives)	
1.775	log(lbf)
59.5	lbf
s (using positives)	
0.7433	log(lbf)
5.5	lbf

Figure B100: Bruceton Friction H_{50} Calculations for Mix ID SS #9 – Medium Al - Medium MoO_3

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #9 (medium, medium)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force		Frequency	
(lbf)	log(lbf)	+	-
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	0	0
795.0	2.9	0	0
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	1	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	2	0
160.0	2.2	1	1
127.0	2.1	1	1
100.0	2.0	2	2
80.0	1.9	3	2
64.0	1.8	2	3
51.0	1.7	7	2
0.0000	0	0	0
	SUM	**19**	**11**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
15	0	0	0	
14	0	0	0	0.094
13	0	0	0	0.107
12	0	0	0	0.100
11	0	0	0	0.098
10	0	0	0	0.099
9	0	0	0	0.101
8	0	0	0	0.097
7	0	0	0	0.099
6	0	0	0	0.106
5	1	5	25	0.097
4	1	4	16	0.100
3	2	6	18	0.104
2	2	4	8	0.097
1	3	3	3	0.097
0	2	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
1.708	11	22	70	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
15	0	0	0	
14	0	0	0	0.094
13	0	0	0	0.107
12	0	0	0	0.100
11	0	0	0	0.098
10	0	0	0	0.099
9	1	9	81	0.101
8	0	0	0	0.097
7	0	0	0	0.099
6	2	12	72	0.106
5	1	5	25	0.097
4	1	4	16	0.100
3	2	6	18	0.104
2	3	6	12	0.097
1	2	2	2	0.097
0	7	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
1.708	19	44	226	0.100

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
1.957 log(lbf)
90.5 lbf
s (using negatives)
0.3860 log(lbf)
2.4 lbf

H_{50} (using positives)
1.888 log(lbf)
77.3 lbf
s (using positives)
1.0585 log(lbf)
11.4 lbf

Figure B101: Bruceton Friction H_{50} Calculations for Mix ID SS #9 – Medium Al - Coarse MoO_3

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #9 (medium, coarse)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force		Frequency	
(lbf)	log(lbf)	+	-
1590	3.2	1	0
1280.0	3.1	1	2
1000.0	3.0	3	2
795.0	2.9	3	4
635.0	2.8	4	4
505.0	2.7	0	4
400.0	2.6	0	1
320.0	2.5	0	1
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	12	18

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
7	0	0	0	
6	2	12	72	0.094
5	2	10	50	0.107
4	4	16	64	0.100
3	4	12	36	0.098
2	4	8	16	0.099
1	1	1	1	0.101
0	1	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	N_S	A	B	d
2.505	18	59	239	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
4	1	4	16	
3	1	3	9	0.094
2	3	6	12	0.107
1	3	3	3	0.100
0	4	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	N_S	A	B	d
2.803	12	16	40	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.881	log(lbf)
761.0	lbf
s (using negatives)	
0.4135	log(lbf)
2.6	lbf

H_{50} (using positives)	
2.886	log(lbf)
768.7	lbf
s (using positives)	
0.2556	log(lbf)
1.8	lbf

Figure B102: Bruceton Friction H_{50} Calculations for Mix ID SS #9 – Coarse Al - Fine MoO_3

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #9 (coarse, fine)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	1	0
1000.0	3.0	1	1
795.0	2.9	3	1
635.0	2.8	5	3
505.0	2.7	2	5
400.0	2.6	1	3
320.0	2.5	1	2
255.0	2.4	0	1
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	**14**	**16**

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
8	0	0	0	
7	0	0	0	0.094
6	1	6	36	0.107
5	1	5	25	0.100
4	3	12	48	0.098
3	5	15	45	0.099
2	3	6	12	0.101
1	2	2	2	0.097
0	1	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.407	16	46	168	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
7	0	0	0	
6	1	6	36	0.094
5	1	5	25	0.107
4	3	12	48	0.100
3	5	15	45	0.098
2	2	4	8	0.099
1	1	1	1	0.101
0	1	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.505	14	43	163	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.743 log(lbf)
552.9 lbf
s (using negatives)
0.3652 log(lbf)
2.3 lbf

H_{50} (using positives)
2.761 log(lbf)
577.1 lbf
s (using positives)
0.3611 log(lbf)
2.3 lbf

Figure B103: Bruceton Friction H_{50} Calculations for Mix ID SS #9 – Coarse Al - Medium MoO_3

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #9 (coarse, medium)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	Force log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	0	0
795.0	2.9	0	0
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	4	0
320.0	2.5	6	3
255.0	2.4	4	6
200.0	2.3	1	5
160.0	2.2	0	1
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	15	15

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
10	0	0	0	
9	0	0	0	0.094
8	0	0	0	0.107
7	0	0	0	0.100
6	0	0	0	0.098
5	0	0	0	0.099
4	0	0	0	0.101
3	3	9	27	0.097
2	6	12	24	0.099
1	5	5	5	0.106
0	1	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	N_S	A	B	d
2.204	15	26	56	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
9	0	0	0	
8	0	0	0	0.094
7	0	0	0	0.107
6	0	0	0	0.100
5	0	0	0	0.098
4	0	0	0	0.099
3	4	12	36	0.101
2	6	12	24	0.097
1	4	4	4	0.099
0	1	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	N_S	A	B	d
2.301	15	28	64	0.100

USE EITHER NEGATIVES OR POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.427	log(lbf)
267.0	lbf
s (using negatives)	
0.1223	log(lbf)
1.3	lbf

H_{50} (using positives)	
2.437	log(lbf)
273.6	lbf
s (using positives)	
0.1309	log(lbf)
1.4	lbf

Figure B104: Bruceton Friction H_{50} Calculations for Mix ID SS #9 – Coarse Al - Coarse MoO_3

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #9 (coarse, coarse)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	3	6
795.0	2.9	5	2
635.0	2.8	1	4
505.0	2.7	4	0
400.0	2.6	1	4
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	14	16

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
6	0	0	0	
5	0	0	0	0.094
4	6	24	96	0.107
3	2	6	18	0.100
2	4	8	16	0.098
1	0	0	0	0.099
0	4	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.602	16	38	130	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
6	0	0	0	
5	0	0	0	0.094
4	3	12	48	0.107
3	5	15	45	0.100
2	1	2	4	0.098
1	4	4	4	0.099
0	1	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.602	14	33	101	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.888	log(lbf)
773.4	lbf
s (using negatives)	
0.4055	log(lbf)
2.5	lbf

H_{50} (using positives)	
2.787	log(lbf)
612.4	lbf
s (using positives)	
0.2722	log(lbf)
1.9	lbf

Figure B105: Bruceton Friction H_{50} Calculations for Mix ID SS #19 – Fine Al - Medium SnO_2

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #19 (fine, medium)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	1	27
795.0	2.9	0	1
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	0	1
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	1	29

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
6	0	0	0	
5	0	0	0	0.094
4	27	108	432	0.107
3	1	3	9	0.100
2	0	0	0	0.098
1	0	0	0	0.099
0	1	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.602	29	111	441	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
2	0	0	0	
1	0	0	0	0.094
0	1	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
3.000	1	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
3.033	log(lbf)
1079.0	lbf
s (using negatives)	
0.0945	log(lbf)
1.2	lbf

H_{50} (using positives)	
2.950	log(lbf)
891.7	lbf
s (using positives)	
0.0047	log(lbf)
1.0	lbf

Figure B106: Bruceton Friction H_{50} Calculations for Mix ID SS #19 – Fine Al - Coarse SnO_2

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #19 (fine, coarse)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force		Frequency	
(lbf)	log(lbf)	+	-
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	2	24
795.0	2.9	1	2
635.0	2.8	0	1
505.0	2.7	0	0
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	3	27

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
4	0	0	0	
3	0	0	0	0.094
2	24	48	96	0.107
1	2	2	2	0.100
0	1	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	N_S	A	B	d
2.803	27	50	98	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
3	0	0	0	
2	0	0	0	0.094
1	2	2	2	0.107
0	1	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	N_S	A	B	d
2.900	3	2	2	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
3.037	log(lbf)
1088.9	lbf
s (using negatives)	
0.0370	log(lbf)
1.1	lbf

H_{50} (using positives)	
2.917	log(lbf)
826.0	lbf
s (using positives)	
0.0405	log(lbf)
1.1	lbf

Figure B107: Bruceton Friction H_{50} Calculations for Mix ID SS #19 – Medium Al - Fine SnO_2

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #19 (medium, fine)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	4	10
795.0	2.9	3	4
635.0	2.8	3	3
505.0	2.7	0	3
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	10	20

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
5	0	0	0	
4	0	0	0	0.094
3	10	30	90	0.107
2	4	8	16	0.100
1	3	3	3	0.098
0	3	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	N_S	A	B	d
2.703	20	41	109	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
4	0	0	0	
3	0	0	0	0.094
2	4	8	16	0.107
1	3	3	3	0.100
0	3	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	N_S	A	B	d
2.803	10	11	19	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.957	log(lbf)
906.2	lbf
s (using negatives)	
0.2059	log(lbf)
1.6	lbf

H_{50} (using positives)	
2.863	log(lbf)
728.7	lbf
s (using positives)	
0.1160	log(lbf)
1.3	lbf

Figure B108: Bruceton Friction H_{50} Calculations for Mix ID SS #19 – Medium Al - Medium SnO_2

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #19 (medium, medium)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	4	16
795.0	2.9	3	4
635.0	2.8	0	3
505.0	2.7	0	0
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	7	23

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
4	0	0	0	
3	0	0	0	0.094
2	16	32	64	0.107
1	4	4	4	0.100
0	3	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.803	23	36	68	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
3	0	0	0	
2	0	0	0	0.094
1	4	4	4	0.107
0	3	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.900	7	4	4	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
3.008	log(lbf)
1019.6	lbf
s (using negatives)	
0.0864	log(lbf)
1.2	lbf

H_{50} (using positives)	
2.907	log(lbf)
808.1	lbf
s (using positives)	
0.0442	log(lbf)
1.1	lbf

Figure B109: Bruceton Friction H_{50} Calculations for Mix ID SS #19 – Medium Al - Coarse SnO_2

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #19 (medium, coarse)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	5	6
795.0	2.9	8	4
635.0	2.8	0	7
505.0	2.7	0	0
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	13	17

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
4	0	0	0	
3	0	0	0	0.094
2	6	12	24	0.107
1	4	4	4	0.100
0	7	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.803	17	16	28	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
3	0	0	0	
2	0	0	0	0.094
1	5	5	5	0.107
0	8	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.900	13	5	5	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.946 log(lbf)
883.7 lbf
s (using negatives)
0.1275 log(lbf)
1.3 lbf

H_{50} (using positives)
2.889 log(lbf)
774.2 lbf
s (using positives)
0.0429 log(lbf)
1.1 lbf

Figure B110: Bruceton Friction H_{50} Calculations for Mix ID SS #19 – Coarse Al – Fine SnO_2

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #19 (coarse, fine)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	1	3
795.0	2.9	4	0
635.0	2.8	3	3
505.0	2.7	5	2
400.0	2.6	2	4
320.0	2.5	1	1
255.0	2.4	0	1
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	16	14

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
8	0	0	0	
7	0	0	0	0.094
6	3	18	108	0.107
5	0	0	0	0.100
4	3	12	48	0.098
3	2	6	18	0.099
2	4	8	16	0.101
1	1	1	1	0.097
0	1	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.407	14	45	191	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
7	0	0	0	
6	0	0	0	0.094
5	1	5	25	0.107
4	4	16	64	0.100
3	3	9	27	0.098
2	5	10	20	0.099
1	2	2	2	0.101
0	1	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.505	16	42	138	0.100

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.776 log(lbf)
597.6 lbf
s (using negatives)
0.5389 log(lbf)
3.5 lbf

H_{50} (using positives)
2.717 log(lbf)
520.9 lbf
s (using positives)
0.2845 log(lbf)
1.9 lbf

Figure B111: Bruceton Friction H_{50} Calculations for Mix ID SS #19 – Coarse Al - Medium SnO_2

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #19 (coarse, medium)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	7	12
795.0	2.9	2	7
635.0	2.8	0	2
505.0	2.7	0	0
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	9	21

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
4	0	0	0	
3	0	0	0	0.094
2	12	24	48	0.107
1	7	7	7	0.100
0	2	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.803	21	31	55	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
3	0	0	0	
2	0	0	0	0.094
1	7	7	7	0.107
0	2	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.900	9	7	7	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
3.000 log(lbf)
999.0 lbf

s (using negatives)
0.0757 log(lbf)
1.2 lbf

H_{50} (using positives)
2.928 log(lbf)
847.3 lbf

s (using positives)
0.0326 log(lbf)
1.1 lbf

Figure B112: Bruceton Friction H_{50} Calculations for Mix ID SS #19 – Coarse Al - Coarse SnO_2

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #19 (coarse, coarse)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force		Frequency	
(lbf)	log(lbf)	+	-
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	4	0
795.0	2.9	1	3
635.0	2.8	1	1
505.0	2.7	3	2
400.0	2.6	3	3
320.0	2.5	2	3
255.0	2.4	1	2
200.0	2.3	0	1
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	15	15

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
9	0	0	0	
8	0	0	0	0.094
7	0	0	0	0.107
6	3	18	108	0.100
5	1	5	25	0.098
4	2	8	32	0.099
3	3	9	27	0.101
2	3	6	12	0.097
1	2	2	2	0.099
0	1	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	N_S	A	B	d
2.301	15	48	206	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
8	0	0	0	
7	0	0	0	0.094
6	4	24	144	0.107
5	1	5	25	0.100
4	1	4	16	0.098
3	3	9	27	0.099
2	3	6	12	0.101
1	2	2	2	0.097
0	1	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	N_S	A	B	d
2.407	15	50	226	0.100

USE EITHER NEGATIVES OR POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.670	log(lbf)
467.2	lbf
s (using negatives)	
0.5683	log(lbf)
3.7	lbf

H_{50} (using positives)	
2.689	log(lbf)
488.3	lbf
s (using positives)	
0.6428	log(lbf)
4.4	lbf

Figure B113: Bruceton Friction H_{50} Calculations for Mix ID SS #24 – Fine Al - Medium Bi_2O_3

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #24 (fine, medium)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	Force log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	4	21
795.0	2.9	0	4
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	0	1
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	**4**	**26**

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
6	0	0	0	
5	0	0	0	0.094
4	21	84	336	0.107
3	4	12	36	0.100
2	0	0	0	0.098
1	0	0	0	0.099
0	1	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.602	26	96	372	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
2	0	0	0	
1	0	0	0	0.094
0	4	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
3.000	4	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
3.020	log(lbf)
1046.1	lbf
s (using negatives)	
0.1135	log(lbf)
1.3	lbf

H_{50} (using positives)	
2.950	log(lbf)
891.7	lbf
s (using positives)	
0.0047	log(lbf)
1.0	lbf

Figure B114: Bruceton Friction H_{50} Calculations for Mix ID SS #24 – Fine Al - Coarse Bi_2O_3

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #24 (fine, coarse)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	0	29
795.0	2.9	0	0
635.0	2.8	0	1
505.0	2.7	0	0
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
4	0	0	0	
3	0	0	0	0.094
2	29	58	116	0.107
1	0	0	0	0.100
0	1	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.803	30	58	116	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.094
FALSE	0	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#N/A	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
3.045	log(lbf)
1109.4	lbf
s (using negatives)	
0.0255	log(lbf)
1.1	lbf

H_{50} (using positives)	
#N/A	log(lbf)
#N/A	lbf
s (using positives)	
#DIV/0!	log(lbf)
#DIV/0!	lbf

Figure B115: Bruceton Friction H_{50} Calculations for Mix ID SS #24 – Medium Al - Fine Bi_2O_3

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #24 (medium, fine)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	4	19
1280.0	3.1	0	4
1000.0	3.0	0	1
795.0	2.9	0	1
635.0	2.8	0	1
505.0	2.7	0	0
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	4	26

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
4	19	76	304	
3	4	12	36	0.094
2	1	2	4	0.107
1	1	1	1	0.100
0	1	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.803	26	91	345	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
0	4	0	0	
FALSE	0	0	0	0.094
FALSE	0	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
3.201	4	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
3.201	log(lbf)
1589.0	lbf
s (using negatives)	
0.1691	log(lbf)
1.5	lbf

H_{50} (using positives)	
3.152	log(lbf)
1417.8	lbf
s (using positives)	
0.0047	log(lbf)
1.0	lbf

Figure B116: Bruceton Friction H_{50} Calculations for Mix ID SS #24 – Medium Al - Medium Bi_2O_3

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #24 (medium, medium)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	5	19
795.0	2.9	0	5
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	0	1
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	5	25

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
6	0	0	0	
5	0	0	0	0.094
4	19	76	304	0.107
3	5	15	45	0.100
2	0	0	0	0.098
1	0	0	0	0.099
0	1	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.602	25	91	349	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
2	0	0	0	
1	0	0	0	0.094
0	5	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
3.000	5	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
3.014	log(lbf)
1033.6	lbf
s (using negatives)	
0.1193	log(lbf)
1.3	lbf

H_{50} (using positives)	
2.950	log(lbf)
891.7	lbf
s (using positives)	
0.0047	log(lbf)
1.0	lbf

Figure B117: Bruceton Friction H_{50} Calculations for Mix ID SS #24 – Medium Al - Coarse Bi_2O_3

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #24 (medium, coarse)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -	Neg: i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval	Pos: i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
1590	3.2	0	0	5	0	0	0		4	0	0	0	
1280.0	3.1	0	0	4	0	0	0	0.094	3	0	0	0	0.094
1000.0	3.0	2	20	3	20	60	180	0.107	2	2	4	8	0.107
795.0	2.9	1	2	2	2	4	8	0.100	1	1	1	1	0.100
635.0	2.8	2	1	1	1	1	1	0.098	0	2	0	0	0.098
505.0	2.7	0	2	0	2	0	0	0.099	FALSE	0	0	0	0.099
400.0	2.6	0	0	FALSE	0	0	0	0.101	FALSE	0	0	0	0.101
320.0	2.5	0	0	FALSE	0	0	0	0.097	FALSE	0	0	0	0.097
255.0	2.4	0	0	FALSE	0	0	0	0.099	FALSE	0	0	0	0.099
200.0	2.3	0	0	FALSE	0	0	0	0.106	FALSE	0	0	0	0.106
160.0	2.2	0	0	FALSE	0	0	0	0.097	FALSE	0	0	0	0.097
127.0	2.1	0	0	FALSE	0	0	0	0.100	FALSE	0	0	0	0.100
100.0	2.0	0	0	FALSE	0	0	0	0.104	FALSE	0	0	0	0.104
80.0	1.9	0	0	FALSE	0	0	0	0.097	FALSE	0	0	0	0.097
64.0	1.8	0	0	FALSE	0	0	0	0.097	FALSE	0	0	0	0.097
51.0	1.7	0	0	FALSE	0	0	0	0.099	FALSE	0	0	0	0.099
0.0000	0	0	0	FALSE	0	0	0		FALSE	0	0	0	0.000
	SUM	5	25	c	N_S	A	B	d	c	N_S	A	B	d
				2.703	25	65	189	0.100	2.803	5	5	9	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	H_{50} (using positives)
3.012 log(lbf)	2.853 log(lbf)
1028.1 lbf	712.1 lbf
s (using negatives)	**s (using positives)**
0.1337 log(lbf)	0.1337 log(lbf)
1.4 lbf	1.4 lbf

Figure B118: Bruceton Friction H_{50} Calculations for Mix ID SS #24 – Coarse Al - Fine Bi_2O_3

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #24 (coarse, fine)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	Force log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	3	14
795.0	2.9	1	4
635.0	2.8	0	2
505.0	2.7	0	1
400.0	2.6	0	2
320.0	2.5	0	1
255.0	2.4	0	1
200.0	2.3	0	1
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	4	26

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
9	0	0	0	
8	0	0	0	0.094
7	14	98	686	0.107
6	4	24	144	0.100
5	2	10	50	0.098
4	1	4	16	0.099
3	2	6	18	0.101
2	1	2	4	0.097
1	1	1	1	0.099
0	1	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.301	26	145	919	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
3	0	0	0	
2	0	0	0	0.094
1	3	3	3	0.107
0	1	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.900	4	3	3	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.906	log(lbf)
805.8	lbf
s (using negatives)	
0.6894	log(lbf)
4.9	lbf

H_{50} (using positives)	
2.925	log(lbf)
841.9	lbf
s (using positives)	
0.0349	log(lbf)
1.1	lbf

Figure B119: Bruceton Friction H_{50} Calculations for Mix ID SS #24 – Coarse Al - Medium Bi_2O_3

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #24 (coarse, medium)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	4	4
795.0	2.9	5	3
635.0	2.8	2	4
505.0	2.7	2	2
400.0	2.6	1	2
320.0	2.5	0	1
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	14	16

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
7	0	0	0	
6	0	0	0	0.094
5	4	20	100	0.107
4	3	12	48	0.100
3	4	12	36	0.098
2	2	4	8	0.099
1	2	2	2	0.101
0	1	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.505	16	50	194	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
6	0	0	0	
5	0	0	0	0.094
4	4	16	64	0.107
3	5	15	45	0.100
2	2	4	8	0.098
1	2	2	2	0.099
0	1	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.602	14	37	119	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.866	log(lbf)
734.8	lbf
s (using negatives)	
0.3853	log(lbf)
2.4	lbf

H_{50} (using positives)	
2.815	log(lbf)
653.8	lbf
s (using positives)	
0.2491	log(lbf)
1.8	lbf

Figure B120: Bruceton Friction H_{50} Calculations for Mix ID SS #24 – Coarse Al - Coarse Bi_2O_3

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #24 (coarse, coarse)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	5	7
795.0	2.9	2	4
635.0	2.8	4	2
505.0	2.7	1	3
400.0	2.6	0	2
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	12	18

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
6	0	0	0	
5	0	0	0	0.094
4	7	28	112	0.107
3	4	12	36	0.100
2	2	4	8	0.098
1	3	3	3	0.099
0	2	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.602	18	47	159	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
5	0	0	0	
4	0	0	0	0.094
3	5	15	45	0.107
2	2	4	8	0.100
1	4	4	4	0.098
0	1	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.703	12	23	57	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.912	log(lbf)
816.4	lbf
s (using negatives)	
0.3298	log(lbf)
2.1	lbf

H_{50} (using positives)	
2.844	log(lbf)
698.8	lbf
s (using positives)	
0.1783	log(lbf)
1.5	lbf

Figure B121: Bruceton Friction H_{50} Calculations for Mix ID SS #48 – Fine Ti - Medium Bi_2O_3

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #48 (fine, medium)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	7	13
795.0	2.9	0	7
635.0	2.8	0	1
505.0	2.7	0	1
400.0	2.6	0	1
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	7	23

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
6	0	0	0	
5	0	0	0	0.094
4	13	52	208	0.107
3	7	21	63	0.100
2	1	2	4	0.098
1	1	1	1	0.099
0	1	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.602	23	76	276	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
2	0	0	0	
1	0	0	0	0.094
0	7	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
3.000	7	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	H_{50} (using positives)
2.981 log(lbf)	2.950 log(lbf)
957.0 lbf	891.7 lbf
s (using negatives)	**s (using positives)**
0.1791 log(lbf)	0.0047 log(lbf)
1.5 lbf	1.0 lbf

Figure B122: Bruceton Friction H_{50} Calculations for Mix ID SS #48 – Fine Ti - Coarse Bi_2O_3

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #48 (fine, coarse)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	6	16
795.0	2.9	1	6
635.0	2.8	0	1
505.0	2.7	0	0
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	7	23

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
4	0	0	0	
3	0	0	0	0.094
2	16	32	64	0.107
1	6	6	6	0.100
0	1	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.803	23	38	70	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
3	0	0	0	
2	0	0	0	0.094
1	6	6	6	0.107
0	1	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.900	7	6	6	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
3.017	log(lbf)
1040.2	lbf
s (using negatives)	
0.0553	log(lbf)
1.1	lbf

H_{50} (using positives)	
2.936	log(lbf)
862.8	lbf
s (using positives)	
0.0244	log(lbf)
1.1	lbf

Figure B123: Bruceton Friction H_{50} Calculations for Mix ID SS #48 – Medium Ti - Fine Bi_2O_3

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #48 (medium, fine)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	2	15
795.0	2.9	0	3
635.0	2.8	0	1
505.0	2.7	0	1
400.0	2.6	0	1
320.0	2.5	0	1
255.0	2.4	1	1
200.0	2.3	1	1
160.0	2.2	0	1
127.0	2.1	0	0
100.0	2.0	0	1
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	4	26

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
12	0	0	0	
11	0	0	0	0.094
10	15	150	1500	0.107
9	3	27	243	0.100
8	1	8	64	0.098
7	1	7	49	0.099
6	1	6	36	0.101
5	1	5	25	0.097
4	1	4	16	0.099
3	1	3	9	0.106
2	1	2	4	0.097
1	0	0	0	0.100
0	1	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.000	26	212	1946	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
9	0	0	0	
8	0	0	0	0.094
7	2	14	98	0.107
6	0	0	0	0.100
5	0	0	0	0.098
4	0	0	0	0.099
3	0	0	0	0.101
2	0	0	0	0.097
1	1	1	1	0.099
0	1	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.301	4	15	99	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.862 log(lbf)
727.5 lbf

s (using negatives)
1.3536 log(lbf)
22.6 lbf

H_{50} (using positives)
2.625 log(lbf)
421.4 lbf

s (using positives)
1.7289 log(lbf)
53.6 lbf

Figure B124: Bruceton Friction H_{50} Calculations for Mix ID SS #48 – Medium Ti - Medium Bi_2O_3

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #48 (medium, medium)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	5	11
795.0	2.9	2	6
635.0	2.8	2	2
505.0	2.7	0	2
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	9	21

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
5	0	0	0	
4	0	0	0	0.094
3	11	33	99	0.107
2	6	12	24	0.100
1	2	2	2	0.098
0	2	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.703	21	47	125	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
4	0	0	0	
3	0	0	0	0.094
2	5	10	20	0.107
1	2	2	2	0.100
0	2	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.803	9	12	22	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.976 log(lbf)
946.2 lbf

s (using negatives)
0.1569 log(lbf)
1.4 lbf

H_{50} (using positives)
2.886 log(lbf)
768.7 lbf

s (using positives)
0.1122 log(lbf)
1.3 lbf

Figure B125: Bruceton Friction H_{50} Calculations for Mix ID SS #48 – Medium Ti - Coarse Bi_2O_3

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #48 (medium, coarse)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i{\cdot}n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2{\cdot}n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	5	17
795.0	2.9	1	5
635.0	2.8	0	1
505.0	2.7	0	0
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	1
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	6	24

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
8	0	0	0	
7	0	0	0	0.094
6	17	102	612	0.107
5	5	25	125	0.100
4	1	4	16	0.098
3	0	0	0	0.099
2	0	0	0	0.101
1	0	0	0	0.097
0	1	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.407	24	131	753	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
3	0	0	0	
2	0	0	0	0.094
1	5	5	5	0.107
0	1	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.900	6	5	5	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
3.000	log(lbf)
999.8	lbf
s (using negatives)	
0.2598	log(lbf)
1.8	lbf

H_{50} (using positives)	
2.934	log(lbf)
858.2	lbf
s (using positives)	
0.0271	log(lbf)
1.1	lbf

Figure B126: Bruceton Friction H_{50} Calculations for Mix ID SS #48 – Coarse Ti - Fine Bi_2O_3

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #48 (coarse, fine)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	7	12
795.0	2.9	2	6
635.0	2.8	1	1
505.0	2.7	0	1
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	10	20

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
5	0	0	0	
4	0	0	0	0.094
3	12	36	108	0.107
2	6	12	24	0.100
1	1	1	1	0.098
0	1	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.703	20	49	133	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
4	0	0	0	
3	0	0	0	0.094
2	7	14	28	0.107
1	2	2	2	0.100
0	1	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.803	10	16	30	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.997	log(lbf)
993.3	lbf
s (using negatives)	
0.1091	log(lbf)
1.3	lbf

H_{50} (using positives)	
2.912	log(lbf)
817.2	lbf
s (using positives)	
0.0757	log(lbf)
1.2	lbf

Figure B127: Bruceton Friction H_{50} Calculations for Mix ID SS #48 – Coarse Ti - Medium Bi_2O_3

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #48 (coarse, medium)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force (lbf)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	6	17
795.0	2.9	0	5
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	0	0
320.0	2.5	0	1
255.0	2.4	0	1
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	6	24

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
8	0	0	0	
7	0	0	0	0.094
6	17	102	612	0.107
5	5	25	125	0.100
4	0	0	0	0.098
3	0	0	0	0.099
2	0	0	0	0.101
1	1	1	1	0.097
0	1	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.407	24	128	738	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
2	0	0	0	
1	0	0	0	0.094
0	6	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
3.000	6	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.987 log(lbf)
971.6 lbf

s (using negatives)
0.3766 log(lbf)
2.4 lbf

H_{50} (using positives)
2.950 log(lbf)
891.7 lbf

s (using positives)
0.0047 log(lbf)
1.0 lbf

Figure B128: Bruceton Friction H_{50} Calculations for Mix ID SS #48 – Coarse Ti - Coarse Bi_2O_3

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity Test

Sample: **SS #48 (coarse, coarse)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Force		Frequency	
(lbf)	log(lbf)	+	-
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	7	14
795.0	2.9	0	8
635.0	2.8	0	1
505.0	2.7	0	0
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0	0	0
	SUM	7	23

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
4	0	0	0	
3	0	0	0	0.094
2	14	28	56	0.107
1	8	8	8	0.100
0	1	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	N_S	A	B	d
2.803	23	36	64	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
2	0	0	0	
1	0	0	0	0.094
0	7	0	0	0.107
FALSE	0	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	N_S	A	B	d
3.000	7	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
3.008	log(lbf)
1019.6	lbf
s (using negatives)	
0.0584	log(lbf)
1.1	lbf

H_{50} (using positives)	
2.950	log(lbf)
891.7	lbf
s (using positives)	
0.0047	log(lbf)
1.0	lbf

Figure B129: Bruceton ESD H_{50} Calculations for Mix ID LS #7 – Fine Al - Medium MnO_2

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **LS #7 (fine, medium)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i{\cdot}n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2{\cdot}n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	1	0
0.030	-1.5	5	1
0.015	-1.8	4	5
0.010	-2.0	2	4
0.0050	-2.3	3	2
0.0025	-2.6	0	3
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	15	15

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
9	0	0	0	
8	0	0	0	0.331
7	0	0	0	0.243
6	0	0	0	0.222
5	0	0	0	0.301
4	1	4	16	0.301
3	5	15	45	0.301
2	4	8	16	0.176
1	2	2	2	0.301
0	3	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.602	15	29	79	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
8	0	0	0	
7	0	0	0	0.331
6	0	0	0	0.243
5	0	0	0	0.222
4	1	4	16	0.301
3	5	15	45	0.301
2	4	8	16	0.301
1	2	2	2	0.176
0	3	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.301	15	29	79	0.275

USE EITHER NEGATIVES OR POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-1.933 log(microF)
0.0 microF

s (using negatives)
0.6939 log(microF)
4.9 microF

H_{50} (using positives)
-1.907 log(microF)
0.0124 microF

s (using positives)
0.6939 log(microF)
4.9 microF

Figure B130: Bruceton ESD H_{50} Calculations for Mix ID LS #7 – Fine Al - Coarse MnO_2

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **LS #7 (fine, coarse)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance		Frequency	
(microF)	log(micro F)	+	-
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	1	0
0.060	-1.2	3	1
0.030	-1.5	2	4
0.015	-1.8	2	3
0.010	-2.0	3	2
0.0050	-2.3	3	3
0.0025	-2.6	0	3
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	**14**	**16**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
9	0	0	0	
8	0	0	0	0.331
7	0	0	0	0.243
6	0	0	0	0.222
5	1	5	25	0.301
4	4	16	64	0.301
3	3	9	27	0.301
2	2	4	8	0.176
1	3	3	3	0.301
0	3	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.602	16	37	127	0.275

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
8	0	0	0	
7	0	0	0	0.331
6	0	0	0	0.243
5	1	5	25	0.222
4	3	12	48	0.301
3	2	6	18	0.301
2	2	4	8	0.301
1	3	3	3	0.176
0	3	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.301	14	30	102	0.275

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-1.829 log(microF)
0.0 microF
s (using negatives)
1.1664 log(microF)
14.7 microF

H_{50} (using positives)
-1.849 log(microF)
0.0141 microF
s (using positives)
1.2127 log(microF)
16.3 microF

Figure B131: Bruceton ESD H_{50} Calculations for Mix ID LS #7 – Medium Al - Fine MnO_2

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **LS #7 (medium, fine)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	2	0
0.120	-0.9	6	2
0.060	-1.2	5	6
0.030	-1.5	1	6
0.015	-1.8	0	2
0.010	-2.0	0	0
0.0050	-2.3	0	0
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	14	16

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
6	0	0	0	
5	0	0	0	0.331
4	0	0	0	0.243
3	2	6	18	0.222
2	6	12	24	0.301
1	6	6	6	0.301
0	2	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-1.824	16	24	48	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
5	0	0	0	
4	0	0	0	0.331
3	2	6	18	0.243
2	6	12	24	0.222
1	5	5	5	0.301
0	1	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-1.523	14	23	47	0.275

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-1.274 log(microF)
0.1 microF
s (using negatives)
0.3470 log(microF)
2.2 microF

H_{50} (using positives)
-1.209 log(microF)
0.0618 microF
s (using positives)
0.3060 log(microF)
2.0 microF

Figure B132: Bruceton ESD H_{50} Calculations for Mix ID LS #7 – Medium Al - Medium MnO_2

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **LS #7 (medium, medium)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	1	0
0.120	-0.9	0	1
0.060	-1.2	4	1
0.030	-1.5	5	5
0.015	-1.8	4	5
0.010	-2.0	0	4
0.0050	-2.3	0	0
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	14	16

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
7	0	0	0	
6	0	0	0	0.331
5	0	0	0	0.243
4	1	4	16	0.222
3	1	3	9	0.301
2	5	10	20	0.301
1	5	5	5	0.301
0	4	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.000	16	22	50	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
6	0	0	0	
5	0	0	0	0.331
4	1	4	16	0.243
3	0	0	0	0.222
2	4	8	16	0.301
1	5	5	5	0.301
0	4	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-1.824	14	17	37	0.275

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-1.485 log(microF)
0.0 microF

s (using negatives)
0.5627 log(microF)
3.7 microF

H_{50} (using positives)
-1.628 log(microF)
0.0236 microF

s (using positives)
0.5333 log(microF)
3.4 microF

Figure B133: Bruceton ESD H_{50} Calculations for Mix ID LS #7 – Medium Al - Coarse MnO_2

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **LS #7 (medium, coarse)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance		Frequency	
(microF)	log(micro F)	+	-
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	2	0
0.060	-1.2	3	2
0.030	-1.5	6	3
0.015	-1.8	4	6
0.010	-2.0	0	4
0.0050	-2.3	0	0
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	15	15

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
7	0	0	0	
6	0	0	0	0.331
5	0	0	0	0.243
4	0	0	0	0.222
3	2	6	18	0.301
2	3	6	12	0.301
1	6	6	6	0.301
0	4	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	N_S	A	B	d
-2.000	15	18	36	0.275

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
6	0	0	0	
5	0	0	0	0.331
4	0	0	0	0.243
3	2	6	18	0.222
2	3	6	12	0.301
1	6	6	6	0.301
0	4	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	N_S	A	B	d
-1.824	15	18	36	0.275

USE EITHER NEGATIVES OR POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-1.533 log(microF)
0.0293 microF
s (using negatives)
0.4405 log(microF)
2.8 microF

H_{50} (using positives)
-1.631 log(microF)
0.0234 microF
s (using positives)
0.4405 log(microF)
2.8 microF

Figure B134: Bruceton ESD H_{50} Calculations for Mix ID LS #7 – Coarse Al - Fine MnO_2

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **LS #7 (coarse, fine)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	2	0
0.350	-0.5	4	2
0.200	-0.7	3	5
0.120	-0.9	2	4
0.060	-1.2	2	3
0.030	-1.5	0	3
0.015	-1.8	0	0
0.010	-2.0	0	0
0.0050	-2.3	0	0
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	13	17

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
5	0	0	0	
4	2	8	32	0.331
3	5	15	45	0.243
2	4	8	16	0.222
1	3	3	3	0.301
0	3	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-1.523	17	34	96	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
4	2	8	32	
3	4	12	36	0.331
2	3	6	12	0.243
1	2	2	2	0.222
0	2	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-1.222	13	28	82	0.275

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-0.836 log(microF)
0.1 microF
s (using negatives)
0.7465 log(microF)
5.6 microF

H_{50} (using positives)
-0.767 log(microF)
0.1709 microF
s (using positives)
0.7561 log(microF)
5.7 microF

Figure B135: Bruceton ESD H_{50} Calculations for Mix ID LS #7 – Coarse Al - Medium MnO_2

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **LS #7 (coarse, medium)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance		Frequency	
(microF)	log(microF)	+	-
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	1	0
0.120	-0.9	3	1
0.060	-1.2	8	3
0.030	-1.5	3	8
0.015	-1.8	0	3
0.010	-2.0	0	0
0.0050	-2.3	0	0
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	15	15

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
6	0	0	0	
5	0	0	0	0.331
4	0	0	0	0.243
3	1	3	9	0.222
2	3	6	12	0.301
1	8	8	8	0.301
0	3	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	N_S	A	B	d
-1.824	15	17	29	0.275

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
5	0	0	0	
4	0	0	0	0.331
3	1	3	9	0.243
2	3	6	12	0.222
1	8	8	8	0.301
0	3	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	N_S	A	B	d
-1.523	15	17	29	0.275

USE EITHER NEGATIVES OR POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-1.375 log(microF)
0.0422 microF
s (using negatives)
0.3019 log(microF)
2.0 microF

H_{50} (using positives)
-1.349 log(microF)
0.0448 microF
s (using positives)
0.3019 log(microF)
2.0 microF

Figure B136: Bruceton ESD H_{50} Calculations for Mix ID LS #7 – Coarse Al - Coarse MnO_2

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **LS #7 (coarse, coarse)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance		Frequency	
(microF)	log(microF)	+	-
0.750	-0.1	5	4
0.350	-0.5	4	6
0.200	-0.7	1	5
0.120	-0.9	0	2
0.060	-1.2	1	1
0.030	-1.5	0	1
0.015	-1.8	0	0
0.010	-2.0	0	0
0.0050	-2.3	0	0
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	11	19

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
5	4	20	100	
4	6	24	96	0.331
3	5	15	45	0.243
2	2	4	8	0.222
1	1	1	1	0.301
0	1	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	N_S	A	B	d
-1.523	19	64	250	0.275

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
4	5	20	80	
3	4	12	36	0.331
2	1	2	4	0.243
1	0	0	0	0.222
0	1	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	N_S	A	B	d
-1.222	11	34	120	0.275

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-0.459 log(microF)
0.3 microF
s (using negatives)
0.8198 log(microF)
6.6 microF

H_{50} (using positives)
-0.510 log(microF)
0.3094 microF
s (using positives)
0.6166 log(microF)
4.1 microF

Figure B137: Bruceton ESD H_{50} Calculations for Mix ID LS #8 – Fine Mg & Al - Medium MoO_3 & CuO

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **LS #8 (fine, medium)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	0	0
0.030	-1.5	0	0
0.015	-1.8	10	0
0.010	-2.0	4	10
0.0050	-2.3	1	4
0.0025	-2.6	0	1
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	15	15

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
9	0	0	0	
8	0	0	0	0.331
7	0	0	0	0.243
6	0	0	0	0.222
5	0	0	0	0.301
4	0	0	0	0.301
3	0	0	0	0.301
2	10	20	40	0.176
1	4	4	4	0.301
0	1	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.602	15	24	44	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
8	0	0	0	
7	0	0	0	0.331
6	0	0	0	0.243
5	0	0	0	0.222
4	0	0	0	0.301
3	0	0	0	0.301
2	10	20	40	0.301
1	4	4	4	0.176
0	1	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.301	15	24	44	0.275

USE EITHER NEGATIVES OR POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	**H_{50} (using positives)**
-2.025 log(microF)	-1.999 log(microF)
0.0094 microF	0.0100 microF
s (using negatives)	**s (using positives)**
0.1792 log(microF)	0.1792 log(microF)
1.5 microF	1.5 microF

Figure B138: Bruceton ESD H_{50} Calculations for Mix ID LS #8 – Fine Mg & Al - Coarse MoO_3 & CuO

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **LS #8 (fine, coarse)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.
where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$
where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	2	0
0.030	-1.5	7	2
0.015	-1.8	4	7
0.010	-2.0	2	4
0.0050	-2.3	0	2
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	15	15

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
8	0	0	0	
7	0	0	0	0.331
6	0	0	0	0.243
5	0	0	0	0.222
4	0	0	0	0.301
3	2	6	18	0.301
2	7	14	28	0.301
1	4	4	4	0.176
0	2	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.301	15	24	50	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
7	0	0	0	
6	0	0	0	0.331
5	0	0	0	0.243
4	0	0	0	0.222
3	2	6	18	0.301
2	7	14	28	0.301
1	4	4	4	0.301
0	2	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.000	15	24	50	0.275

USE EITHER NEGATIVES OR POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-1.724 log(microF)
0.0189 microF

s (using negatives)
0.3573 log(microF)
2.3 microF

H_{50} (using positives)
-1.698 log(microF)
0.0201 microF

s (using positives)
0.3573 log(microF)
2.3 microF

Figure B139: Bruceton ESD H_{50} Calculations for Mix ID LS #8 – Medium Mg & Al - Fine MoO_3 & CuO

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **LS #8 (medium, fine)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance		Frequency	
(microF)	log(microF)	+	-
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	5	0
0.030	-1.5	3	5
0.015	-1.8	7	3
0.010	-2.0	0	7
0.0050	-2.3	0	0
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	15	15

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
7	0	0	0	
6	0	0	0	0.331
5	0	0	0	0.243
4	0	0	0	0.222
3	0	0	0	0.301
2	5	10	20	0.301
1	3	3	3	0.301
0	7	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	N_S	A	B	d
-2.000	15	13	23	0.275

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
6	0	0	0	
5	0	0	0	0.331
4	0	0	0	0.243
3	0	0	0	0.222
2	5	10	20	0.301
1	3	3	3	0.301
0	7	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	N_S	A	B	d
-1.824	15	13	23	0.275

USE EITHER NEGATIVES OR POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-1.624 log(microF)
0.0238 microF
s (using negatives)
0.3613 log(microF)
2.3 microF

H_{50} (using positives)
-1.723 log(microF)
0.0189 microF
s (using positives)
0.3613 log(microF)
2.3 microF

Figure B140: Bruceton ESD H_{50} Calculations for Mix ID LS #8 – Medium Mg & Al - Medium MoO_3 & CuO

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **LS #8 (medium, medium)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	1	0
0.030	-1.5	5	1
0.015	-1.8	6	5
0.010	-2.0	3	6
0.0050	-2.3	0	3
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	15	15

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
8	0	0	0	
7	0	0	0	0.331
6	0	0	0	0.243
5	0	0	0	0.222
4	0	0	0	0.301
3	1	3	9	0.301
2	5	10	20	0.301
1	6	6	6	0.176
0	3	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.301	15	19	35	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
7	0	0	0	
6	0	0	0	0.331
5	0	0	0	0.243
4	0	0	0	0.222
3	1	3	9	0.301
2	5	10	20	0.301
1	6	6	6	0.301
0	3	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.000	15	19	35	0.275

USE EITHER NEGATIVES OR POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-1.815 log(microF)
0.0153 microF
s (using negatives)
0.3375 log(microF)
2.2 microF

H_{50} (using positives)
-1.789 log(microF)
0.0162 microF
s (using positives)
0.3375 log(microF)
2.2 microF

Figure B141: Bruceton ESD H_{50} Calculations for Mix ID LS #8 – Medium Mg & Al - Coarse MoO_3 & CuO

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **LS #8 (medium, coarse)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	1	0
0.120	-0.9	2	1
0.060	-1.2	5	2
0.030	-1.5	5	5
0.015	-1.8	2	5
0.010	-2.0	0	2
0.0050	-2.3	0	0
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	15	15

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
7	0	0	0	
6	0	0	0	0.331
5	0	0	0	0.243
4	1	4	16	0.222
3	2	6	18	0.301
2	5	10	20	0.301
1	5	5	5	0.301
0	2	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.000	15	25	59	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
6	0	0	0	
5	0	0	0	0.331
4	1	4	16	0.243
3	2	6	18	0.222
2	5	10	20	0.301
1	5	5	5	0.301
0	2	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-1.824	15	25	59	0.275

USE EITHER NEGATIVES OR POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-1.404 log(microF)
0.0394 microF

s (using negatives)
0.5276 log(microF)
3.4 microF

H_{50} (using positives)
-1.503 log(microF)
0.0314 microF

s (using positives)
0.5276 log(microF)
3.4 microF

Figure B142: Bruceton ESD H_{50} Calculations for Mix ID LS #8 – Coarse Mg & Al - Fine MoO_3 & CuO

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **LS #8 (coarse, fine)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	2	0
0.030	-1.5	7	2
0.015	-1.8	6	6
0.010	-2.0	1	5
0.0050	-2.3	0	1
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	16	14

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
8	0	0	0	
7	0	0	0	0.331
6	0	0	0	0.243
5	0	0	0	0.222
4	0	0	0	0.301
3	2	6	18	0.301
2	6	12	24	0.301
1	5	5	5	0.176
0	1	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.301	14	23	47	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
7	0	0	0	
6	0	0	0	0.331
5	0	0	0	0.243
4	0	0	0	0.222
3	2	6	18	0.301
2	7	14	28	0.301
1	6	6	6	0.301
0	1	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.000	16	26	52	0.275

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-1.712 log(microF)
0.0194 microF

s (using negatives)
0.3060 log(microF)
2.0 microF

H_{50} (using positives)
-1.691 log(microF)
0.0204 microF

s (using positives)
0.2843 log(microF)
1.9 microF

Figure B143: Bruceton ESD H_{50} Calculations for Mix ID LS #8 – Coarse Mg & Al - Medium MoO_3 & CuO

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **LS #8 (coarse, medium)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	9	0
0.030	-1.5	4	9
0.015	-1.8	2	4
0.010	-2.0	0	2
0.0050	-2.3	0	0
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	15	15

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
7	0	0	0	
6	0	0	0	0.331
5	0	0	0	0.243
4	0	0	0	0.222
3	0	0	0	0.301
2	9	18	36	0.301
1	4	4	4	0.301
0	2	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.000	15	22	40	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
6	0	0	0	
5	0	0	0	0.331
4	0	0	0	0.243
3	0	0	0	0.222
2	9	18	36	0.301
1	4	4	4	0.301
0	2	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-1.824	15	22	40	0.275

USE EITHER NEGATIVES OR POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-1.459 log(microF)
0.0347 microF
s (using negatives)
0.2425 log(microF)
1.7 microF

H_{50} (using positives)
-1.558 log(microF)
0.0277 microF
s (using positives)
0.2425 log(microF)
1.7 microF

Figure B144: Bruceton ESD H_{50} Calculations for Mix ID LS #8 – Coarse Mg & Al - Coarse MoO_3 & CuO

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **LS #8 (coarse, coarse)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	5	0
0.030	-1.5	4	6
0.015	-1.8	6	6
0.010	-2.0	0	6
0.0050	-2.3	0	0
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	15	18

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
7	0	0	0	
6	0	0	0	0.331
5	0	0	0	0.243
4	0	0	0	0.222
3	0	0	0	0.301
2	6	12	24	0.301
1	6	6	6	0.301
0	6	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.000	18	18	30	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
6	0	0	0	
5	0	0	0	0.331
4	0	0	0	0.243
3	0	0	0	0.222
2	5	10	20	0.301
1	4	4	4	0.301
0	6	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-1.824	15	14	24	0.275

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-1.588 log(microF)
0.0258 microF
s (using negatives)
0.3098 log(microF)
2.0 microF

H_{50} (using positives)
-1.705 log(microF)
0.0197 microF
s (using positives)
0.3375 log(microF)
2.2 microF

Figure B145: Bruceton ESD H_{50} Calculations for Mix ID SS #3B – Fine Ti - Medium MnO_2

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #3B (fine, medium)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	0	0
0.350	-0.5	3	0
0.200	-0.7	3	3
0.120	-0.9	1	3
0.060	-1.2	0	2
0.030	-1.5	1	1
0.015	-1.8	3	2
0.010	-2.0	2	4
0.0050	-2.3	0	2
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	13	17

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
8	0	0	0	
7	0	0	0	0.331
6	3	18	108	0.243
5	3	15	75	0.222
4	2	8	32	0.301
3	1	3	9	0.301
2	2	4	8	0.301
1	4	4	4	0.176
0	2	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.301	17	52	236	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
7	0	0	0	
6	3	18	108	0.331
5	3	15	75	0.243
4	1	4	16	0.222
3	0	0	0	0.301
2	1	2	4	0.301
1	3	3	3	0.301
0	2	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.000	13	42	206	0.275

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-1.323 log(microF)
0.0476 microF
s (using negatives)
2.0287 log(microF)
106.8 microF

H_{50} (using positives)
-1.249 log(microF)
0.0563 microF
s (using positives)
2.4217 log(microF)
264.0 microF

Figure B146: Bruceton ESD H_{50} Calculations for Mix ID SS #3B – Fine Ti - Coarse MnO_2

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #3B (fine, coarse)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance		Frequency	
(microF)	log(microF)	+	-
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	3	1
0.120	-0.9	2	4
0.060	-1.2	3	3
0.030	-1.5	2	4
0.015	-1.8	3	2
0.010	-2.0	0	3
0.0050	-2.3	0	0
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	13	17

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
7	0	0	0	
6	0	0	0	0.331
5	1	5	25	0.243
4	4	16	64	0.222
3	3	9	27	0.301
2	4	8	16	0.301
1	2	2	2	0.301
0	3	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	N_S	A	B	d
-2.000	17	40	134	0.275

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
6	0	0	0	
5	0	0	0	0.331
4	3	12	48	0.243
3	2	6	18	0.222
2	3	6	12	0.301
1	2	2	2	0.301
0	3	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	N_S	A	B	d
-1.824	13	26	80	0.275

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-1.216 log(microF)
0.0609 microF
s (using negatives)
1.0578 log(microF)
11.4 microF

H_{50} (using positives)
-1.412 log(microF)
0.0388 microF
s (using positives)
0.9722 log(microF)
9.4 microF

Figure B147: Bruceton ESD H_{50} Calculations for Mix ID SS #3B – Medium Ti - Fine MnO_2

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #3B (medium, fine)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	3	7
0.350	-0.5	1	4
0.200	-0.7	0	2
0.120	-0.9	0	0
0.060	-1.2	1	1
0.030	-1.5	1	2
0.015	-1.8	2	2
0.010	-2.0	1	2
0.0050	-2.3	0	1
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	9	21

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
8	7	56	448	
7	4	28	196	0.331
6	2	12	72	0.243
5	0	0	0	0.222
4	1	4	16	0.301
3	2	6	18	0.301
2	2	4	8	0.301
1	2	2	2	0.176
0	1	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.301	21	112	760	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
7	3	21	147	
6	1	6	36	0.331
5	0	0	0	0.243
4	0	0	0	0.222
3	1	3	9	0.301
2	1	2	4	0.301
1	2	2	2	0.301
0	1	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.000	9	34	198	0.275

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-0.697 log(microF)
0.2008 microF

s (using negatives)
3.4628 log(microF)
2902.9 microF

H_{50} (using positives)
-1.099 log(microF)
0.0796 microF

s (using positives)
3.4550 log(microF)
2850.9 microF

Figure B148: Bruceton ESD H_{50} Calculations for Mix ID SS #3B – Medium Ti - Medium MnO_2

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #3B (medium, medium)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance		Frequency	
(microF)	log(microF)	+	-
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	1	0
0.060	-1.2	6	1
0.030	-1.5	3	6
0.015	-1.8	6	2
0.010	-2.0	0	5
0.0050	-2.3	0	0
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	16	14

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
7	0	0	0	
6	0	0	0	0.331
5	0	0	0	0.243
4	0	0	0	0.222
3	1	3	9	0.301
2	6	12	24	0.301
1	2	2	2	0.301
0	5	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	N_S	A	B	d
-2.000	14	17	35	0.275

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
6	0	0	0	
5	0	0	0	0.331
4	0	0	0	0.243
3	1	3	9	0.222
2	6	12	24	0.301
1	3	3	3	0.301
0	6	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	N_S	A	B	d
-1.824	16	18	36	0.275

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-1.529 log(microF)
0.0296 microF
s (using negatives)
0.4697 log(microF)
2.9 microF

H_{50} (using positives)
-1.652 log(microF)
0.0223 microF
s (using positives)
0.4513 log(microF)
2.8 microF

Figure B149: Bruceton ESD H_{50} Calculations for Mix ID SS #3B – Medium Ti - Coarse MnO_2

Figure B150: Bruceton ESD H_{50} Calculations for Mix ID SS #3B – Coarse Ti - Fine MnO_2

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #3B (medium, coarse)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	0	1
0.350	-0.5	3	1
0.200	-0.7	3	3
0.120	-0.9	2	3
0.060	-1.2	3	3
0.030	-1.5	2	4
0.015	-1.8	0	2
0.010	-2.0	0	0
0.0050	-2.3	0	0
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	13	17

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
6	1	6	36	
5	1	5	25	0.331
4	3	12	48	0.243
3	3	9	27	0.222
2	3	6	12	0.301
1	4	4	4	0.301
0	2	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-1.824	17	42	152	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
5	0	0	0	
4	3	12	48	0.331
3	3	9	27	0.243
2	2	4	8	0.222
1	3	3	3	0.301
0	2	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-1.523	13	28	86	0.275

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-1.007 log(microF)
0.0984 microF

s (using negatives)
1.2766 log(microF)
18.9 microF

H_{50} (using positives)
-1.068 log(microF)
0.0855 microF

s (using positives)
0.8931 log(microF)
7.8 microF

Figure B151: Bruceton ESD H_{50} Calculations for Mix ID SS #3B – Coarse Ti - Medium MnO_2

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #3B (coarse, medium)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance		Frequency	
(microF)	log(microF)	+	-
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	2	1
0.030	-1.5	3	3
0.015	-1.8	7	4
0.010	-2.0	1	8
0.0050	-2.3	0	1
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	13	17

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i²(-)·n(-)	Interval
8	0	0	0	
7	0	0	0	0.331
6	0	0	0	0.243
5	0	0	0	0.222
4	1	4	16	0.301
3	3	9	27	0.301
2	4	8	16	0.301
1	8	8	8	0.176
0	1	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.301	17	29	67	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i²(+)·n(+)	Interval
7	0	0	0	
6	0	0	0	0.331
5	0	0	0	0.243
4	0	0	0	0.222
3	2	6	18	0.301
2	3	6	12	0.301
1	7	7	7	0.301
0	1	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.000	13	19	37	0.275

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-1.695 log(microF)
0.0202 microF
s (using negatives)
0.4722 log(microF)
3.0 microF

H_{50} (using positives)
-1.736 log(microF)
0.0184 microF
s (using positives)
0.3292 log(microF)
2.1 microF

Figure B152: Bruceton ESD H_{50} Calculations for Mix ID SS #3B – Coarse Ti - Coarse MnO_2

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #3B (coarse, coarse)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	1	0
0.350	-0.5	5	1
0.200	-0.7	4	5
0.120	-0.9	2	5
0.060	-1.2	1	3
0.030	-1.5	1	1
0.015	-1.8	0	1
0.010	-2.0	0	0
0.0050	-2.3	0	0
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	14	16

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
6	0	0	0	
5	1	5	25	0.331
4	5	20	80	0.243
3	5	15	45	0.222
2	3	6	12	0.301
1	1	1	1	0.301
0	1	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-1.824	16	47	163	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
5	1	5	25	
4	5	20	80	0.331
3	4	12	36	0.243
2	2	4	8	0.222
1	1	1	1	0.301
0	1	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-1.523	14	42	150	0.275

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-0.879 log(microF)
0.1322 microF
s (using negatives)
0.7071 log(microF)
5.1 microF

H_{50} (using positives)
-0.836 log(microF)
0.1460 microF
s (using positives)
0.7764 log(microF)
6.0 microF

Figure B153: Bruceton ESD H_{50} Calculations for Mix ID SS #4 – Fine Mg - Medium MnO_2

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #4 (fine, medium)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance		Frequency	
(microF)	log(microF)	+	-
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	1	0
0.120	-0.9	3	1
0.060	-1.2	4	3
0.030	-1.5	2	4
0.015	-1.8	3	2
0.010	-2.0	1	3
0.0050	-2.3	1	1
0.0025	-2.6	0	1
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	15	15

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
9	0	0	0	
8	0	0	0	0.331
7	0	0	0	0.243
6	1	6	36	0.222
5	3	15	75	0.301
4	4	16	64	0.301
3	2	6	18	0.301
2	3	6	12	0.176
1	1	1	1	0.301
0	1	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	N_S	A	B	d
-2.602	15	50	206	0.275

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
8	0	0	0	
7	0	0	0	0.331
6	1	6	36	0.243
5	3	15	75	0.222
4	4	16	64	0.301
3	2	6	18	0.301
2	3	6	12	0.301
1	1	1	1	0.176
0	1	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	N_S	A	B	d
-2.301	15	50	206	0.275

USE EITHER NEGATIVES OR POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-1.548 log(microF)
0.0283 microF
s (using negatives)
1.1808 log(microF)
15.2 microF

H_{50} (using positives)
-1.522 log(microF)
0.0301 microF
s (using positives)
1.1808 log(microF)
15.2 microF

Figure B154: Bruceton ESD H_{50} Calculations for Mix ID SS #4 – Fine Mg - Coarse MnO_2

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #4 (fine, coarse)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	1	0
0.060	-1.2	3	1
0.030	-1.5	4	3
0.015	-1.8	6	4
0.010	-2.0	1	6
0.0050	-2.3	0	1
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	15	15

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
8	0	0	0	
7	0	0	0	0.331
6	0	0	0	0.243
5	0	0	0	0.222
4	1	4	16	0.301
3	3	9	27	0.301
2	4	8	16	0.301
1	6	6	6	0.176
0	1	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.301	15	27	65	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
7	0	0	0	
6	0	0	0	0.331
5	0	0	0	0.243
4	1	4	16	0.222
3	3	9	27	0.301
2	4	8	16	0.301
1	6	6	6	0.301
0	1	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.000	15	27	65	0.275

USE EITHER NEGATIVES OR POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-1.669 log(microF)
0.0214 microF

s (using negatives)
0.4999 log(microF)
3.2 microF

H_{50} (using positives)
-1.643 log(microF)
0.0228 microF

s (using positives)
0.4999 log(microF)
3.2 microF

Figure B155: Bruceton ESD H_{50} Calculations for Mix ID SS #4 – Medium Mg - Fine MnO_2

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #4 (medium, fine)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	2	0
0.030	-1.5	6	2
0.015	-1.8	6	6
0.010	-2.0	1	6
0.0050	-2.3	0	1
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	15	15

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
8	0	0	0	
7	0	0	0	0.331
6	0	0	0	0.243
5	0	0	0	0.222
4	0	0	0	0.301
3	2	6	18	0.301
2	6	12	24	0.301
1	6	6	6	0.176
0	1	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.301	15	24	48	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
7	0	0	0	
6	0	0	0	0.331
5	0	0	0	0.243
4	0	0	0	0.222
3	2	6	18	0.301
2	6	12	24	0.301
1	6	6	6	0.301
0	1	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.000	15	24	48	0.275

USE EITHER NEGATIVES OR POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-1.724 log(microF)
0.0189 microF
s (using negatives)
0.2980 log(microF)
2.0 microF

H_{50} (using positives)
-1.698 log(microF)
0.0201 microF
s (using positives)
0.2980 log(microF)
2.0 microF

Figure B156: Bruceton ESD H_{50} Calculations for Mix ID SS #4 – Medium Mg - Medium MnO_2

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #4 (medium, medium)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	0	0
0.030	-1.5	3	0
0.015	-1.8	9	3
0.010	-2.0	2	9
0.0050	-2.3	2	1
0.0025	-2.6	0	1
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	16	14

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
9	0	0	0	
8	0	0	0	0.331
7	0	0	0	0.243
6	0	0	0	0.222
5	0	0	0	0.301
4	0	0	0	0.301
3	3	9	27	0.301
2	9	18	36	0.176
1	1	1	1	0.301
0	1	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.602	14	28	64	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
8	0	0	0	
7	0	0	0	0.331
6	0	0	0	0.243
5	0	0	0	0.222
4	0	0	0	0.301
3	3	9	27	0.301
2	9	18	36	0.301
1	2	2	2	0.176
0	2	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.301	16	29	65	0.275

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
-1.915	log(microF)
0.0122	microF
s (using negatives)	
0.2674	log(microF)
1.9	microF

H_{50} (using positives)	
-1.940	log(microF)
0.0115	microF
s (using positives)	
0.3591	log(microF)
2.3	microF

Figure B157: Bruceton ESD H_{50} Calculations for Mix ID SS #4 – Medium Mg - Coarse MnO_2

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #4 (medium, coarse)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance		Frequency	
(microF)	log(microF)	+	-
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	0	0
0.030	-1.5	0	0
0.015	-1.8	1	0
0.010	-2.0	9	1
0.0050	-2.3	5	8
0.0025	-2.6	1	4
0.0012	-2.9	0	1
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	16	14

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
10	0	0	0	
9	0	0	0	0.331
8	0	0	0	0.243
7	0	0	0	0.222
6	0	0	0	0.301
5	0	0	0	0.301
4	0	0	0	0.301
3	1	3	9	0.176
2	8	16	32	0.301
1	4	4	4	0.301
0	1	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	N_S	A	B	d
-2.921	14	23	45	0.275

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
9	0	0	0	
8	0	0	0	0.331
7	0	0	0	0.243
6	0	0	0	0.222
5	0	0	0	0.301
4	0	0	0	0.301
3	1	3	9	0.301
2	9	18	36	0.176
1	5	5	5	0.301
0	1	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	N_S	A	B	d
-2.602	16	26	50	0.275

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-2.332 log(microF)
0.0047 microF
s (using negatives)
0.2424 log(microF)
1.7 microF

H_{50} (using positives)
-2.293 log(microF)
0.0051 microF
s (using positives)
0.2286 log(microF)
1.7 microF

Figure B158: Bruceton ESD H_{50} Calculations for Mix ID SS #4 – Coarse Mg - Fine MnO_2

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #4 (coarse, fine)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	3	0
0.030	-1.5	7	3
0.015	-1.8	4	8
0.010	-2.0	0	5
0.0050	-2.3	0	0
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	14	16

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
7	0	0	0	
6	0	0	0	0.331
5	0	0	0	0.243
4	0	0	0	0.222
3	0	0	0	0.301
2	3	6	12	0.301
1	8	8	8	0.301
0	5	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.000	16	14	20	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
6	0	0	0	
5	0	0	0	0.331
4	0	0	0	0.243
3	0	0	0	0.222
2	3	6	12	0.301
1	7	7	7	0.301
0	4	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-1.824	14	13	19	0.275

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-1.622 log(microF)
0.0239 microF
s (using negatives)
0.2286 log(microF)
1.7 microF

H_{50} (using positives)
-1.706 log(microF)
0.0197 microF
s (using positives)
0.2333 log(microF)
1.7 microF

Figure B159: Bruceton ESD H_{50} Calculations for Mix ID SS #4 – Coarse Mg - Medium MnO_2

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #4 (coarse, medium)**

H_{50} = c + d (A/N_S ± 0.5) NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, A = Σi·n_i, and N_S = Σn_i

s = 1.62 d ((N_S B - A^2)/N_S^2 + 0.029)

where B = Σi^2·n_i

Capacitance		Frequency	
(microF)	log(micro F)	+	-
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	1	0
0.030	-1.5	1	1
0.015	-1.8	4	2
0.010	-2.0	8	5
0.0050	-2.3	0	8
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	14	16

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
8	0	0	0	
7	0	0	0	0.331
6	0	0	0	0.243
5	0	0	0	0.222
4	0	0	0	0.301
3	1	3	9	0.301
2	2	4	8	0.301
1	5	5	5	0.176
0	8	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	N_S	A	B	d
-2.301	16	12	22	0.275

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
7	0	0	0	
6	0	0	0	0.331
5	0	0	0	0.243
4	0	0	0	0.222
3	1	3	9	0.301
2	1	2	4	0.301
1	4	4	4	0.301
0	8	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	N_S	A	B	d
-2.000	14	9	17	0.275

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-1.957 log(microF)
0.0110 microF
s (using negatives)
0.3748 log(microF)
2.4 microF

H_{50} (using positives)
-1.961 log(microF)
0.0109 microF
s (using positives)
0.3697 log(microF)
2.3 microF

Figure B160: Bruceton ESD H_{50} Calculations for Mix ID SS #4 – Coarse Mg - Coarse MnO_2

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #4 (coarse, coarse)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance		Frequency	
(microF)	log(microF)	+	-
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	0	0
0.030	-1.5	0	0
0.015	-1.8	5	0
0.010	-2.0	7	5
0.0050	-2.3	3	7
0.0025	-2.6	0	3
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	**15**	**15**

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
9	0	0	0	
8	0	0	0	0.331
7	0	0	0	0.243
6	0	0	0	0.222
5	0	0	0	0.301
4	0	0	0	0.301
3	0	0	0	0.301
2	5	10	20	0.176
1	7	7	7	0.301
0	3	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.602	15	17	27	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
8	0	0	0	
7	0	0	0	0.331
6	0	0	0	0.243
5	0	0	0	0.222
4	0	0	0	0.301
3	0	0	0	0.301
2	5	10	20	0.301
1	7	7	7	0.176
0	3	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.301	15	17	27	0.275

USE EITHER NEGATIVES OR POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-2.153 log(microF)
0.0070 microF
s (using negatives)
0.2425 log(microF)
1.7 microF

H_{50} (using positives)
-2.127 log(microF)
0.0075 microF
s (using positives)
0.2425 log(microF)
1.7 microF

Figure B161: Bruceton ESD H_{50} Calculations for Mix ID SS #9 – Fine Al - Medium MoO_3

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #9 (fine, medium)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	1	0
0.120	-0.9	1	1
0.060	-1.2	2	1
0.030	-1.5	2	2
0.015	-1.8	5	1
0.010	-2.0	2	4
0.0050	-2.3	2	1
0.0025	-2.6	1	1
0.0012	-2.9	1	1
0.0007	-3.2	0	1
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	**17**	**13**

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
11	0	0	0	
10	0	0	0	0.331
9	0	0	0	0.243
8	1	8	64	0.222
7	1	7	49	0.301
6	2	12	72	0.301
5	1	5	25	0.301
4	4	16	64	0.176
3	1	3	9	0.301
2	1	2	4	0.301
1	1	1	1	0.319
0	1	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-3.155	13	54	288	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
10	0	0	0	
9	0	0	0	0.331
8	1	8	64	0.243
7	1	7	49	0.222
6	2	12	72	0.301
5	2	10	50	0.301
4	5	20	80	0.301
3	2	6	18	0.176
2	2	4	8	0.301
1	1	1	1	0.301
0	1	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.921	17	68	342	0.275

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-1.875 log(microF)
0.0133 microF
s (using negatives)
2.1950 log(microF)
156.7 microF

H_{50} (using positives)
-1.959 log(microF)
0.0110 microF
s (using positives)
1.8468 log(microF)
70.3 microF

Figure B162: Bruceton ESD H_{50} Calculations for Mix ID SS #9 – Fine Al - Coarse MoO_3

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #9 (fine, coarse)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	1	0
0.350	-0.5	1	1
0.200	-0.7	4	1
0.120	-0.9	2	4
0.060	-1.2	3	2
0.030	-1.5	2	3
0.015	-1.8	2	2
0.010	-2.0	0	2
0.0050	-2.3	0	0
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	15	15

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
7	0	0	0	
6	1	6	36	0.331
5	1	5	25	0.243
4	4	16	64	0.222
3	2	6	18	0.301
2	3	6	12	0.301
1	2	2	2	0.301
0	2	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.000	15	41	157	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
6	1	6	36	
5	1	5	25	0.331
4	4	16	64	0.243
3	2	6	18	0.222
2	3	6	12	0.301
1	2	2	2	0.301
0	2	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-1.824	15	41	157	0.275

USE EITHER NEGATIVES OR POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-1.111 log(microF)
0.0774 microF

s (using negatives)
1.3471 log(microF)
22.2 microF

H_{50} (using positives)
-1.210 log(microF)
0.0617 microF

s (using positives)
1.3471 log(microF)
22.2 microF

Figure B163: Bruceton ESD H_{50} Calculations for Mix ID SS #9 – Medium Al - Fine MoO_3

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #9 (medium, fine)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	2	0
0.120	-0.9	6	3
0.060	-1.2	4	7
0.030	-1.5	0	5
0.015	-1.8	0	1
0.010	-2.0	0	1
0.0050	-2.3	0	0
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	12	17

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
7	0	0	0	
6	0	0	0	0.331
5	0	0	0	0.243
4	3	12	48	0.222
3	7	21	63	0.301
2	5	10	20	0.301
1	1	1	1	0.301
0	1	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.000	17	44	132	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
4	0	0	0	
3	0	0	0	0.331
2	2	4	8	0.243
1	6	6	6	0.222
0	4	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-1.222	12	10	14	0.275

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-1.151 log(microF)
0.0706 microF

s (using negatives)
0.4876 log(microF)
3.1 microF

H_{50} (using positives)
-1.130 log(microF)
0.0741 microF

s (using positives)
0.2232 log(microF)
1.7 microF

Figure B164: Bruceton ESD H_{50} Calculations for Mix ID SS #9 – Medium Al - Medium MoO_3

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #9 (medium, medium)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	0	0
0.350	-0.5	1	0
0.200	-0.7	1	1
0.120	-0.9	5	1
0.060	-1.2	6	6
0.030	-1.5	0	7
0.015	-1.8	0	1
0.010	-2.0	0	1
0.0050	-2.3	0	0
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	13	17

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
7	0	0	0	
6	0	0	0	0.331
5	1	5	25	0.243
4	1	4	16	0.222
3	6	18	54	0.301
2	7	14	28	0.301
1	1	1	1	0.301
0	1	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.000	17	42	124	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
4	0	0	0	
3	1	3	9	0.331
2	1	2	4	0.243
1	5	5	5	0.222
0	6	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-1.222	13	10	18	0.275

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-1.183 log(microF)
0.0656 microF

s (using negatives)
0.5431 log(microF)
3.5 microF

H_{50} (using positives)
-1.148 log(microF)
0.0711 microF

s (using positives)
0.3661 log(microF)
2.3 microF

Figure B165: Bruceton ESD H_{50} Calculations for Mix ID SS #9 – Medium Al - Coarse MoO_3

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #9 (medium, coarse)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	4	5
0.350	-0.5	6	4
0.200	-0.7	1	7
0.120	-0.9	0	2
0.060	-1.2	0	1
0.030	-1.5	0	0
0.015	-1.8	0	0
0.010	-2.0	0	0
0.0050	-2.3	0	0
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	11	19

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
4	5	20	80	
3	4	12	36	0.331
2	7	14	28	0.243
1	2	2	2	0.222
0	1	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-1.222	19	48	146	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
2	4	8	16	
1	6	6	6	0.331
0	1	0	0	0.243
FALSE	0	0	0	0.222
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-0.699	11	14	22	0.275

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-0.390 log(microF)
0.4075 microF
s (using negatives)
0.5928 log(microF)
3.9 microF

H_{50} (using positives)
-0.487 log(microF)
0.3262 microF
s (using positives)
0.1822 log(microF)
1.5 microF

Figure B166: Bruceton ESD H_{50} Calculations for Mix ID SS #9 – Coarse Al - Fine MoO_3

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #9 (coarse, fine)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	6	6
0.350	-0.5	3	7
0.200	-0.7	0	4
0.120	-0.9	0	1
0.060	-1.2	1	1
0.030	-1.5	0	1
0.015	-1.8	0	0
0.010	-2.0	0	0
0.0050	-2.3	0	0
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	10	20

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
5	6	30	150	
4	7	28	112	0.331
3	4	12	36	0.243
2	1	2	4	0.222
1	1	1	1	0.301
0	1	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-1.523	20	73	303	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
4	6	24	96	
3	3	9	27	0.331
2	0	0	0	0.243
1	0	0	0	0.222
0	1	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-1.222	10	33	123	0.275

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-0.382 log(microF)
0.4150 microF
s (using negatives)
0.8268 log(microF)
6.7 microF

H_{50} (using positives)
-0.452 log(microF)
0.3531 microF
s (using positives)
0.6409 log(microF)
4.4 microF

Figure B167: Bruceton ESD H_{50} Calculations for Mix ID SS #9 – Coarse Al - Medium MoO_3

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #9 (coarse, medium)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance		Frequency	
(microF)	log(microF)	+	-
0.750	-0.1	3	10
0.350	-0.5	5	4
0.200	-0.7	0	6
0.120	-0.9	0	1
0.060	-1.2	0	1
0.030	-1.5	0	0
0.015	-1.8	0	0
0.010	-2.0	0	0
0.0050	-2.3	0	0
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	8	22

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
4	10	40	160	
3	4	12	36	0.331
2	6	12	24	0.243
1	1	1	1	0.222
0	1	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	N_S	A	B	d
-1.222	22	65	221	0.275

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
1	3	3	3	
0	5	0	0	0.331
FALSE	0	0	0	0.243
FALSE	0	0	0	0.222
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	N_S	A	B	d
-0.456	8	3	3	0.275

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-0.272 log(microF)
0.5344 microF
s (using negatives)
0.5991 log(microF)
4.0 microF

H_{50} (using positives)
-0.490 log(microF)
0.3234 microF
s (using positives)
0.1173 log(microF)
1.3 microF

Figure B168: Bruceton ESD H_{50} Calculations for Mix ID SS #9 – Coarse Al - Coarse MoO_3

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #9 (coarse, coarse)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance		Frequency	
(microF)	log(microF)	+	-
0.750	-0.1	4	21
0.350	-0.5	0	4
0.200	-0.7	0	1
0.120	-0.9	0	0
0.060	-1.2	0	0
0.030	-1.5	0	0
0.015	-1.8	0	0
0.010	-2.0	0	0
0.0050	-2.3	0	0
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	4	26

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
2	21	42	84	
1	4	4	4	0.331
0	1	0	0	0.243
FALSE	0	0	0	0.222
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	N_S	A	B	d
-0.699	26	46	88	0.275

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
0	4	0	0	
FALSE	0	0	0	0.331
FALSE	0	0	0	0.243
FALSE	0	0	0	0.222
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	N_S	A	B	d
-0.125	4	0	0	0.275

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-0.075 log(microF)
0.8412 microF
s (using negatives)
0.1262 log(microF)
1.3 microF

H_{50} (using positives)
-0.262 log(microF)
0.5465 microF
s (using positives)
0.0129 log(microF)
1.0 microF

Figure B169: Bruceton ESD H_{50} Calculations for Mix ID SS #19 – Fine Al - Medium SnO_2

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #19 (fine, medium)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	5	0
0.030	-1.5	4	5
0.015	-1.8	4	5
0.010	-2.0	1	5
0.0050	-2.3	0	1
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	14	16

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
8	0	0	0	
7	0	0	0	0.331
6	0	0	0	0.243
5	0	0	0	0.222
4	0	0	0	0.301
3	5	15	45	0.301
2	5	10	20	0.301
1	5	5	5	0.176
0	1	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.301	16	30	70	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
7	0	0	0	
6	0	0	0	0.331
5	0	0	0	0.243
4	0	0	0	0.222
3	5	15	45	0.301
2	4	8	16	0.301
1	4	4	4	0.301
0	1	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.000	14	27	65	0.275

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-1.648 log(microF)
0.0225 microF
s (using negatives)
0.3957 log(microF)
2.5 microF

H_{50} (using positives)
-1.607 log(microF)
0.0247 microF
s (using positives)
0.4242 log(microF)
2.7 microF

Figure B170: Bruceton ESD H_{50} Calculations for Mix ID SS #19 – Fine Al - Coarse SnO_2

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #19 (fine, coarse)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance		Frequency	
(microF)	log(microF)	+	-
0.750	-0.1	2	5
0.350	-0.5	4	2
0.200	-0.7	0	4
0.120	-0.9	1	1
0.060	-1.2	0	2
0.030	-1.5	2	2
0.015	-1.8	1	2
0.010	-2.0	0	2
0.0050	-2.3	0	0
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	**10**	**20**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
7	5	35	245	
6	2	12	72	0.331
5	4	20	100	0.243
4	1	4	16	0.222
3	2	6	18	0.301
2	2	4	8	0.301
1	2	2	2	0.301
0	2	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.000	20	83	461	0.275

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
6	2	12	72	
5	4	20	100	0.331
4	0	0	0	0.243
3	1	3	9	0.222
2	0	0	0	0.301
1	2	2	2	0.301
0	1	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-1.824	10	37	183	0.275

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-0.722 log(microF)
0.1898 microF
s (using negatives)
2.6084 log(microF)
405.8 microF

H_{50} (using positives)
-0.944 log(microF)
0.1137 microF
s (using positives)
2.0661 log(microF)
116.4 microF

Figure B171: Bruceton ESD H_{50} Calculations for Mix ID SS #19 – Medium Al - Fine SnO_2

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #19 (medium, fine)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	0	0
0.030	-1.5	3	0
0.015	-1.8	3	3
0.010	-2.0	2	3
0.0050	-2.3	2	1
0.0025	-2.6	6	1
0.0012	-2.9	0	6
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	16	14

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
10	0	0	0	
9	0	0	0	0.331
8	0	0	0	0.243
7	0	0	0	0.222
6	0	0	0	0.301
5	0	0	0	0.301
4	3	12	48	0.301
3	3	9	27	0.176
2	1	2	4	0.301
1	1	1	1	0.301
0	6	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.921	14	24	80	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
9	0	0	0	
8	0	0	0	0.331
7	0	0	0	0.243
6	0	0	0	0.222
5	0	0	0	0.301
4	3	12	48	0.301
3	3	9	27	0.301
2	2	4	8	0.176
1	2	2	2	0.301
0	6	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.602	16	27	85	0.275

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-2.312 log(microF)
0.0049 microF
s (using negatives)
1.2491 log(microF)
17.7 microF

H_{50} (using positives)
-2.276 log(microF)
0.0053 microF
s (using positives)
1.1107 log(microF)
12.9 microF

Figure B172: Bruceton ESD H_{50} Calculations for Mix ID SS #19 – Medium Al - Medium SnO_2

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #19 (medium, medium)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	0	0
0.030	-1.5	6	0
0.015	-1.8	7	7
0.010	-2.0	1	8
0.0050	-2.3	0	1
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	14	16

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
8	0	0	0	
7	0	0	0	0.331
6	0	0	0	0.243
5	0	0	0	0.222
4	0	0	0	0.301
3	0	0	0	0.301
2	7	14	28	0.301
1	8	8	8	0.176
0	1	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.301	16	22	36	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
7	0	0	0	
6	0	0	0	0.331
5	0	0	0	0.243
4	0	0	0	0.222
3	0	0	0	0.301
2	6	12	24	0.301
1	7	7	7	0.301
0	1	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.000	14	19	31	0.275

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-1.786 log(microF)
0.0164 microF
s (using negatives)
0.1730 log(microF)
1.5 microF

H_{50} (using positives)
-1.764 log(microF)
0.0172 microF
s (using positives)
0.1788 log(microF)
1.5 microF

Figure B173: Bruceton ESD H_{50} Calculations for Mix ID SS #19 – Medium Al - Coarse SnO_2

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #19 (medium, coarse)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance		Frequency	
(microF)	log(microF)	+	-
0.750	-0.1	4	8
0.350	-0.5	2	5
0.200	-0.7	1	3
0.120	-0.9	1	2
0.060	-1.2	0	2
0.030	-1.5	0	1
0.015	-1.8	0	1
0.010	-2.0	0	0
0.0050	-2.3	0	0
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	8	22

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
6	8	48	288	
5	5	25	125	0.331
4	3	12	48	0.243
3	2	6	18	0.222
2	2	4	8	0.301
1	1	1	1	0.301
0	1	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	N_S	A	B	d
-1.824	22	96	488	0.275

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
3	4	12	36	
2	2	4	8	0.331
1	1	1	1	0.243
0	1	0	0	0.222
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	N_S	A	B	d
-0.921	8	17	45	0.275

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-0.487 log(microF)
0.3260 microF

s (using negatives)
1.4116 log(microF)
25.8 microF

H_{50} (using positives)
-0.474 log(microF)
0.3357 microF

s (using positives)
0.5070 log(microF)
3.2 microF

Figure B174: Bruceton ESD H_{50} Calculations for Mix ID SS #19 – Coarse Al – Fine SnO_2

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #19 (coarse, fine)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i{\cdot}n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2{\cdot}n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	0	0
0.030	-1.5	0	0
0.015	-1.8	0	0
0.010	-2.0	1	0
0.0050	-2.3	4	1
0.0025	-2.6	7	4
0.0012	-2.9	3	7
0.0007	-3.2	0	3
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	15	15

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
11	0	0	0	
10	0	0	0	0.331
9	0	0	0	0.243
8	0	0	0	0.222
7	0	0	0	0.301
6	0	0	0	0.301
5	0	0	0	0.301
4	0	0	0	0.176
3	1	3	9	0.301
2	4	8	16	0.301
1	7	7	7	0.319
0	3	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-3.155	15	18	32	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
10	0	0	0	
9	0	0	0	0.331
8	0	0	0	0.243
7	0	0	0	0.222
6	0	0	0	0.301
5	0	0	0	0.301
4	0	0	0	0.301
3	1	3	9	0.176
2	4	8	16	0.301
1	7	7	7	0.301
0	3	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.921	15	18	32	0.275

USE EITHER NEGATIVES OR POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-2.688 log(microF)
0.0021 microF
s (using negatives)
0.3217 log(microF)
2.1 microF

H_{50} (using positives)
-2.728 log(microF)
0.0019 microF
s (using positives)
0.3217 log(microF)
2.1 microF

Figure B175: Bruceton ESD H_{50} Calculations for Mix ID SS #19 – Coarse Al - Medium SnO_2

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #19 (coarse, medium)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	7	8
0.350	-0.5	3	8
0.200	-0.7	0	4
0.120	-0.9	0	0
0.060	-1.2	0	0
0.030	-1.5	0	0
0.015	-1.8	0	0
0.010	-2.0	0	0
0.0050	-2.3	0	0
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	10	20

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
2	8	16	32	
1	8	8	8	0.331
0	4	0	0	0.243
FALSE	0	0	0	0.222
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-0.699	20	24	40	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
1	7	7	7	
0	3	0	0	0.331
FALSE	0	0	0	0.243
FALSE	0	0	0	0.222
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-0.456	10	7	7	0.275

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-0.232 log(microF)
0.5867 microF

s (using negatives)
0.2623 log(microF)
1.8 microF

H_{50} (using positives)
-0.401 log(microF)
0.3972 microF

s (using positives)
0.1064 log(microF)
1.3 microF

Figure B176: Bruceton ESD H_{50} Calculations for Mix ID SS #19 – Coarse Al - Coarse SnO_2

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #19 (coarse, coarse)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	5	18
0.350	-0.5	1	5
0.200	-0.7	0	1
0.120	-0.9	0	0
0.060	-1.2	0	0
0.030	-1.5	0	0
0.015	-1.8	0	0
0.010	-2.0	0	0
0.0050	-2.3	0	0
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	**6**	**24**

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
2	18	36	72	
1	5	5	5	0.331
0	1	0	0	0.243
FALSE	0	0	0	0.222
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-0.699	24	41	77	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
1	5	5	5	
0	1	0	0	0.331
FALSE	0	0	0	0.243
FALSE	0	0	0	0.222
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-0.456	6	5	5	0.275

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-0.092 log(microF)
0.8094 microF

s (using negatives)
0.1420 log(microF)
1.4 microF

H_{50} (using positives)
-0.364 log(microF)
0.4322 microF

s (using positives)
0.0748 log(microF)
1.2 microF

Figure B177: Bruceton ESD H_{50} Calculations for Mix ID SS #24 – Fine Al - Medium Bi_2O_3

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #24 (fine, medium)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	0	0
0.030	-1.5	1	0
0.015	-1.8	1	0
0.010	-2.0	1	0
0.0050	-2.3	2	0
0.0025	-2.6	7	1
0.0012	-2.9	2	6
0.0007	-3.2	2	2
0.0003	-3.5	1	2
0.0002	-3.7	1	1
0.0000	0	0	0
	SUM	18	12

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
13	0	0	0	
12	0	0	0	0.331
11	0	0	0	0.243
10	0	0	0	0.222
9	0	0	0	0.301
8	0	0	0	0.301
7	0	0	0	0.301
6	0	0	0	0.176
5	0	0	0	0.301
4	1	4	16	0.301
3	6	18	54	0.319
2	2	4	8	0.234
1	2	2	2	0.368
0	1	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-3.699	12	28	80	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
13	0	0	0	
12	0	0	0	0.331
11	0	0	0	0.243
10	0	0	0	0.222
9	0	0	0	0.301
8	1	8	64	0.301
7	1	7	49	0.301
6	1	6	36	0.176
5	2	10	50	0.301
4	7	28	112	0.301
3	2	6	18	0.319
2	2	4	8	0.234
1	1	1	1	0.368
0	1	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-3.699	18	70	338	0.275

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-2.920 log(microF)
0.0012 microF

s (using negatives)
0.5573 log(microF)
3.6 microF

H_{50} (using positives)
-2.767 log(microF)
0.0017 microF

s (using positives)
1.6405 log(microF)
43.7 microF

Figure B178: Bruceton ESD H_{50} Calculations for Mix ID SS #24 – Fine Al - Coarse Bi_2O_3

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #24 (fine, coarse)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	0	0
0.030	-1.5	0	0
0.015	-1.8	3	0
0.010	-2.0	5	3
0.0050	-2.3	4	4
0.0025	-2.6	3	3
0.0012	-2.9	2	2
0.0007	-3.2	0	1
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	17	13

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
11	0	0	0	
10	0	0	0	0.331
9	0	0	0	0.243
8	0	0	0	0.222
7	0	0	0	0.301
6	0	0	0	0.301
5	0	0	0	0.301
4	3	12	48	0.176
3	4	12	36	0.301
2	3	6	12	0.301
1	2	2	2	0.319
0	1	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-3.155	13	32	98	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
10	0	0	0	
9	0	0	0	0.331
8	0	0	0	0.243
7	0	0	0	0.222
6	0	0	0	0.301
5	0	0	0	0.301
4	3	12	48	0.301
3	5	15	45	0.176
2	4	8	16	0.301
1	3	3	3	0.301
0	2	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.921	17	38	112	0.275

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-2.341 log(microF)
0.0046 microF

s (using negatives)
0.6718 log(microF)
4.7 microF

H_{50} (using positives)
-2.444 log(microF)
0.0036 microF

s (using positives)
0.7218 log(microF)
5.3 microF

Figure B179: Bruceton ESD H_{50} Calculations for Mix ID SS #24 – Medium Al - Fine Bi_2O_3

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #24 (medium, fine)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance		Frequency	
(microF)	log(microF)	+	-
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	5	0
0.030	-1.5	7	5
0.015	-1.8	1	8
0.010	-2.0	0	2
0.0050	-2.3	0	1
0.0025	-2.6	0	1
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	13	17

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
9	0	0	0	
8	0	0	0	0.331
7	0	0	0	0.243
6	0	0	0	0.222
5	0	0	0	0.301
4	5	20	80	0.301
3	8	24	72	0.301
2	2	4	8	0.176
1	1	1	1	0.301
0	1	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	N_S	A	B	d
-2.602	17	49	161	0.275

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
6	0	0	0	
5	0	0	0	0.331
4	0	0	0	0.243
3	0	0	0	0.222
2	5	10	20	0.301
1	7	7	7	0.301
0	1	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	N_S	A	B	d
-1.824	13	17	27	0.275

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-1.672 log(microF)
0.0213 microF
s (using negatives)
0.5307 log(microF)
3.4 microF

H_{50} (using positives)
-1.602 log(microF)
0.0250 microF
s (using positives)
0.1763 log(microF)
1.5 microF

Figure B180: Bruceton ESD H_{50} Calculations for Mix ID SS #24 – Medium Al - Medium Bi_2O_3

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #24 (medium, medium)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	0	0
0.030	-1.5	1	0
0.015	-1.8	2	1
0.010	-2.0	3	2
0.0050	-2.3	3	3
0.0025	-2.6	6	3
0.0012	-2.9	0	6
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	15	15

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
10	0	0	0	
9	0	0	0	0.331
8	0	0	0	0.243
7	0	0	0	0.222
6	0	0	0	0.301
5	0	0	0	0.301
4	1	4	16	0.301
3	2	6	18	0.176
2	3	6	12	0.301
1	3	3	3	0.301
0	6	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.921	15	19	49	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
9	0	0	0	
8	0	0	0	0.331
7	0	0	0	0.243
6	0	0	0	0.222
5	0	0	0	0.301
4	1	4	16	0.301
3	2	6	18	0.301
2	3	6	12	0.176
1	3	3	3	0.301
0	6	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.602	15	19	49	0.275

USE EITHER NEGATIVES OR POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-2.435 log(microF)
0.0037 microF

s (using negatives)
0.7532 log(microF)
5.7 microF

H_{50} (using positives)
-2.391 log(microF)
0.0041 microF

s (using positives)
0.7532 log(microF)
5.7 microF

Figure B181: Bruceton ESD H_{50} Calculations for Mix ID SS #24 – Medium Al - Coarse Bi_2O_3

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #24 (medium, coarse)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance		Frequency	
(microF)	log(microF)	+	-
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	2	0
0.030	-1.5	4	2
0.015	-1.8	4	4
0.010	-2.0	4	4
0.0050	-2.3	1	4
0.0025	-2.6	0	1
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	15	15

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
9	0	0	0	
8	0	0	0	0.331
7	0	0	0	0.243
6	0	0	0	0.222
5	0	0	0	0.301
4	2	8	32	0.301
3	4	12	36	0.301
2	4	8	16	0.176
1	4	4	4	0.301
0	1	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	N_S	A	B	d
-2.602	15	32	88	0.275

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
8	0	0	0	
7	0	0	0	0.331
6	0	0	0	0.243
5	0	0	0	0.222
4	2	8	32	0.301
3	4	12	36	0.301
2	4	8	16	0.301
1	4	4	4	0.176
0	1	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	N_S	A	B	d
-2.301	15	32	88	0.275

USE EITHER NEGATIVES OR POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-1.878 log(microF)
0.0132 microF
s (using negatives)
0.5988 log(microF)
4.0 microF

H_{50} (using positives)
-1.852 log(microF)
0.0141 microF
s (using positives)
0.5988 log(microF)
4.0 microF

Figure B182: Bruceton ESD H_{50} Calculations for Mix ID SS #24 – Coarse Al - Fine Bi_2O_3

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #24 (coarse, fine)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	2	0
0.060	-1.2	7	2
0.030	-1.5	3	8
0.015	-1.8	0	5
0.010	-2.0	0	2
0.0050	-2.3	0	1
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	12	18

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
8	0	0	0	
7	0	0	0	0.331
6	0	0	0	0.243
5	0	0	0	0.222
4	2	8	32	0.301
3	8	24	72	0.301
2	5	10	20	0.301
1	2	2	2	0.176
0	1	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.301	18	44	126	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
5	0	0	0	
4	0	0	0	0.331
3	0	0	0	0.243
2	2	4	8	0.222
1	7	7	7	0.301
0	3	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-1.523	12	11	15	0.275

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-1.492 log(microF)
0.0322 microF
s (using negatives)
0.4693 log(microF)
2.9 microF

H_{50} (using positives)
-1.408 log(microF)
0.0391 microF
s (using positives)
0.1954 log(microF)
1.6 microF

Figure B183: Bruceton ESD H_{50} Calculations for Mix ID SS #24 – Coarse Al - Medium Bi_2O_3

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #24 (coarse, medium)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	2	0
0.060	-1.2	4	2
0.030	-1.5	6	4
0.015	-1.8	0	6
0.010	-2.0	2	1
0.0050	-2.3	0	3
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	14	16

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
8	0	0	0	
7	0	0	0	0.331
6	0	0	0	0.243
5	0	0	0	0.222
4	2	8	32	0.301
3	4	12	36	0.301
2	6	12	24	0.301
1	1	1	1	0.176
0	3	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.301	16	33	93	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
7	0	0	0	
6	0	0	0	0.331
5	0	0	0	0.243
4	2	8	32	0.222
3	4	12	36	0.301
2	6	12	24	0.301
1	0	0	0	0.301
0	2	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.000	14	32	92	0.275

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
-1.597	log(microF)
0.0253	microF
s (using negatives)	
0.7071	log(microF)
5.1	microF

H_{50} (using positives)	
-1.509	log(microF)
0.0310	microF
s (using positives)	
0.6128	log(microF)
4.1	microF

Figure B184: Bruceton ESD H_{50} Calculations for Mix ID SS #24 – Coarse Al - Coarse Bi_2O_3

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #24 (coarse, coarse)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	1	0
0.060	-1.2	5	1
0.030	-1.5	2	5
0.015	-1.8	4	2
0.010	-2.0	3	4
0.0050	-2.3	0	3
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	15	15

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
8	0	0	0	
7	0	0	0	0.331
6	0	0	0	0.243
5	0	0	0	0.222
4	1	4	16	0.301
3	5	15	45	0.301
2	2	4	8	0.301
1	4	4	4	0.176
0	3	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.301	15	27	73	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
7	0	0	0	
6	0	0	0	0.331
5	0	0	0	0.243
4	1	4	16	0.222
3	5	15	45	0.301
2	2	4	8	0.301
1	4	4	4	0.301
0	3	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.000	15	27	73	0.275

USE EITHER NEGATIVES OR POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-1.669 log(microF)
0.0214 microF

s (using negatives)
0.7374 log(microF)
5.5 microF

H_{50} (using positives)
-1.643 log(microF)
0.0228 microF

s (using positives)
0.7374 log(microF)
5.5 microF

Figure B185: Bruceton ESD H_{50} Calculations for Mix ID SS #48 – Fine Ti - Medium Bi_2O_3

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #48 (fine, medium)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	0	0
0.030	-1.5	0	0
0.015	-1.8	0	0
0.010	-2.0	0	0
0.0050	-2.3	2	0
0.0025	-2.6	4	2
0.0012	-2.9	2	4
0.0007	-3.2	5	2
0.0003	-3.5	2	5
0.0002	-3.7	0	2
0.0000	0	0	0
	SUM	**15**	**15**

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
13	0	0	0	
12	0	0	0	0.331
11	0	0	0	0.243
10	0	0	0	0.222
9	0	0	0	0.301
8	0	0	0	0.301
7	0	0	0	0.301
6	0	0	0	0.176
5	0	0	0	0.301
4	2	8	32	0.301
3	4	12	36	0.319
2	2	4	8	0.234
1	5	5	5	0.368
0	2	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-3.699	15	29	81	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
12	0	0	0	
11	0	0	0	0.331
10	0	0	0	0.243
9	0	0	0	0.222
8	0	0	0	0.301
7	0	0	0	0.301
6	0	0	0	0.301
5	0	0	0	0.176
4	2	8	32	0.301
3	4	12	36	0.301
2	2	4	8	0.319
1	5	5	5	0.234
0	2	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-3.523	15	29	81	0.275

USE EITHER NEGATIVES OR POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-3.030 log(microF)
0.0009 microF
s (using negatives)
0.7532 log(microF)
5.7 microF

H_{50} (using positives)
-3.129 log(microF)
0.0007 microF
s (using positives)
0.7532 log(microF)
5.7 microF

Figure B186: Bruceton ESD H_{50} Calculations for Mix ID SS #48 – Fine Ti - Coarse Bi_2O_3

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #48 (fine, coarse)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	0	0
0.030	-1.5	0	0
0.015	-1.8	0	0
0.010	-2.0	0	0
0.0050	-2.3	2	0
0.0025	-2.6	6	2
0.0012	-2.9	6	6
0.0007	-3.2	1	6
0.0003	-3.5	0	1
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	15	15

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
12	0	0	0	
11	0	0	0	0.331
10	0	0	0	0.243
9	0	0	0	0.222
8	0	0	0	0.301
7	0	0	0	0.301
6	0	0	0	0.301
5	0	0	0	0.176
4	0	0	0	0.301
3	2	6	18	0.301
2	6	12	24	0.319
1	6	6	6	0.234
0	1	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-3.523	15	24	48	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
11	0	0	0	
10	0	0	0	0.331
9	0	0	0	0.243
8	0	0	0	0.222
7	0	0	0	0.301
6	0	0	0	0.301
5	0	0	0	0.301
4	0	0	0	0.176
3	2	6	18	0.301
2	6	12	24	0.301
1	6	6	6	0.319
0	1	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-3.155	15	24	48	0.275

USE EITHER NEGATIVES OR POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-2.946 log(microF)
0.0011 microF
s (using negatives)
0.2980 log(microF)
2.0 microF

H_{50} (using positives)
-2.852 log(microF)
0.0014 microF
s (using positives)
0.2980 log(microF)
2.0 microF

Figure B187: Bruceton ESD H_{50} Calculations for Mix ID SS #48 – Medium Ti - Fine Bi_2O_3

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #48 (medium, fine)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	0	0
0.030	-1.5	0	0
0.015	-1.8	0	0
0.010	-2.0	1	0
0.0050	-2.3	0	0
0.0025	-2.6	1	0
0.0012	-2.9	0	0
0.0007	-3.2	1	0
0.0003	-3.5	2	0
0.0002	-3.7	22	3
0.0000	0	0	0
	SUM	27	3

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
13	0	0	0	
12	0	0	0	0.331
11	0	0	0	0.243
10	0	0	0	0.222
9	0	0	0	0.301
8	0	0	0	0.301
7	0	0	0	0.301
6	0	0	0	0.176
5	0	0	0	0.301
4	0	0	0	0.301
3	0	0	0	0.319
2	0	0	0	0.234
1	0	0	0	0.368
0	3	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-3.699	3	0	0	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
13	0	0	0	
12	0	0	0	0.331
11	0	0	0	0.243
10	0	0	0	0.222
9	0	0	0	0.301
8	0	0	0	0.301
7	0	0	0	0.301
6	1	6	36	0.176
5	0	0	0	0.301
4	1	4	16	0.301
3	0	0	0	0.319
2	1	2	4	0.234
1	2	2	2	0.368
0	22	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-3.699	27	14	58	0.275

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-3.562 log(microF)
0.0003 microF

s (using negatives)
0.0129 log(microF)
1.0 microF

H_{50} (using positives)
-3.694 log(microF)
0.0002 microF

s (using positives)
0.8499 log(microF)
7.1 microF

Figure B188: Bruceton ESD H_{50} Calculations for Mix ID SS #48 – Medium Ti - Medium Bi_2O_3

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #48 (medium, medium)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	0	0
0.030	-1.5	0	0
0.015	-1.8	0	0
0.010	-2.0	0	0
0.0050	-2.3	1	0
0.0025	-2.6	4	1
0.0012	-2.9	7	4
0.0007	-3.2	3	7
0.0003	-3.5	0	3
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	15	15

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
12	0	0	0	
11	0	0	0	0.331
10	0	0	0	0.243
9	0	0	0	0.222
8	0	0	0	0.301
7	0	0	0	0.301
6	0	0	0	0.301
5	0	0	0	0.176
4	0	0	0	0.301
3	1	3	9	0.301
2	4	8	16	0.319
1	7	7	7	0.234
0	3	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-3.523	15	18	32	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
11	0	0	0	
10	0	0	0	0.331
9	0	0	0	0.243
8	0	0	0	0.222
7	0	0	0	0.301
6	0	0	0	0.301
5	0	0	0	0.301
4	0	0	0	0.176
3	1	3	9	0.301
2	4	8	16	0.301
1	7	7	7	0.319
0	3	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-3.155	15	18	32	0.275

USE EITHER NEGATIVES OR POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-3.056 log(microF)
0.0009 microF
s (using negatives)
0.3217 log(microF)
2.1 microF

H_{50} (using positives)
-2.962 log(microF)
0.0011 microF
s (using positives)
0.3217 log(microF)
2.1 microF

Figure B189: Bruceton ESD H_{50} Calculations for Mix ID SS #48 – Medium Ti - Coarse Bi_2O_3

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #48 (medium, coarse)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	0	0
0.030	-1.5	0	0
0.015	-1.8	0	0
0.010	-2.0	0	0
0.0050	-2.3	1	0
0.0025	-2.6	3	1
0.0012	-2.9	3	4
0.0007	-3.2	3	3
0.0003	-3.5	4	3
0.0002	-3.7	1	4
0.0000	0	0	0
	SUM	**15**	**15**

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
13	0	0	0	
12	0	0	0	0.331
11	0	0	0	0.243
10	0	0	0	0.222
9	0	0	0	0.301
8	0	0	0	0.301
7	0	0	0	0.301
6	0	0	0	0.176
5	0	0	0	0.301
4	1	4	16	0.301
3	4	12	36	0.319
2	3	6	12	0.234
1	3	3	3	0.368
0	4	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-3.699	15	25	67	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
13	0	0	0	
12	0	0	0	0.331
11	0	0	0	0.243
10	0	0	0	0.222
9	0	0	0	0.301
8	0	0	0	0.301
7	0	0	0	0.301
6	0	0	0	0.176
5	1	5	25	0.301
4	3	12	48	0.301
3	3	9	27	0.319
2	3	6	12	0.234
1	4	4	4	0.368
0	1	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-3.699	15	36	116	0.275

USE EITHER NEGATIVES OR POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-3.103 log(microF)
0.0008 microF

s (using negatives)
0.7651 log(microF)
5.8 microF

H_{50} (using positives)
-3.177 log(microF)
0.0007 microF

s (using positives)
0.8918 log(microF)
7.8 microF

Figure B190: Bruceton ESD H_{50} Calculations for Mix ID SS #48 – Coarse Ti - Fine Bi_2O_3

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #48 (coarse, fine)**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance		Frequency	
(microF)	log(microF)	+	-
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	0	0
0.030	-1.5	0	0
0.015	-1.8	0	0
0.010	-2.0	0	0
0.0050	-2.3	0	0
0.0025	-2.6	0	0
0.0012	-2.9	0	0
0.0007	-3.2	0	0
0.0003	-3.5	2	0
0.0002	-3.7	27	1
0.0000	0	0	0
	SUM	29	1

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
13	0	0	0	
12	0	0	0	0.331
11	0	0	0	0.243
10	0	0	0	0.222
9	0	0	0	0.301
8	0	0	0	0.301
7	0	0	0	0.301
6	0	0	0	0.176
5	0	0	0	0.301
4	0	0	0	0.301
3	0	0	0	0.319
2	0	0	0	0.234
1	0	0	0	0.368
0	1	0	0	0.176
FALSE	0	0	0	
c	N_S	A	B	d
-3.699	1	0	0	0.275

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
13	0	0	0	
12	0	0	0	0.331
11	0	0	0	0.243
10	0	0	0	0.222
9	0	0	0	0.301
8	0	0	0	0.301
7	0	0	0	0.301
6	0	0	0	0.176
5	0	0	0	0.301
4	0	0	0	0.301
3	0	0	0	0.319
2	0	0	0	0.234
1	2	2	2	0.368
0	27	0	0	0.176
FALSE	0	0	0	
c	N_S	A	B	d
-3.699	29	2	2	0.275

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-3.562 log(microF)
0.0003 microF
s (using negatives)
0.0129 log(microF)
1.0 microF

H_{50} (using positives)
-3.817 log(microF)
0.0002 microF
s (using positives)
0.0415 log(microF)
1.1 microF

Figure B191: Bruceton ESD H_{50} Calculations for Mix ID SS #48 – Coarse Ti - Medium Bi_2O_3

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #48 (coarse, medium)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance		Frequency	
(microF)	log(microF)	+	-
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	0	0
0.030	-1.5	0	0
0.015	-1.8	0	0
0.010	-2.0	0	0
0.0050	-2.3	1	0
0.0025	-2.6	3	2
0.0012	-2.9	5	4
0.0007	-3.2	3	5
0.0003	-3.5	2	3
0.0002	-3.7	0	2
0.0000	0	0	0
	SUM	14	16

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
13	0	0	0	
12	0	0	0	0.331
11	0	0	0	0.243
10	0	0	0	0.222
9	0	0	0	0.301
8	0	0	0	0.301
7	0	0	0	0.301
6	0	0	0	0.176
5	0	0	0	0.301
4	2	8	32	0.301
3	4	12	36	0.319
2	5	10	20	0.234
1	3	3	3	0.368
0	2	0	0	0.176
FALSE	0	0	0	
c	N_S	A	B	d
-3.699	16	33	91	0.275

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
12	0	0	0	
11	0	0	0	0.331
10	0	0	0	0.243
9	0	0	0	0.222
8	0	0	0	0.301
7	0	0	0	0.301
6	0	0	0	0.301
5	0	0	0	0.176
4	1	4	16	0.301
3	3	9	27	0.301
2	5	10	20	0.319
1	3	3	3	0.234
0	2	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	N_S	A	B	d
-3.523	14	26	66	0.275

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-2.994 log(microF)
0.0010 microF
s (using negatives)
0.6514 log(microF)
4.5 microF

H_{50} (using positives)
-3.150 log(microF)
0.0007 microF
s (using positives)
0.5765 log(microF)
3.8 microF

Figure B192: Bruceton ESD H_{50} Calculations for Mix ID SS #48 – Coarse Ti - Coarse Bi_2O_3

Calculation of 50% ESD initiation level from Bruceton data

ABL Electrostatic Discharge Test

Sample: **SS #48 (coarse, coarse)**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Capacitance (microF)	log(microF)	Frequency +	Frequency -
0.750	-0.1	0	0
0.350	-0.5	0	0
0.200	-0.7	0	0
0.120	-0.9	0	0
0.060	-1.2	0	0
0.030	-1.5	0	0
0.015	-1.8	0	0
0.010	-2.0	0	0
0.0050	-2.3	3	0
0.0025	-2.6	8	3
0.0012	-2.9	4	8
0.0007	-3.2	0	4
0.0003	-3.5	0	0
0.0002	-3.7	0	0
0.0000	0	0	0
	SUM	15	15

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
11	0	0	0	
10	0	0	0	0.331
9	0	0	0	0.243
8	0	0	0	0.222
7	0	0	0	0.301
6	0	0	0	0.301
5	0	0	0	0.301
4	0	0	0	0.176
3	0	0	0	0.301
2	3	6	12	0.301
1	8	8	8	0.319
0	4	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-3.155	15	14	20	0.275

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
10	0	0	0	
9	0	0	0	0.331
8	0	0	0	0.243
7	0	0	0	0.222
6	0	0	0	0.301
5	0	0	0	0.301
4	0	0	0	0.301
3	0	0	0	0.176
2	3	6	12	0.301
1	8	8	8	0.301
0	4	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
-2.921	15	14	20	0.275

USE EITHER NEGATIVES OR POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
-2.761 log(microF)
0.0017 microF

s (using negatives)
0.2188 log(microF)
1.7 microF

H_{50} (using positives)
-2.802 log(microF)
0.0016 microF

s (using positives)
0.2188 log(microF)
1.7 microF

APPENDIX C
– DSC Plots

Figure C1: High-Temp DSC Plots for Mix ID LS #7 – Fine Al - Fine MnO_2, Trial 1

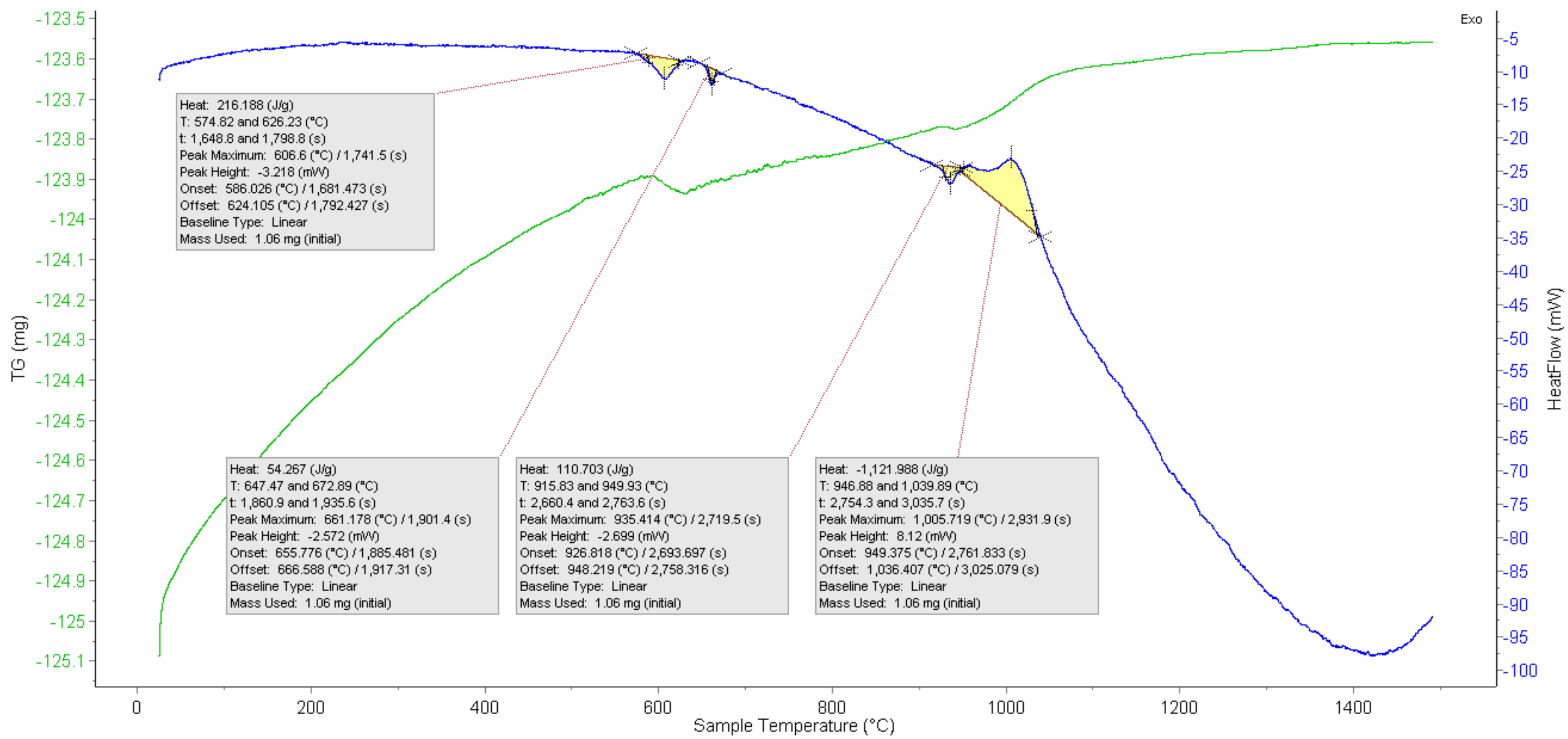


Figure C2: High-Temp Plots for Mix ID LS #7 – Fine Al - Fine MnO_2, Trial 2

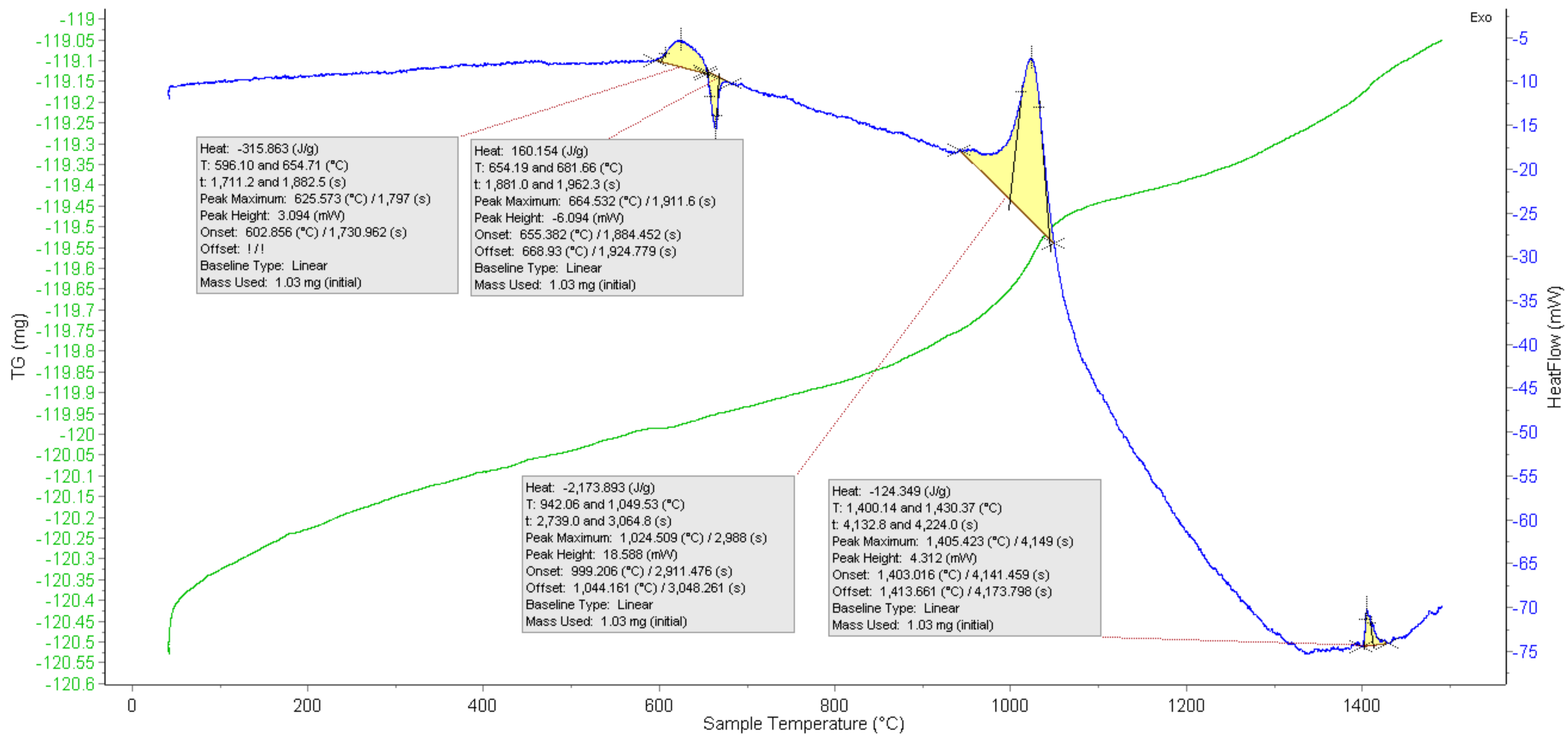


Figure C3: High-Temp DSC Plots for Mix ID LS #7 – Fine Al - Medium MnO_2, Trial 1

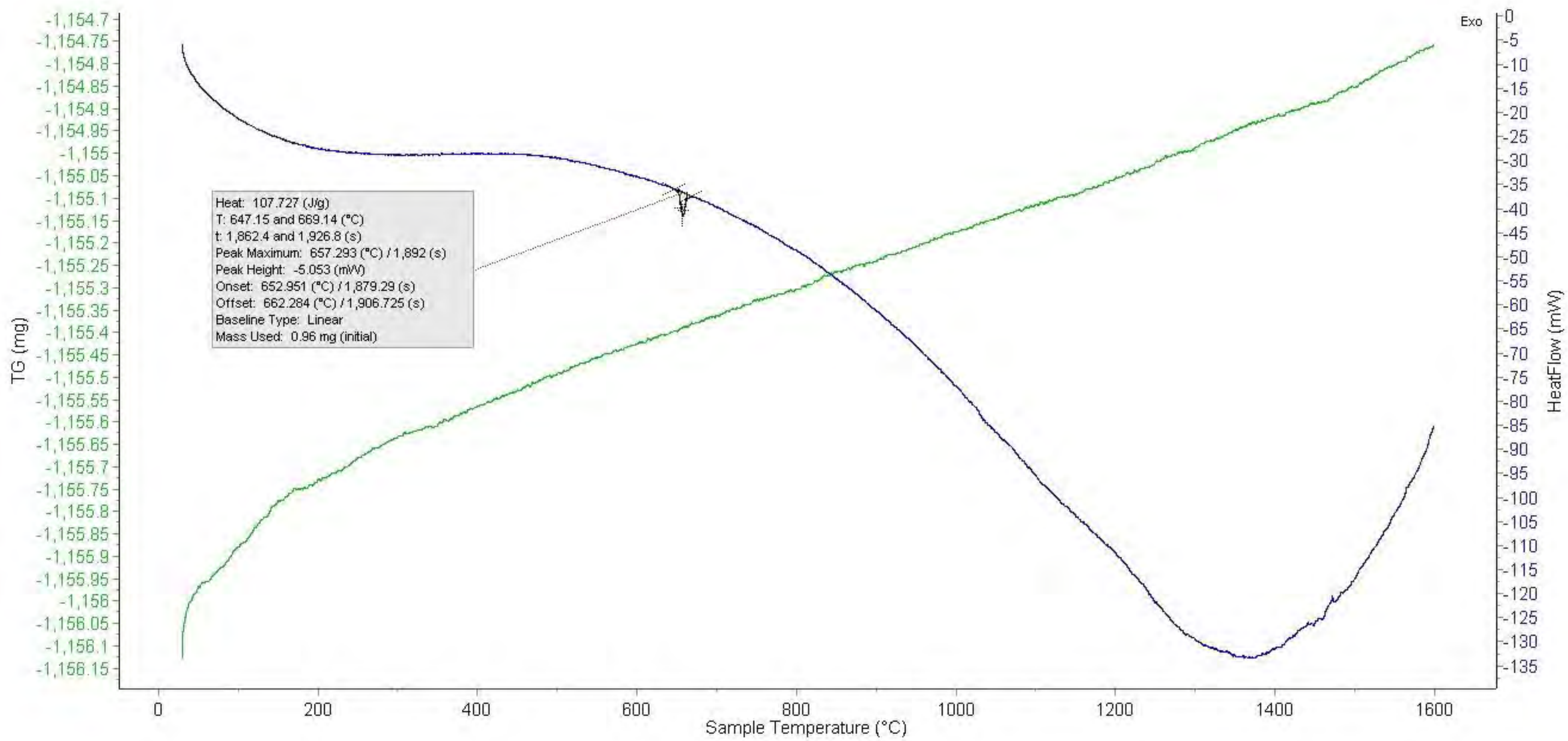


Figure C4: High-Temp DSC Plots for Mix ID LS #7 – Fine Al - Medium MnO_2, Trial 2

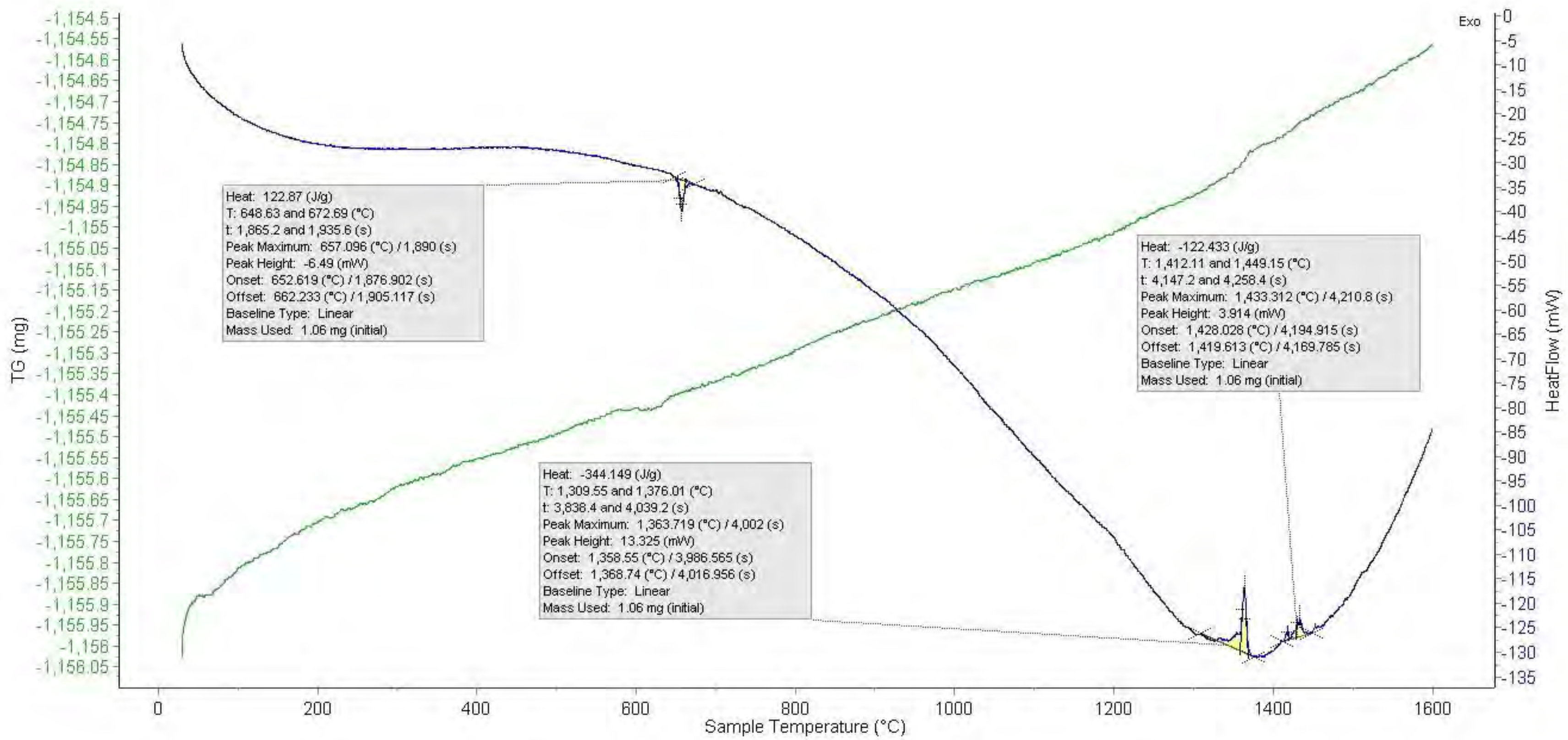


Figure C5: High-Temp DSC Plots for Mix ID LS #7 – Fine Al - Coarse MnO_2, Trial 1

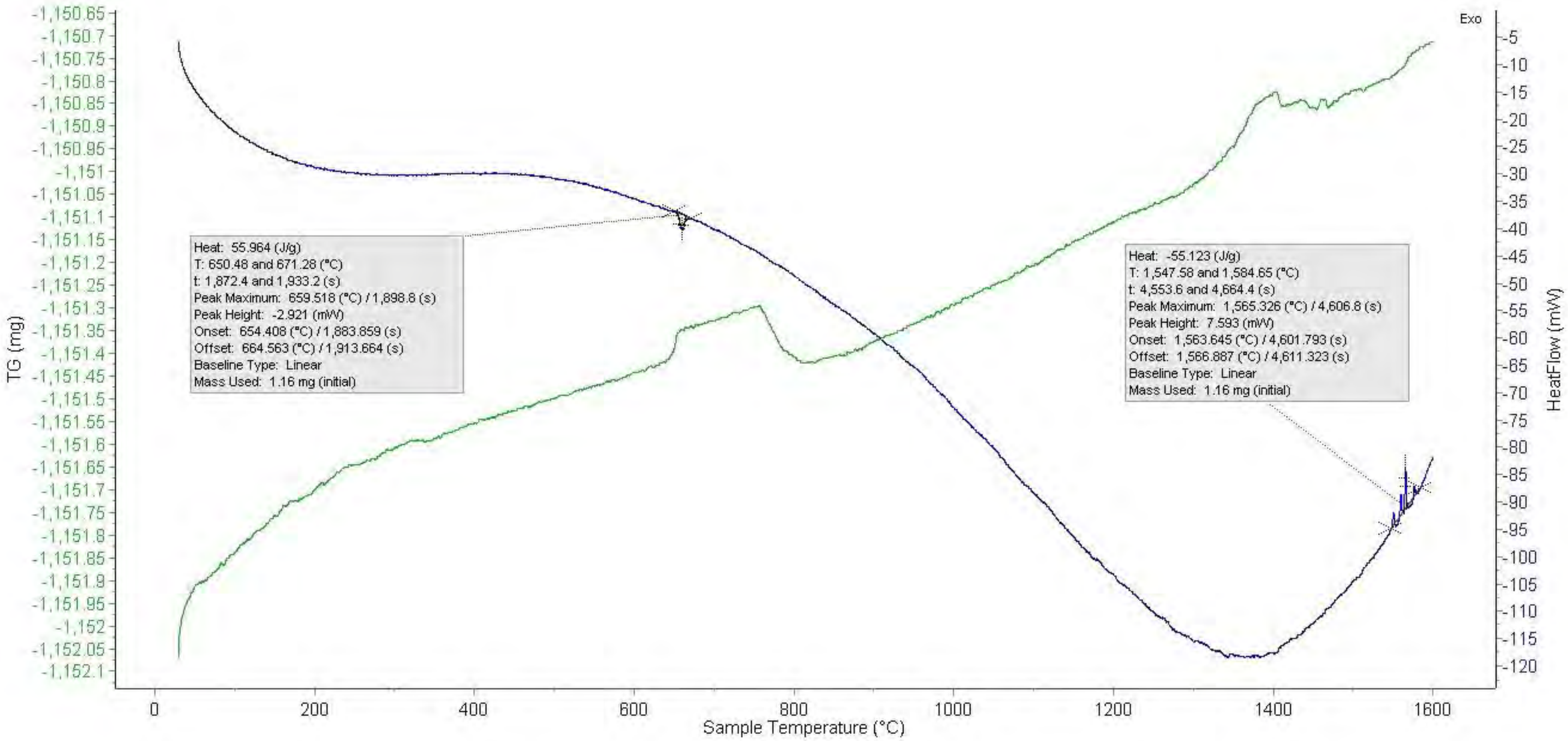


Figure C6: High-Temp DSC Plots for Mix ID LS #7 – Fine Al - Coarse MnO_2, Trial 2

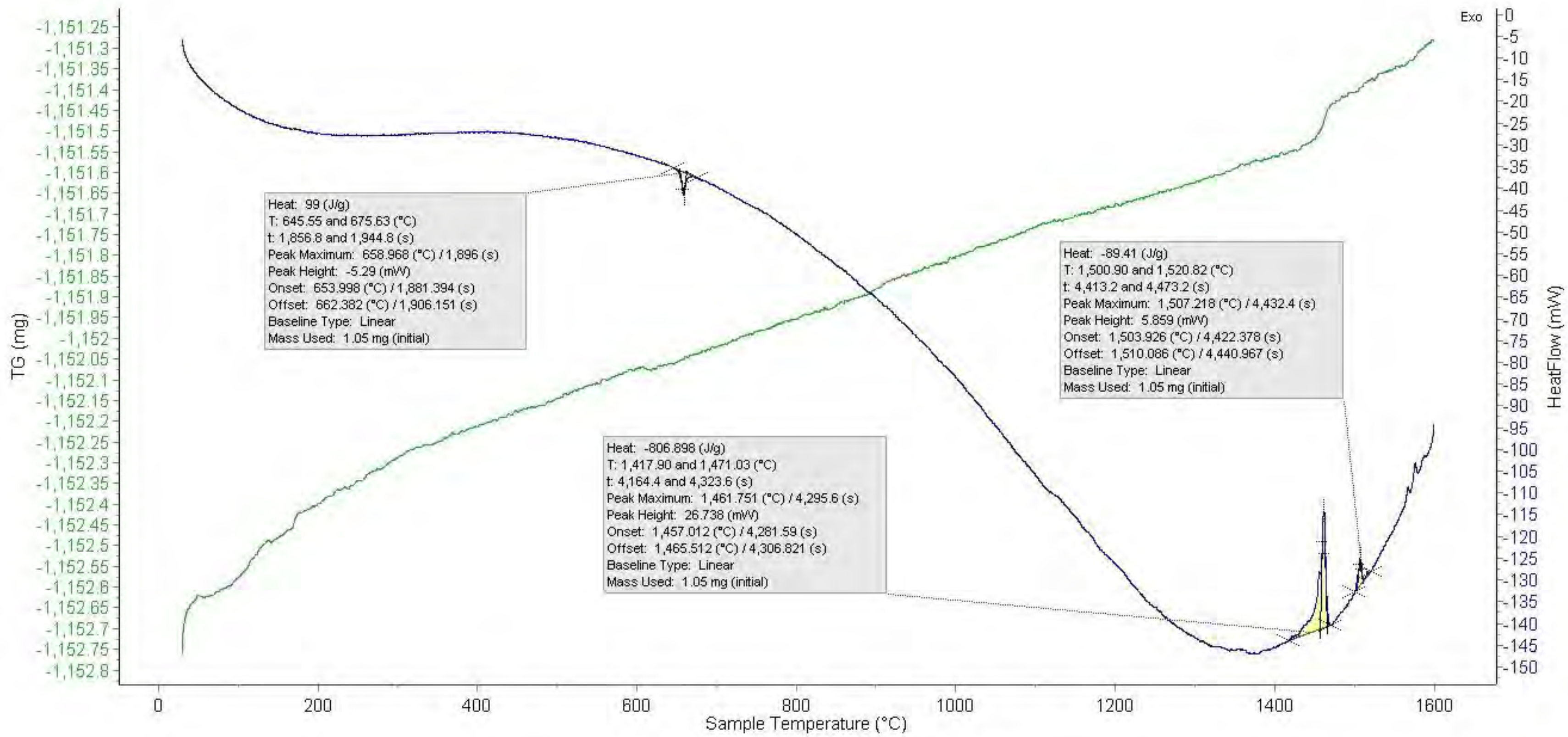


Figure C7: High-Temp DSC Plots for Mix ID LS #7 – Medium Al - Fine MnO_2, Trial 1

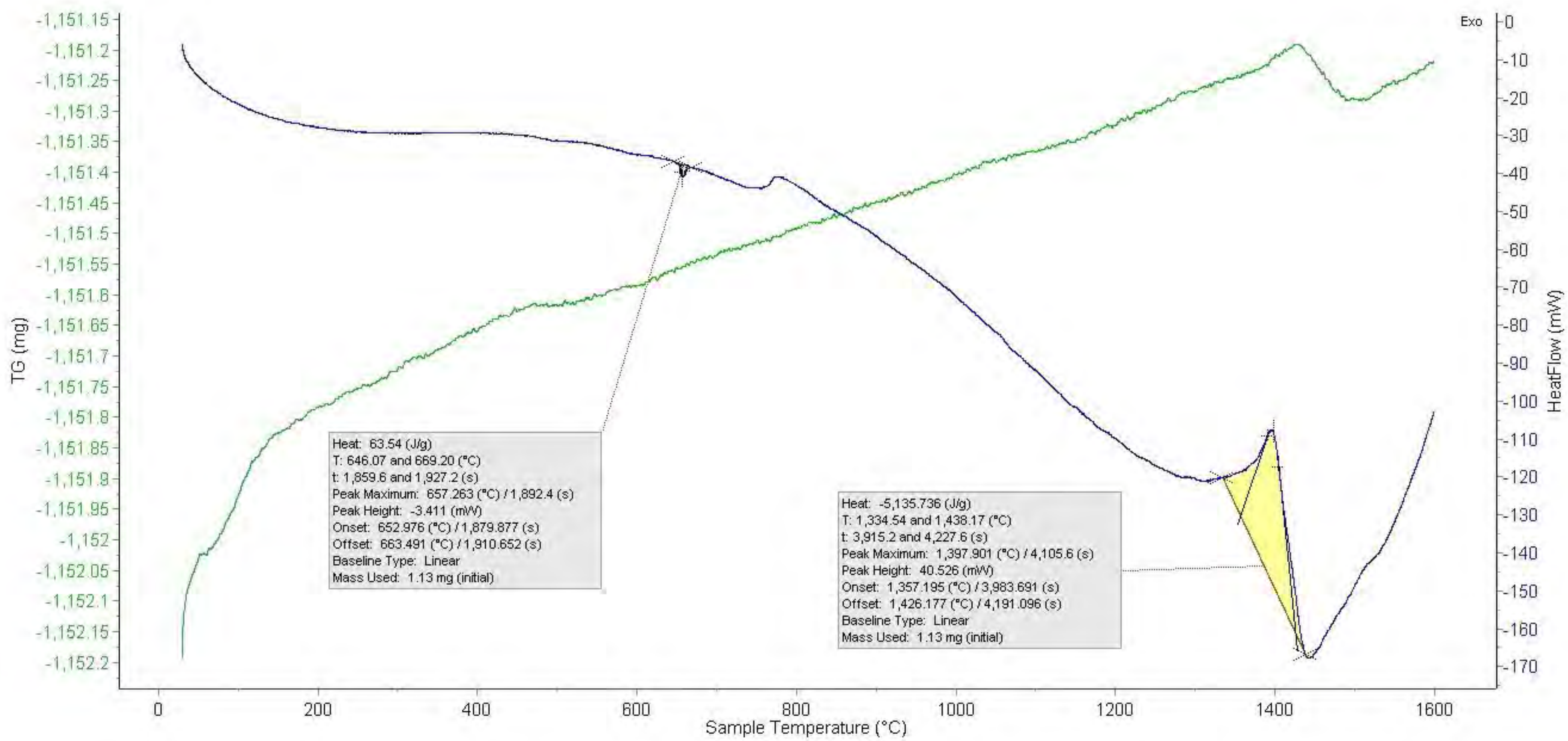


Figure C8: High-Temp DSC Plots for Mix ID LS #7 – Medium Al - Fine MnO_2, Trial 2

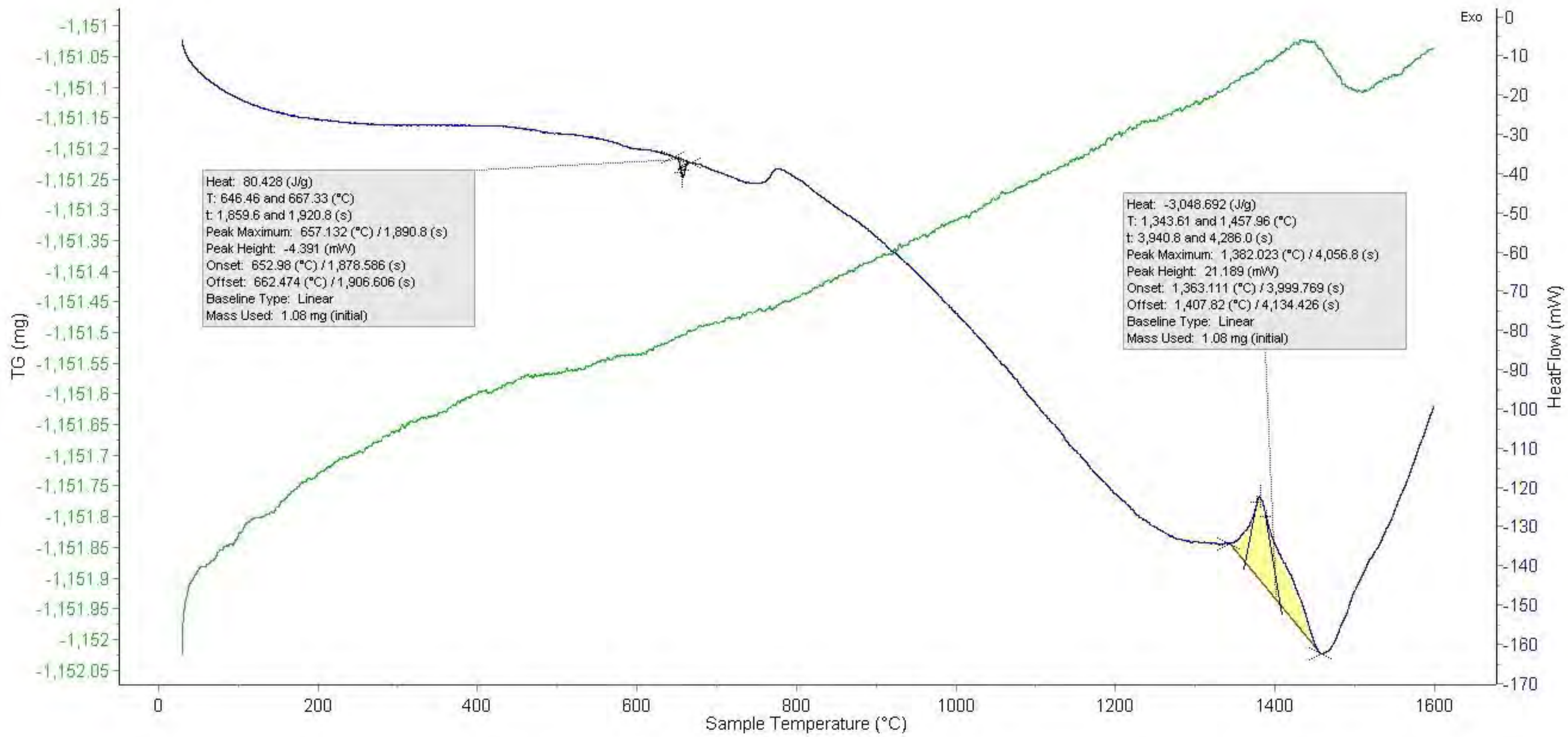


Figure C9: High-Temp DSC Plots for Mix ID LS #7 – Medium Al - Medium MnO_2, Trial 1

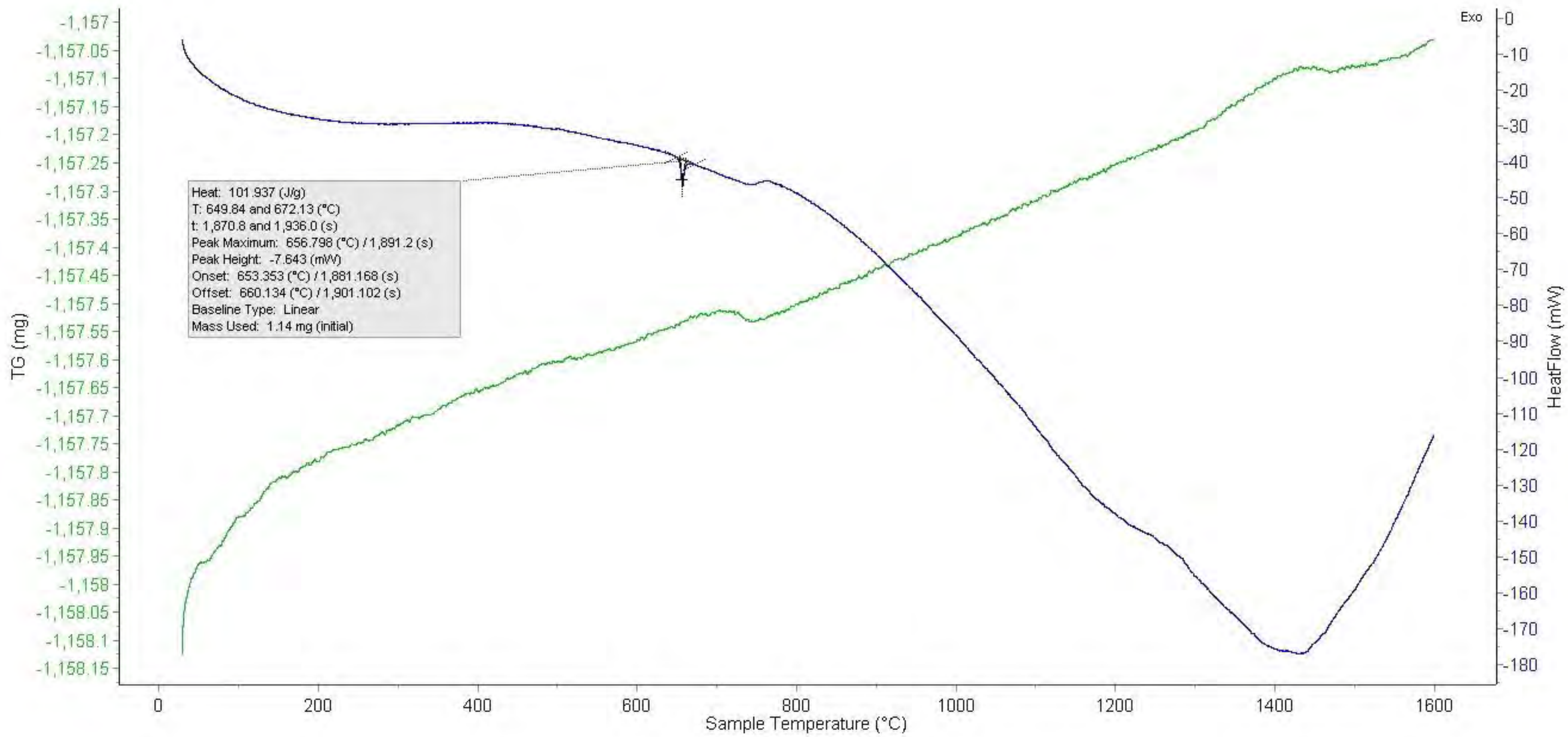


Figure C10: High-Temp DSC Plots for Mix ID LS #7 – Medium Al - Medium MnO_2, Trial 2

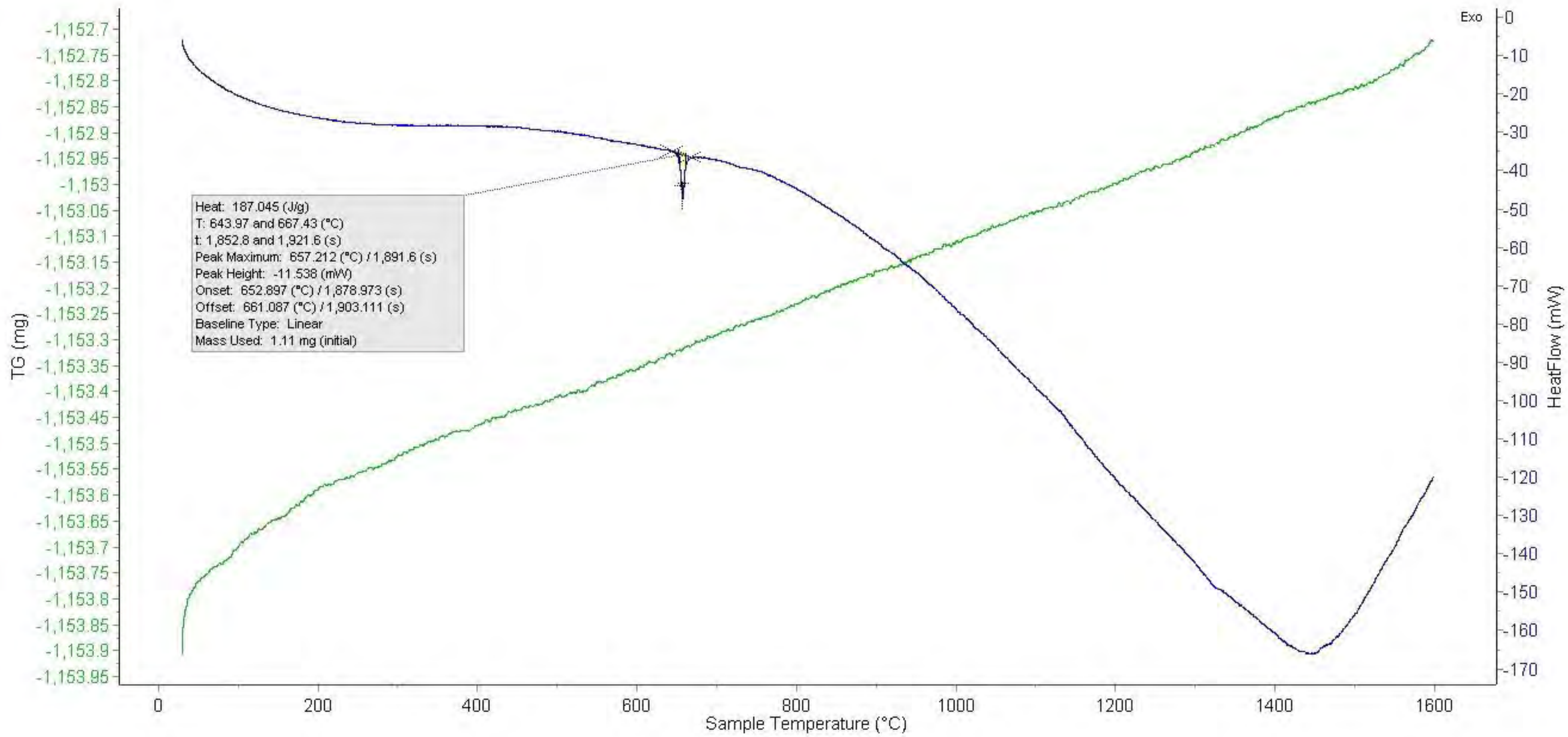


Figure C11: High-Temp DSC Plots for Mix ID LS #7 – Medium Al - Coarse MnO_2, Trial 1

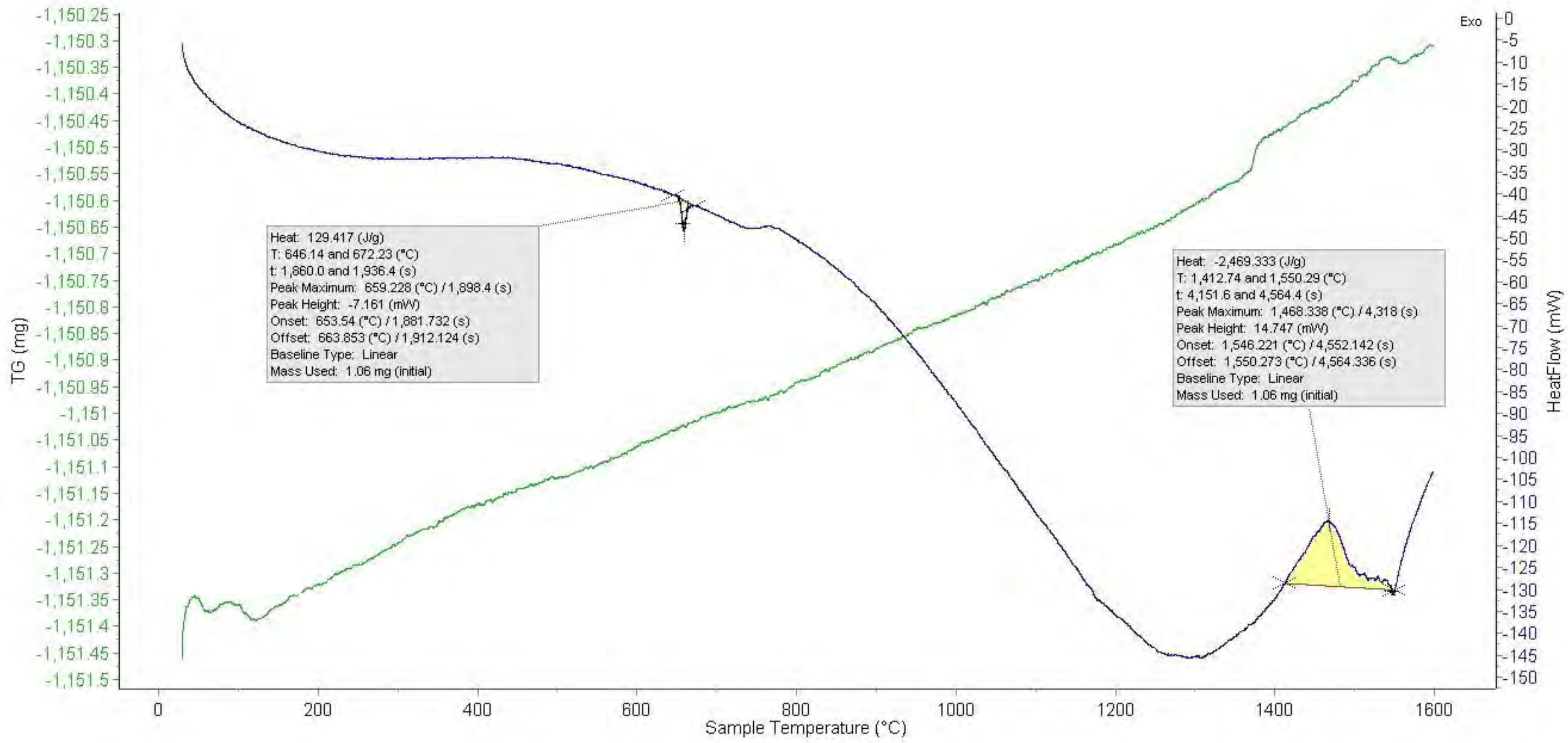


Figure C12: High-Temp DSC Plots for Mix ID LS #7 – Medium Al - Coarse MnO_2, Trial 2

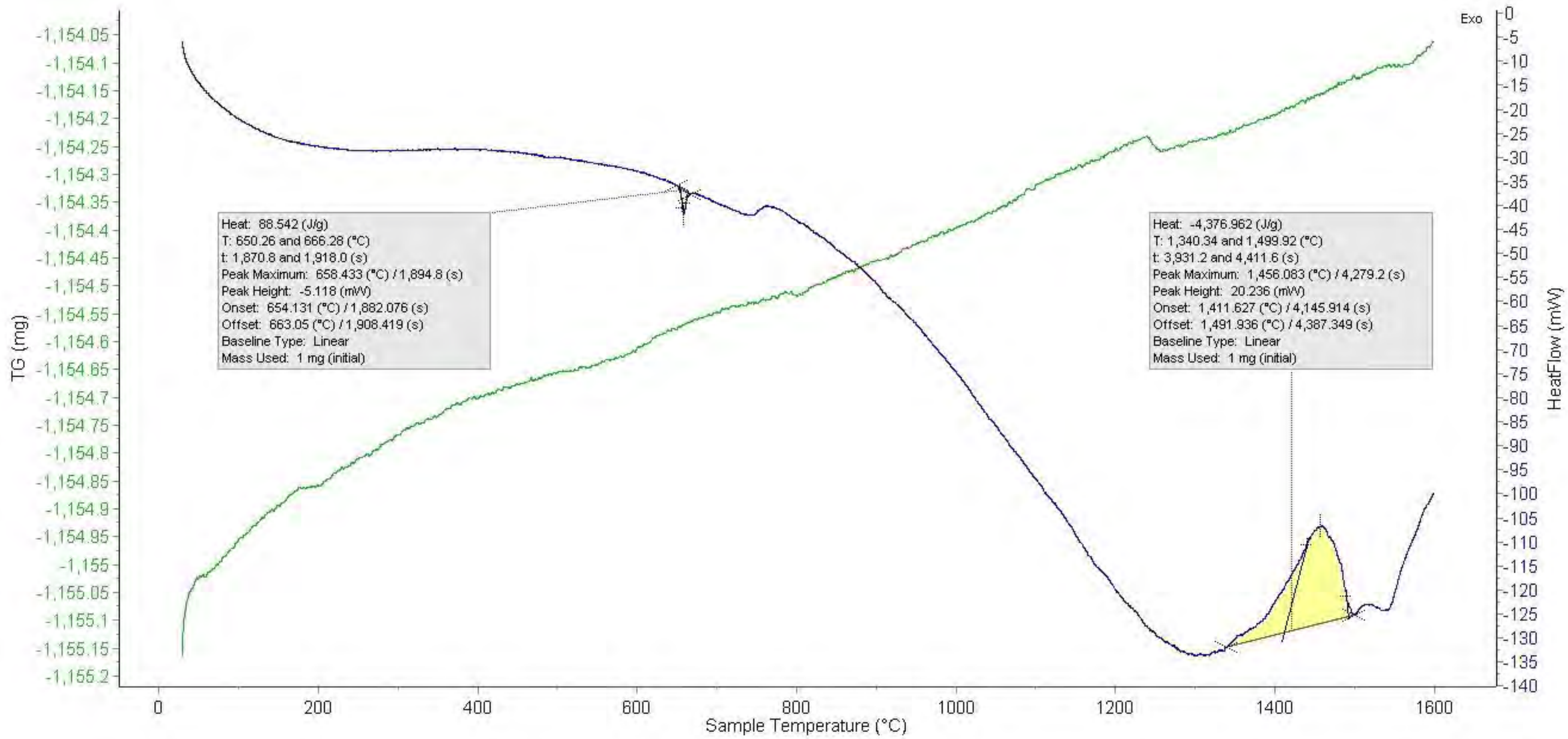


Figure C13: High-Temp DSC Plots for Mix ID LS #7 – Coarse Al - Fine MnO_2, Trial 1

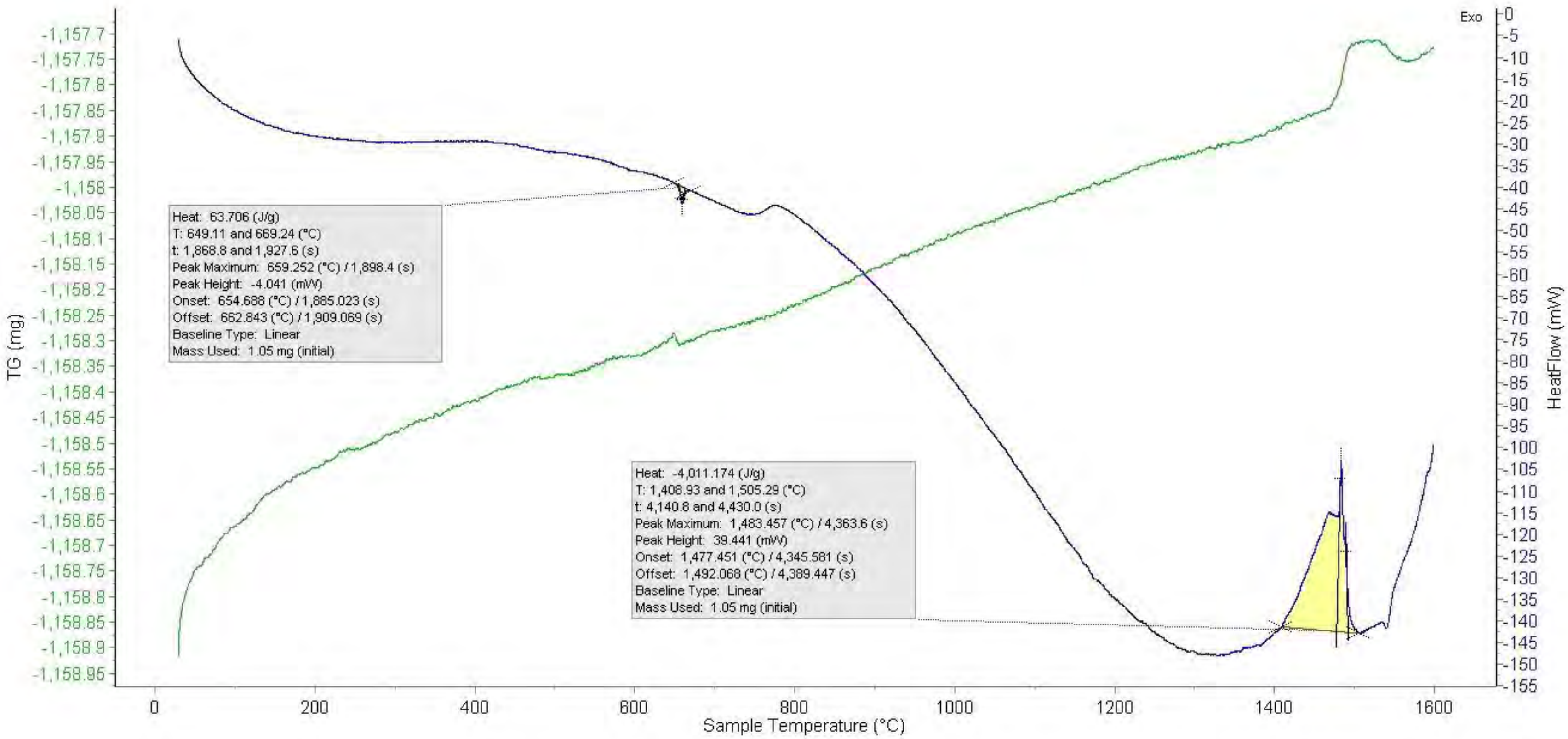


Figure C14: High-Temp DSC Plots for Mix ID LS #7 – Coarse Al - Fine MnO_2, Trial 2

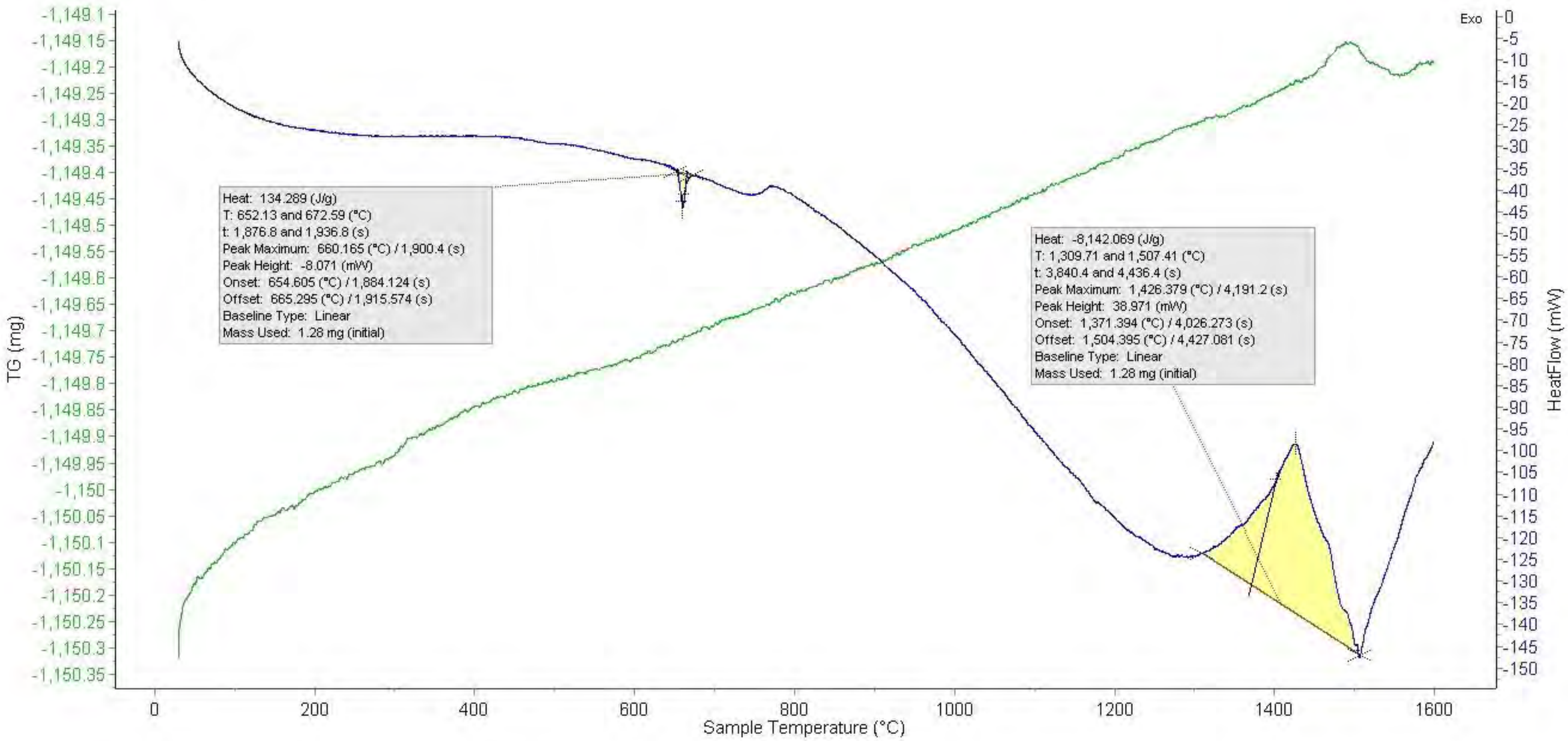


Figure C15: High-Temp DSC Plots for Mix ID LS #7 – Coarse Al - Medium MnO_2, Trial 1

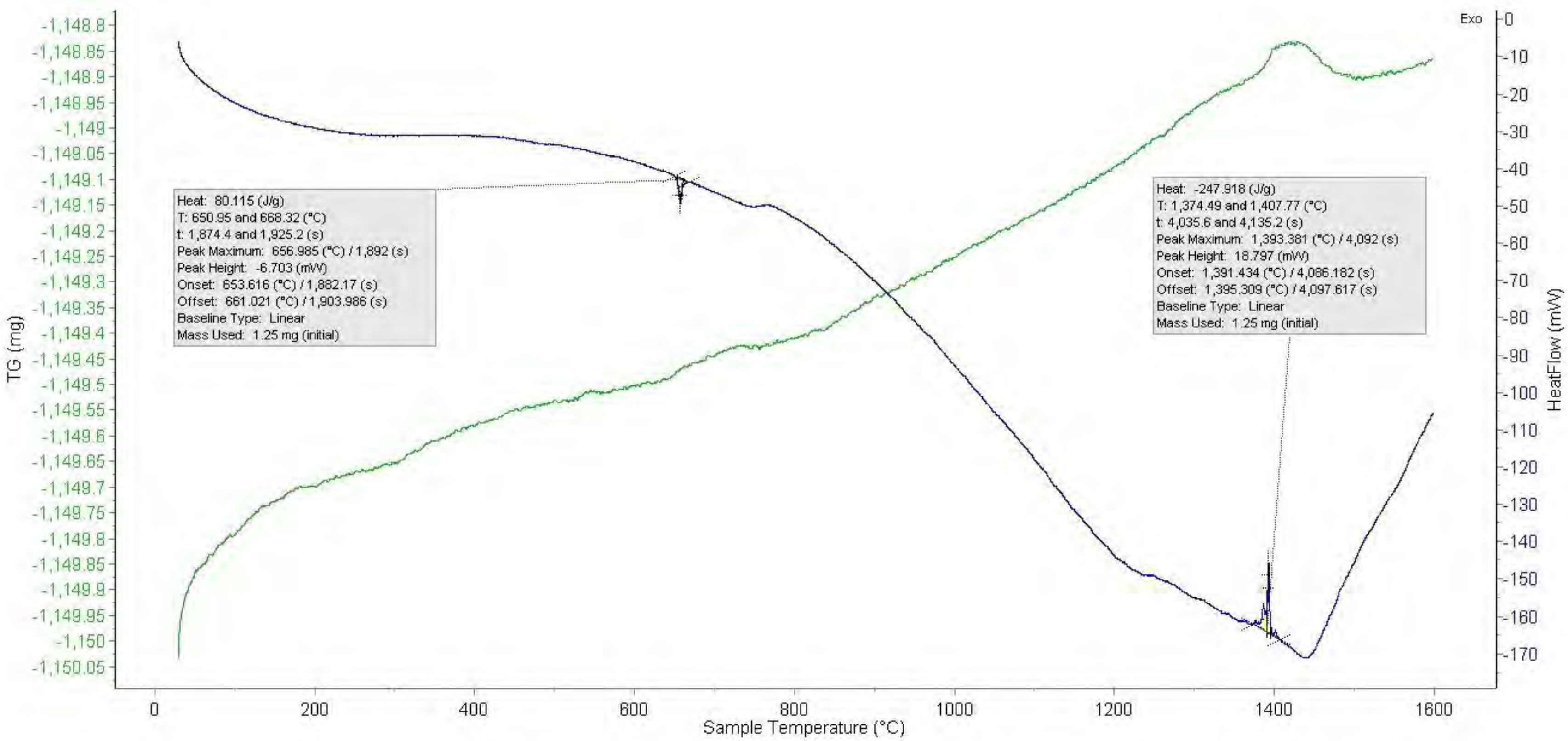


Figure C16: High-Temp DSC Plots for Mix ID LS #7 – Coarse Al - Medium MnO_2, Trial 2

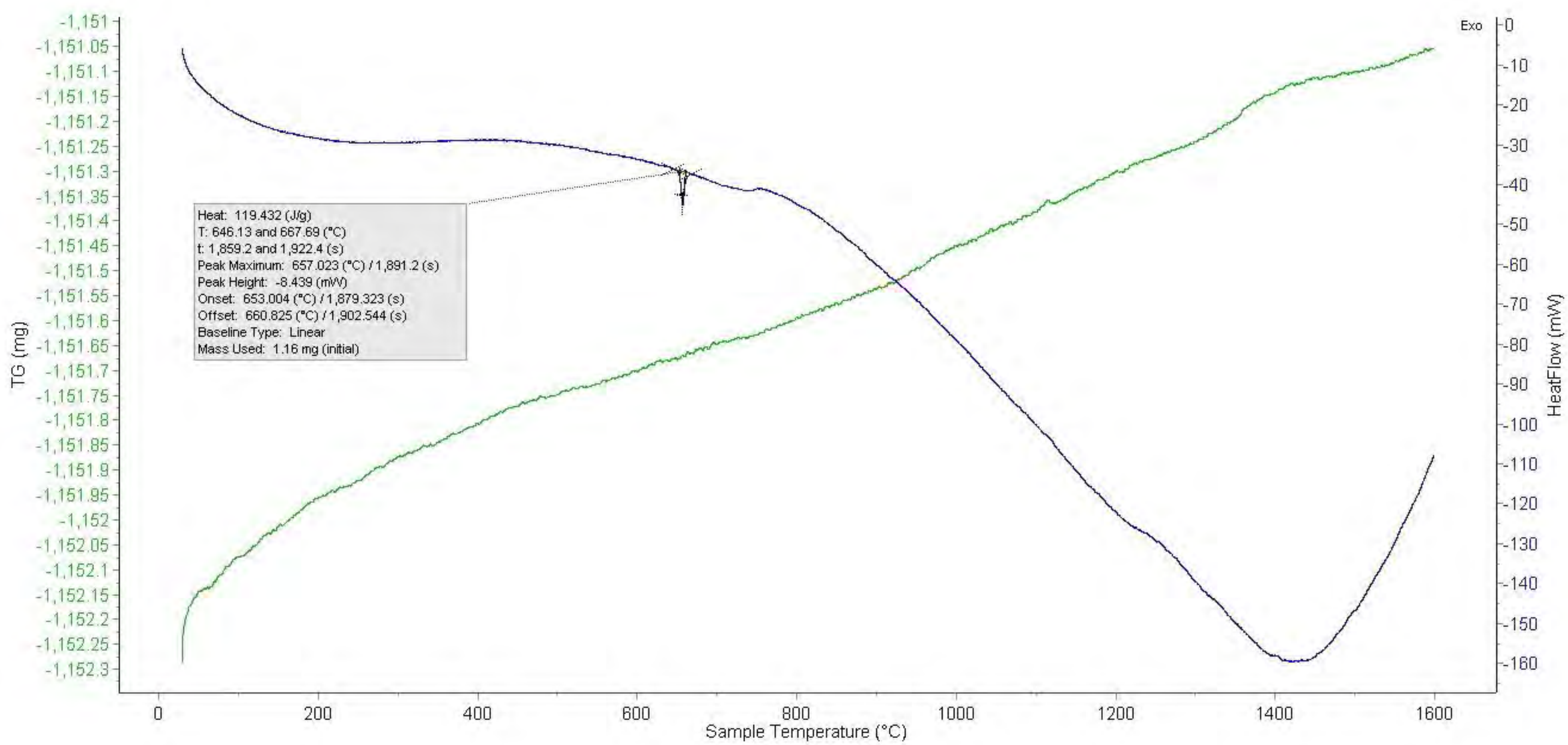


Figure C17: High-Temp DSC Plots for Mix ID LS #7 – Coarse Al - Coarse MnO_2, Trial 1

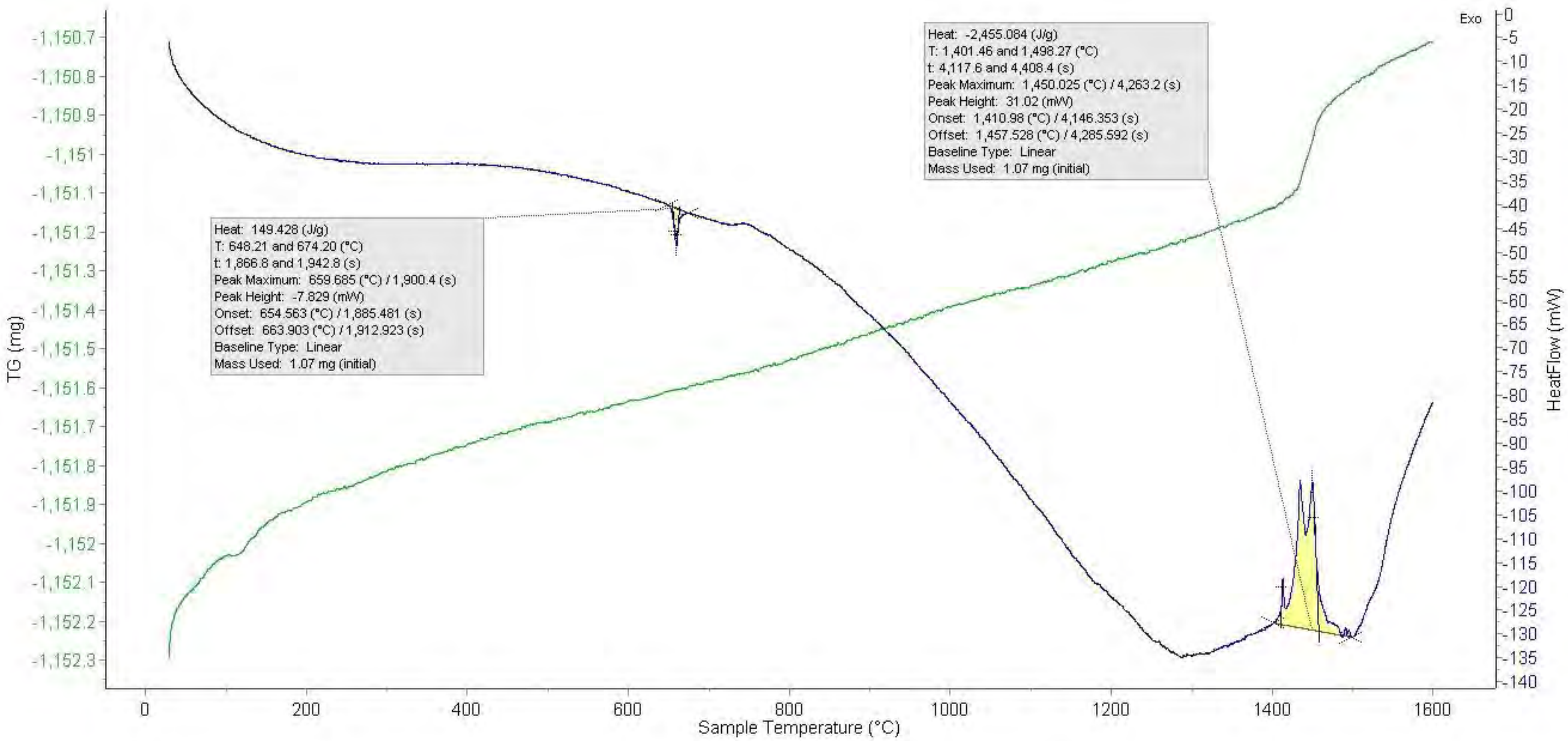


Figure C18: High-Temp DSC Plots for Mix ID LS #7 – Coarse Al - Coarse MnO_2, Trial 2

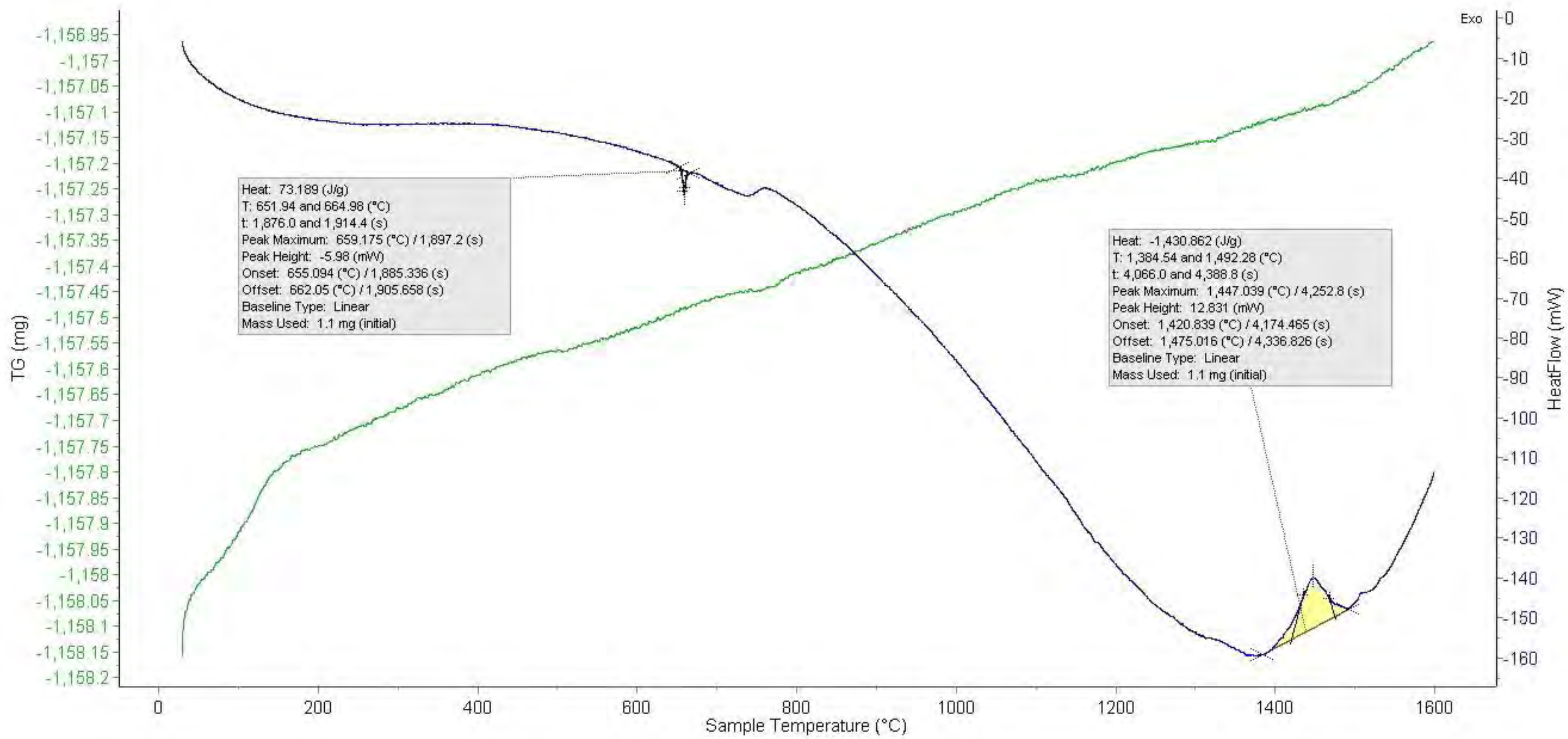


Figure C19: High-Temp DSC Plots for Mix ID LS #8 – Fine Mg & Al - Fine MoO_3 & CuO, Trial 1

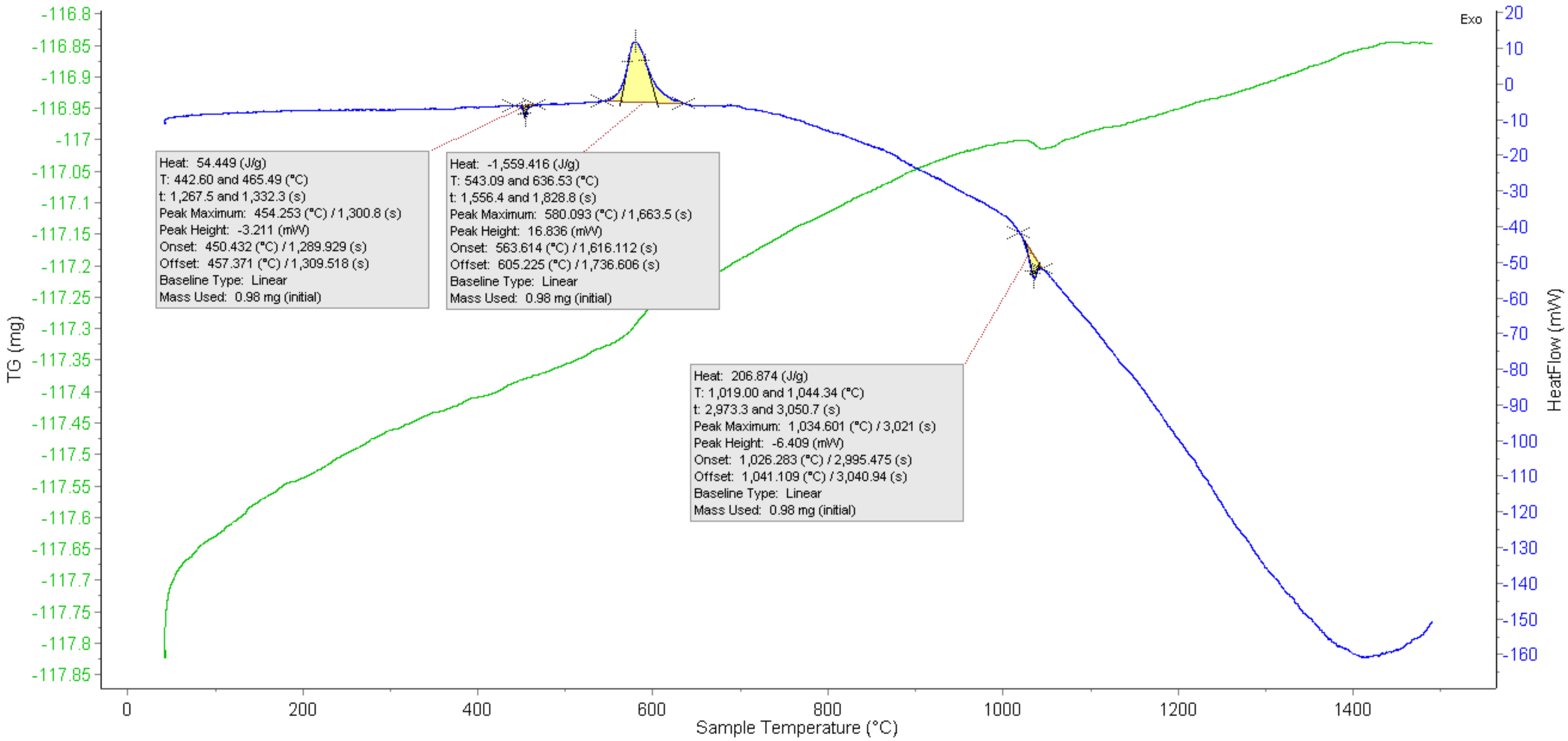


Figure C20: High-Temp DSC Plots for Mix ID LS #8 – Fine Mg & Al - Fine MoO_3 & CuO, Trial 2

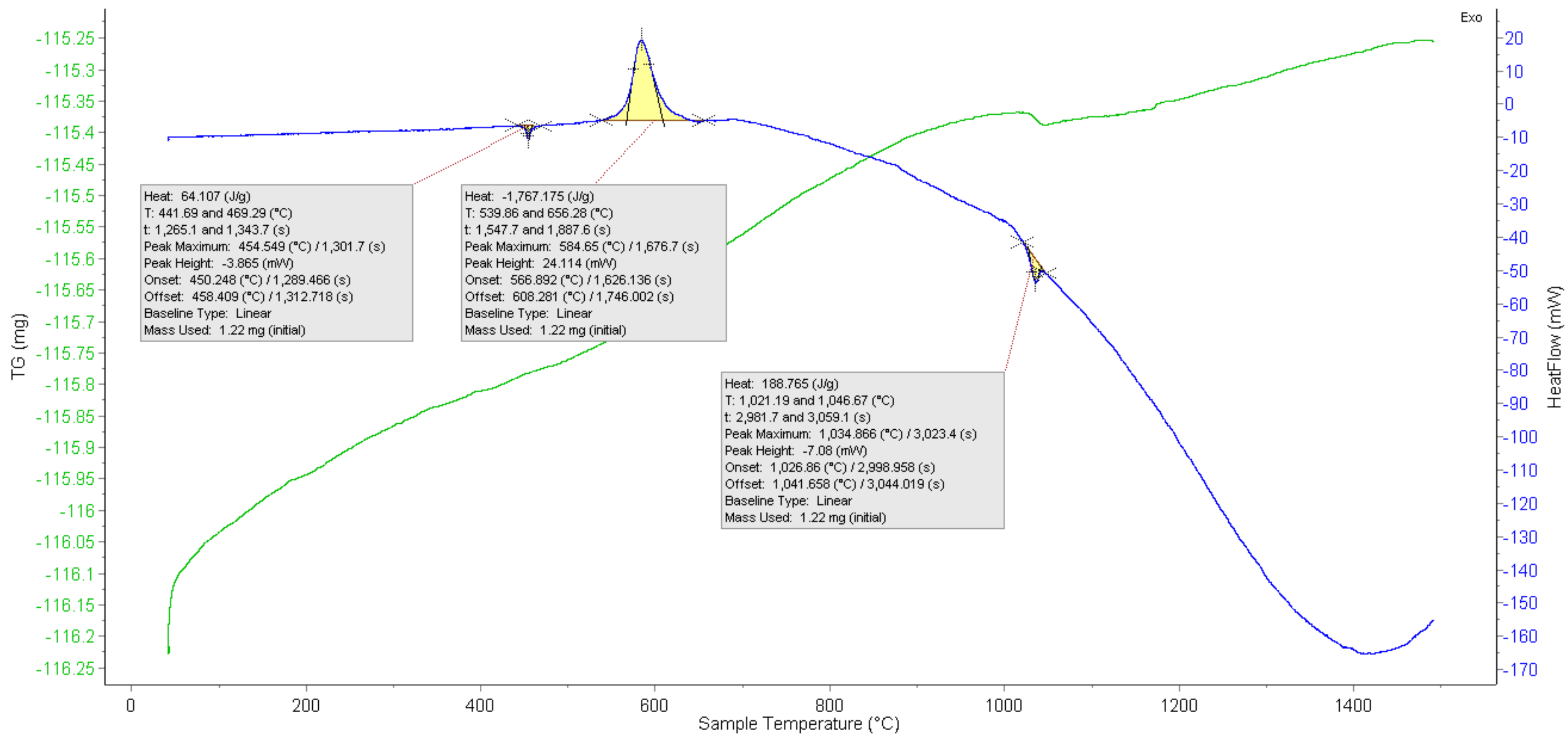


Figure C21: High-Temp DSC Plots for Mix ID LS #8 – Fine Mg & Al - Medium MoO_3 & CuO, Trial 1

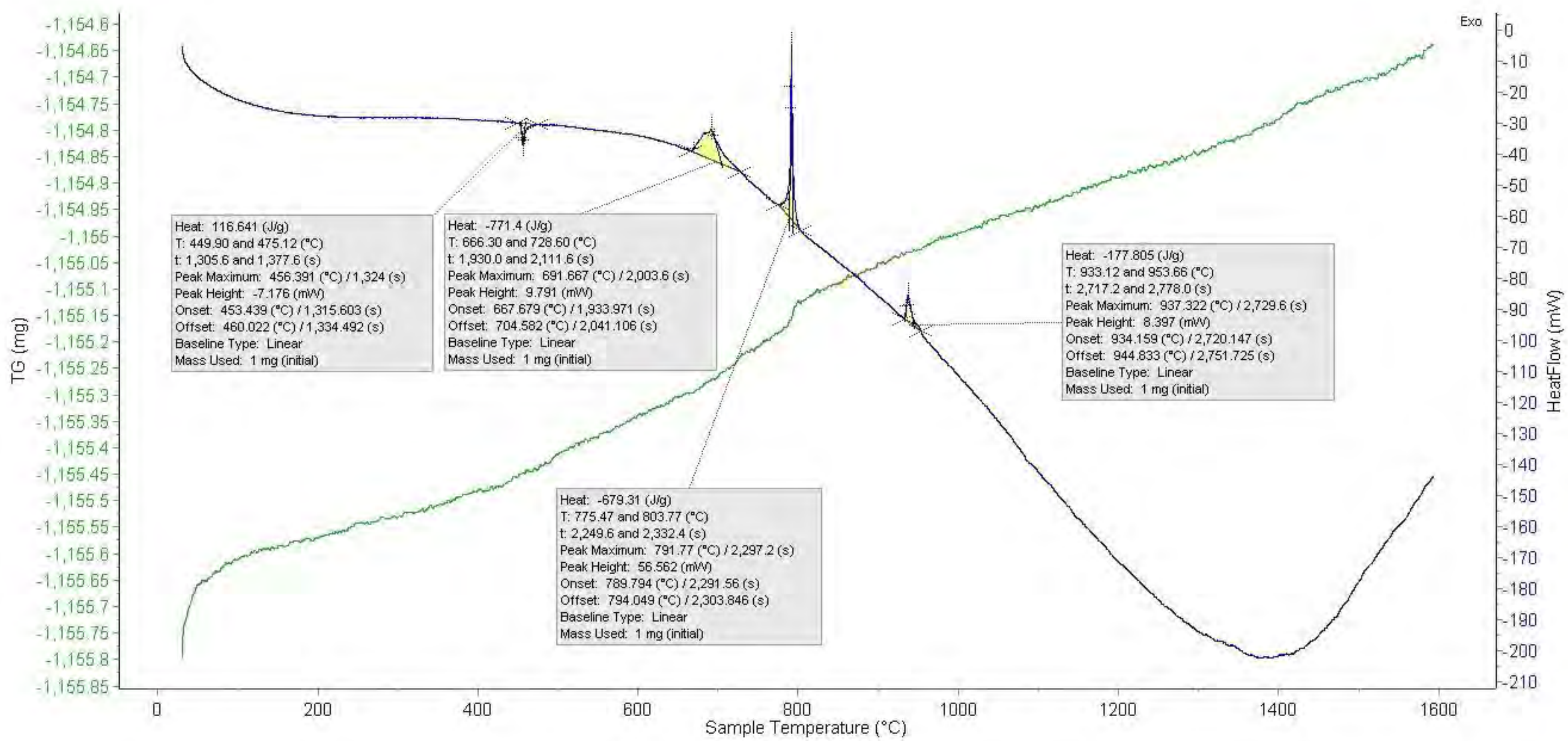


Figure C22: High-Temp DSC Plots for Mix ID LS #8 – Fine Mg & Al - Medium MoO_3 & CuO, Trial 2

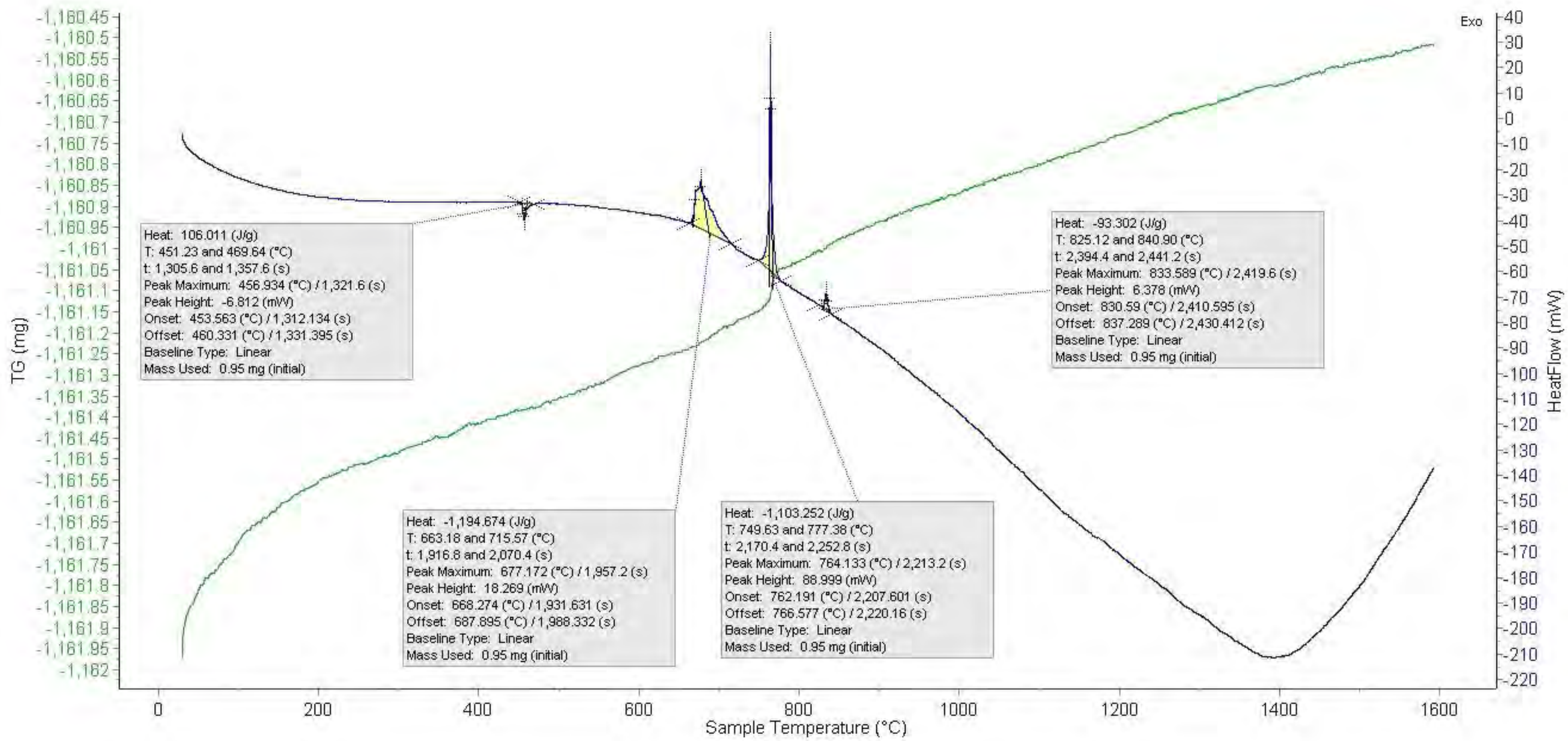


Figure C23: High-Temp DSC Plots for Mix ID LS #8 – Fine Mg & Al - Coarse MoO_3 & CuO, Trial 1

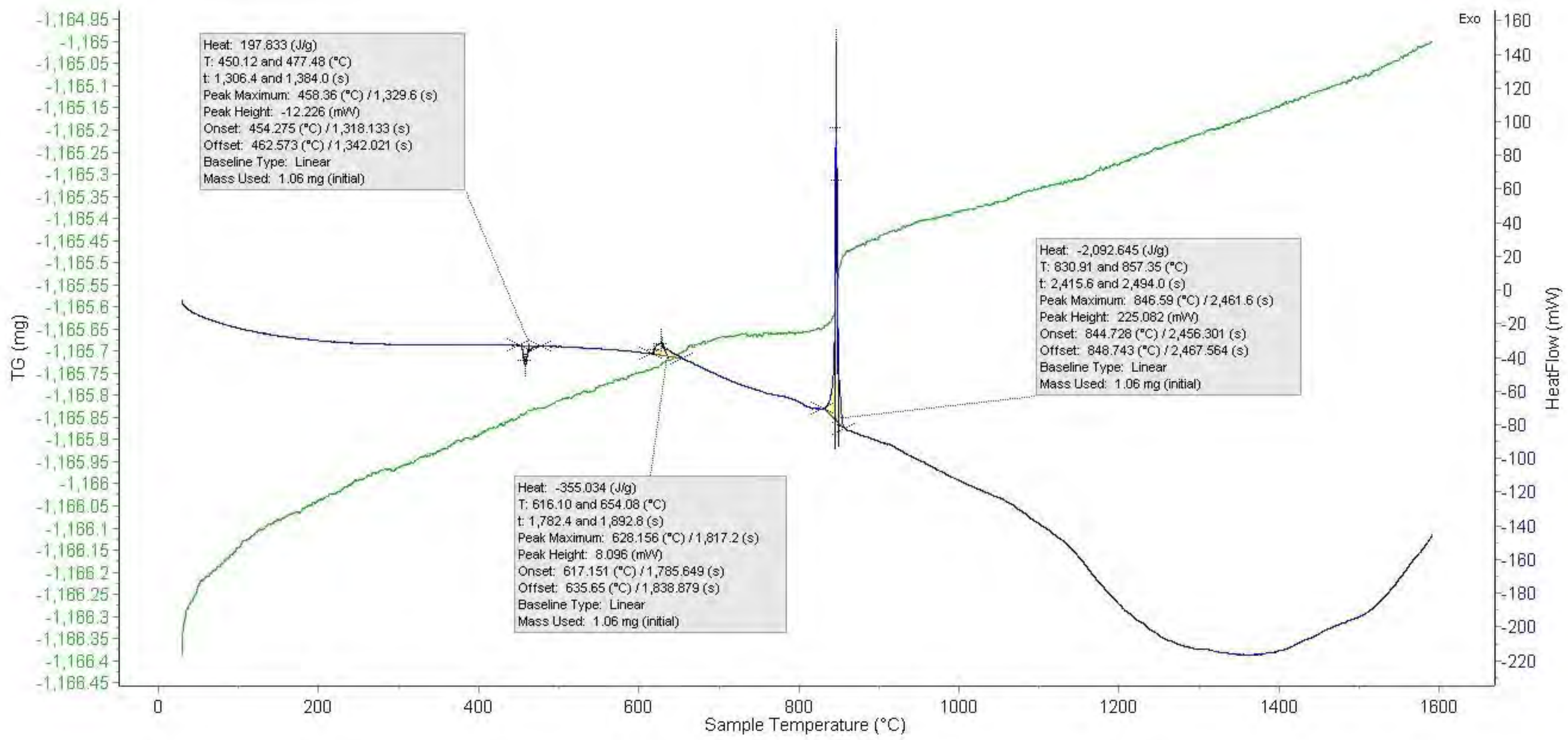


Figure C24: High-Temp DSC Plots for Mix ID LS #8 – Fine Mg & Al - Coarse MoO_3 & CuO, Trial 2

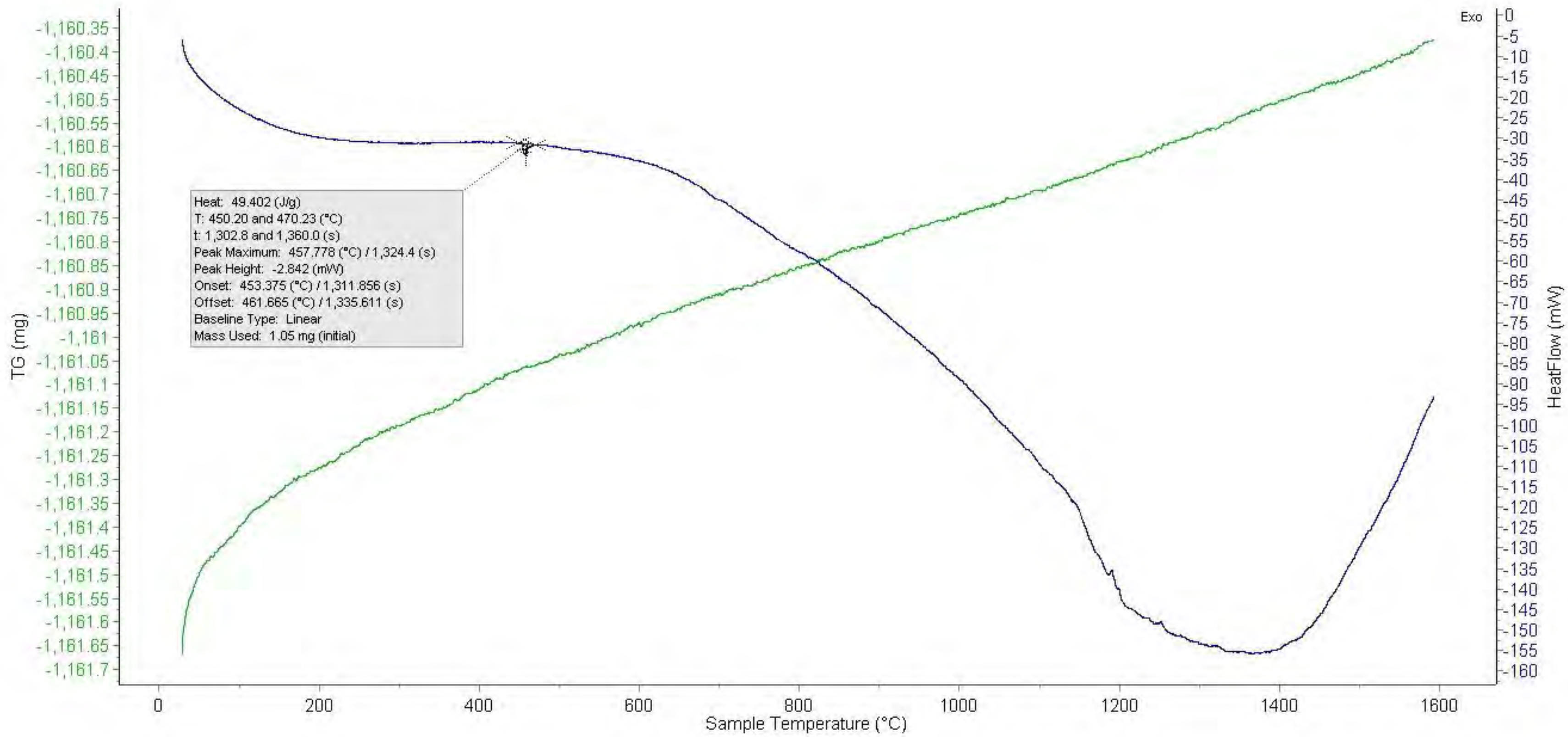


Figure C25: High-Temp DSC Plots for Mix ID LS #8 – Medium Mg & Al - Fine MoO_3 & CuO, Trial 1

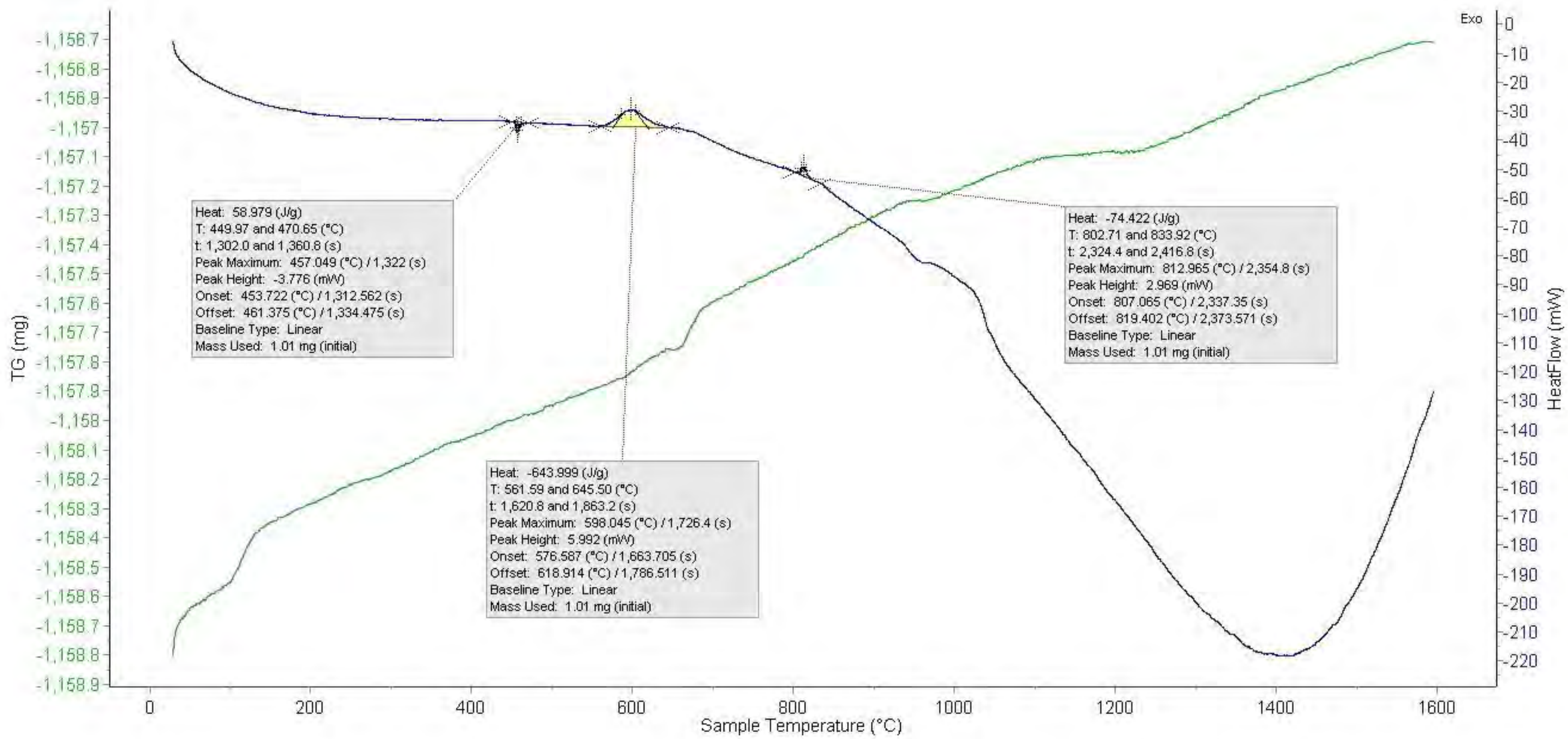


Figure C26: High-Temp DSC Plots for Mix ID LS #8 – Medium Mg & Al - Fine MoO_3 & CuO, Trial 2

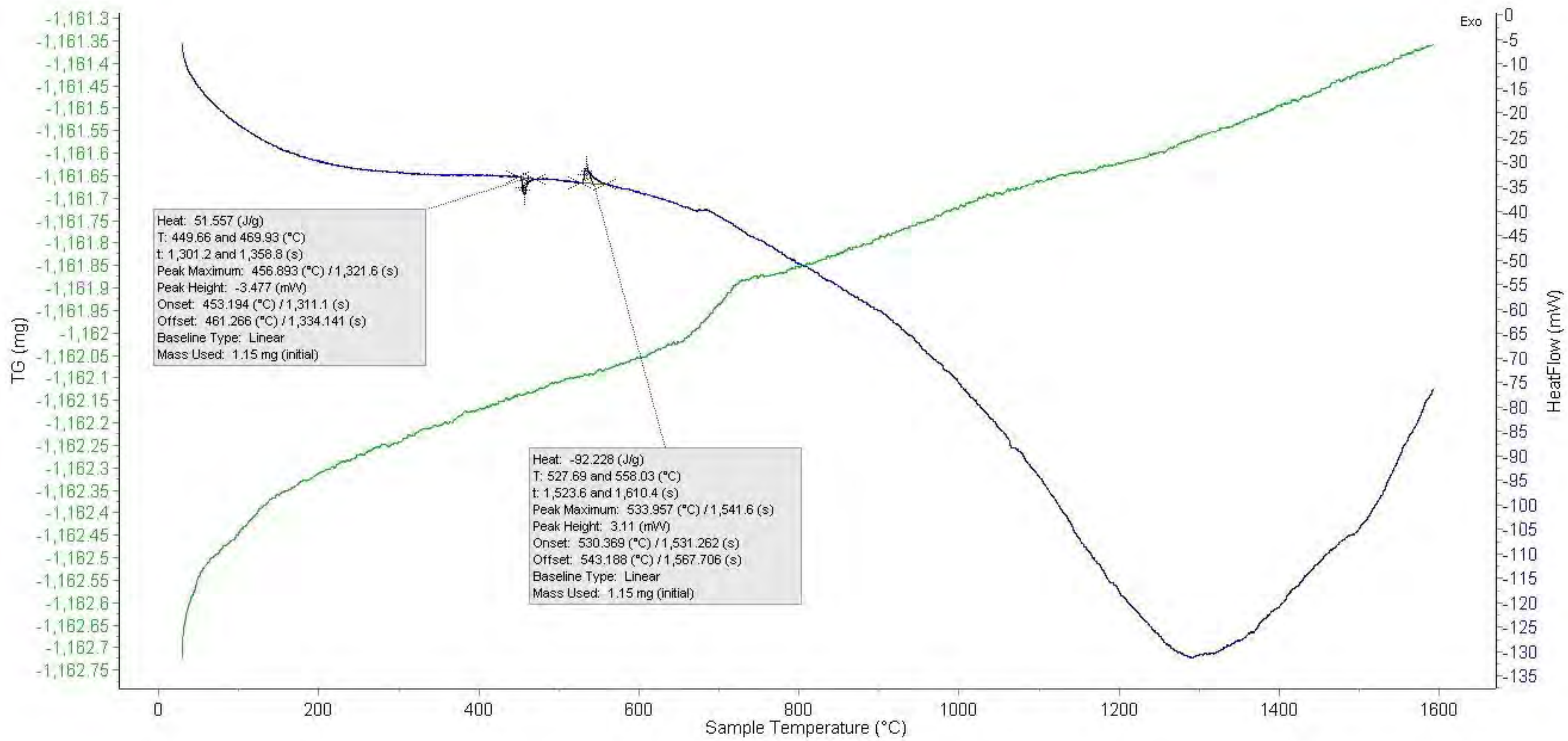


Figure C27: High-Temp DSC Plots for Mix ID LS #8 – Medium Mg & Al - Medium MoO_3 & CuO, Trial 1

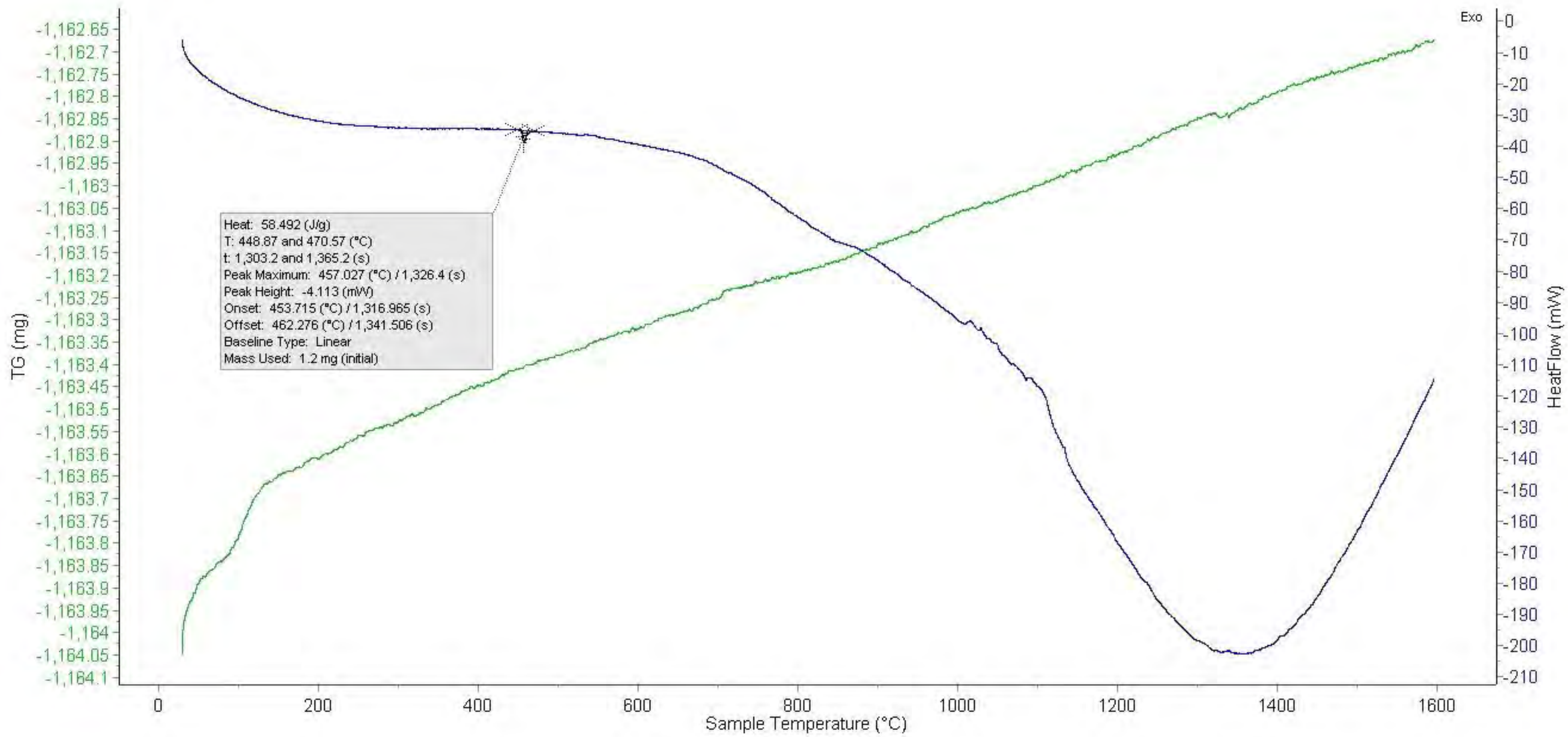


Figure C28: High-Temp DSC Plots for Mix ID LS #8 – Medium Mg & Al - Medium MoO_3 & CuO, Trial 2

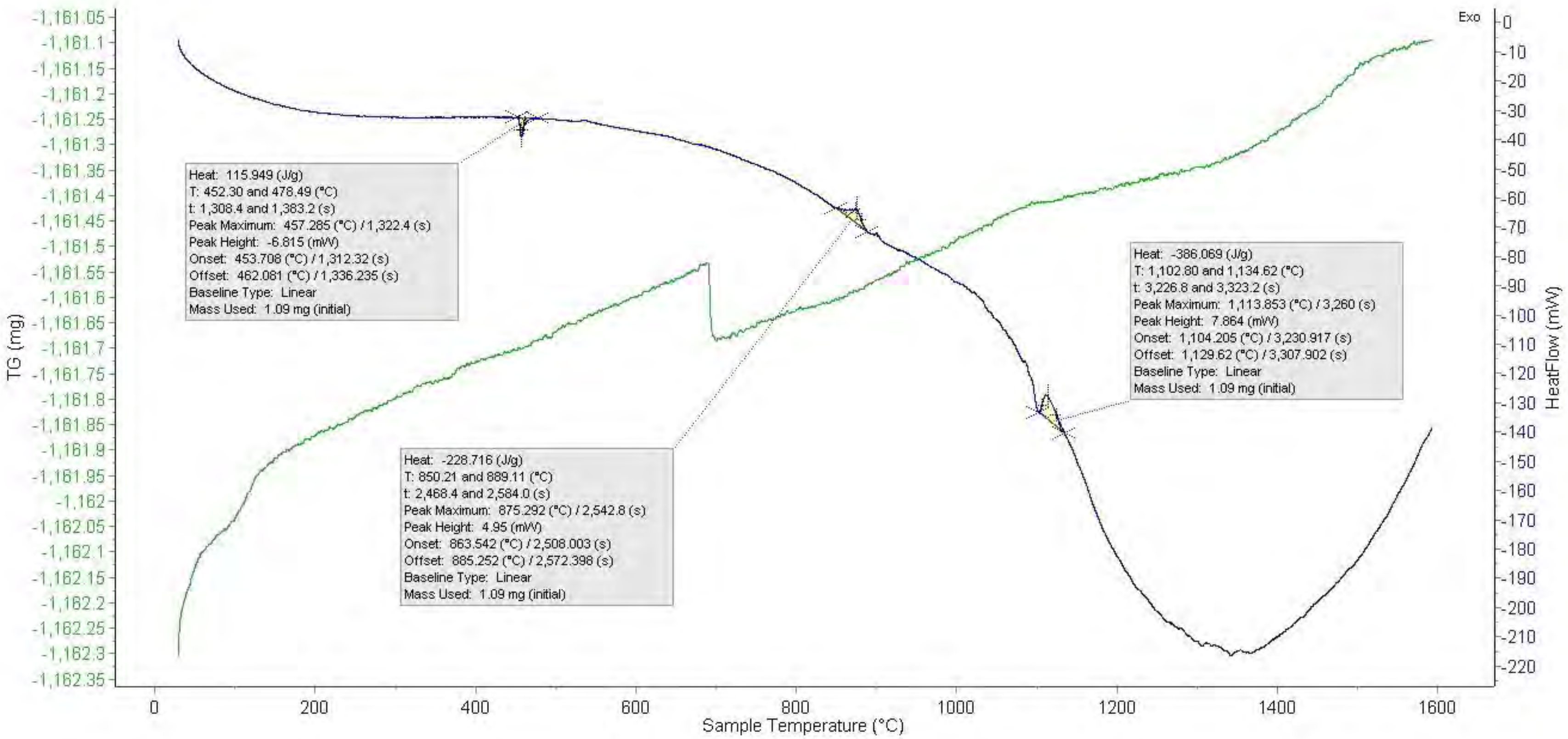


Figure C29: High-Temp DSC Plots for Mix ID LS #8 – Medium Mg & Al - Coarse MoO_3 & CuO, Trial 1

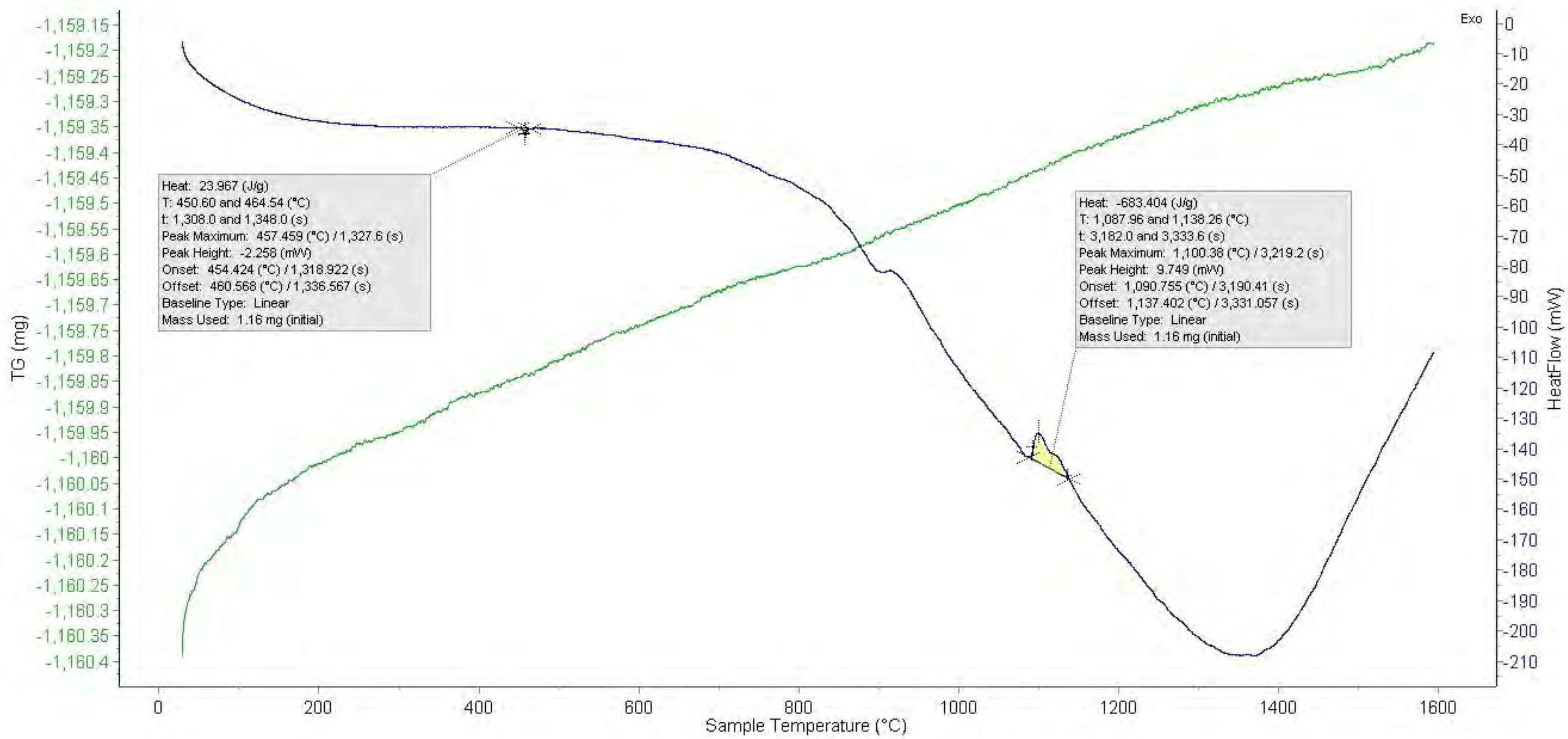


Figure C30: High-Temp DSC Plots for Mix ID LS #8 – Medium Mg & Al - Coarse MoO_3 & CuO, Trial 2

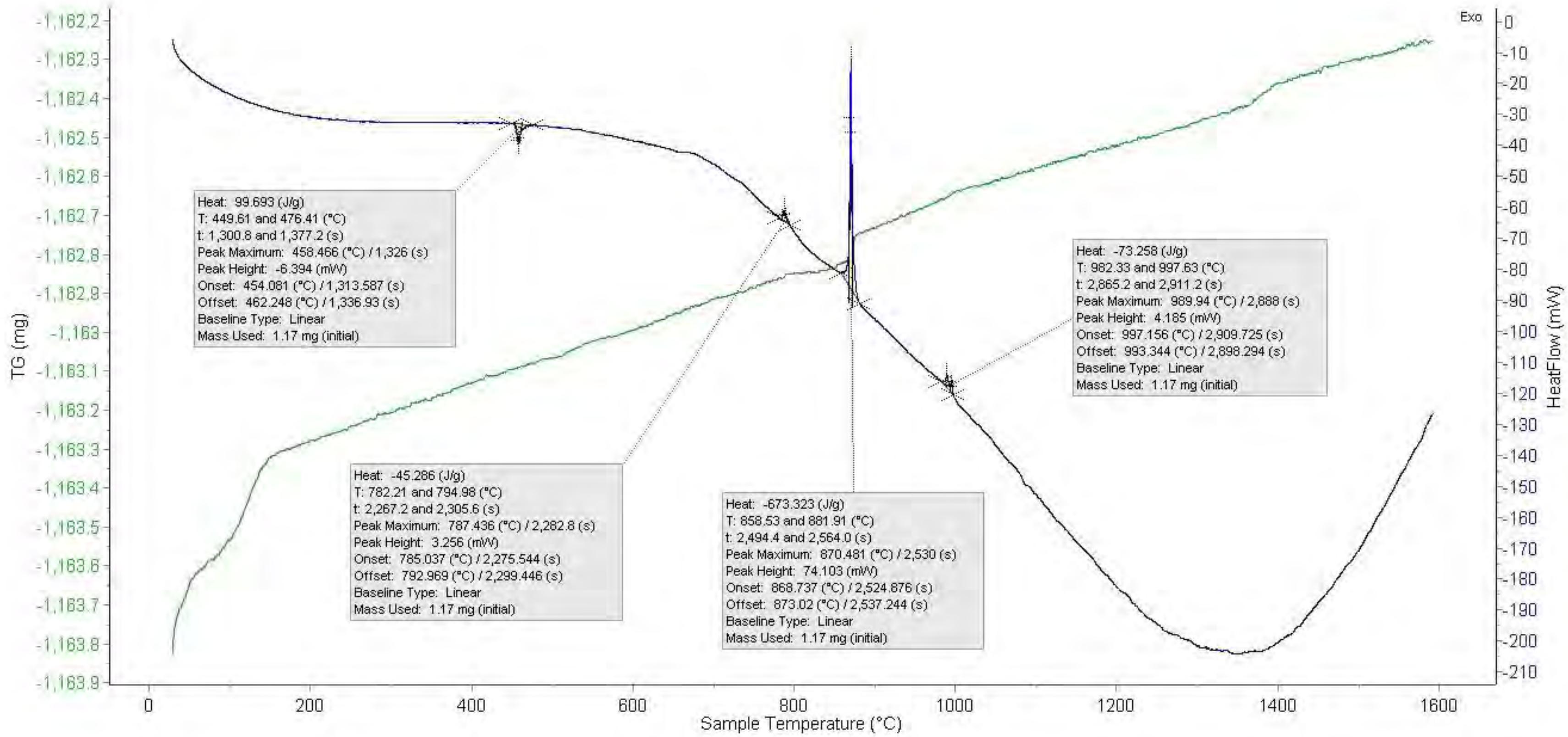


Figure C31: High-Temp DSC Plots for Mix ID LS #8 – Coarse Mg & Al - Fine MoO_3 & CuO, Trial 1

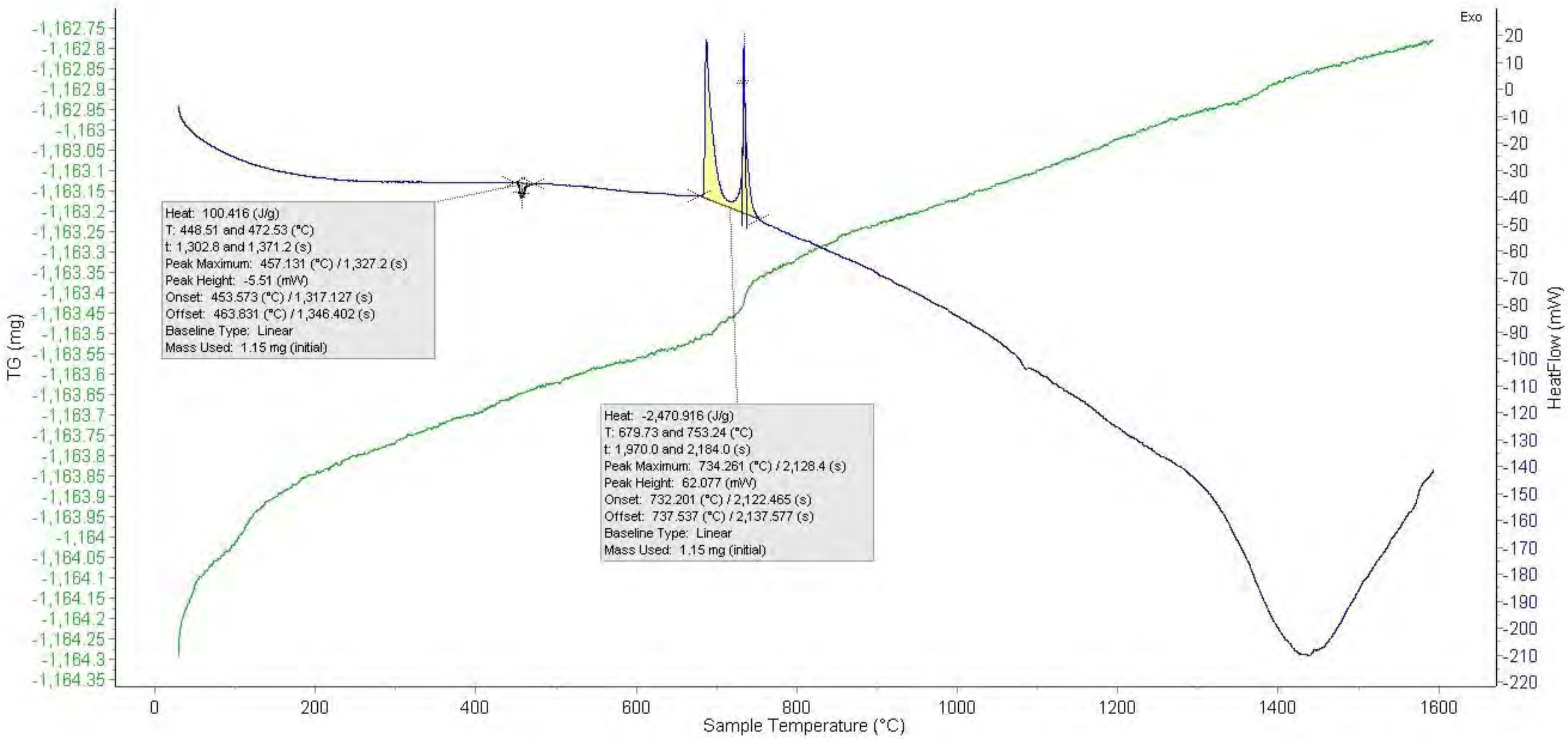


Figure C32: High-Temp DSC Plots for Mix ID LS #8 – Coarse Mg & Al - Fine MoO_3 & CuO, Trial 2

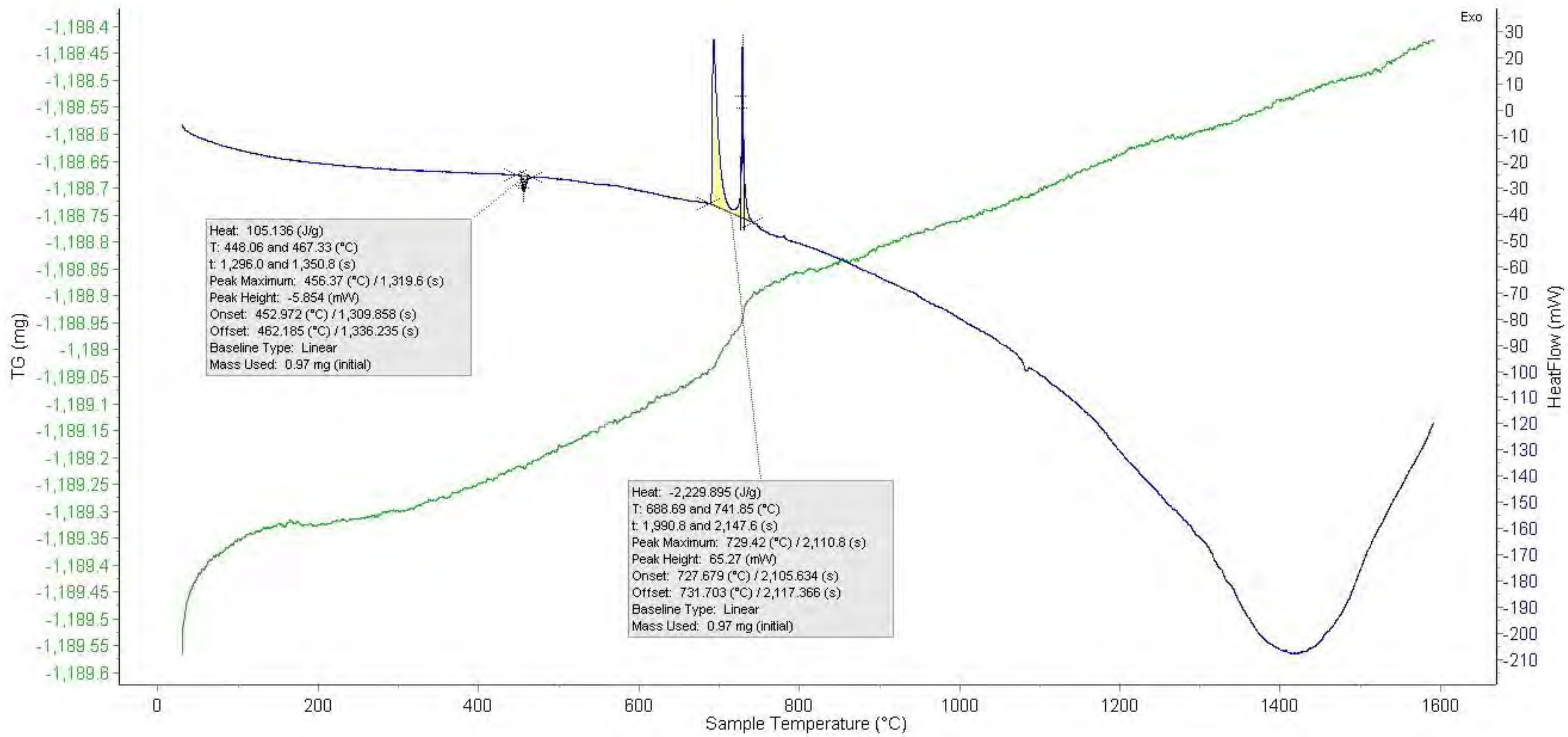


Figure C33: High-Temp DSC Plots for Mix ID LS #8 – Coarse Mg & Al - Medium MoO_3 & CuO, Trial 1

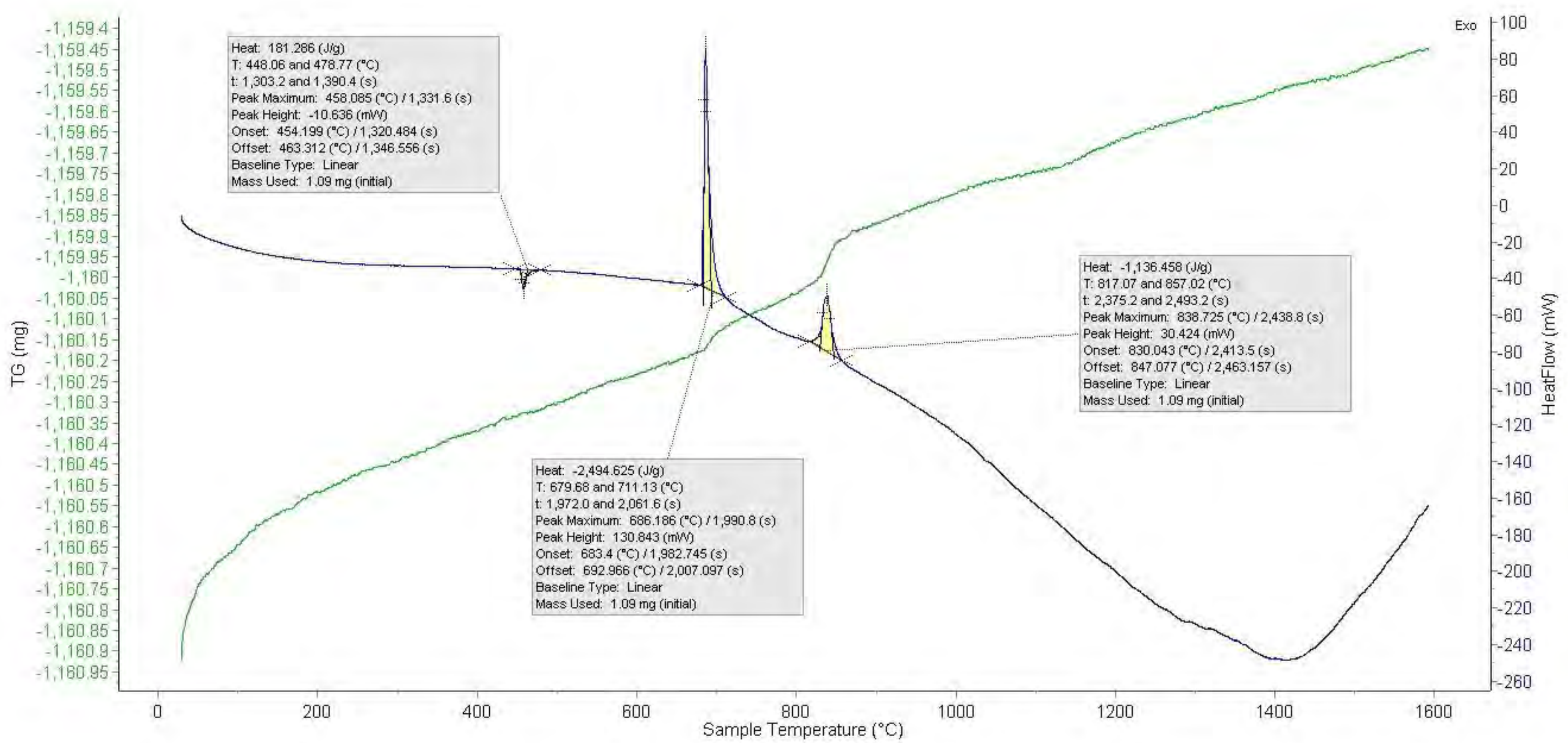


Figure C34: High-Temp DSC Plots for Mix ID LS #8 – Coarse Mg & Al - Medium MoO_3 & CuO, Trial 2

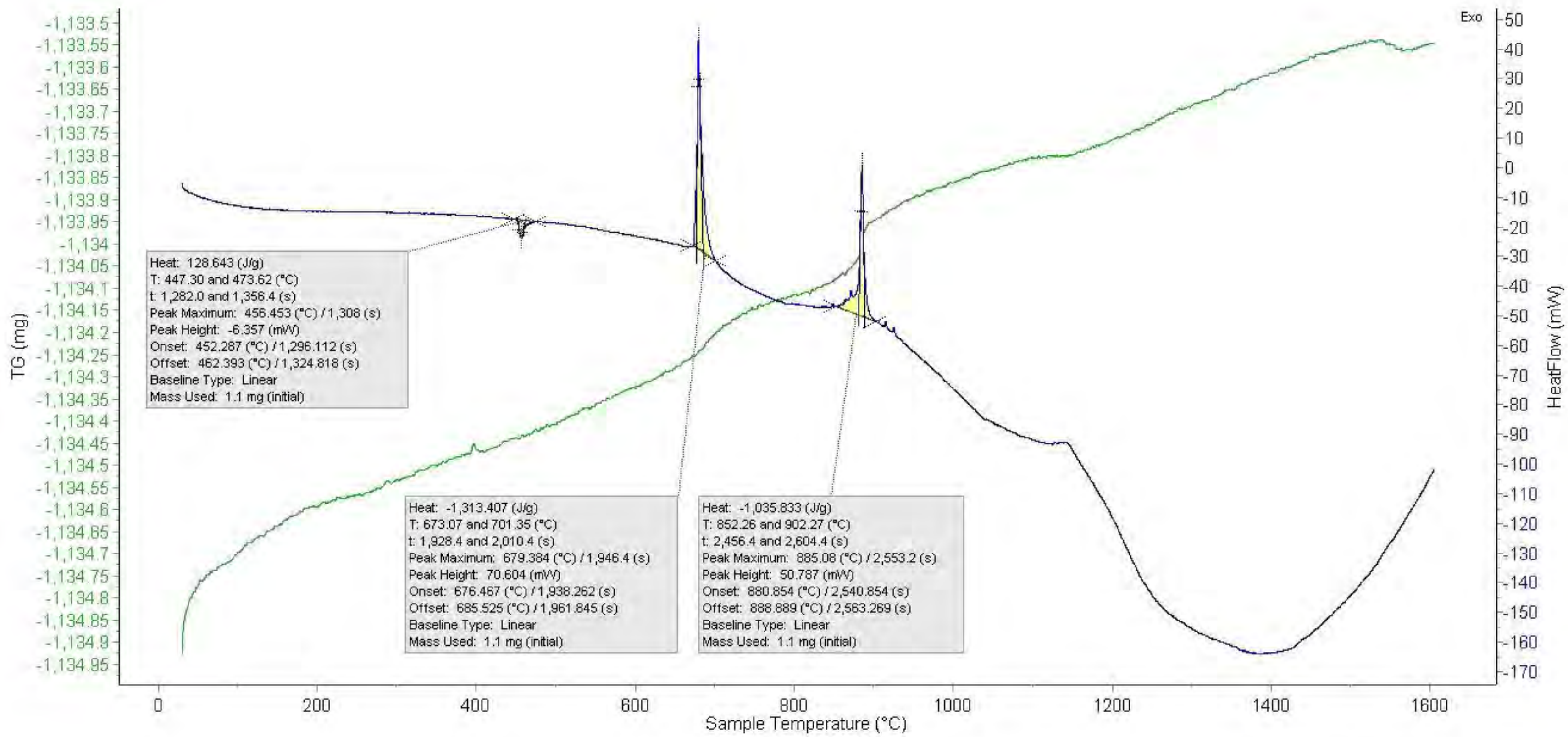


Figure C35: High-Temp DSC Plots for Mix ID LS #8 – Coarse Mg & Al - Coarse MoO_3 & CuO, Trial 1

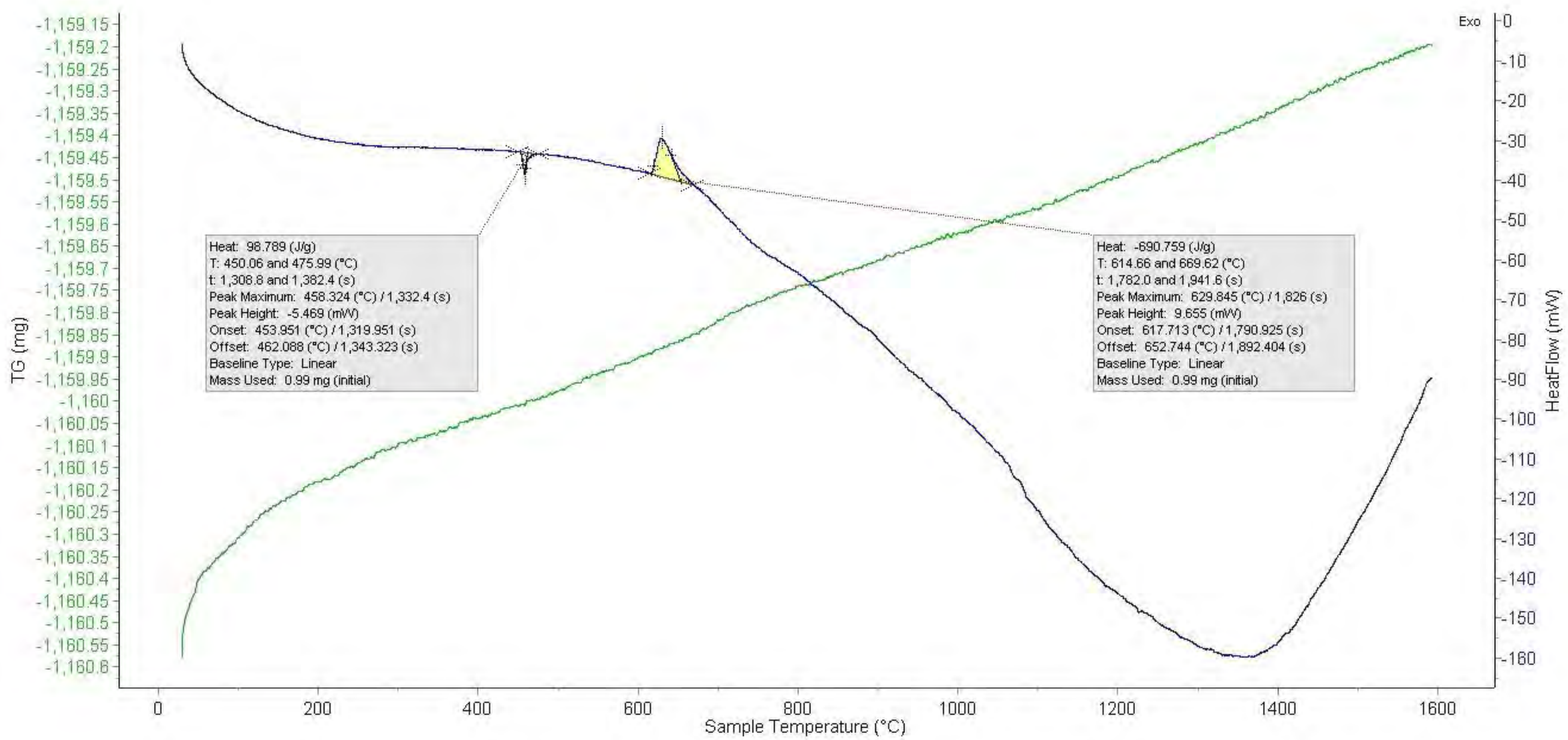


Figure C36: High-Temp DSC Plots for Mix ID LS #8 – Coarse Mg & Al - Coarse MoO_3 & CuO, Trial 2

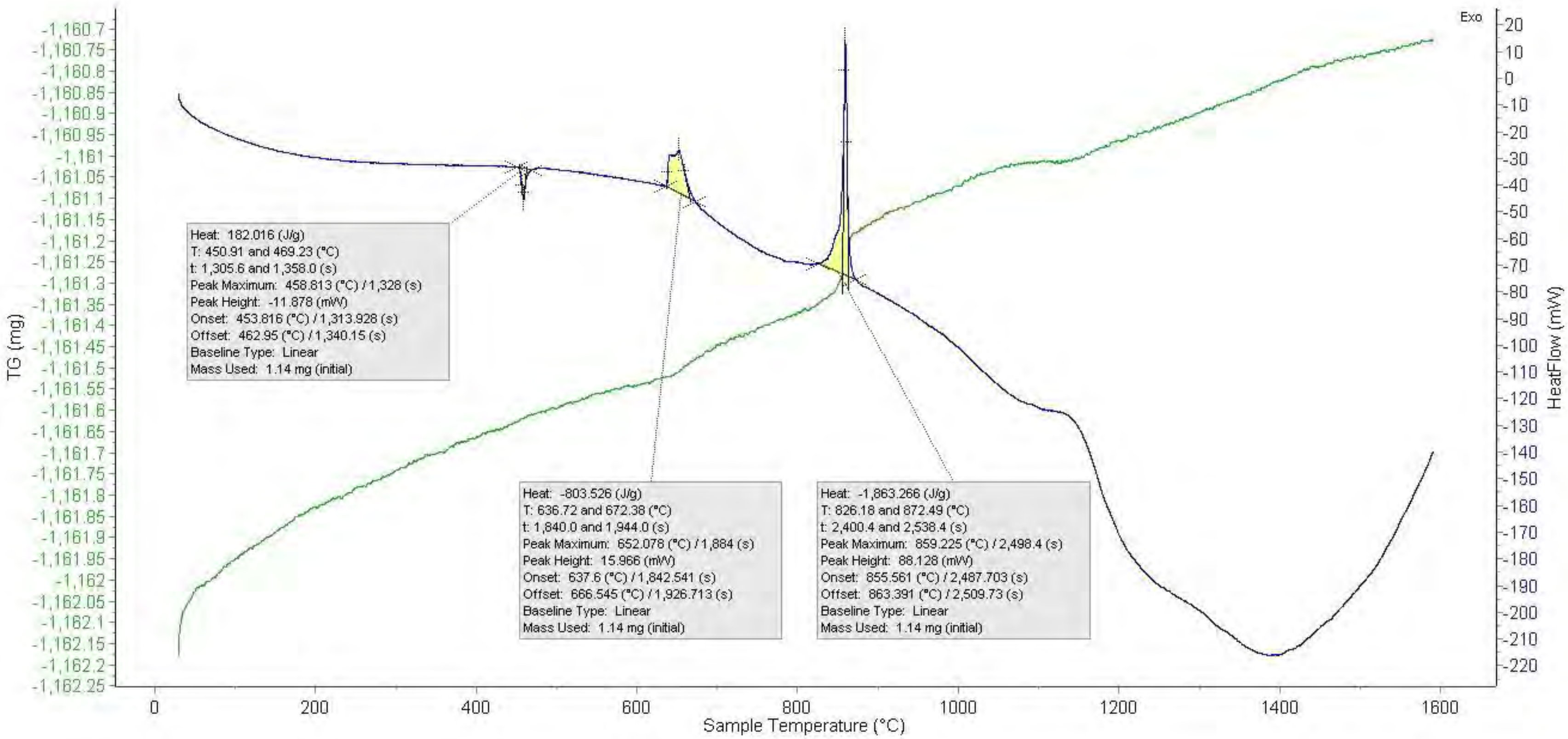


Figure C37: High-Temp DSC Plots for Mix ID SS #3B – Fine Ti - Fine MnO_2, Trial 1

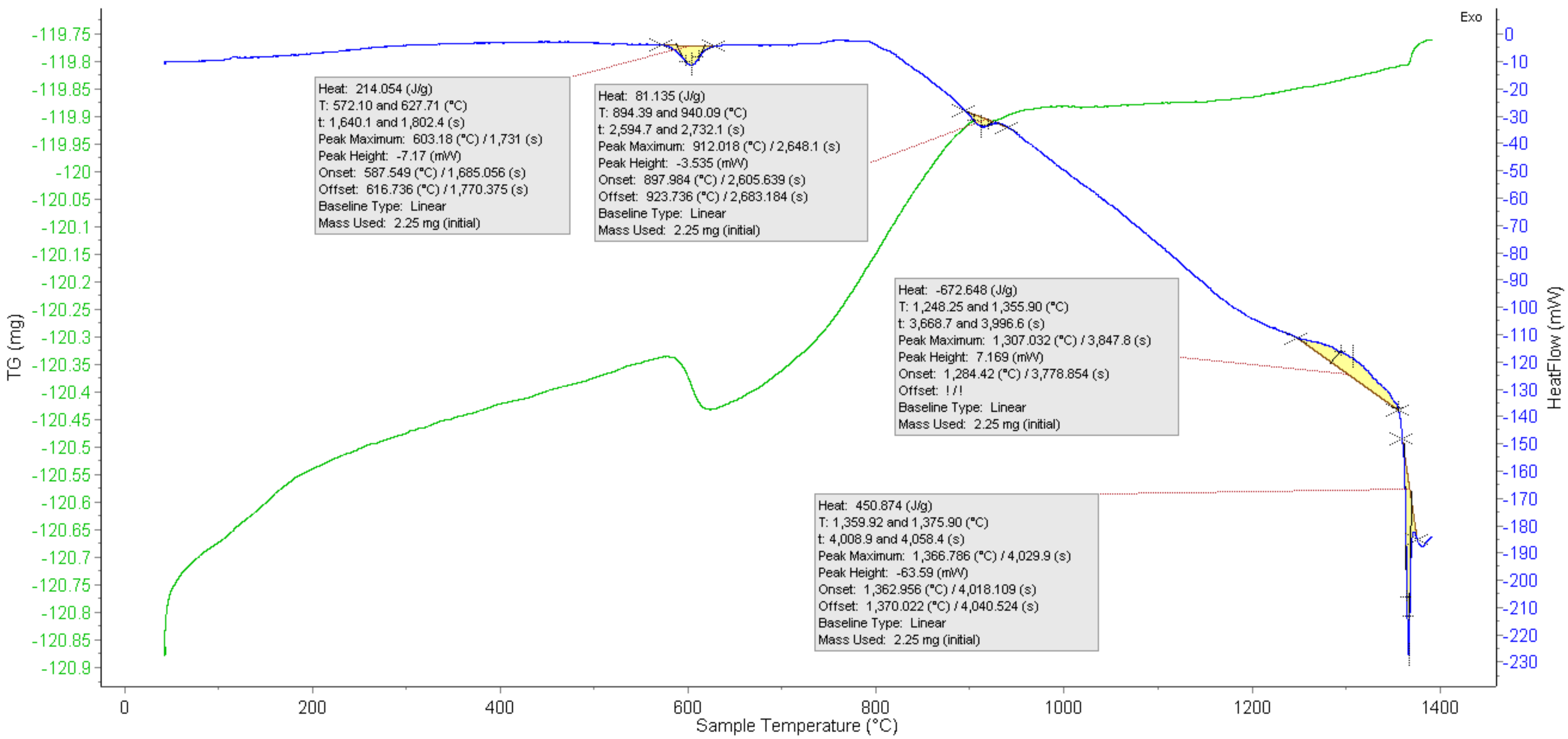


Figure C38: High-Temp DSC Plots for Mix ID SS #3B – Fine Ti - Fine MnO_2, Trial 2

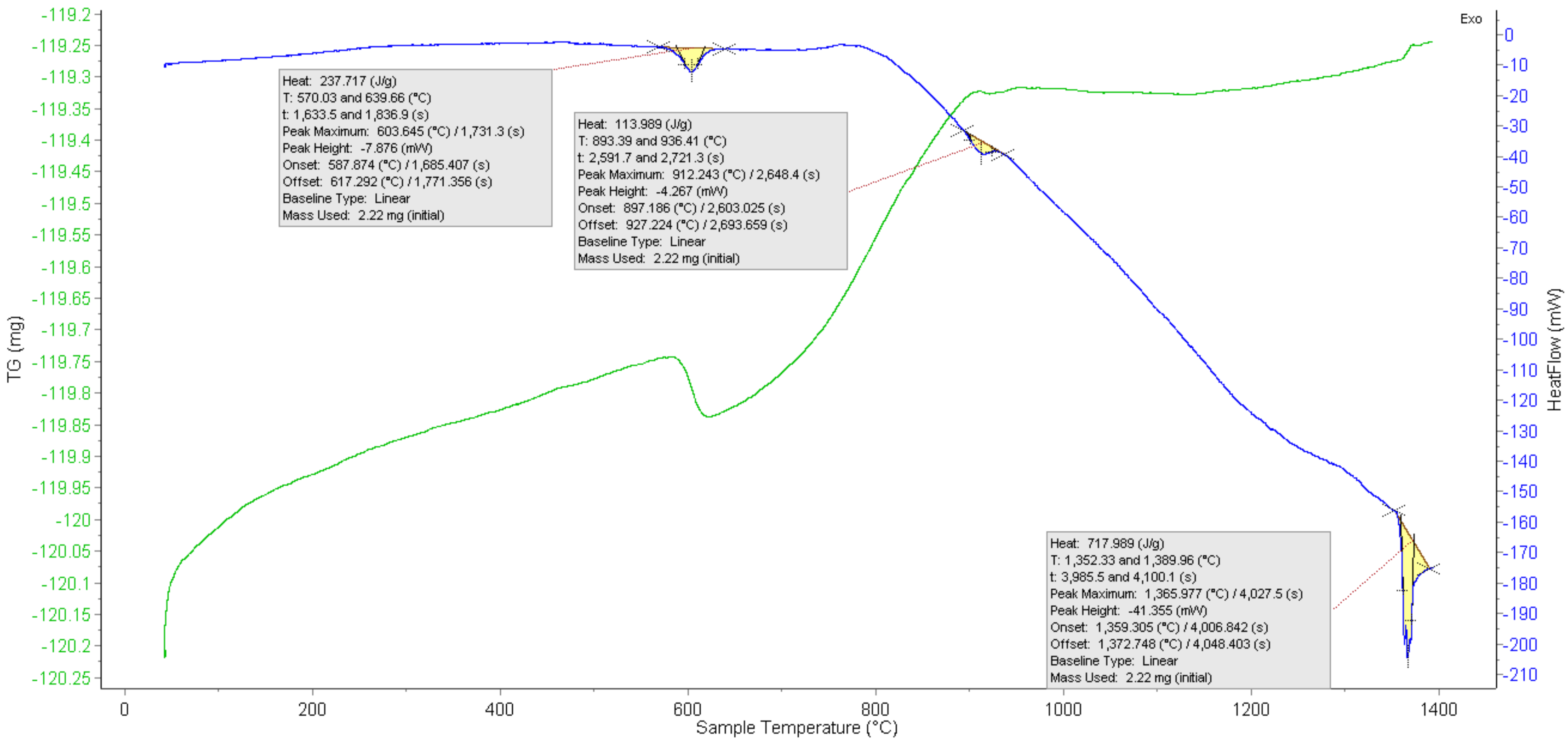


Figure C39: High-Temp DSC Plots for Mix ID SS #3B – Fine Ti - Medium MnO_2, Trial 1

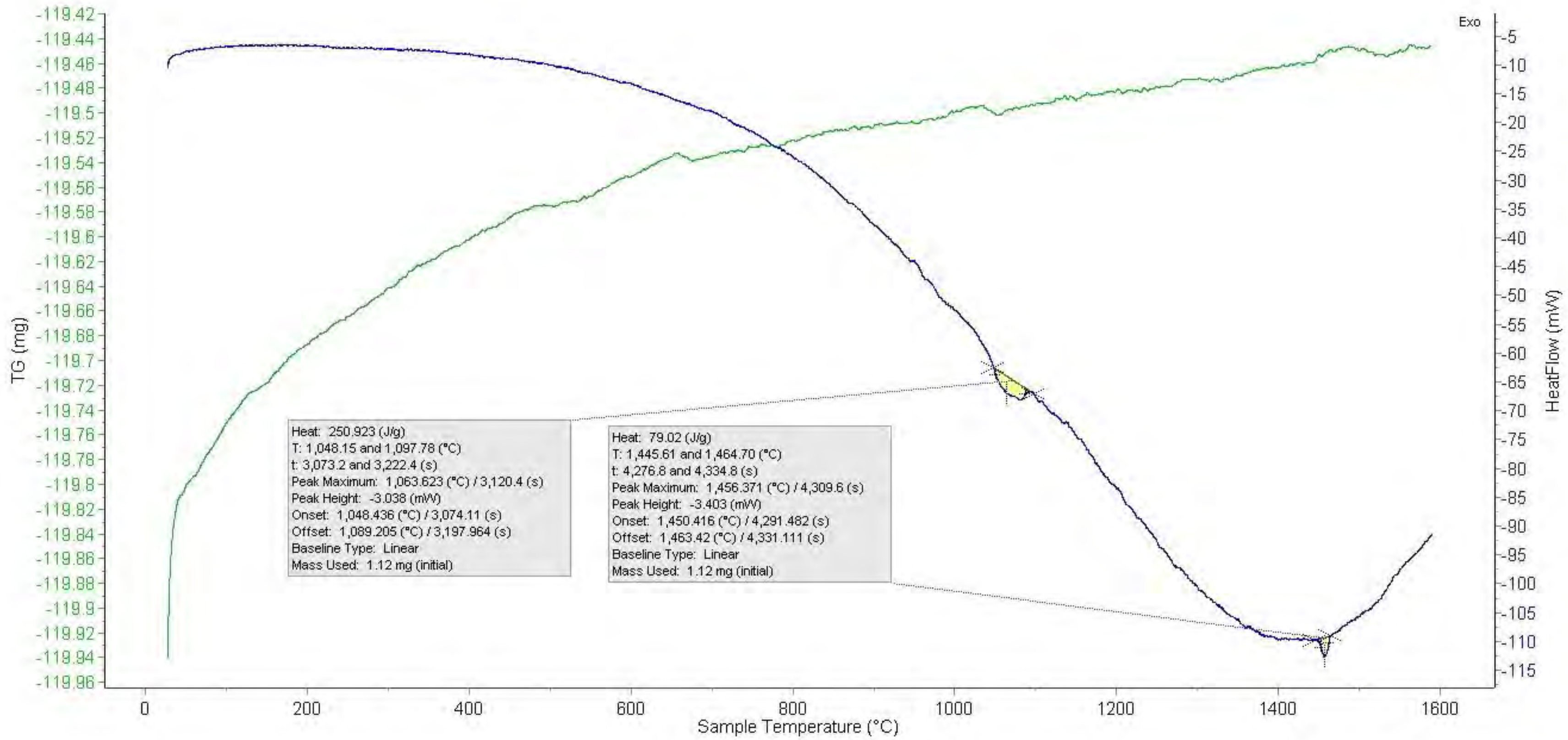


Figure C40: High-Temp DSC Plots for Mix ID SS #3B – Fine Ti - Medium MnO_2, Trial 2

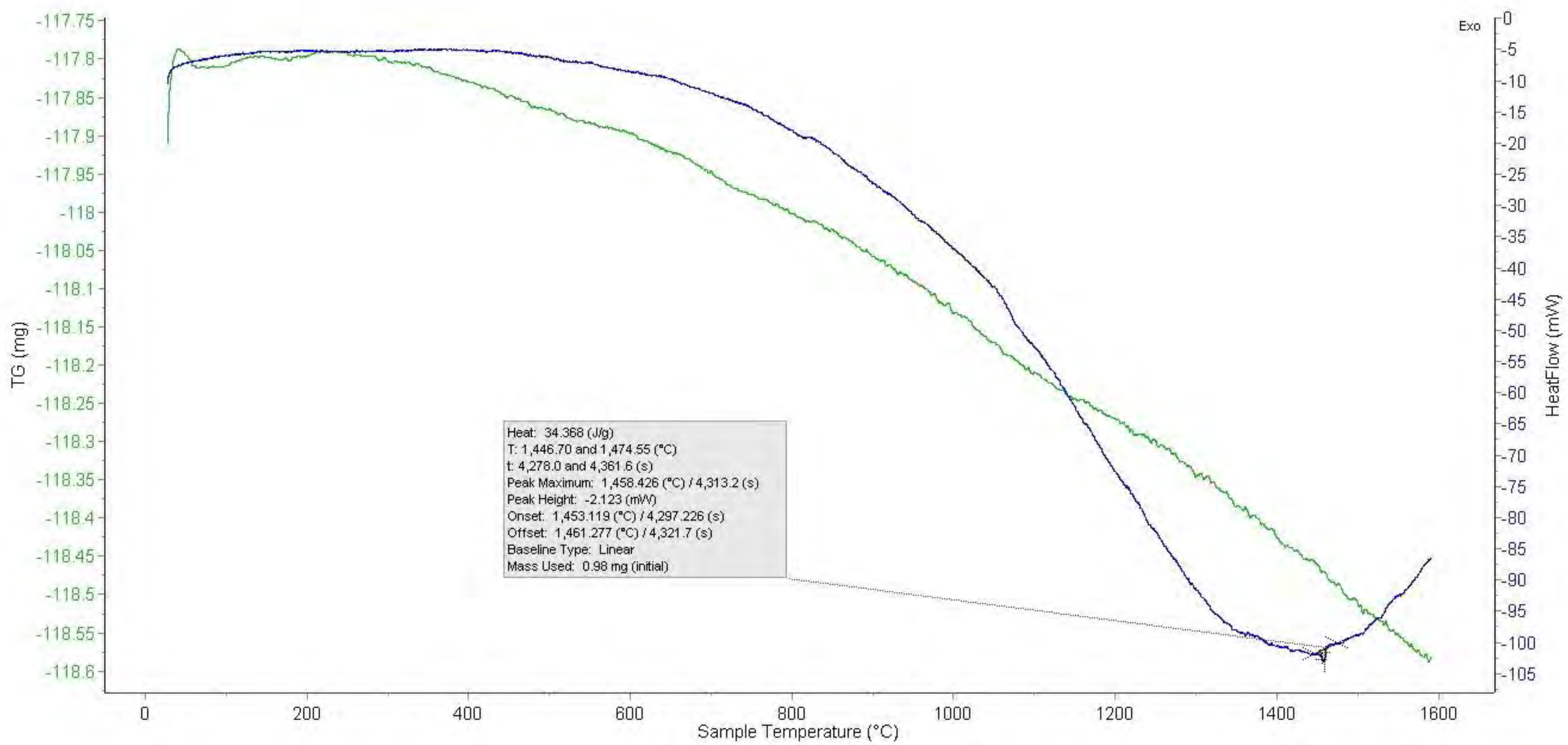


Figure C41: High-Temp DSC Plots for Mix ID SS #3B – Fine Ti - Coarse MnO_2, Trial 1

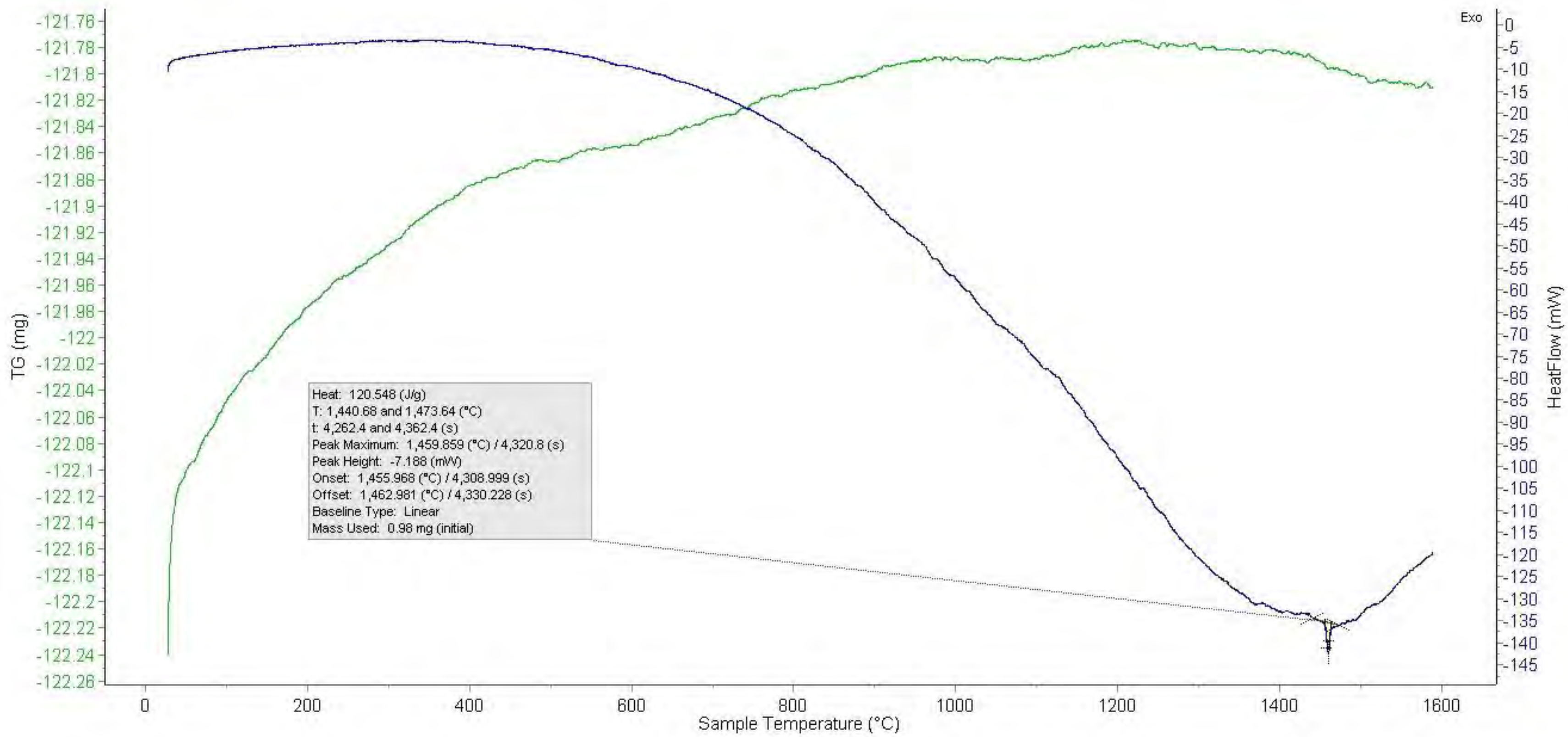


Figure C42: High-Temp DSC Plots for Mix ID SS #3B – Fine Ti - Coarse MnO_2, Trial 2

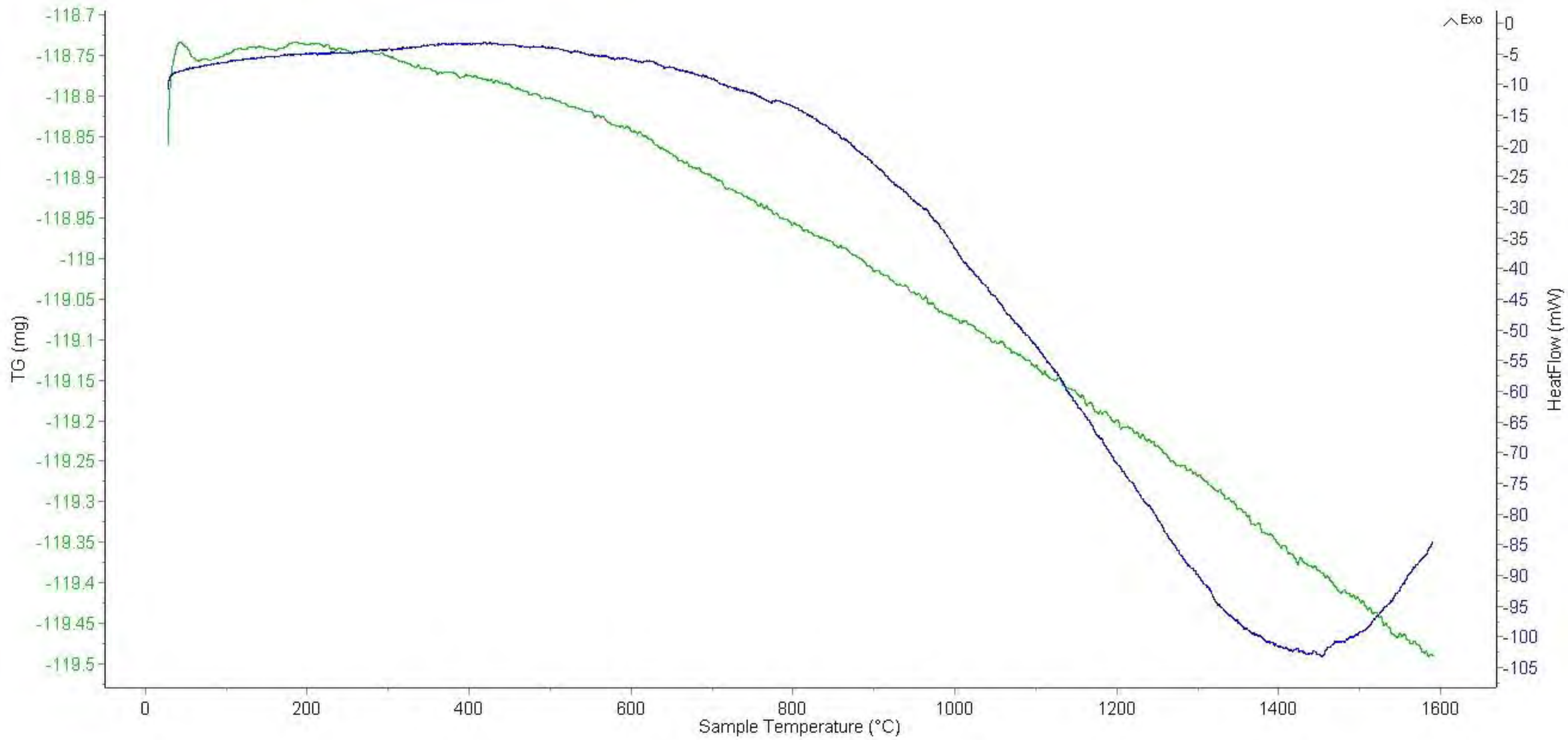


Figure C43: High-Temp DSC Plots for Mix ID SS #3B – Medium Ti - Fine MnO_2, Trial 1

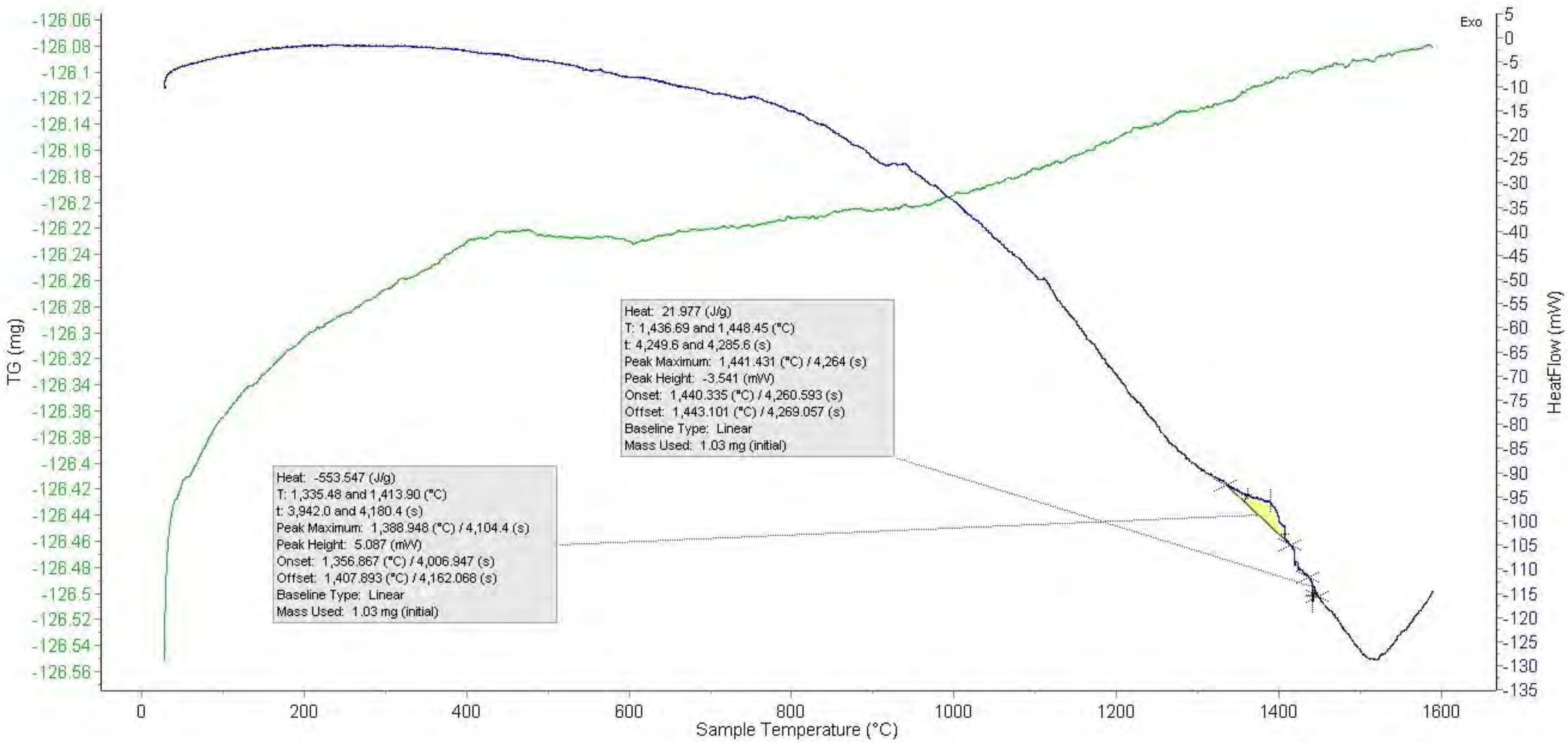


Figure C44: High-Temp DSC Plots for Mix ID SS #3B – Medium Ti - Fine MnO_2, Trial 2

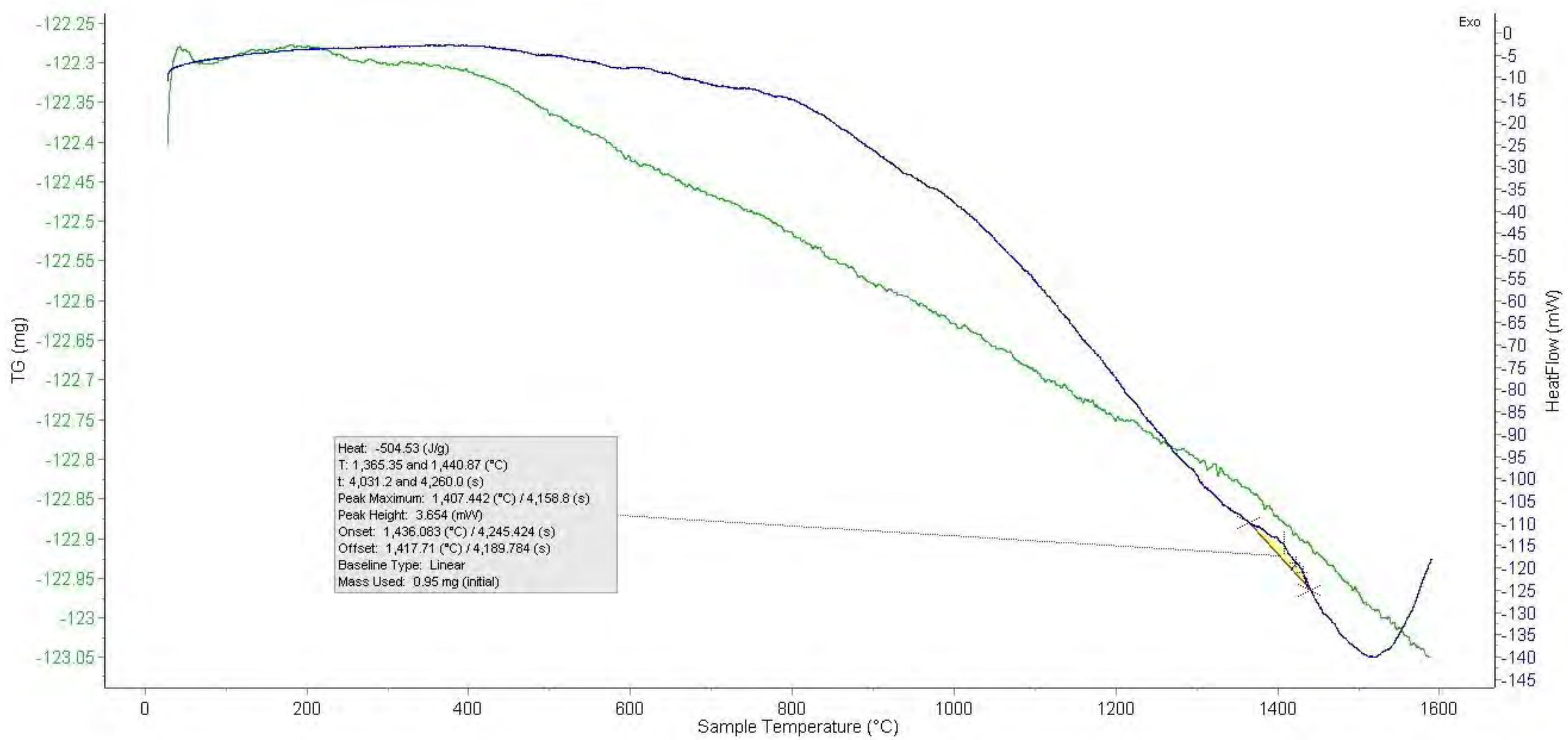


Figure C45: High-Temp DSC Plots for Mix ID SS #3B – Medium Ti - Medium MnO_2, Trial 1

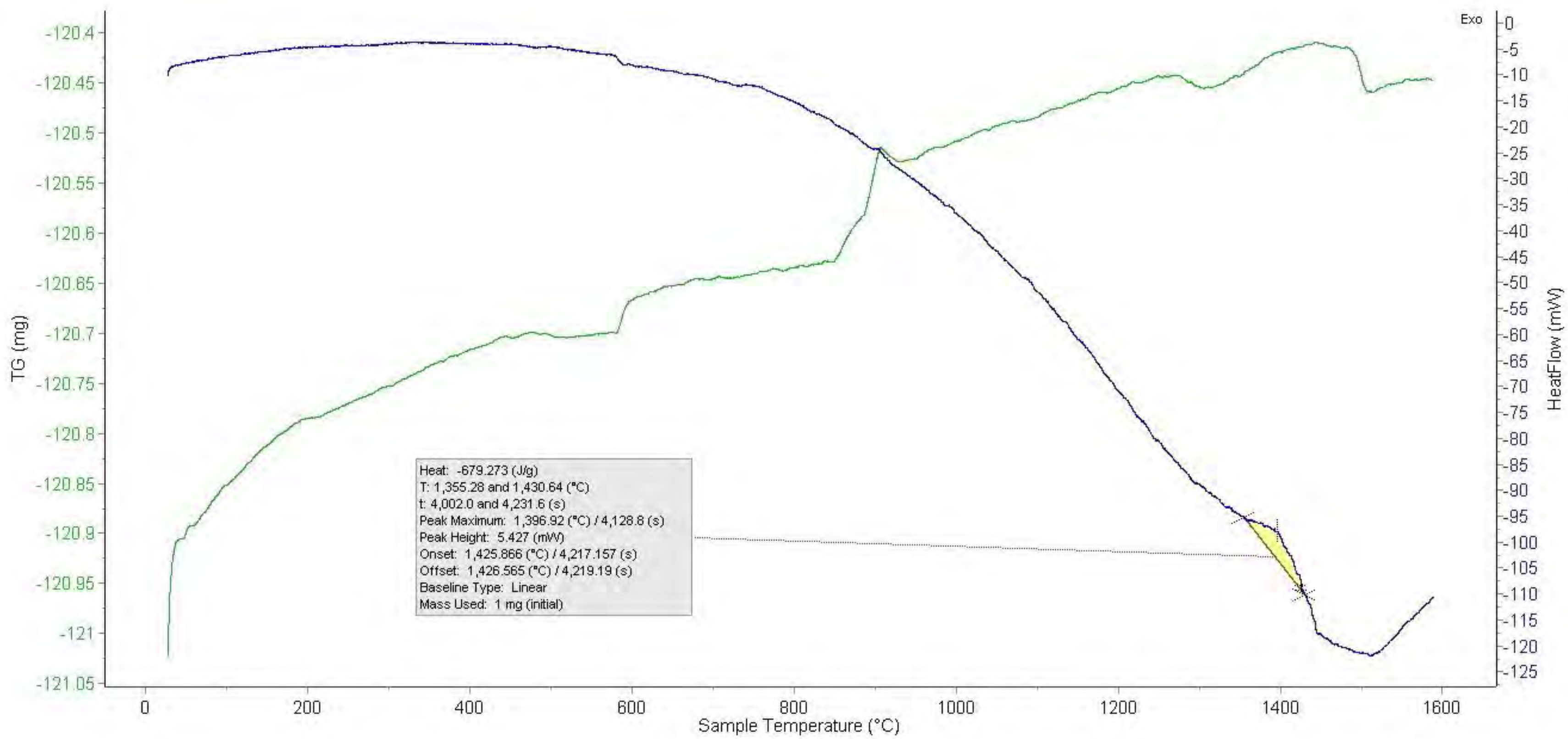


Figure C46: High-Temp DSC Plots for Mix ID SS #3B – Medium Ti - Medium MnO_2, Trial 2

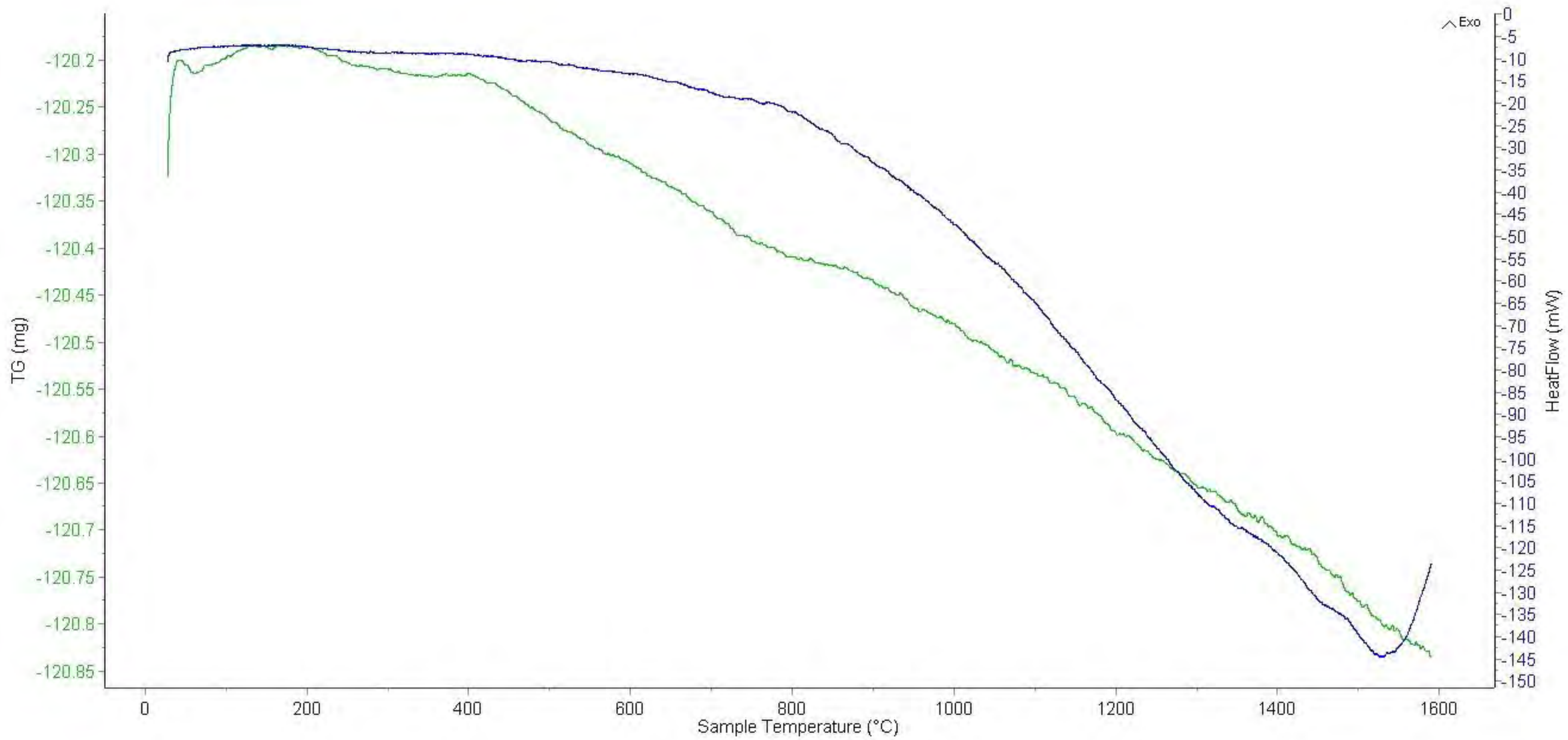


Figure C47: High-Temp DSC Plots for Mix ID SS #3B – Medium Ti - Coarse MnO_2, Trial 1

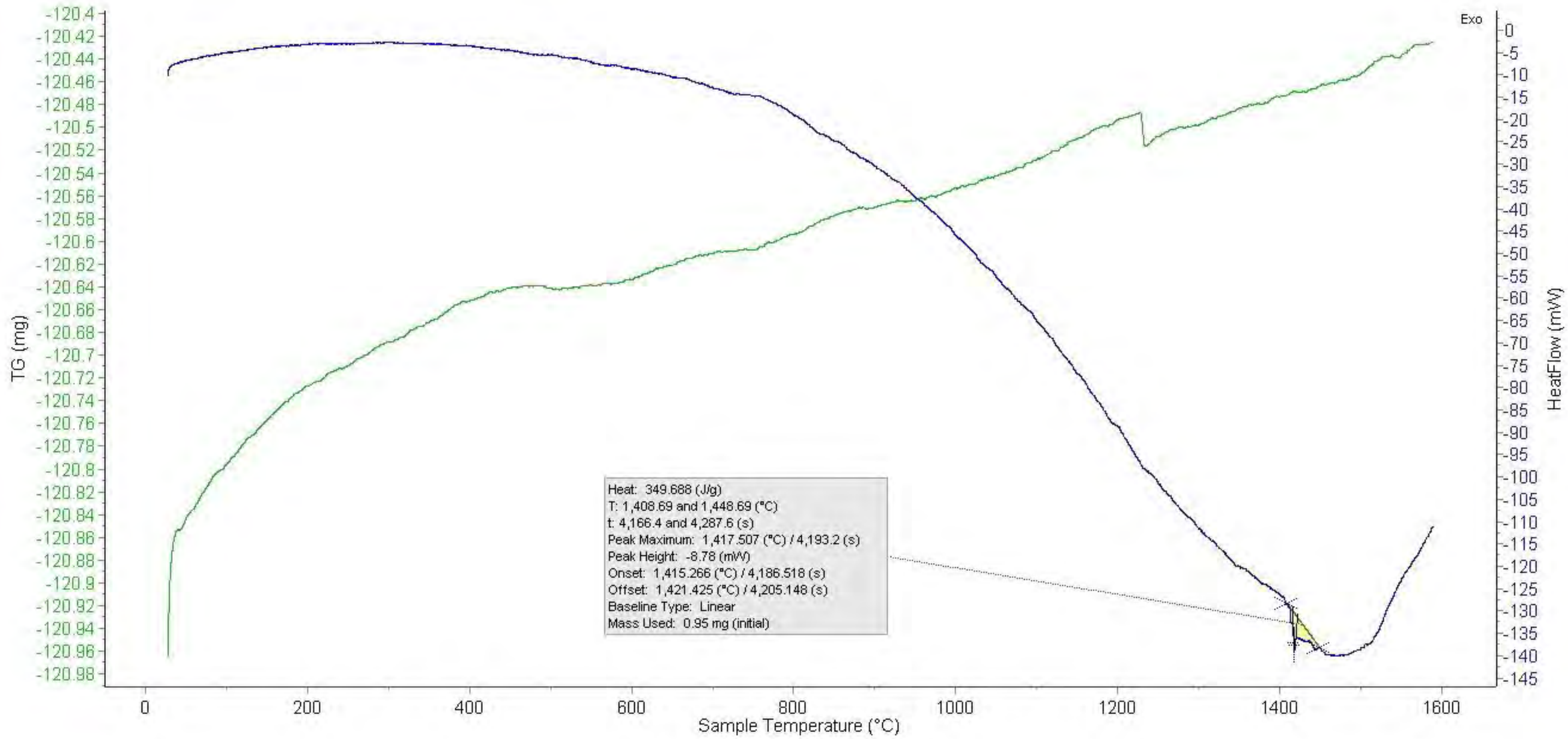


Figure C48: High-Temp DSC Plots for Mix ID SS #3B – Medium Ti - Coarse MnO_2, Trial 2

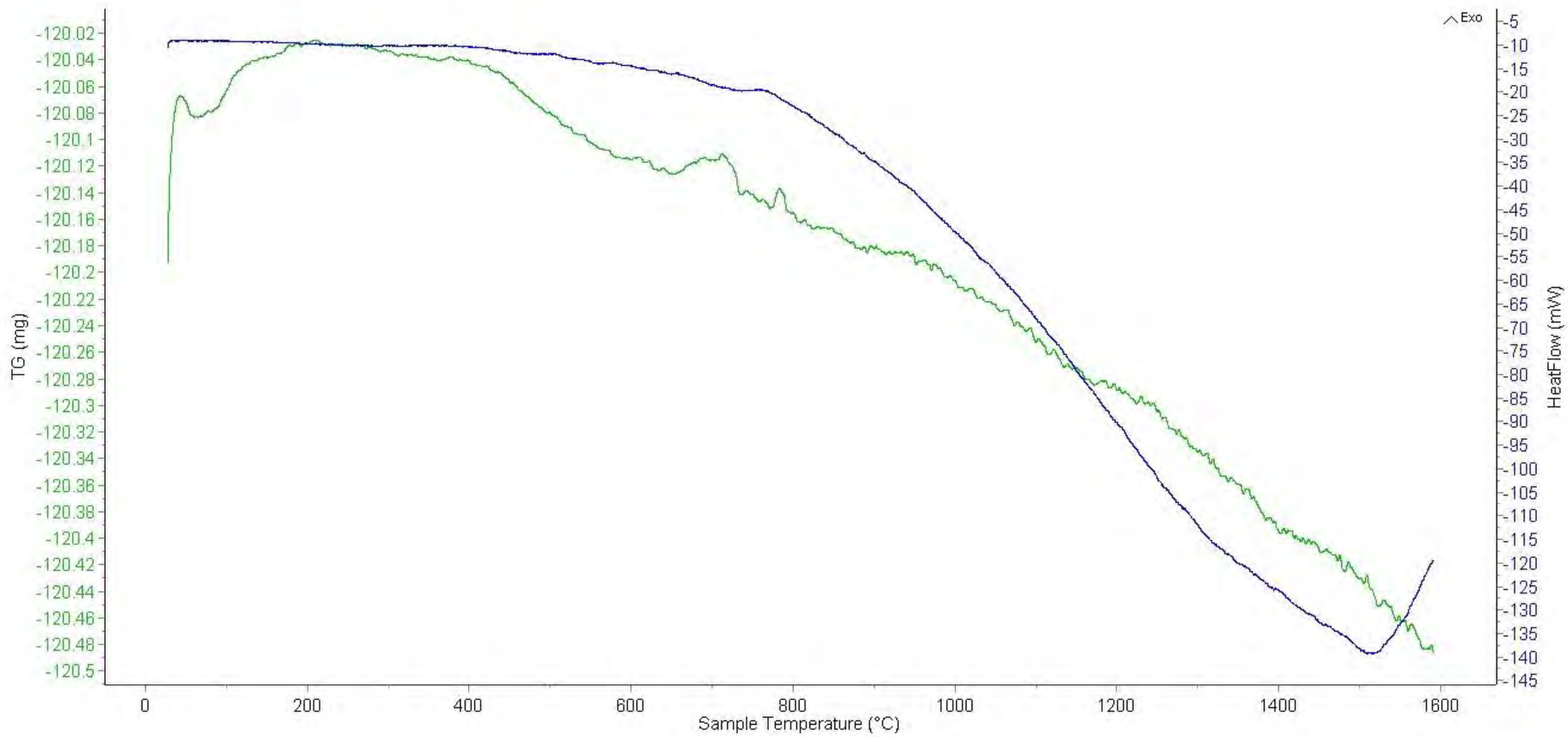


Figure C49: High-Temp DSC Plots for Mix ID SS #3B – Coarse Ti - Fine MnO_2, Trial 1

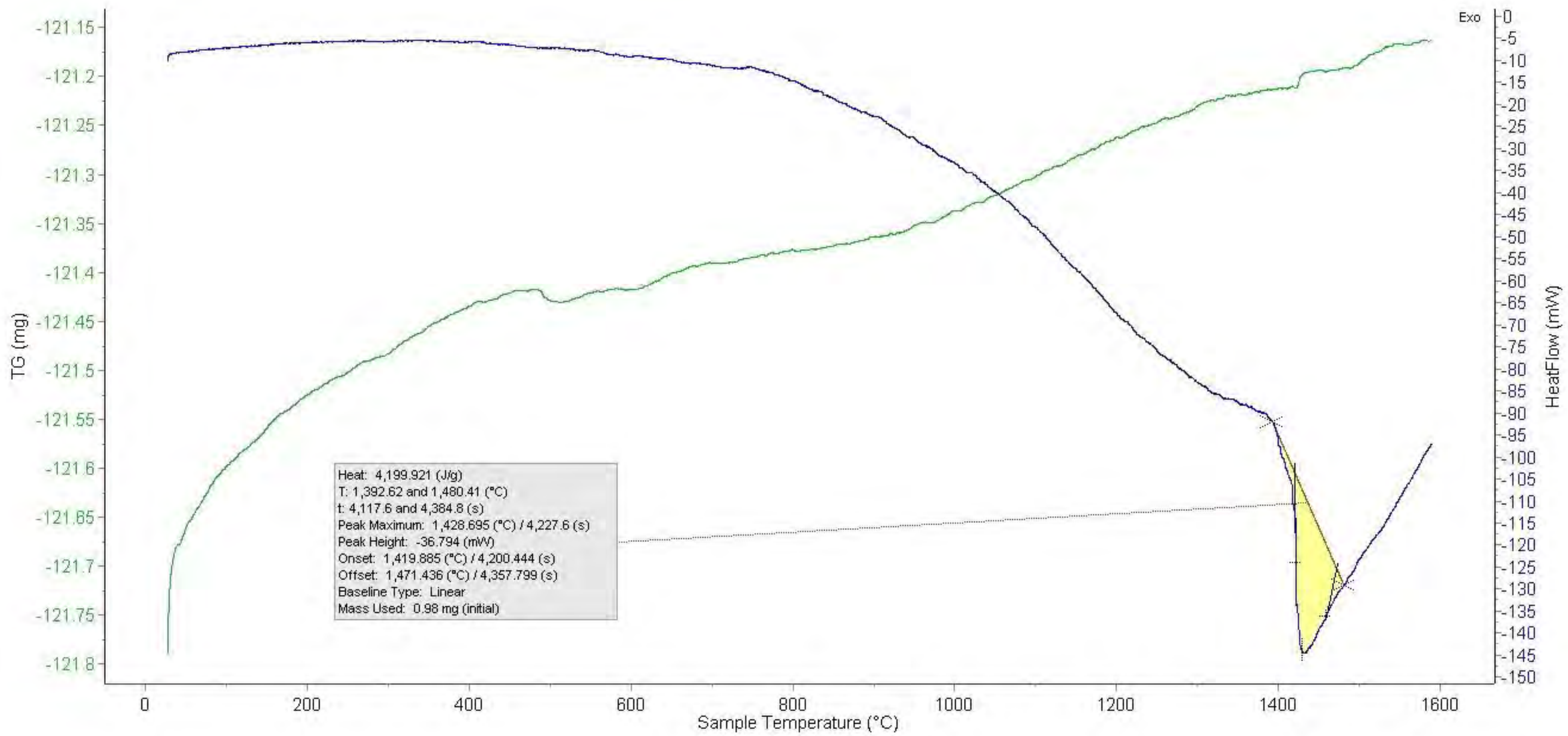


Figure C50: High-Temp DSC Plots for Mix ID SS #3B – Coarse Ti - Fine MnO_2, Trial 2

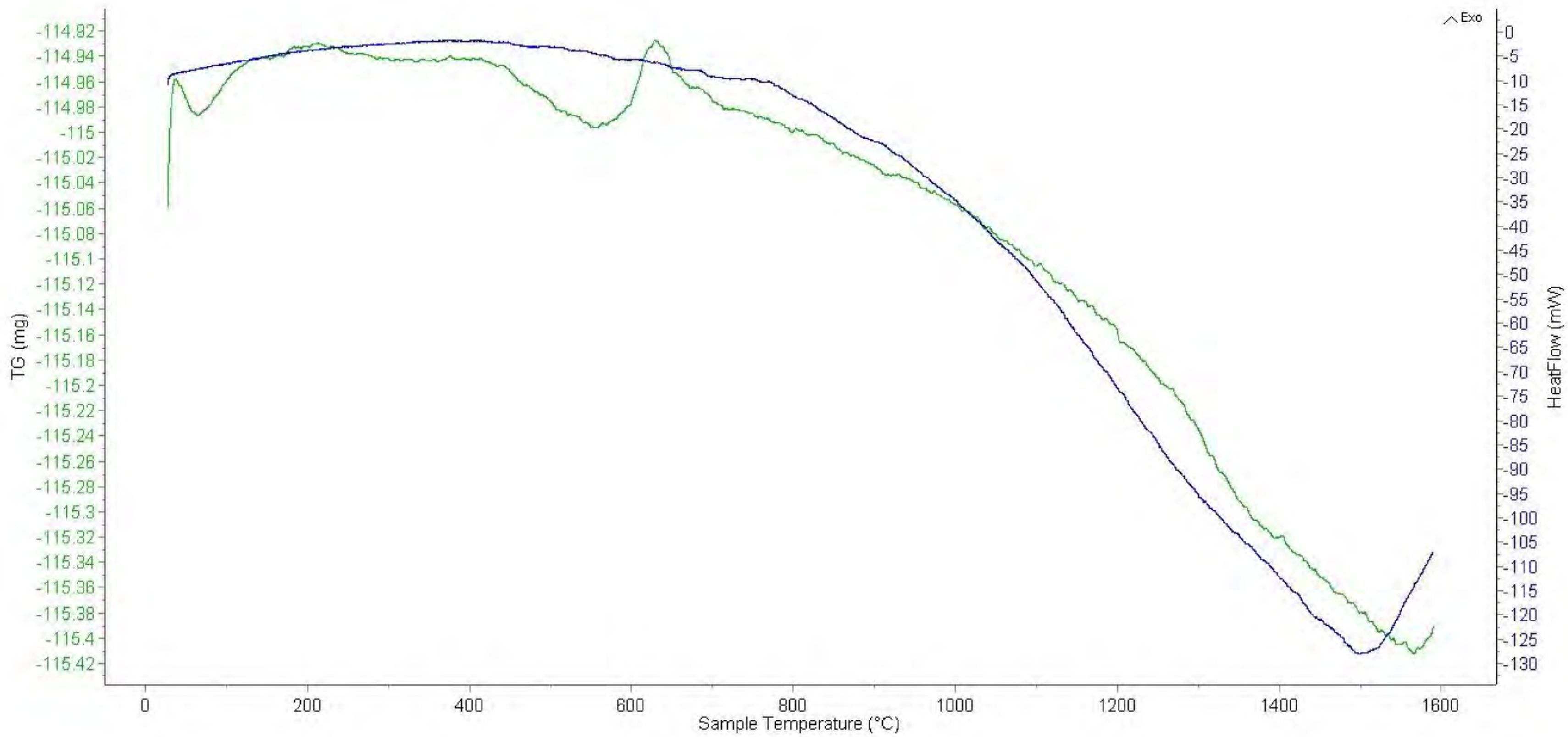


Figure C51: High-Temp DSC Plots for Mix ID SS #3B – Coarse Ti - Medium MnO_2, Trial 1

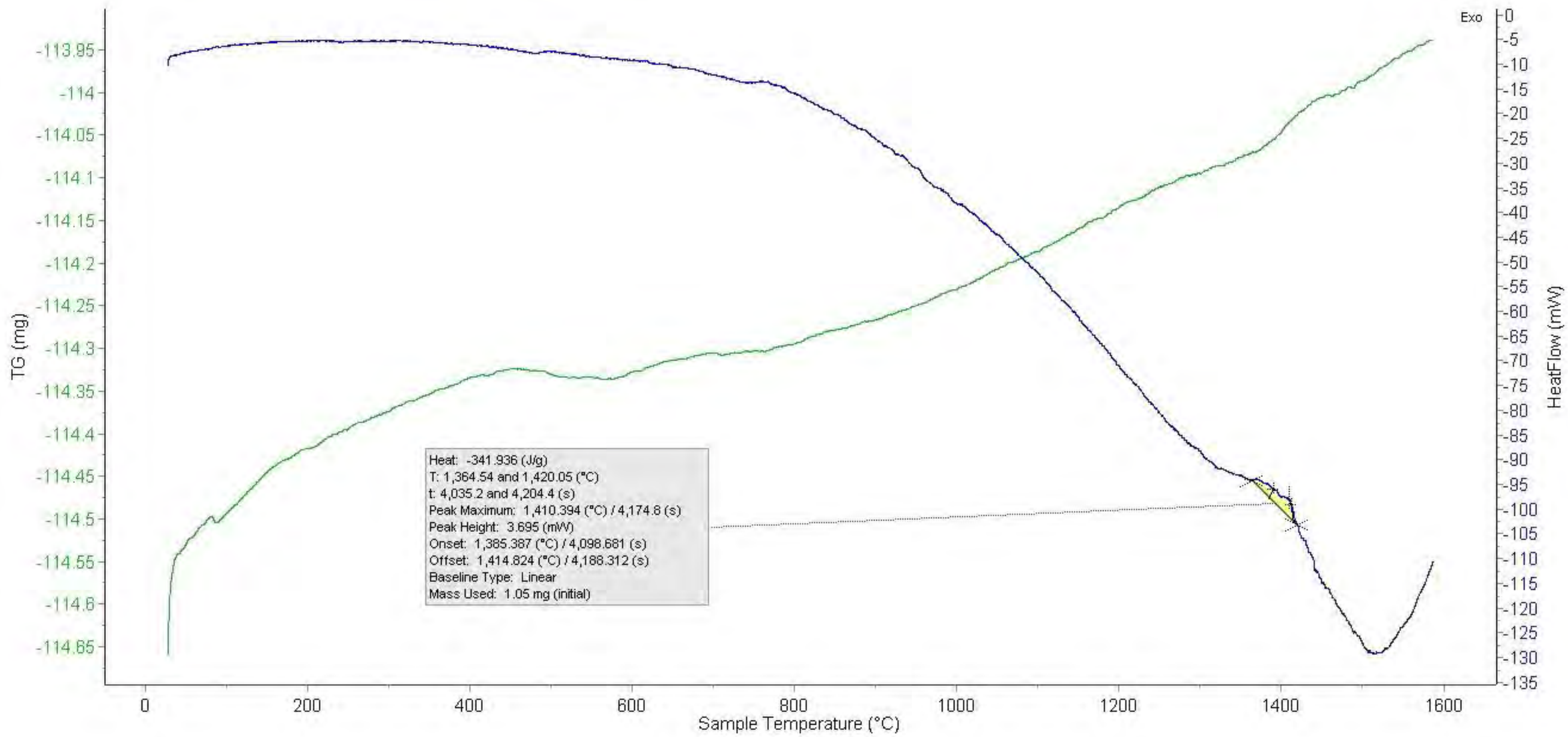


Figure C52: High-Temp DSC Plots for Mix ID SS #3B – Coarse Ti - Medium MnO_2, Trial 2

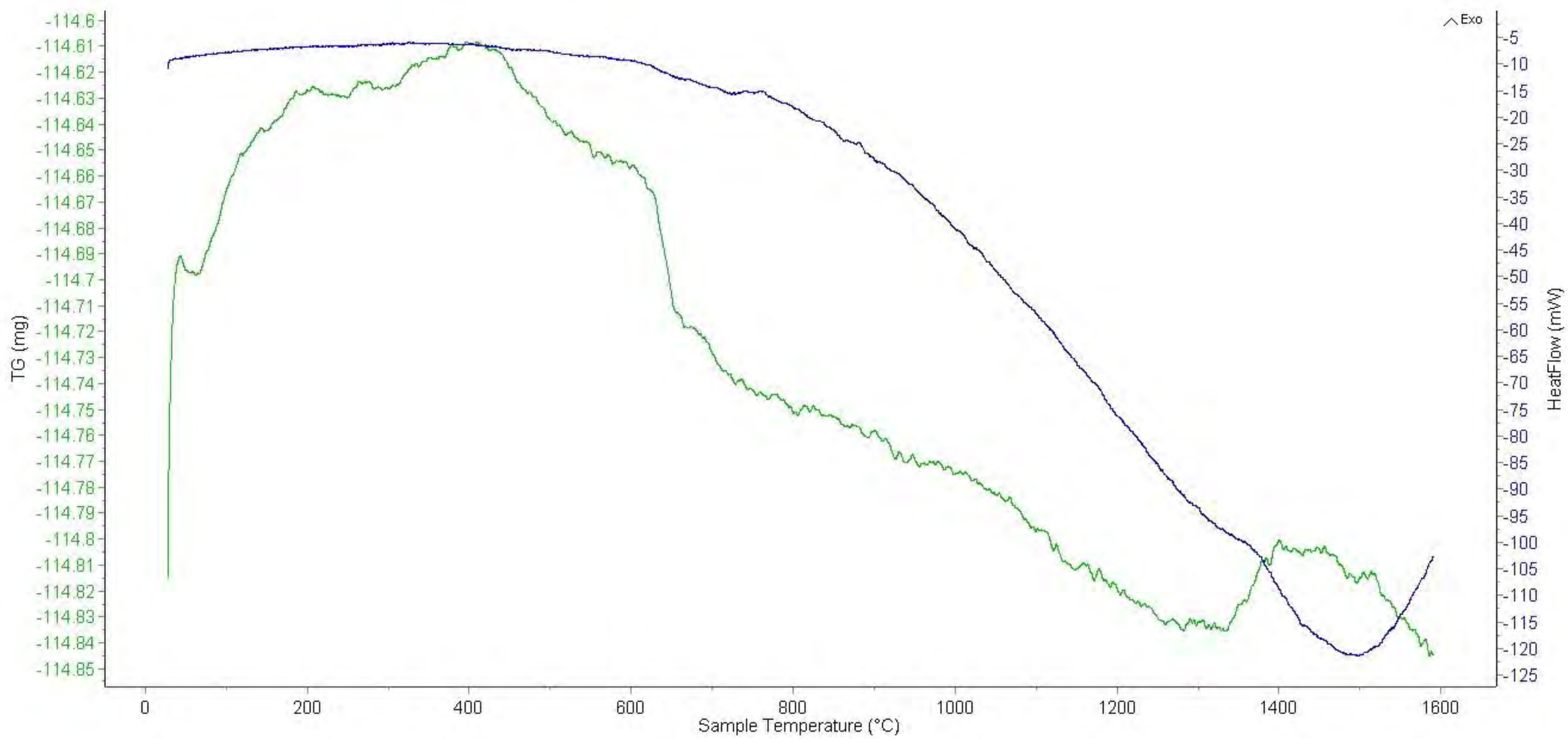


Figure C53: High-Temp DSC Plots for Mix ID SS #3B – Coarse Ti - Coarse MnO_2, Trial 1

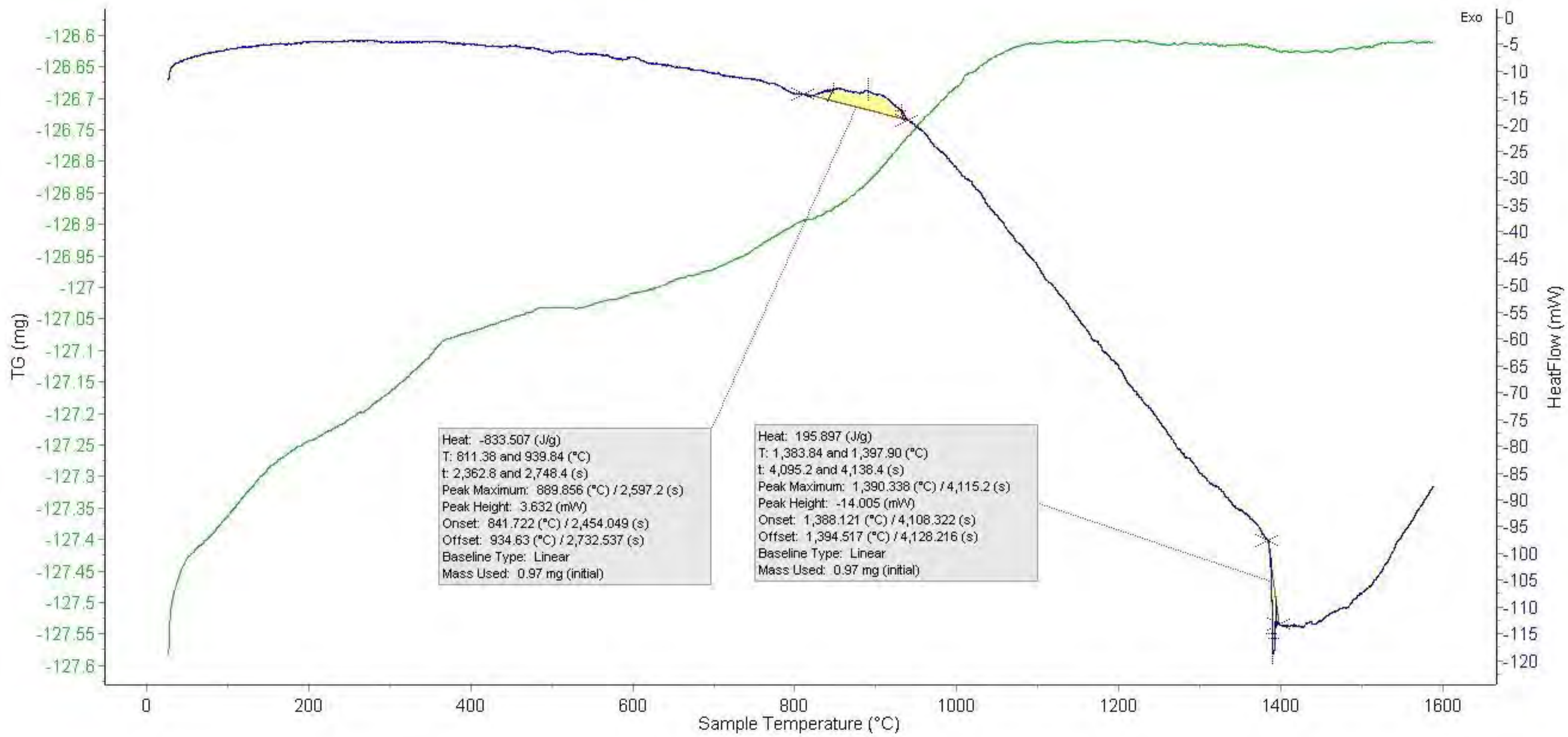


Figure C54: High-Temp DSC Plots for Mix ID SS #3B – Coarse Ti - Coarse MnO_2, Trial 2

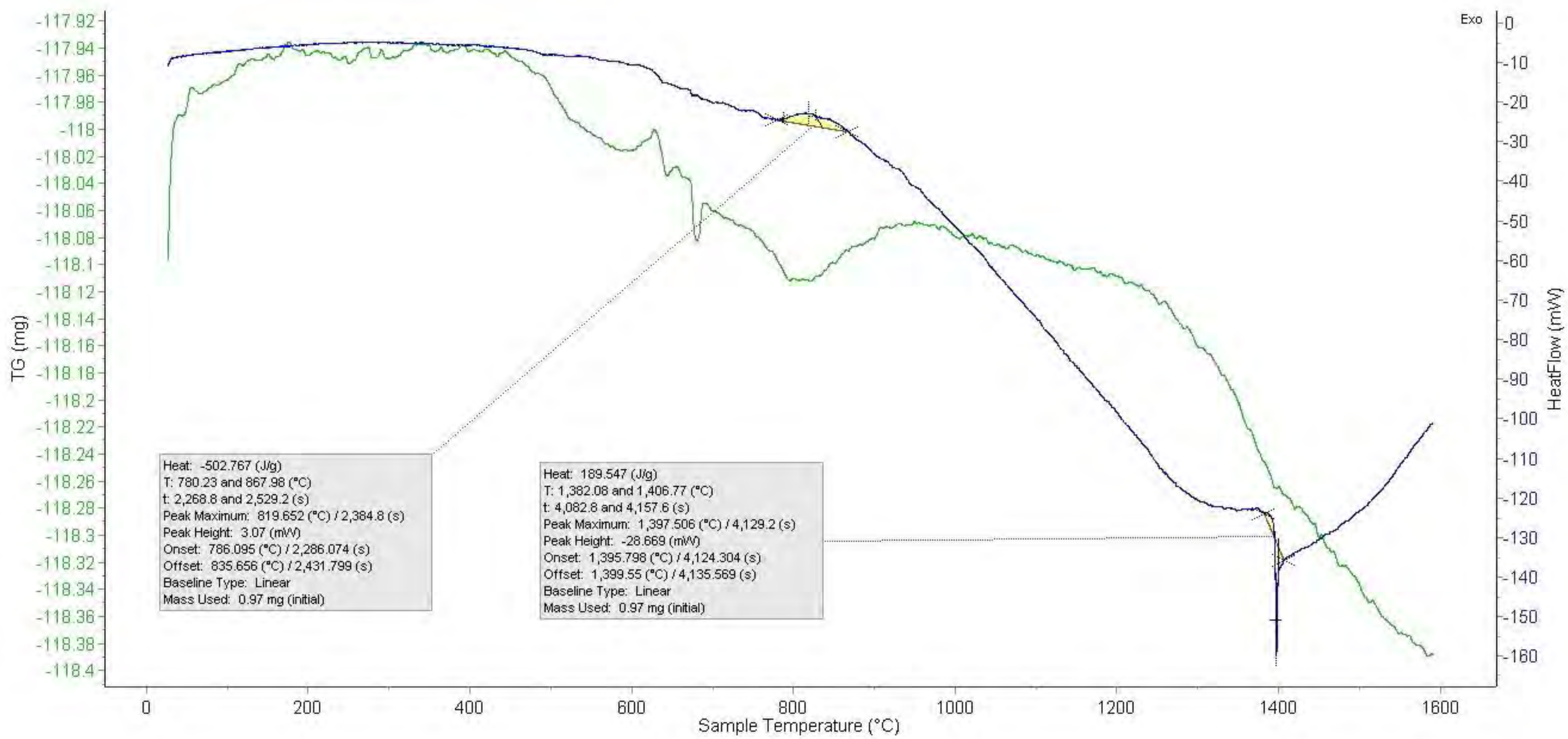


Figure C55: High-Temp DSC Plots for Mix ID SS #4 – Fine Mg - Fine MnO_2, Trial 1

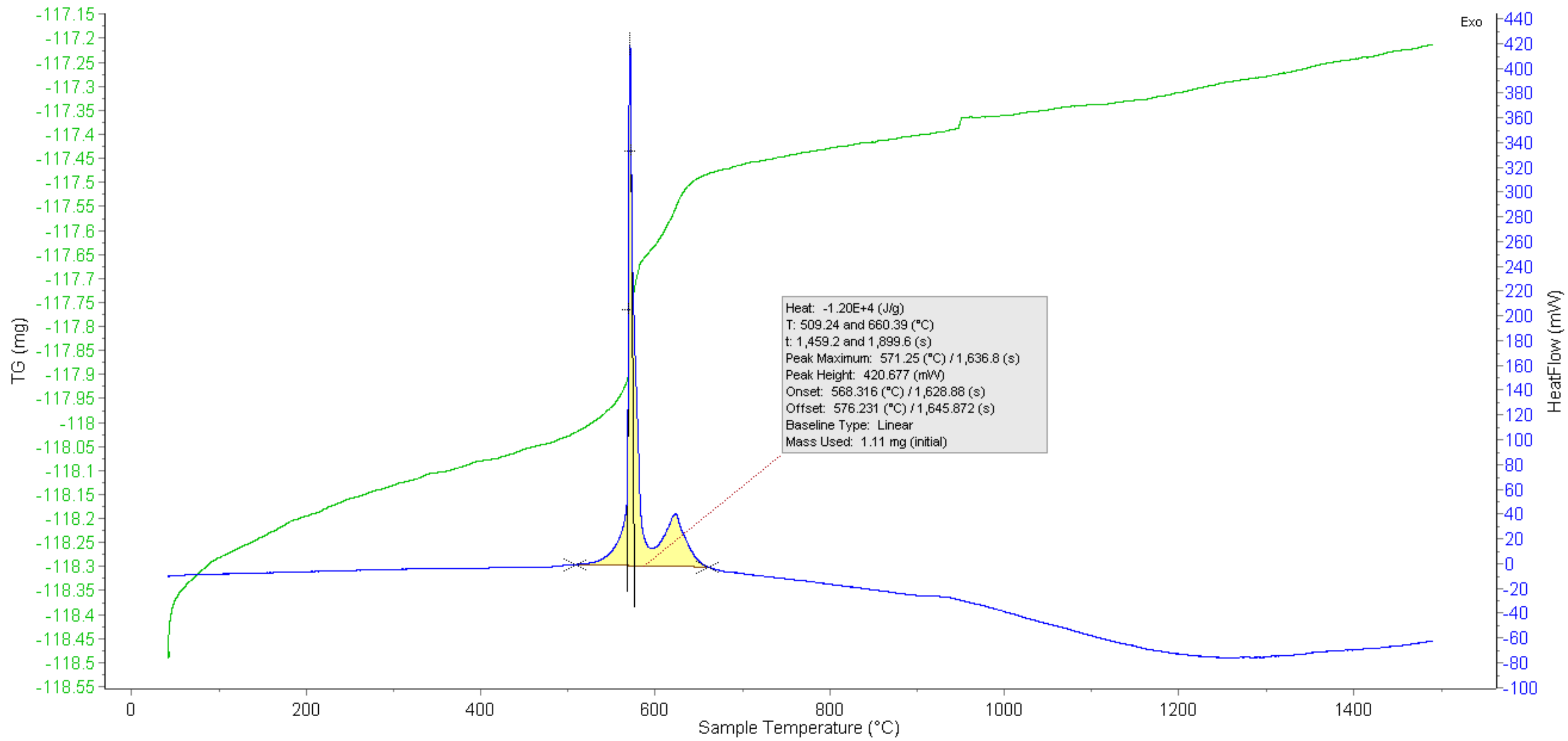


Figure C56: High-Temp DSC Plots for Mix ID SS #4 – Fine Mg - Fine MnO_2, Trial 2

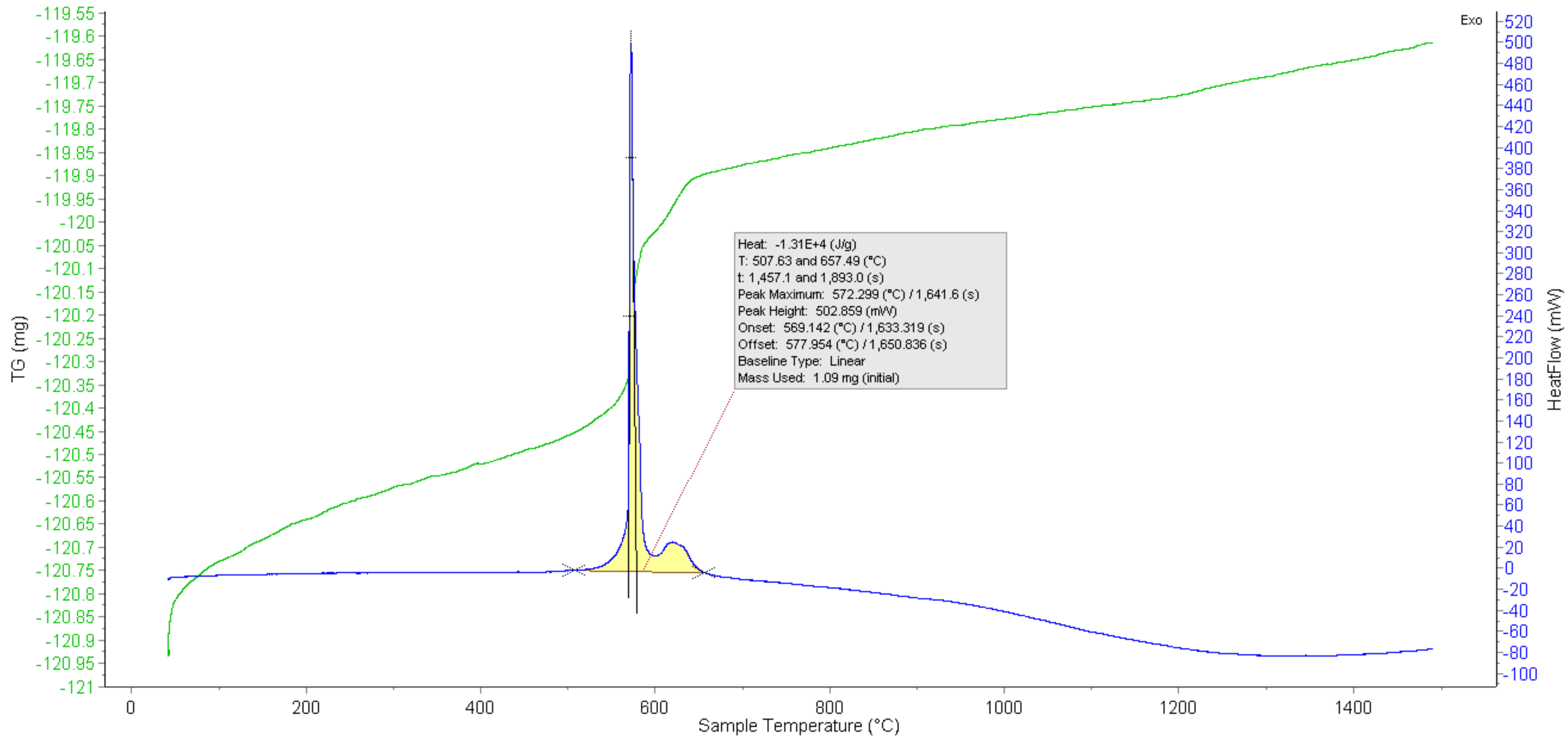


Figure C57: High-Temp DSC Plots for Mix ID SS #4 – Fine Mg - Medium MnO_2, Trial 1

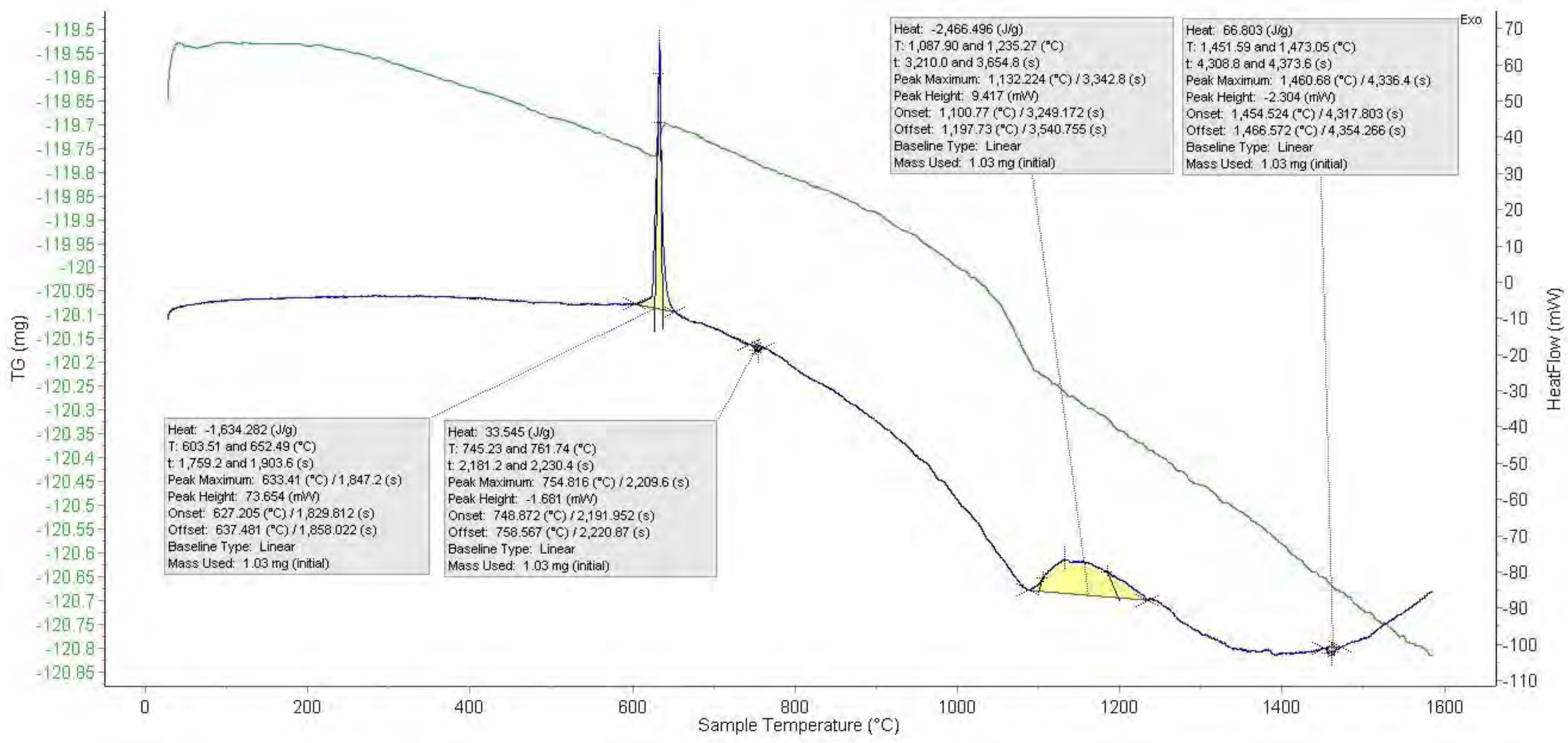


Figure C58: High-Temp DSC Plots for Mix ID SS #4 – Fine Mg - Medium MnO_2, Trial 2

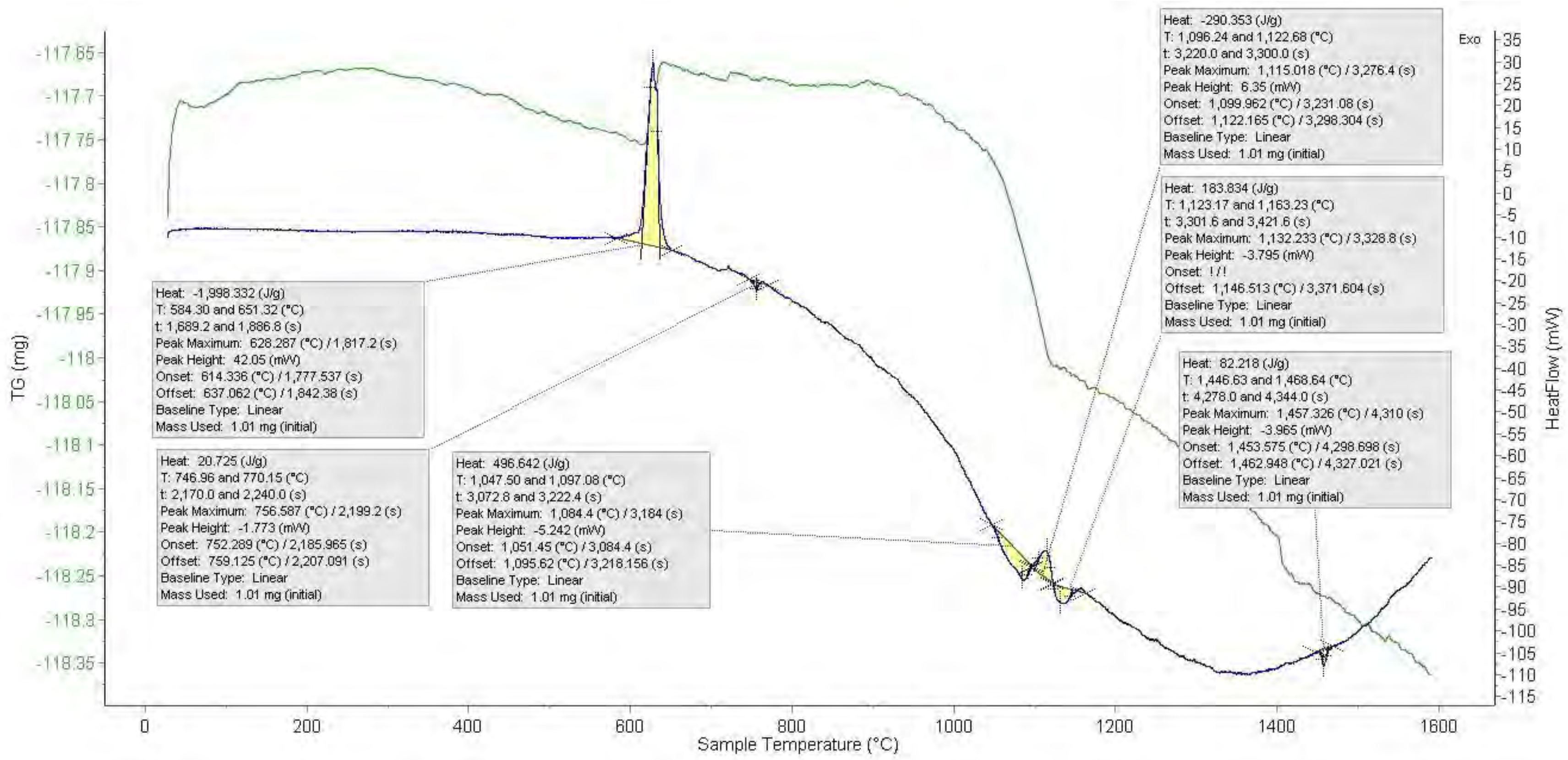


Figure C59: High-Temp DSC Plots for Mix ID SS #4 – Fine Mg - Coarse MnO_2, Trial 1

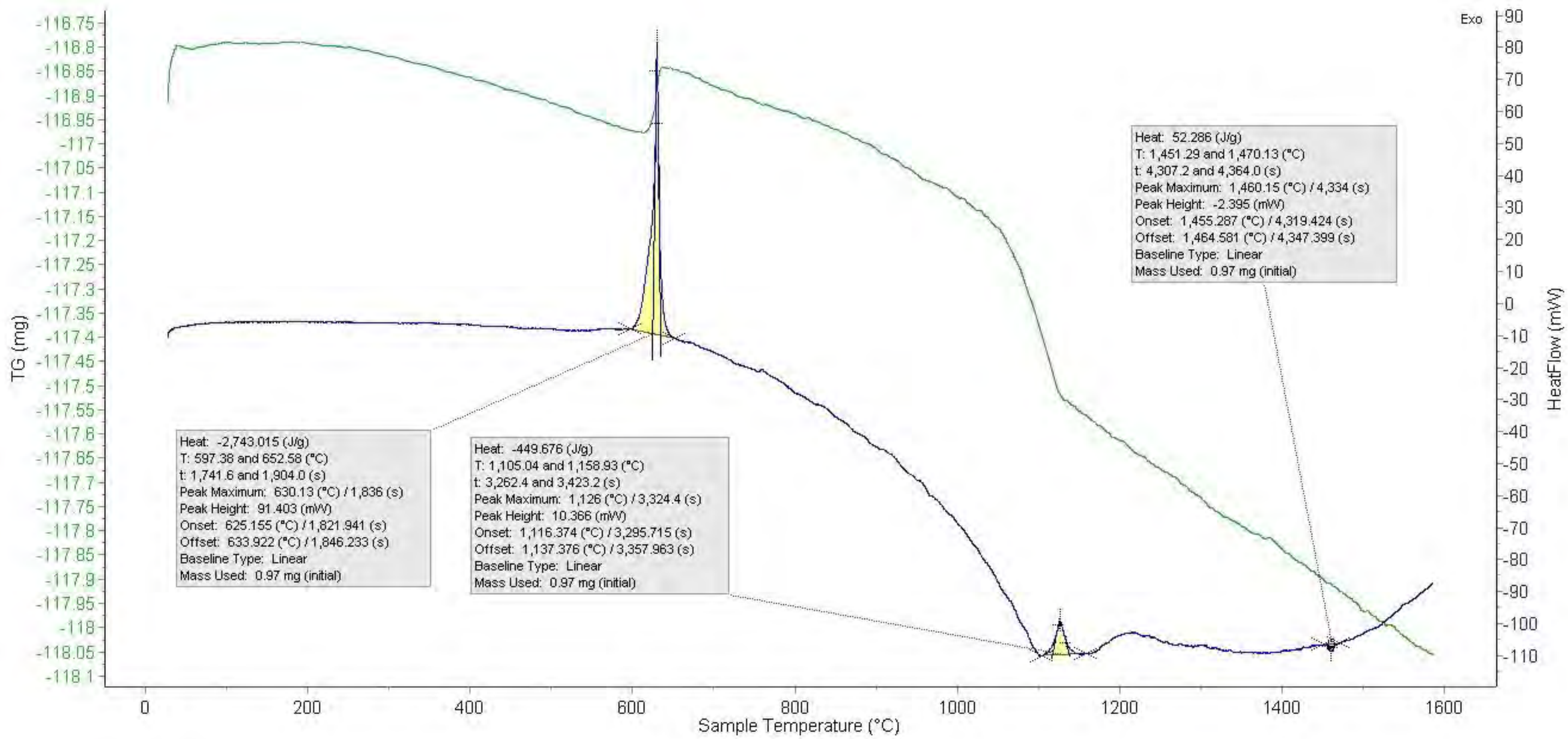


Figure C60: High-Temp DSC Plots for Mix ID SS #4 – Fine Mg - Coarse MnO_2, Trial 2

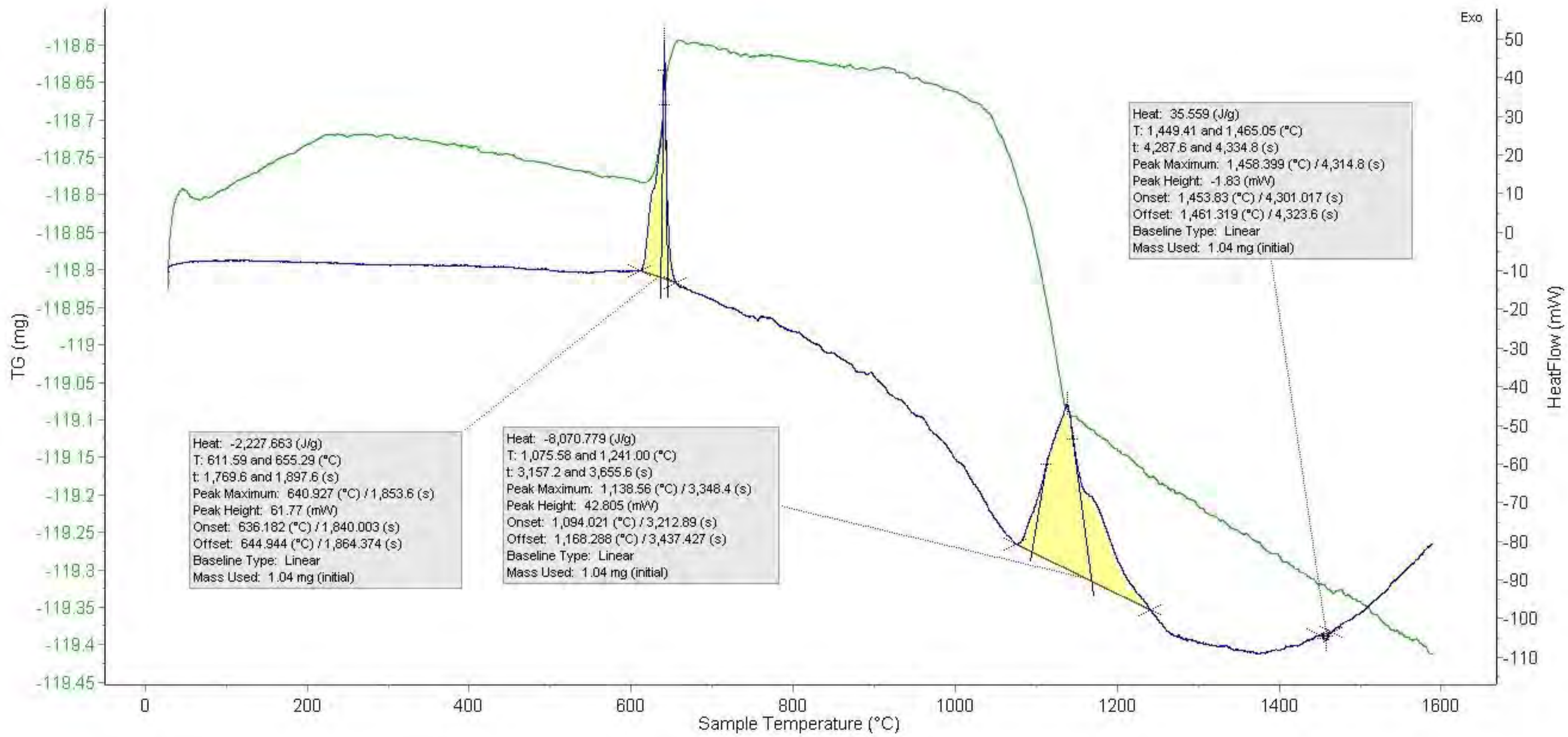


Figure C61: High-Temp DSC Plots for Mix ID SS #4 – Medium Mg - Fine MnO_2, Trial 1

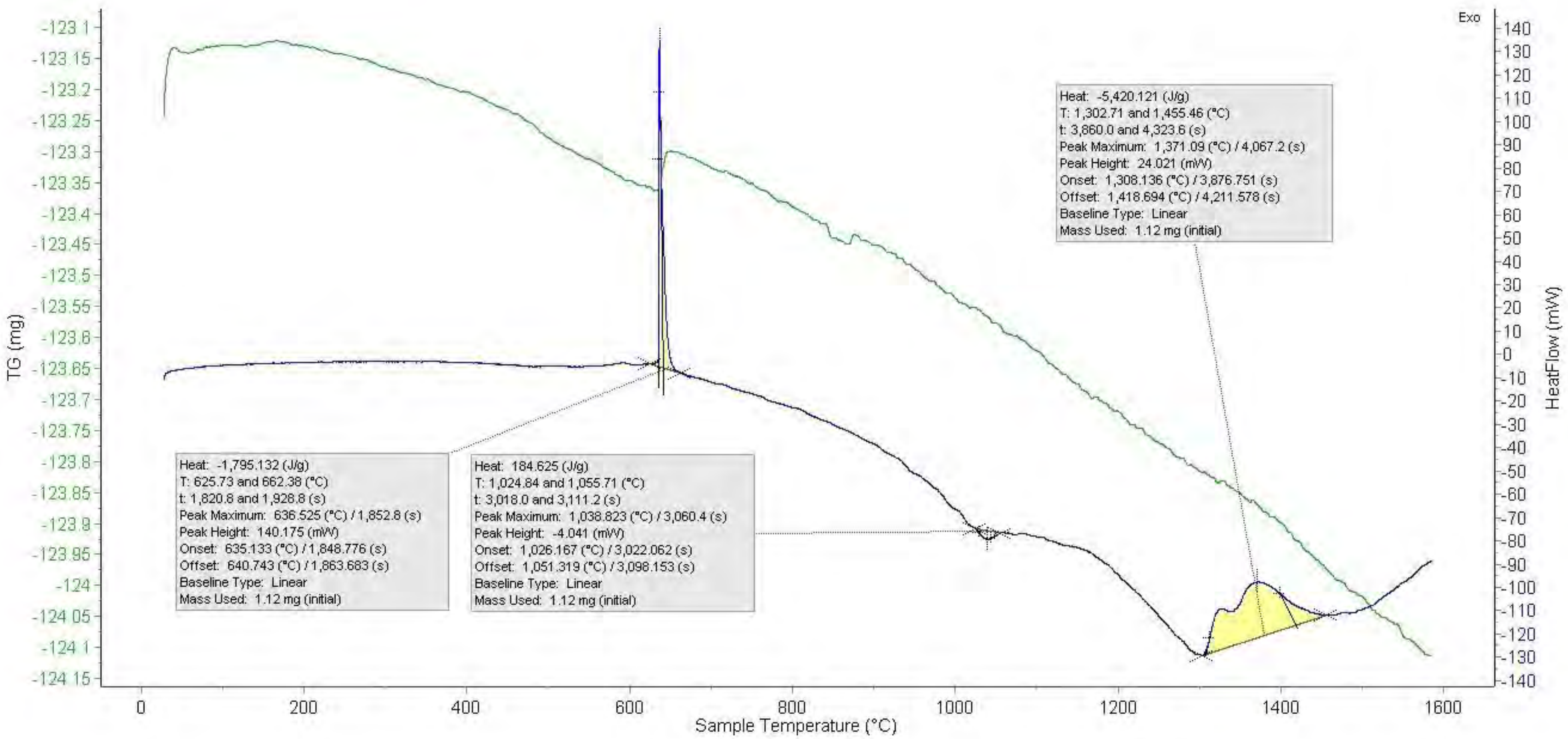


Figure C62: High-Temp DSC Plots for Mix ID SS #4 – Medium Mg - Fine MnO_2, Trial 2

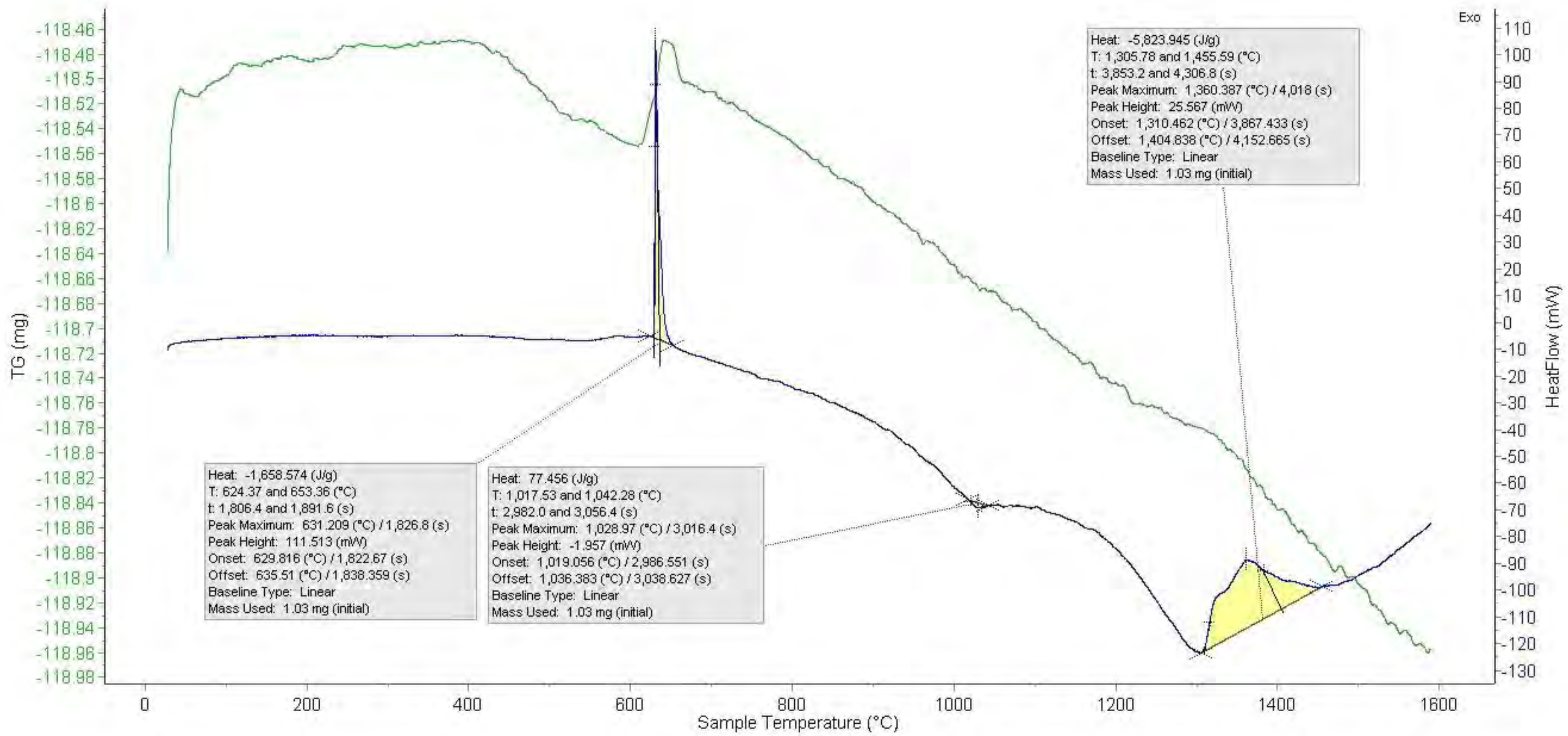


Figure C63: High-Temp DSC Plots for Mix ID SS #4 – Medium Mg - Medium MnO_2, Trial 1

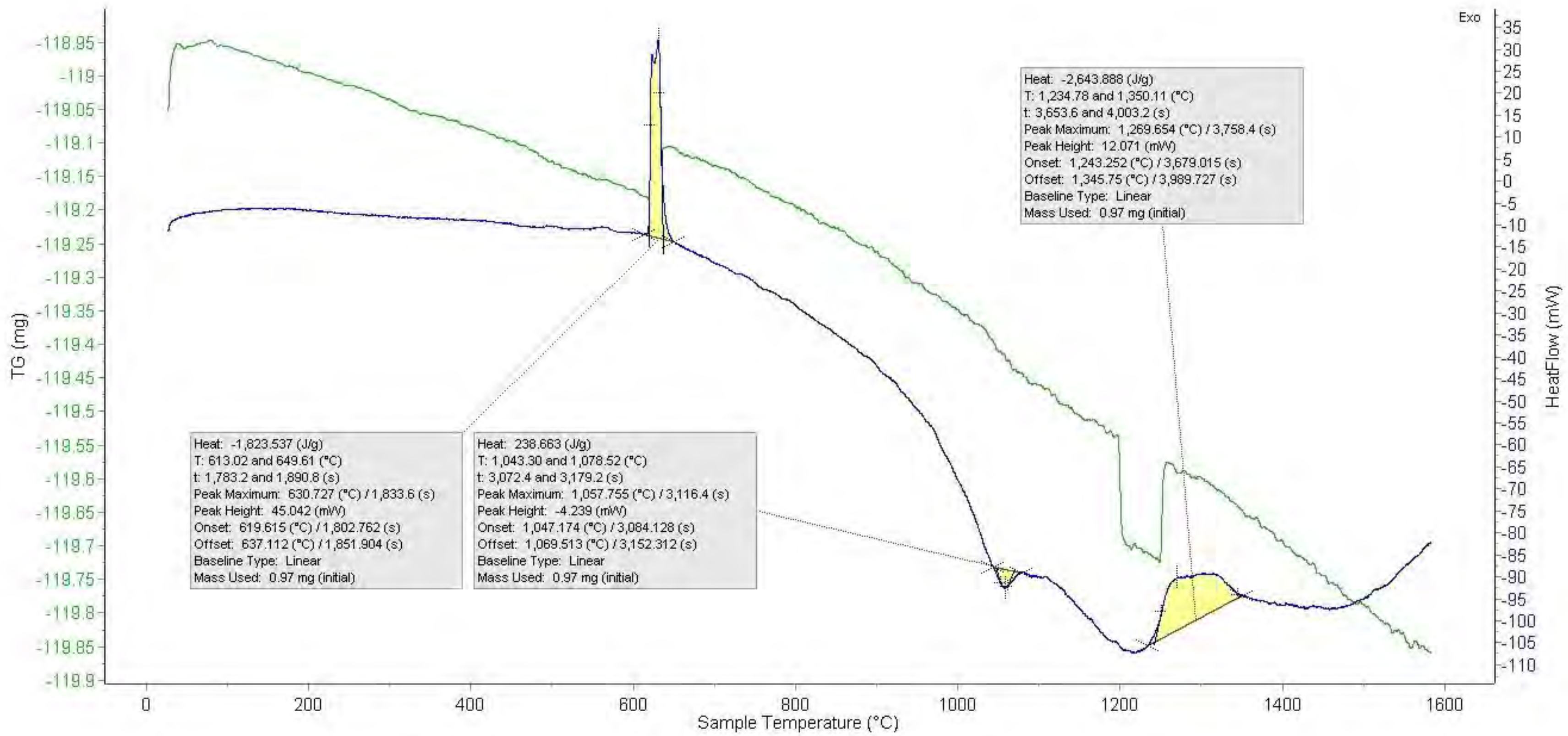


Figure C64: High-Temp DSC Plots for Mix ID SS #4 – Medium Mg - Medium MnO_2, Trial 2

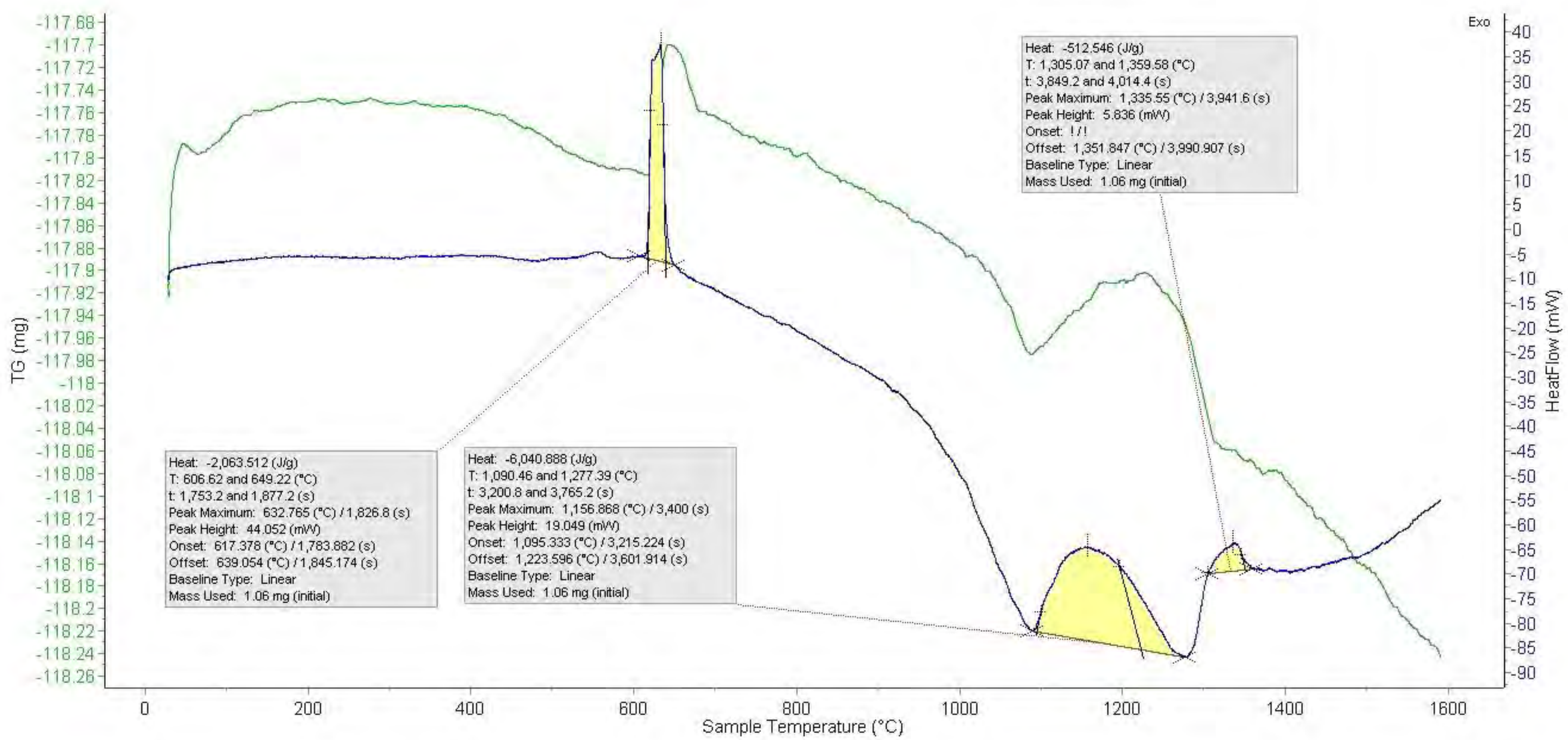


Figure C65: High-Temp DSC Plots for Mix ID SS #4 – Medium Mg - Coarse MnO_2, Trial 1

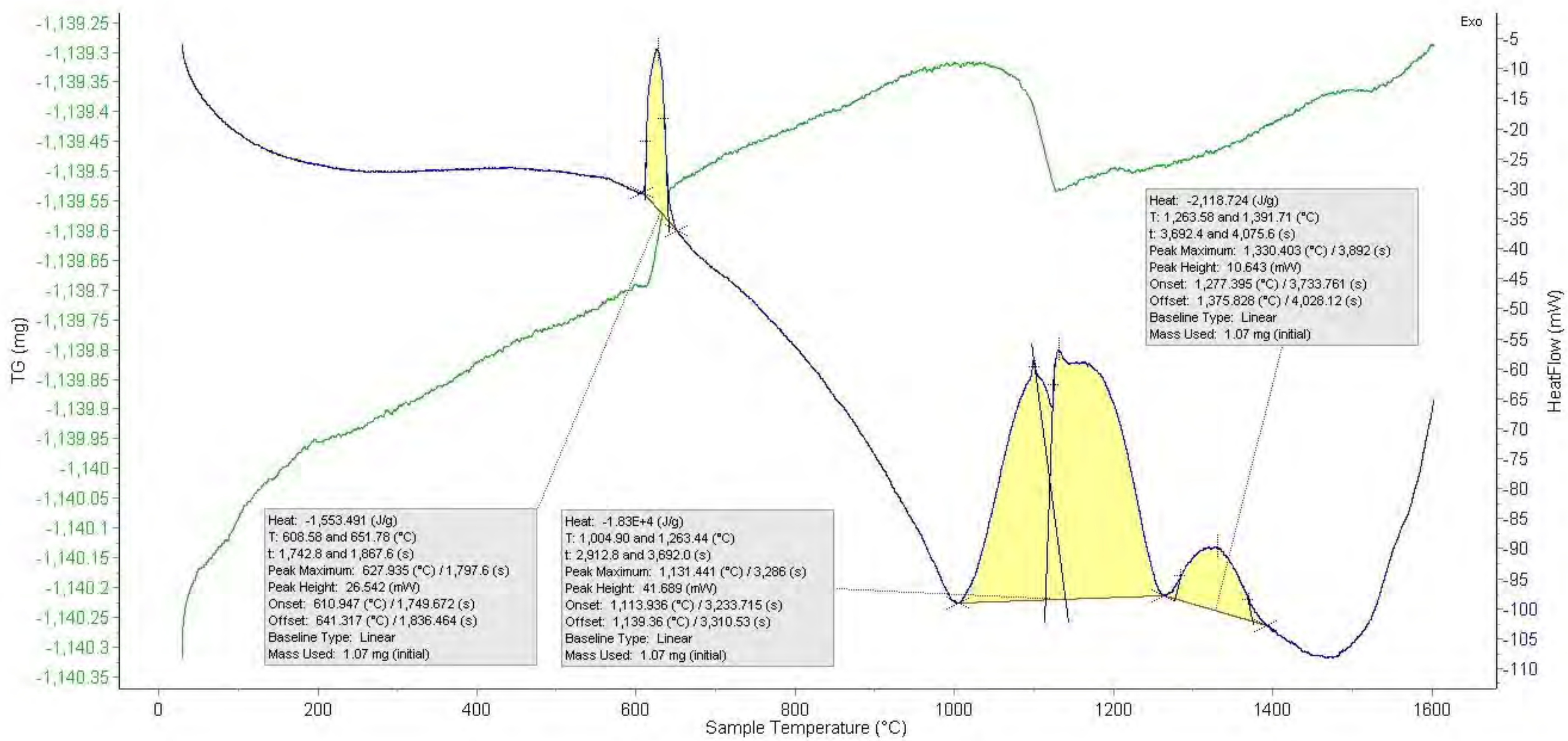


Figure C66: High-Temp DSC Plots for Mix ID SS #4 – Medium Mg - Coarse MnO_2, Trial 2

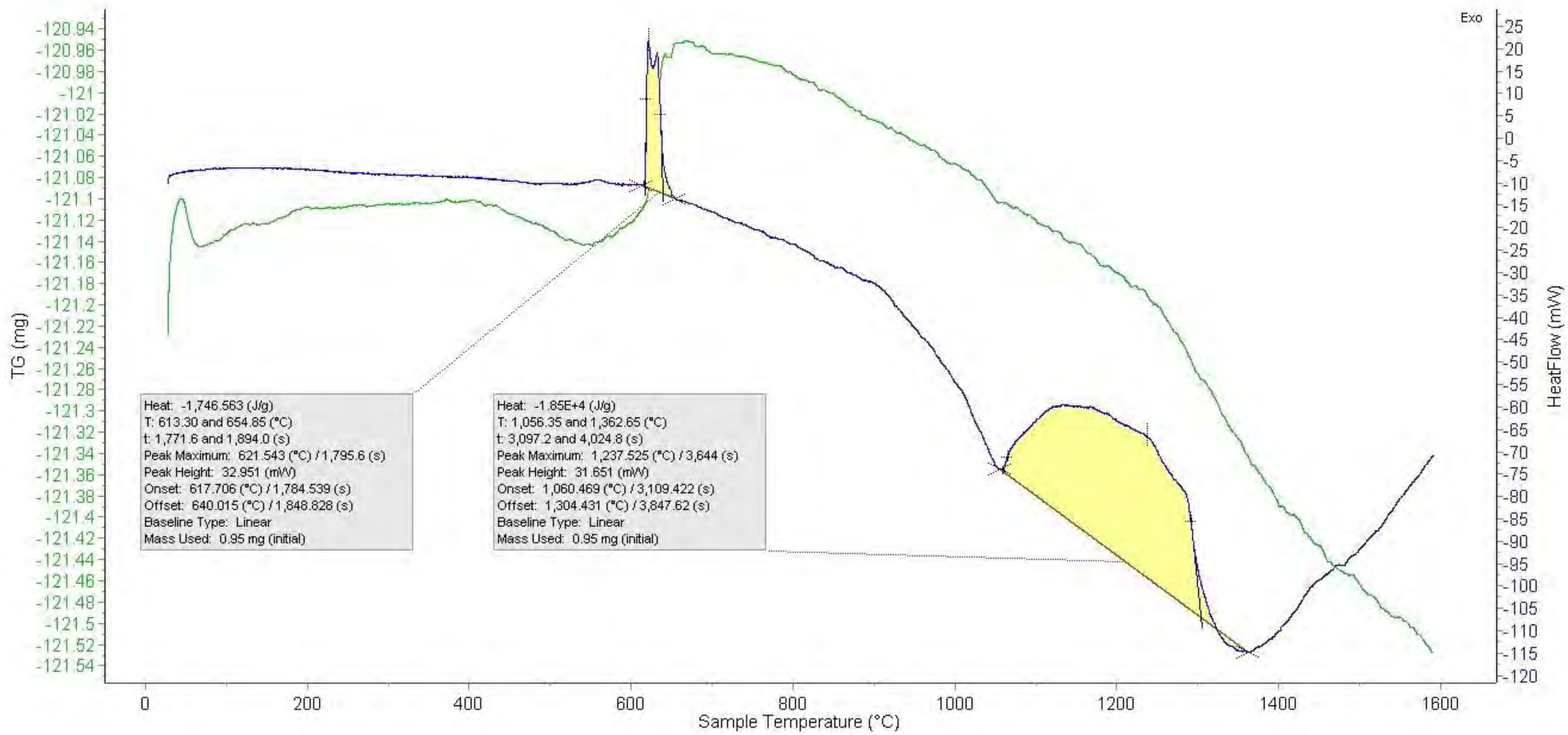


Figure C67: High-Temp DSC Plots for Mix ID SS #4 – Coarse Mg - Fine MnO_2, Trial 1

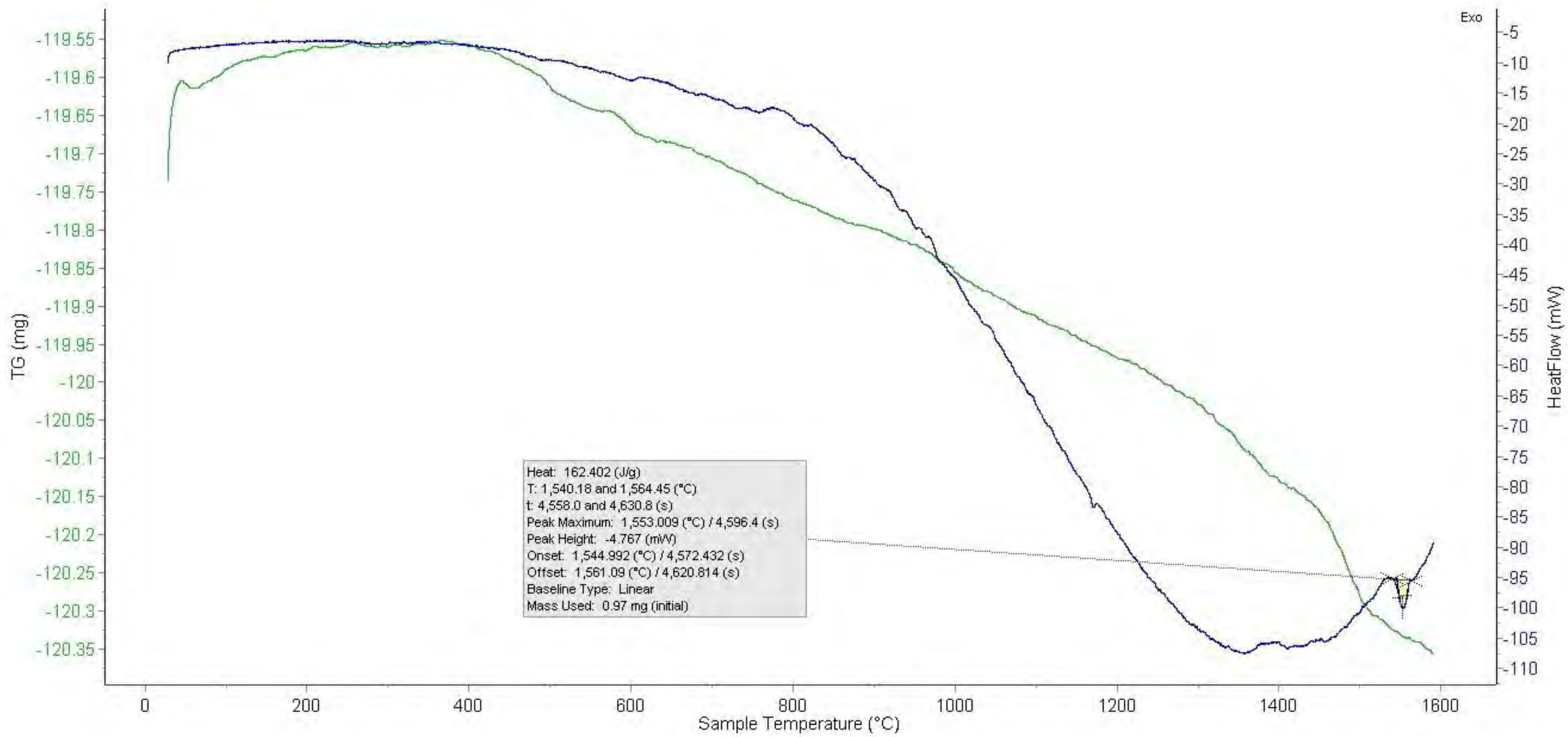


Figure C68: High-Temp DSC Plots for Mix ID SS #4 – Coarse Mg - Fine MnO_2, Trial 2

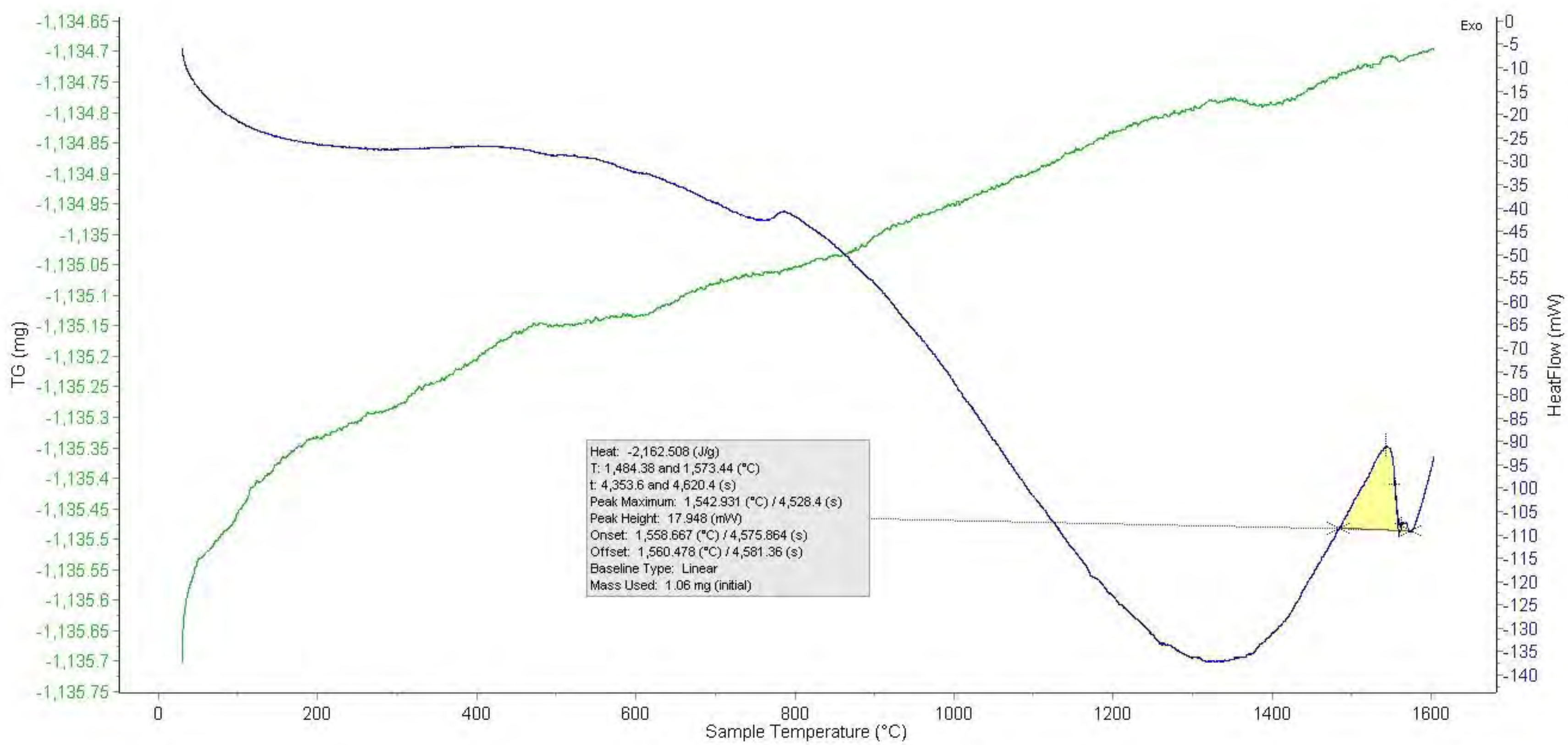


Figure C69: High-Temp DSC Plots for Mix ID SS #4 – Coarse Mg - Medium MnO_2, Trial 1

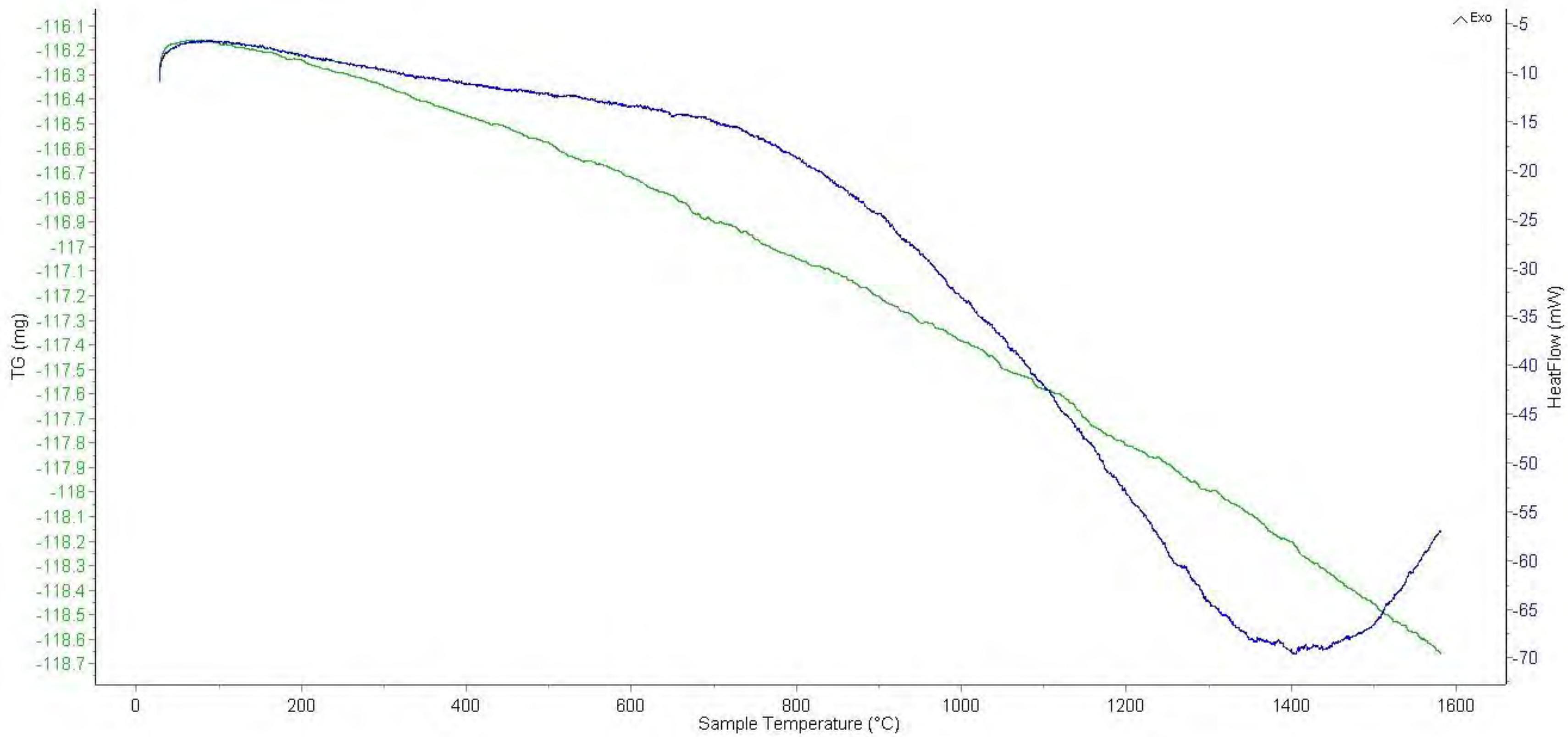


Figure C70: High-Temp DSC Plots for Mix ID SS #4 – Coarse Mg - Medium MnO_2, Trial 2

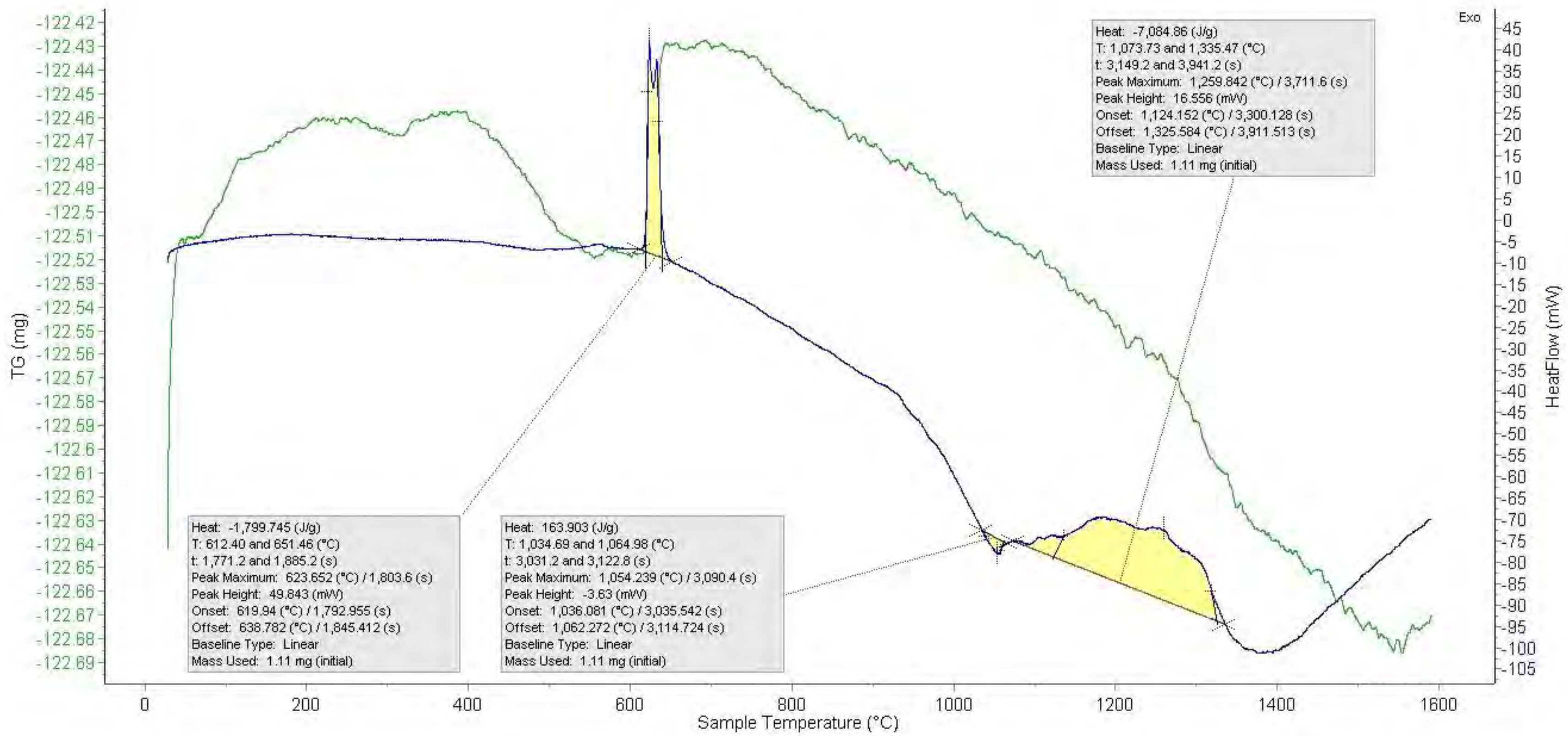


Figure C71: High-Temp DSC Plots for Mix ID SS #4 – Coarse Mg - Coarse MnO_2, Trial 1

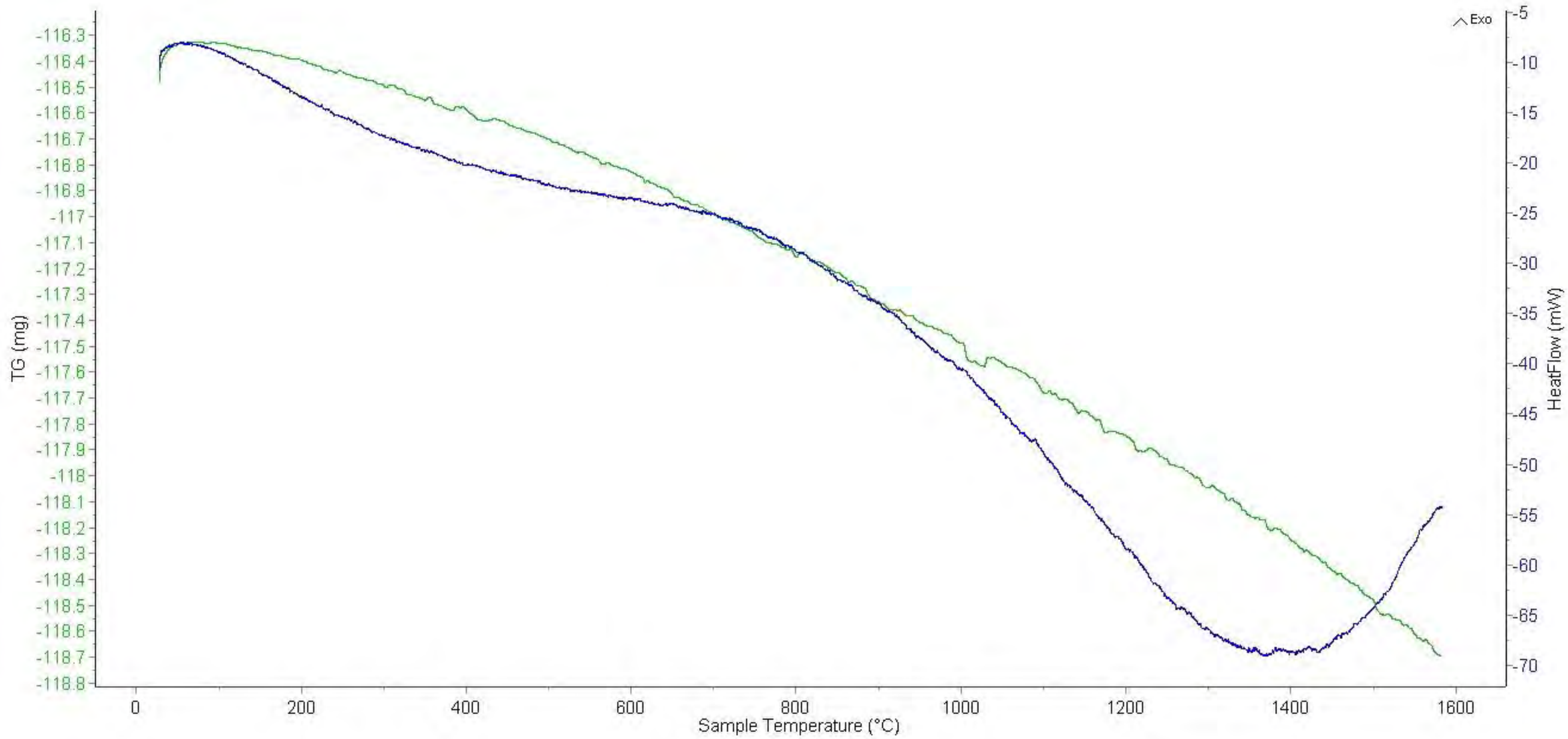


Figure C72: High-Temp DSC Plots for Mix ID SS #4 – Coarse Mg - Coarse MnO_2, Trial 2

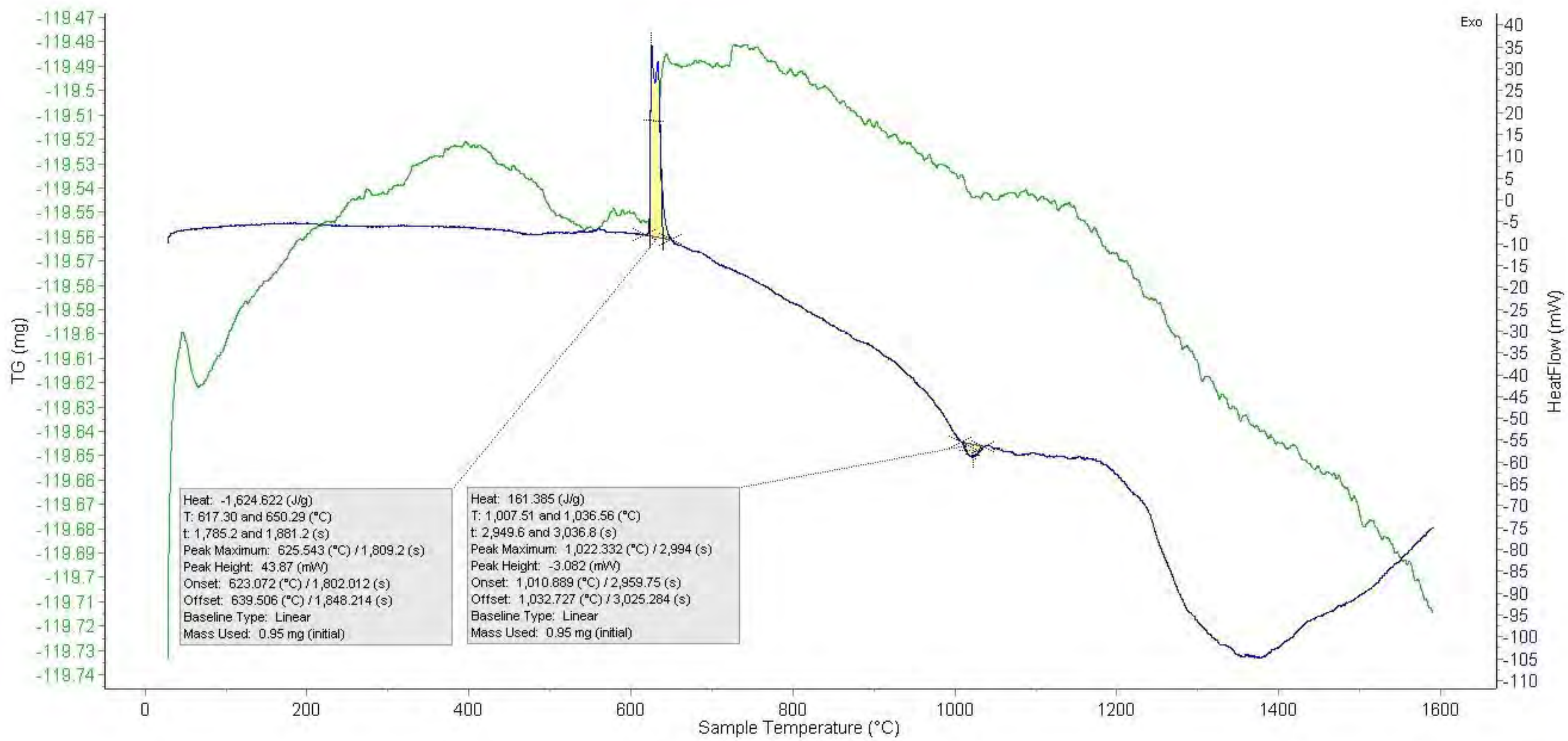


Figure C73: High-Temp DSC Plots for Mix ID SS #9 – Fine Al - Fine MoO_3, Trial 1

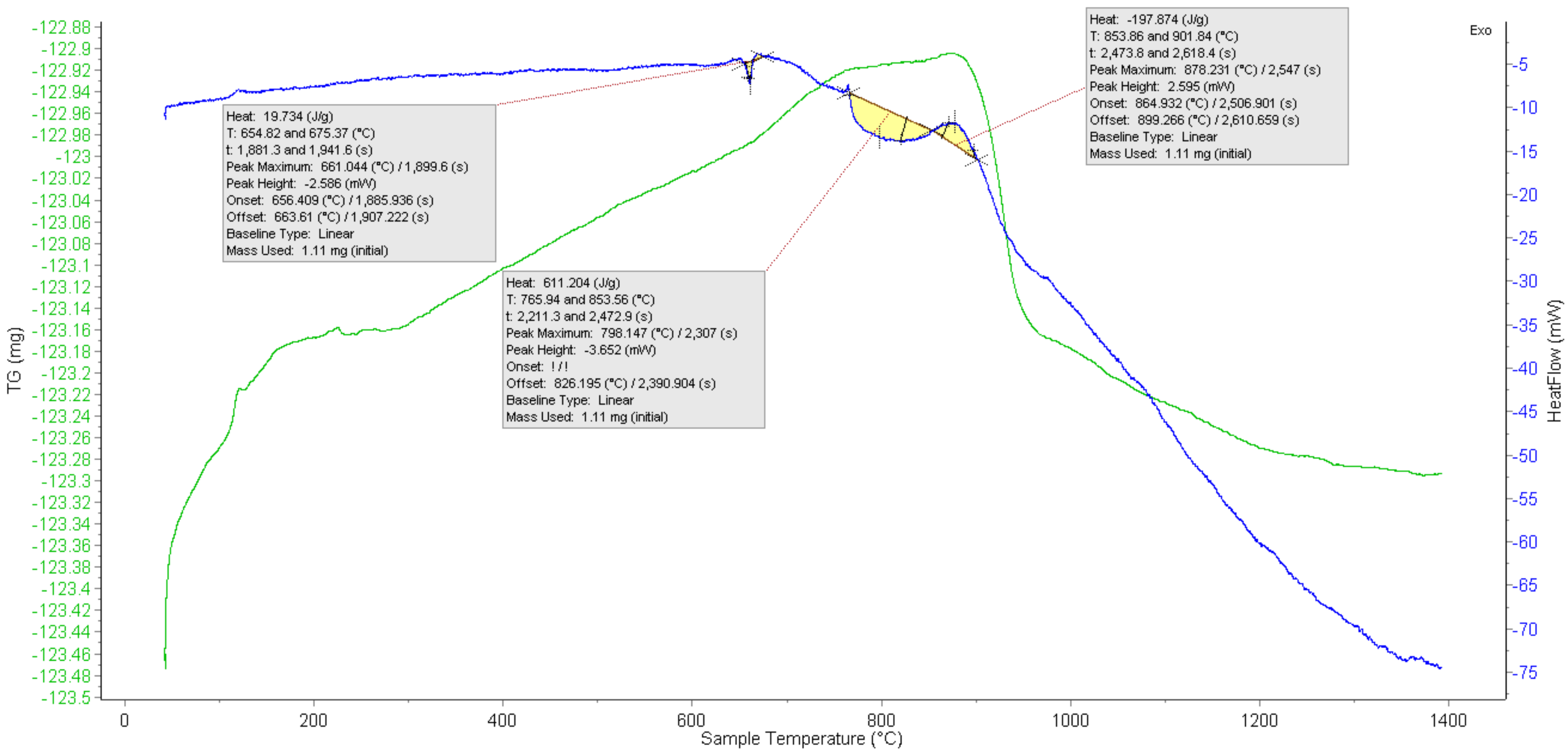


Figure C74: High-Temp DSC Plots for Mix ID SS #9 – Fine Al - Fine MoO_3, Trial 2

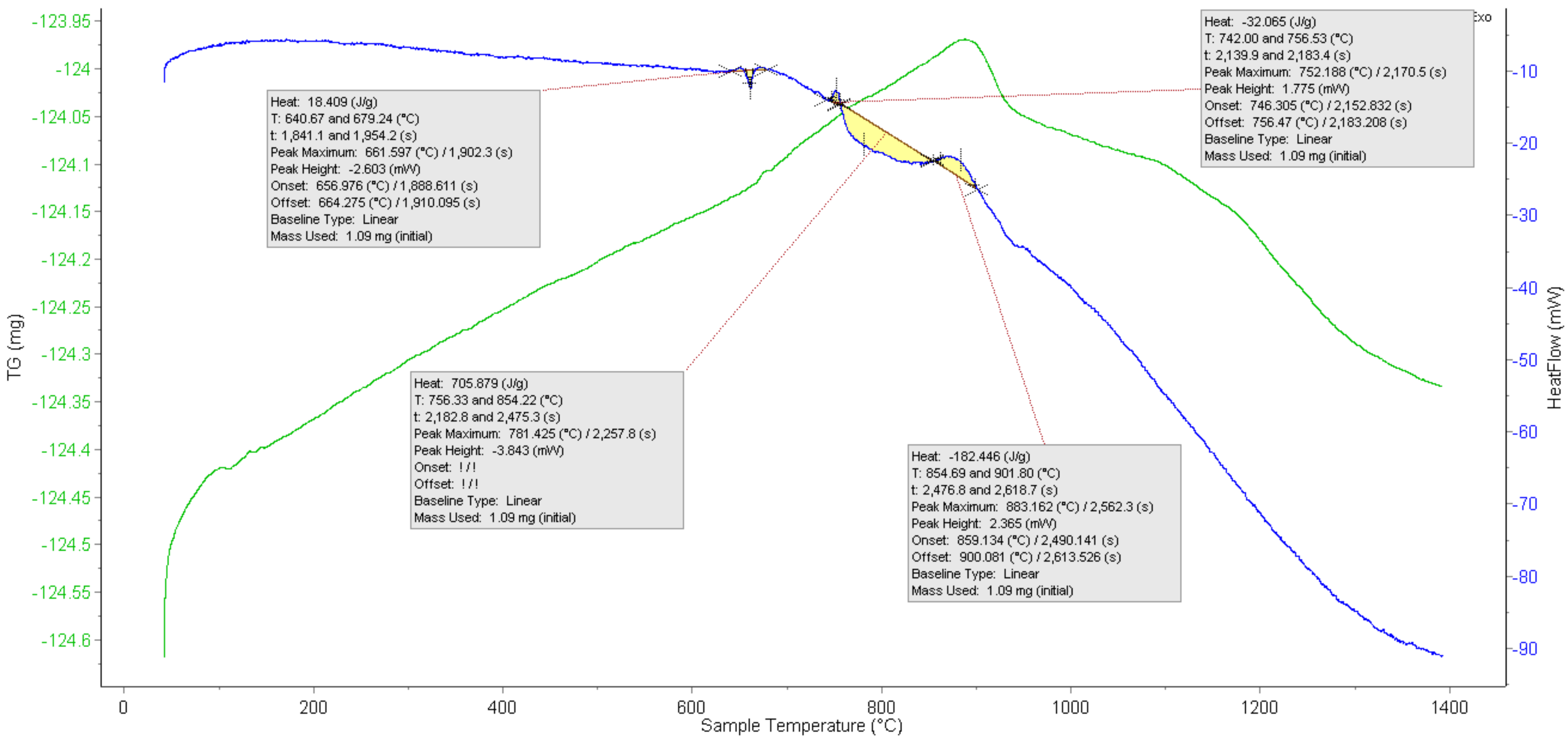


Figure C75: High-Temp DSC Plots for Mix ID SS #9 – Fine Al - Medium MoO_3, Trial 1

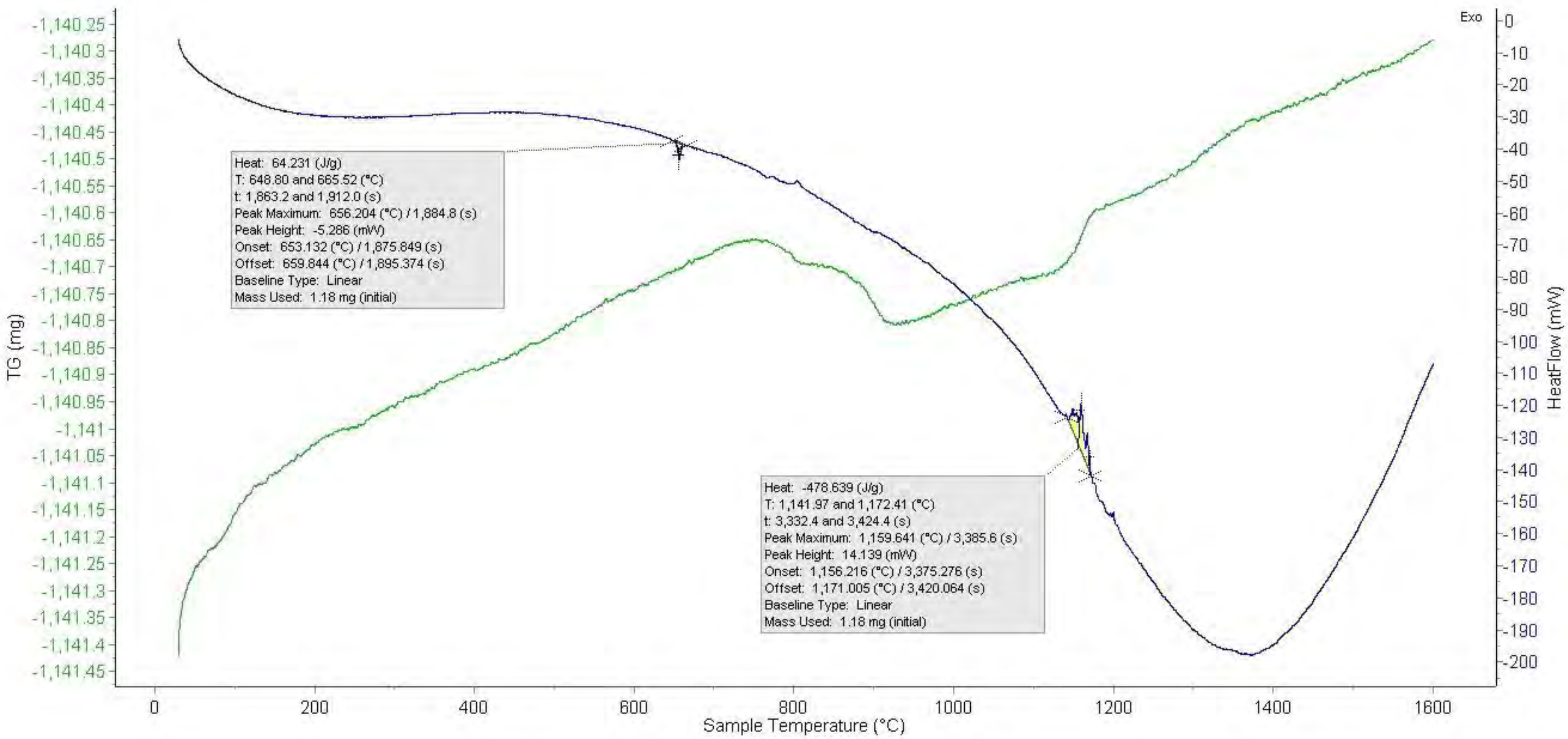


Figure C76: High-Temp DSC Plots for Mix ID SS #9 – Fine Al - Medium MoO_3, Trial 2

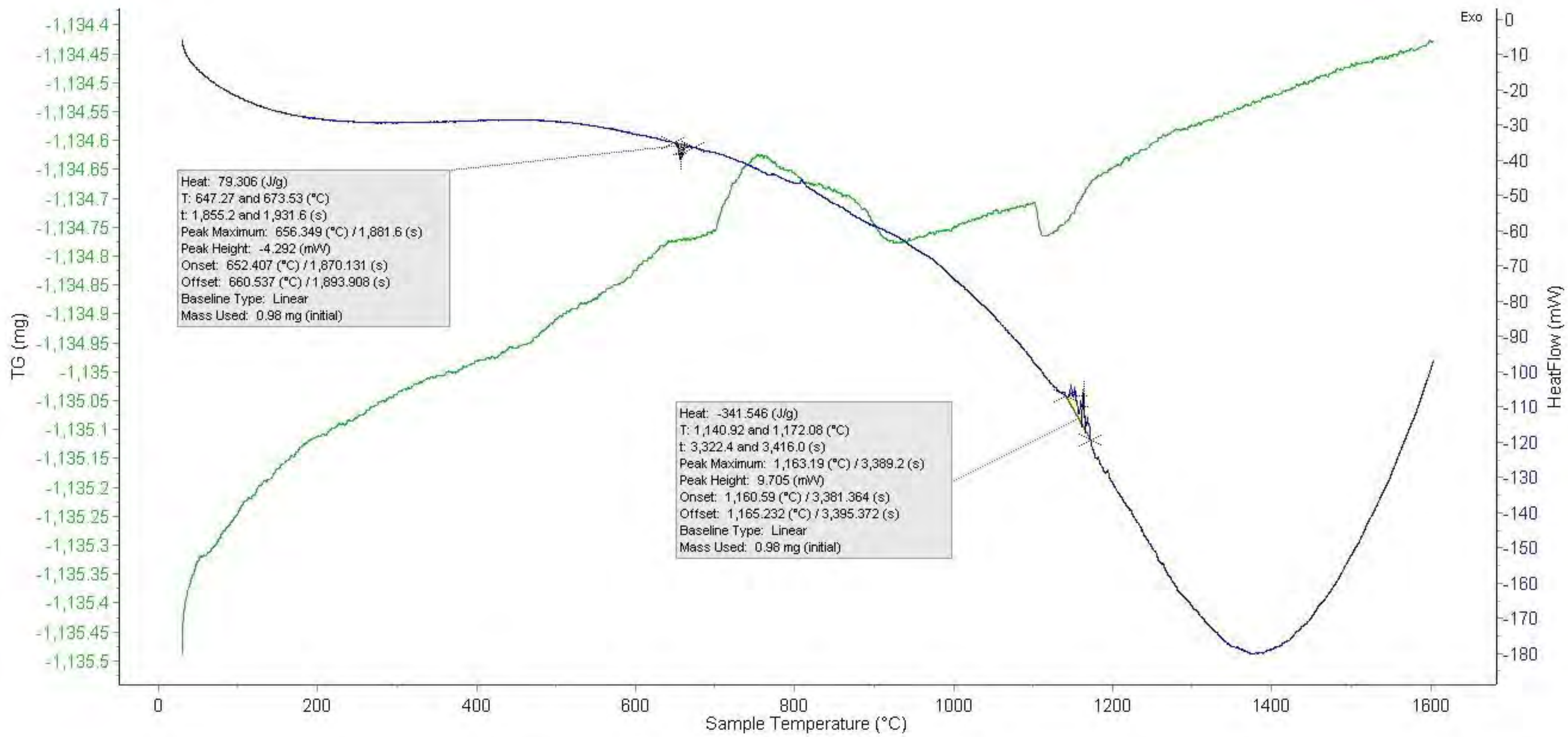


Figure C77: High-Temp DSC Plots for Mix ID SS #9 – Fine Al - Coarse MoO_3, Trial 1

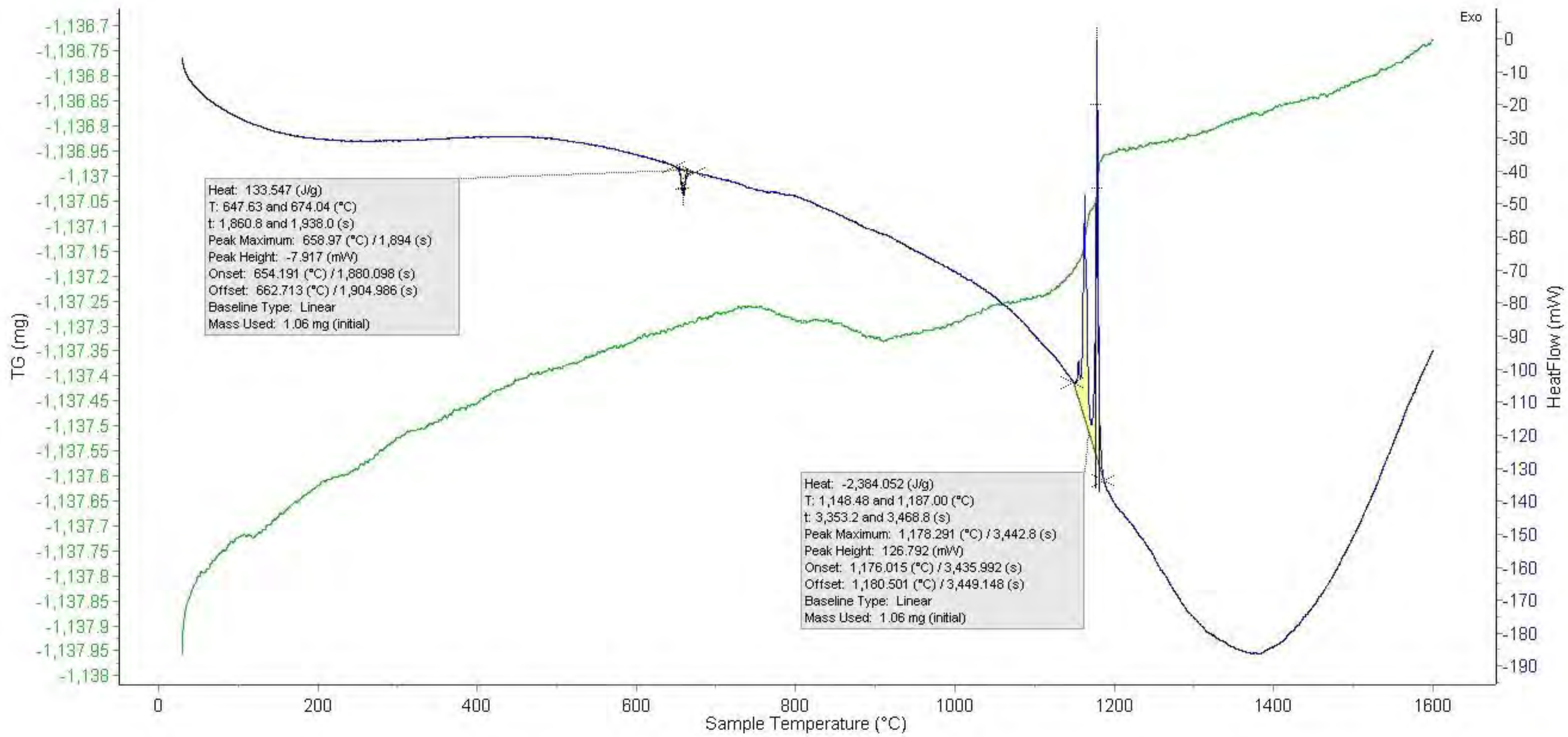


Figure C78: High-Temp DSC Plots for Mix ID SS #9 – Fine Al - Coarse MoO_3, Trial 2

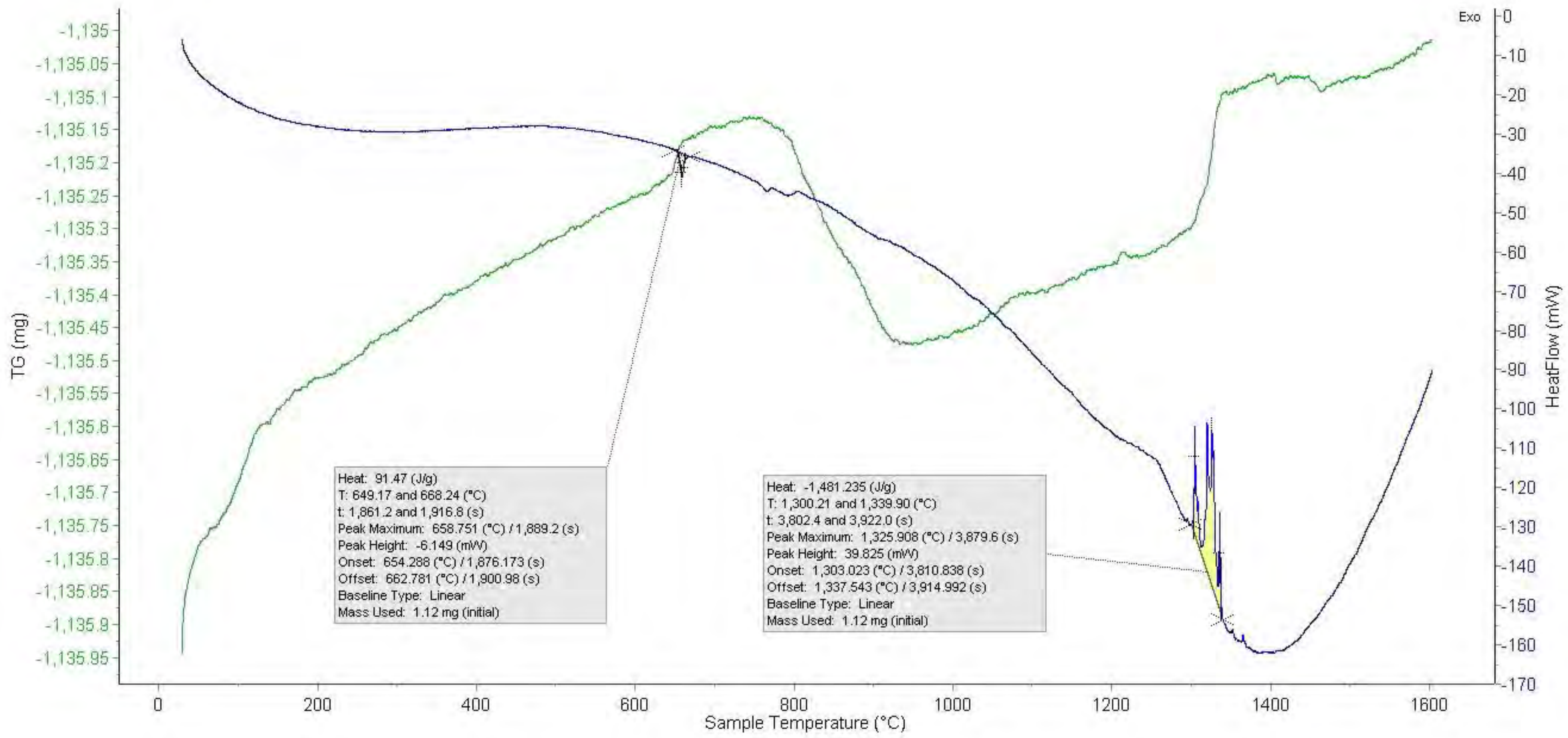


Figure C79: High-Temp DSC Plots for Mix ID SS #9 – Medium Al - Fine MoO_3, Trial 1

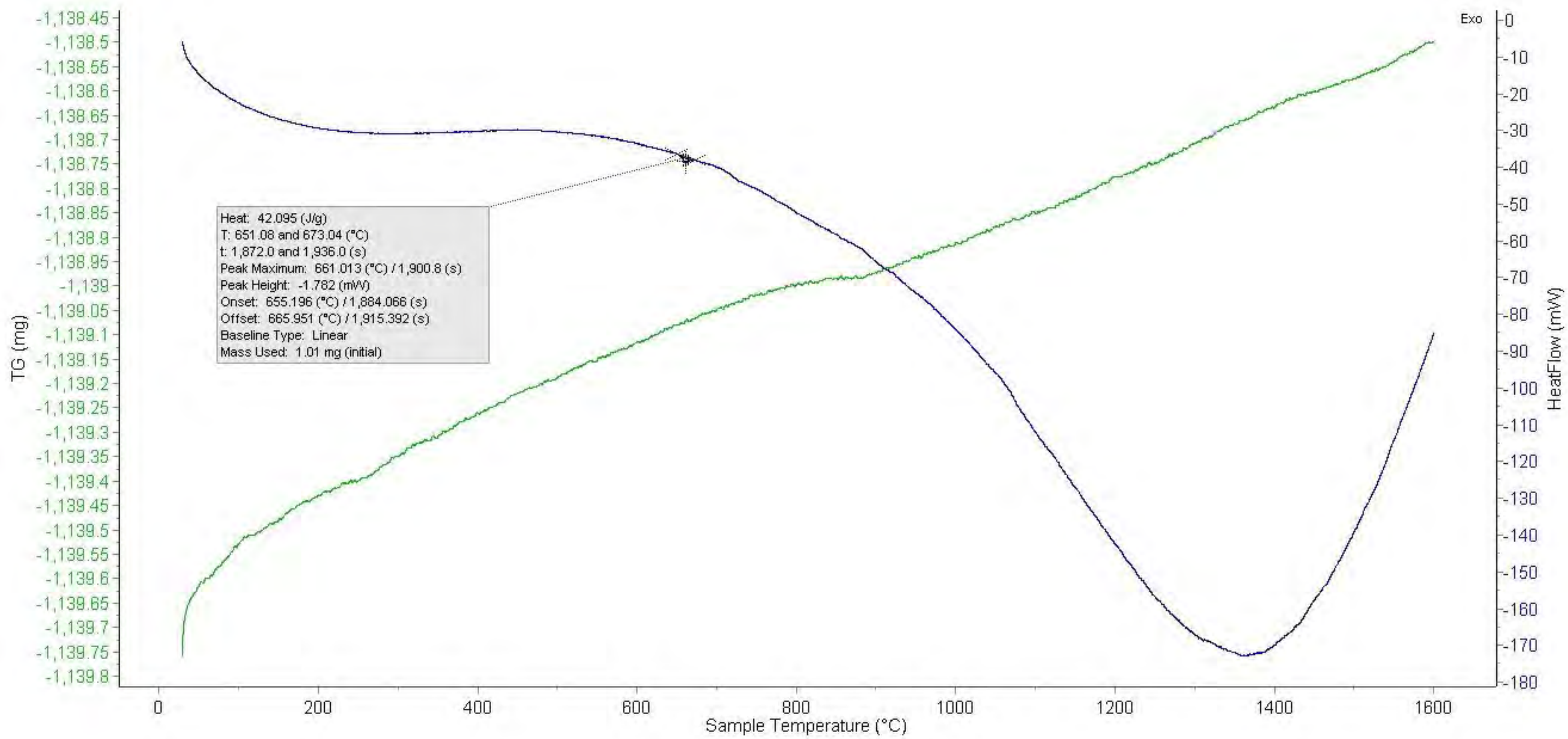


Figure C80: High-Temp DSC Plots for Mix ID SS #9 – Medium Al - Fine MoO_3, Trial 2

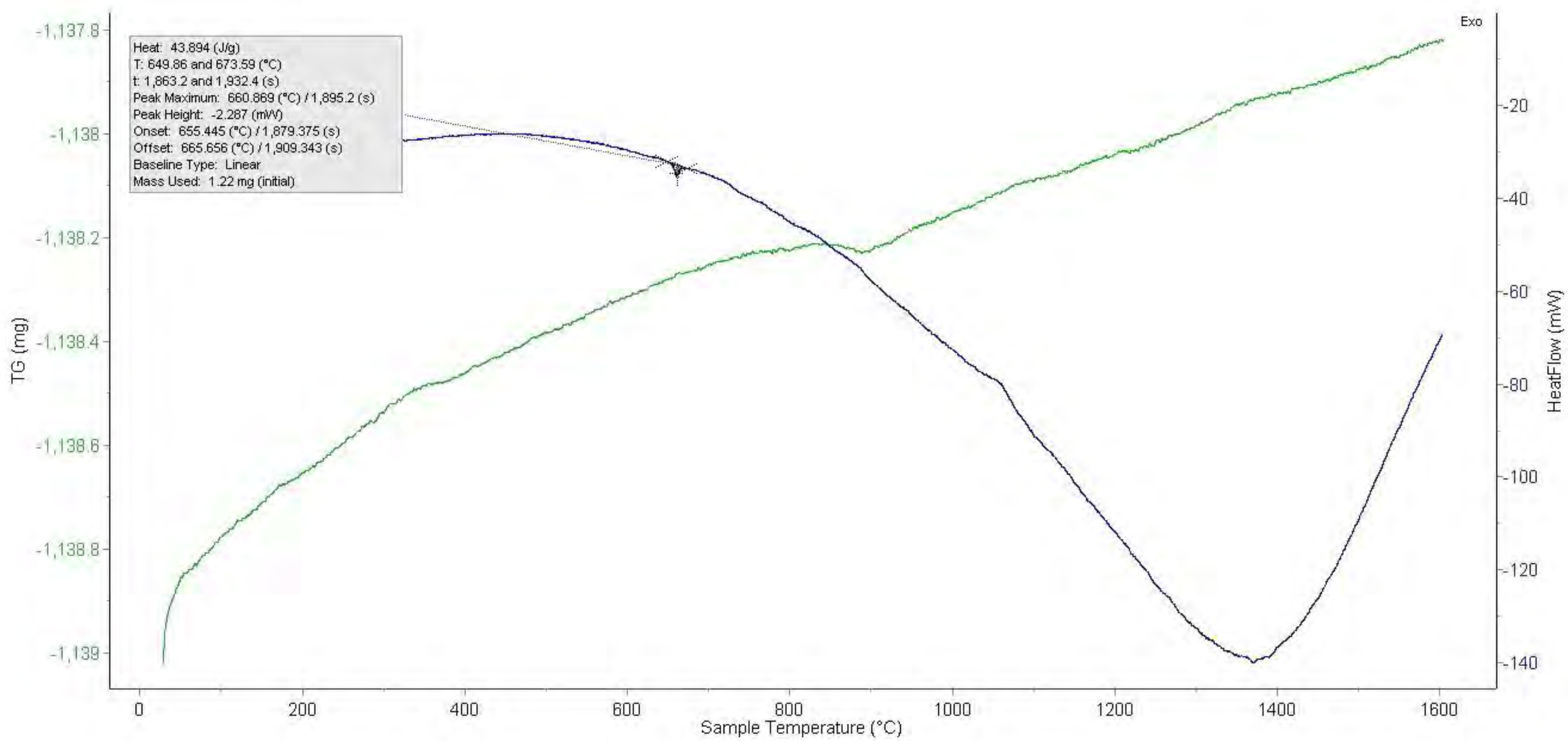


Figure C81: High-Temp DSC Plots for Mix ID SS #9 – Medium Al - Medium MoO_3, Trial 1

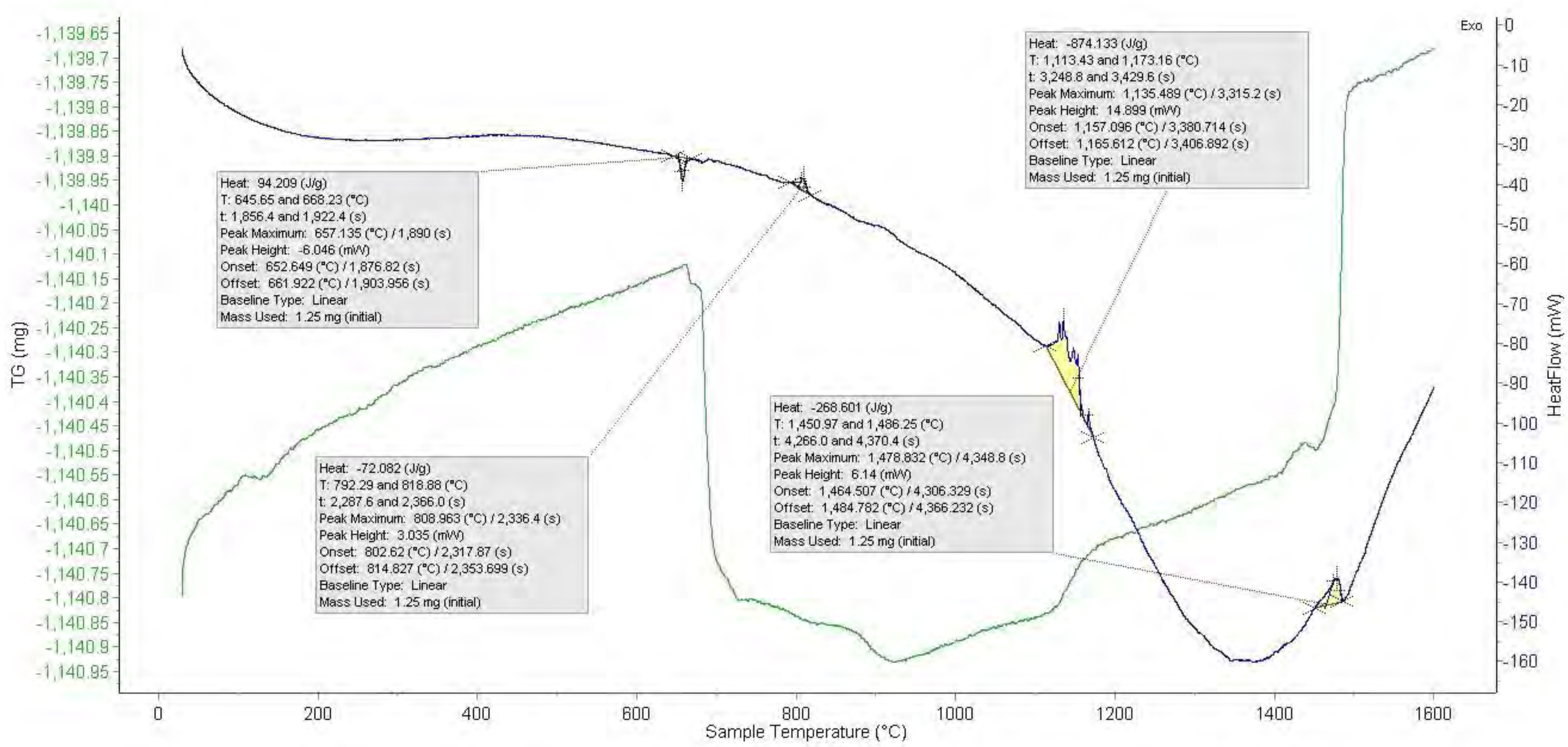


Figure C82: High-Temp DSC Plots for Mix ID SS #9 – Medium Al - Medium MoO_3, Trial 2

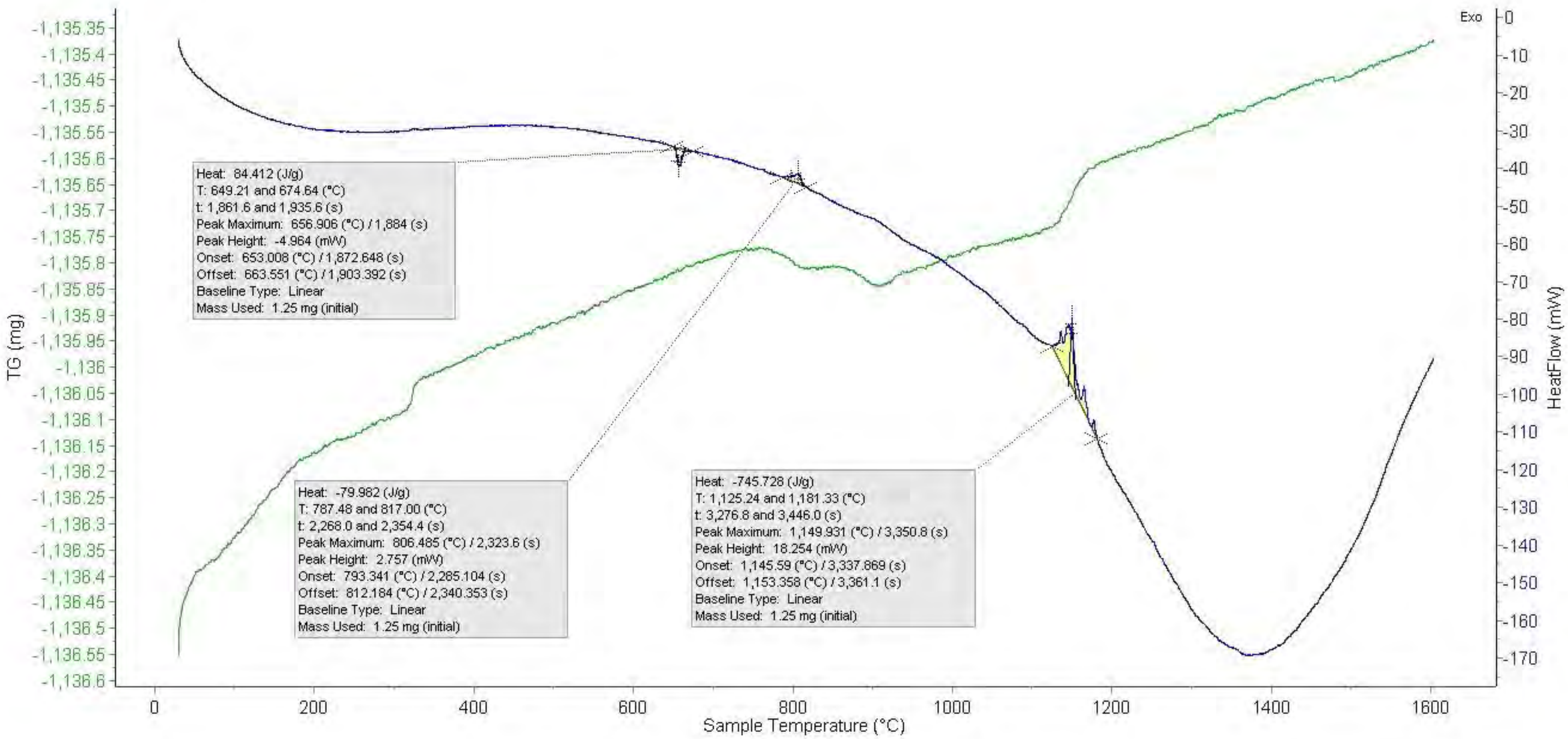


Figure C83: High-Temp DSC Plots for Mix ID SS #9 – Medium Al - Coarse MoO_3, Trial 1

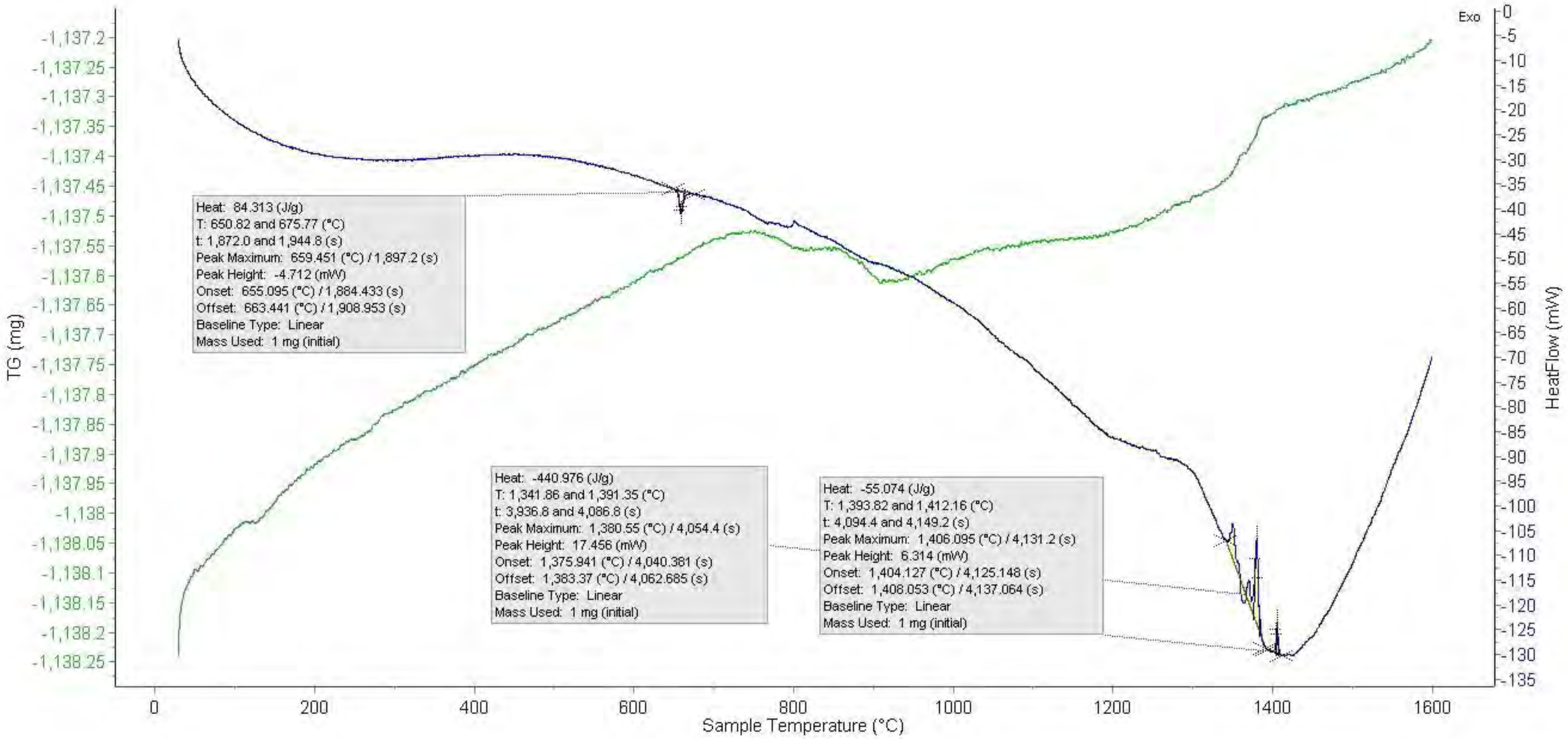


Figure C84: High-Temp DSC Plots for Mix ID SS #9 – Medium Al - Coarse MoO_3, Trial 2

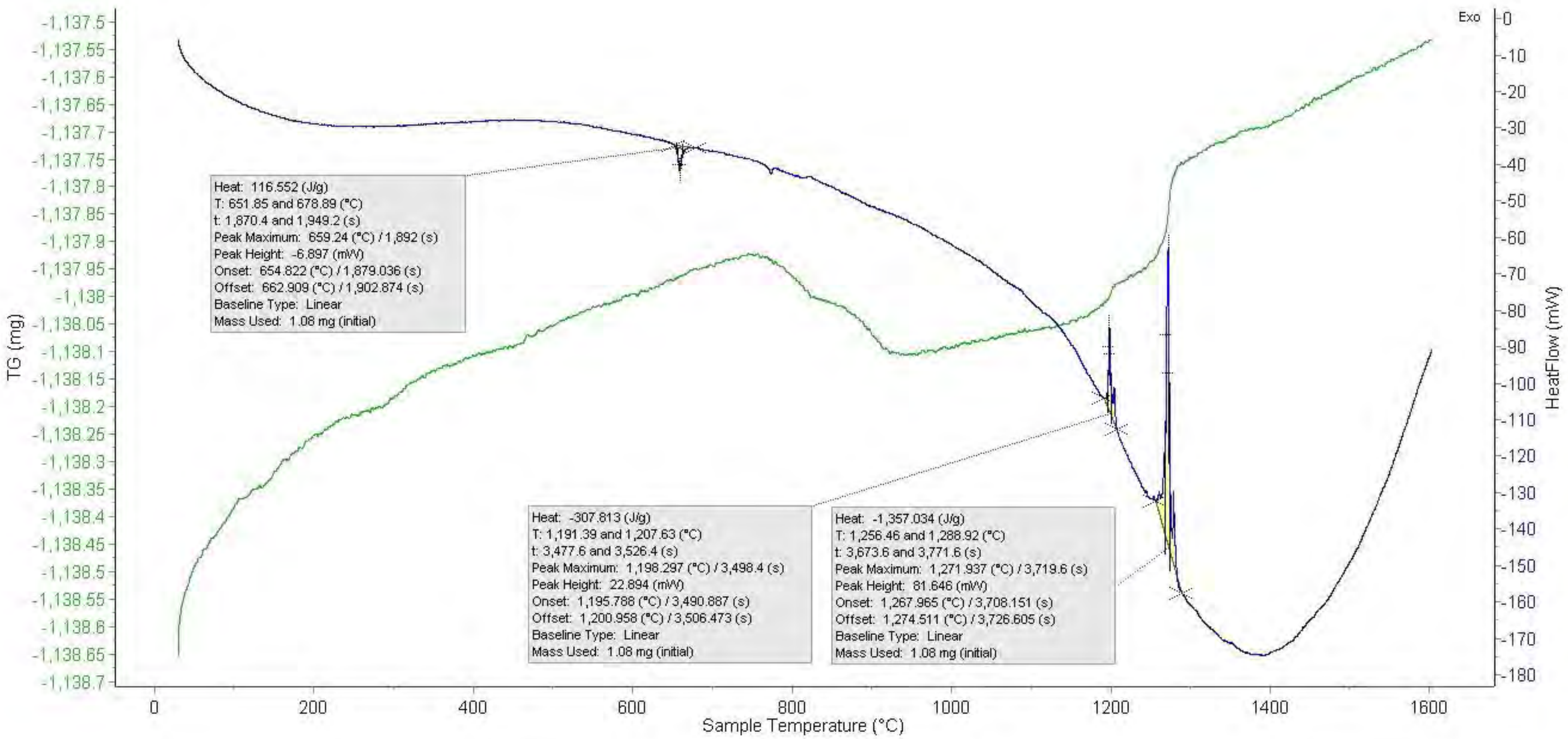


Figure C85: High-Temp DSC Plots for Mix ID SS #9 – Coarse Al - Fine MoO_3, Trial 1

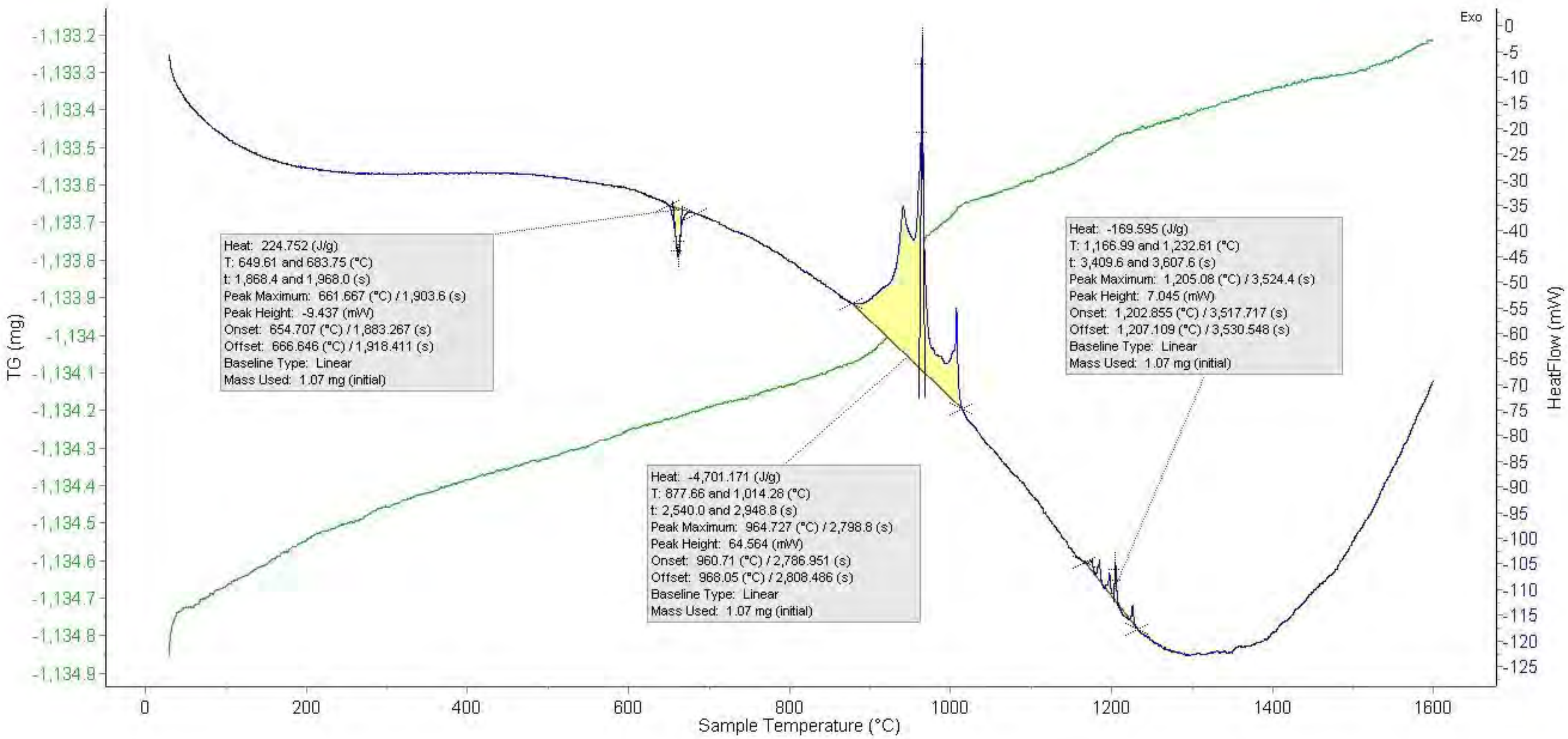


Figure C86: High-Temp DSC Plots for Mix ID SS #9 – Coarse Al - Fine MoO_3, Trial 2

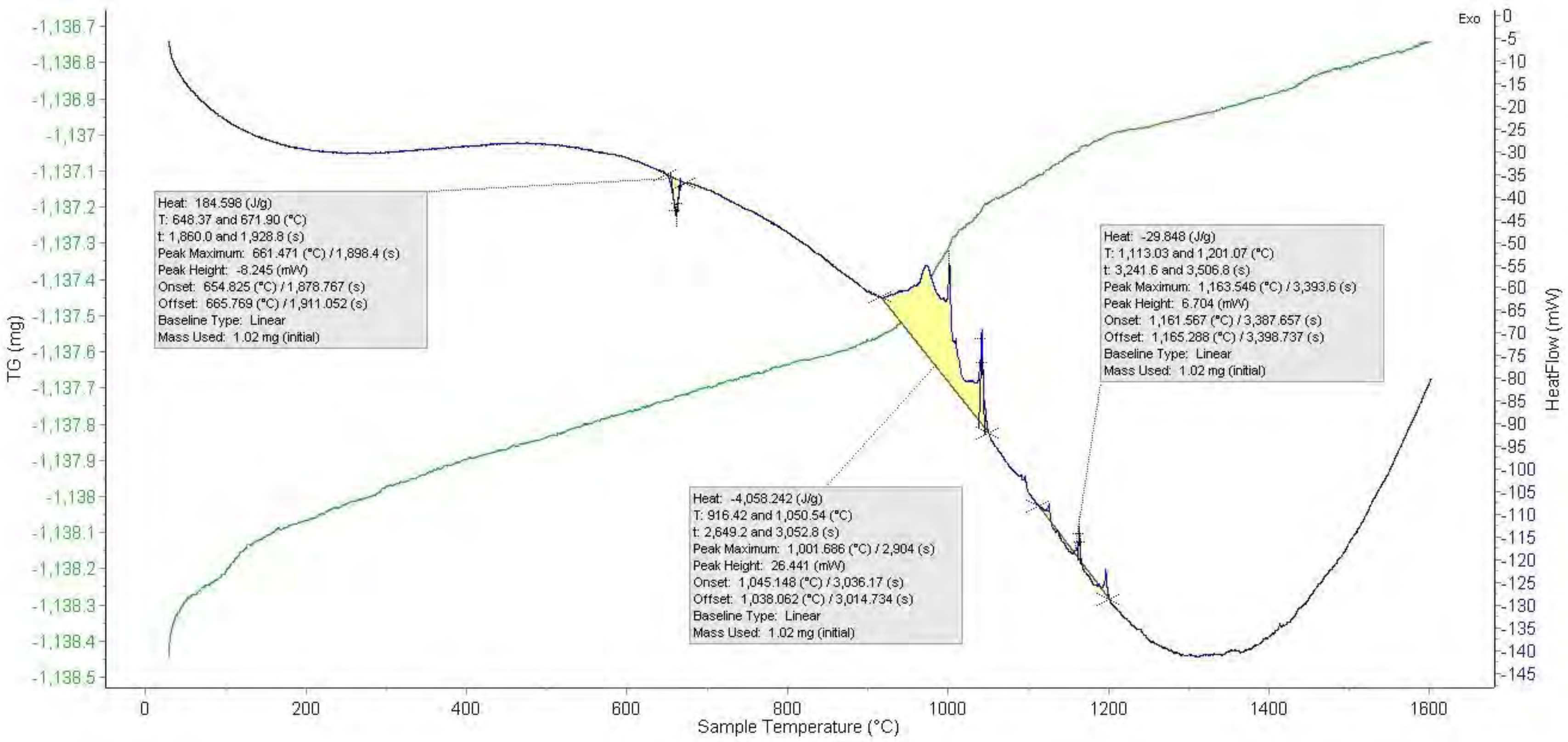


Figure C87: High-Temp DSC Plots for Mix ID SS #9 – Coarse Al - Medium MoO_3, Trial 1

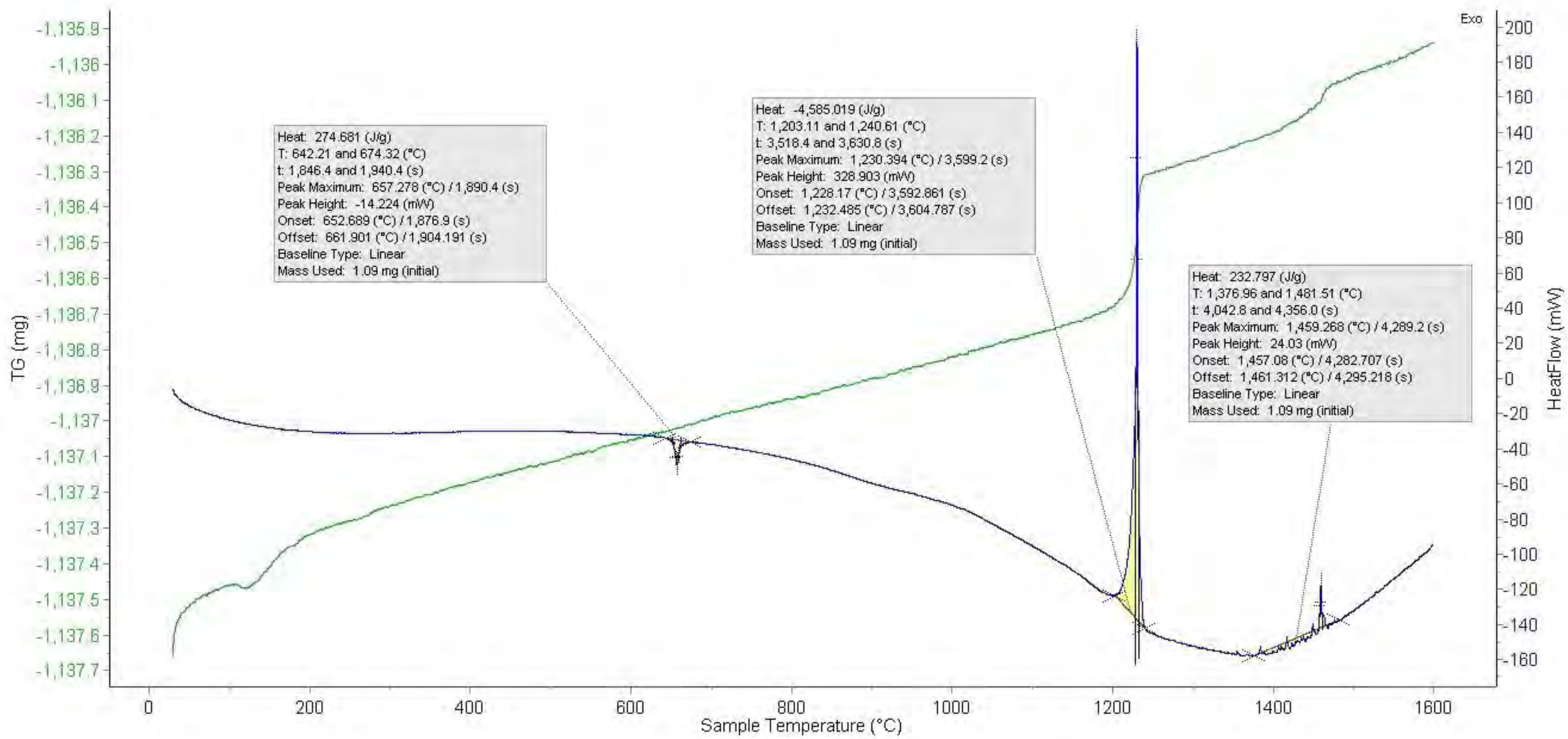


Figure C88: High-Temp DSC Plots for Mix ID SS #9 – Coarse Al - Medium MoO_3, Trial 2

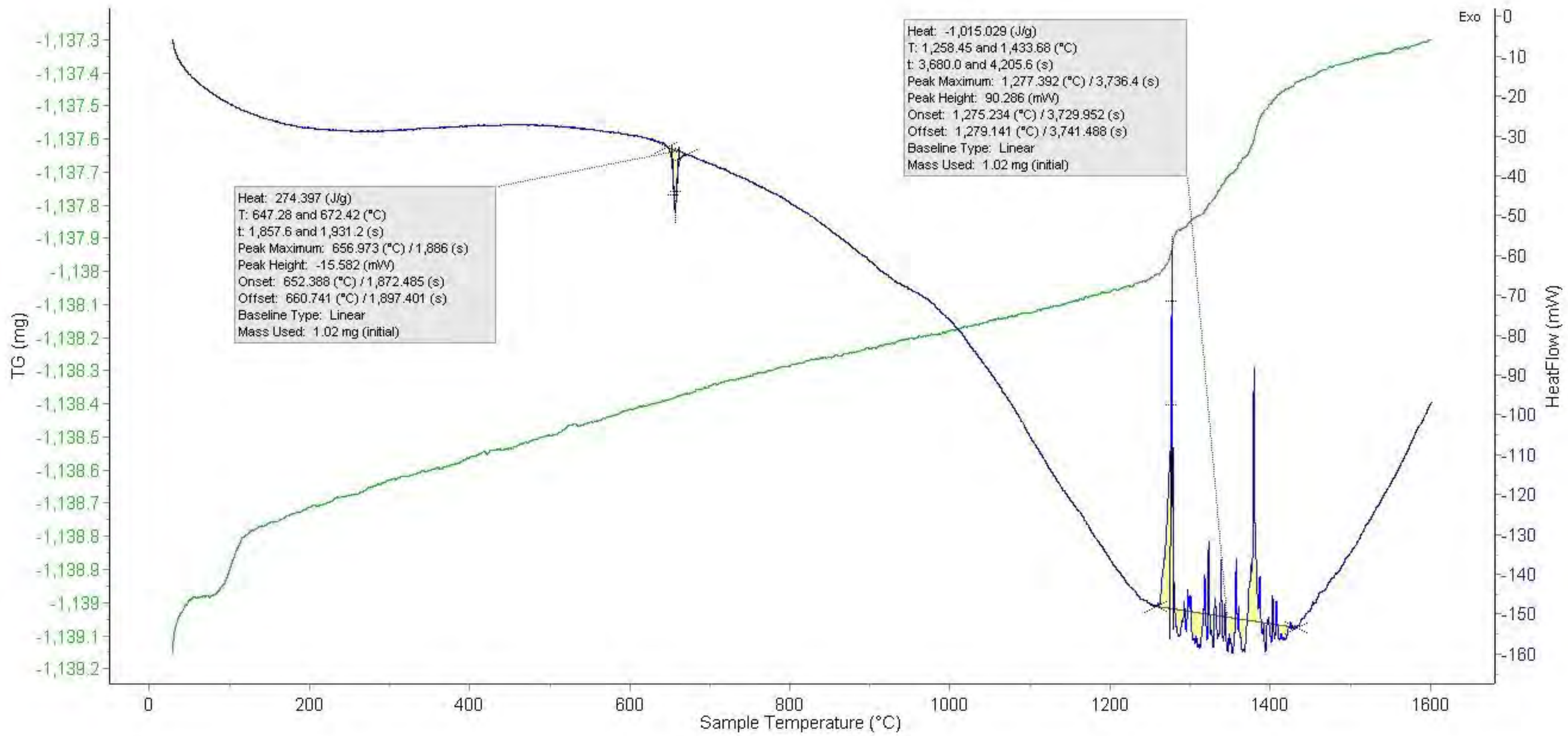


Figure C89: High-Temp DSC Plots for Mix ID SS #9 – Coarse Al - Coarse MoO_3, Trial 1

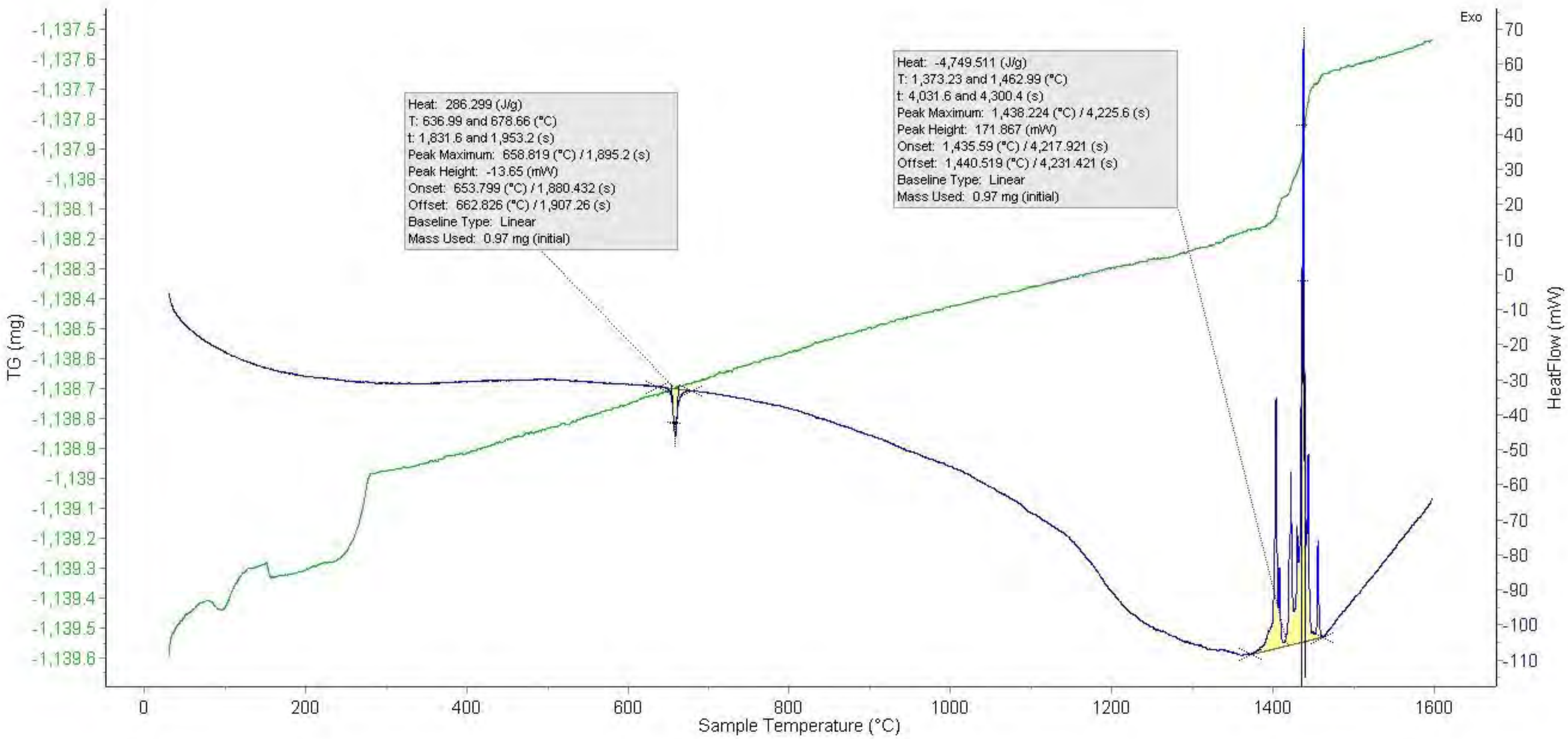


Figure C90: High-Temp DSC Plots for Mix ID SS #9 – Coarse Al - Coarse MoO_3, Trial 2

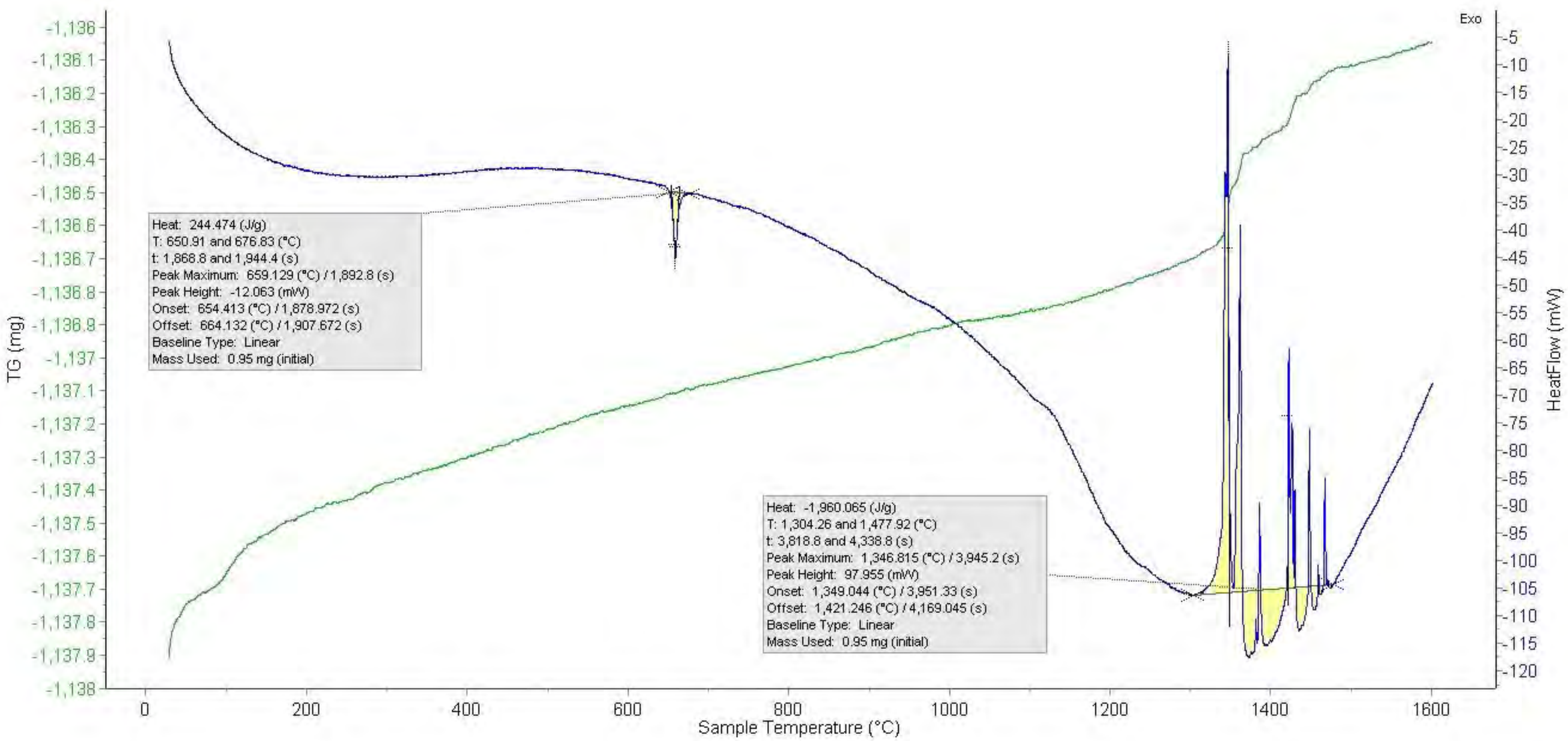


Figure C91: High-Temp DSC Plots for Mix ID SS #19 – Fine Al - Fine SnO_2, Trial 1

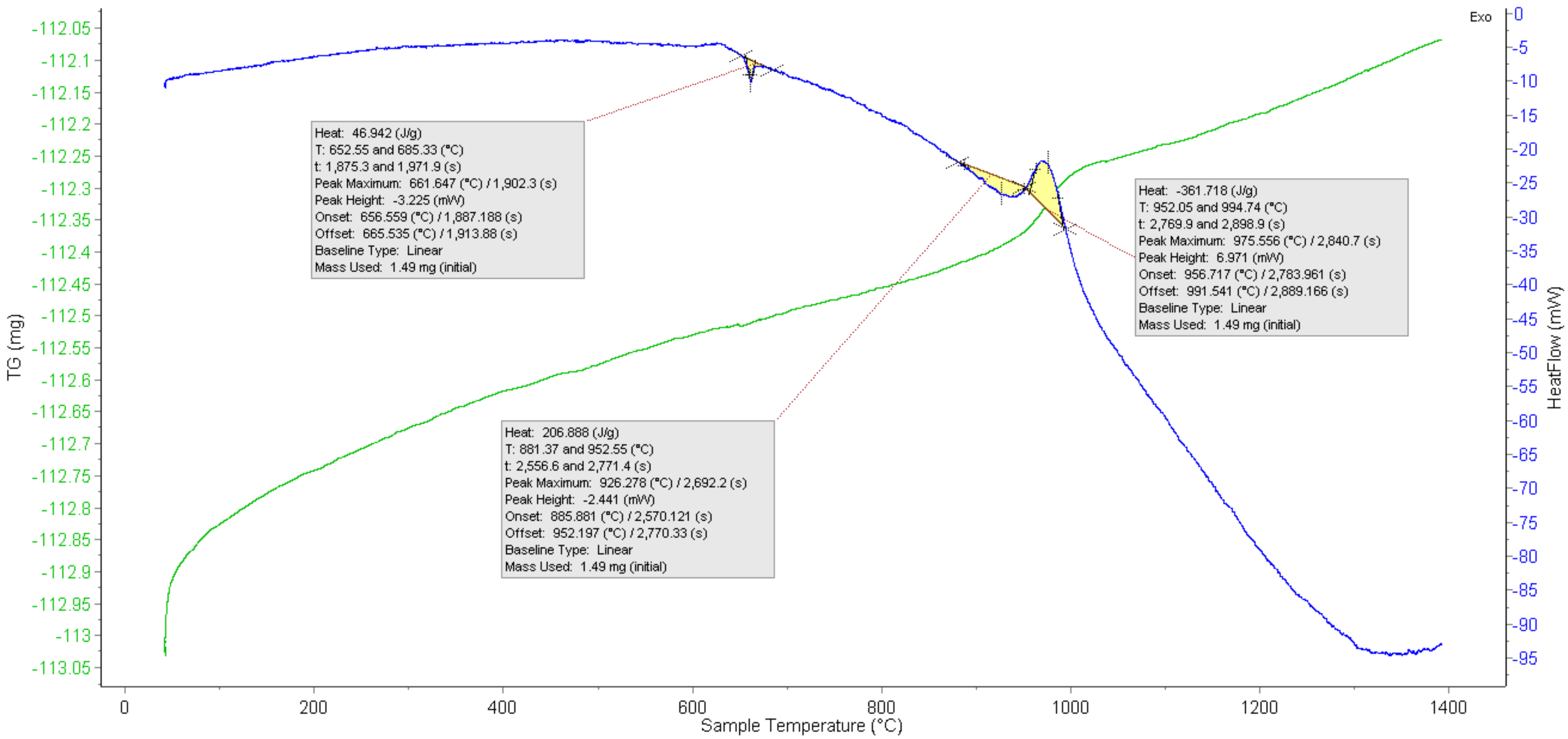


Figure C92: High-Temp DSC Plots for Mix ID SS #19 – Fine Al - Fine SnO_2, Trial 2

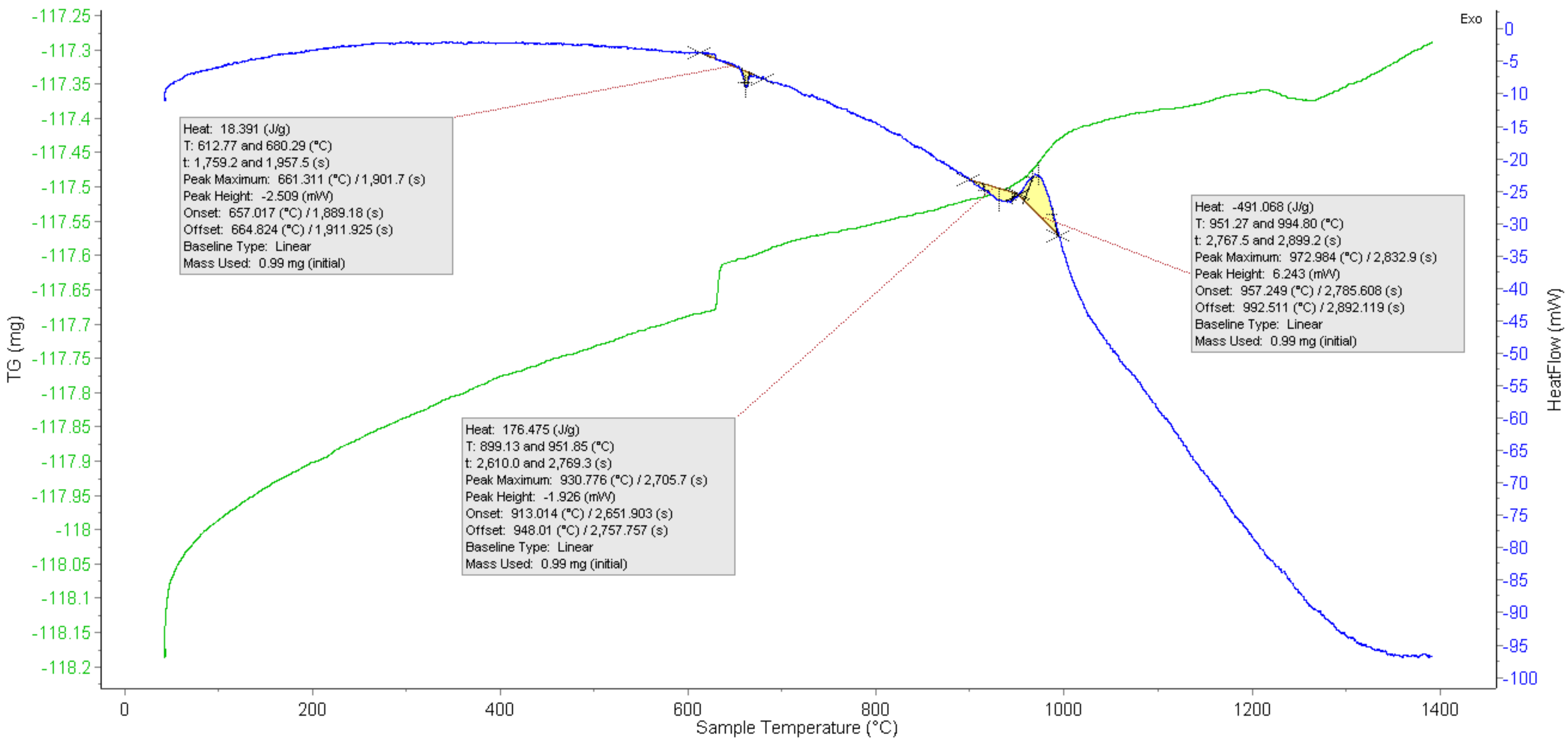


Figure C93: High-Temp DSC Plots for Mix ID SS #19 – Fine Al - Medium SnO_2, Trial 1

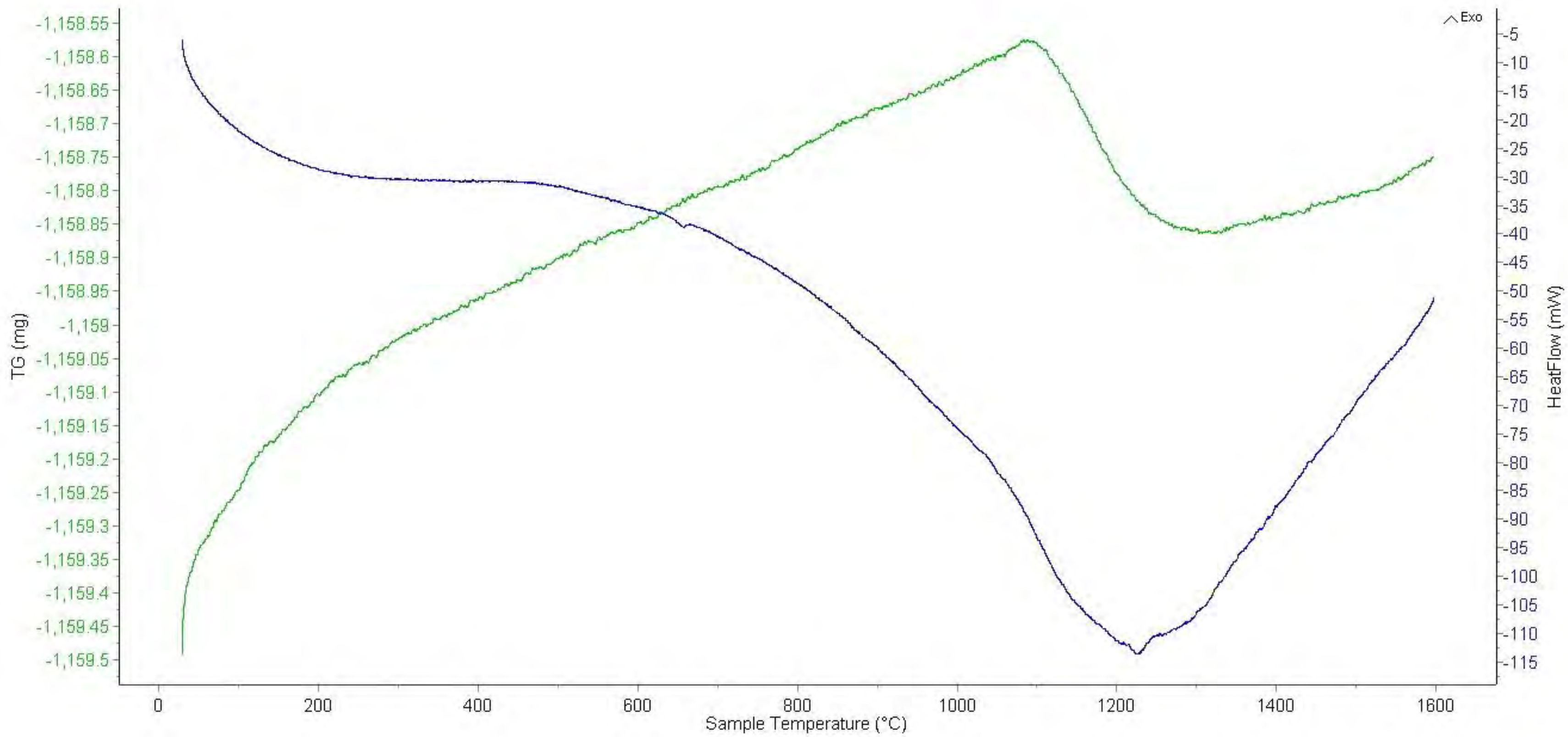


Figure C94: High-Temp DSC Plots for Mix ID SS #19 – Fine Al - Medium SnO_2, Trial 2

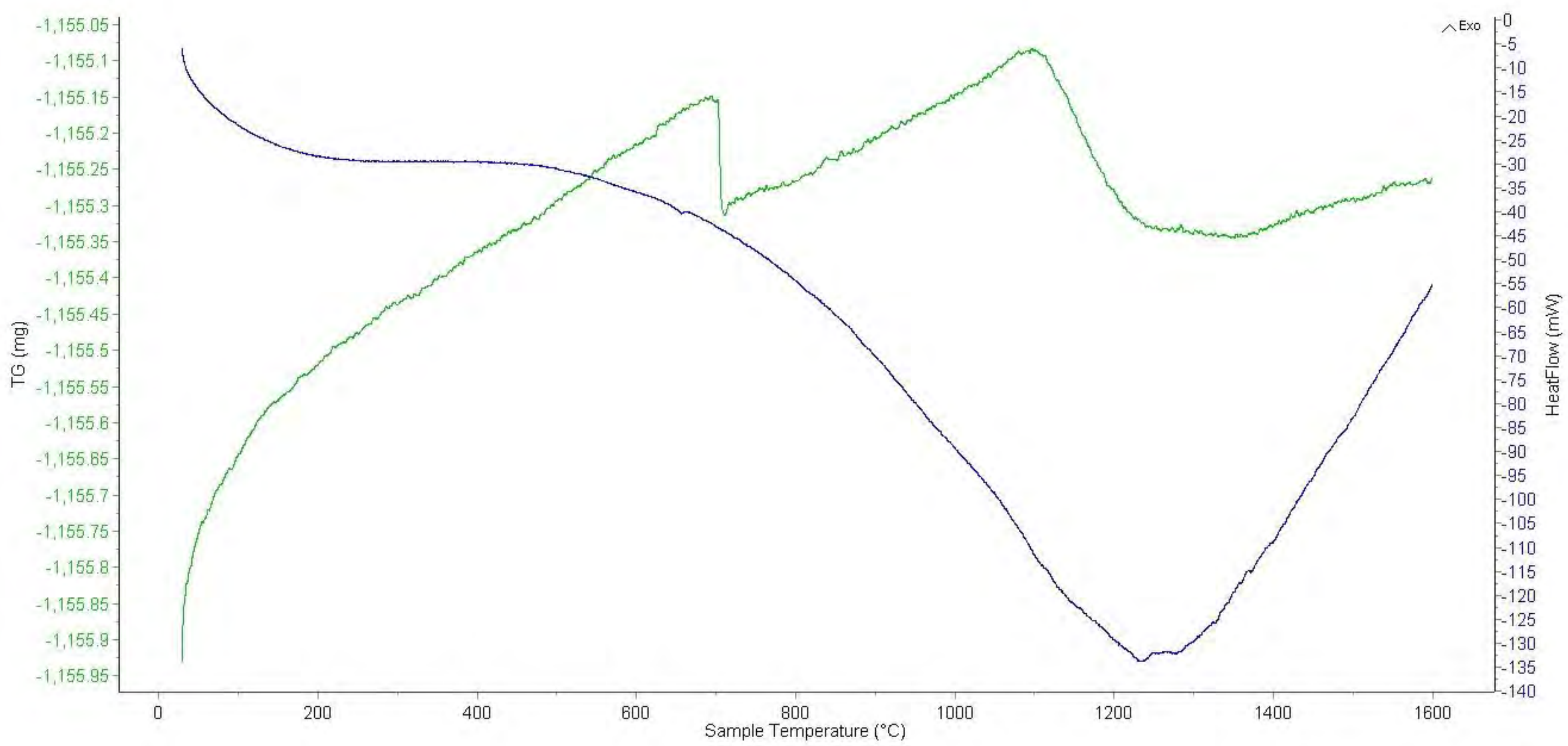


Figure C95: High-Temp DSC Plots for Mix ID SS #19 – Fine Al - Coarse SnO_2, Trial 1

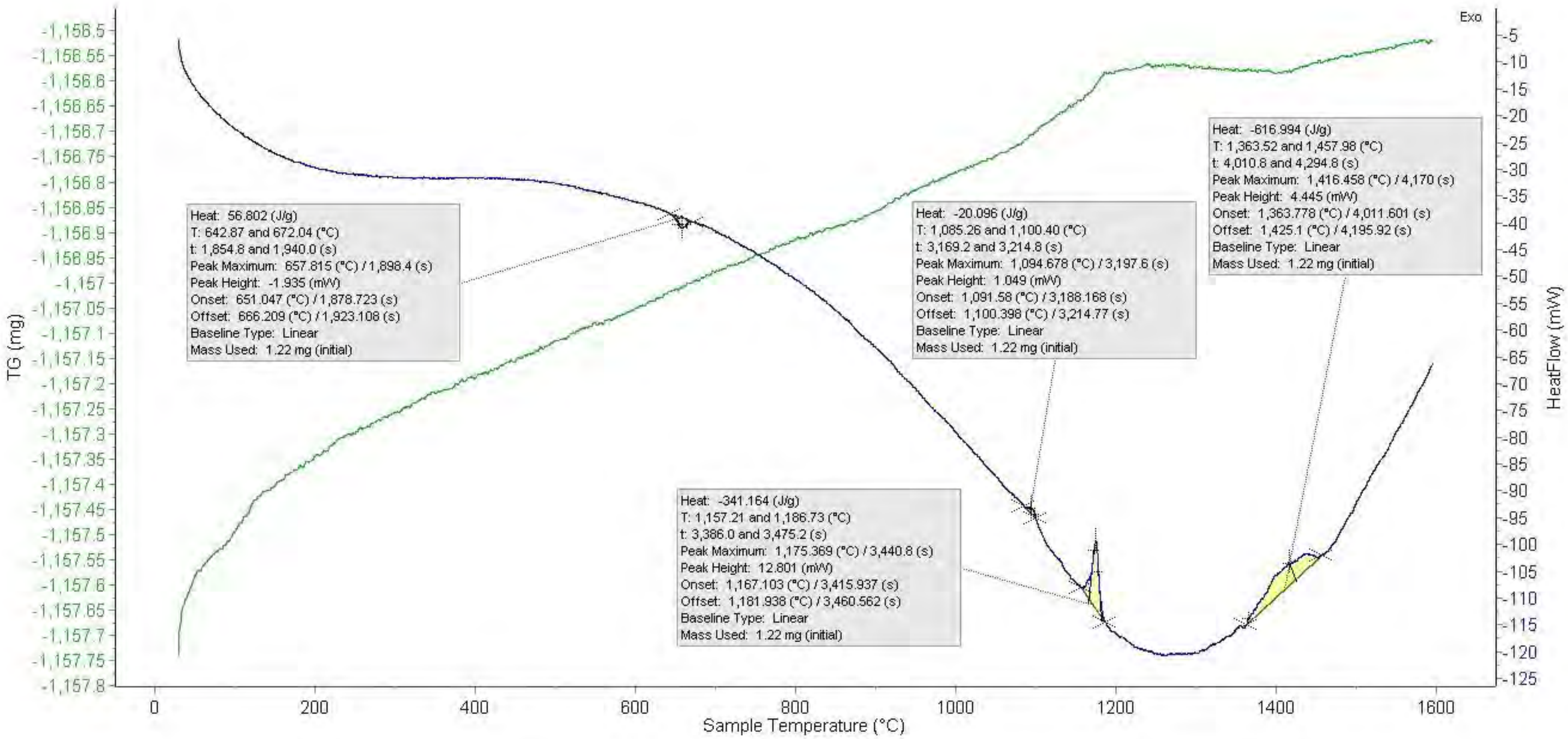


Figure C96: High-Temp DSC Plots for Mix ID SS #19 – Fine Al - Coarse SnO_2, Trial 2

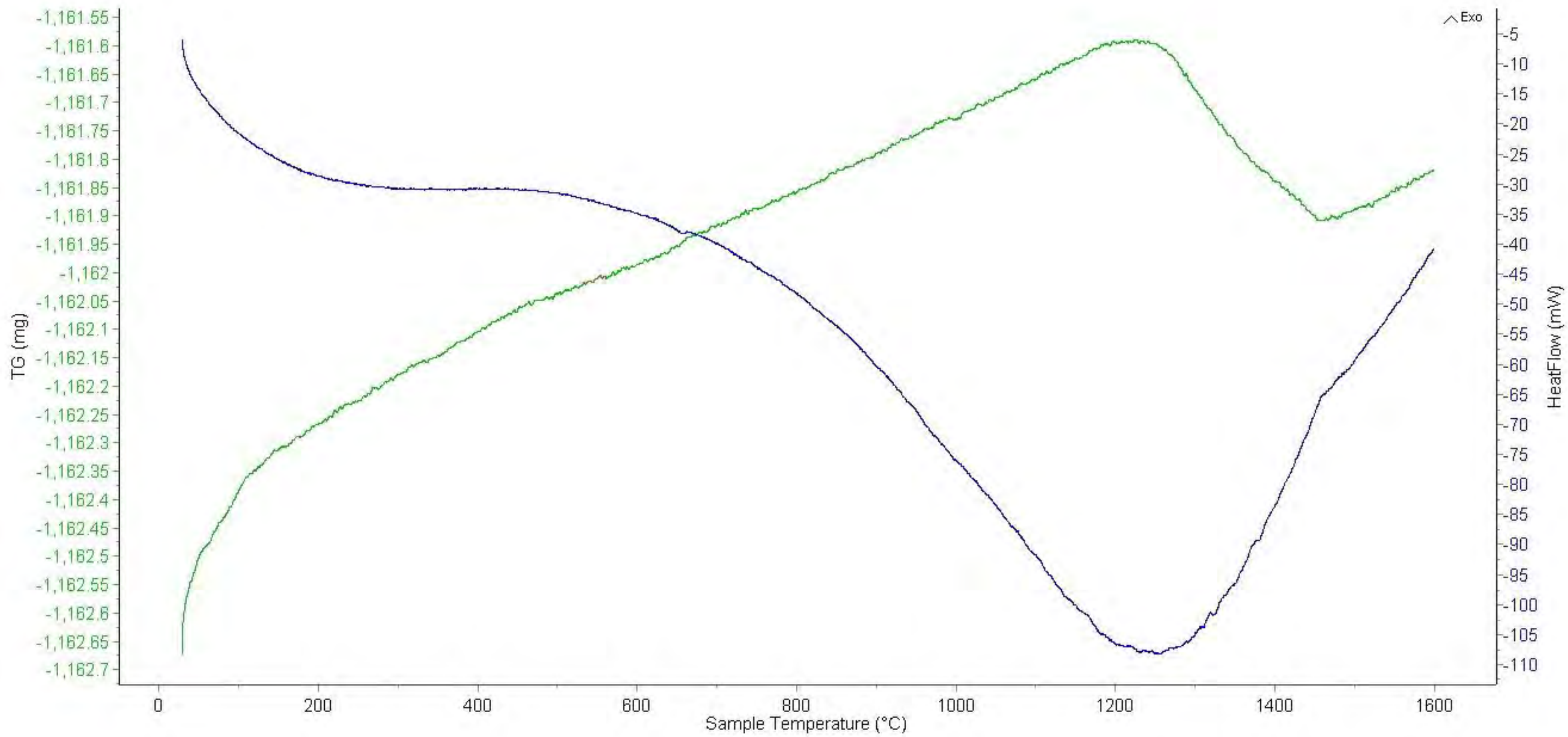


Figure C97: High-Temp DSC Plots for Mix ID SS #19 – Medium Al - Fine SnO_2, Trial 1

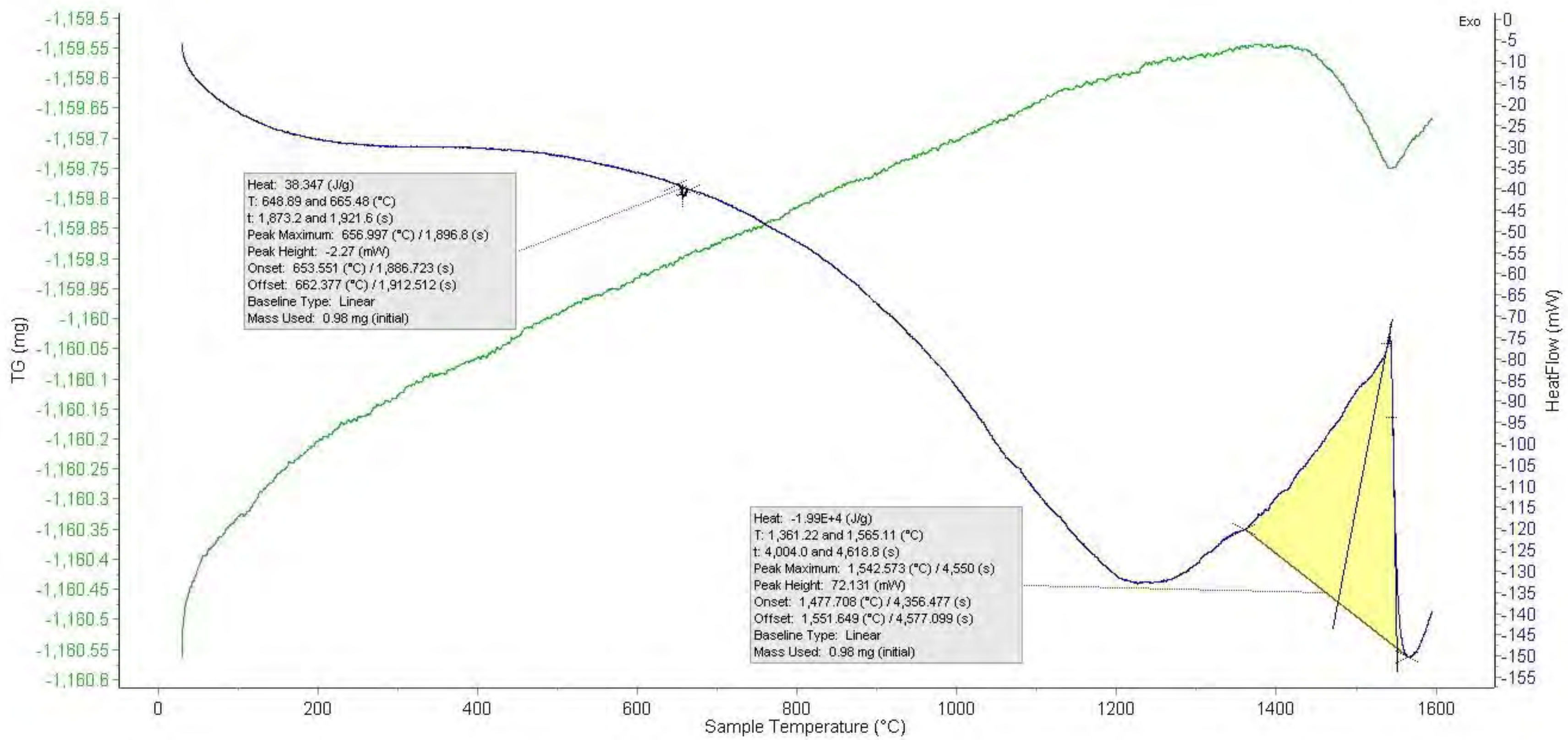


Figure C98: High-Temp DSC Plots for Mix ID SS #19 – Medium Al - Fine SnO_2, Trial 2

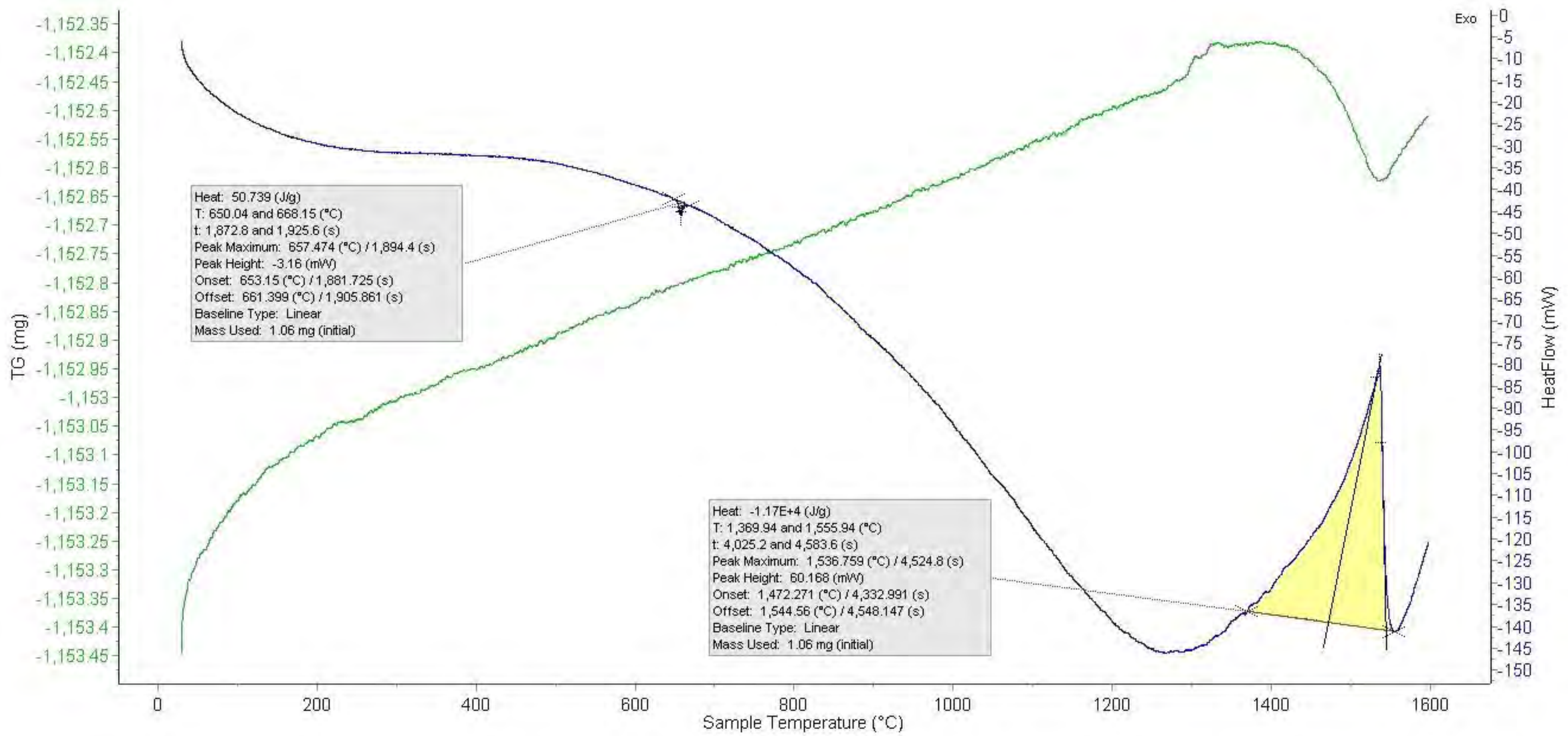


Figure C99: High-Temp DSC Plots for Mix ID SS #19 – Medium Al - Medium SnO_2, Trial 1

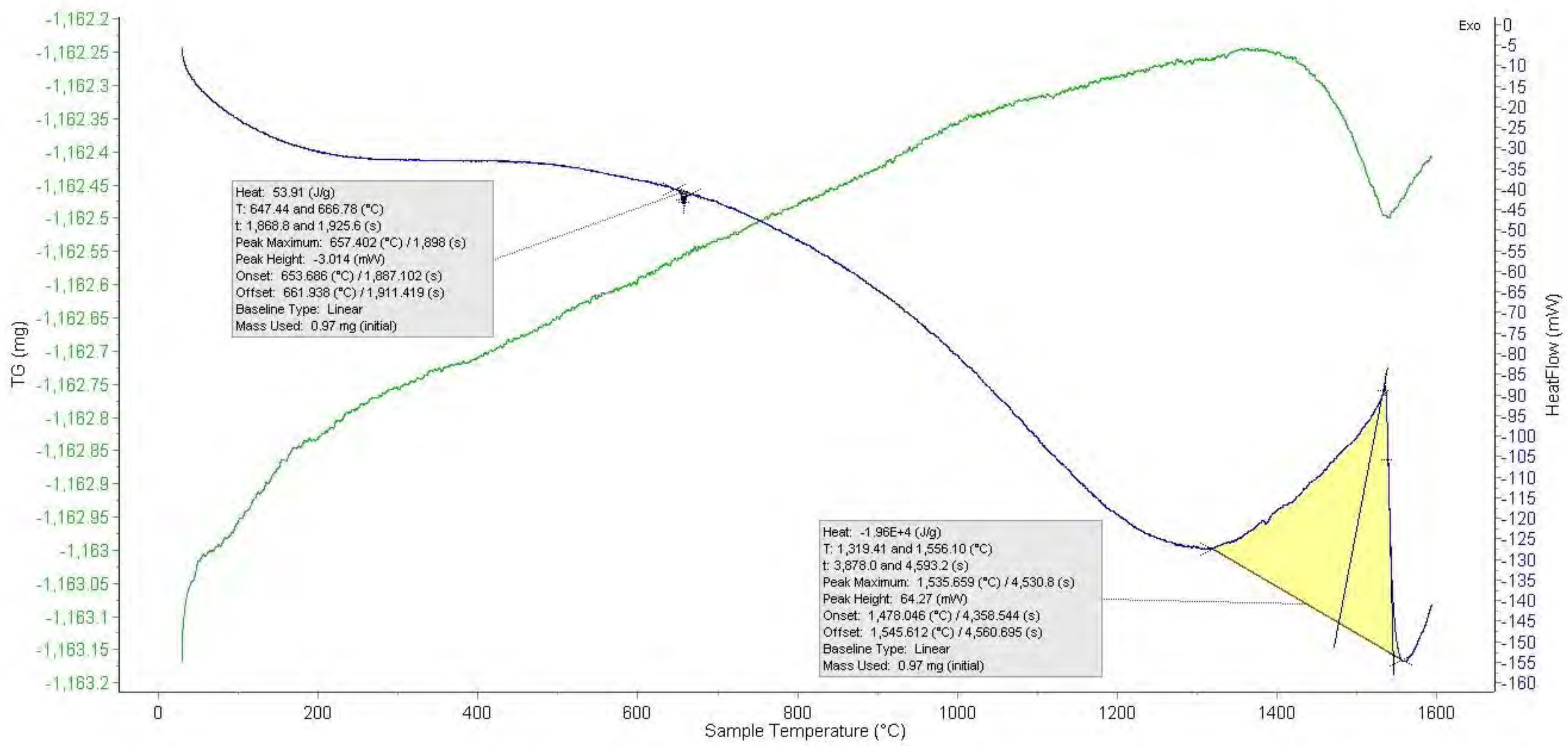


Figure C100: High-Temp DSC Plots for Mix ID SS #19 – Medium Al - Medium SnO_2, Trial 2

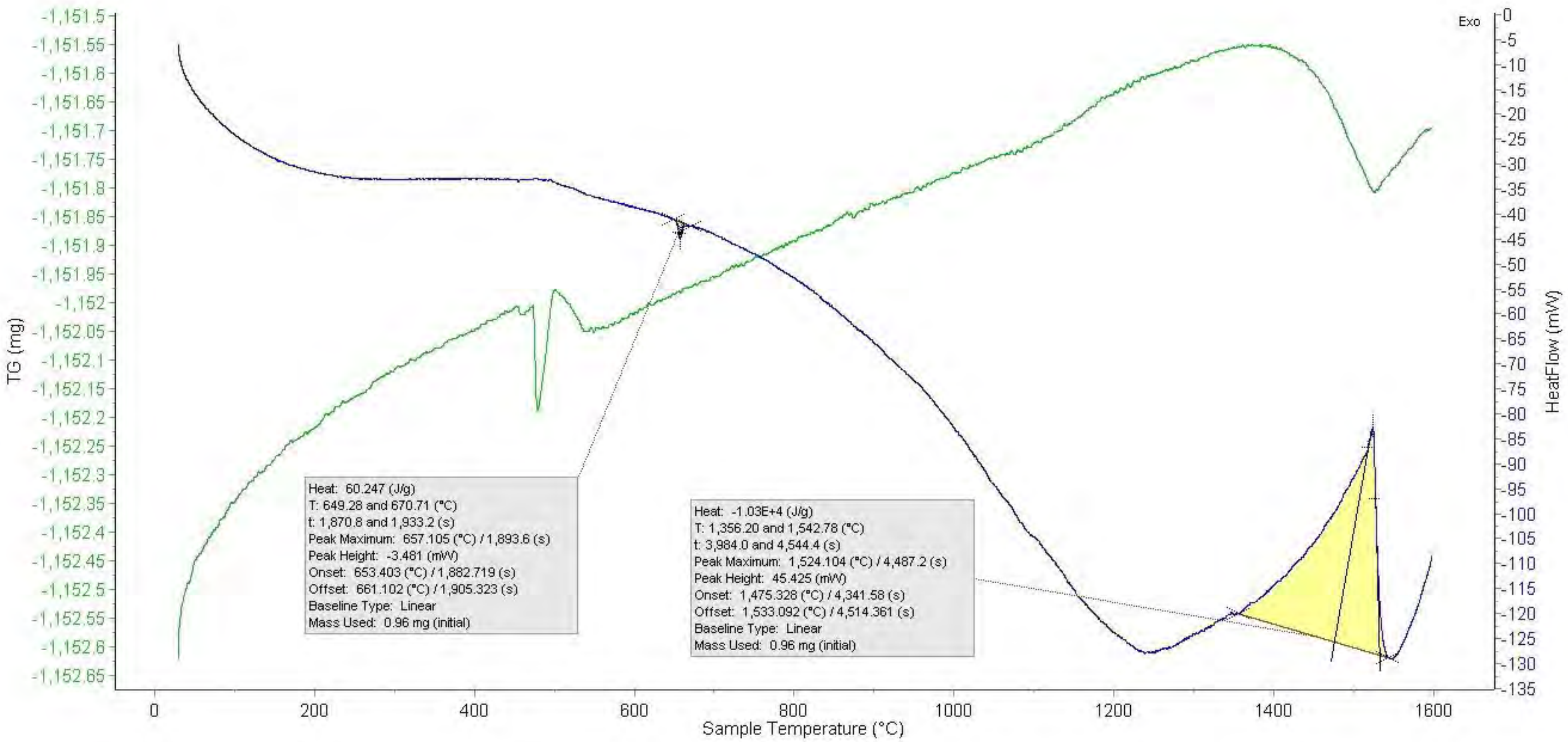


Figure C101: High-Temp DSC Plots for Mix ID SS #19 – Medium Al - Coarse SnO_2, Trial 1

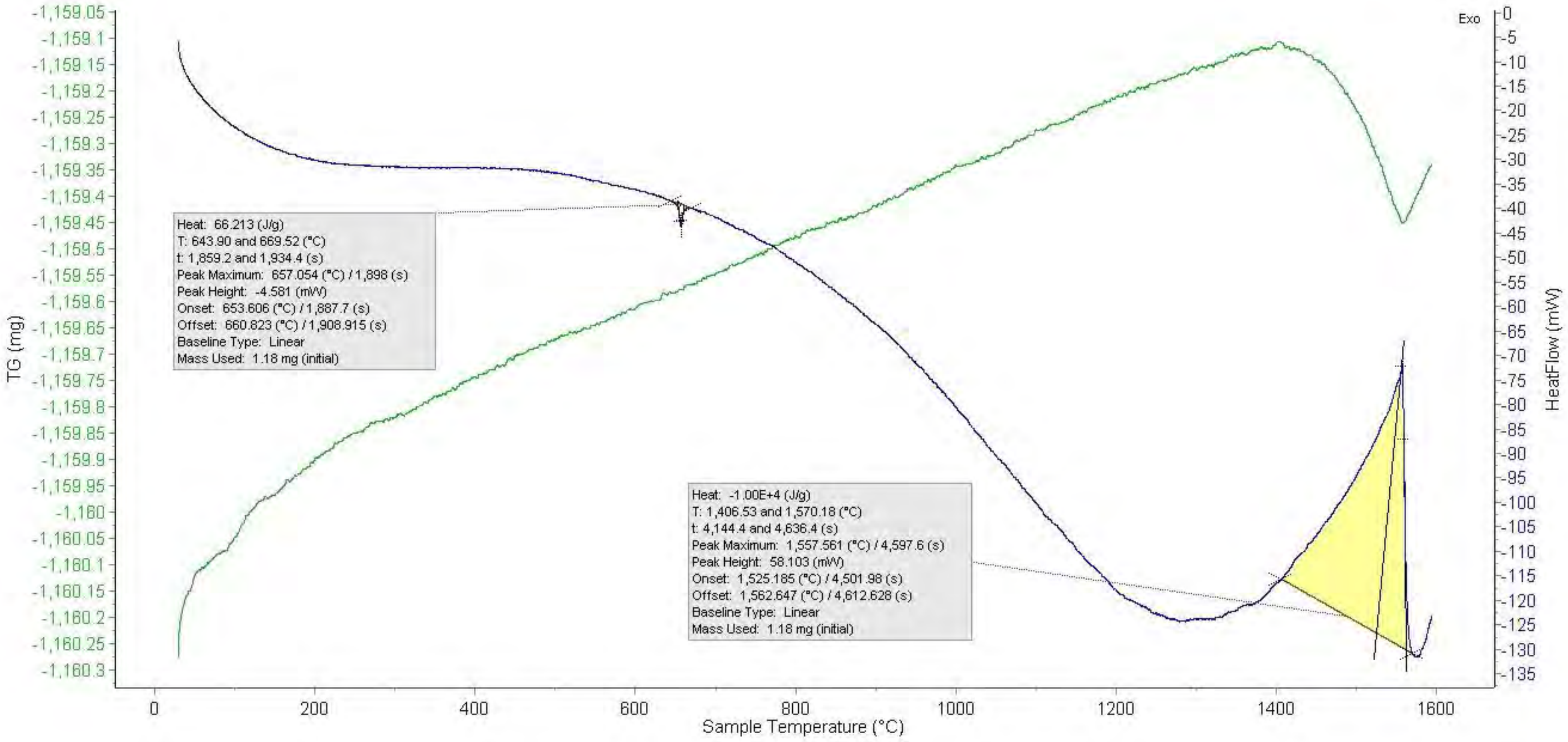


Figure C102: High-Temp DSC Plots for Mix ID SS #19 – Medium Al - Coarse SnO_2, Trial 2

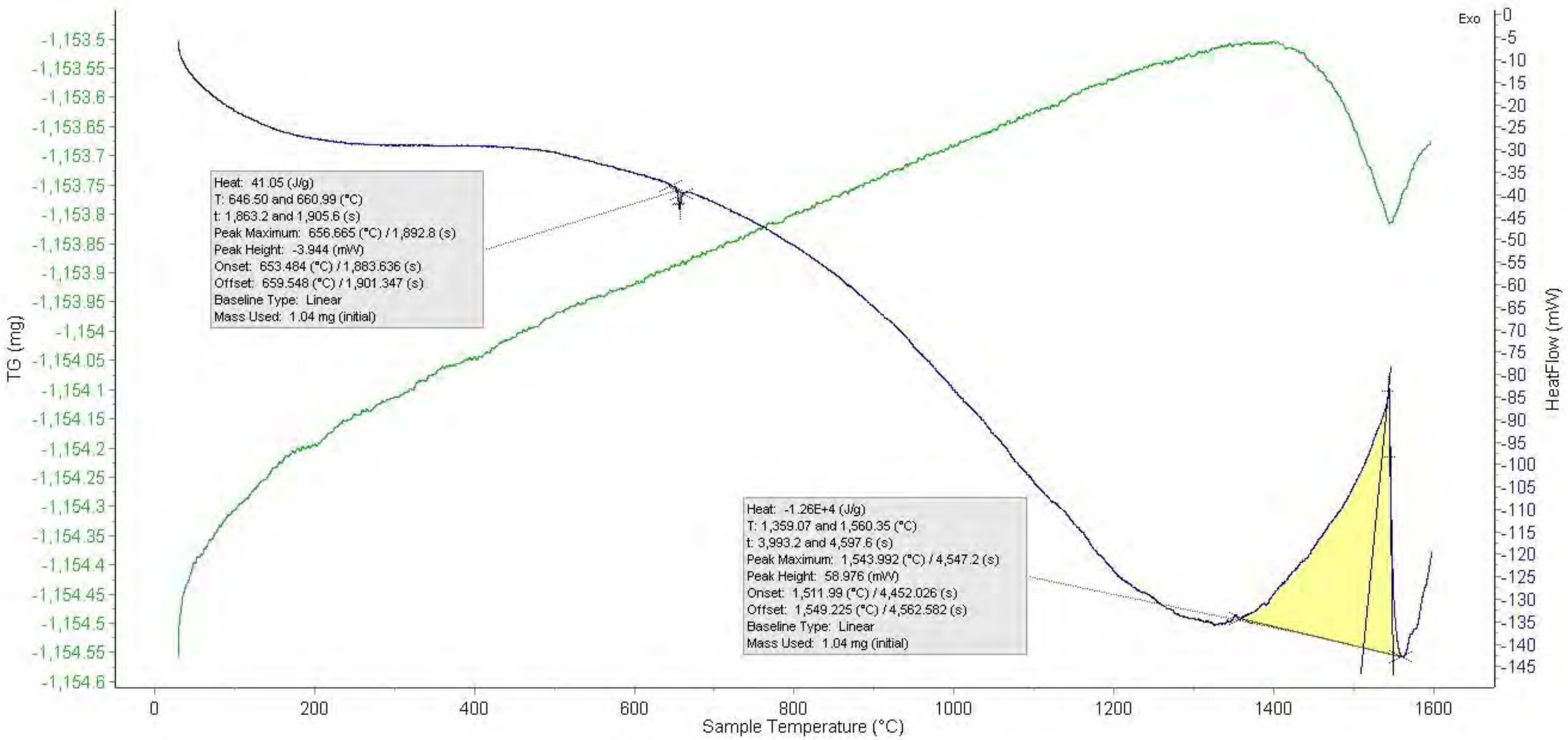


Figure C103: High-Temp DSC Plots for Mix ID SS #19 – Coarse Al – Fine SnO_2, Trial 1

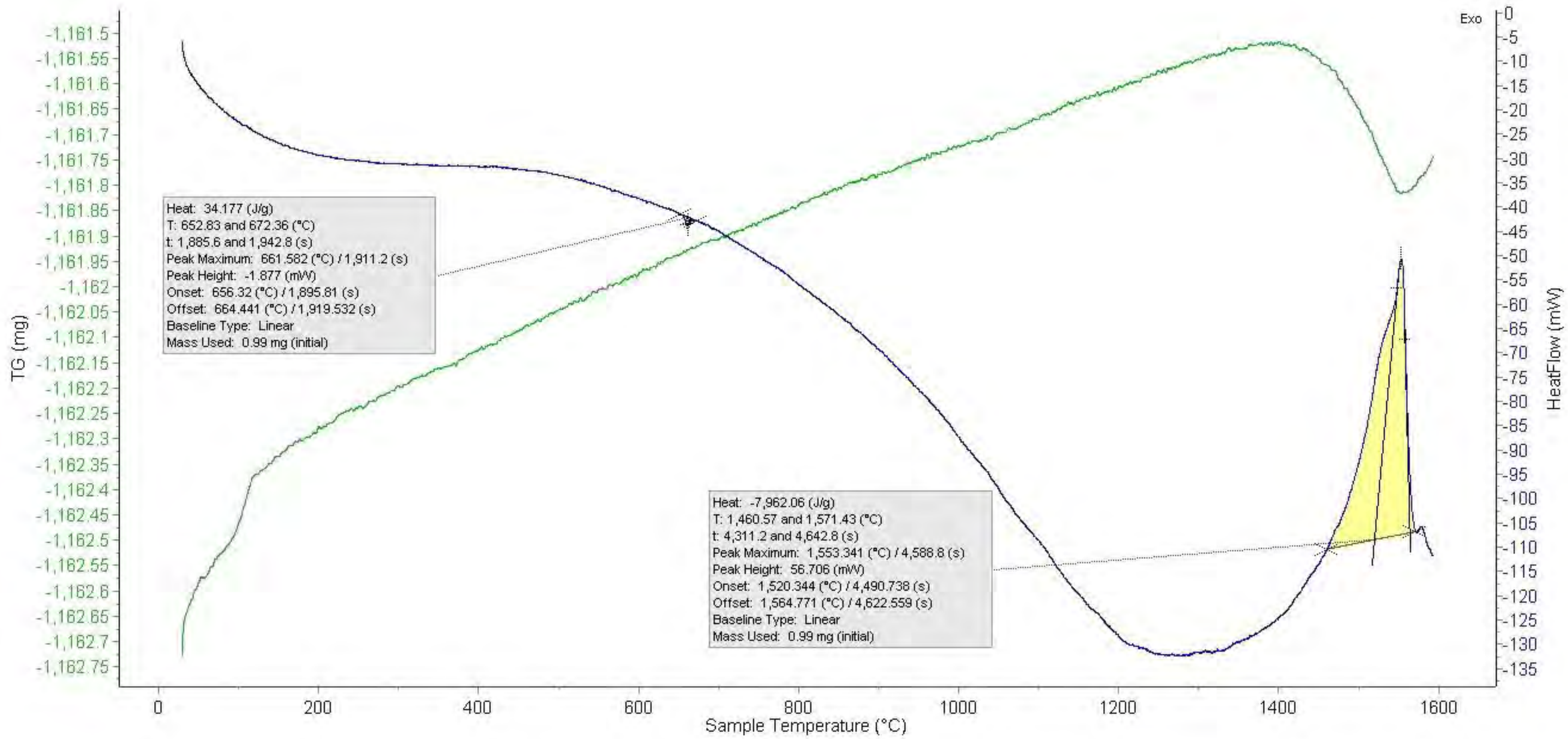


Figure C104: High-Temp DSC Plots for Mix ID SS #19 – Coarse Al – Fine SnO_2, Trial 2

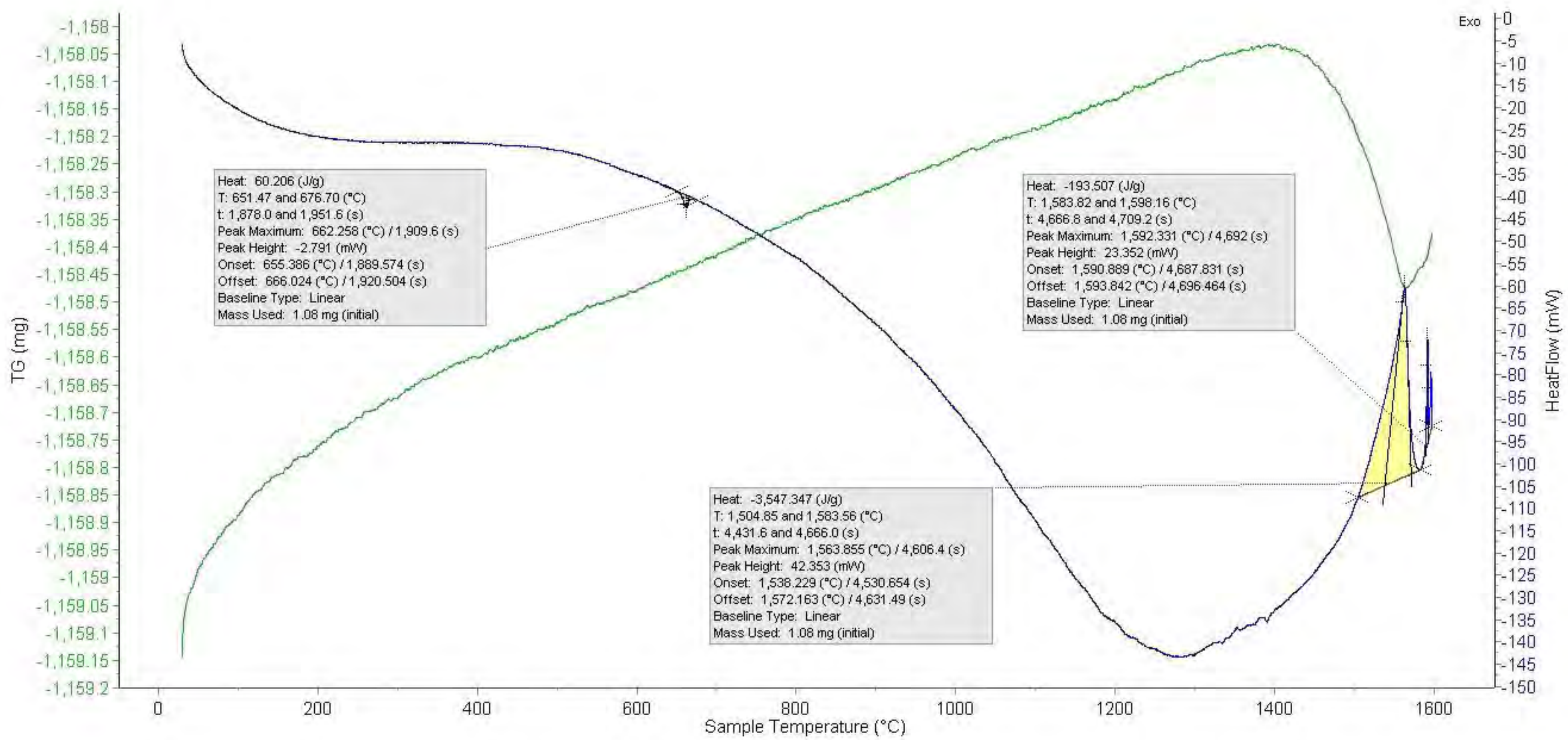


Figure C105: High-Temp DSC Plots for Mix ID SS #19 – Coarse Al - Medium SnO_2, Trial 1

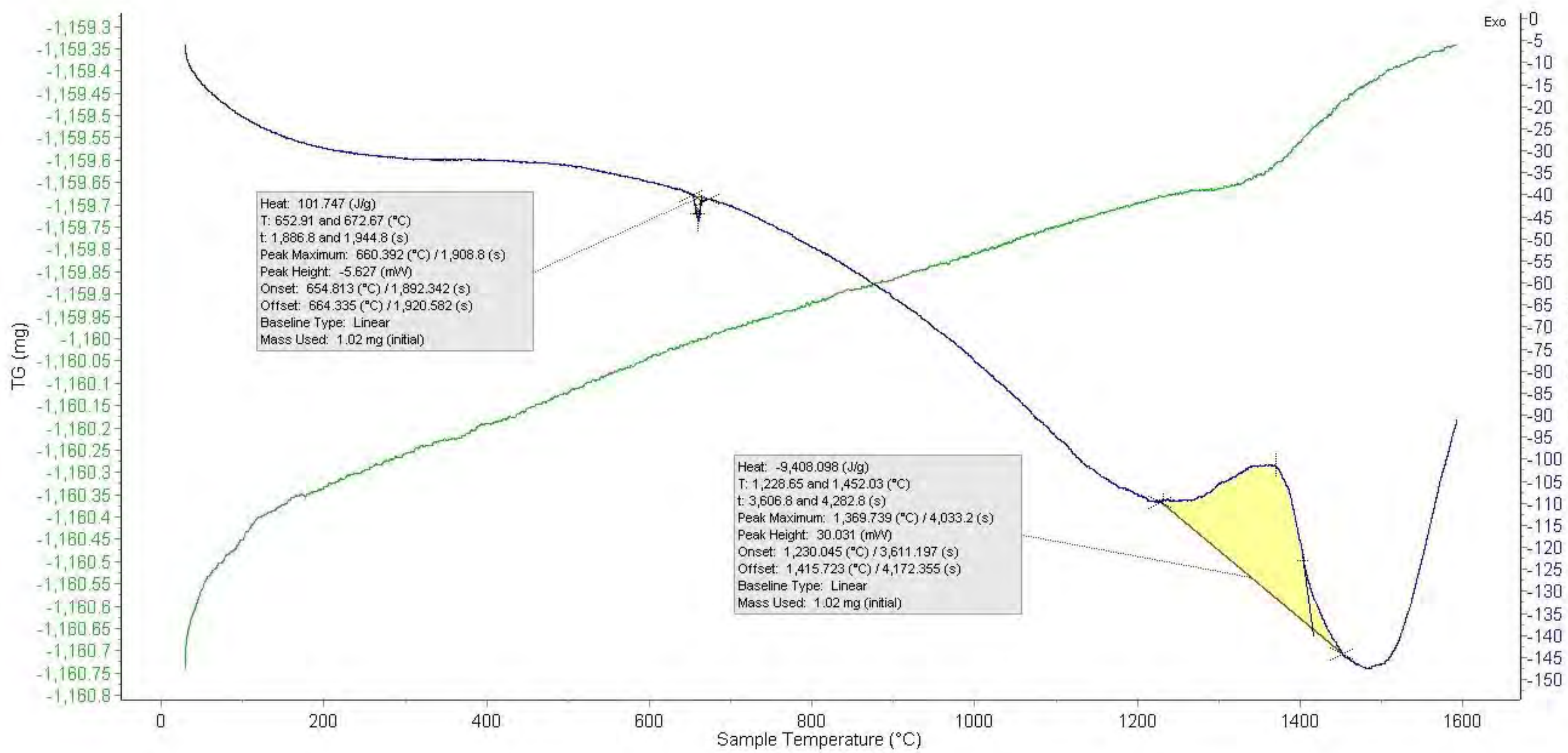


Figure C106: High-Temp DSC Plots for Mix ID SS #19 – Coarse Al - Medium SnO_2, Trial 2

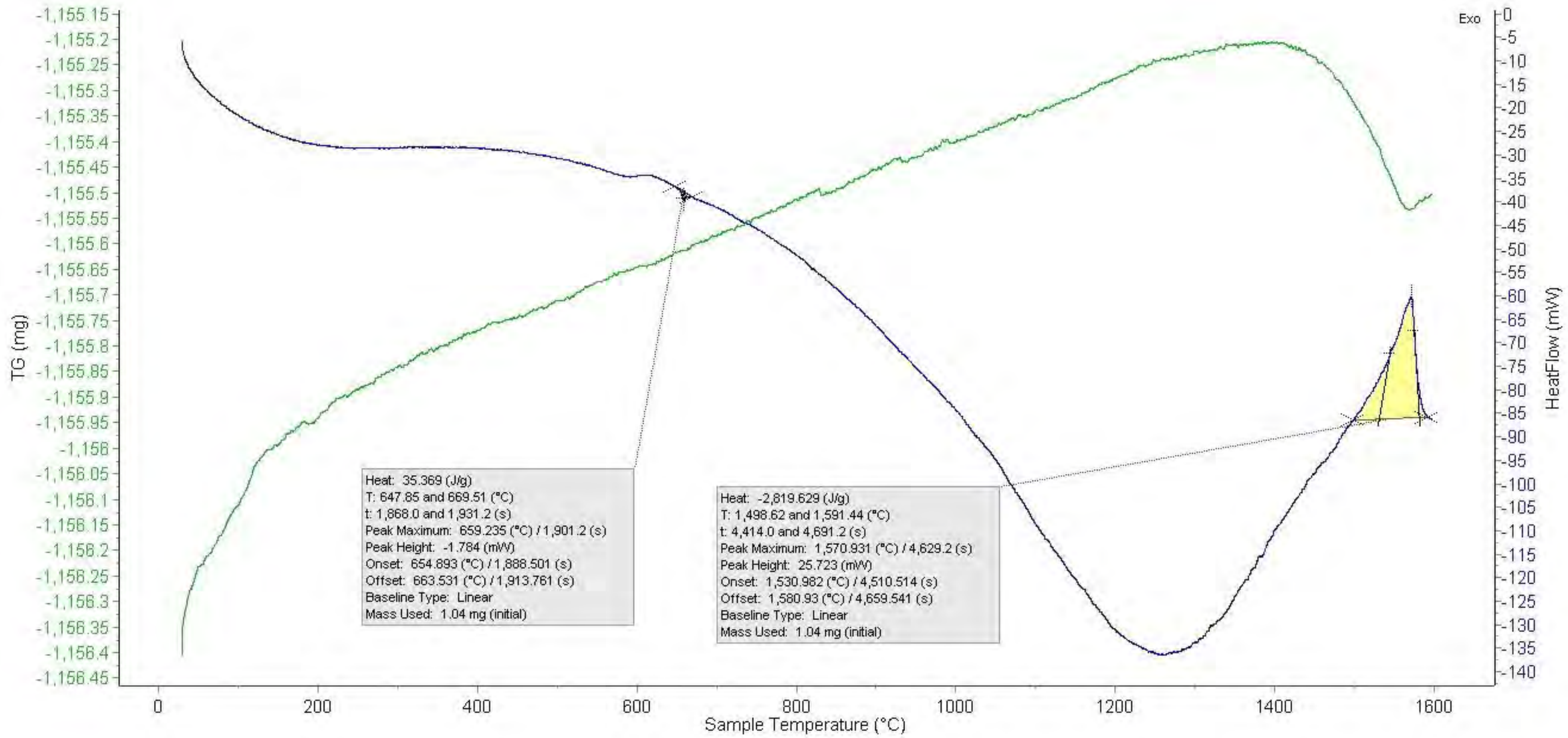


Figure C107: High-Temp DSC Plots for Mix ID SS #19 – Coarse Al - Coarse SnO_2, Trial 1

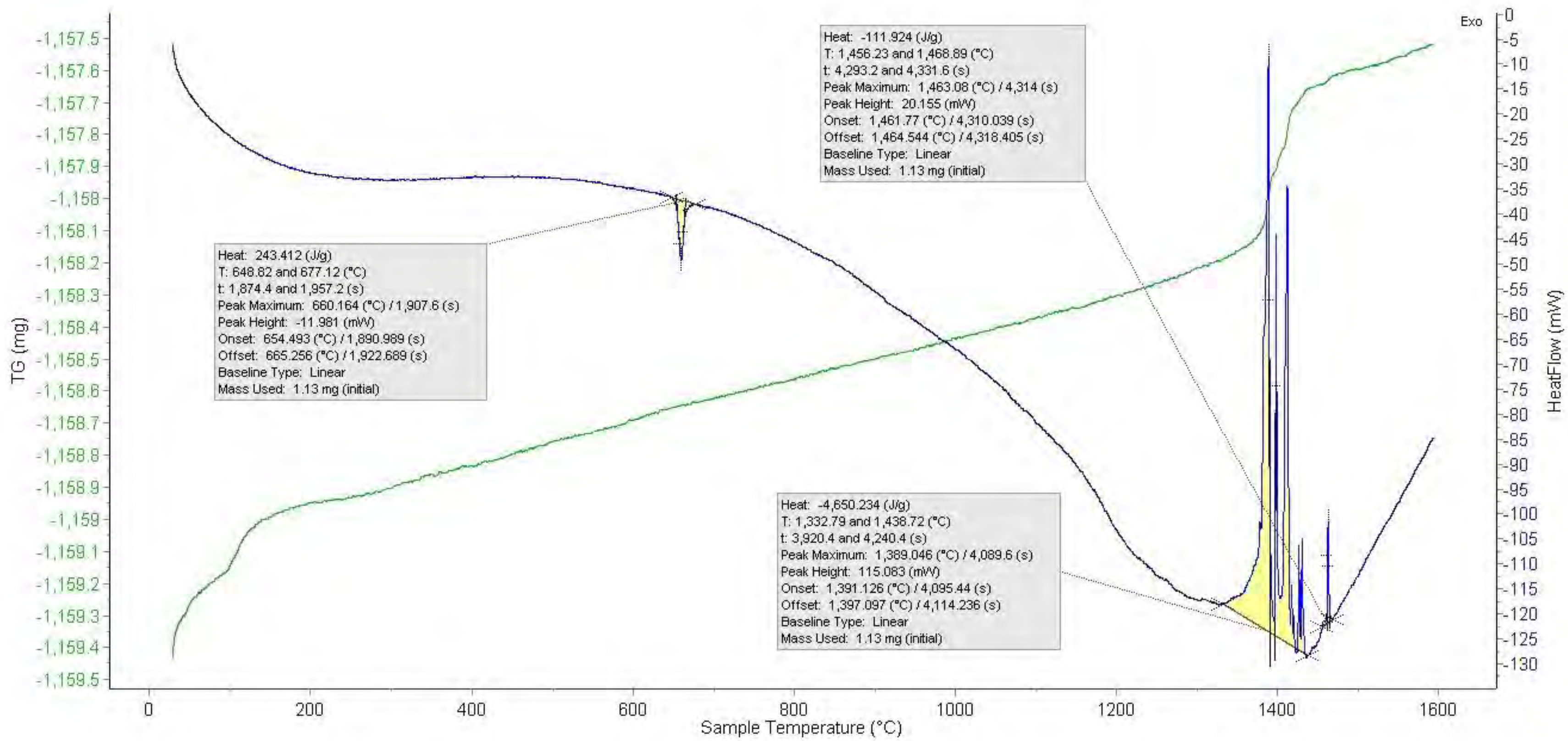


Figure C108: High-Temp DSC Plots for Mix ID SS #19 – Coarse Al - Coarse SnO_2, Trial 2

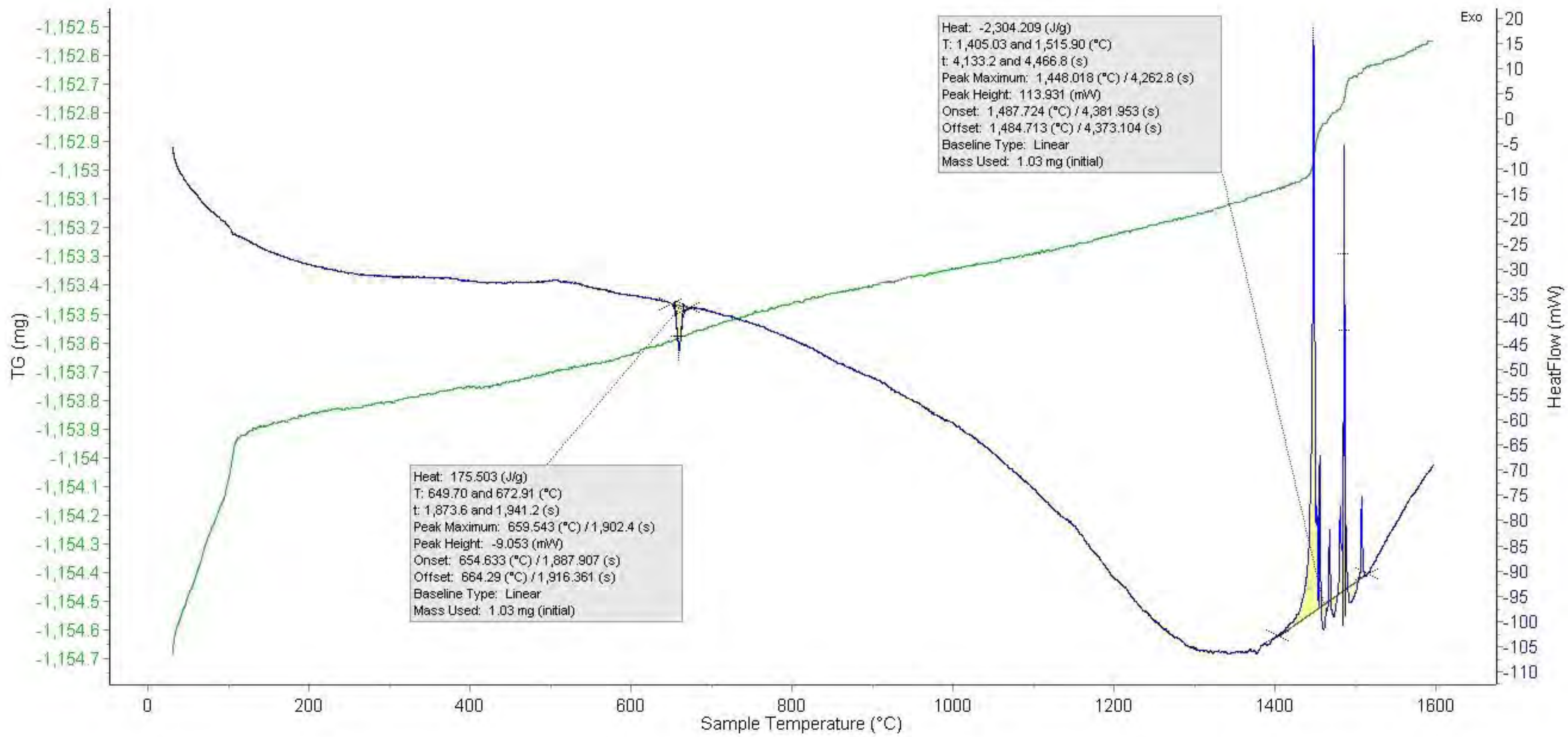


Figure C109: High-Temp DSC Plots for Mix ID SS #24 – Fine Al - Fine Bi_2O_3, Trial 1

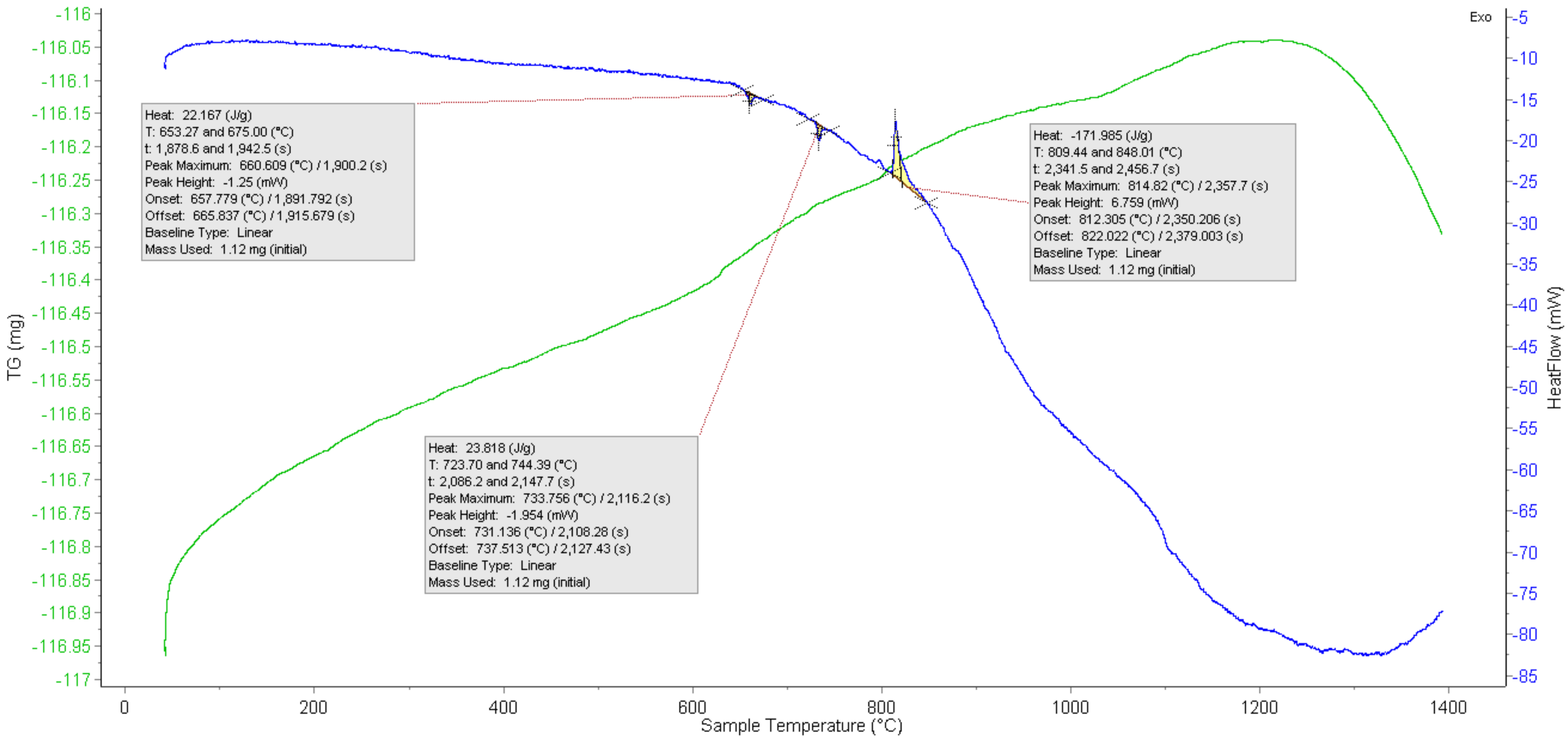


Figure C110: High-Temp DSC Plots for Mix ID SS #24 – Fine Al - Fine Bi_2O_3, Trial 2

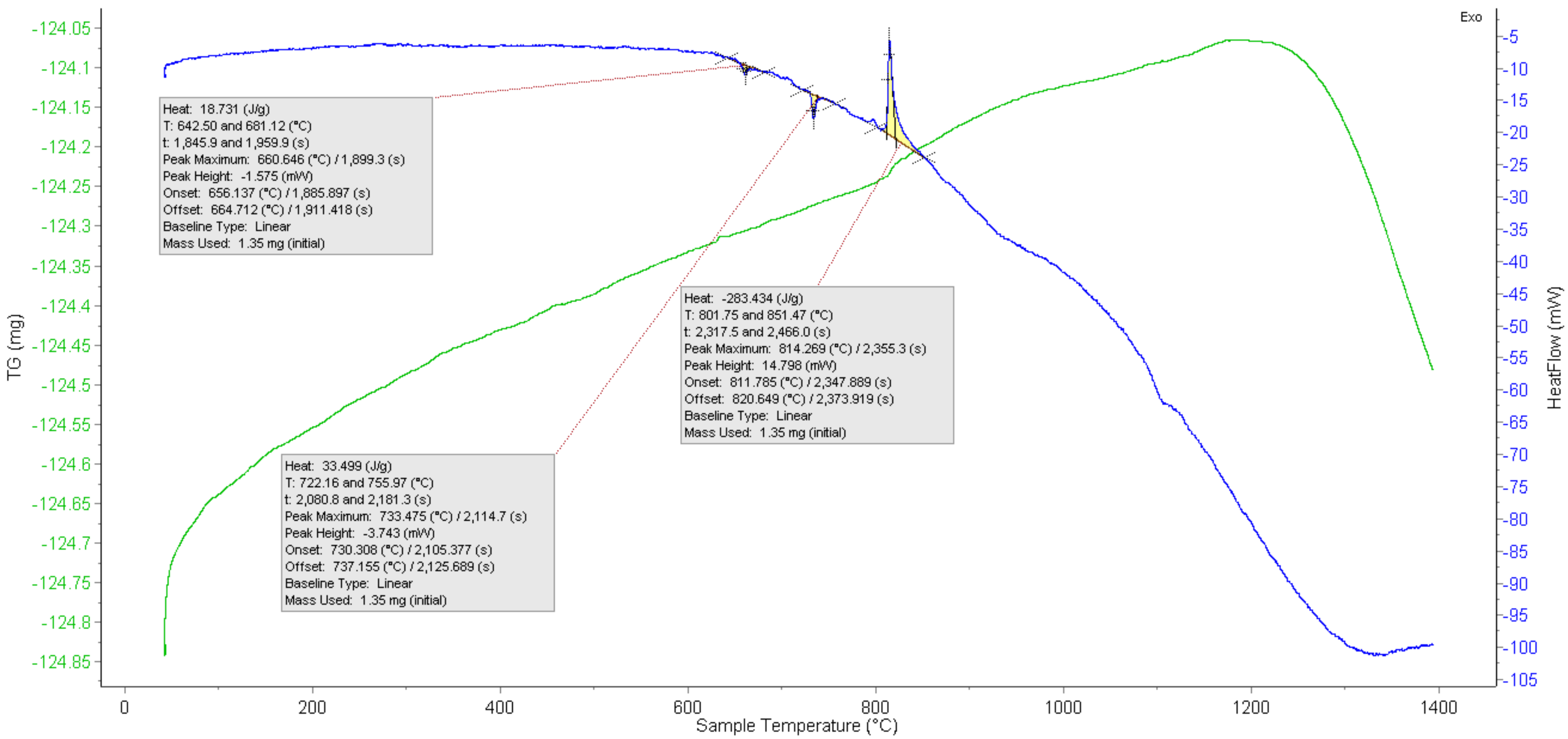


Figure C111: High-Temp DSC Plots for Mix ID SS #24 – Fine Al - Medium Bi_2O_3, Trial 1

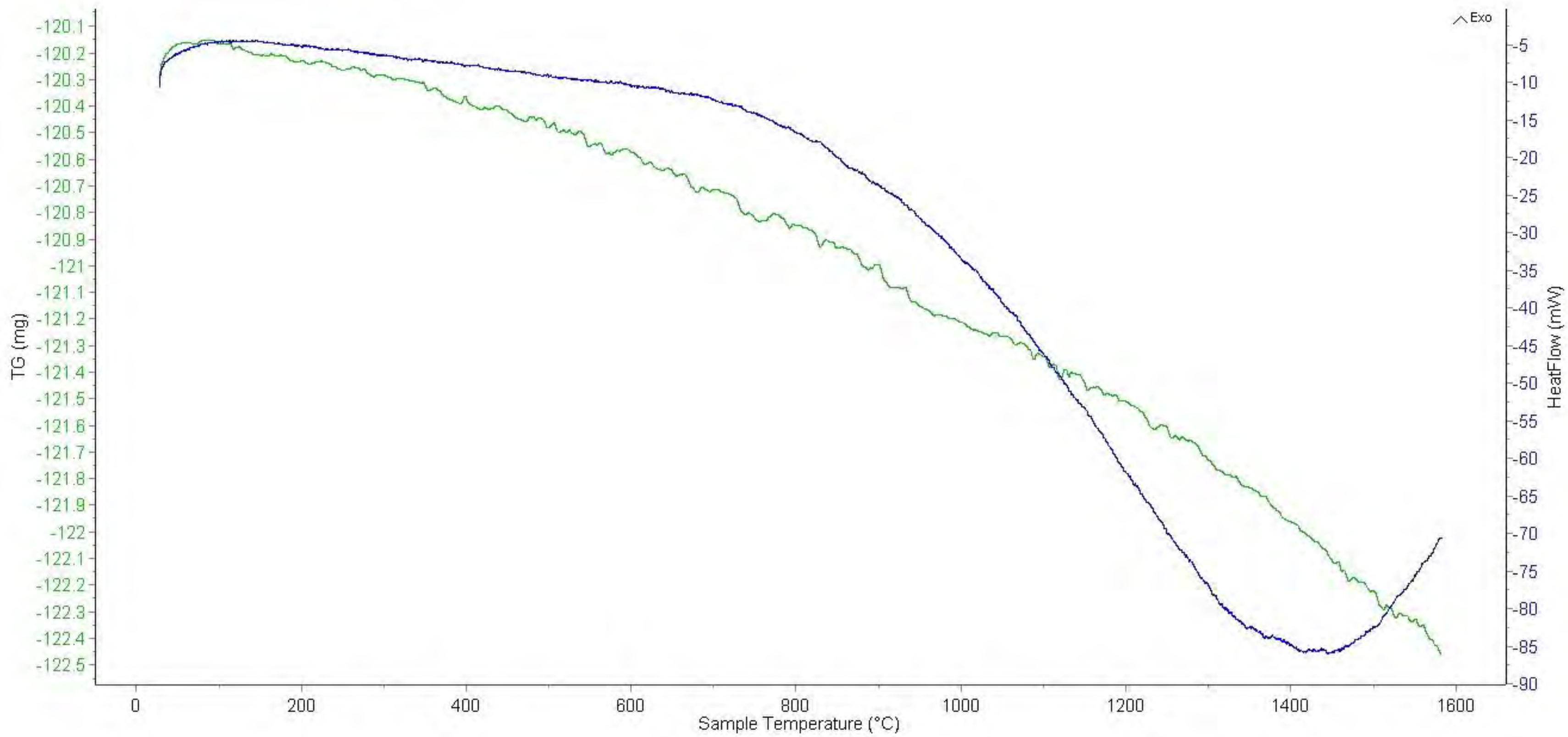


Figure C112: High-Temp DSC Plots for Mix ID SS #24 – Fine Al - Medium Bi_2O_3, Trial 2

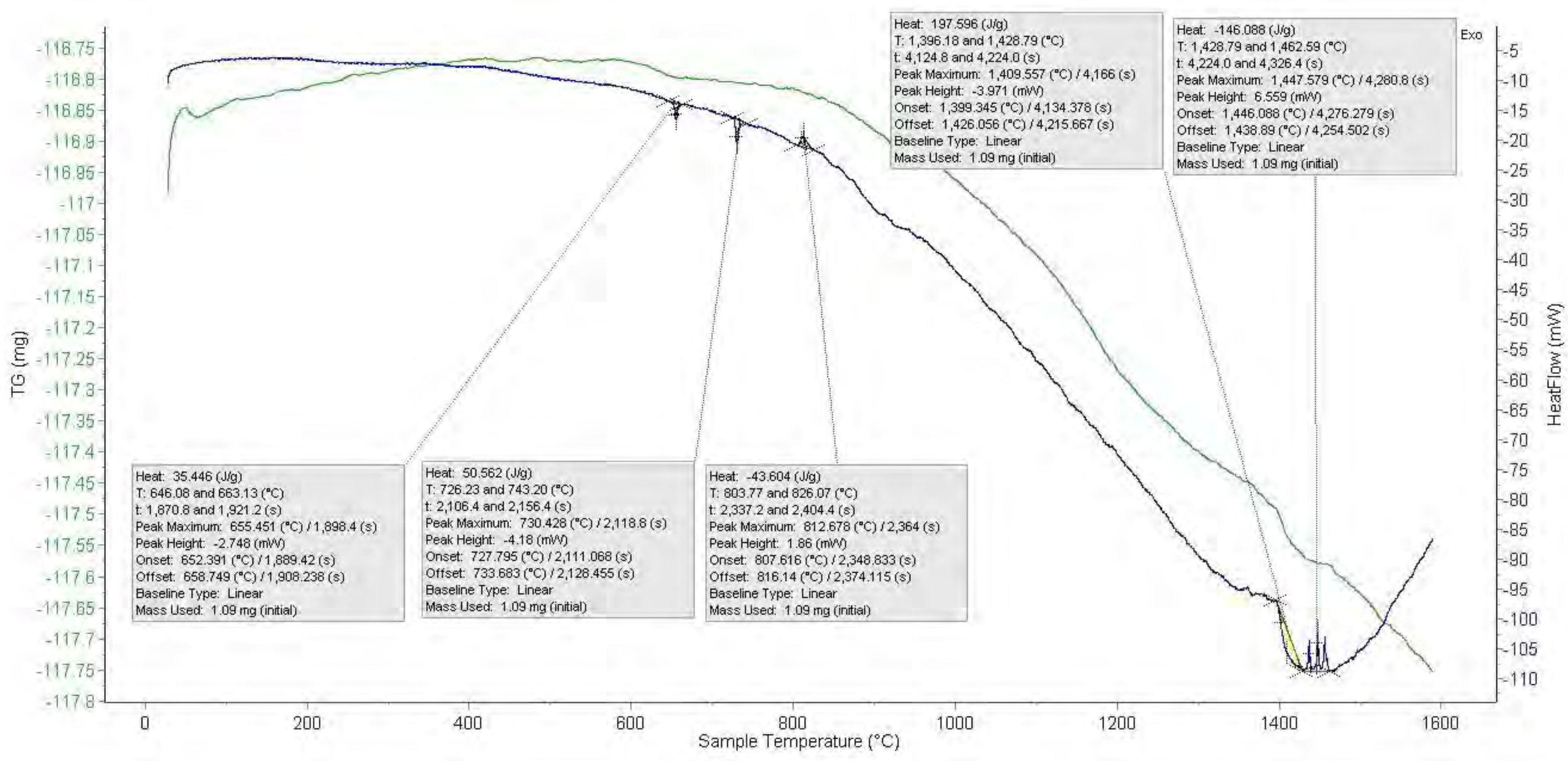


Figure C113: High-Temp DSC Plots for Mix ID SS #24 – Fine Al - Coarse Bi_2O_3, Trial 1

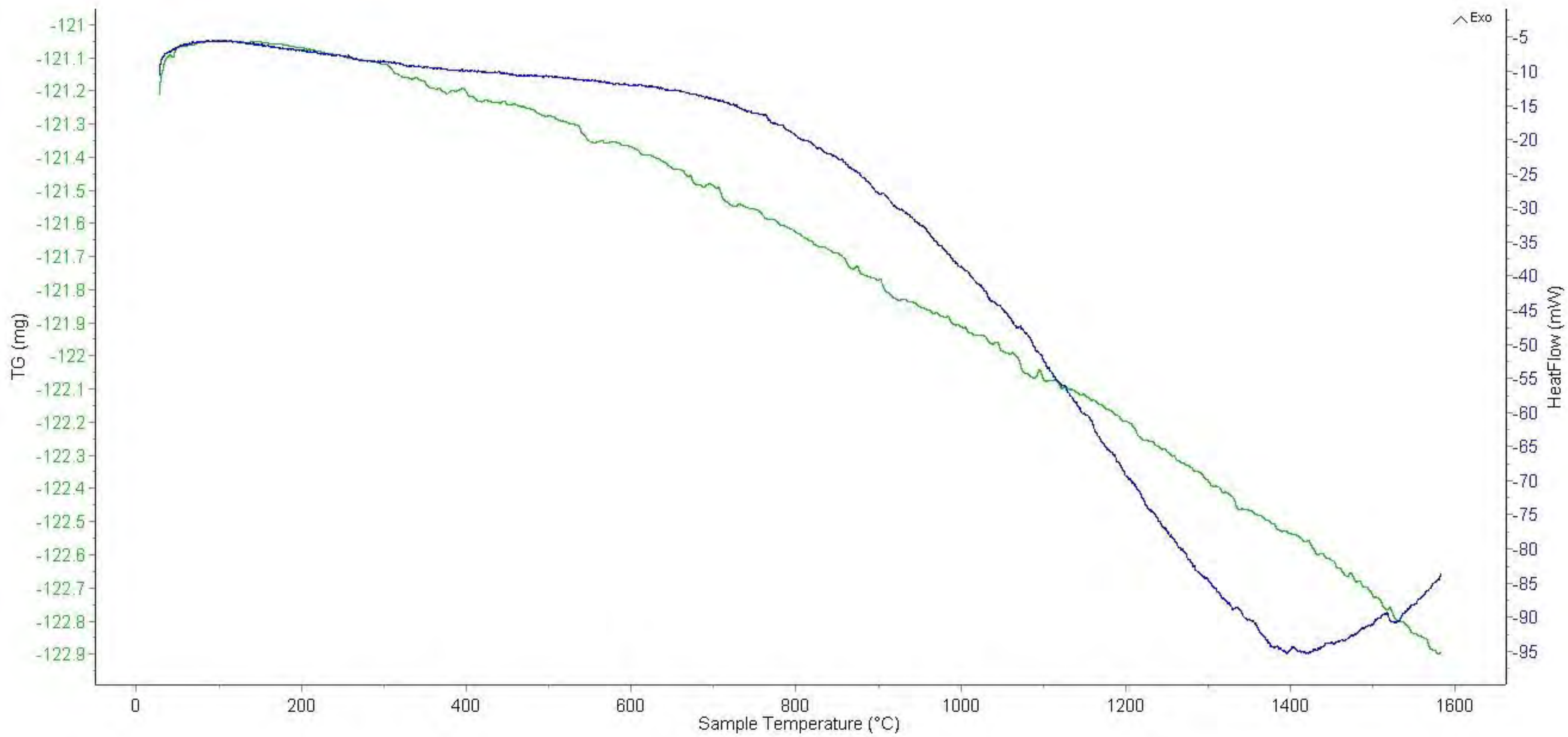


Figure C114: High-Temp DSC Plots for Mix ID SS #24 – Fine Al - Coarse Bi_2O_3, Trial 2

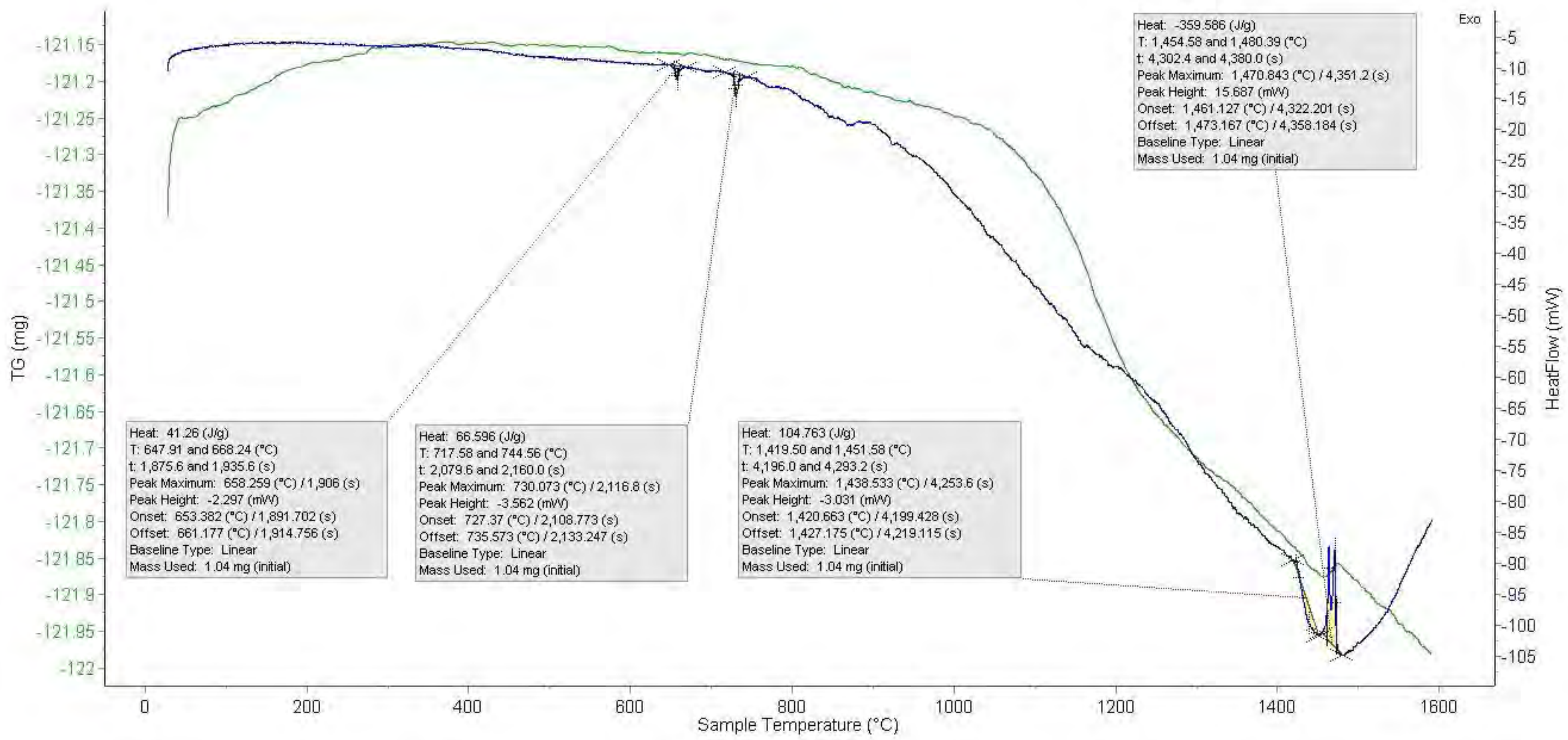


Figure C115: High-Temp DSC Plots for Mix ID SS #24 – Medium Al - Fine Bi_2O_3, Trial 1

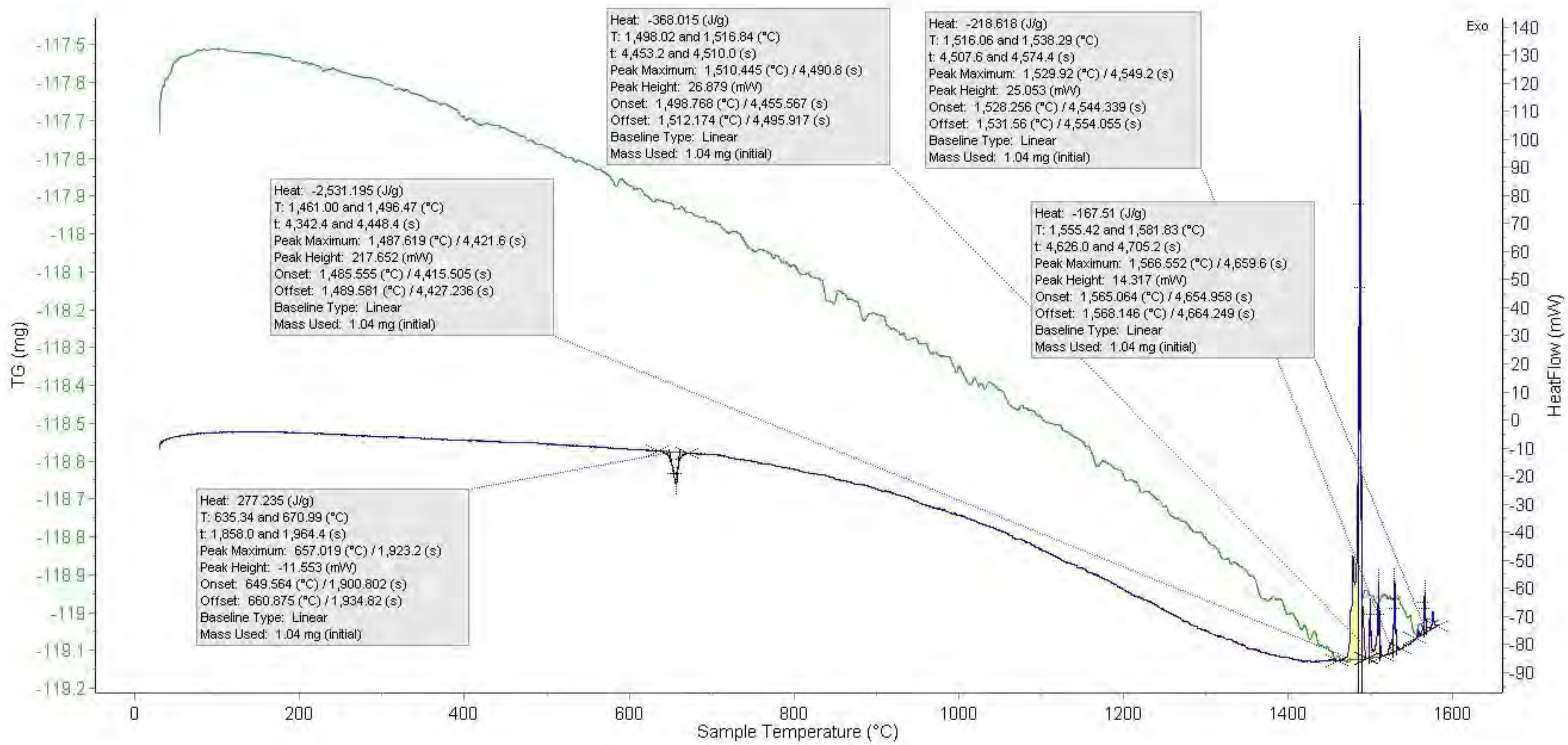


Figure C116: High-Temp DSC Plots for Mix ID SS #24 – Medium Al - Fine Bi_2O_3, Trial 2

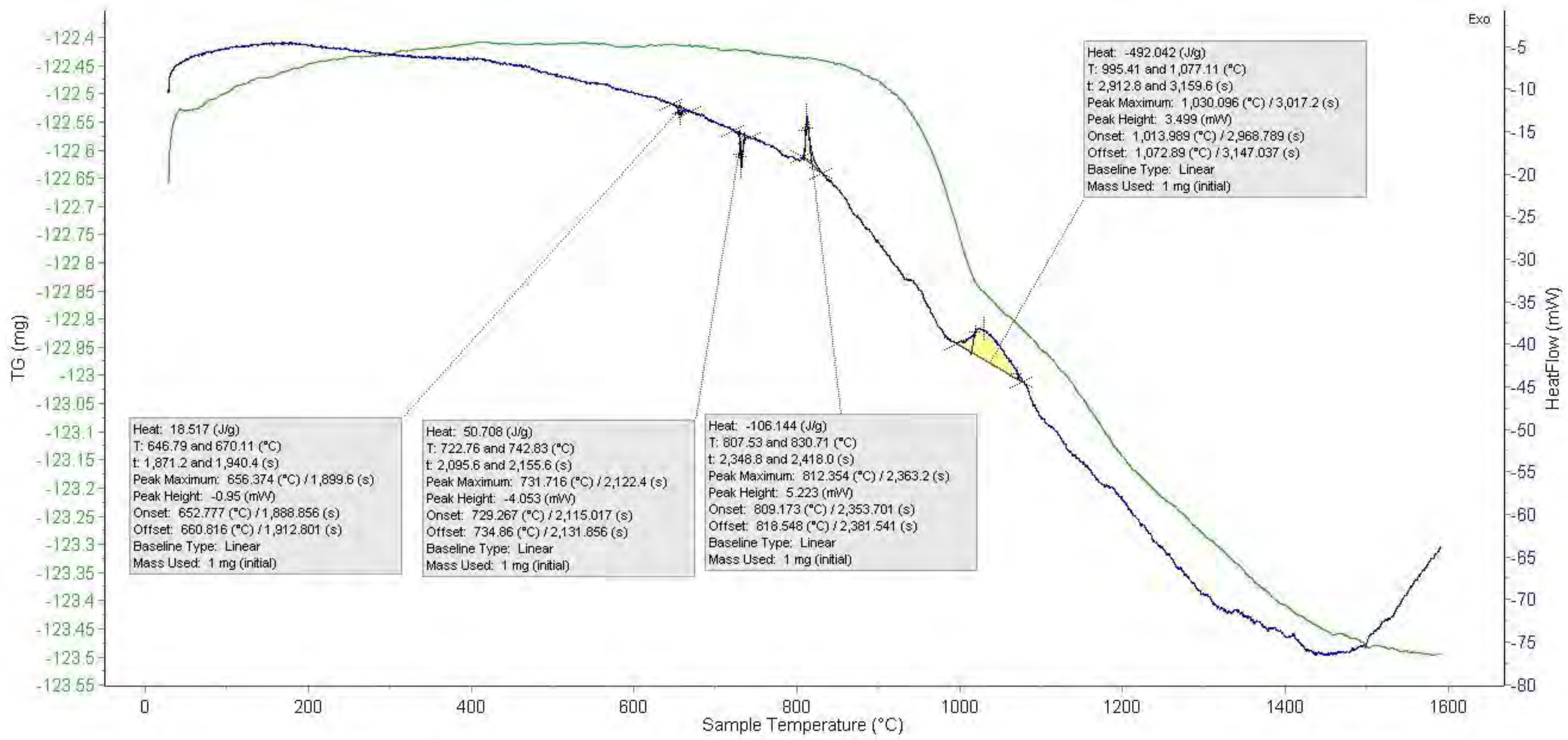


Figure C117: High-Temp DSC Plots for Mix ID SS #24 – Medium Al - Medium Bi_2O_3, Trial 1

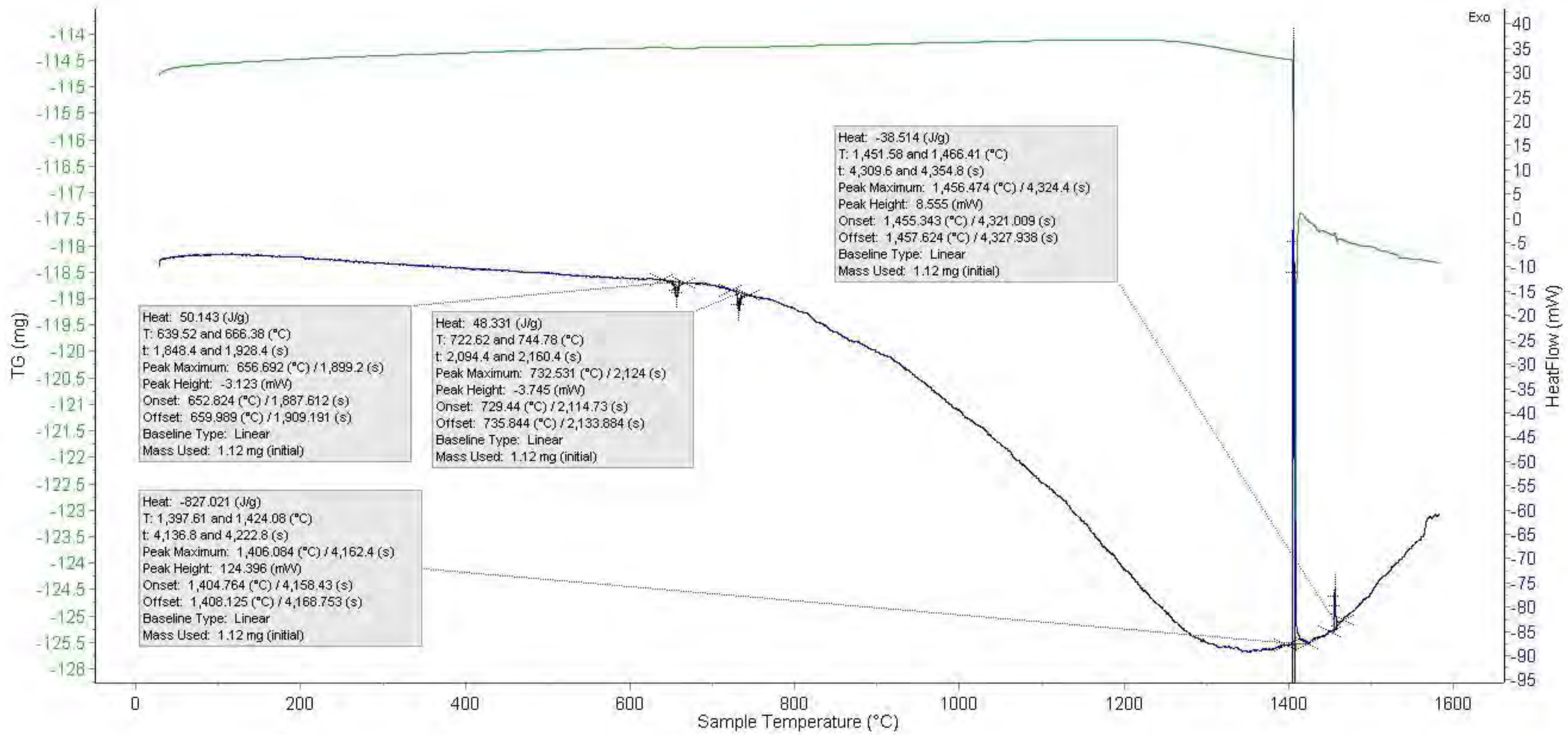


Figure C118: High-Temp DSC Plots for Mix ID SS #24 – Medium Al - Medium Bi_2O_3, Trial 2

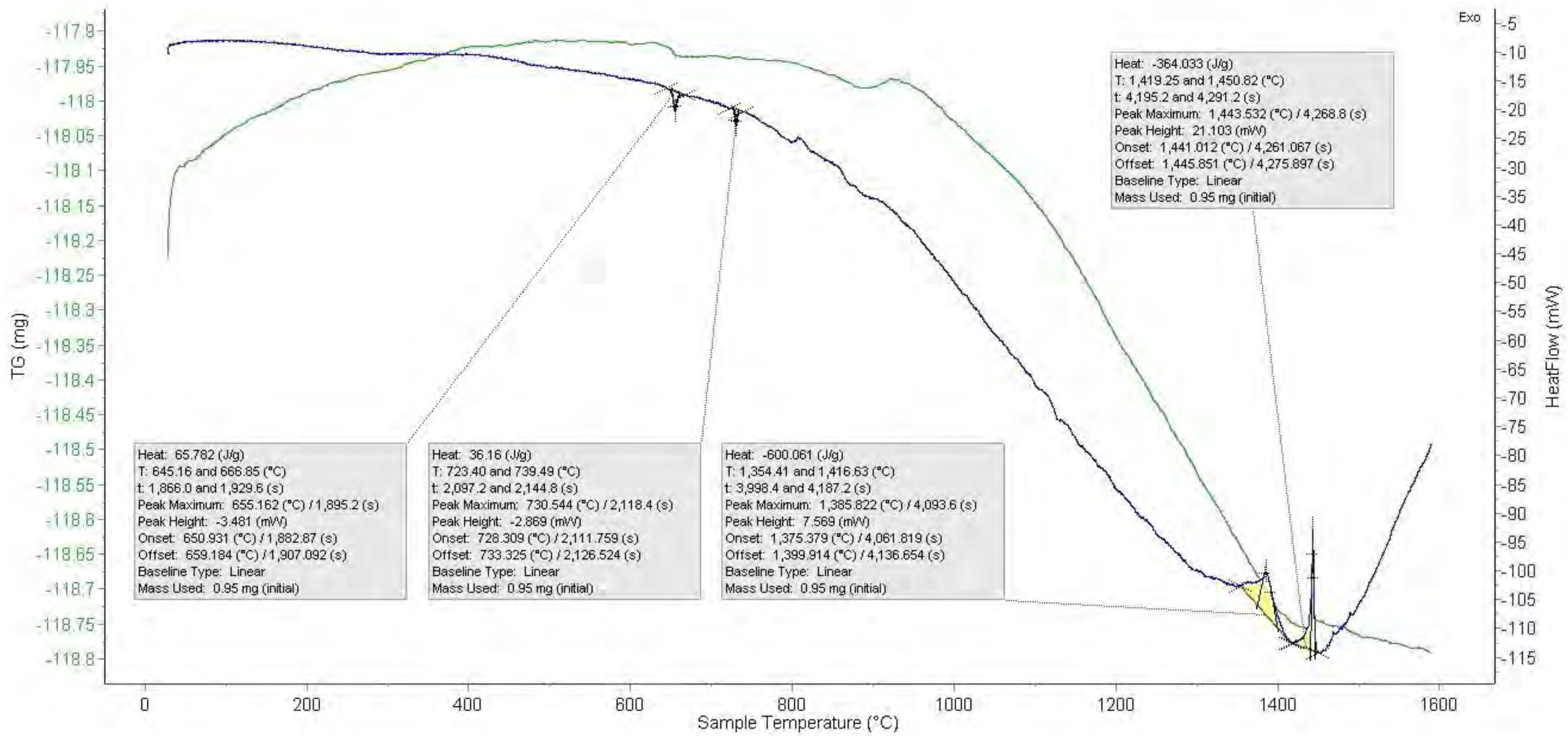


Figure C119: High-Temp DSC Plots for Mix ID SS #24 – Medium Al - Coarse Bi_2O_3, Trial 1

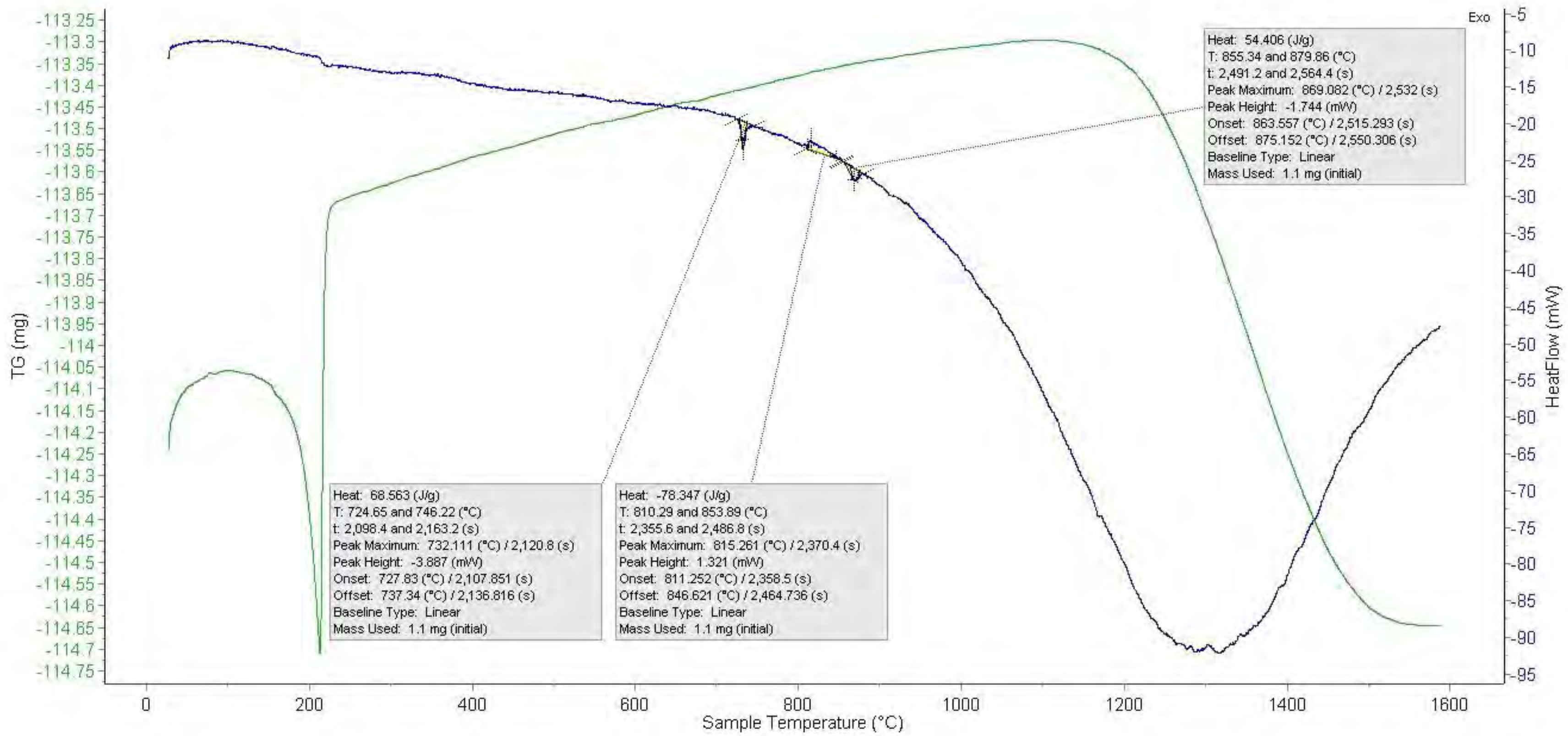


Figure C120: High-Temp DSC Plots for Mix ID SS #24 – Medium Al - Coarse Bi_2O_3, Trial 2

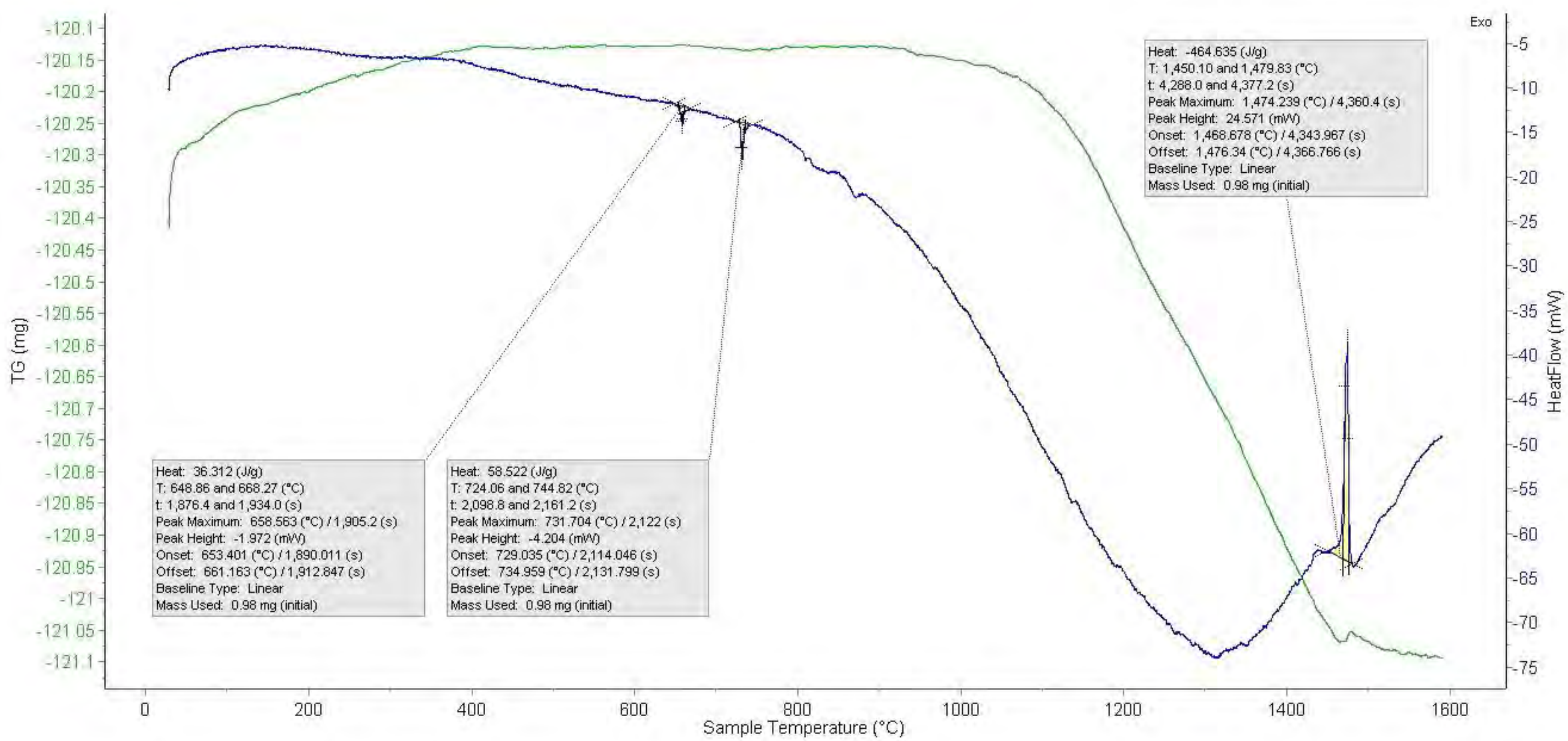


Figure C121: High-Temp DSC Plots for Mix ID SS #24 – Coarse Al - Fine Bi_2O_3, Trial 1

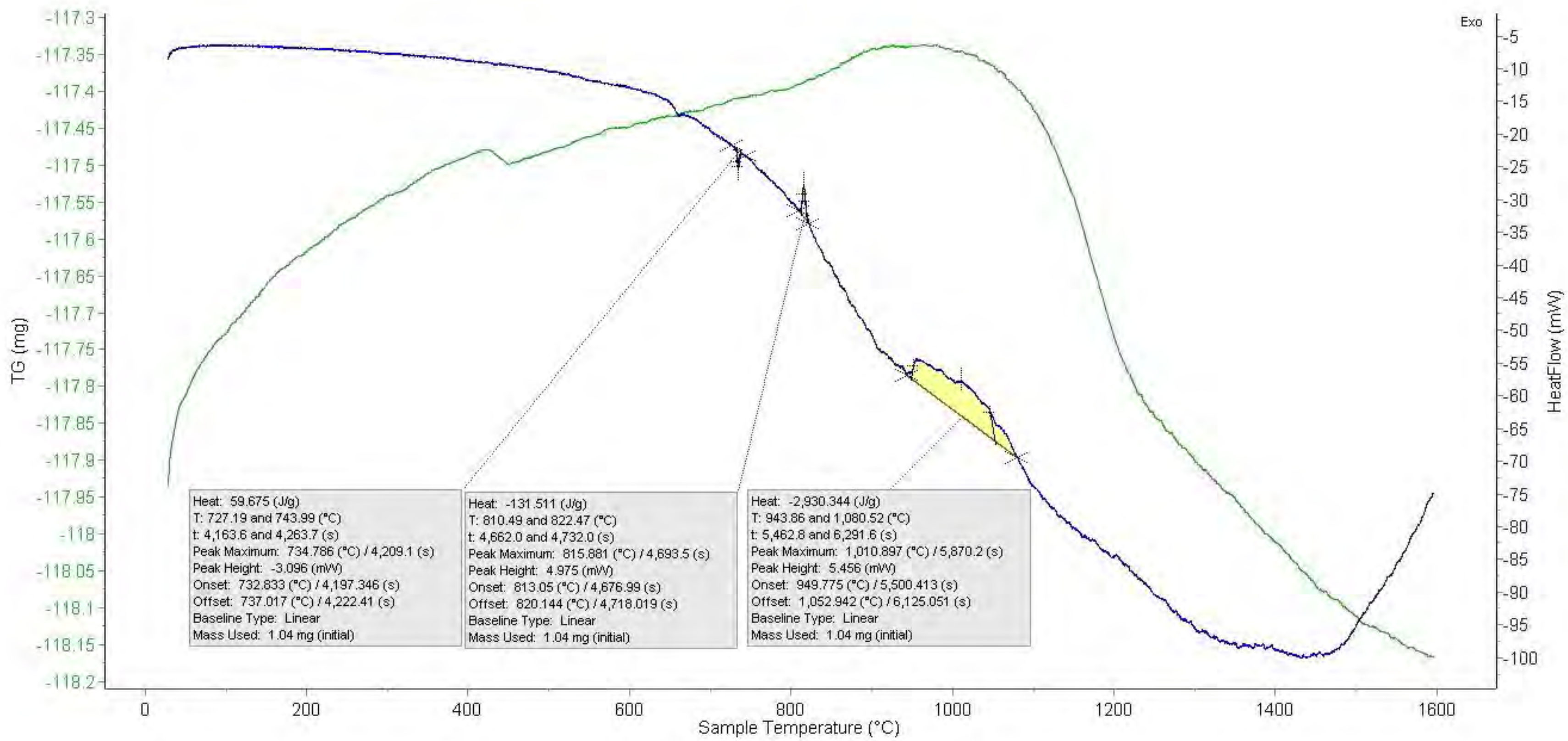


Figure C122: High-Temp DSC Plots for Mix ID SS #24 – Coarse Al - Fine Bi_2O_3, Trial 2

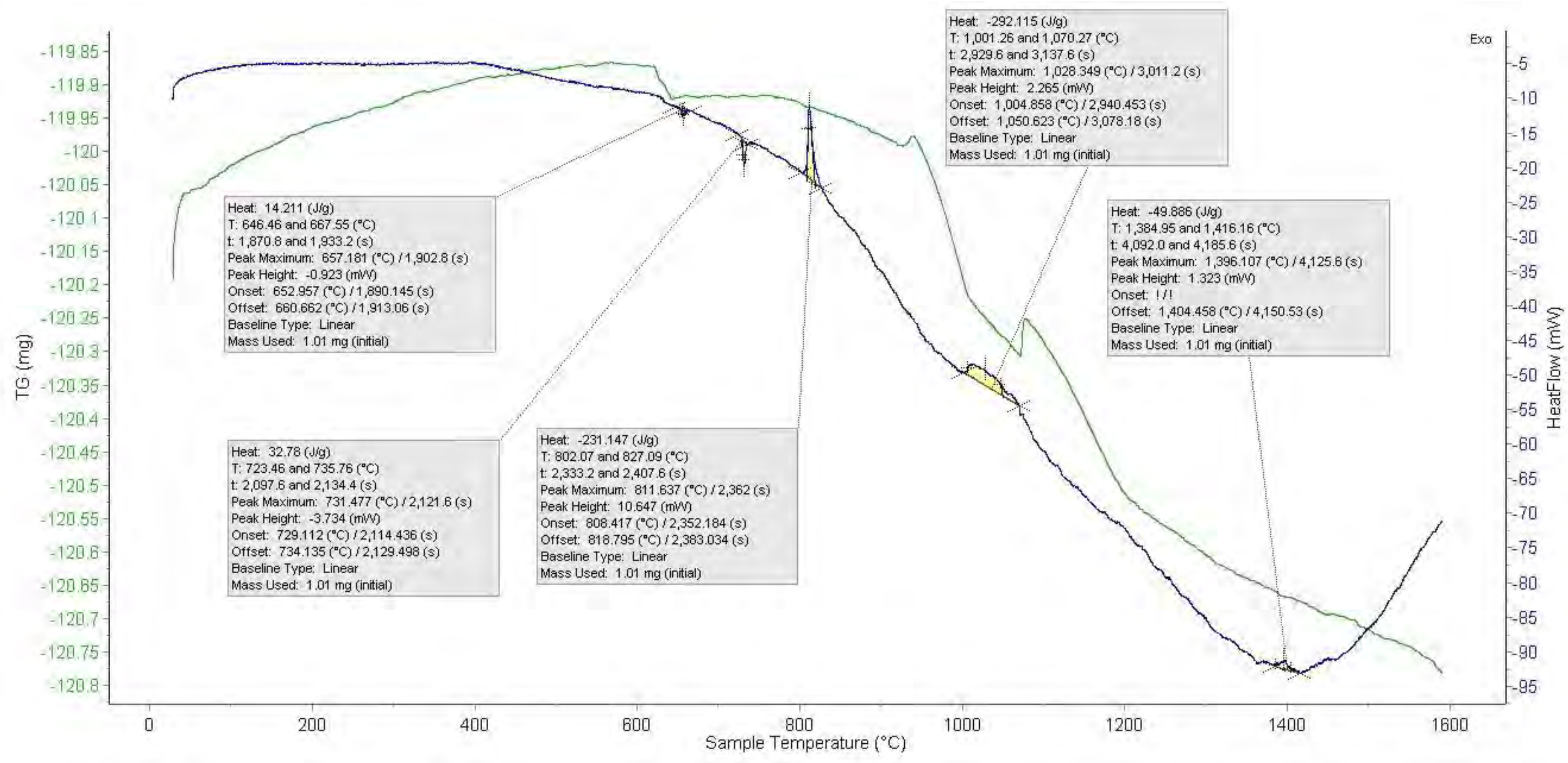


Figure C123: High-Temp DSC Plots for Mix ID SS #24 – Coarse Al - Medium Bi_2O_3, Trial 1

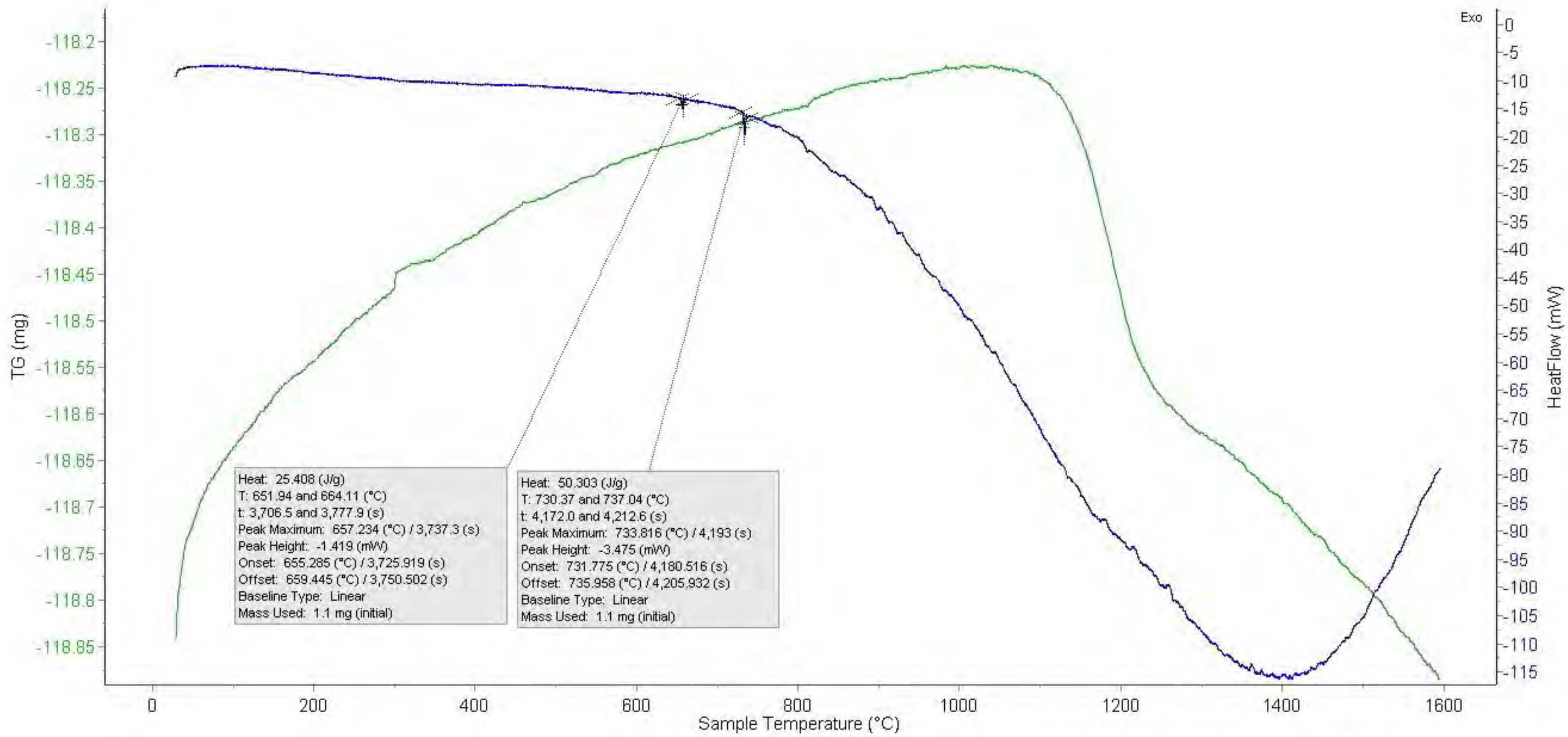


Figure C124: High-Temp DSC Plots for Mix ID SS #24 – Coarse Al - Medium Bi_2O_3, Trial 2

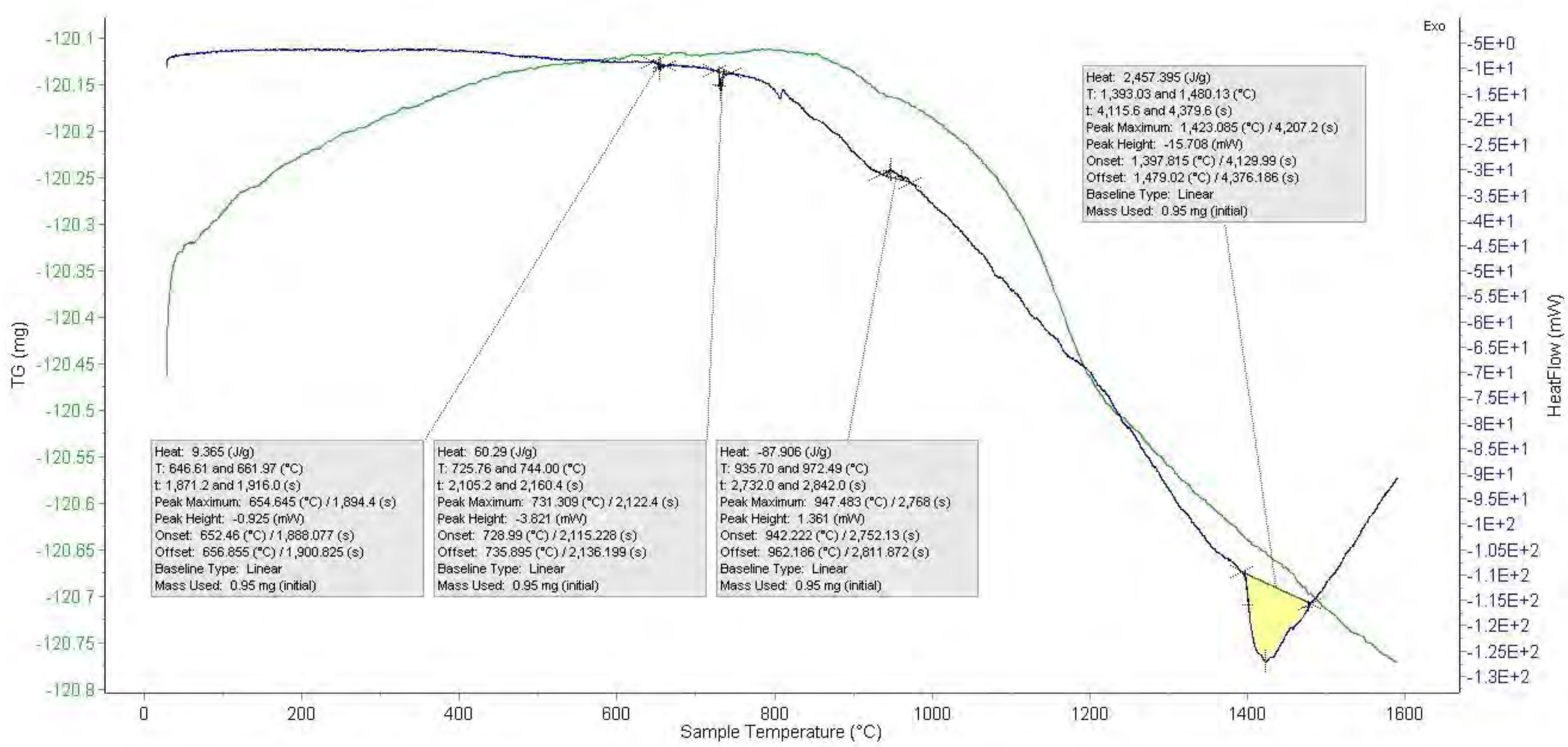


Figure C125: High-Temp DSC Plots for Mix ID SS #24 – Coarse Al - Coarse Bi_2O_3, Trial 1

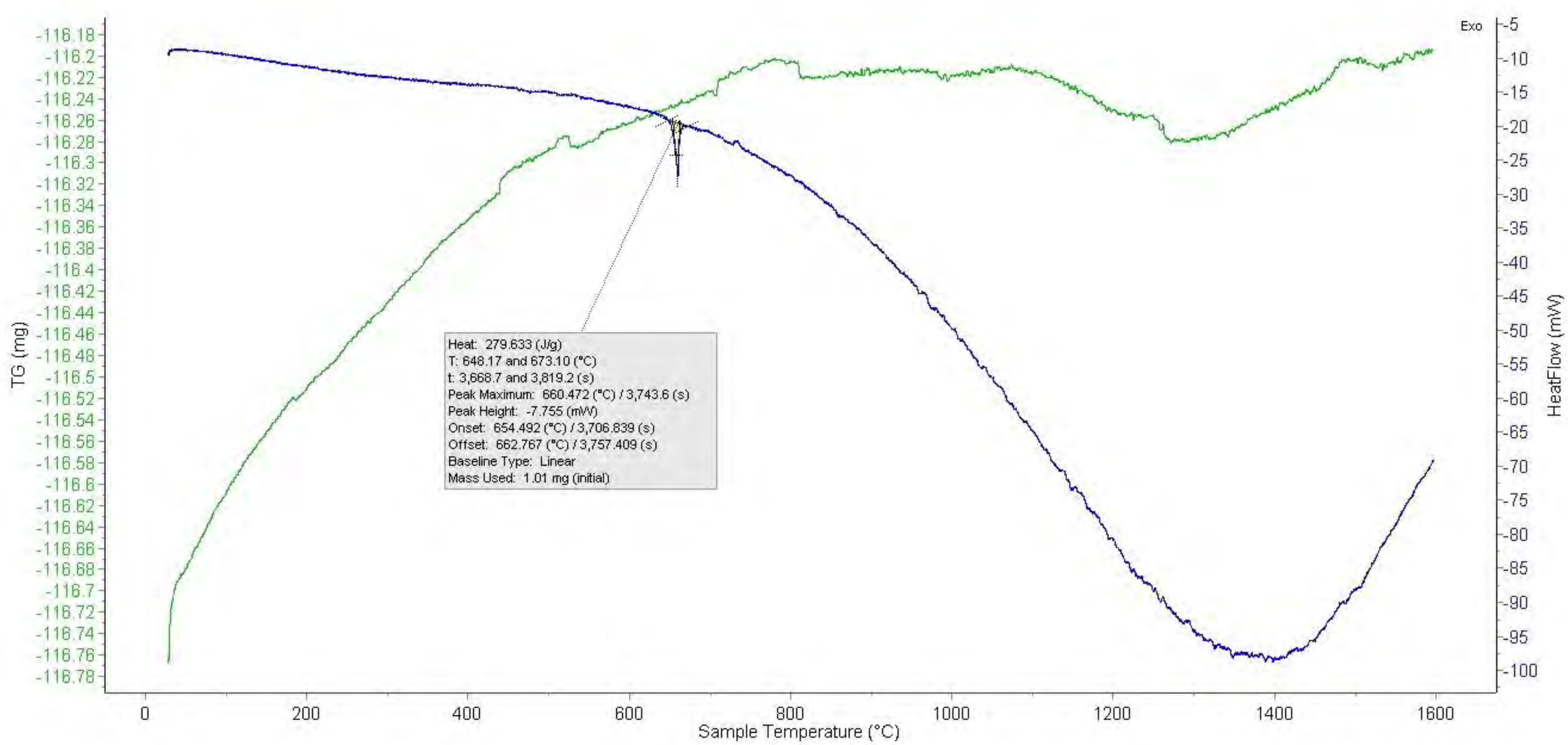


Figure C126: High-Temp DSC Plots for Mix ID SS #24 – Coarse Al - Coarse Bi_2O_3, Trial 2

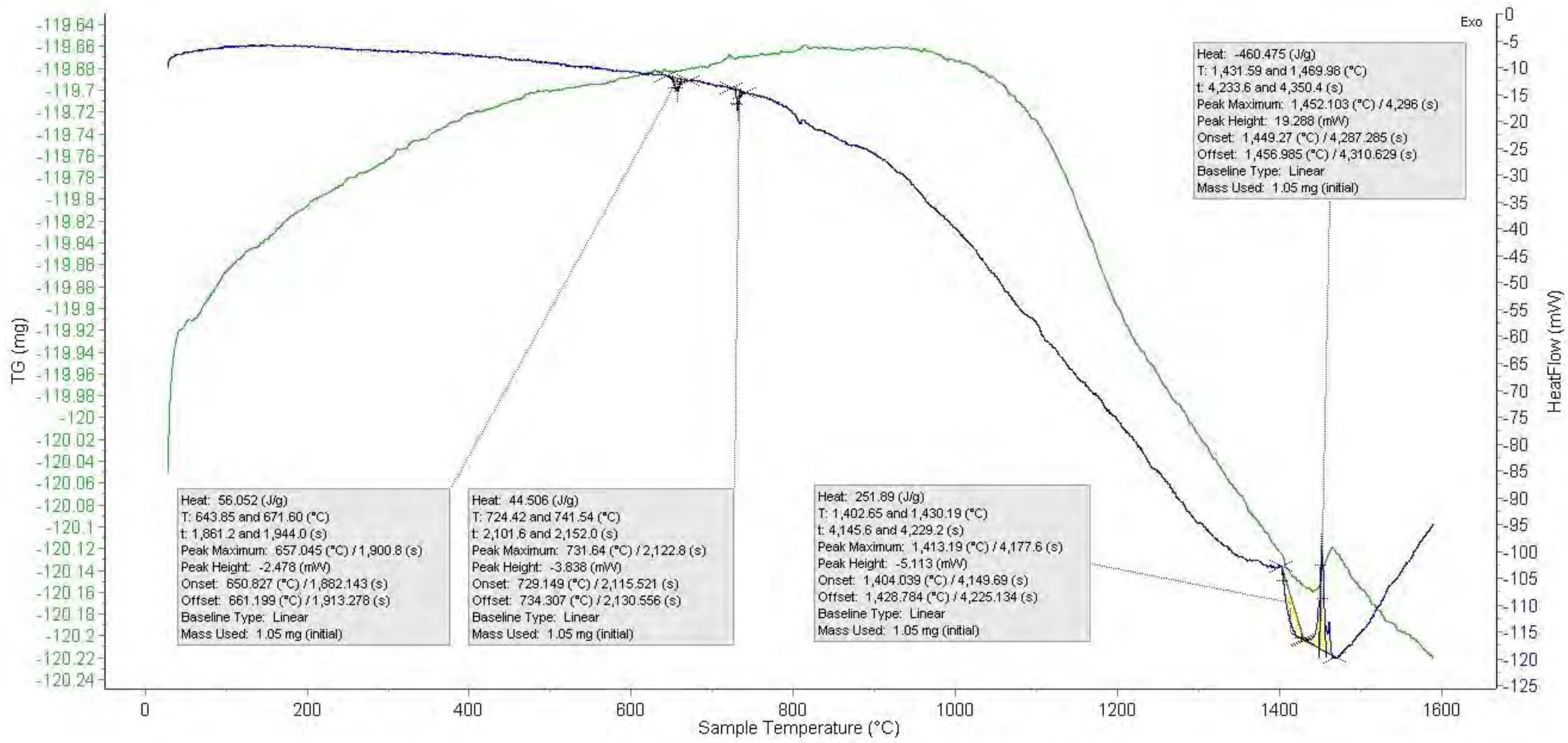


Figure C127: High-Temp DSC Plots for Mix ID SS #48 – Fine Ti - Fine Bi_2O_3, Trial 1

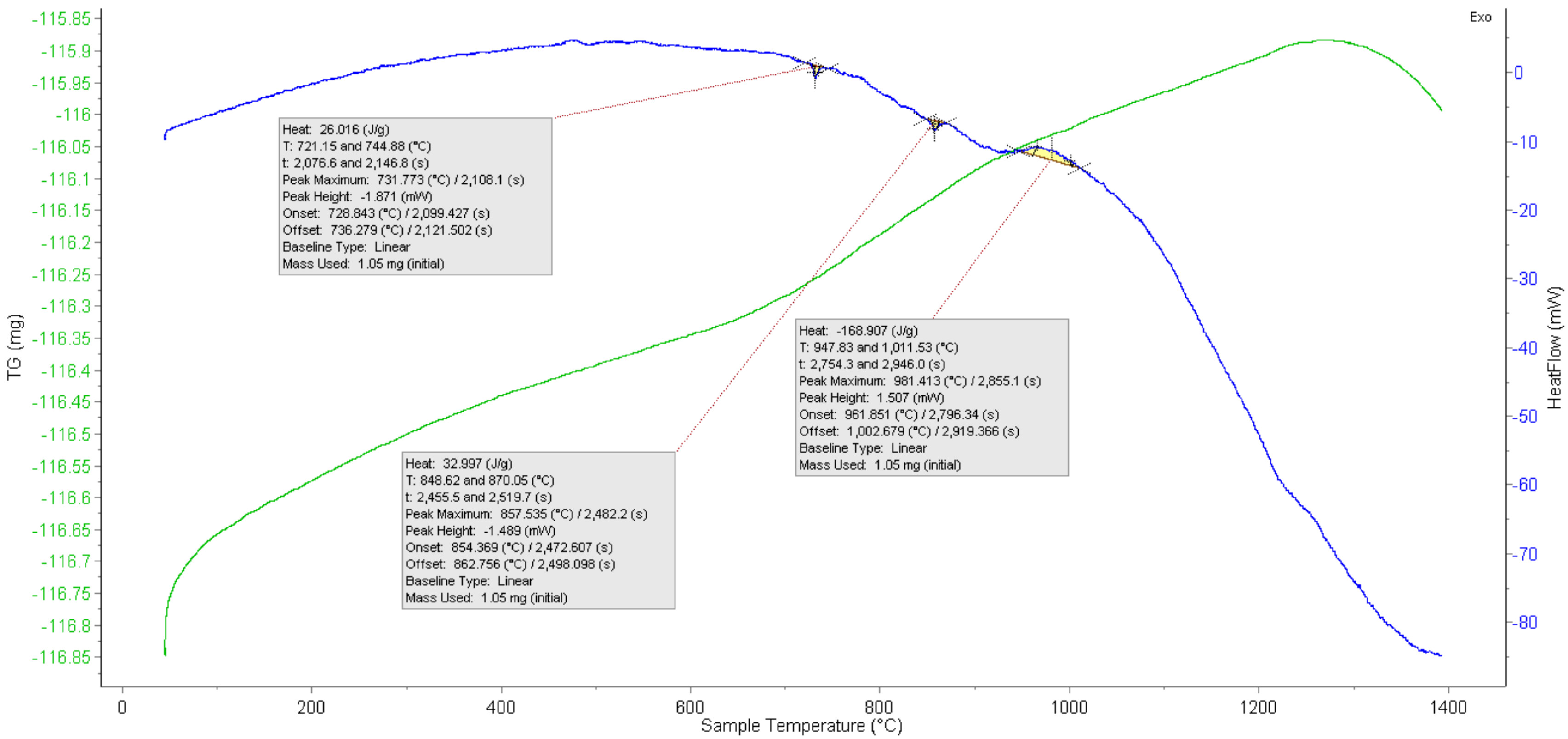


Figure C128: High-Temp DSC Plots for Mix ID SS #48 – Fine Ti - Fine Bi_2O_3, Trial 2

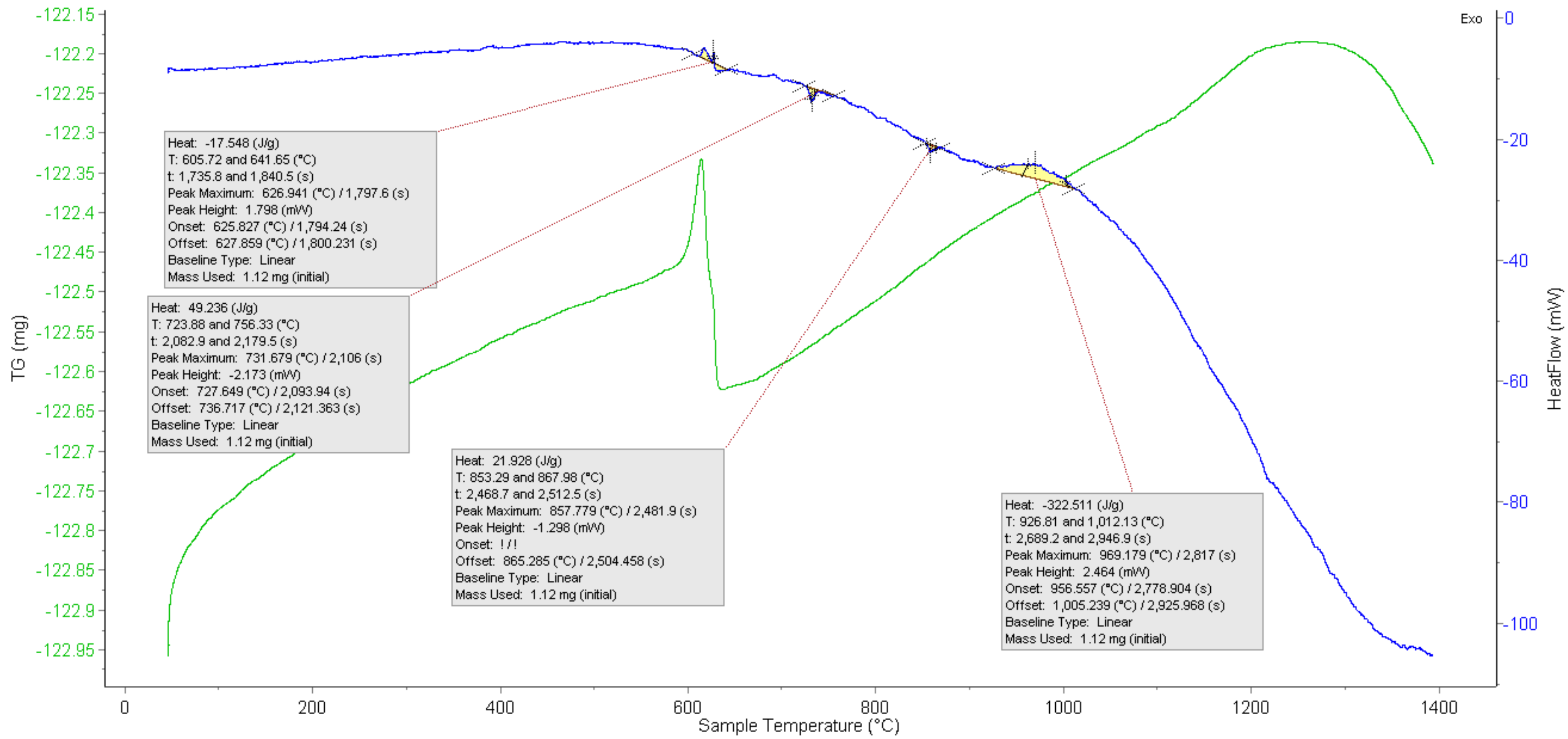


Figure C129: High-Temp DSC Plots for Mix ID SS #48 – Fine Ti - Medium Bi_2O_3, Trial 1

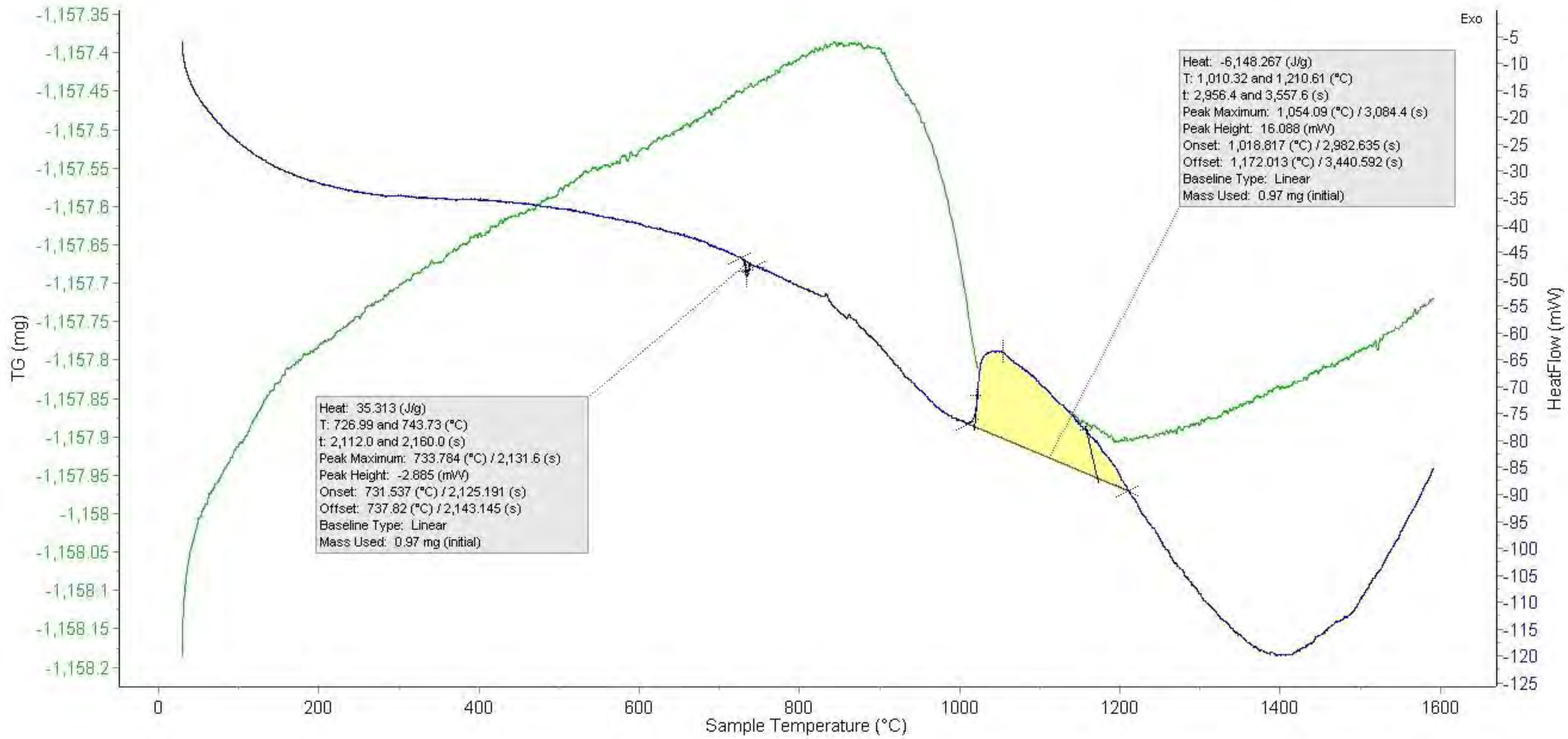


Figure C130: High-Temp DSC Plots for Mix ID SS #48 – Fine Ti - Medium Bi_2O_3, Trial 2

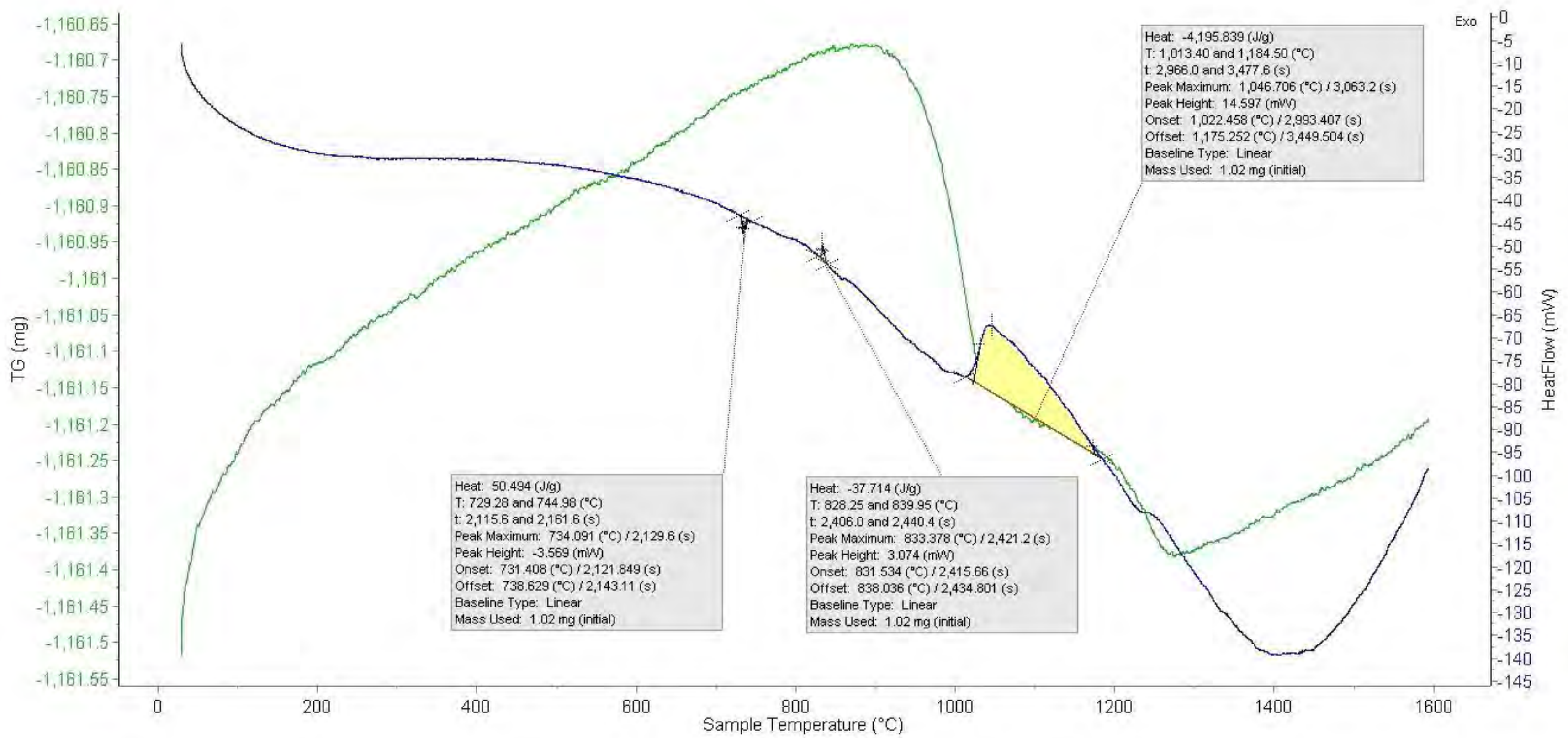


Figure C131: High-Temp DSC Plots for Mix ID SS #48 – Fine Ti - Coarse Bi_2O_3, Trial 1

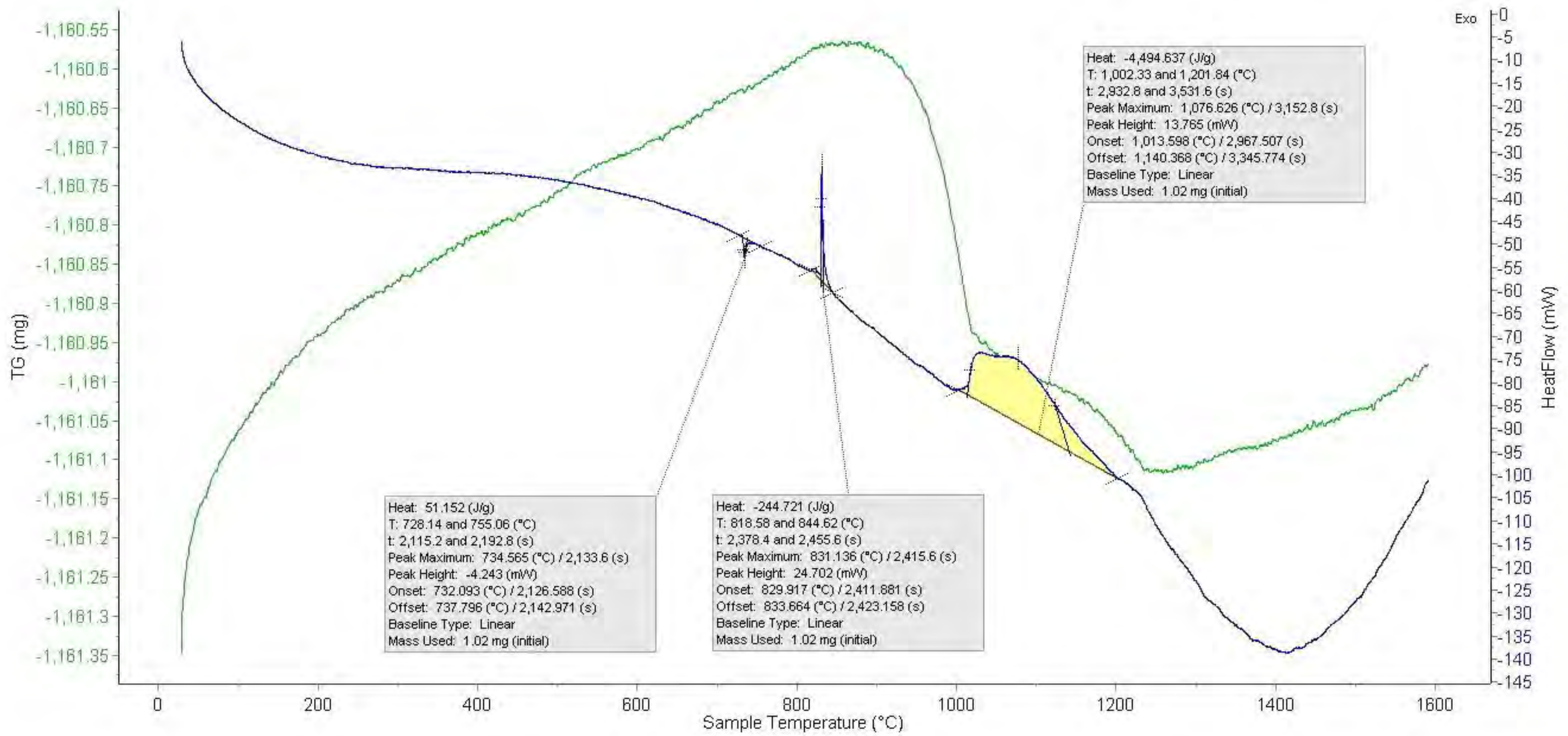


Figure C132: High-Temp DSC Plots for Mix ID SS #48 – Fine Ti - Coarse Bi_2O_3, Trial 2

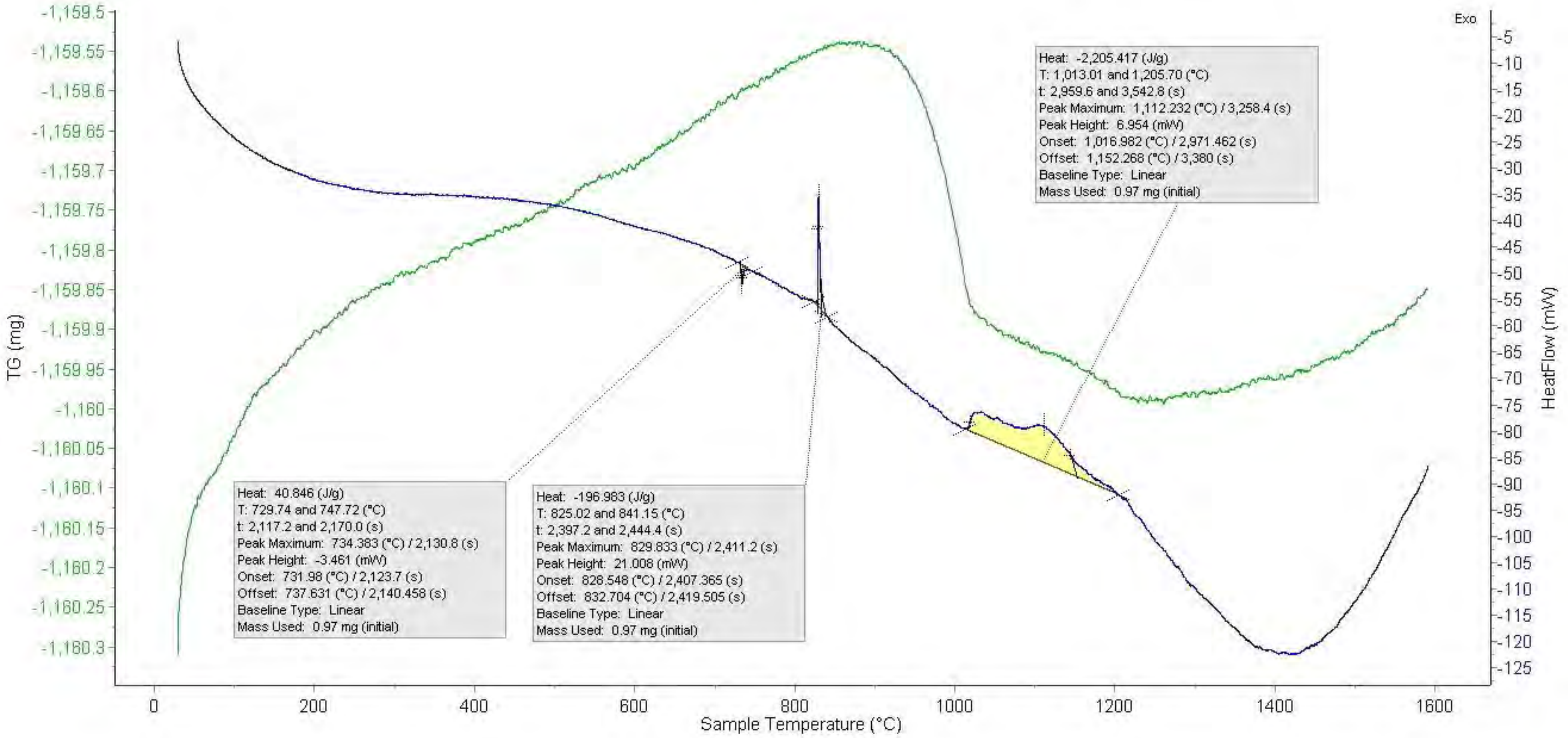


Figure C133: High-Temp DSC Plots for Mix ID SS #48 – Medium Ti - Fine Bi_2O_3, Trial 1

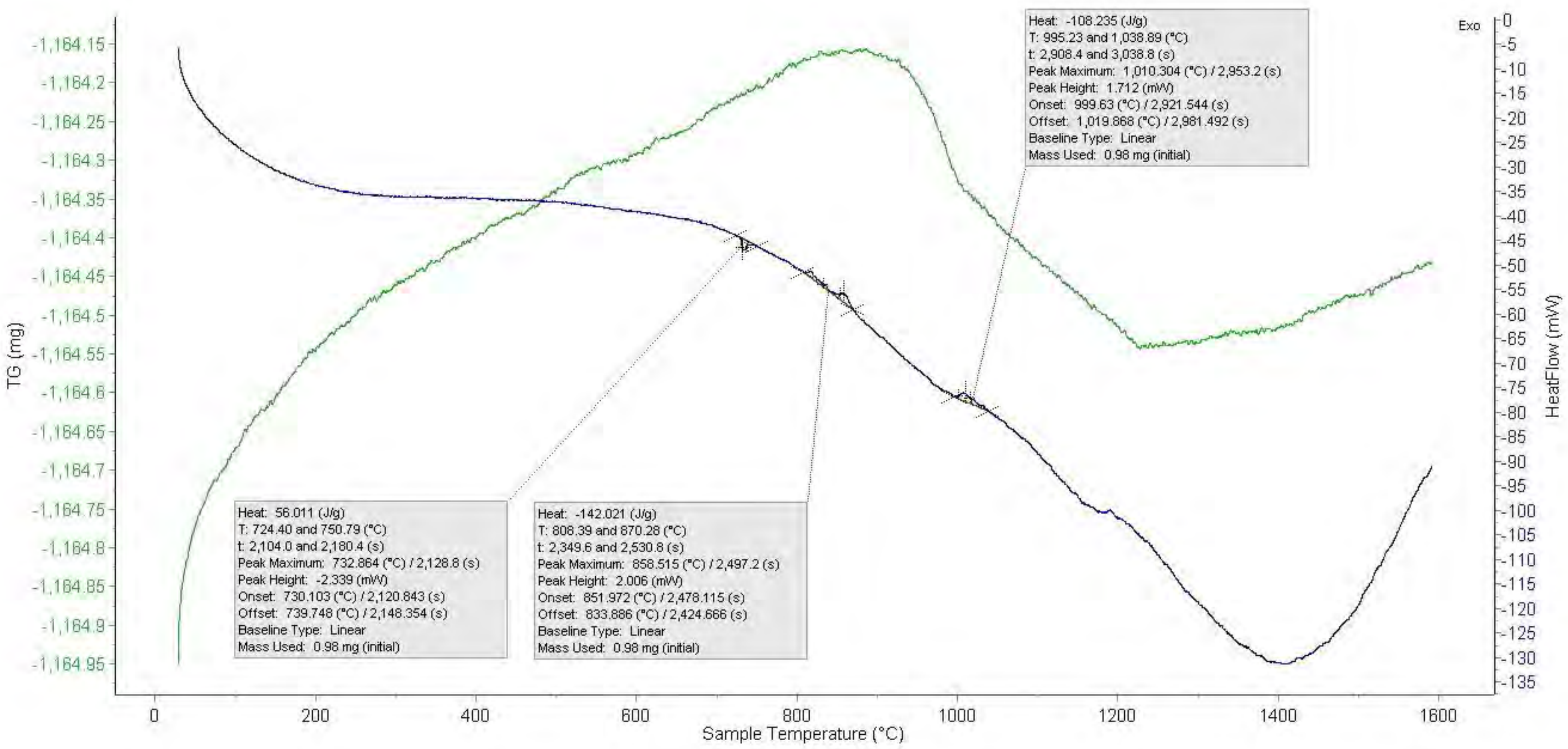


Figure C134: High-Temp DSC Plots for Mix ID SS #48 – Medium Ti - Fine Bi_2O_3, Trial 2

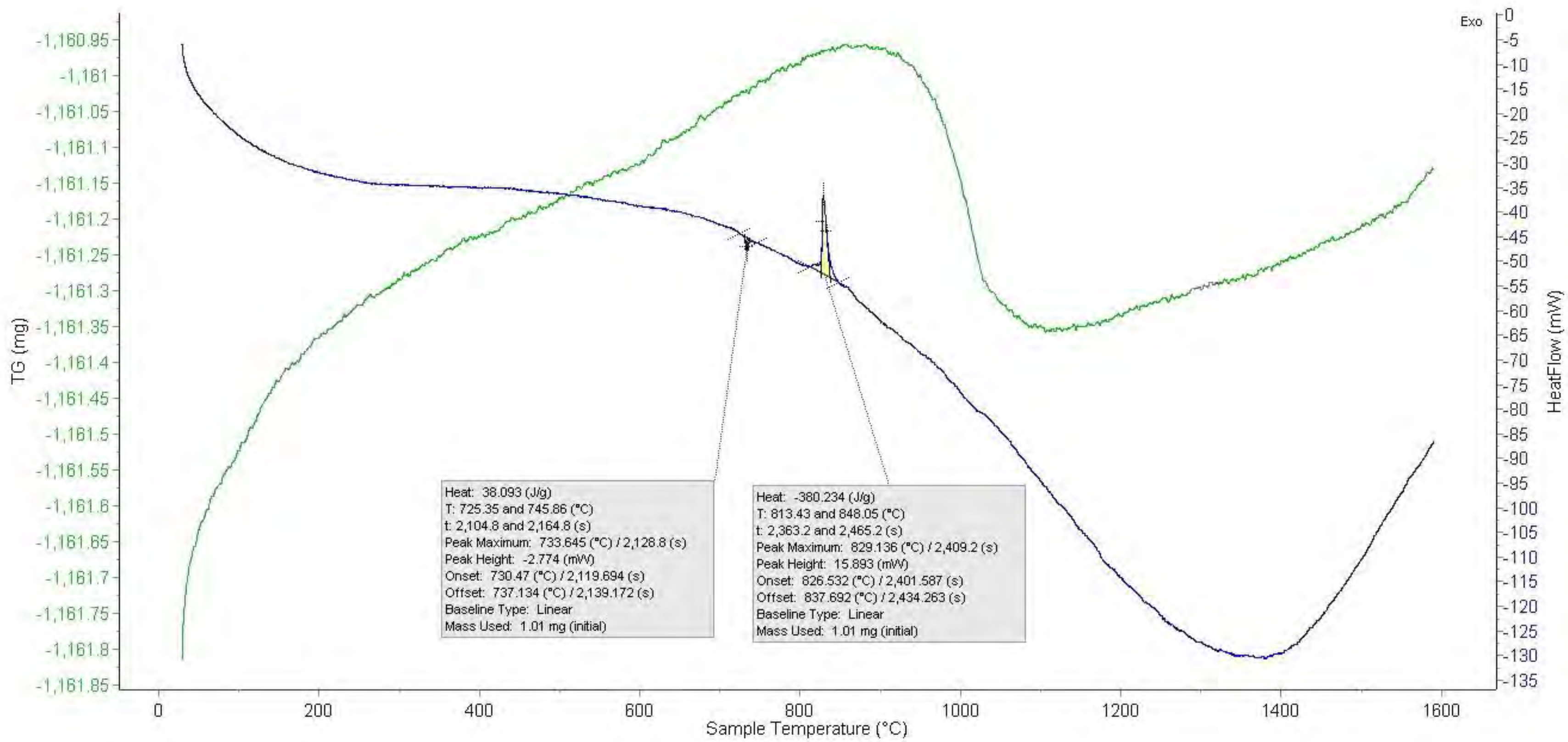


Figure C135: High-Temp DSC Plots for Mix ID SS #48 – Medium Ti - Medium Bi_2O_3, Trial 1

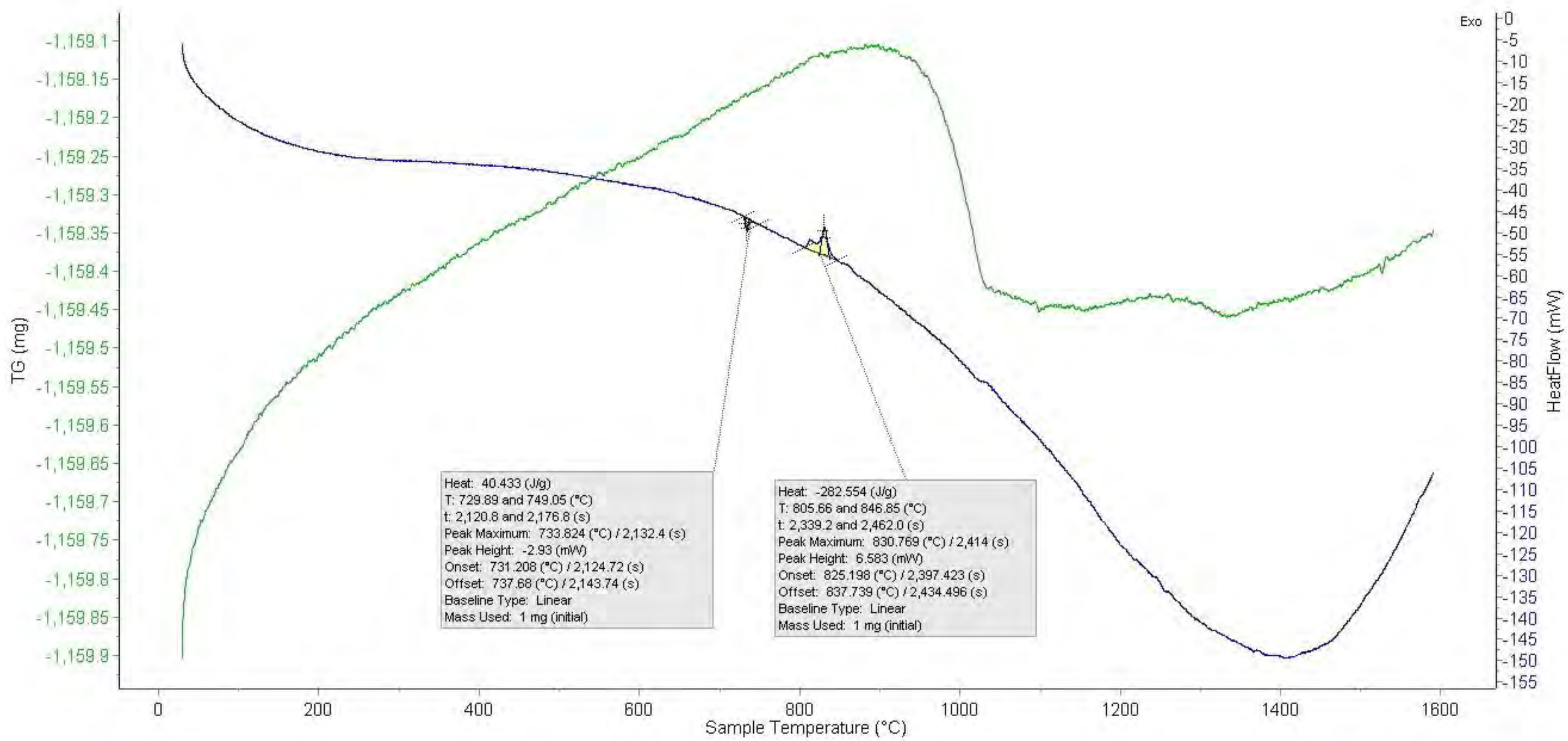


Figure C136: High-Temp DSC Plots for Mix ID SS #48 – Medium Ti - Medium Bi_2O_3, Trial 2

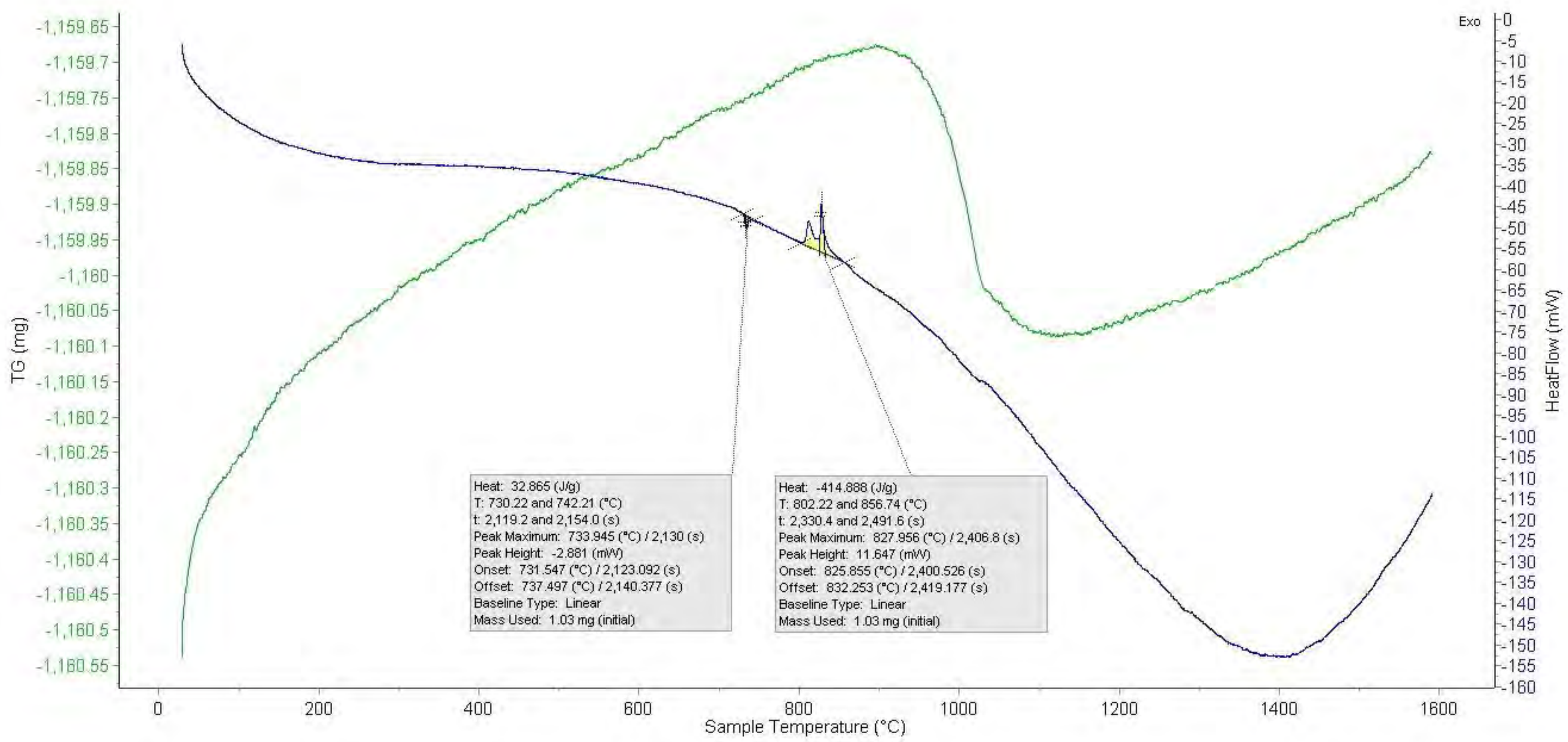


Figure C137: High-Temp DSC Plots for Mix ID SS #48 – Medium Ti - Coarse Bi_2O_3, Trial 1

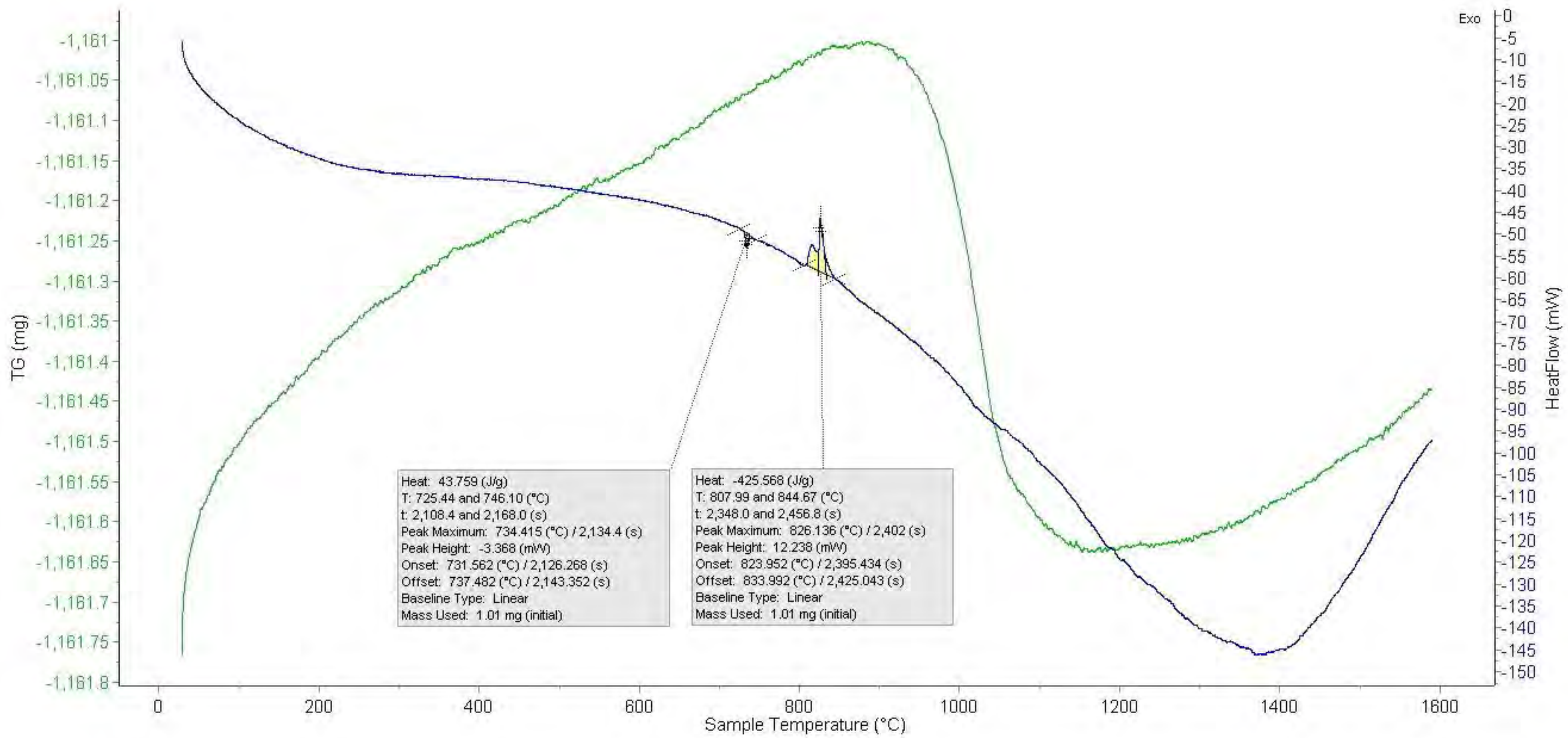


Figure C138: High-Temp DSC Plots for Mix ID SS #48 – Medium Ti - Coarse Bi_2O_3, Trial 2

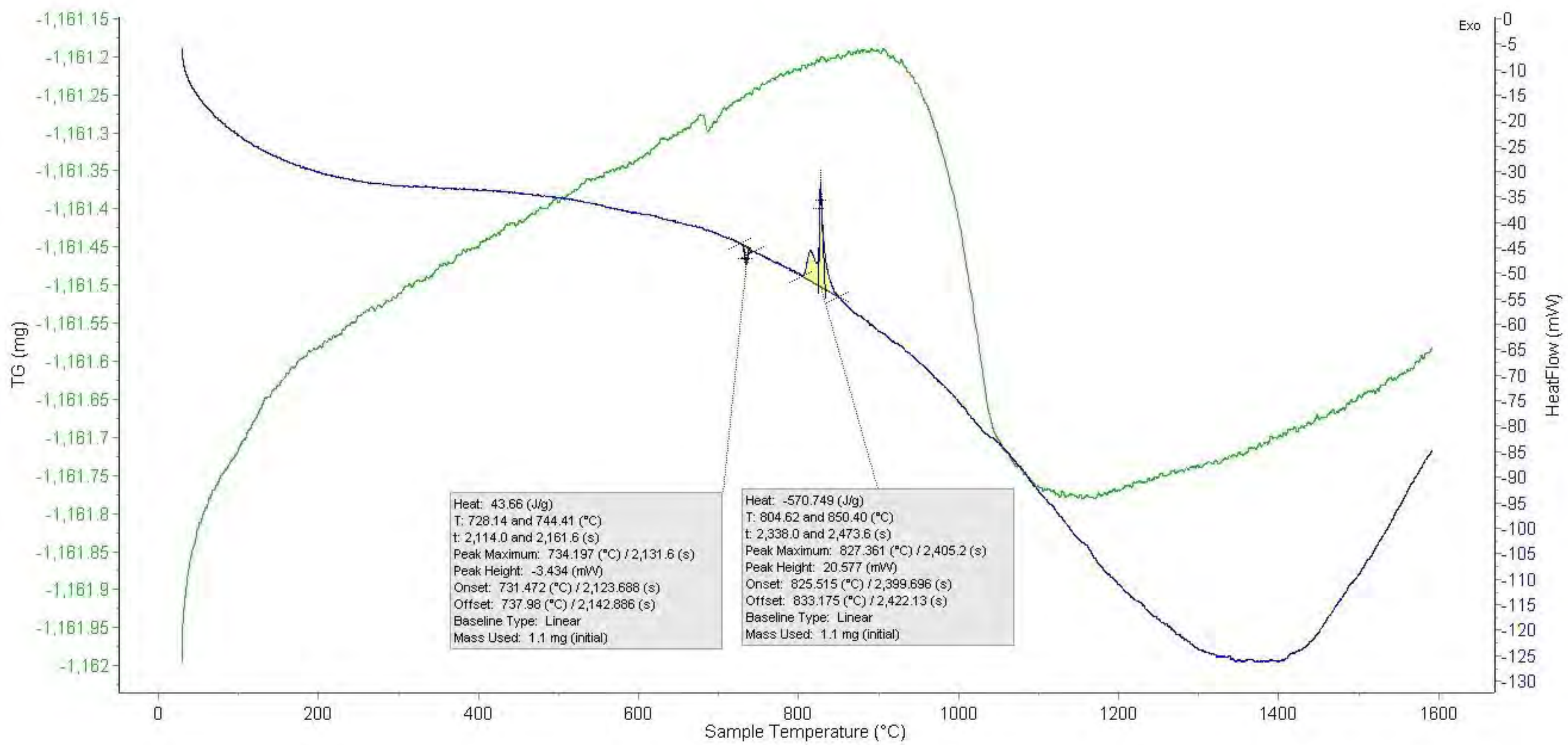


Figure C139: High-Temp DSC Plots for Mix ID SS #48 – Coarse Ti - Fine Bi_2O_3, Trial 1

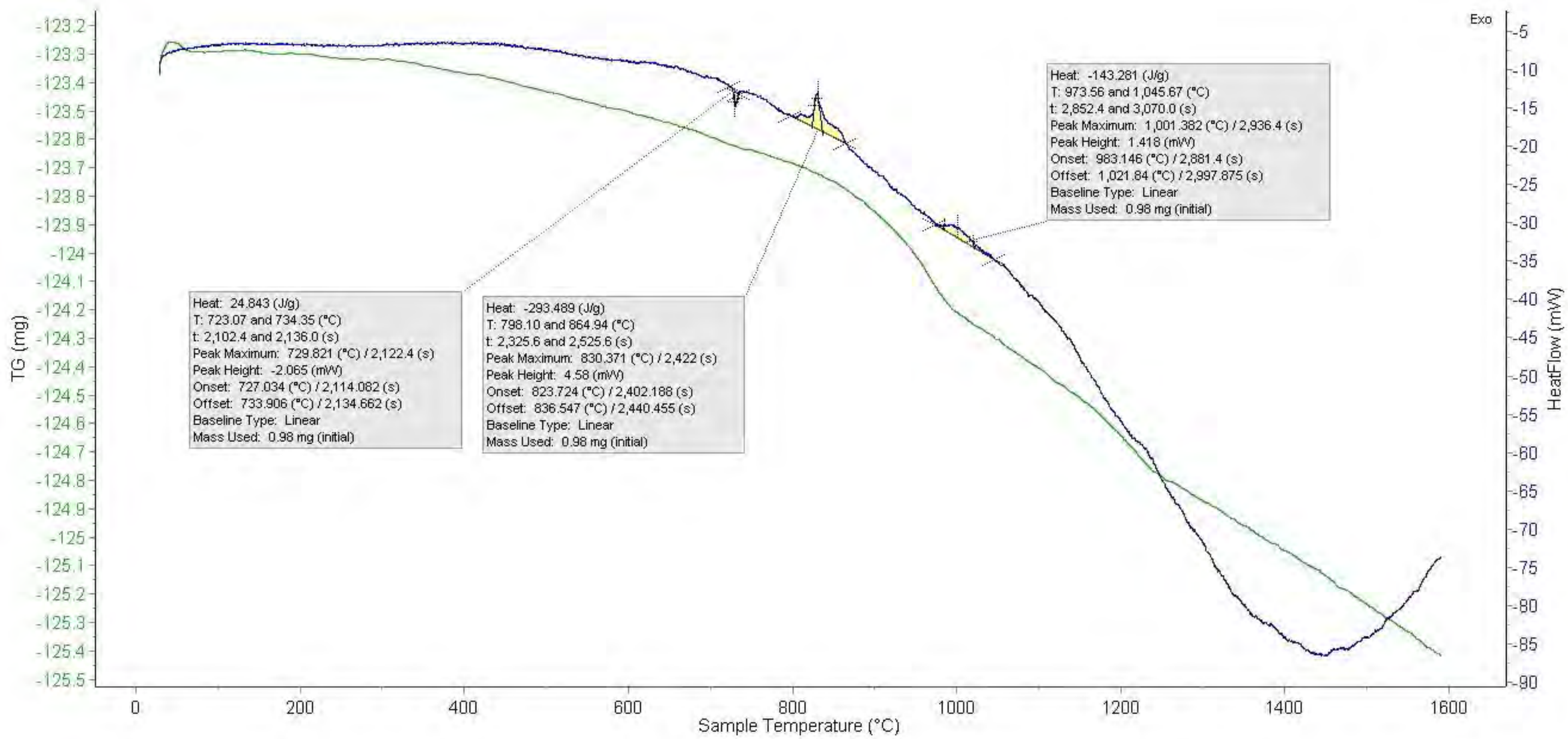


Figure C140: High-Temp DSC Plots for Mix ID SS #48 – Coarse Ti - Fine Bi_2O_3, Trial 2

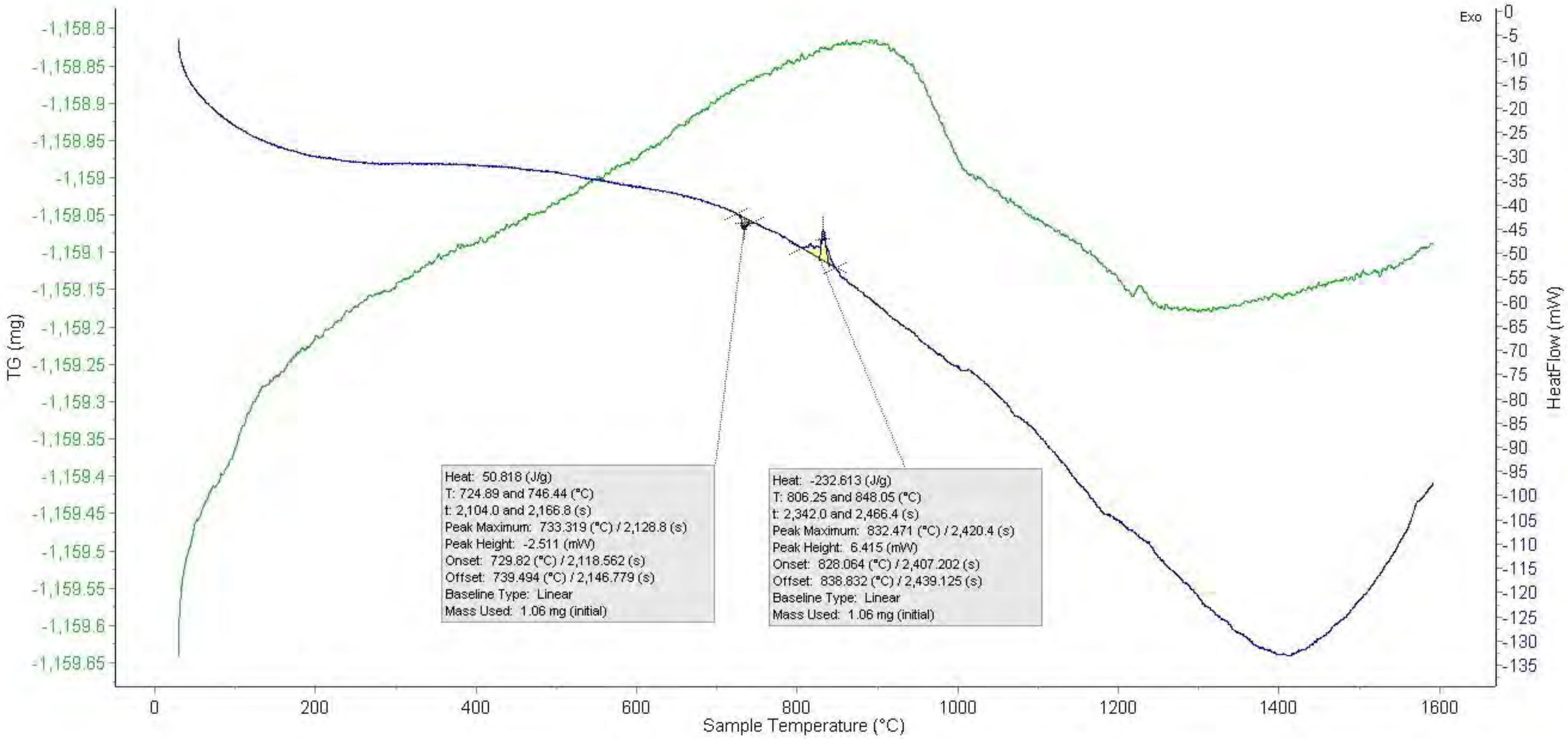


Figure C141: High-Temp DSC Plots for Mix ID SS #48 – Coarse Ti - Medium Bi_2O_3, Trial 1

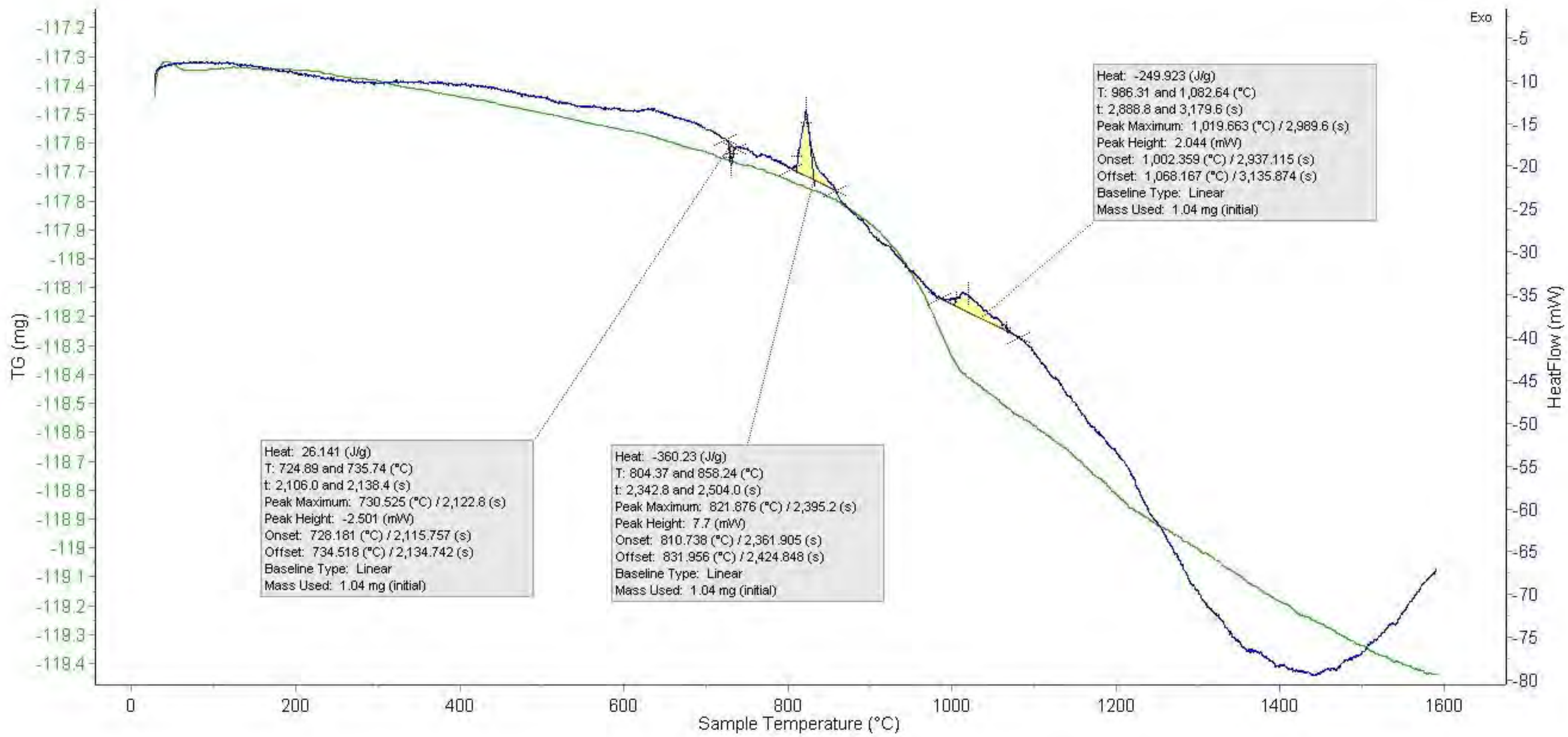


Figure C142: High-Temp DSC Plots for Mix ID SS #48 – Coarse Ti - Medium Bi_2O_3, Trial 2

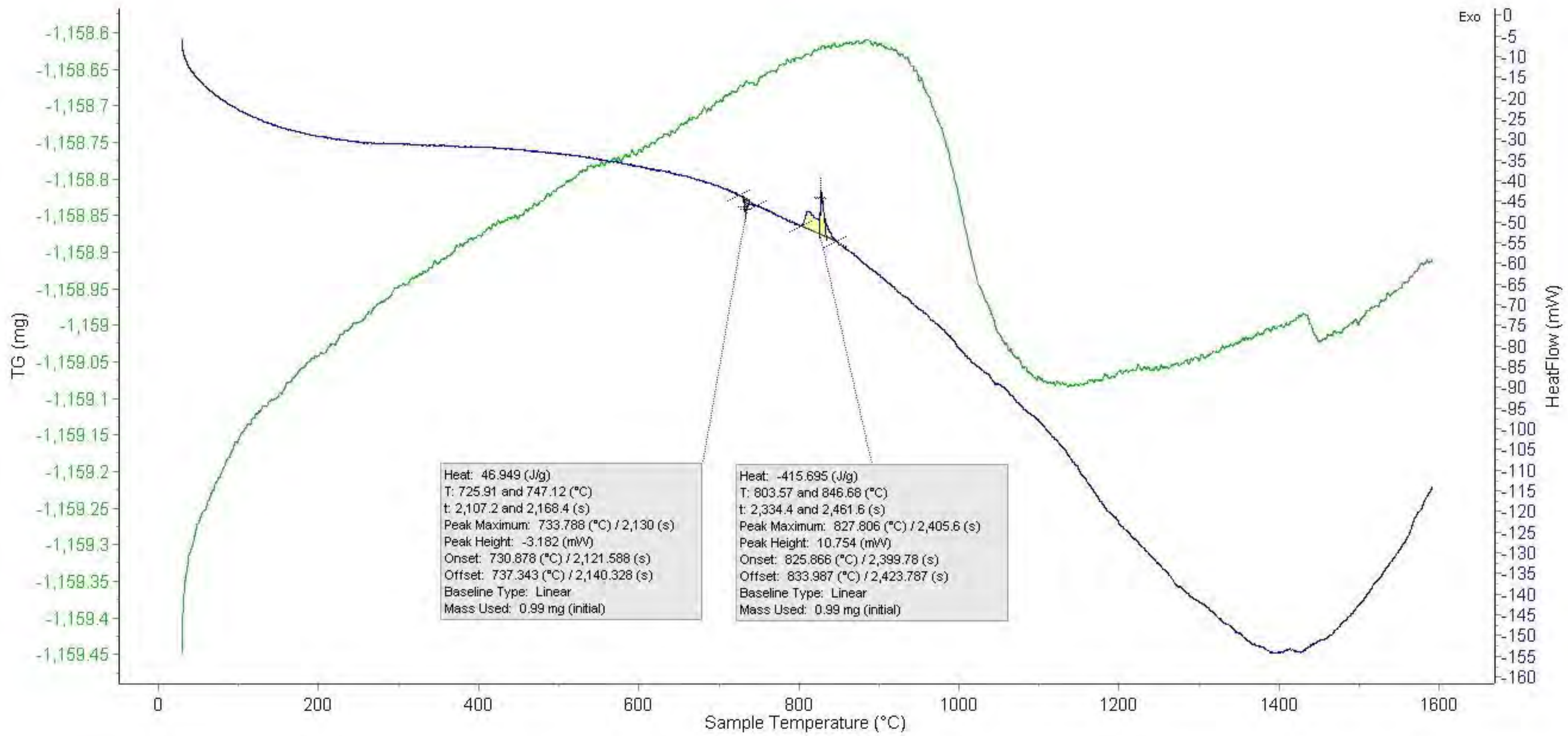


Figure C143: High-Temp DSC Plots for Mix ID SS #48 – Coarse Ti - Coarse Bi_2O_3, Trial 1

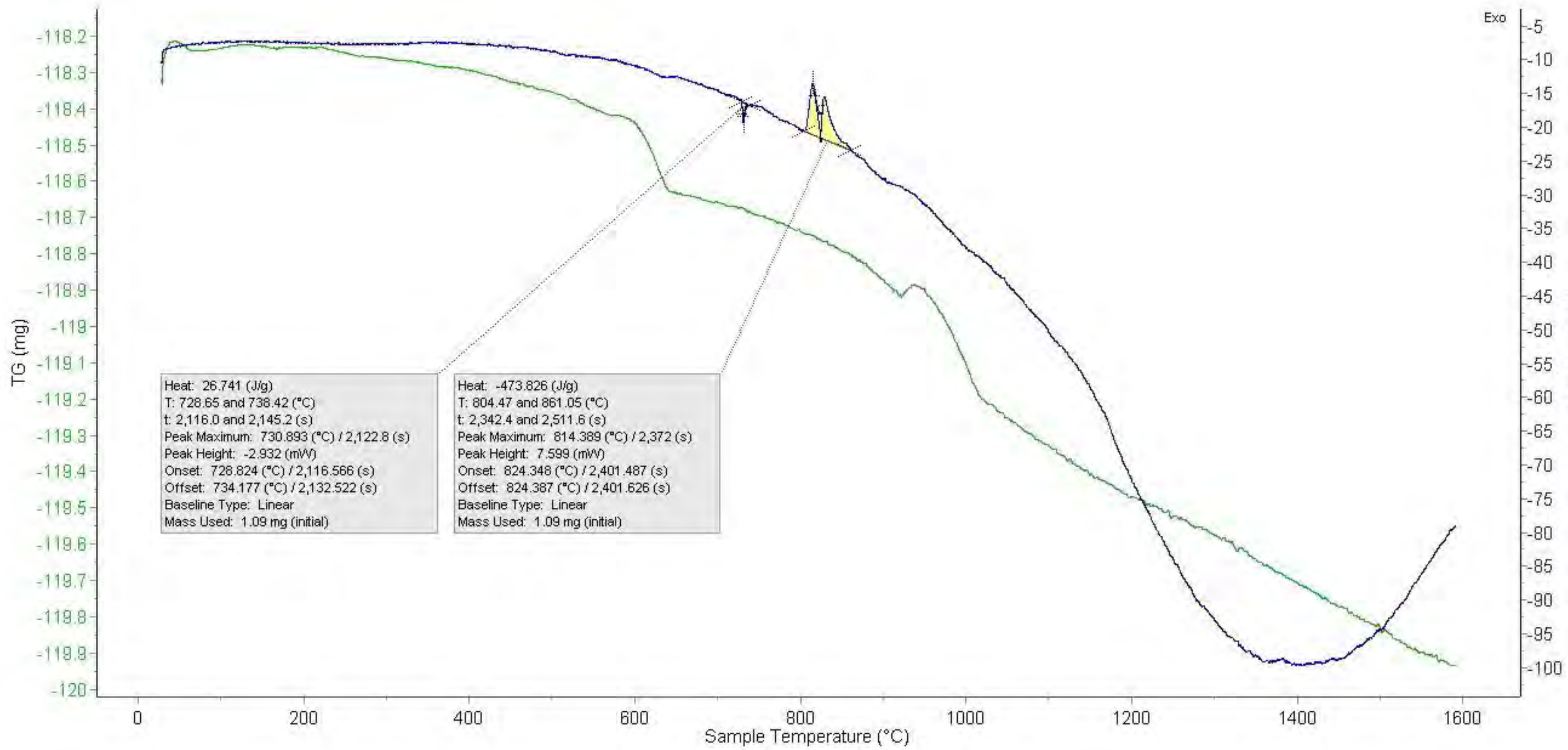
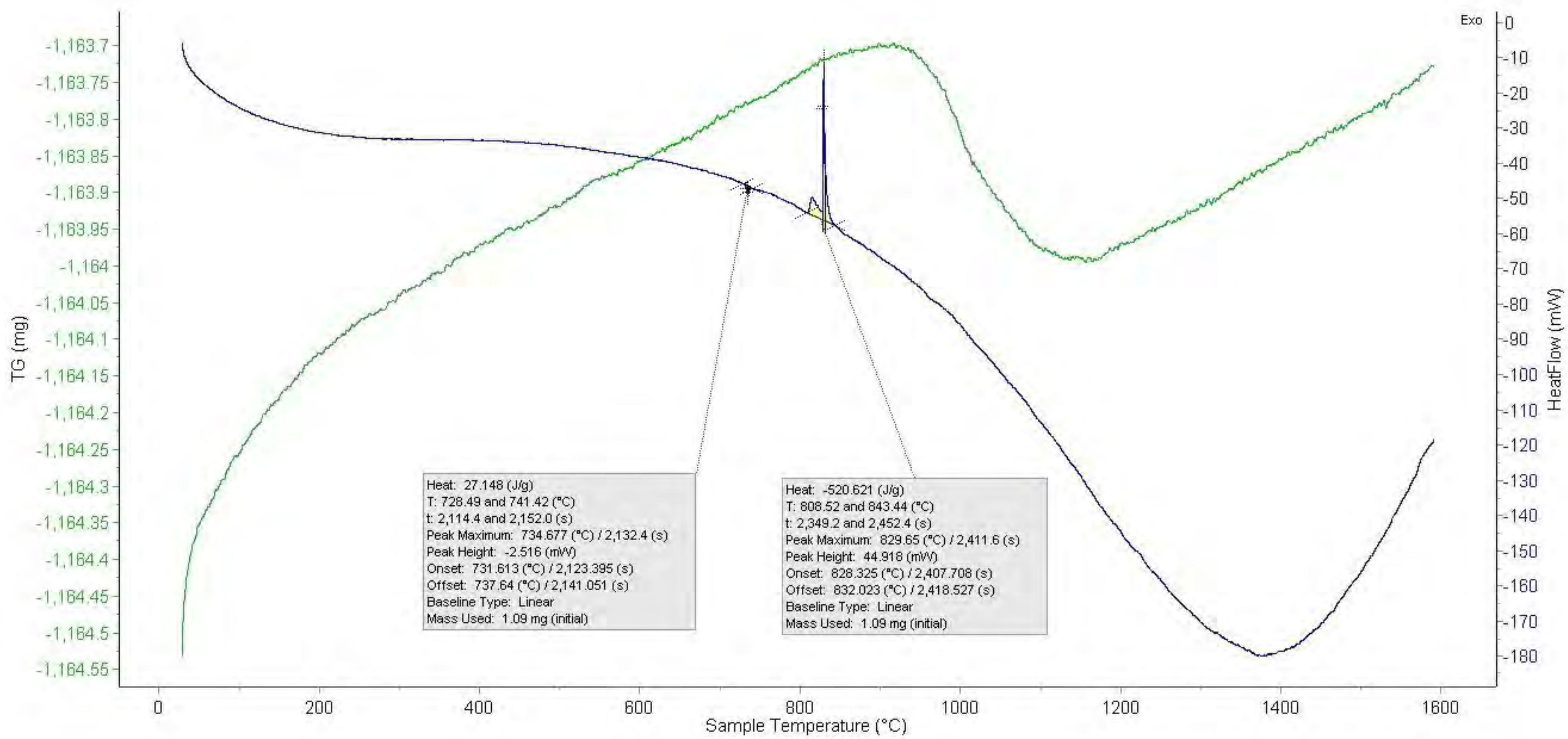


Figure C144: High-Temp DSC Plots for Mix ID SS #48 – Coarse Ti - Coarse Bi_2O_3, Trial 2



APPENDIX D
– Product Certifications

Figure D1: Product Certification for Al Metal Powder

ATLANTIC EQUIPMENT ENGINEERS
HIGH PURITY METALS AND COMPOUNDS

Certificate of Analysis
ALUMINUM METAL POWDER
AL-100

1.1 General

SOLD TO	PURCHASE ORDER #	SHIP DATE	DOCUMENT NUMBER
SAFETY MANAGEMENT SERVICES for COMMANDER TOOELE ARMY DEPOT	1526	9 MAR 2021	2101018
CATALOG NUMBER	LOT NUMBER	QUANTITY	CAS NUMBER
AL-100	2002510-6	173 LBS	7429-90-5

2.1 Chemical Analysis (in percentage (%) unless otherwise stated)

Al	Ti	Si	Fe
99.9%	<0.06	<0.10	<0.20

3.1 Screen Analysis (percent passing) / Other

Size	D 10	D 50	D 90
1-5 microns	1.5 microns	3.6 microns	9 microns

4.1 Notes

5.1 Statement

Shelf life is indefinite when material is stored in a tightly sealed container in a cool, dry place.

The above analysis is carried out as part of our internal quality control testing and is based upon our analysis methods.

We do not assume any warranty, liability, or risk based on such findings. Our quality is warranted within the scope of our general sales conditions.

Please refer to SDS for material handling instructions.

Very Truly Yours,

M. Gerald, QA

24 Industrial Ave, Upper Saddle River, NJ 07458 Tel: 201.828.9400 Fax: 201.387.0291
On the web at: www.micronmetals.com Email: info@micronmetals.com

Page 1 of 1

Figure D2: Product Certification for Ti Metal Powder

ATLANTIC EQUIPMENT ENGINEERS
HIGH PURITY METALS AND COMPOUNDS

Certificate of Analysis
TITANIUM METAL POWDER
TI 101

1.1 General

SOLD TO	PURCHASE ORDER #	SHIP DATE	DOCUMENT NUMBER
SAFETY MANAGEMENT SERVICES for COMMANDER TOOELE ARMY DEPOT	1526	9 MAR 2021	2101018
CATALOG NUMBER	LOT NUMBER	QUANTITY	CAS NUMBER
TI 101	2012519	7 LBS	7440-32-6

2.1 Chemical Analysis (in percentage (%) unless otherwise stated)

Al	Cl	Cr	Fe	H	Mg	Mn
0.007	<0.025	0.004	0.028	0.51	<0.010	<0.005
Mo	Zr	Na	Ni	O	P	Pb & Cd
<0.005	<0.01	<0.001	0.006	0.91	<0.010	<0.002
Si	Sn	V	Ti			
0.007	<0.010	<0.005	99.8% min			

3.1 Screen Analysis (percent passing) / Other

Size	
< 20 microns	

4.1 Notes
99.8% min metals basis

5.1 Statement

The above analysis is carried out as part of our internal quality control testing and is based upon our analysis methods.

We do not assume any warranty, liability, or risk based on such findings. Our quality is warranted within the scope of our general sales conditions.

Please refer to SDS for material handling instructions.

Very Truly Yours,

M. Gerald, QA

24 Industrial Ave, Upper Saddle River, NJ 07458 Tel: 201.828.9400 Fax: 201.387.0291
On the web at: www.micronmetals.com Email: info@micronmetals.com

Page 1 of 1

Figure D3: Product Certification for Mg Metal Powder

SIGMA-ALDRICH

3050 Spruce Street, Saint Louis, MO 63103 USA
Email USA: techserv@sial.com Outside USA: eurtechserv@sial.com

Certificate of Analysis

Product Name:	MAGNESIUM powder, >= 99 %
Product Number:	13112
Batch Number:	STBH6715
Brand:	Aldrich
CAS Number:	7439-95-4
Formula:	Mg
Formula Weight:	24.31
Quality Release Date:	09 JUL 2018
Recommended Retest Date:	DEC 2021

TEST	SPECIFICATION	RESULT
APPEARANCE (COLOR)	WHITE TO GREY	LIGHT GREY
APPEARANCE (FORM)	POWDER	POWDER
ASSAY	≥ 99 %	100.7 %
INSOLUBLE MATTER	≤ 0.05 % (INSOLUBLE IN HCL)	< 0.05 %
IRON	≤ 0.05 %	< 0.05 %

Claudia Mayer
Manager Quality Control
Steinheim, Germany

Sigma-Aldrich warrants that at the time of the quality release or subsequent retest date this product conformed to the information contained in this publication. The current specification sheet may be available at Sigma-Aldrich.com. For further inquiries, please contact Technical Service. Purchaser must determine the suitability of the product for its particular use. See reverse side of invoice or packing slip for additional terms and conditions of sale.

Figure D4: Product Certification for CuO

ATLANTIC EQUIPMENT ENGINEERS
HIGH PURITY METALS AND COMPOUNDS

Certificate of Analysis
CUPRIC OXIDE
CU-602

1.1 General

SOLD TO	PURCHASE ORDER #	SHIP DATE	DOCUMENT NUMBER
SAFETY MANAGEMENT SERVICES for COMMANDER TOOELE ARMY DEPOT	1526	9 MAR 2021	2101018
CATALOG NUMBER	LOT NUMBER	QUANTITY	CAS NUMBER
CU-602	2102518	548 LBS	1317-38-0

2.1 Chemical Analysis (in percentage (%) unless otherwise stated)

Cu	CuO	Cu2O	Zn	Fe	Ca	Mg
75	94	3	0.3	0.02	0.01	0.002
Mn	Pb	Cd	As	Sb	Moisture	
0.001	0.05	0.01	0.01	0.01	0.2	

3.1 Screen Analysis (percent passing) / Other

Size	Specific Gravity	-325 mesh	Loose Bulk Density
1-5 microns	8.7 g/cc	99.9	80 lbs / ft^3

4.1 Notes

5.1 Statement

The above analysis is carried out as part of our internal quality control testing and is based upon our analysis methods.

We do not assume any warranty, liability, or risk based on such findings. Our quality is warranted within the scope of our general sales conditions.

Please refer to SDS for material handling instructions.

Very Truly Yours,

M. Gerald, QA

24 Industrial Ave, Upper Saddle River, NJ 07458 Tel: 201.828.9400 Fax: 201.387.0291
On the web at: www.micronmetals.com Email: info@micronmetals.com

Page 1 of 1

Figure D5: Product Certification for Fine MnO_2

AMERICAN ELEMENTS
World's Leading Manufacturer of Rare Earth and Advanced Material Products

A MERELEX CORPORATION • 10884 WEYBURN AVE. LOS ANGELES, CA 90024
TEL. 310-208-0551 • FAX 310-208-0351 • E-MAIL: customerservice@americanelements.com

CERTIFICATE OF COMPLIANCE

99+% (metals basis) Manganese Oxide Powder
MnO2
Product Code: MN-OX-021M-P.5UM
CAS #: 1313-13-9
LOT #: 1441516447-410

American Elements certifies that the materials listed below and shipped on 4/8/2021 meets the purity and dimensional requirements set forth in SMS Energetics, Inc. purchase order: DOT1-6265D.

99+% (metals basis) Manganese Oxide Powder
MnO2
APS: 5 um

AMERICAN ELEMENTS

By ____________

AEC FORM 102:CA REV. APP. 2/3/99

Figure D6: Product Certification for Medium MnO_2

AMERICAN ELEMENTS

World's Leading Manufacturer of Rare Earth and Advanced Material Products

A MERELEX CORPORATION • 10884 WEYBURN AVE. LOS ANGELES, CA 90024
TEL. 310-208-0551 • FAX 310-208-0351 • E-MAIL: customerservice@americanelements.com

CERTIFICATE OF COMPLIANCE

99+% (metals basis) Manganese Oxide Powder

MnO2

Product Code: MN-OX-021M-P.50T70

CAS #: 1313-13-9

LOT #: 1441516447-411

American Elements certifies that the materials listed below and shipped on 4/8/2021 meets the purity and dimensional requirements set forth in SMS Energetics, Inc. purchase order: DOT1-6265D.

99+% (metals basis) Manganese Oxide Powder
MnO2
APS: 50-70 um

AMERICAN ELEMENTS

By ____________

AEC FORM 102:CA REV. APP. 2/3/99

Figure D7: Product Certification for Large MnO_2

AMERICAN ELEMENTS

World's Leading Manufacturer of Rare Earth and Advanced Material Products

A MERELEX CORPORATION • 10884 WEYBURN AVE. LOS ANGELES, CA 90024
TEL 310-208-0551 • FAX 310-208-0351 • E-MAIL: customerservice@americanelements.com

CERTIFICATE OF COMPLIANCE

99+% (metals basis) Manganese Oxide Powder

MnO2

Product Code: MN-OX-021M-P.150T200

CAS #: 1313-13-9

LOT #: 1441516447-412

American Elements certifies that the materials listed below and shipped on 4/8/2021 meets the purity and dimensional requirements set forth in SMS Energetics, Inc. purchase order: DOT1-6265D.

99+% (metals basis) Manganese Oxide Powder
MnO2
APS: 150-200 um

AMERICAN ELEMENTS

By ______________

AEC FORM 102:CA REV. APP. 2/3/99

Figure D8: Product Certification for Bi_2O_3

SANTECH Changsha Santech Materials Co.,Ltd.
长沙盛特新材料有限公司

Address: B-22 Bldg, Jinke Yida Industry Creation Town, No. 77 of East Sixth Road, Economic Development Zone, Changsha, Hunan, 410001, China

地 址：中国湖南省长沙市经济技术开发区东六路 77 号长沙科技新城 B22 栋 Web: www.santechchem.com

Certificate of Analysis / 产品质检单

Customer(客户): ______________ Analyst(检验员): ______________

Item 项目	Purity 纯度	Specs 规格	Total 批量	Lot NO. 批号	Structure 结构
Bi2O3	99.9% up	Powder	100 KGS	CS200512	Tetragonal crystal structure(α type)

Chemical Composition 化学成分 (max %)					
Element 元素	Test Result 实测值	Element 元素	Test Result 实测值	Element 元素	Test Result 实测值
Li	0.0001%	Si	0.0001%	Ni	0.0001%
Na	0.0001%	As	0.0001%	Cu	0.0001%
K	0.0001%	Cd	0.0001%	Pb	0.0003%
Ca	0.0002%	Fe	0.0003%	Ag	0.0003%
Mg	0.0003%	Sn	0.0001%	Sb	0.0001%
Al	0.0005%	Cr	0.0001%		

氯化物 Chloride Radical	0.0006%
硫酸根 Sulfate Radical	0.0008%
烧失量 Loss on Ignition	0.2%
硝酸不溶物 Insoluble Matter in Nitric Acid	0.0044%

Conclusion of Analysis(检验结论): Product's purity is 99.9% 产品纯度为 99.9%

产品检验章

Figure D9: Product Certification for Fine SnO_2

SIGMA-ALDRICH

sigmaaldrich.com

3050 Spruce Street, Saint Louis, MO 63103, USA
Website: www.sigmaaldrich.com
Email USA: techserv@sial.com
Outside USA: eurtechserv@sial.com

Certificate of Analysis

Product Name:
Tin(IV) oxide - -325 mesh, 99.9% trace metals basis

Product Number:	**244651**
Batch Number:	**MKBX0592V**
Brand:	ALDRICH
CAS Number:	18282-10-5
MDL Number:	MFCD00011244
Formula:	O2Sn
Formula Weight:	150.71 g/mol
Quality Release Date:	16 DEC 2015

SnO_2

Test	Specification	Result
Appearance (Color) Off-White to Grey	Conforms to Requirements	Light Grey
Appearance (Form)	Powder	Powder
X-Ray Diffraction	Conforms to Structure	Conforms
Loss on Ignition 1 Hour at 1000 Degrees Celsius	≤ 0.5 %	0.1 %
ICP Major Analysis Confirms Tin Component	Confirmed	Conforms
Purity 99.9% Based On Trace Metals Analysis	Conforms	Conforms
Trace Metal Analysis	≤ 1000.0 ppm	579.0 ppm
Silver (Ag)		9.0 ppm
Aluminum (Al)		4.4 ppm
Arsenic (As)		4.5 ppm
Bismuth (Bi)		16.0 ppm
Calcium (Ca)		35.0 ppm
Chromium (Cr)		2.2 ppm
Copper (Cu)		15.0 ppm
Iron (Fe)		120.0 ppm
Potassium (K)		2.0 ppm
Magnesium (Mg)		24.0 ppm
Manganese (Mn)		0.7 ppm
Sodium (Na)		11.0 ppm
Nickel (Ni)		1.9 ppm

Version Number: 1

Figure D10: Product Certification for Medium SnO_2

AMERICAN ELEMENTS

THE ADVANCED MATERIALS MANUFACTURER®

MERELEX CORPORATION • 10884 WEYBURN AVE. LOS ANGELES, CA 90024
TEL. 310-208-0551 • FAX 310-208-0351 • E-MAIL: orders@americanelements.com

CERTIFICATE OF ANALYSIS

99% (metals basis) Tin(IV) Oxide Powder

Email, 8/11/21, Jack Zarbock

Product Code: SN4-OX-02M-P
Lot #: 2131516147-400
CAS #: 18282-10-5
Description: Particle Size: -125 mesh

Analysis	%
Fe	0.0114
Pb	0.0016
Sb	0.0109
SO42-	0.0195
Hydrochloride acid soluble	0.433
LOI	0.645

AMERICAN ELEMENTS

By ____________

AEC FORM 102 CA REV. APP. 2/3/99

Figure D11: Product Certification for Coarse SnO_2

ALB Materials Inc
2360 Corporate Circle . Suite 400
Henderson, NV 89074-7739

Website: www.albmaterials.com
Email: sales@albmaterials.com

Certificate of Analysis

Item Code: ALB-semi-SnO2
Product Name: Tin Oxide (SnO2) Powder
Lot Number: ALB-202108
Date: 8/9/2021

Purity (%)		>99.999	
Impurities(ppm, max):			
Ag (ppm)	0.5	Fe (ppm)	0.5
Al (ppm)	0.1	In (ppm)	0.1
Au (ppm)	0.1	Mg (ppm)	0.5
Bi (ppm)	0.5	Na (ppm)	/
Ca (ppm)	0.5	Ni (ppm)	0.5
Cd (ppm)	/	Pb (ppm)	1
Co (ppm)	0.1	Sb (ppm)	0.5
Cr (ppm)	/	Se (ppm)	/
Cu (ppm)	0.5	Zn (ppm)	0.5

Size: -60 mesh

ALB Materials Inc
By.. Leo Wang

Figure D12: Product Certification for Fine MoO_3

STANFORD ADVANCED MATERIALS

Stanford Advanced Materials
23661 Birtcher Dr. Lake Forest, CA 92630, USA
Tel: (949) 407-8904 Fax: (949) 812-6690

Certificate of Analysis

Product Name:	Molybdenum Trioxide (MoO3) Powder
Purity:	≥99.5%
Particle Size:	-325mesh
Lot Number:	OC210201-12629-1
Date:	2/1/21

Purity (wt%)	99.5
C (wt%)	0.05
H (wt%)	0.02
O (wt%)	0.01
N (wt%)	0.01
Mg (wt%)	0.01
Al (wt%)	0.01
Si (wt%)	0.02
Ca (wt%)	0.01
Ti (wt%)	0.01
Fe (wt%)	0.08
Ni (wt%)	0.01
Cu (wt%)	0.02
Sn (wt%)	0.01
W (wt%)	0.03
Pb (wt%)	0.01

Stanford Advanced Materials

Figure D13: Product Certification for Medium and Coarse MoO_3

STANFORD ADVANCED MATERIALS

Stanford Advanced Materials
23661 Birtcher Dr. Lake Forest, CA 92630, USA
Tel: (949) 407-8904 Fax: (949) 812-6690

Certificate of Analysis

Product Name:	Molybdenum Trioxide (MoO3) Pellet
Purity:	⩾99.5%
Particle Size:	1-3mm
Lot Number:	OC210201-12629-2
Date:	2/1/21

Purity (wt%)	99.5
Mg (wt%)	0.02
Al (wt%)	0.01
Si (wt%)	0.01
Ca (wt%)	0.02
Ti (wt%)	0.02
Fe (wt%)	0.15
Ni (wt%)	0.05
Cu (wt%)	0.02
Sn (wt%)	0.01
W (wt%)	0.01
Pb (wt%)	0.01

Stanford Advanced Materials

TEST REPORT

UN Series 6 Testing of Non-Exploding, Large-Scale Thermites

DOT Contract # 693JK320C000005

U.S. Department of Transportation
Pipeline and Hazardous Materials Safety Administration (PHMSA)

Attention: PHH-20
Hazardous Materials Technology
1200 New Jersey Avenue, SE
E21-317
Washington, DC 20590

Troy A. Gardner, PE, CSP
Jackson Zarbock

January 31, 2022
SMS-6265d-R1, Rev 1

1847 West 9000 South, Suite 205 • West Jordan, Utah 84088 • 801-567-0456 • www.smsenergetics.com

Test Report

UN Series 6 Testing of Non-Exploding, Large-Scale Thermites

January 31, 2022
SMS-6265d-R1, Rev 1

Troy A. Gardner, PE, CSP
Testing & Classifications Manager
Safety Management Services, Inc.

Jackson D. Zarbock
Project Engineer

TABLE OF CONTENTS

TABLES

FIGURES

PHOTOS

1.0 STATEMENT OF WORK

DOT Contract # 693JK320C000005 with Safety Management Services, Inc. (SMS) of West Jordan, Utah defines that for Task 4, "Conduct Full UN Series 6 (a) and 6 (c) Testing on Large-scale Thermite Compositions", SMS shall:

1) Order and receive a) sufficient raw ingredients for mixing 0.175 m^3 of each of the fine, non-exploding, large-scale thermite mixes, and b) 0.175 m^3 each of the three commercial thermites.
2) Order and receive typical thermite fiberboard box packaging.
3) Mix 0.175 m^3 of each the three non-exploding, large-scale thermite mixes.
4) Perform UN Series 6 (a) Single package and 6 (c) External bonfire tests on each of the six non-exploding thermite mixes.
5) Provide the COR with a test report and video(s).

2.0 SUMMARY AND CONCLUSIONS

SMS performed UN Series 6 (a) Single Package and UN Series 6 (c) External Fire Tests on the following thermite mixtures:

1) Fine Al-Fe_2O_3 Thermite – Large-Scale Mix ID #1 (SMS Mixed)
2) Coarse Al-Fe_2O_3 Thermite A – Large-Scale Mix ID #2 (Commercial)
3) Coarse Al-Fe_2O_3 Thermite B – Large-Scale Mix ID #3 (Commercial)
4) Fine Al-CuO Thermite – Large-Scale Mix ID #4 (SMS Mixed)
5) Medium Al-CuO Thermite – Large-Scale Mix ID #5 (Commercial)
6) Fine Al-Ni_2O_3 Thermite – Large-Scale Mix ID #6 (SMS Mixed)

None of the thermites exhibited hazards consistent with a mass explosion hazard (Division 1.1). The behavior of the three commercial thermites (Large-Scale Mix ID's #2, #3 and #5) were consistent with Division 1.4 other than Compatibility Group S criteria, while that of the fine thermites mixed by SMS (Large-Scale Mix ID's #1, #4 and #6) were consistent with Division 1.3 criteria. A test video of the testing performed on each of the thermites (SMS-6265d-V1 through V6) is being sent to the attention of the Contracting Officer's Representative (COR). The following tables summarize the test results.

Table 1: Summary of UN Series 6 Testing on Fine Al-Fe_2O_3 Thermite – Large-Scale Mix ID #1 (SMS mixed)

Item	Test	Conditions and Results	Assessment
1	UN Series 6 (a) Single Package (confined)	Three trials on 11.3 kg of thermite in fiberboard box confined with loose sand resulted in no crater, molten-metal damage to the witness plate, no blast and no scattering of the confining material.	**No mass explosion for the tested configuration**

Item	Test	Conditions and Results	Assessment
2	UN Series 6 (c) External fire (bonfire)	Substance in eleven outer packages (0.20 m^3) ignited at 38 seconds and burned rapidly with a product burn time of 2.0 seconds for 125 kg, producing a fireball that extended approximately 4 meters beyond the witness screen frames. No mass explosions or fiery projections observed. • At the peak of reaction, the thermal flux at 15 meters was 0.62 kW/m^2 for the flames of the fire and an additional 24.5 kW/m^2 for the thermite.	**Mass fire hazard (behavior consistent with Division 1.3 criteria)**

Table 2: Summary of UN Series 6 Testing on Coarse Al-Fe_2O_3 Thermite A – Large-Scale Mix ID #2 (Commercial)

Item	Test	Conditions and Results	Assessment
1	UN Series 6 (a) Single Package (confined)	Three trials on 11.3 kg of thermite in fiberboard box confined with loose sand resulted in no crater, molten-metal damage to the witness plate, no blast and no scattering of the confining material.	**No mass explosion for the tested configuration**
2	UN Series 6 (c) External fire (bonfire)	Substance in twenty-four outer packages (0.22 m^3) ignited around 14 minutes with the 272 kg burning intensely for 10.5 seconds and moderately for another 50 seconds, producing a fireball 3 meters in radius within the witness screen frames. No mass explosions or fiery projections observed. • Thermal flux was not measured.	**Moderate fire hazard (behavior consistent with Division 1.4 criteria)**

Table 3: Summary of UN Series 6 Testing on Coarse Al-Fe_2O_3 Thermite B – Large-Scale Mix ID #3 (Commercial)

Item	Test	Conditions and Results	Assessment
1	UN Series 6 (a) Single Package (confined)	Three trials on 11.3 kg of thermite in fiberboard box confined with loose sand resulted in no crater, molten-metal damage to the witness plate, no blast and no scattering of the confining material.	**No mass explosion for the tested configuration**

Item	Test	Conditions and Results	Assessment
2	UN Series 6 (c) External fire (bonfire)	Substance in twenty-four outer packages (0.22 m^3) ignited around 8.2 minutes with the 272 kg burning intensely for 15.5 seconds and moderately for another 50 seconds, with flames that extended just over 1 meter from the flames of the fire. No mass explosions or fiery projections observed. • Thermal flux was not measured.	**Moderate fire hazard (behavior consistent with Division 1.4 criteria)**

Table 4: Summary of UN Series 6 Testing on Fine Al-CuO Thermite – Large-Scale Mix ID #4 (SMS mixed)

Item	Test	Conditions and Results	Assessment
1	UN Series 6 (a) Single Package (confined)	Three trials on 11.3 kg of thermite in fiberboard box confined with loose sand resulted in no crater, molten-metal damage to the witness plate, no blast and no scattering of the confining material.	**No mass explosion for the tested configuration**
2	UN Series 6 (c) External fire (bonfire)	Substance in eighteen outer packages (0.25 m^3) ignited at 36 seconds and burned rapidly with a product burn time of 2.0 seconds for 204 kg, producing a fireball that extended 2 - 3 meters beyond the witness screen frames. No mass explosions or fiery projections observed; however, a low-order audible report was heard. • At the peak of reaction, the thermal flux at 15 meters was 0.51 kW/m^2 for the flames of the fire and an additional 19.6 kW/m^2 for the thermite.	**Mass fire hazard (behavior consistent with Division 1.3 criteria)**

Table 5: Summary of UN Series 6 Testing on Medium Al-CuO Thermite – Large-Scale Mix ID #5 (Commercial)

Item	Test	Conditions and Results	Assessment
1	UN Series 6 (a) Single Package (confined)	Three trials on 11.3 kg of thermite in fiberboard box confined with loose sand resulted in no crater, molten-metal damage to the witness plate, no blast and no scattering of the confining material.	**No mass explosion for the tested configuration**

Item	Test	Conditions and Results	Assessment
2	UN Series 6 (c) External fire (bonfire)	Substance in twenty-four outer packages (0.22 m^3) ignited around two minutes and burned intermittently with a product burn time of 9.5 minutes (570 seconds) for 272 kg, with flames within 1 meter of the flames of the fire. No mass explosions or fiery projections observed. • At the peak of reaction, the thermal flux at 15 meters was 0.56 kW/m^2 for the flames of the fire and an additional 2.54 kW/m^2 for the thermite; these values scale[a] at 5 meters to 5.04 kW/m^2 for the flames of the fire and an additional 22.9 kW/m^2 for the thermite.	**Moderate fire hazard (behavior consistent with Division 1.4 criteria)**

Table 6: Summary of UN Series 6 Testing on Fine Al-Ni_2O_3 Thermite – Large-Scale Mix ID #6 (SMS mixed)

Item	Test	Conditions and Results	Assessment
1	UN Series 6 (a) Single Package (confined)	Three trials on 11.3 kg of thermite in fiberboard box confined with loose sand resulted in no crater, molten-metal damage to the witness plate, no blast and no scattering of the confining material.	**No mass explosion for the tested configuration**
2	UN Series 6 (c) External fire (bonfire)	Substance in eighteen outer packages (0.25 m^3) ignited at 41 seconds and burned steadily with a product burn time of 15.0 seconds for 204 kg, producing a fireball that extended beyond the witness screen frames. No mass explosions or fiery projections observed. • At the peak of reaction, the thermal flux at 15 meters was 0.56 kW/m^2 for the flames of the fire and an additional 36.8 kW/m^2 for the thermite.	**Mass fire hazard (behavior consistent with Division 1.3 criteria)**

3.0 ACKNOWLEDGEMENTS

Mixing of fine thermites was performed by Greg J. Dohm, Jordan D. Dzubak, Derek J. Holmstead, Derek M. Sutton and Jackson D. Zarbock. Test setup was performed by Jason T. Ford, Rustyn K. Christensen, Collin L. Boren, Jackson D. Zarbock, and Troy A. Gardner. Sensors and data acquisition system setup and checkout were performed by Collin L. Boren, Jackson D. Zarbock, and Troy A. Gardner.

[a] Thermal flux is inversely proportional to the square of the distance from the source: $F = F_0 (D_0^2/D^2)$.

4.0 BACKGROUND

Historically, industry has offered traditional thermite formulations (containing only metal and metal oxides) for transport in Class 4 as flammable or water-reactive solids. The reaction produces a burst of heat, high temperature, and molten metal for various uses including joining steel railroad ties or copper transmission lines, metal refining, disabling munitions, etc. Traditional thermite formulations pass the UN Manual of Tests and Criteria, Appendix 6 "Screening Procedures" for substances which may have explosive properties as they do not contain any of the chemical groups listed in Table A6.1 that are associated with explosive properties. NOTE: The Appendix 6 Screening Procedures cannot be used for substances manufactured with the view to producing a practical explosive or pyrotechnic effect.

Newer "exotic" thermite formulations include those with additives such as plastics, oxidizers, nano materials, explosives, etc. to confer special compositions or actions upon use. Thermite research was needed to identify families of new and existing thermite compositions and to determine their hazards in transport and to transport vehicles.

Safety Management Services, Inc. (SMS) was contracted to perform research on thermite formulations in cooperation with Southwest Research Institute (SwRI) and the U.S. Department of Transportation (DOT) Pipeline and Hazardous Materials Safety Administration (PHMSA). This effort is considered to be Phase I of thermite testing (DOT Contract # DTPH5616D00001). During Phase I, eight thermites for large-scale testing and fifteen thermite formulations were selected for small-scale testing. It was discovered that thermite mixtures exhibited hazards from ranging from rapid reactions that were consistent with 1.3G materials to exploding when ignited in unconfined 5-gram quantities, similar to 1.1G flash powders.

These findings prompted the request for SMS to perform additional testing to further research the energetic properties of thermite and develop the technical basis to base policies and decision on thermite-based products. This additional testing is considered Phase II of thermite testing. During Task 4 of Phase II, thermites were subjected to the UN Series 6 (a) Single-Package Test and the UN Series 6 (c) External Fire Test to determine the hazard division of each thermite when packaged in 11.3-kg (25-lb) quantities and fiberboard boxes. The following six thermites were tested:

- Fine Al-Fe_2O_3 Thermite – Large-Scale Mix ID #1 (SMS mixed)
- Coarse Al-Fe_2O_3 Thermite A – Large-Scale Mix ID #2 (Commercial)
- Coarse Al-Fe_2O_3 Thermite B – Large-Scale Mix ID #3 (Commercial)
- Fine Al-CuO Thermite – Large-Scale Mix ID #4 (SMS mixed)
- Medium Al-CuO Thermite – Large-Scale Mix ID #5 (Commercial)
- Fine Al-Ni_2O_3 Thermite – Large-Scale Mix ID #6 (SMS mixed)

5.0 DESCRIPTION OF THERMITE TEST SAMPLES

5.1 Fine Al-Fe_2O_3 Thermite – Large-Scale Mix ID #1 (SMS mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 25.26% aluminum (Al) and 74.74% ferric oxide (Fe_2O_3). The aluminum was 3N purity (99.9% pure), 1 - 5 micrometers (microns) in size, and offered for transport as a Division 4.1 flammable solid. The ferric oxide was 2N purity (99% pure), 1 - 5 microns in size, and offered for transport as non-regulated. This thermite was a fine, red powder when fully mixed.

Photo 1: Fine Al-Fe_2O_3 Thermite – Large-Scale Mix ID #1 (SMS mixed)

5.2 Coarse Al-Fe_2O_3 Thermite A – Large-Scale Mix ID #2 (Commercial)

SMS procured this thermite from a commercial supplier. This thermite contained 25% aluminum (Al) and 75% iron(III)/ferric oxide (Fe_2O_3) by mass. The thermite was a coarse powder that was a mixture of black and light gray particles.

Photo 2: Coarse Al-Fe_2O_3 Thermite A – Large-Scale Mix ID #2 (Commercial)

5.3 Coarse Al-Fe_2O_3 Thermite B – Large-Scale Mix ID #3 (Commercial)

SMS procured this thermite from a commercial supplier. This thermite contained 25% aluminum (Al), 60% iron(III)/ferric oxide (Fe_2O_3), 5% mild steel, and 10% ferro manganese by mass. The thermite was a coarse powder that was a mixture of black and light gray particles with occasional pieces of steel punching.

Photo 3: Coarse Al-Fe_2O_3 Thermite B – Large-Scale Mix ID #3 (Commercial)

5.4 Fine Al-CuO Thermite – Large-Scale Mix ID #4 (SMS mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 18.44% aluminum (Al) and 81.56% copper(II)/cupric oxide (CuO). The aluminum was 3N purity (99.9% pure), 1 - 5 micrometers (microns) in size, and offered for transport as a Division 4.1 flammable solid. The cupric oxide was 3N purity (99.9% pure), 1 - 5 microns in size, and offered for transport as Class 9. This thermite was a very fine, dark gray powder when fully mixed.

Photo 4: Fine Al-CuO Thermite – Large-Scale Mix ID #4 (SMS mixed)

5.5 Medium Al-CuO Thermite – Large-Scale Mix ID #5 (Commercial)

SMS procured this thermite from a commercial supplier. This thermite contains 18% aluminum (Al) and 82% cupric oxide (CuO). The thermite was gray and silver speckled powder with medium-sized particles.

Photo 5: Medium Al-CuO Thermite – Large-Scale Mix ID #5 (Commercial)

5.6 Fine Al-Ni_2O_3 Thermite – Large-Scale Mix ID #6 (SMS mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 24.6% aluminum (Al) and 75.4% nickel(III) oxide (Ni_2O_3). The aluminum was 3N purity (99.9% pure), 1 - 5 micrometers (microns) in size, and offered for transport as a Division 4.1 flammable solid. The nickel(III) oxide was 2N purity (99% pure), 5 microns in size, and offered for transport as non-regulated. This thermite was very fine, light gray powder when fully mixed.

Photo 6: Fine Al-Ni_2O_3 Thermite – Large-Scale Mix ID #6 (SMS mixed)

6.0 PACKAGING

To maintain uniformity of test parameters between thermite samples, each thermite was packaged in a similar fashion to Large-scale Mix ID #2 and #3 commercial thermites after they were mixed or received from the commercial vendor; Photo 7 shows an example inner and outer packaging. Each package consisted of 11.3 kg (25 lbs) of thermite placed in a robust plastic bag that was sealed and placed into a fiberboard box.

Photo 7: The Inner and Outer Packaging - typical

The length and width for all fiberboard boxes used to package the thermites was 14 inches by 10 inches, respectively; the box height was determined by the density of each thermite. Details for box dimensions used for each thermite are shown in the following table.

Table 7: Densities and Packaging Dimensions for Thermite Samples

Sample	Density (kg/m^3)	Thermite Mass Per Package (kg)	Dimension (inches)		
			Length	Width	Height
Fine Al-Fe_2O_3 Thermite – Large-Scale Mix ID #1 (SMS mixed)	910	11.3	14	10	8
Coarse Al-Fe_2O_3 Thermite A – Large-Scale Mix ID #2 (Commercial)	2020	11.3	14	10	4
Coarse Al-Fe_2O_3 Thermite B – Large-Scale Mix ID #3 (Commercial)	2480	11.3	14	10	4
Fine Al-CuO Thermite – Large-Scale Mix ID #4 (SMS mixed)	1560	11.3	14	10	6
Medium Al-CuO Thermite – Large-Scale Mix ID #5 (Commercial)	2340	11.3	14	10	4
Fine Al-Ni_2O_3 Thermite – Large-Scale Mix ID #6 (SMS mixed)	1550	11.3	14	10	6

7.0 TEST DESCRIPTIONS AND RESULTS

7.1 Confined UN Series 6 (a) Single Package Test

7.1.1 Test Description

This test is applied to a packaged substance in the condition and form in which it will be offered for transport to determine whether there is a mass explosion of the package contents. Substances intended to function by detonation are tested with a standard detonator inserted into the top of the substance; substances intended to function by deflagration are tested with an igniter located in the center of the substance in the package that is just sufficient (but not more than 30 grams of black powder) to ensure ignition of the substance.

The package is placed on a 3mm-thick mild steel witness plate on the ground. Sand (bagged, boxed, or piled) is placed as closely as possible around the test package to a minimum thickness of confinement, in every direction of 0.5 meters for a package not exceeding 0.15 m³ and 1.0 meter for a package greater than 0.15 m³. The igniter is functioned and observations made on the following: evidence of thermal effects, projection effects, detonation, deflagration or explosion of the total contents of the package. The test is performed three times unless a decisive result occurs earlier (e.g. explosion of the total contents). Evidence of a mass explosion (a crater at the test site, damage to the witness plate beneath the package, measurement of a blast, and disruption and scattering of the confining material) indicates a candidate for Division 1.1.

Photo 8: UN Series 6 (a) Single Package Test Setup - typical

7.1.2 Test Configuration

For the commercial Al-Fe_2O_3 thermites (Large-scale Mix ID's #2 and #3) a thermite igniter provided by the thermite manufacturer was used. All other thermites were ignited using a 1.5-gram pyrogen electric match and 25 grams of thermite starter mix provided by the manufacturer of the commercial Al-CuO thermite (Large-scale Mix ID #5).

Photo 9: Placement of Igniter - typical

7.1.3 Test Results

Jason Ford witnessed each of the Single Package tests. The test results for the single package test for each trial are detailed below.

Table 8: Summary of UN Series 6 (a) Single Package Test Results

Item	Sample	Results			Assessment
		Trial 1	Trial 2	Trial 3	
1	Fine Al-Fe_2O_3 Thermite – Large-Scale Mix ID #1 (SMS mixed)	Large volcano effect, two-thirds of sand pile was dispersed from witness plate, sparks were thrown 25 feet from pile, thermite welded to witness plate	Large volcano effect, two-thirds of sand pile was dispersed from witness plate, sparks were thrown 25 feet from pile, thermite welded to witness plate	Large volcano effect, two-thirds of sand pile was dispersed from witness plate, sparks were thrown 25 feet from pile, thermite welded to witness plate	No mass explosion for the tested configuration
2	Coarse Al-Fe_2O_3 Thermite A – Large-Scale Mix ID #2 (Commercial)	Small volcano effect, no mass explosion, thermite melted through and welded to the witness plate	Small volcano effect, no mass explosion, thermite melted through and welded to the witness plate	Small volcano effect, no mass explosion, thermite melted through and welded to the witness plate	No mass explosion for the tested configuration

Item	Sample	Results			Assessment
		Trial 1	Trial 2	Trial 3	
3	Coarse Al-Fe_2O_3 Thermite B – Large-Scale Mix ID #3 (Commercial)	Small volcano effect, no mass explosion, thermite melted through and welded to the witness plate	Small volcano effect, no mass explosion, thermite melted through and welded to the witness plate	Small volcano effect, no mass explosion, thermite melted through and welded to the witness plate	No mass explosion for the tested configuration
4	Fine Al-CuO Thermite – Large-Scale Mix ID #4 (SMS mixed)	Large volcano effect, majority of sand was dispersed from witness plate, no damage to witness plate	Large volcano effect, majority of sand was dispersed from witness plate, no damage to witness plate, **audible report heard**	Large volcano effect, majority of sand was dispersed from witness plate, no damage to witness plate	No mass explosion for the tested configuration
5	Medium Al-CuO Thermite – Large-Scale Mix ID #5 (Commercial)	Small volcano effect, no mass explosion, thermite welded to the witness plate	Small volcano effect, no mass explosion, thermite welded to the witness plate	Small volcano effect, no mass explosion, thermite welded to the witness plate	No mass explosion for the tested configuration
6	Fine Al-Ni_2O_3 Thermite – Large-Scale Mix ID #6 (SMS mixed)	Small volcano effect, no mass explosion, thermite welded to the witness plate	Small volcano effect, no mass explosion, thermite welded to the witness plate	Small volcano effect, no mass explosion, thermite welded to the witness plate	No mass explosion for the tested configuration

All samples disturbed the confining medium with a volcano effect but did not scatter the sand. There was no evidence of cratering or a blast wave in any test. Damage to the witness plate was limited to that associated with welding and molten metal. The test results are shown in the following photos.

Photo 10: UN Series 6 (a) Single Package Test Results for Fine Al-Fe_2O_3 Thermite – Large-Scale Mix ID #1 (SMS mixed)

Photo 11: UN Series 6 (a) Single Package Test Results for Coarse Al-Fe_2O_3 Thermite A – Large-Scale Mix ID #2 (Commercial)

Photo 12: UN Series 6 (a) Single Package Test Results for Coarse Al-Fe_2O_3 Thermite B – Large-Scale Mix ID #3 (Commercial)

Photo 13: UN Series 6 (a) Single Package Test Results for Fine Al-CuO Thermite – Large-Scale Mix ID #4 (SMS mixed)

Photo 14: UN Series 6 (a) Single Package Test Results for Medium Al-CuO Thermite – Large-Scale Mix ID #5 (Commercial)

Photo 15: UN Series 6 (a) Single Package Test Results for Fine Al-Ni_2O_3 Thermite – Large-Scale Mix ID #6 (SMS mixed)

7.1.4 Conclusions

Based on the test results, Large-Scale Mix ID's #1 - #6 did not exhibit a mass explosion hazard in an 11.3-kg quantity packaged in a fiberboard box and confined with sand.

7.2 UN Series 6 (c) External fire (bonfire) test

7.2.1 Test Description

This test demonstrates the reaction of packaged substances or articles when exposed to a fire. The test is performed on a stack of packages in the condition and form in which they will be offered for transport. A stack of packages with a total volume of at least 0.15 m³ with a minimum of three packages is placed in the center of a non-combustible surface (steel grate) above sufficient quantity of fuel to provide a thirty-minute fire. Three 200-cm × 200-cm × 0.2-cm aluminum witness screens or witness screen frames are placed four meters from the edge of the stack to serve as visible distance markers. The fuel is ignited simultaneously on at least two sides and the material is observed for a) evidence of detonation, deflagration, or explosion of the total contents; b) potentially hazardous projections; and c) thermal effects (i.e. rate of burn, size of any fireball, etc.). The test is recorded using regular video with audio from two angles and visual distance marking devices; additionally, air-blast gauges and/or radiometers may also be utilized.

7.2.2 Test Configuration

Packages for each product containing 11.3-kg (25-lbs) each were uniformly arranged on a steel grate in a three-by-two array, as shown in Figure 1.

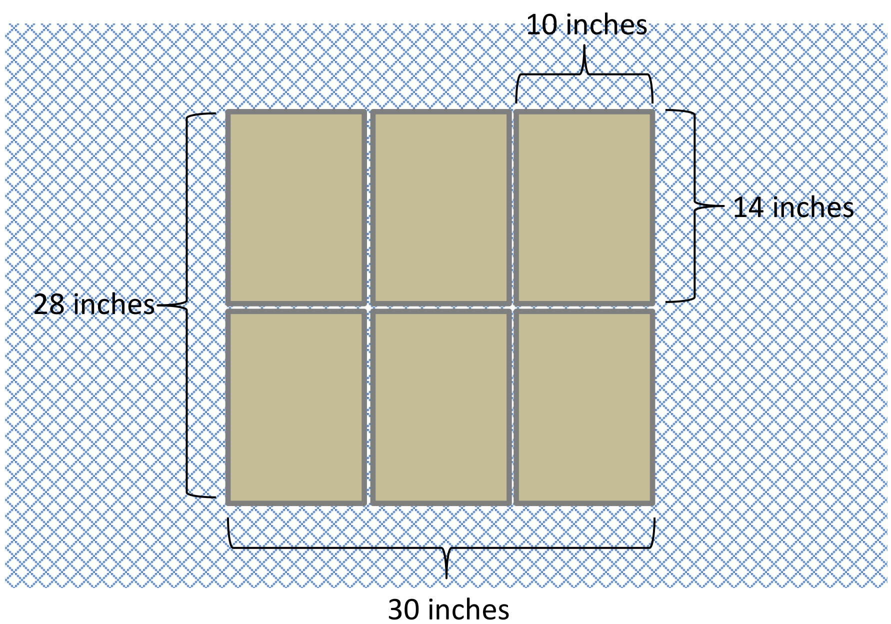


Figure 1: Base Array of Packages for the UN Series 6 (c) External Fire Test

Packages were stacked on this base array until the total volume of packages was at least 0.15 m³; the number of packages and layers varied depending upon each thermite's density. Details of packaging configuration are shown in the following table.

Table 9: UN Series 6 (c) External Fire – Stack Setup Details

Sample	Package Height (in)	Number of Layers	Total Number of Packages	Total Volume (m^3)	Total Thermite Mass (kg)
Fine Al-Fe_2O_3 Thermite – Large-Scale Mix ID #1 (SMS mixed)	8	~2	11	0.20	125
Coarse Al-Fe_2O_3 Thermite A – Large-Scale Mix ID #2 (Commercial)	4	4	24	0.22	272
Coarse Al-Fe_2O_3 Thermite B – Large-Scale Mix ID #3 (Commercial)	4	4	24	0.22	272
Fine Al-CuO Thermite – Large-Scale Mix ID #4 (SMS mixed)	6	3	18	0.25	204
Medium Al-CuO Thermite – Large-Scale Mix ID #5 (Commercial)	4	4	24	0.22	272
Fine Al-Ni_2O_3 Thermite – Large-Scale Mix ID #6 (SMS mixed)	6	3	18	0.25	204

Wood pallets were used as the fuel source and liquid fuel was used as an accelerant for ignition of the wood. Photos of the test setup for each sample are shown below.

Photo 16: UN Series 6 (c) External Fire Test Setup for Fine Al-Fe_2O_3 Thermite – Large-Scale Mix ID #1 (SMS mixed)

Photo 17: UN Series 6 (c) External Fire Test Setup for Coarse Al-Fe_2O_3 Thermite A – Large-Scale Mix ID #2 (Commercial)

Photo 18: UN Series 6 (c) External Fire Test Setup for Coarse Al-Fe_2O_3 Thermite B – Large-Scale Mix ID #3 (Commercial)

Photo 19: UN Series 6 (c) External Fire Test Setup for Fine Al-CuO Thermite – Large-Scale Mix ID #4 (SMS mixed)

Photo 20: UN Series 6 (c) External Fire Test Setup for Medium Al-CuO Thermite – Large-Scale Mix ID #5 (Commercial)

Photo 21: UN Series 6 (c) External Fire Test Setup for Fine Al-Ni_2O_3 Thermite – Large-Scale Mix ID #6 (SMS mixed)

The environmental conditions at the start of each bonfire test were as follows:

- Fine Al-Fe_2O_3 Thermite – Large-Scale Mix ID #1 (SMS mixed): 7 °C, 1.3 m/s, 69% RH.
- Coarse Al-Fe_2O_3 Thermite A – Large-Scale Mix ID #2 (Commercial): 8 °C, 1.3 m/s, 58% RH.
- Coarse Al-Fe_2O_3 Thermite B – Large-Scale Mix ID #3 (Commercial): 6 °C, 3.1 m/s, 66% RH.
- Fine Al-CuO Thermite – Large-Scale Mix ID #4 (SMS mixed): 8 °C, 1.8 m/s, 59% RH.
- Medium Al-CuO Thermite – Large-Scale Mix ID #5 (Commercial): 8 °C, 1.8 m/s, 59% RH.
- Fine Al-Ni_2O_3 Thermite – Large-Scale Mix ID #6 (SMS mixed): 11 °C, 2.2 m/s, 50% RH.

7.2.3 Instrumentation

After conducting the first two thermite bonfires (Large-Scale Mix ID's #2 and #3), SMS felt it would be of benefit to measure the irradiance of the thermite reactions for further characterization of the thermites. Therefore, heat flux was measured and recorded for the subsequent testing of Large-Scale Mix ID's #1, #4, #5, and #6. SMS utilized five MEDTHERM Schmidt-Boelter gauges, model 64-0.5 (water-cooled, calibrated for 0 - 5 kW/m², linear output over calibrated range), for each of the tests, arranged in the configuration shown in Figure 2. Distances D_1 through D_5 for each test are specified in Table 10. Distances were measured from the edge of the stack of packages.

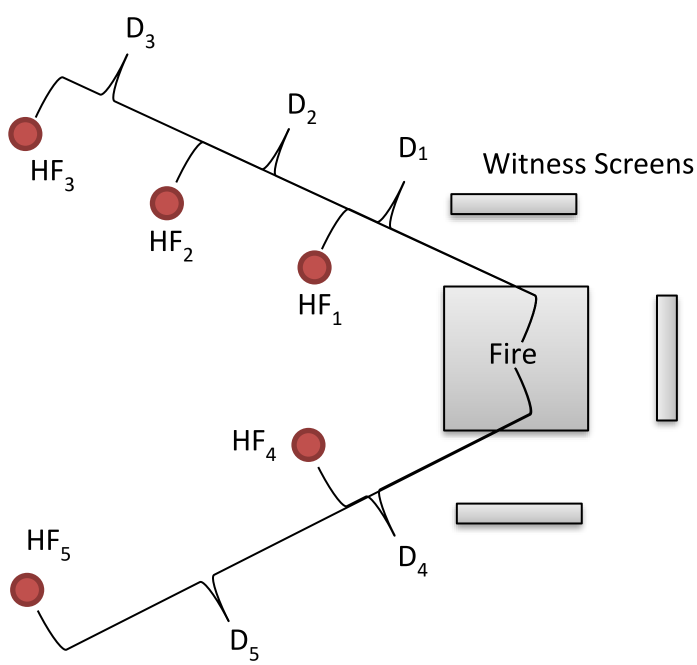


Figure 2: UN Series 6 (c) External Fire Test – Instrumentation Setup

Table 10: UN Series 6 (c) External Fire Test – Sensor Distances

Sample	Distance (m)				
	D_1	D_2	D_3	D_4	D_5
Fine Al-Fe_2O_3 Thermite – Large-Scale Mix ID #1 (SMS mixed)	15	17.5	20	17.5	20
Fine Al-CuO Thermite – Large-Scale Mix ID #4 (SMS mixed)	7	11	15	7	15
Medium Al-CuO Thermite – Large-Scale Mix ID #5 (Commercial)	7	11	15	7	15
Fine Al-Ni_2O_3 Thermite – Large-Scale Mix ID #6 (SMS mixed)	7	11	15	7	15

The heat flux data was recorded at a 100 Hz sampling rate. Continuity of each sensor line and calibration of each sensor was verified prior to each test. Photos of the typical sensor set-up are shown in the following photos.

Photo 22: UN Series 6 (c) External Fire – Thermal Flux Instrumentation Setup for Line A - typical

Photo 23: UN Series 6 (c) External Fire – Thermal Flux Instrumentation Setup for Line B - typical

7.2.4 Test Results

Jason Ford witnessed the bonfire test on Large-Scale Mix ID's #2 and #3; Ben Barrett with DG Advisor, LLC of Dubois, Wyoming and Troy Gardner witnessed all other bonfire tests.

Each test had a single event in which the majority of the material was consumed, with the exception of Large-Scale Mix ID #5. Each event was distinguishable from the flames of the fire. Each of the fine thermites (Large-Scale Mix ID's #1, #4, and #6) began reacting less than one minute after the start of the test. In each case, the material was consumed within a few seconds, producing a fireball that exceeded the witness screens at four meters. Each coarser commercial mixture (Large-Scale Mix ID's #2, #3, and #5) took several minutes to react. They were consumed slower with smaller fireballs than the fine thermites. The test results are summarized in the following table.

Table 11: Summary of UN Series 6 (c) External Bonfire Test Results

Item	Sample	Conditions and Results	Assessment
1	Fine Al-Fe_2O_3 Thermite – Large-Scale Mix ID #1 (SMS mixed)	Substance in eleven outer packages (0.20 m³) ignited at 38 seconds and burned rapidly with a product burn time of 2.0 seconds for 125 kg, producing a fireball that extended approximately 4 meters beyond the witness screen frames. No mass explosions or fiery projections observed. Scaling burn time qualifiers for mass[b] (125 kg) yields 37.7 seconds for 1.3/1.4 and 355 seconds for 1.4/1.4S; further scaling for energy content (3956 J/gm for Al-Fe_2O_3 thermite[c]) yields 11.9 seconds for 1.3/1.4 and 113 seconds for 1.4/1.4S.	**Mass fire hazard (behavior consistent with Division 1.3 criteria)**
2	Coarse Al-Fe_2O_3 Thermite A – Large-Scale Mix ID #2 (Commercial)	Substance in twenty-four outer packages (0.22 m³) ignited around 14 minutes with the 272 kg burning intensely for 10.5 seconds and moderately for another 50 seconds, producing a fireball 3 meters in radius within the witness screen frames. No mass explosions or fiery projections observed. Scaling burn time qualifiers for mass (272 kg) yields 48.9 seconds for 1.3/1.4 and 461 seconds for 1.4/1.4S; further scaling for energy content (3956 J/gm for Al-Fe_2O_3 thermite) yields 15.5 seconds for 1.3/1.4 and 146 seconds for 1.4/1.4S.	**Moderate fire hazard (behavior consistent with Division 1.4 criteria)**
3	Coarse Al-Fe_2O_3 Thermite B – Large-Scale Mix ID #3 (Commercial)	Substance in twenty-four outer packages (0.22 m³) ignited around 8.2 minutes with the 272 kg burning intensely for 15.5 seconds and moderately for another 50 seconds, with flames that extended just over 1 meter from the flames of the fire. No mass explosions or fiery projections observed. Scaling burn time qualifiers for mass (272 kg) yields 48.9 seconds for 1.3/1.4 and 461 seconds for 1.4/1.4S; further scaling for energy content (3956 J/gm for Al-Fe_2O_3 thermite) yields 15.5 seconds for 1.3/1.4 and 146 seconds for 1.4/1.4S.	**Moderate fire hazard (behavior consistent with Division 1.4 criteria)**

[b] Per the UN Manual 16.6.1.4.8 notes, burn-time qualifiers are scaled on the basis of $t = t_0 (m/m_0)^{1/3}$ *for* net explosive mass and $t = t_0 (H/H_0)$ for energy content.

[c] SAND95-2448C, "A Survey of Combustible Metals, Thermites, and Intermetallics for Pyrotechnic Applications", S. H. Fisher and M. C. Grubelich, Sandia National Laboratories, July 1996, Table 1 - Thermite Reactions.

Item	Sample	Conditions and Results	Assessment
4	Fine Al-CuO Thermite – Large-Scale Mix ID #4 (SMS mixed)	Substance in eighteen outer packages (0.25 m^3) ignited at 36 seconds and burned rapidly with a product burn time of 2.0 seconds for 204 kg, producing a fireball that extended 2 - 3 meters beyond the witness screen frames. No mass explosions or fiery projections observed; however, a low-order audible report was heard. Scaling burn time qualifiers for mass (204 kg) yields 44.4 seconds for 1.3/1.4 and 419 seconds for 1.4/1.4S; further scaling for energy content (4076 J/gm for Al-CuO thermite[d]) yields 14.5 seconds for 1.3/1.4 and 136 seconds for 1.4/1.4S.	**Mass fire hazard (behavior consistent with Division 1.3 criteria)**
5	Medium Al-CuO Thermite – Large-Scale Mix ID #5 (Commercial)	Substance in twenty-four outer packages (0.22 m^3) ignited around 78 seconds and burned steadily with a product burn time of 3.8 minutes (230 seconds) for 272 kg, with flames within 1 meter of the flames of the fire. No mass explosions or fiery projections observed. Scaling burn time qualifiers for mass (272 kg) yields 48.9 seconds for 1.3/1.4 and 461 seconds for 1.4/1.4S; further scaling for energy content (4076 J/gm for Al-CuO thermite) yields 15.9 seconds for 1.3/1.4 and 150 seconds for 1.4/1.4S.	**Minor fire hazard (behavior consistent with Division 1.4S criteria)**
6	Fine Al-Ni_2O_3 Thermite – Large-Scale Mix ID #6 (SMS mixed)	Substance in eighteen outer packages (0.25 m^3) ignited at 41 seconds and burned steadily with a product burn time of 15.0 seconds for 204 kg, producing a fireball that extended beyond the witness screen frames. No mass explosions or fiery projections observed. Scaling burn time qualifiers for mass (204 kg) yields 44.4 seconds for 1.3/1.4 and 419 seconds for 1.4/1.4S; further scaling for energy content (5406 J/gm for Al-Ni_2O_3 thermite[e]) yields 19.2 seconds for 1.3/1.4 and 181 seconds for 1.4/1.4S.	**Mass fire hazard (behavior consistent with Division 1.3 criteria)**

[d] SAND95-2448C, "A Survey of Combustible Metals, Thermites, and Intermetallics for Pyrotechnic Applications", S. H. Fisher and M. C. Grubelich, Sandia National Laboratories, July 1996, Table 1 - Thermite Reactions.
[e] SAND95-2448C, "A Survey of Combustible Metals, Thermites, and Intermetallics for Pyrotechnic Applications", S. H. Fisher and M. C. Grubelich, Sandia National Laboratories, July 1996, Table 1 - Thermite Reactions.

Photo 24: UN Series 6 (c) External Fire – Test Progression for Fine Al-Fe_2O_3 Thermite – Large-Scale Mix ID #1 (SMS mixed)

Photo 25: UN Series 6 (c) External Fire – Test Progression for Coarse Al-Fe_2O_3 Thermite A – Large-Scale Mix ID #2 (Commercial)

Photo 26: UN Series 6 (c) External Fire – Test Progression for Coarse Al-Fe_2O_3 Thermite B – Large-Scale Mix ID #3 (Commercial)

Photo 27: UN Series 6 (c) External Fire – Test Progression for Fine Al-CuO Thermite – Large-Scale Mix ID #4 (SMS mixed)

Photo 28: UN Series 6 (c) External Fire – Test Progression for Medium Al-CuO Thermite – Large-Scale Mix ID #5 (Commercial)

Photo 29: UN Series 6 (c) External Fire – Test Progression for Fine Al-Ni_2O_3 Thermite – Large-Scale Mix ID #6 (SMS mixed)

7.2.5 Thermal Flux Hazards

The maximum values recorded during the event by each heat flux sensor for each test are detailed below. The distances from the test to each sensor location are given in Table 10. Photos of sensor set-up and graphs of full data sets for each test are given in the Appendix.

Table 12: Maximum Heat Flux Values Record by Each Sensor for External Fire Tests

Sample	Maximum Heat Flux (kW/m²)				
	HF_1 (15m)	**HF_2 (17.5m)**	**HF_3 (20m)**	**HF_4 (15m)**	**HF_5 (20M)**
Fine Al-Fe_2O_3 Thermite – Large-Scale Mix ID #1 (SMS mixed)	24.5	13.1	8.4	23.8	8.4
Sample	**HF_1 (7m)**	**HF_2 (11m)**	**HF_3 (15m)**	**HF_4 (7m)**	**HF_5 (15m)**
Fine Al-CuO Thermite – Large-Scale Mix ID #4 (SMS mixed)	77.3	35.1	20.3	89.1	11.4
Medium Al-CuO Thermite – Large-Scale Mix ID #5 (Commercial)	7.1	3.7	2.2	10.8	3.1
Fine Al-Ni_2O_3 Thermite – Large-Scale Mix ID #6 (SMS mixed)	135.9*	68.8	37.5	73.3	22.8
*thermite material landed on the housing for this heat flux gauge, causing it to catch fire. The maximum heat flux is recorded after the event while the housing was on fire.					

Section 16.6.2.4.4 (c) of the UN Manual of Tests and Criteria states that the material should be assigned to Division 1.3 if "the irradiance of the burning product exceeds that of the fire by more than 4 kW/m² [for 100 kg] at a distance of 15 m from the edge of the packages of unpackaged articles. The irradiance is measured over 5 seconds, during the period of maximum output". Table 16.2 details how thermal flux values at 15 meters are scaled for varying masses of HD 1.3/1.4 type materials. Comparative thermal flux is scaled by mass with the following equation.

$$F = F_0 \left(\frac{m}{m_0}\right)^{\frac{2}{3}}$$

Where, F_o is the expected thermal heat flux at 15 meters for 1.3/1.4 materials and 5 meters for 1.4/1.4S materials (4 kW/m²). m is the mass of the material being tested, and m_o is the comparative mass (100 kg).

Table 13 shows the scaled thermal flux based on the above equation and the maximum thermal flux values measured at 15 meters during the period of highest thermal output. The irradiance of the bonfire was determined by taking the average measured thermal flux between 10 and 25 seconds after the start of the test. This period of time was chosen to allow sufficient time for the bonfire to come to burning full capacity and produce heat before any of the material reacted. The difference between the maximum measured thermal flux and the average bonfire irradiance is shown in the far-right column of Table 13.

Table 13: Scaled Thermal Flux Values and Measured Thermal Flux for the External Fire Tests

Sample	Mass (kg)	Scaled Thermal Flux from Table 16.2	Maximum Thermal Flux Measured at 15 m	Average Bonfire Irradiance	Thermal Flux Difference at 15 m
Fine Al-Fe_2O_3 Thermite – Large-Scale Mix ID #1 (SMS mixed)	125	4.64	24.5	0.62	23.6
Fine Al-CuO Thermite – Large-Scale Mix ID #4 (SMS mixed)	204	6.44	20.3	0.51	19.6
Medium Al-CuO Thermite – Large-Scale Mix ID #5 (Commercial)	272	7.80	3.1	0.56	2.54
Fine Al-Ni_2O_3 Thermite – Large-Scale Mix ID #6 (SMS mixed)	204	6.44	37.5	0.56	36.8

It can be determined from the calculations above that the thermal flux difference measured at 15 meters for Large-Scale ID #5 was less than the 4 kW/m² threshold; scaling this measurement[f] to 5 meters for Division 1.4/1.4S results in to 5.04 kW/m² for the flames of the fire and an additional 22.9 kW/m² for the thermite, which is greater than the 4 kW/m² threshold (does not qualify for 1.4S).

It can be determined from the calculations above that the thermal flux difference measured at 15 meters for Large-Scale ID's #1, #4 and #6 exceed the scaled thermal flux calculated for their corresponding mass. As such, these materials emit thermal heat flux consistent with Division 1.3 type materials. To further assess the hazards of the thermal effects from these thermites, it is useful to determine the amount of time that each thermite reaction emitted a thermal heat

[f] Thermal flux is inversely proportional to the square of the distance from the source: $F = F_0 (D_0^2/D^2)$.

flux difference that exceeded the scaled thermal flux from Table 16.2. Table 14 shows the total time at each measured distance for Large-Scale Mix ID's #1, #4 and #6.

Table 14: Time Duration That the Thermal Flux Difference Exceed Scaled Thermal Flux for External Fire Tests on Large-scale Mix ID's #1, #4, and #6

Sample	Time Above the Scaled Thermal Flux (s)				
	HF_1 (15m)	**HF_2 (17.5m)**	**HF_3 (20m)**	**HF_4 (15m)**	**HF_5 (20M)**
Fine Al-Fe_2O_3 Thermite – Large-Scale Mix ID #1 (SMS mixed)	4.60	3.53	2.55	4.54	2.72
Sample	**HF_1 (7m)**	**HF_2 (11m)**	**HF_3 (15m)**	**HF_4 (7m)**	**HF_5 (15m)**
Fine Al-CuO Thermite – Large-Scale Mix ID #4 (SMS mixed)	6.85	5.10	4.20	6.74	2.19
Fine Al-Ni_2O_3 Thermite – Large-Scale Mix ID #6 (SMS mixed)	*74.51	17.89	12.67	29.69	9.93
*thermite material landed on the housing for this heat flux gauge, causing it to catch fire. The maximum heat flux is recorded after the event while the housing was on fire.					

7.2.6 Conclusions

Based on the test results and heat flux data collected from UN Series 6 (c) External Fire Test, the three commercial thermites (Large-Scale Mix ID's #2, #3 and #5) were consistent with Division 1.4 other than Compatibility Group S criteria, while the behavior of the fine thermites mixed by SMS (Large-Scale Mix ID's #1, #4 and #6) were consistent with Division 1.3 criteria.

APPENDIX A

– Thermal Flux Data Collected from UN Series 6 (c) External Fire Tests on Large-Scale Mix ID's #1, #4, #5, and #6

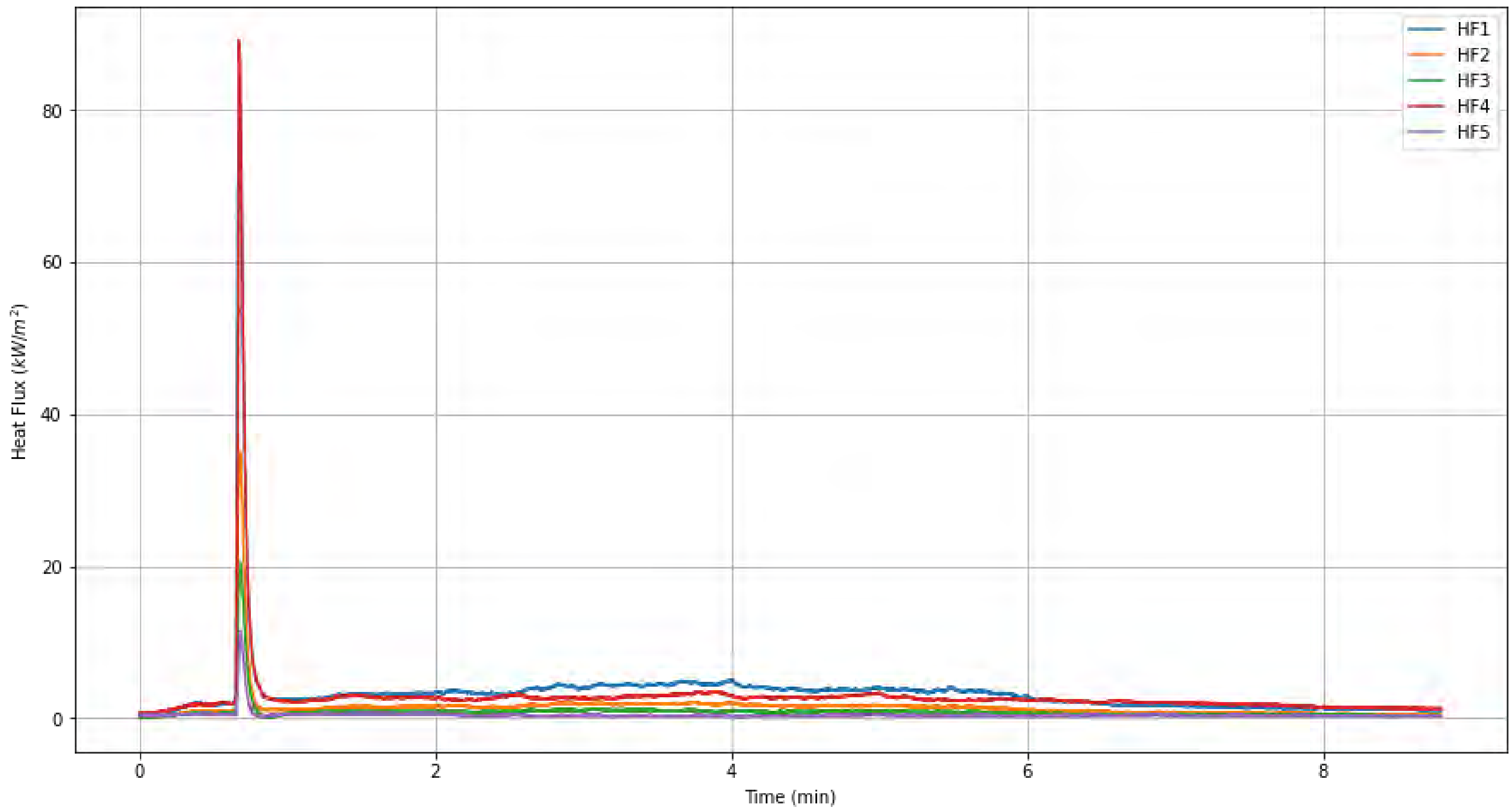


Figure A1: UN Series 6 (c) External Fire Thermal Flux for Fine Al-Fe_2O_3 Thermite – Large-Scale Mix ID #1 (SMS mixed)

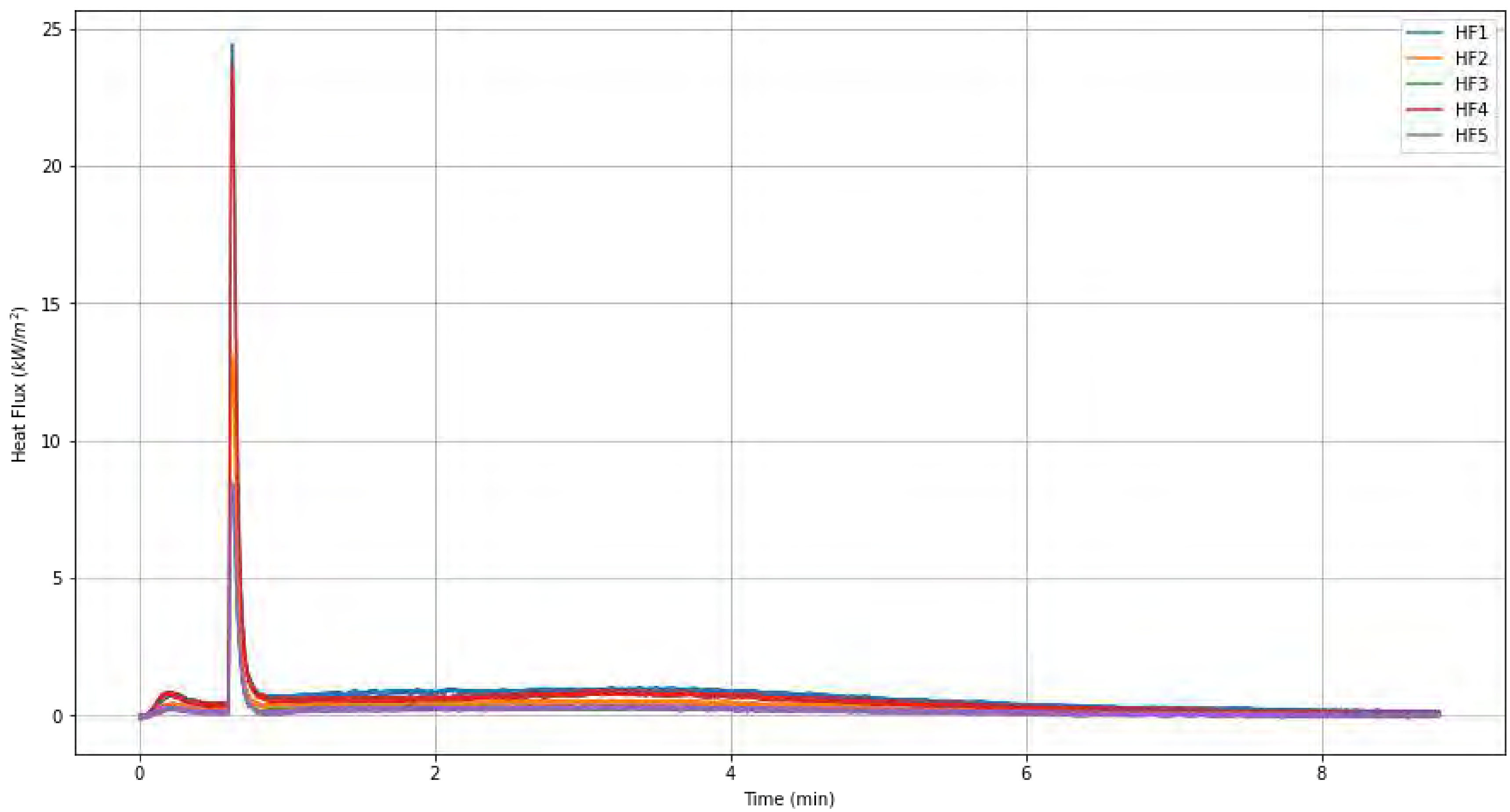


Figure A2: UN Series 6 (c) External Fire Thermal Flux for Fine Al-CuO Thermite – Large-Scale Mix ID #4 (SMS mixed)

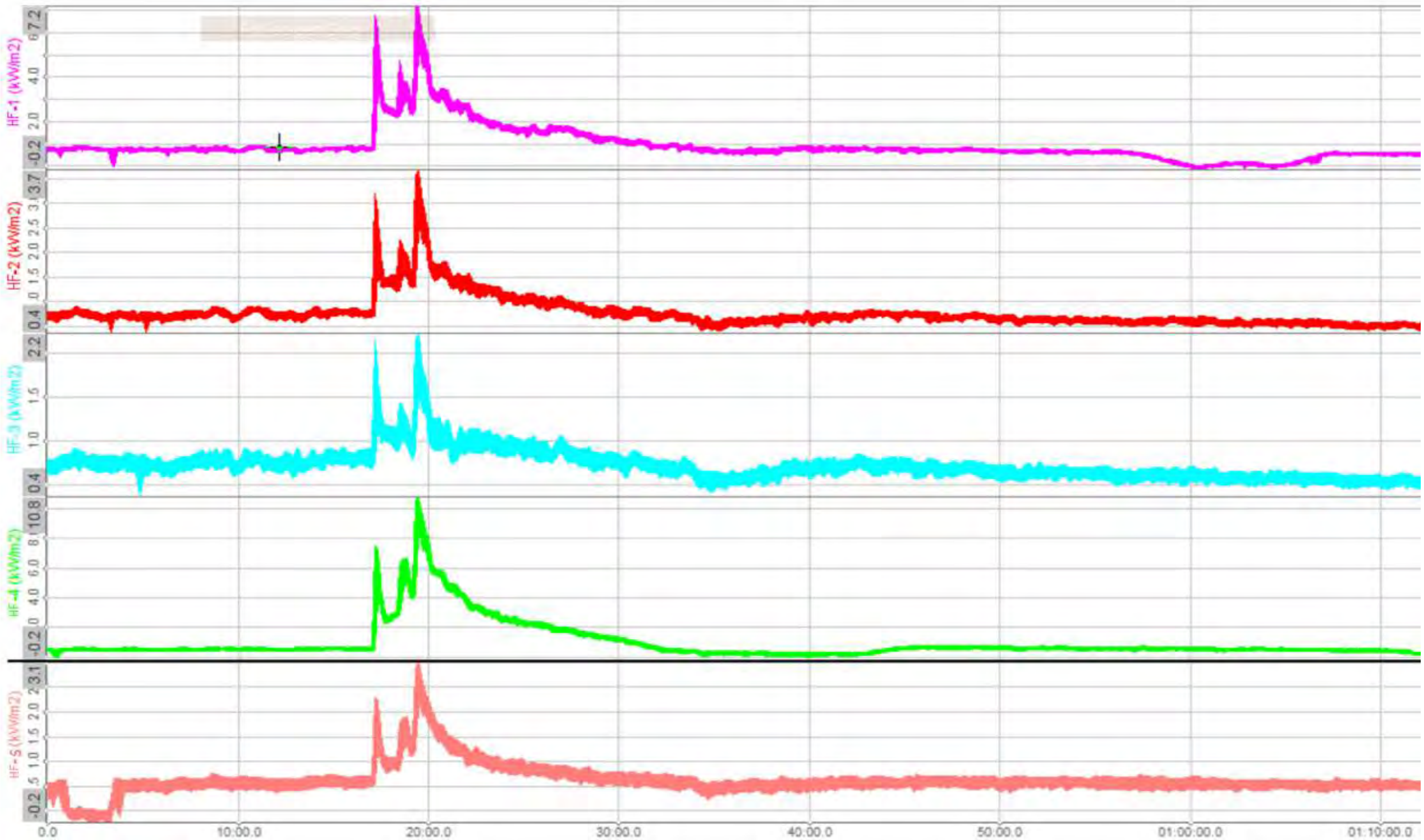


Figure A3: UN Series 6 (c) External Fire Thermal Flux for Medium Al-CuO Thermite – Large-Scale Mix ID #5 (Commercial)

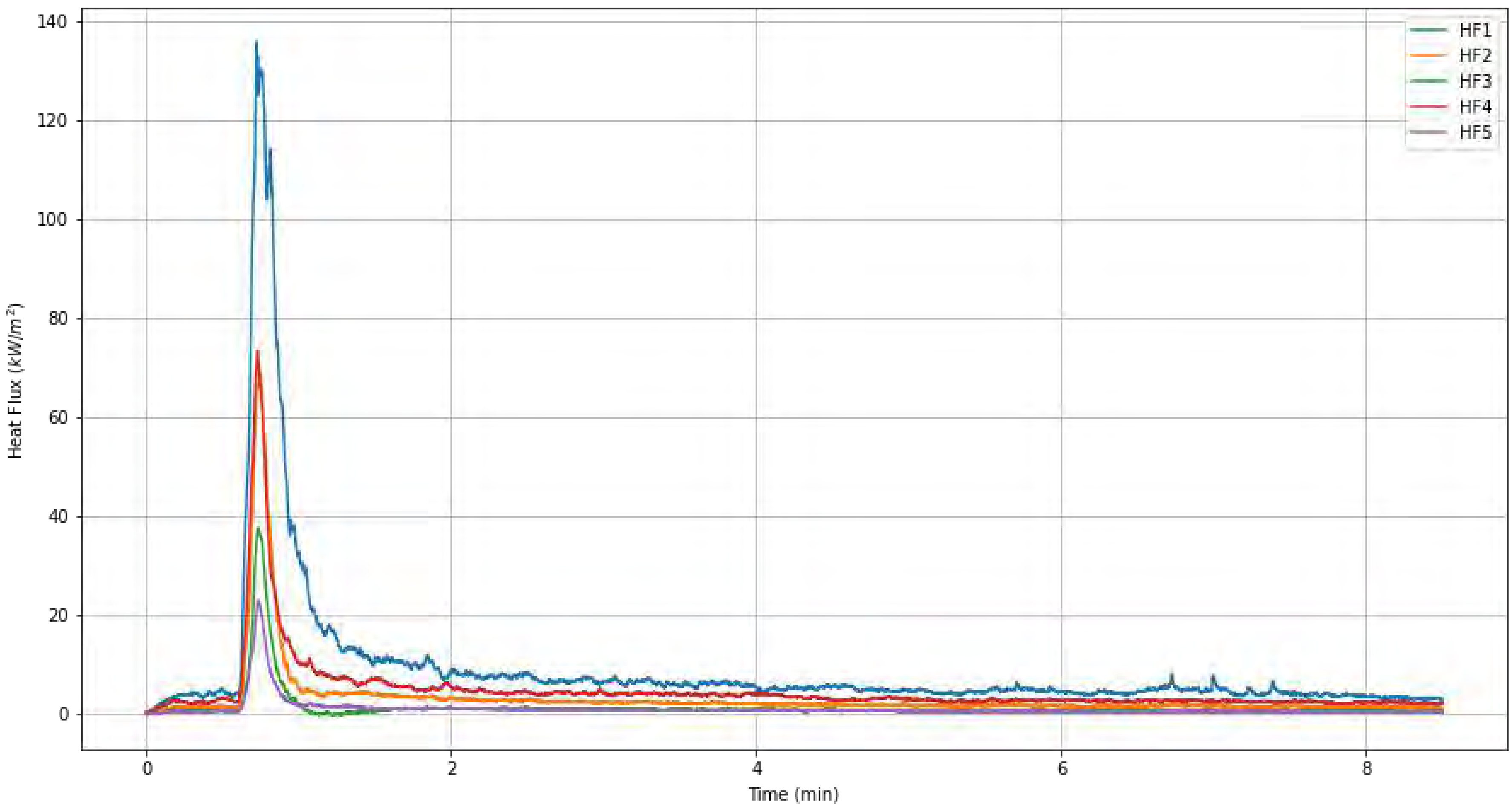


Figure A4: UN Series 6 (c) External Fire Thermal Flux for Fine Al-Ni_2O_3 Thermite – Large-Scale Mix ID #6 (SMS mixed)

APPENDIX B
– Product Certifications

Figure B1: Product Certification for Large-Scale Mix ID #2 and #3

[*REDACTED*]

Figure B2: Product Certification for Al Metal Powder

ATLANTIC EQUIPMENT ENGINEERS
HIGH PURITY METALS AND COMPOUNDS

Certificate of Analysis

ALUMINUM METAL POWDER
AL-100

1.1 General

SOLD TO	PURCHASE ORDER #	SHIP DATE	DOCUMENT NUMBER
SAFETY MANAGEMENT SERVICES for COMMANDER TOOELE ARMY DEPOT	1526	9 MAR 2021	2101018
CATALOG NUMBER	LOT NUMBER	QUANTITY	CAS NUMBER
AL-100	2002510-6	173 LBS	7429-90-5

2.1 Chemical Analysis (in percentage (%) unless otherwise stated)

Al	Ti	Si	Fe
99.9%	<0.06	<0.10	<0.20

3.1 Screen Analysis (percent passing) / Other

Size	D 10	D 50	D 90
1-5 microns	1.6 microns	3.6 microns	9 microns

4.1 Notes

5.1 Statement

Shelf life is indefinite when material is stored in a tightly sealed container in a cool, dry place.

The above analysis is carried out as part of our internal quality control testing and is based upon our analysis methods.

We do not assume any warranty, liability, or risk based on such findings. Our quality is warranted within the scope of our general sales conditions.

Please refer to SDS for material handling instructions.

Very Truly Yours,

M. Gerald, QA

24 Industrial Ave, Upper Saddle River, NJ 07458 Tel: 201.828.9400 Fax: 201.387.0291
On the web at: www.micronmetals.com Email: info@micronmetals.com

Page 1 of 1

Figure B3: Product Certification for Fe_2O_3

ATLANTIC EQUIPMENT ENGINEERS
HIGH PURITY METALS AND COMPOUNDS

Certificate of Analysis
RED IRON OXIDE POWDER
FE-601

1.1 General

SOLD TO	PURCHASE ORDER #	SHIP DATE	DOCUMENT NUMBER
SAFETY MANAGEMENT SERVICES for COMMANDER TOOELE ARMY DEPOT	1526	9 MAR 2021	2101018
CATALOG NUMBER	LOT NUMBER	QUANTITY	CAS NUMBER
FE-601	2102517-RD	262 LBS	1309-37-1

2.1 Chemical Analysis (in percentage (%) unless otherwise stated)

Tint strength	Moisture	Water soluble
100.4	0.60	0.10
Fe2O3	pH	
99 min	6.1	

3.1 Screen Analysis (percent passing) / Other

Size	+325 mesh
1-5 microns	0.012

4.1 Notes

5.1 Statement

The above analysis is carried out as part of our internal quality control testing and is based upon our analysis methods.

We do not assume any warranty, liability, or risk based on such findings. Our quality is warranted within the scope of our general sales conditions.

Please refer to SDS for material handling instructions.

Very Truly Yours,

M. Gerald, QA

24 Industrial Ave, Upper Saddle River, NJ 07458 Tel: 201.828.9400 Fax: 201.387.0291
On the web at: www.micronmetals.com Email: info@micronmetals.com

Page 1 of 1

Figure B4: Product Certification for CuO

ATLANTIC EQUIPMENT ENGINEERS
HIGH PURITY METALS AND COMPOUNDS

Certificate of Analysis
CUPRIC OXIDE
CU-602

1.1 General

SOLD TO	PURCHASE ORDER #	SHIP DATE	DOCUMENT NUMBER
SAFETY MANAGEMENT SERVICES for COMMANDER TOOELE ARMY DEPOT	1526	9 MAR 2021	2101018
CATALOG NUMBER	LOT NUMBER	QUANTITY	CAS NUMBER
CU-602	2102518	548 LBS	1317-38-0

2.1 Chemical Analysis (in percentage (%) unless otherwise stated)

Cu	CuO	Cu2O	Zn	Fe	Ca	Mg
75	94	3	0.3	0.02	0.01	0.002
Mn	Pb	Cd	As	Sb	Moisture	
0.001	0.05	0.01	0.01	0.01	0.2	

3.1 Screen Analysis (percent passing) / Other

Size	Specific Gravity	-325 mesh	Loose Bulk Density
1-5 microns	8.7 g/cc	99.9	80 lbs / ft³

4.1 Notes

5.1 Statement

The above analysis is carried out as part of our internal quality control testing and is based upon our analysis methods.

We do not assume any warranty, liability, or risk based on such findings. Our quality is warranted within the scope of our general sales conditions.

Please refer to SDS for material handling instructions.

Very Truly Yours,

M. Gerald, QA

24 Industrial Ave, Upper Saddle River, NJ 07458 Tel: 201.828.9400 Fax: 201.387.0291
On the web at: www.micronmetals.com Email: info@micronmetals.com

Page 1 of 1

Figure B5: Product Certification for Ni_2O_3

AMERICAN ELEMENTS

World's Leading Manufacturer of Rare Earth and Advanced Material Products

A MERELEX CORPORATION • 10884 WEYBURN AVE. LOS ANGELES, CA 90024
TEL. 310-208-0551 • FAX 310-208-0351 • E-MAIL: customerservice@americanelements.com

CERTIFICATE OF COMPLIANCE

99+% (metals basis) Nickel Oxide Powder

Ni2O3

Product Code: NI-OX-021M-P.5UM

CAS #: 1314-06-3

LOT #: 1471516447-407

American Elements certifies that the materials listed below and shipped on 4/8/2021 meets the purity and dimensional requirements set forth in SMS Energetics, Inc. purchase order: DOT1-6265D.

99+% (metals basis) Nickel Oxide Powder
Ni2O3
APS: 5 um

AMERICAN ELEMENTS

By ____________

AEC FORM 102:CA REV. APP. 2/3/99

TEST REPORT

Full-Scale Testing of Commercial Thermite in Transport Configurations

DOT Contract # 693JK320C000005

U.S. Department of Transportation
Pipeline and Hazardous Materials Safety Administration
(PHMSA)

Attention: PHH-20
Hazardous Materials Technology
1200 New Jersey Avenue, SE
E21-317
Washington, DC 20590

Troy A. Gardner, PE, CSP
Jackson Zarbock

November 30, 2023
SMS-6265e-R1, Rev 1

1847 West 9000 South, Suite 205 • West Jordan, Utah 84088 • 801-567-0456 • www.smsenergetics.com

Test Report

Full-Scale Testing of Commercial Thermite in Transport Configurations

November 30, 2022
SMS-6265e-R1, Rev 1

Troy A. Gardner, PE, CSP
Testing & Classifications Manager
Safety Management Services, Inc.

Jackson D. Zarbock
Project Engineer

TABLE OF CONTENTS

TABLES

FIGURES

PHOTOS

1.0 STATEMENT OF WORK

DOT Contract # 693JK320C000005 with Safety Management Services, Inc. (SMS) of West Jordan, Utah defines that for Task 5, "Conduct Full-Scale Testing of Commercially Available Thermites in Transport", SMS shall:

1) Order and receive 2.4 m^3 (4,340 kg) of Large-Scale Mix ID #2 (economic, rapid burning commercial thermite).
2) Procure transports (small aircraft fuselage, 15-foot box truck/trailer, double-stacked 20-foot Conex shipping container)
3) Perform full-scale test of 0.3 m^3 (550 kg) commercial thermite aboard a salvaged small aircraft fuselage.
4) Perform full-scale test of 0.85 m^3 (1,540 kg) commercial thermite aboard a box truck trailer.
5) Perform full-scale test of 1.25 m^3 (2,250 kg) commercial thermite in the top container of a double stacked 20-foot Conex shipping container.
6) Provide the COR with a test report and video(s).

2.0 SUMMARY AND CONCLUSIONS

SMS performed full-scale testing of commercial thermite (Coarse Al-Fe_2O_3 Thermite A – Large-Scale Mix ID #2) in the following transport configurations:

1) 362-kg (800-lb) Stack test in a semi-confined simulated pallet to provide a prediction of full-scale reaction severity for test site selection.
2) 544-kg (1200-lb) Stack test stacked in the aft baggage area of a small airplane fuselage, simulating reaction of half a pallet of thermite in an air freight configuration.
3) 1,134-kg (2500-lb) Stack test in a box truck trailer, simulating reaction of a pallet of thermite in a motor freight configuration.
4) 2,268-kg (5000-lb) Stack test in an intermodal shipping container, simulating reaction of two pallets of thermite in a vessel or rail freight configuration.

The tests were witnessed by Troy Gardner. A test video for each of the full-scale tests (SMS-6265e-V1 through V4) is being sent to the attention of the Contracting Officer's Representative (COR).

Each of the tests resulted in ignition and reaction of the commercial thermite with a reaction intensity consistent with Division 1.4 for the tested quantity, producing jetting flames and molten metal that compromised the structural integrity of the transport unit. The most violent thermite reaction was that of the transport unit with the lowest loading density and lightest construction (box truck trailer); increasing the confinement and loading density appeared to lessen the reaction severity (intermodal container). The thermite reaction compromised the intermodal container and could penetrate and compromise an intermodal container stacked beneath it.

3.0 BACKGROUND

Historically, industry has offered traditional thermite formulations (containing only metal and metal oxides) for transport in Class 4 as flammable or water-reactive solids. The reaction produces a burst of heat, high temperature, and molten metal for various uses including joining steel railroad ties or copper transmission lines, metal refining, disabling munitions, etc. Traditional thermite formulations pass the UN Manual of Tests and Criteria, Appendix 6 "Screening Procedures" for substances which may have explosive properties as they do not contain any of the chemical groups listed in Table A6.1 that are associated with explosive properties. NOTE: The Appendix 6 Screening Procedures cannot be used for substances manufactured with the view to producing a practical explosive or pyrotechnic effect.

Newer "exotic" thermite formulations include those with additives such as plastics, oxidizers, nano materials, explosives, etc. to confer special compositions or actions upon use. Thermite research was needed to identify families of new and existing thermite compositions and to determine their hazards in transport and to transport vehicles.

Safety Management Services, Inc. (SMS) was contracted to perform research on thermite formulations in cooperation with Southwest Research Institute (SwRI) and the U.S. Department of Transportation (DOT) Pipeline and Hazardous Materials Safety Administration (PHMSA). This effort is considered to be Phase I of thermite testing (DOT Contract # DTPH5616D00001). During Phase I, eight thermites for large-scale testing and fifteen thermite formulations were selected for small-scale testing. It was discovered that thermite mixtures exhibited hazards from ranging from rapid reactions that were consistent with 1.3G materials to exploding when ignited in unconfined 5-gram quantities, similar to 1.1G flash powders.

These findings prompted the request for SMS to perform additional testing to further research the energetic properties of thermite and develop the technical basis to base policies and decision on thermite-based products. This additional testing is considered Phase II of thermite testing. During Task 5 of Phase II, full-scale testing was performed on commercially available thermite in transport configurations to quantify their potential hazard in the event of their accidental ignition.

4.0 DESCRIPTION OF THERMITE TEST SAMPLE

4.1 Coarse Al-Fe_2O_3 Thermite A – Large-Scale Mix ID #2 (Commercial)

SMS procured this thermite from a commercial supplier. This thermite contained 25% aluminum (Al) and 75% iron(III)/ferric oxide (Fe_2O_3) by mass. The thermite was a coarse powder that was a mixture of black and light gray particles.

Photo 1: Coarse Al-Fe_2O_3 Thermite A – Large-Scale Mix ID #2 (Commercial)

5.0 PACKAGING

This thermite is packaged in quantities of 11.3 kg (25 lbs) in a robust, sealed plastic bag in a fiberboard box that was 356-mm (14 inches) long, 254-mm (10-inches) wide and 102-mm (4-inches) tall. The density of the thermite was approximately 2020 kg/m³.

Photo 2: The Inner and Outer Packaging – typical

6.0 DETAILS REGARDING TRANSPORT UNIT SELECTION, THE INITIATION SYSTEM, AND INSTRUMENTATION

6.1 Transport Unit Selection

Previous testing indicated that loading density and level of confinement are critical factors in the combustion behavior of thermites. Thus, in order to capture the full profile of potential reaction characteristics for large quantities of thermite, a large range of loading densities were tested. Each transport unit was selected to test a different loading density that may be present during transport. The internal dimensions of each transport unit were obtained and compared against the thermite quantity that would be loaded. The thermite quantities and loading densities for each transport unit are summarized in Table 1.

Table 1: Test Parameters for Each Transport Configuration

Test	Transport Configuration	Materials of Construction		Thermite Quantity (lb)	Internal Volume (ft³)	Loading Density (lb/ft³)
		Frame	Skin			
1	Semi-confined Structure	Concrete	Plywood	800	32	25
2	Airplane Fuselage	Aluminum	Aluminum	1200	194	6.2
3	Box Truck Trailer	Steel	Aluminum	2500	926	2.7
4	Intermodal Container	Steel	Steel	5000	1190	4.2

6.2 Initiation System

All tests were initiated using 30 grams of magnesium-based thermite starter mix. The starter mix was initiated using a standard electric match. Two primary igniters were used in each test to provide a backup initiation source. The bag igniters were placed inside the inner packaging of a thermite package. These donor packages were resealed and centrally located in the stack. Secondary igniters were also placed in the stack for the 800-lb and 1200-lb tests. If the potential for a slow cook-off event was observed, the secondary igniters could be initiated to consume any thermite material that did not react during the initial reaction. A representative igniter and placement inside the inner packaging is shown in Photo 3. Secondary igniters were not utilized in the subsequent tests since the potential for slow cook-off was negligible due to the rigorous reaction of the thermite.

Photo 3: Thermite Igniter (left) and Placement Inside Inner Packaging (right) – typical

6.3 Instrumentation

Each test was instrumented with thermocouples to determine reaction propagation rate and monitor the slow cook-off potential. A matrix of type K thermocouples was embedded in each stack and remotely monitored using a data acquisition (DAQ) system. DAQ channel functionality was established prior to each test via DAQ channel tests. Sensor functionality was verified prior to placement inside the stack and confirmed remotely before the start of each test. Data was collected at a rate of 100 Hz.

Two thermocouples were placed in close proximity to the donor packages to indicate the start of the reaction. Reaction propagation was determined by the distance of each thermocouple from the point of initiation and the time at which the thermocouple measured elevated temperatures. During all tests, the majority of thermocouples experienced temperatures exceeding the measurement capacity of the type K thermocouples (> 1260 °C) and were destroyed.

7.0 FULL-SCALE TEST DESCRIPTIONS AND RESULTS

7.1 Modified 362-kg (800-lb) Stack Test in a Semi-confined Simulated Pallet

7.1.1 Test Description

SMS performed an intermediate modified Stack Test to assess the worst-case reaction of a semi-confined simulated pallet of thermite. The test consisted of four stacks of eight 25-pound packages of thermite on a simulated wood pallet on a steel witness plate, confined by reinforced concrete blocks on the sides with restricted venting on the ends and top by covering the air gaps with 0.5-inch-thick plywood secured by concrete blocks.

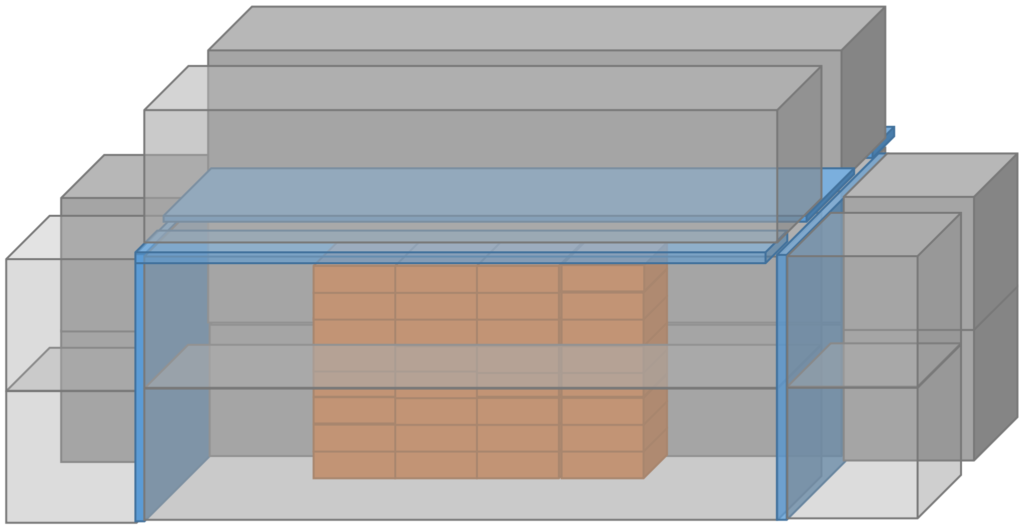


Figure 1: Isometric View of Modified 800-lb Stack Test

The concrete blocks to the side of the thermite packages represented the confinement afforded by the surrounding boxes of dense thermite on a full pallet. The air gaps to the top, front and back represent the air gaps that will be present in the full-scale tests between the thermite and the aircraft fuselage, box truck trailer, or Conex shipping container. A simulated pallet constructed of standard 2x4 wood studs was utilized since the thermite packages are shipped on a wooden pallet; 0.5-inch thick plywood sidewalls were added to the simulated pallet to provide structural support for the stack and inhibit flame from flashing down gaps between the box and the walls of the concrete blocks, which would result in a much faster rate of reaction propagation than would be present with a full pallet and not accurately assess the risk of slow-cook off due to slow reaction propagation. The plywood coverings over the top, front and back of the initial stack of concrete blocks provided resistance to venting, similar to that afforded by the sidewalls of a fuselage or box truck trailer; heavier confinement (such as that of a Conex shipping container) is anticipated to suppress and reduce the severity of reaction, as evidenced by the results of the Single Package test confined with loose sand.

7.1.2 Test Setup

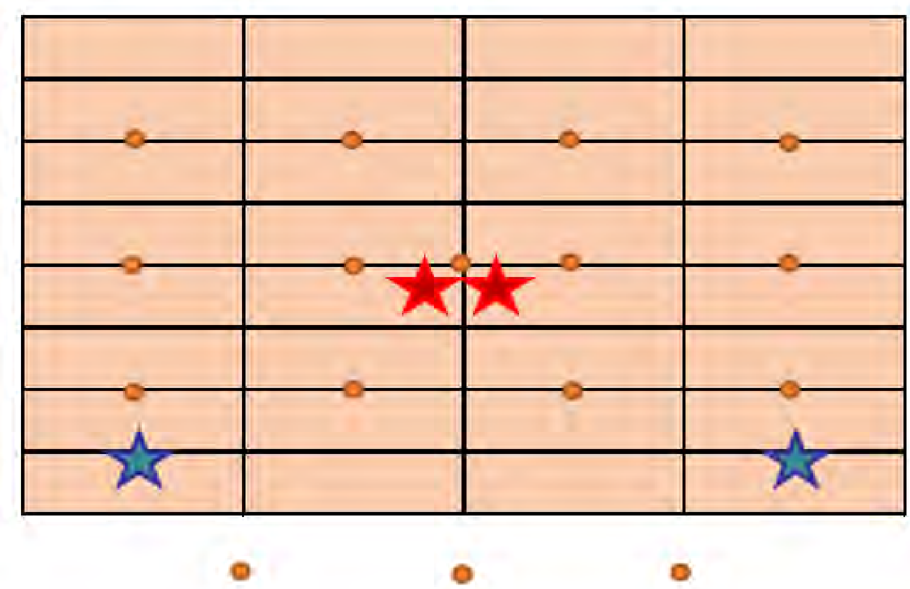
To set up the test structure, a standard Single Package mild steel witness plate (1-mm thick, 2-foot x 2-foot) was placed on the ground. Four (4) 2-foot x 2-foot x 6-foot concrete blocks, each weighing 4,000 pounds, were arranged to form the confining walls of the proposed test structure (see Photo 4). The simulated pallet with 1/2-inch-thick plywood sidewalls was positioned in the middle of the stack of concrete blocks.

Photo 4: Placement of Witness plate, Concrete Blocks and Simulated Pallet

The top was then closed off with 1/2-inch-thick plywood that was braced/secured with concrete blocks (see Photo 5).

Photo 5: Secured Plywood Covering the Top of the Modified Stack Test Structure

The thermite packages were then loaded into the simulated pallet one layer at a time. The matrix of thermocouples arranged inside the thermite stack are shown as orange circles in Figure 2. Three of the thermocouples were buried one inch below the witness plate to monitor the temperature under the test structure. The primary igniters were inserted into the top-middle of packages near the sidewall (i.e., so that igniters were adjacent to each other in neighboring packages) on the fourth row, as represented by red stars in Figure 2. Secondary igniters (shown as blue stars) were inserted into the top-middle of the outermost packages on the bottom row.



Red stars represent primary igniters, blue stars are secondary igniters, and orange circles are thermocouples

Figure 2: Side View of the Modified Stack Test

Photo 6 shows the loading of the test sled at various stages of completion.

Four layers | Six Layers | Eight Layers

Photo 6: Simulated Pallet at Various Stages of Loading

Once the simulated pallet was fully loaded, the sides of the test structure were covered with 1/2-inch-thick plywood and braced/secured with additional concrete blocks. Witness screens were placed 4 meters from the end of the thermite stack as visible distance markers. Photo 7 shows the final test structure set up.

Photo 7: Final Test Setup for the Semi-confined Simulated Pallet

7.1.3 Test Results

The majority of the thermite was consumed in approximately twenty seconds. The reaction propagated at 3 - 5 inches per second. The reaction melted through the witness plate and focused flames vented around the edges of the plywood and concrete. Due to the shape of the test structure, a significant directional effect occurred. Jetting flames were observed out to 8 meters with a shower of molten metal out to 20 meters on the downwind side. No detonation or explosion was observed. Photo 8 shows the peak of reaction. Photos of the reaction progression are provided in the appendix.

Photo 8: Peak of Reaction for the Modified 800-pound Stack Test

After the peak of reaction, the plywood sheeting was still intact, indicating a low-pressure reaction. Detonation or explosion of the stack did not occur. Additional photos of the reaction are included in the appendix. The reaction produced molten aluminum oxide (Al_2O_3) and iron (Fe) slag. The reactants cooled to ambient temperature after several hours. Photo 9 shows the reaction products.

Photo 9: Solidified Pools of Thermite Slag (Fe and Al_2O_3) from the Modified 800-lb Stack Test

The test structure remained intact and displayed no damage resulting from overpressure or an explosion. Photo 10 shows the interior of the structure after the test.

Photo 10: Post-Test Structure

7.1.4 Conclusions

Based on the test results and reaction intensity for the tested quantity, the behavior of the thermite appears to be consistent with that of Division 1.4; a slow cook-off event (with mass explosion hazard) for larger full-scale tests appears unlikely based on this intermediate simulated test.

7.2 544-kg (1200-lb) Stack Test in a Small Aircraft Fuselage

7.2.1 Transport Unit Description

The airplane fuselage selected for testing was a Cessna 320A Skyknight. All non-critical airplane features, including the engine, wings, propeller, electrical and steering system, and seats, were removed prior to the test. The fuselage was 29 feet 4 inches from nose to tail and had a cabin width of approximately 45 inches and a height of 48 inches. The cabin was approximately 9-feet long from the front of the cockpit to the back of the cargo compartment with a cabin volume of approximately 194 cubic feet. When fully operational, the Cessna 320 Skyknight has a maximum payload of 1,800 pounds.

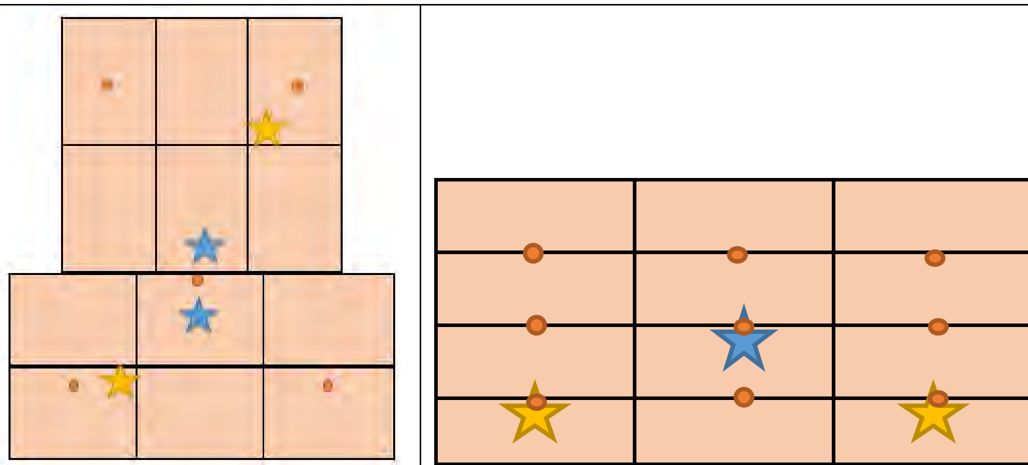
7.2.2 Test Setup

The airplane fuselage was secured on top of two sandbag pillars, supporting each side of the fuselage's cargo area, to view the full effect of the thermite on the fuselage skin and framing. A total of forty-eight (48) boxes of commercial Al-Fe_2O_3 thermite, twenty-five pounds each, were loaded into the cargo area of the fuselage as shown in Photo 11. The product was stacked in a twelve-box footprint, four boxes high.

One Layer	Three Layers	Four Layers

Photo 11: Loading Thermite into the Cargo Area of the Fuselage

The thermocouple matrix was placed between the thermite boxes as shown by the red dots in Figure 3. The primary thermite igniters were placed at the center of the thermite stack, and the secondary igniters were placed at the base of the stack. Figure 3 shows the layout of the thermocouples, primary igniters (blue stars), and secondary igniters (yellow stars) throughout the stack.



Top View | Side View

Blue stars represent primary igniters, yellow stars are secondary igniters, and orange circles are thermocouples

Figure 3: Top and Side Views of the Thermite Stack in the Small Aircraft Fuselage

After the thermite was loaded into the cargo area, all doors, windows, and compartments were sealed to simulate a reaction during flight. Witness screens were placed four meters from the edge of the thermite stack in the cargo area as visible distance markers to aid in gauging fireball size and hazard severity. Photo 12 shows the test-ready fuselage.

Photo 12: Final Test Setup for the Airplane Fuselage

7.2.3 Test Results

The majority of the material was consumed in less than one minute in a rapid burn. The reaction propagated at a rate of 5 - 15 inches per second. The thermite did not detonate or explode. Flames jetted out all seams or vents in the fuselage and melted through the aluminum skin in less than ten seconds. Flames engulfed the fuselage for approximately thirty seconds. The peak of the reaction is shown in Photo 13. Photos of the reaction progression are provided in the appendix.

Photo 13: Peak of Reaction During the 1200-pound Stack Test in Airplane Fuselage

The fuselage burned and broke in half twenty-five seconds after ignition. Remnants of the fuselage are shown in Photo 14 and Photo 15. The reaction produced molten aluminum oxide (Al_2O_3) and iron (Fe) slag. The products cooled to ambient temperature after several hours. Photos of the cooled products are shown in Photo 16.

Photo 14: Test Results of the Airplane Fuselage

Photo 15: Remains of the Fuselage Nose and Tail

Photo 16: Solidified Pool of Thermite Slag (Fe and Al_2O_3) from the 1200-lb Stack Test

7.2.4 Conclusions

Based on the test results and reaction intensity for the tested quantity, the behavior of the thermite appears to be consistent with that of Division 1.4.

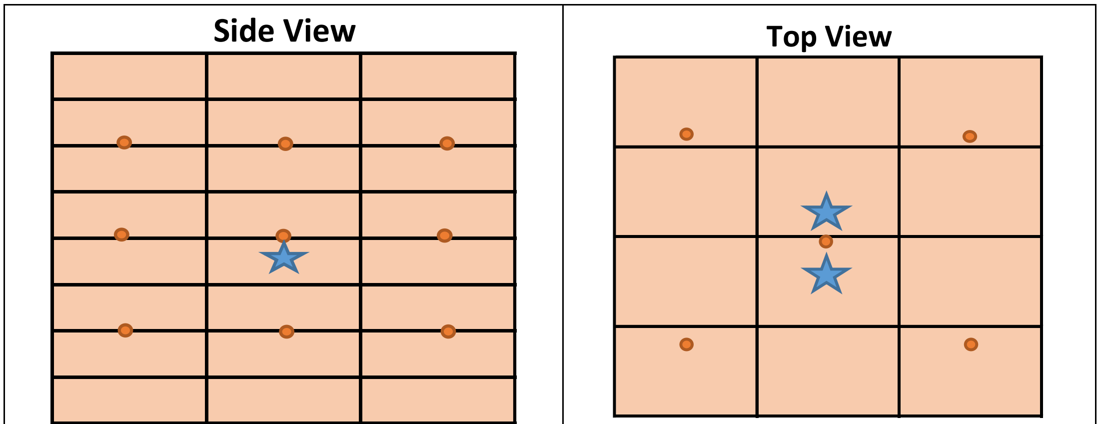
7.3 1134-kg (2500-lb) Stack Test in a Box Truck Trailer

7.3.1 Transport Unit Description

The box truck trailer was 20 feet long, 87 inches tall, and 76 inches wide with an internal volume of approximately 926 cubic feet. All non-essential components (e.g., tires, hydraulic systems, taillights, etc.) were removed prior to testing. The floor was 1/8-thick common steel. The frame was constructed of steel framing with beams along the floor. A steel lift gate frame was installed on the back of the trailer. The trailer had a roll-up door and was covered with aluminum sheeting.

7.3.2 Test Setup

The box truck trailer was supported by a 4,000-pound concrete block at the front and by the rear assembly in the back; the trailer was raised by the hitch until the floor was level to simulate attachment to a truck. A total of one hundred boxes of commercial Al-Fe_2O_3 thermite, twenty-five pounds each, were loaded into the box truck trailer (2500 pounds total). The thermite was configured on a single pallet stacked three packages wide, four packages long, eight packages high with four additional packages on top. The matrix of thermocouples was embedded in the stack before the pallet was loaded into the trailer. Two primary igniters were placed at the center of the stack. The primary igniters were placed at the center of the fourth row of packages. The thermocouples and igniters were configured as shown in Figure 4. Photo 17 shows the instrumentation setup.



Blue stars represent primary igniters and orange circles are thermocouples

Figure 4: Thermocouple and Igniter Configuration for the Box Truck Trailer

Once the stack was fully instrumented, it was placed at the center of the box truck trailer using an all-terrain forklift, as shown in Photo 18. The roll-up door was then lowered and latched. Markers were placed four meters from the edge of the box truck as visible distance indicators. Final test setup is shown in Photo 19.

First Instrumented Layer

Igniter Layer (fourth)

Final Instrument Layer (sixth)

Full Stack of Packages on a Pallet

Photo 17: Instrumentation of Stack for the Box Truck Trailer

Photo 18: Placement of Instrumented Pallet Inside the Box Truck Trailer

Photo 19: Final Test Setup for the Box Truck Trailer

7.3.3 Test Results

The majority of the material was consumed within ninety seconds. The reaction propagated through the stack at 10 - 20 inches per second. Approximately five seconds after ignition, the roof and siding of the box truck trailer visibly flexed from moderate pressurization. The roll gate at the back of the box truck ruptured shortly thereafter. Approximately ten seconds after ignition, flame jets erupted out of the back, sides, and front of the box truck trailer. The flame jet out of the back of the trailer was approximately 30-feet long. Flame jets from the side were less than 12 feet (4 meters) in length. The height of the reaction is shown in Photo 20. Photos of the reaction progression are provided in the appendix. No detonation or explosion was observed. Remnants of the box truck trailer and cooled products are shown in Photo 21 through Photo 24.

The reaction produced molten aluminum oxide (Al_2O_3) and iron (Fe) slag. Molten products melted through the floor and support beams of the box truck trailer and pooled at the base of the trailer. The aluminum roof, siding, and roll-up door were melted as well. The products cooled to ambient temperature after several hours. Photo 25 shows a solidified pool of the cooled thermite slag.

Photo 20: Peak of Reaction for the 2500-lb Stack Test in Box Truck Trailer

Photo 21: Box Truck Trailer Test Results - Right Side

Photo 22: Box Truck Trailer Test Results - Left Side

Photo 23: Box Truck Trailer Test Results - Back End

Photo 24: Box Truck Trailer Test Results - Back Left Corner

Photo 25: Box Truck Trailer Test Results - Solidified Pool of Thermite Slag, Left Side

7.3.4 Conclusions

Based on the test results and reaction intensity for the tested quantity, the behavior of the thermite appears to be consistent with that of Division 1.4. This thermite reaction appeared to be the most violent; the transport unit had the lowest loading density and lightest construction.

7.4 2268-kg (5000-lb) Stack Test in an Intermodal Container

7.4.1 Transport Unit Description

The intermodal shipping container used during the test was 20 feet long, 91 inches wide and 94 inches tall with an internal volume of approximately 1190 cubic feet. The sides and roof were constructed of corrugated steel (14-gauge typical). The frame was constructed of steel c-channel (7-gauge typical). The floor was made of plywood (1.1-inches thick typical) supported by steel beams welded to the frame. The container opening consisted of two doors, each with a latch system connected to two locking bars that interlocked with the container frame.

7.4.2 Test Setup

The shipping container was placed on concrete blocks. A grid of 2-foot-square, 1/8-inch-thick steel witness plates were placed beneath the shipping container to simulate a shipping container stacked below the unit containing thermite, in order to assess potential damage to a container below and/or reaction propagation from one container to another. The shipping container setup is shown in Figure 5 and Photo 26.

Figure 5: Test Configuration for the Intermodal Container

Photo 26: Grid of Steel Witness Plates Underneath the Shipping Container

The thermite was configured in two 2500-pound pallets, each with the same stack layout used for the box truck trailer (three packages wide, four packages long, eight packages high with four more on top; one hundred packages total per pallet). The thermocouple matrix and igniters were placed in stacks before they were loaded into the container. One primary igniter was placed on the edge of each thermite pallet on the face where the two pallets would meet. This location allowed for the igniters to be centrally located between both pallets. The configuration of the thermocouples and igniters is shown in Figure 6.

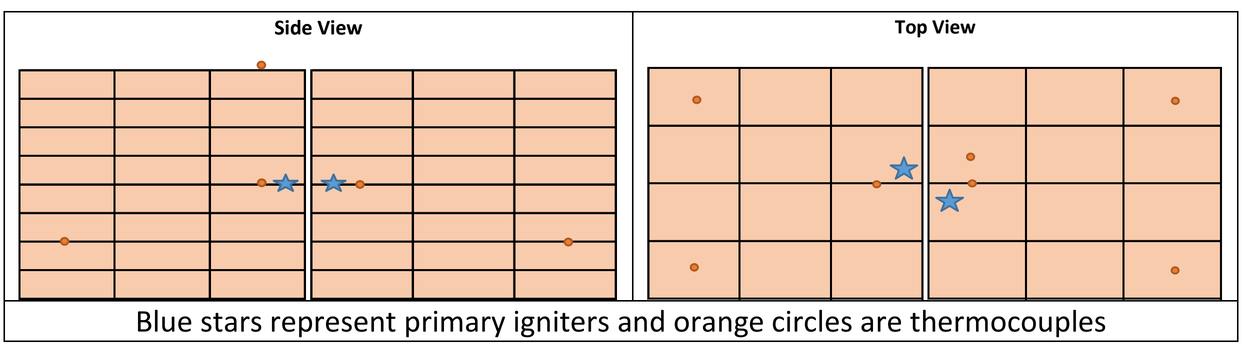


Figure 6: Thermocouple and Igniter Configuration for the Shipping Container Test

Once both pallets were fully instrumented, they were wrapped, banded, and loaded into the shipping container using an all-terrain forklift. The back edge of the thermite pallets was positioned 8.5 feet from the back of the shipping container; the front edge was positioned

3.5 feet from the door. Assembly, instrumentation and loading of the pallets are shown in Photo 27.

First Instrumented Layer

Igniter Layer (fourth)

Full Stack of Packages on a Pallet

Two Pallets Loaded into the Container

Photo 27: Thermite Stack for the Intermodal Shipping Container Test

After the thermite was loaded, the doors were closed and latched shut. The final test setup is shown in Photo 28.

Rear | Front and Left Side Panel | Right Panel | Front

Photo 28: Final Test Setup for the Intermodal Container

7.4.3 Test Results

The majority of the material was consumed within ninety seconds. The reaction propagated through the stack at a rate of 10 - 20 inches per second. The roof and sides of the container visibly flex from moderate pressurization within five seconds of ignition. Flames jetted around the door and seams in the floor at distances greater than 4 meters but did not burst the door. The container is engulfed in flames for approximately twenty seconds. No detonation or explosion was observed. The peak of the reaction is shown in Photo 29. Photos of reaction progression are provided in the appendix.

Photo 29: Peak of the Reaction for the Shipping Container Test

The reaction produced molten aluminum oxide (Al_2O_3) and iron (Fe) slag. The molten products melted through the sides and front of the container, spraying molten material distances greater than 4 meters. Damage to the container is shown in Photo 30 and Photo 31.


Rear


Front and Left Side Panel


Front


Right Side Panel

Photo 30: Intermodal Container Test Results

Left Side and Bottom	Rear and Bottom

Photo 31: Intermodal Container Test Results - Bottom and Siding

The molten products also melted through the support beams of the floor damaging most of the witness plates underneath the witness plates underneath the container. Details of the cooled products and damage to the witness plates beneath the container are shown in Photo 32 through Photo 35.

Photo 32: Intermodal Container Test Results - Perforated Container Floor

Photo 33: Intermodal Container Test Results - Damaged Siding and Witness Plates

Photo 34: Intermodal Container Test Results - Damage to Witness Plates

Photo 35: Intermodal Container Test Results - Damaged Witness Plates (typical)

7.4.4 Conclusions

Based on the test results and reaction intensity for the tested quantity, the behavior of the thermite appears to be consistent with that of Division 1.4. Increasing the confinement and loading density from that of the box truck trailer appears to lessen the reaction severity. The thermite reaction compromised the intermodal container and could penetrate and compromise an intermodal container stacked beneath it.

APPENDIX A

– Photos of Reaction Progression for Each Test

Start of Reaction

Molten Metal Showers Out of Sides of Structure

Peak of Reaction

Peak of Reaction Has Passed

Photo A1: Reaction Progression for the Modified 800-lb Stack Test

Flames Begin to Jet Out of Seams

Flames Begin to Engulf Fuselage

Peak of Reaction, Fuselage Fully Engulfed

Fuselage Breaks into Two Pieces

Photo A2: Reaction Progression for the 1200-lb Stack Test in an Airplane Fuselage

Initial Pressurization of Trailer

Jets of Flame Erupt from Back and Sides

Molten Showers Melt Through Trailer

Reaction Begins to Decrease

Photo A3: Reaction Progression for the 2500-lb Stack Test in a Box Truck Trailer

Initial Pressurization of Container

Flames Begin to Jet Out of Door Floor Seams

Height of Reaction, Container Fully Engulfed in Flames

Slag Melts Through Walls and Floor

Photo A4: Reaction Progression for the 5000-lb Stack Test in a Shipping Container

APPENDIX B
– Product Certifications

Figure B1: Product Certification for Large-Scale Mix ID #2

[*REDACTED*]

TEST REPORT

UN Series 6 (a) Single Package Testing of Exploding, Large-Scale Thermites

DOT Contract # 693JK320C000005

U.S. Department of Transportation
Pipeline and Hazardous Materials Safety Administration
(PHMSA)

Attention: PHH-20
Hazardous Materials Technology
1200 New Jersey Avenue, SE
E21-317
Washington, DC 20590

Troy A. Gardner, PE, CSP
Jackson Zarbock

June 30, 2023
SMS-6265f-R1, Rev 0

1847 West 9000 South, Suite 205 • West Jordan, Utah 84088 • 801-567-0456 • www.smsenergetics.com

Test Report

UN Series 6 (a) Single Package Testing of Exploding, Large-Scale Thermites

June 30, 2023
SMS-6265f-R1, Rev 0

Troy A. Gardner, PE, CSP
Testing & Classifications Manager
Safety Management Services, Inc.

Jackson D. Zarbock
Project Engineer

TABLE OF CONTENTS

TABLES

PHOTOS

1.0 STATEMENT OF WORK

DOT Contract # 693JK320C000005 with Safety Management Services, Inc. (SMS) of West Jordan, Utah defines that in conjunction with Task 6, SMS shall:

1) Order and receive sufficient raw ingredients for mixing a single 25-pound package for each of the two exploding thermites.
2) Mix 25 pounds of each of the two exploding, large-scale thermite mixes.
3) Perform a single UN Series 6 (a) Single package trial on each of the two exploding thermites to determine whether sand confinement affects the test results.
4) Provide the COR with a test report and video(s).

2.0 SUMMARY AND CONCLUSIONS

SMS performed one trial of the UN Series 6 (a) Single Package test on 11.3 kg (25 pounds) of the following thermite mixtures confined with loose sand:

1) Fine Al-MnO_2 Thermite – Large-Scale Mix ID #7 (SMS mixed)
2) Fine Mg&Al-MoO_3-CuO Thermite – Large-Scale Mix ID #8 (SMS mixed)

Each trial exhibited hazards consistent with a mass explosion (Division 1.1) and resulted in a blast, complete scattering of the confining material and slight damage to the witness plate; each blast did not produce a crater. A test video (SMS-6265f-V1) is being sent to the attention of the Contracting Officer's Representative (COR).

3.0 ACKNOWLEDGEMENTS

Mixing of fine thermites was performed by Derek M. Sutton, Jordan D. Dzubak and Jackson D. Zarbock. Tests were performed by Jason T. Ford and Collin L. Boren.

4.0 BACKGROUND

Historically, industry has offered traditional thermite formulations (containing only metal and metal oxides) for transport in Class 4 as flammable or water-reactive solids. The reaction produces a burst of heat, high temperature, and molten metal for various uses including joining steel railroad ties or copper transmission lines, metal refining, disabling munitions, etc. Traditional thermite formulations pass the UN Manual of Tests and Criteria, Appendix 6 "Screening Procedures" for substances which may have explosive properties as they do not contain any of the chemical groups listed in Table A6.1 that are associated with explosive properties. NOTE: The Appendix 6 Screening Procedures cannot be used for substances manufactured with the view to producing a practical explosive or pyrotechnic effect.

Newer "exotic" thermite formulations include those with additives such as plastics, oxidizers, nano materials, explosives, etc. to confer special compositions or actions upon use. Thermite research was needed to identify families of new and existing thermite compositions and to determine their hazards in transport and to transport vehicles.

Safety Management Services, Inc. (SMS) was contracted to perform research on thermite formulations in cooperation with Southwest Research Institute (SwRI) and the U.S. Department of Transportation (DOT) Pipeline and Hazardous Materials Safety Administration (PHMSA). This effort is considered to be Phase I of thermite testing (DOT Contract # DTPH5616D00001). During Phase I, eight thermites for large-scale testing and fifteen thermite formulations were selected for small-scale testing. It was discovered that thermite mixtures exhibited hazards from ranging from rapid reactions that were consistent with 1.3G materials to exploding when ignited in unconfined 5-gram quantities, similar to 1.1G flash powders.

These findings prompted the request for SMS to perform additional testing to further research the energetic properties of thermite and develop the technical basis to base policies and decisions on thermite-based products. This additional testing is considered Phase II of thermite testing. During Task 6 of Phase II, thermites were subjected to the UN Series 6 (a) Single-Package Test to determine the hazard division of each thermite when packaged in 11.3-kg (25-lb) quantities and fiberboard boxes. The following two thermites were tested:

- Fine Al-MnO_2 Thermite – Large-Scale Mix ID #7 (SMS mixed)
- Fine Mg&Al-MoO_3-CuO Thermite – Large-Scale Mix ID #8 (SMS mixed)

5.0 DESCRIPTION OF THERMITE TEST SAMPLES

5.1 Fine Al-MnO_2 Thermite – Large-Scale Mix ID #7 (SMS mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 29.27% aluminum (Al) and 70.73% manganese(IV) oxide (MnO_2). The aluminum was 3N purity (99.9% pure), 1 - 5 micrometers (microns) in size, and offered for transport as a Division 4.1 flammable solid. The manganese(IV) oxide was 2N purity (99% pure), 5 microns in size, and offered for transport as non-regulated. This thermite was a very fine, dark gray powder when fully mixed.

Photo 1: Fine Al-MnO_2 Thermite – Large-Scale Mix ID #7 (SMS mixed)

5.2 Fine Mg&Al-MoO_3-CuO Thermite – Large-Scale Mix ID #8 (SMS mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 25% magnalium (magnesium-aluminum), 34% molybdenum trioxide (MoO_3), and 41% copper(II)/cupric oxide (CuO). The magnalium was 2N purity (99% pure), 44 micrometers (microns) in size, and offered for transport as a Division 4.3 dangerous when wet substance with a subsidiary hazard of Division 4.2 spontaneously combustible. The molybdenum trioxide was 2N purity (99% pure), 44 microns in size, and offered for transport as a Division 6.1 toxic substance. The cupric oxide was 3N purity (99.9% pure), 1 - 5 microns in size, and offered for transport as Class 9. This thermite was a very fine, gray powder when fully mixed.

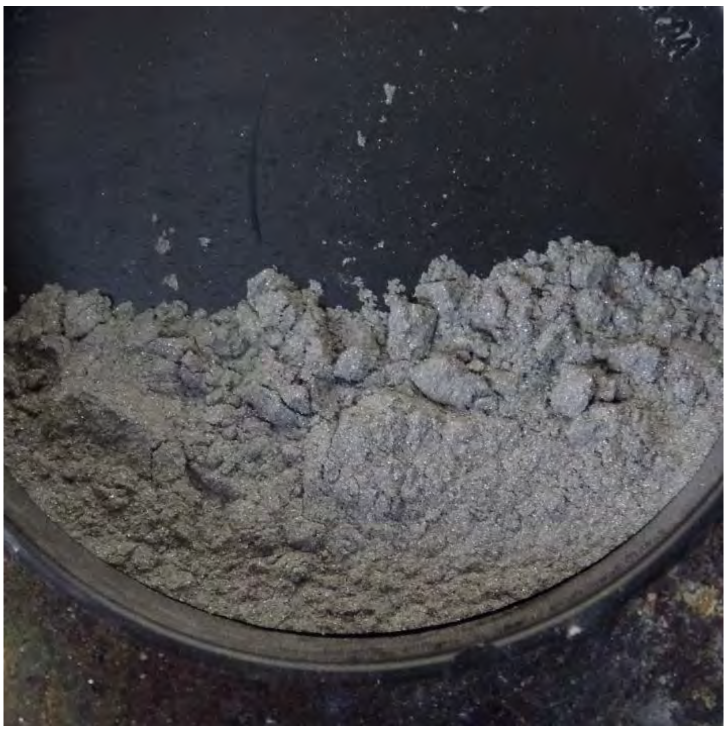


Photo 2: Fine Mg&Al-MoO_3-CuO Thermite – Large-Scale Mix ID #8 (SMS mixed)

6.0 PACKAGING

To maintain uniformity of test parameters between thermite samples, each thermite was packaged in a similar fashion to Large-scale Mix ID #2 and #3 commercial thermites after they were mixed or received from the commercial vendor; Photo 3 shows an example inner and outer packaging. Each package consisted of 11.3 kg (25 lbs) of thermite placed in a robust plastic bag that was sealed and placed into a fiberboard box.

Photo 3: The Inner and Outer Packaging - typical

Packing details for each tested thermite are shown in the following table.

Table 1: Densities and Packaging Dimensions for Thermite Samples

Sample	Density (kg/m^3)	Thermite Mass Per Package (kg)	Dimension (inches)		
			Length	Width	Height
Fine Al-MnO_2 Thermite – Large-Scale Mix ID #7 (SMS mixed)	1370	11.3	14	10	4
Fine Mg&Al-MoO_3-CuO Thermite – Large-Scale Mix ID #8 (SMS mixed)	1355	11.3	14	10	4

7.0 TEST DESCRIPTIONS AND RESULTS

7.1 Confined UN Series 6 (a) Single Package Test

7.1.1 Test Description

This test is applied to a packaged substance in the condition and form in which it will be offered for transport to determine whether there is a mass explosion of the package contents. Substances intended to function by detonation are tested with a standard detonator inserted into the top of the substance; substances intended to function by deflagration are tested with an igniter located in the center of the substance in the package that is just sufficient (but not more than 30 grams of black powder) to ensure ignition of the substance.

The package is placed on a 3mm-thick mild steel witness plate on the ground. Sand (bagged, boxed, or piled) is placed as closely as possible around the test package to a minimum thickness of confinement, in every direction of 0.5 meters for a package not exceeding 0.15 m^3 and 1.0 meter for a package greater than 0.15 m^3. The igniter is functioned and observations made on the following: evidence of thermal effects, projection effects, detonation, deflagration or explosion of the total contents of the package. The test is performed three times unless a decisive result occurs earlier (e.g. explosion of the total contents). Evidence of a mass explosion (a crater at the test site, damage to the witness plate beneath the package, measurement of a blast, and disruption and scattering of the confining material) indicates a candidate for Division 1.1.

Photo 4: UN Series 6 (a) Single Package Test Setup - typical

7.1.2 Test Configuration

The thermites were ignited using an electric match and 25 grams of thermite starter mix provided by the manufacturer of the commercial Al-CuO thermite (Large-scale Mix ID #5).

Photo 5: Preparation and Placement of Igniter - typical

7.1.3 Test Results

Jason Ford witnessed each of the Single Package tests. The test results for the single package test for each trial are detailed in the table below and shown in the following photos.

Table 2: Summary of UN Series 6 (a) Single Package Testing

Item	Sample	Conditions and Results	Assessment
1	Fine Al-MnO_2 Thermite – Large-Scale Mix ID #7 (SMS mixed)	One trial on 11.3 kg of thermite in a fiberboard box confined with loose sand resulted in a blast, complete scattering of the confining material and slight damage to the witness plate; the blast did not produce a crater.	**Mass explosion hazard (Division 1.1)**
2	Fine Mg&Al-MoO_3-CuO Thermite – Large-Scale Mix ID #8 (SMS mixed)	One trial on 11.3 kg of thermite in a fiberboard box confined with loose sand resulted in a blast, complete scattering of the confining material and slight damage to the witness plate; the blast did not produce a crater.	**Mass explosion hazard (Division 1.1)**

Photo 6: Explosion of Fine Al-MnO_2 Thermite – Large-Scale Mix ID #7 (SMS mixed) in the UN Series 6 (a) Single Package Test

Photo 7: UN Series 6 (a) Single Package Test Results for Fine Al-MnO_2 Thermite – Large-Scale Mix ID #7 (SMS mixed)

Photo 8: Explosion of Fine Mg&Al-MoO_3-CuO Thermite – Large-Scale Mix ID #8 (SMS mixed) in the UN Series 6 (a) Single Package Test

Photo 9: UN Series 6 (a) Single Package Test Results for Fine Mg&Al-MoO_3-CuO Thermite – Large-Scale Mix ID #8 (SMS mixed)

Although no blast sensors were utilized, each thermite reaction produced a blast sufficient to damage the witness plate and cause a brief, slight jostle of the video cameras recording the test but insufficient to crater the ground.

7.1.4 Conclusions

Based on the test results, Large-Scale Mix ID's #7 and #8 exhibited a mass explosion hazard in an 11.3-kg quantity packaged in a fiberboard box and confined with loose sand. Propagation from one package to another is likely if a UN Series 6 (b) Stack and UN Series 6 (c) External fire (bonfire) test were to be performed due to the violence of the reaction and the behavior of Large-Scale Mix ID #1 on the bonfire (mass reaction).

APPENDIX B
– Product Certifications

Figure B1: Product Certification for Al Metal Powder

ATLANTIC EQUIPMENT ENGINEERS
HIGH PURITY METALS AND COMPOUNDS

Certificate of Analysis

ALUMINUM METAL POWDER
AL-100

1.1 General

SOLD TO	PURCHASE ORDER #	SHIP DATE	DOCUMENT NUMBER
SAFETY MANAGEMENT SERVICES for COMMANDER TOOELE ARMY DEPOT	1526	9 MAR 2021	2101018
CATALOG NUMBER	LOT NUMBER	QUANTITY	CAS NUMBER
AL-100	2002510-6	173 LBS	7429-90-5

2.1 Chemical Analysis (in percentage (%) unless otherwise stated)

Al	Ti	Si	Fe
99.9%	<0.06	<0.10	<0.20

3.1 Screen Analysis (percent passing) / Other

Size	D 10	D 50	D 90
1-5 microns	1.6 microns	3.6 microns	9 microns

4.1 Notes

5.1 Statement

Shelf life is indefinite when material is stored in a tightly sealed container in a cool, dry place.

The above analysis is carried out as part of our internal quality control testing and is based upon our analysis methods.

We do not assume any warranty, liability, or risk based on such findings. Our quality is warranted within the scope of our general sales conditions.

Please refer to SDS for material handling instructions.

Very Truly Yours,

M. Gerald, QA

24 Industrial Ave, Upper Saddle River, NJ 07458 Tel: 201.828.9400 Fax: 201.387.0291
On the web at: www.micronmetals.com Email: info@micronmetals.com

Page 1 of 1

Figure B2: Product Certification for CuO

ATLANTIC EQUIPMENT ENGINEERS
HIGH PURITY METALS AND COMPOUNDS

Certificate of Analysis

CUPRIC OXIDE
CU-602

1.1 General

SOLD TO	PURCHASE ORDER #	SHIP DATE	DOCUMENT NUMBER
SAFETY MANAGEMENT SERVICES for COMMANDER TOOELE ARMY DEPOT	1526	9 MAR 2021	2101018
CATALOG NUMBER	LOT NUMBER	QUANTITY	CAS NUMBER
CU-602	2102518	548 LBS	1317-38-0

2.1 Chemical Analysis (in percentage (%) unless otherwise stated)

Cu	CuO	Cu2O	Zn	Fe	Ca	Mg
75	94	3	0.3	0.02	0.01	0.002
Mn	Pb	Cd	As	Sb	Moisture	
0.001	0.05	0.01	0.01	0.01	0.2	

3.1 Screen Analysis (percent passing) / Other

Size	Specific Gravity	-325 mesh	Loose Bulk Density
1-5 microns	8.7 g/cc	99.9	80 lbs / ft³

4.1 Notes

5.1 Statement

The above analysis is carried out as part of our internal quality control testing and is based upon our analysis methods.

We do not assume any warranty, liability, or risk based on such findings. Our quality is warranted within the scope of our general sales conditions.

Please refer to SDS for material handling instructions.

Very Truly Yours,

M. Gerald, QA

24 Industrial Ave, Upper Saddle River, NJ 07458 Tel: 201.828.9400 Fax: 201.387.0291
On the web at: www.micronmetals.com Email: info@micronmetals.com

Figure D3: Product Certification for MnO_2

AMERICAN ELEMENTS

World's Leading Manufacturer of Rare Earth and Advanced Material Products

A MERELEX CORPORATION • 10884 WEYBURN AVE. LOS ANGELES, CA 90024
TEL. 310-208-0551 • FAX 310-208-0351 • E-MAIL: customerservice@americanelements.com

CERTIFICATE OF COMPLIANCE

99+% (metals basis) Manganese Oxide Powder

MnO2

Product Code: MN-OX-021M-P.5UM

CAS #: 1313-13-9

LOT #: 1441516447-410

American Elements certifies that the materials listed below and shipped on 4/8/2021 meets the purity and dimensional requirements set forth in SMS Energetics, Inc. purchase order: DOT1-6265D.

99+% (metals basis) Manganese Oxide Powder
MnO2
APS: 5 um

AMERICAN ELEMENTS

By ______________

AEC FORM 102:CA REV. APP. 2/3/99

Figure D4: Product Certification for MoO_3

STANFORD ADVANCED MATERIALS

Stanford Advanced Materials
23661 Birtcher Dr. Lake Forest, CA 92630, USA
Tel: (949) 407-8904 Fax: (949) 812-6690

Certificate of Analysis

Product Name:	Molybdenum Trioxide (MoO3) Powder
Purity:	≥99.5%
Particle Size:	-325mesh
Lot Number:	OC210201-12629-1
Date:	2/1/21

Purity (wt%)	99.5
C (wt%)	0.05
H (wt%)	0.02
O (wt%)	0.01
N (wt%)	0.01
Mg (wt%)	0.01
Al (wt%)	0.01
Si (wt%)	0.02
Ca (wt%)	0.01
Ti (wt%)	0.01
Fe (wt%)	0.08
Ni (wt%)	0.01
Cu (wt%)	0.02
Sn (wt%)	0.01
W (wt%)	0.03
Pb (wt%)	0.01

Stanford Advanced Materials

TEST REPORT

Explosive Power of Unconfined Exploding Thermites

DOT Contract # 693JK320C000005

U.S. Department of Transportation
Pipeline and Hazardous Materials Safety Administration
(PHMSA)

Attention: PHH-20
Hazardous Materials Technology
1200 New Jersey Avenue, SE
E21-317
Washington, DC 20590

Troy A. Gardner, PE, CSP
Jackson D. Zarbock

September 27, 2023
SMS-6265f-R2, Rev 1

1847 West 9000 South, Suite 205 • West Jordan, Utah 84088 • 801-567-0456 • www.smsenergetics.com

Test Report

Explosive Power of Unconfined Exploding Thermites

September 27, 2023
SMS-6265f-R2, Rev 1

Troy A. Gardner, PE, CSP
Testing & Classifications Manager
Safety Management Services, Inc.

Jackson D. Zarbock
Project Engineer
Safety Management Services, Inc.

TABLE OF CONTENTS

FIGURES

PHOTOS

TABLES

1.0 STATEMENT OF WORK

DOT Contract # 693JK320C000005 with Safety Management Services, Inc. (SMS) of West Jordan, Utah defines that Task 6, "Explosive Power of Unconfined Exploding Thermites", SMS shall:

1) Order and receive fine metal and metal oxides for mixing sixty pounds of each exploding thermite and also order and receive three twenty-pound hemispherical charges of TNT.
2) Mix sixty pounds of each exploding thermite.
3) For each exploding thermite, perform an unconfined ignition test with the thermite on the ground in a hemispherical shape instrumented with blast overpressure sensors. Perform three twenty-pound trials: one trial with the igniter on top of the hemisphere, one in the middle and one at the bottom.
4) Provide the COR with a test report and video(s).

1.0 SUMMARY AND CONCLUSIONS

SMS conducted unconfined ignition tests (top, middle and bottom ignition) on 20-pound hemispherical mounds of the following eight thermite powders, measuring the free-field pressure variation over time:

- Large-Scale Mix ID #7 – Al-MnO_2
- Large-Scale Mix ID #8 – Mg&Al-MoO_3-CuO
- Small-Scale Mix ID #4 – Mg-MnO_2
- Small-Scale Mix ID #19 – Al-SnO_2
- Small-Scale Mix ID #24 – Al-Bi_2O_3
- Small-Scale Mix ID #27 – Al-Fe_3O_4
- Small-Scale Mix ID #30 – Al-NiO
- Small-Scale Mix ID #48 – Ti-Bi_2O_3

SMS also performed surface detonation tests on 20-pound hemispherical charges of cast trinitrotoluene (TNT) for reference. The tests were witnessed by Kirt N. Sasser and Troy A. Gardner.

The acquired waveforms (Appendix) were assessed for peak pressure (after filtering momentary spikes from data) and positive incident impulse. After scaling the data to sea level, a logarithm was taken of the values and plotted on a linear plot so that a smooth polynomial curve could be fitted through the average measured values. The smoothed peak pressure and positive incident impulse were compared with that of the TNT reference standard and equivalency factors calculated. Based on that assessment, the following table summarizes the test results and the average explosive equivalency in comparison to the TNT reference standard; Small-Scale Mix ID's #19, #27 and #30 did not explode when top, middle or bottom ignited.

Table 1: Explosive Equivalency of 20-lb Charges to the TNT Reference Standard

Sample	Test Result	Average Percentage	
		Blast Pressure	Scaled Impulse
Large-Scale Mix ID #7	Explosion (pressure pulse)	0.02	4
Large-Scale Mix ID #8	Explosion (pressure pulse)	1	11
Small-Scale Mix ID #4	Explosion (pressure pulse)	0.1	3
Small-Scale Mix ID #24*	Detonation (shock wave)	3	13
Small-Scale Mix ID #48*	Detonation (shock wave)	4	4
Hemispherical cast TNT	Detonation (shock wave)	96	90

*Unconfined sample detonated upon ignition.

2.0 ACKNOWLEDGEMENTS

Mixing of all thermites was performed by Derek M. Sutton, Jordan D. Dzubak and Jackson D. Zarbock. Testing was performed by Jackson D. Zarbock. Data acquisition and reduction were performed by Joshua A. Kneeland with assessment of acquired data by Troy A. Gardner.

3.0 BACKGROUND

3.1 Blast Wave Phenomena

UFC 3-340-2 (Reference 1) Section 2-12 describes blast-wave phenomena:

> *The violent release of energy from a detonation converts the explosive material into a very high pressure gas at very high temperatures. A pressure front associated with the high pressure gas propagates radially into the surrounding atmosphere as a strong shock wave, driven and supported by the hot gases. The shock front, termed the blast wave, is characterized by an almost instantaneous rise from ambient pressure to a peak incident pressure P_{so} (Figure 2-2).*
>
> *This pressure increase or shock front travels radially from the burst point with a diminishing shock velocity U which is always in excess of the sonic velocity of the medium. Gas molecules behind the front move at lower flow velocities, termed particle velocities u. These latter particle velocities are associated with the dynamic pressures, whose maximum values are denoted q_o' or the pressures formed by the winds produced by the passage of the shock front. As the shock front expands into increasingly larger volumes of the medium, the peak incident pressures at the fronts decrease and the durations of the pressures increase. Those parameters which vary as the peak incident pressure varies are presented in Figure 2-3.*
>
> *At any point away from the burst, the pressure disturbance has the shape shown in Figure 2-2. The shock front arrives at a given location at time t_A and, after the rise to the peak value, P_{so} the incident pressure decays to the ambient value in time to which is the positive phase duration. This is followed by a negative phase with a duration t_o^- that is usually much longer than the positive phase and characterized by a negative pressure (below ambient pressure) having a maximum value of P_{so}^- as well as a reversal of the particle flow. The negative phase is usually less important in a design than is the positive phase, and its amplitude P_s^- must, in all cases, be less than ambient atmosphere pressure P_o. The incident impulse density associated with the blast wave is the integrated area under the pressure-time curve and is denoted as i_s for the positive phase and i_s^- for the negative phase.*

An additional parameter of the blast wave, the wave length, is sometimes required in the analysis of structures. The positive wave length L_w^+ is that length at a given distance from the detonation which, at a particular instant of time, is experiencing positive pressure. The negative wave length L_w^- is similarly defined for negative pressures.

The above treatment of the blast wave phenomena is general. In subsequent sections of this chapter, the magnitude of the various parameters is presented depending upon the category of the detonation as previously described: free air burst, surface burst, exterior or leakage pressures, or interior or high pressure blast loading.

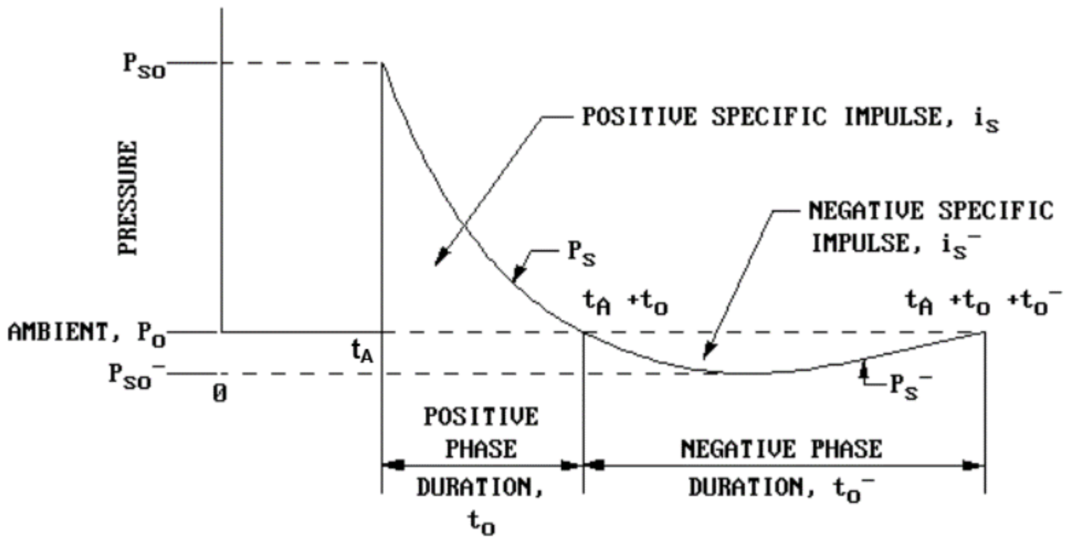


Figure 1: Free-Field Pressure-Time Variation for an Unconfined Explosion (UFC 3-340-02 Figure 2-2)

3.2 The TNT Reference Standard

UFC 3-340-02 (Reference 1) Figure 2-15 and Technical Report ARBRL-TR-02555 (Reference 2) Table 4 contain the data for airblast parameters from TNT hemispherical bursts on the surface at sea level, including shockwave arrival time t_A, incident peak pressure P_{so}, positive phase duration t_o, positive specific impulse i_s, et al., as a function of scaled observation distance. The scaled distance is a function of the distance D divided by the cubed root of the explosive weight W:

$$Z(D, W) = \frac{D}{W^{1/3}} \qquad (1)$$

The data was compiled from many different sources with Hopkinson and Sachs Scaling of all blast parameters to standard atmospheric sea level conditions (101.3 kPa, 15°C). The data for these airblast parameters have become known as the TNT reference standard; a subset of this data is shown in the following figure.

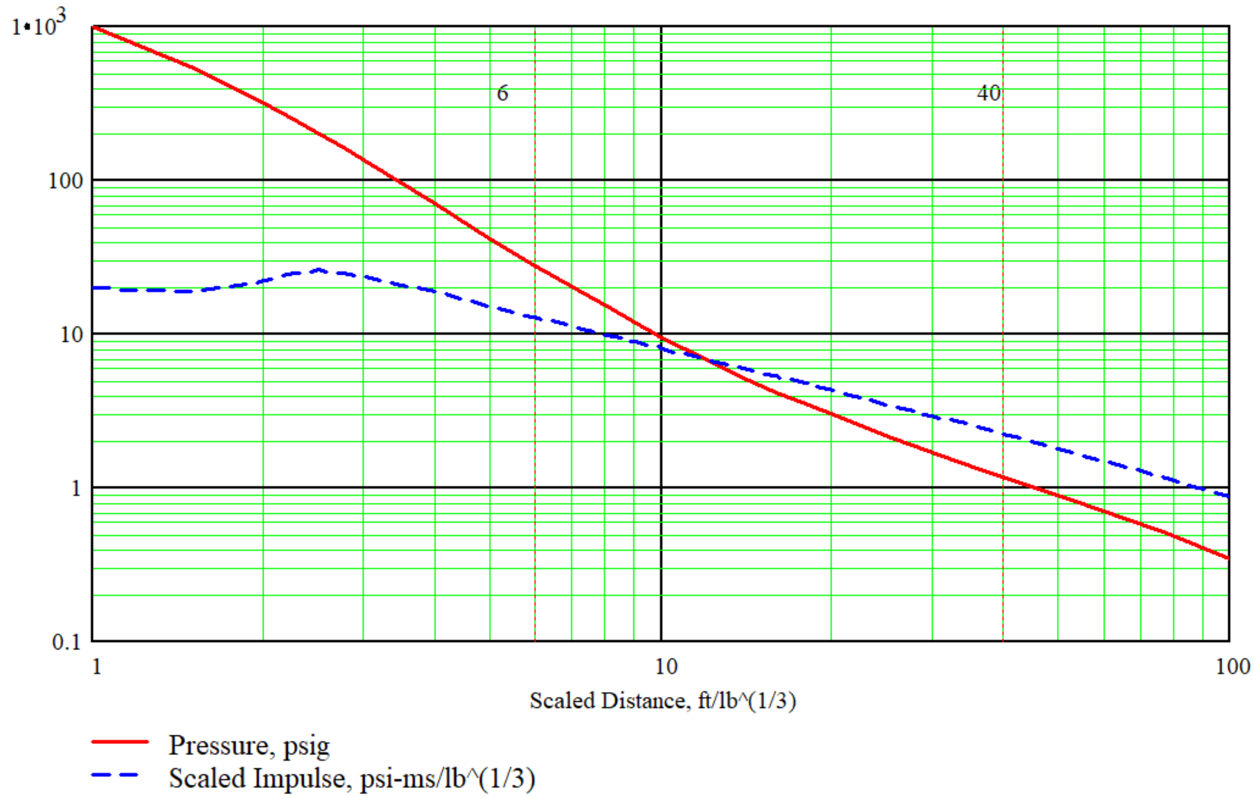


Figure 2: Subset of the UFC 3-340-02 Figure 2-15 TNT Reference Standard

The TNT reference standard is utilized in facility siting tables to determine limits of explosive quantity versus scaled distance (K-factors) for a potential explosion site (PES):

- K6 (27.7 psig): Aboveground Magazine (AGM) distance.
- K9 (11.7 psig): Barricaded Intraline distance (ILD).
- K11 (8.0 psig): Unbarricaded AGM.
- K18 (3.5 psig): Unbarricaded ILD.
- K24 (2.3 psig): Public Traffic Route distance (PTRD) for PES less than 100,000 pounds.
- K30 (1.7 psig): PTRD for >250,000 pounds.
- K40 (1.2 psig): Inhabited Building Distance (IBD) for PES less than 100,000 pounds.
- K50 (0.9 psig): IBD for PES greater than 250,000 pounds.

3.3 Explosive Equivalence

In accordance with TB 700-2 (Reference 3), the equivalent explosive weight, EEW, is the ratio of the weight of the TNT reference standard (hemisphere on the surface at sea level), W_{TNT}, that produces the same free-field overpressure or impulse at the same distance to that of the weight of the tested explosive, W:

$$EEW = \frac{W_{TNT}}{W} \tag{2}$$

The EEW, varies based on any given blast parameter, and also varies based on distance from the charge, geometry and configuration (i.e., the pressure-distance or impulse-distance curve of a particular explosive is not parallel to that of the TNT reference standard). For many purposes, it is sufficient to cite a single EEW -- the average of equivalent weights over a selected range. The EEW of an explosive more powerful than TNT is greater than 1.0 (100%); the EEW of one less powerful is less than 1.0 (100%).

3.4 Equivalency Testing

Airblast tests are performed, instrumented with blast overpressure transducers, to determine its equivalency to that of the TNT reference standard. The testing is conducted on a hard surface in a clear, flat area to prevent absorption or reflection of the blast energy where the shockwave can expand without interruption or interference. At least two lines of blast overpressure transducers are placed at scaled distances of interest (e.g., 3 to 40 ft/lb$^{1/3}$) to measure the free-field pressure-time variation.

For readily detonable materials, a standard detonator is sufficient for initiation; otherwise, the test explosive is initiated using a booster that contains up to ten percent of the test explosive's weight (the blast contribution of the booster is removed during the equivalency calculations). The test explosive is caused to detonate; the free-field pressure-time variation creates voltage changes at the powered blast overpressure transducers that are transmitted by coaxial cable to a data acquisition system and recorded (100,000 samples per second per channel typical).

3.5 Data Reduction

The recorded waveforms are analyzed, extracting peak pressures. The waveform's positive pressure phase is integrated over time (area under the curve) to determine the incident impulse of the shock wave at that observation distance. The blast parameters are scaled to sea level using the reciprocal of the Sachs scaling factors.

The logarithm of each scaled blast parameter is plotted against the logarithm of the scaled distance; data anomalies are identified and discarded. Then a smooth curve is fitted through the average measured values. NOTE: A published collection of the smoothed airblast parameter curves for different explosives, distances, geometries and configurations are contained in UFC 3-340-02 Figure 2-18 through Figure 2-49.

3.6 Equivalent Weight Determination

3.6.1 Pressure Equivalency

As peak overpressure P_{so} is a function of scaled distance (which is a function of distance D and charge weight W), the weight of the TNT reference explosive W_{TNT} required to produce the same overpressure as the weight of a test explosive W at a specific distance D_1 can be determined by equating the peak pressure of a test explosive $P_{so.test}$ with that of TNT reference standard $P_{so.TNT}$ and solving for W_{TNT}:

$$P_{so.test}(D_1, W) = P_{so.TNT}(D_1, W_{TNT}) \quad (3)$$

This calculation is graphically depicted in the following figure on a log-log scale with scaled distances taken where the selected pressure P_1 (horizontal line) intersects the test explosive and TNT reference standard curves:

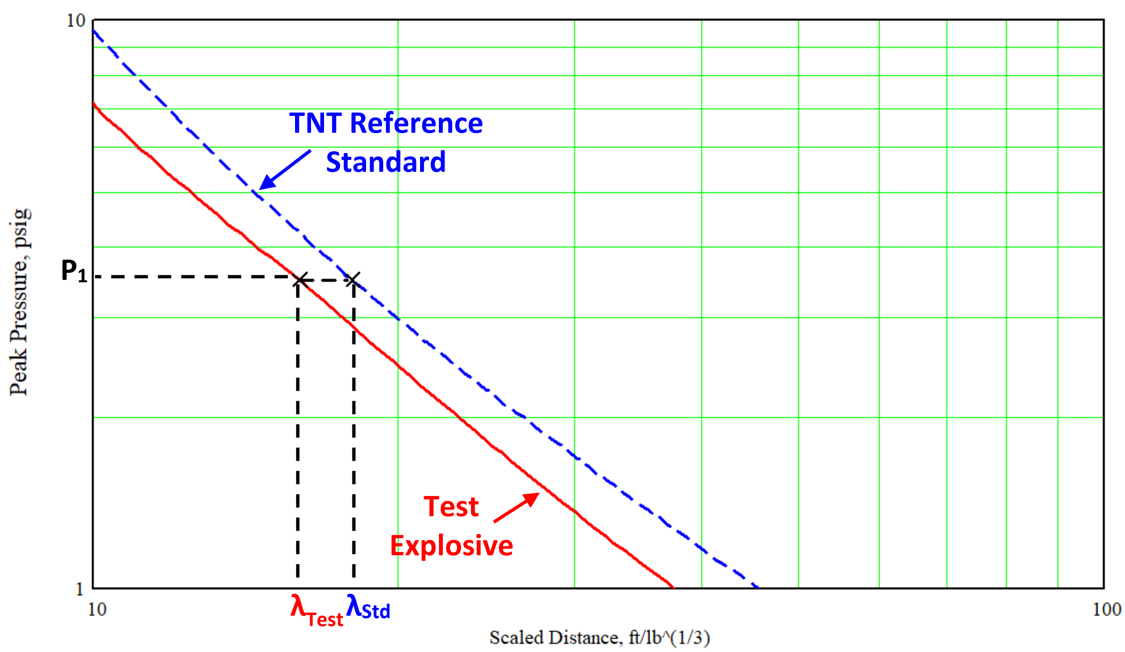


Figure 3: Equivalent Weight Determination — Pressure

3.6.2 Impulse Equivalency

Scaled specific impulse is defined as:

$$i_{s.scaled} = \frac{i_s}{W^{1/3}} \quad (4)$$

As scaled specific impulse $i_{s.scaled}$ is a function of scaled distance (which is a function of distance D and charge weight W), the weight of the TNT reference explosive W_{TNT} required to produce the same impulse as the weight of a test explosive W at a specific distance D_1 can be determined by equating the impulse of the test explosive $i_{s.test}$ with that of TNT reference standard $i_{s.TNT}$:

$$i_{s.test}(D_1, W) = i_{s.TNT}(D_1, W_{TNT}) \quad (5)$$

Substituting equation 4 results in the following equation that can be iteratively solved for W_{TNT}:

$$i_{s.scaled.test}(D_1, W) \cdot W^{⅓} = i_{s.scaled.TNT}(D_1, W_{TNT}) \cdot {W_{TNT}}^{⅓} \quad (6)$$

This calculation is graphically depicted in the following figure on a log-log scale where the scaled distance of the test explosive is taken where the specific impulse of interest $i_{s.1}$ divided by the cubed root of the mass $W^{⅓}$ (a horizontal line) intersects with that of the test explosive curve; the scaled distance of the TNT reference standard is taken by following a line of slope 1.0 that passes through that intersection point until it intersects with the TNT reference standard curve:

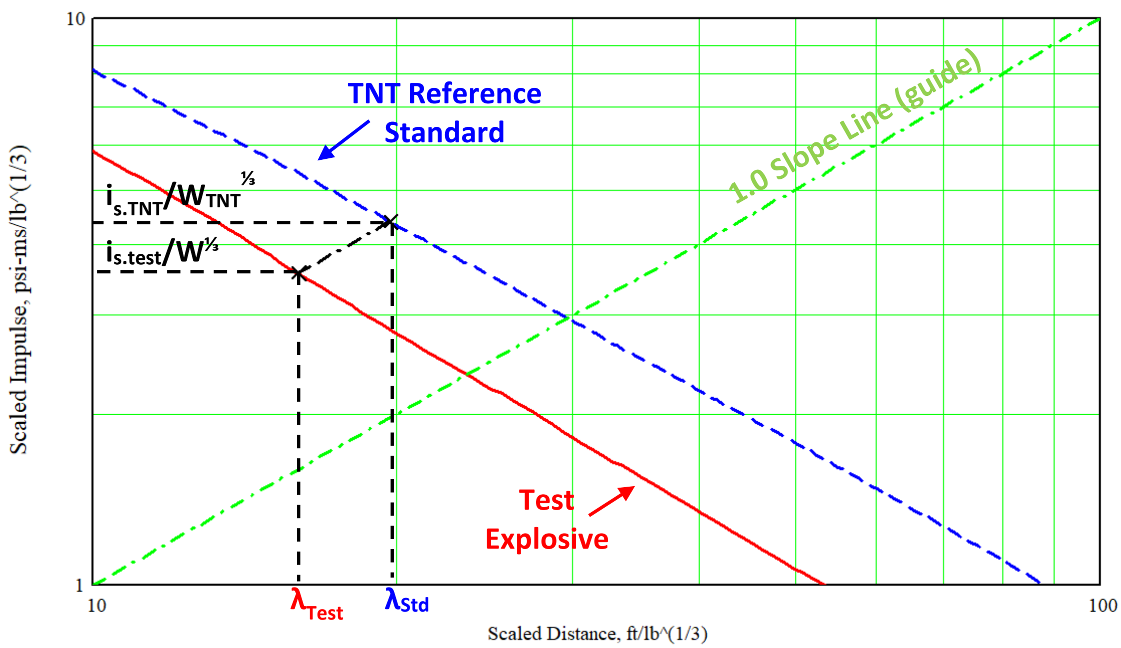


Figure 4: Equivalent Weight Determination — Impulse

The EEW can be calculated from the cubed ratio of the test explosive's scaled distance λ_{Test} to that of the TNT reference standard's scaled distance λ_{Std} for a given peak pressure or specific impulse:

$$EEW = \left(\frac{\lambda_{Test}}{\lambda_{Std}}\right)^3 = \left(\frac{\frac{D_1}{W^{⅓}}}{\frac{D_1}{{W_{TNT}}^{⅓}}}\right)^3 = \frac{W_{TNT}}{W} \quad (7)$$

Similarly, since the specific impulse of the test explosive $i_{s.test}$ is equal to that of the TNT reference standard $i_{s.TNT}$, the EEW can be calculated from the cubed ratio of the test explosive's scaled specific impulse $i_{s.scaled.Test}$ to that of the TNT reference standard $i_{s.scaled.Std}$:

$$EEW = \left(\frac{i_{s.scaled.Test}}{i_{s.scaled.Std}}\right)^3 = \left(\frac{\frac{i_{s.test}}{W^{1/3}}}{\frac{i_{s.TNT}}{W_{TNT}{}^{1/3}}}\right)^3 = \frac{W_{TNT}}{W} \tag{8}$$

The EEW for peak pressure and specific impulse are calculated as a function of scaled distance over the scaled distances of interest and reported in both graphical and tabular form. The average and maximum EEW for peak overpressure and positive impulse are also reported. The scaled distance of interest for TB 700-2 is 10 - 0.5 psig (K9.77 - K77.3); for facility siting and quantity-distance, it is normally 27.7 - 1.18 psig (K6 - K40).
i.e., between K6 (27.7 psig) and K40 (1.18 psig).

3.6.3 Accounting for the Booster's Contribution

The test charge is comprised of mixed weights: the weight of the test sample W_s and the booster weight W_b:

$$W_{mixed} = W_s + W_b \tag{9}$$

This mixed weight can be expressed as a uniform sample weight:

$$W_{uniform} = W_s + W_{s.b} \tag{10}$$

The booster weight is converted to TNT equivalent weight $W_{TNT.b}$ using its average explosive equivalency EEW_b for peak pressure and specific impulse:

$$W_{TNT.b} = W_b(EEW_b) \tag{11}$$

The booster's TNT weight $W_{TNT.b}$ is converted to sample weight using the test sample's average equivalency EEW_s for peak pressure and specific impulse:

$$W_{s.b} = \frac{W_{TNT.b}}{EEW_s} \tag{12}$$

Simplifying:

$$W_{uniform} = W_s + \frac{W_b(EEW_b)}{EEW_s} \tag{13}$$

The booster's average explosive equivalency EEW_b for peak pressure and specific impulse are determined through assessing data from trials with the booster alone and comparing the measured values to the TNT reference standard. However, the test sample's average explosive equivalency EEW_s for peak pressure and specific impulse has not yet been determined. Therefore, the calculations are conducted iteratively, making initial guesses for the test sample's average explosive equivalency EEW_s for peak pressure and specific impulse, performing the calculations to determine the test sample's average explosive equivalency EEW_s for both pressure and impulse, using those determinations as the new EEW_s guess values, and proceeding iteratively until the guess and determined EEW_s values converge. In this manner, the contribution of the booster is removed from the explosive equivalency determination.

4.0 SAMPLE DESCRIPTION

4.1 Fine Al-MnO_2 Thermite – Large-Scale Mix ID #7 (SMS mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 29.27% aluminum (Al) and 70.73% manganese(IV) oxide (MnO_2). The aluminum was 3N purity (99.9% pure), 1 - 5 micrometers (microns) in size, and offered for transport as a Division 4.1 flammable solid. The manganese(IV) oxide was 2N purity (99% pure), 5 microns in size, and offered for transport as non-regulated. This thermite was a very fine, dark gray powder when fully mixed.

Photo 1: Fine Al-MnO_2 Thermite – Large-Scale Mix ID #7 (SMS mixed)

4.2 Fine Mg&Al-MoO_3-CuO Thermite – Large-Scale Mix ID #8 (SMS mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 25% magnalium (magnesium-aluminum), 34% molybdenum trioxide (MoO_3), and 41% copper(II)/cupric oxide (CuO). The magnalium was 2N purity (99% pure), 44 micrometers (microns) in size, and offered for transport as a Division 4.3 dangerous when wet substance with a subsidiary hazard of Division 4.2 spontaneously combustible. The molybdenum trioxide was 2N purity (99% pure), 44 microns in size, and offered for transport as a Division 6.1 toxic substance. The cupric oxide was 3N purity (99.9% pure), 1 - 5 microns in size, and offered for transport as Class 9. This thermite was a very fine, gray powder when fully mixed.

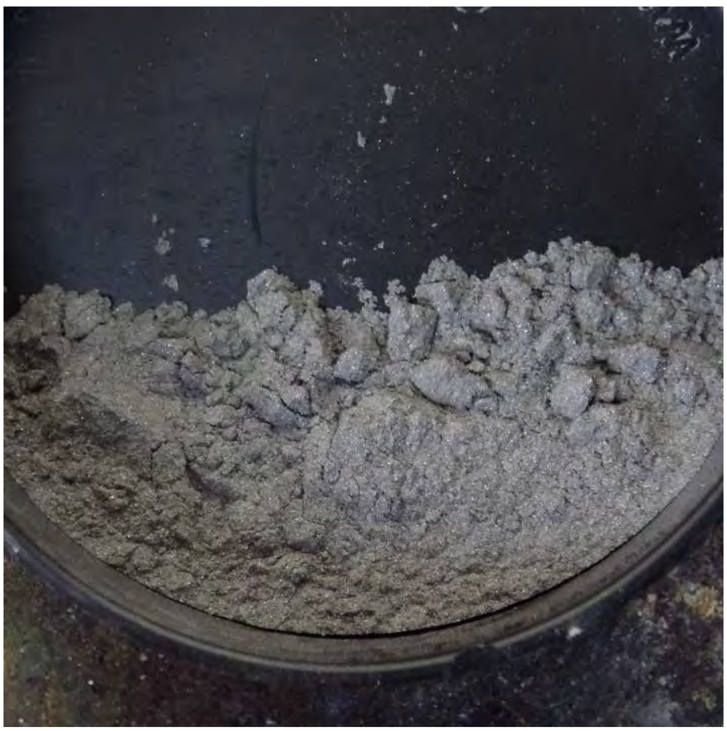


Photo 2: Fine Mg&Al-MoO_3-CuO Thermite – Large-Scale Mix ID #8 (SMS mixed)

4.3 Fine Mg-MnO_2 Thermite – Small-Scale Mix ID #4 (SMS mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 35.86% magnesium (Mg) and 64.14% manganese(IV) oxide (MnO_2). The manganese(IV) oxide was 2N purity (99% pure), 5 microns in size, and offered for transport as non-regulated. This thermite was a very fine, gray powder when fully mixed.

Photo 3: Fine Mg-MnO_2 Thermite – Small-Scale Mix ID #4 (SMS mixed)

4.4 Fine Al-SnO_2 Thermite – Small-Scale Mix ID #19 (SMS mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 19.27% aluminum (Al) and 80.73% tin(IV) oxide (SnO_2). The aluminum was 3N purity (99.9% pure), 1 - 5 micrometers (microns) in size, and offered for transport as a Division 4.1 flammable solid. This thermite was a very fine, off-white powder when fully mixed.

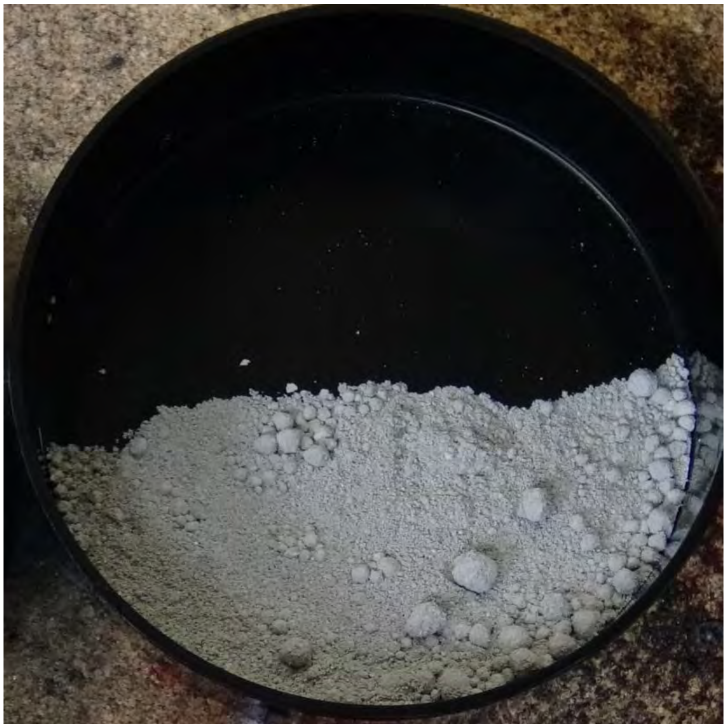


Photo 4: Fine Al-SnO_2 Thermite – Small-Scale Mix ID #19 (SMS mixed)

4.5 Fine Al-Bi_2O_3 Thermite – Small-Scale Mix ID #24 (SMS mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 10.38% aluminum (Al) and 89.62% bismuth oxide (Bi_2O_3). The aluminum was 3N purity (99.9% pure), 1 - 5 micrometers (microns) in size, and offered for transport as a Division 4.1 flammable solid. This thermite was a very fine, off-white powder when fully mixed.

Photo 5: Fine Al-Bi_2O_3 Thermite – Small-Scale Mix ID #24 (SMS mixed)

4.6 Fine Al-Fe_3O_4 – Small-Scale Mix ID #27 (SMS Mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 23.71% aluminum (Al) and 76.29% iron tetroxide (Fe_3O_4). The aluminum was 3N purity (99.9% pure), 1 - 5 micrometers (microns) in size, and offered for transport as a Division 4.1 flammable solid. The iron tetroxide was 3N purity (99.9% pure) and 1-5 micrometers (microns) in size. This thermite was a fine, dark gray powder when fully mixed.

Photo 6: Fine Al-Fe_3O_4 – Small-Scale Mix ID #27

4.7 Fine Al-NiO – Small-Scale Mix ID #30 (SMS Mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 19.41% aluminum (Al) and 80.59% nickel oxide (NiO). The aluminum was 3N purity (99.9% pure), 1 - 5 micrometers (microns) in size, and offered for transport as a Division 4.1 flammable solid. The nickel oxide was 1N purity (99% pure) and 1 - 5 micrometers (microns) in size. This thermite was a fine light green powder when fully mixed.

Photo 7: Fine Al-NiO – Small-Scale Mix ID #30

4.8 Fine Ti-Bi_2O_3 – Small-Scale Mix ID #48 (SMS Mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 13.35% titanium (Ti) and 86.65% bismuth trioxide (Bi_2O_3). The titanium was 2N purity (99.9% pure), less than 20 micrometers in size, and offered for transport as a Division 4.1 flammable solid. The bismuth trioxide was 3N purity (99.9% pure) and 1- 5 micrometers (micron) in size. This thermite was a fine, light-yellow powder when fully mixed.

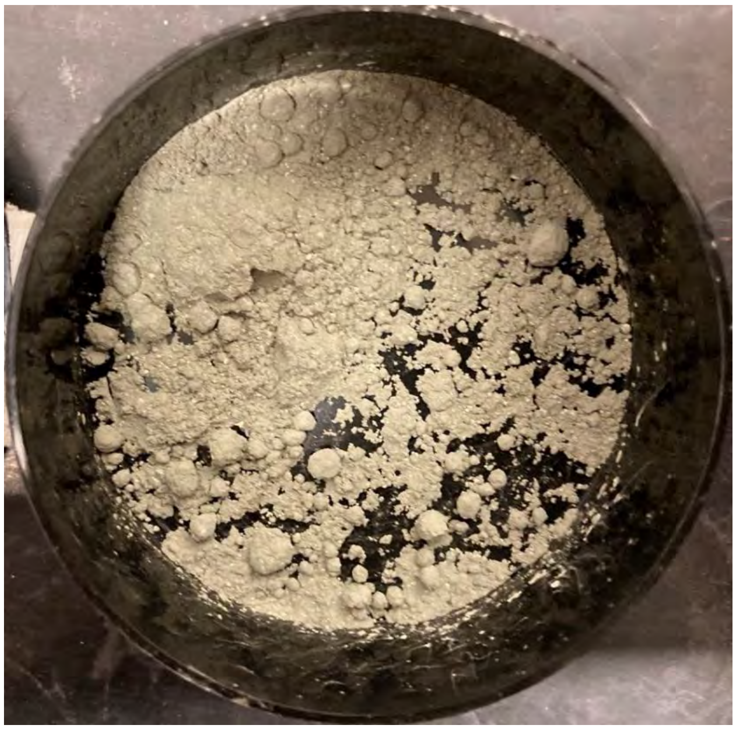


Photo 8: Fine Ti- Bi_2O_3 – Small-Scale Mix ID #48

4.9 Composition A-5 booster pellet

All explosive charges were initiated using an electric detonator (containing 0.45 grams of pentaerythritol tetranitrate (PETN) and 0.075 grams of dextrinated lead azide) and a 21.25-gram, 1.0-inch diameter, 1.0-inch tall cylindrical Composition A-5 booster pellet (1.78 g/cm^3), which is comprised of approximately 98.5% cyclotrimethylenetrinitramine (RDX) and 1.5% stearic acid.

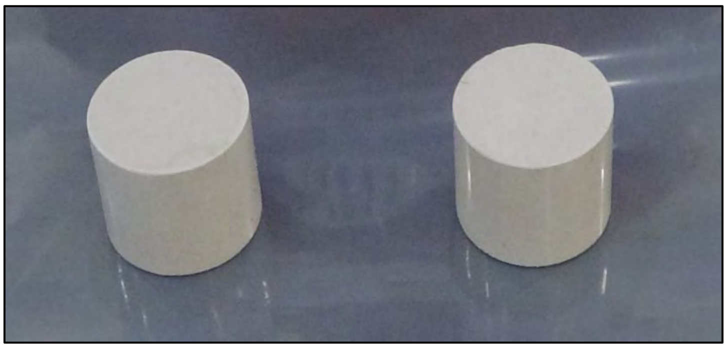


Photo 9: Composition A-5 Booster Pellet

4.10 Hemispherical Cast TNT

Each hemispherical cast charge of trinitrotoluene (TNT) weighed 19.0 pounds with a diameter of 11.1 inches and was supplied by Accurate Energetic Systems, LLC of McEwen, Tennessee as P/N FB-10073, “20 LB TNT CAST HEMISPHERE”. The charges are shown in the following photo.

Photo 10: Hemispherical Cast TNT

5.0 TEST DESCRIPTION

5.1 Test Site

Tests were performed at SMS's test site in Tooele, Utah. Incident (side-on) blast overpressure was measured using two lines of piezoelectric pencil probes pointed towards the blast and positioned 90 degrees apart. A schematic plan view of the test site is shown in the following figure. Radiating from ground zero were two 40-foot-wide by 100-foot-long level land areas cleared of brush.

A series of seven pressure transducer stations were located at discrete intervals in the cleared areas of the test site along two lines: A (north) and B (west). Each station was equipped with two sensors to provide full redundancy at each distance. The first two stations along lines A and B were flush-mounted in stainless steel blast probes that were flush-mounted with the ground surface and facing upward to minimize their exposure to the intense thermite reaction; the remaining probes were staggered and mounted 6 inches above the ground with the sensor facing sideways. Each probe was pointing towards ground zero; each transducer was coated with one layer of vinyl electrical tape for thermal insulation and water resistance. The distance to each transducer did not vary between trials and was between the scaled distances of 3 to 40 ft/lb$^{1/3}$ for the maximum weight of the test sample without booster (distances of 8 to 110 feet for a 20-lb charge).

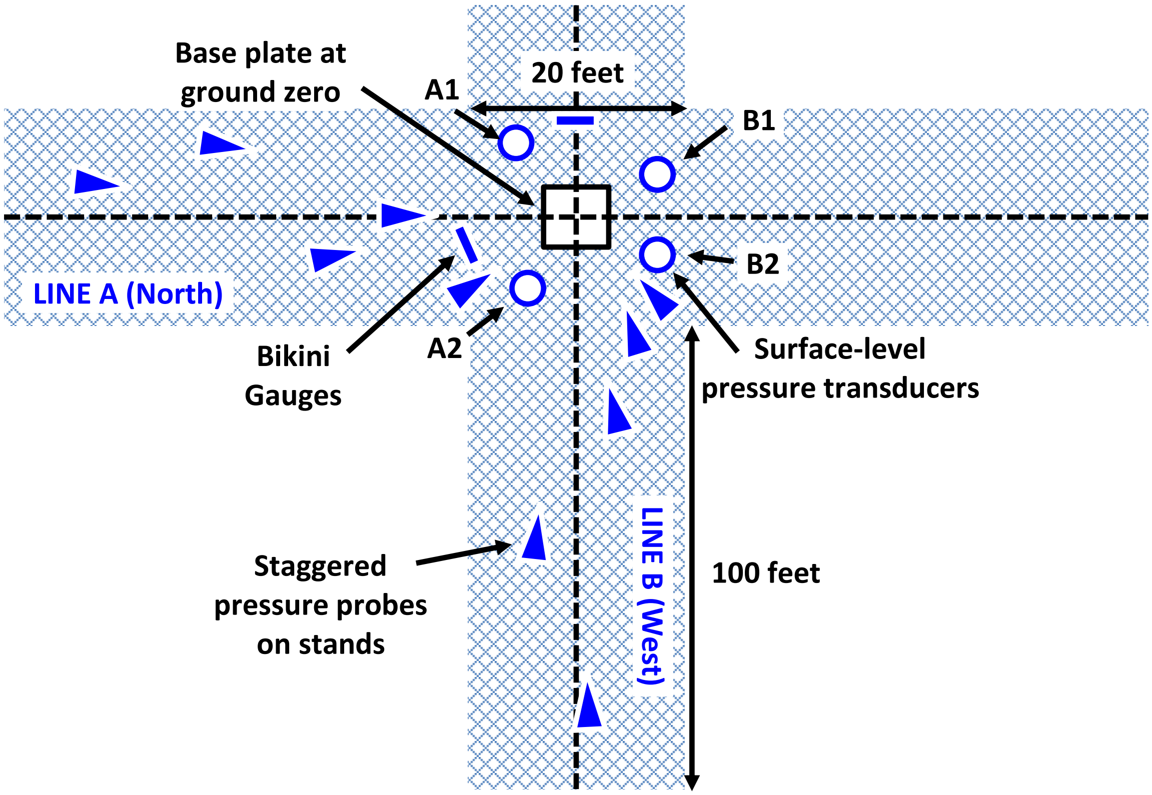


Figure 5: Plan View of Explosive Equivalency Tests

5.2 Test Area Preparation

Prior to test setup, ground zero and the surrounding land used for instrumentation were cleared of brush and flattened to minimize blast wave reflections. A 2-foot by 2-foot by 4-inch thick steel witness plate was buried such that the surface of the plate was level with the ground. A 0.5-inch-thick insulation plate was placed on top of the witness plate to prevent molten metal slag from hardening onto the surface of the witness plate.

5.3 Instrumentation

Two lines of seven sensor stations were deployed at discrete distances corresponding to scaled distances of interest. Each sensor station was equipped with two sensors to provide full measurement redundancy. Sensor stations were identified by the line they were in (A or B) and the distance they were placed, with 1 being closest and 7 being the furthest. Sensors within each station were identified as left or right, based on their location when looking towards ground zero. The distances of each sensor station and the sensor serial numbers used are given in Table 2. Details for each sensor is given in Table 3. The specifications for each of the sensors are listed in the table below. All sensors and equipment were within calibration at the time of test. Data was collected at a rate of 200,000 Hz.

Table 2: Sensor Station Details

Group	Station	Distance	Sensor S/N	
			Left	Right
A	1	8 ft 1.7 in	1935	1930
	2	8 ft 1.7 in	1908	1950
	3	10 ft 10.3 in	1940	1936
	4	14 ft 7.9 in	1938	1937
	5	24 ft 5.2 in	14442	14443
	6	48 ft 10.3 in	13381	13380
	7	108 ft 6.9 in	14360	13268
B	1	8 ft 1.7 in	1934	9814
	2	8 ft 1.7 in	1921	1944
	3	10 ft 10.3 in	1952	1949
	4	14 ft 7.9 in	1945	1933
	5	24 ft 5.2 in	1911	9880
	6	48 ft 10.3 in	133747	1913
	7	108 ft 6.9 in	9882	9883

Table 3: Sensor Details

Serial	Sensor Type	Sensitivity	Calibration
(S/N)	Pressure, incident	(psi/mV)	
1908	PCB 137A22 ICP Pressure Sensor	0.1153	28 FEB 2022
1911	PCB 137A22 ICP Pressure Sensor	0.0105	28 FEB 2022
1913	PCB 137A22 ICP Pressure Sensor	0.0089	28 FEB 2022
1921	PCB 137A22 ICP Pressure Sensor	0.1035	28 FEB 2022
1930	PCB 137A22 ICP Pressure Sensor	0.1036	28 FEB 2022
1933	PCB 137A22 ICP Pressure Sensor	0.1073	28 FEB 2022
1934	PCB 137A22 ICP Pressure Sensor	0.1065	28 FEB 2022
1935	PCB 137A22 ICP Pressure Sensor	0.1093	28 FEB 2022
1936	PCB 137A22 ICP Pressure Sensor	0.1127	28 FEB 2022
1937	PCB 137A22 ICP Pressure Sensor	0.0944	28 FEB 2022
1938	PCB 137A22 ICP Pressure Sensor	0.1048	17 AUG 2021
1944	PCB 137A22 ICP Pressure Sensor	0.1025	28 FEB 2022
1945	PCB 137A22 ICP Pressure Sensor	0.0942	28 FEB 2022
1947	PCB 137A22 ICP Pressure Sensor	0.0916	28 FEB 2022
1950	PCB 137A22 ICP Pressure Sensor	0.1063	28 FEB 2022

Serial	Sensor Type	Sensitivity	Calibration
9814	PCB 137A22 ICP Pressure Sensor	0.1086	28 FEB 2022
1913	PCB 137A23 ICP Pressure Sensor	0.0089	10 FEB 2022
9880	PCB 137A23 ICP Pressure Sensor	0.0105	12 FEB 2022
9882	PCB 137A23 ICP Pressure Sensor	0.0106	12 FEB 2022
9883	PCB 137A23 ICP Pressure Sensor	0.0108	12 FEB 2022
13268	PCB 137B23B ICP Pressure Sensor	0.0105	22 FEB 2022
13374	PCB 137B23B ICP Pressure Sensor	0.0100	22 FEB 2022
13380	PCB 137B23B ICP Pressure Sensor	0.0096	22 FEB 2022
13381	PCB 137B23B ICP Pressure Sensor	0.0099	22 FEB 2022
14360	PCB 137B23B ICP Pressure Sensor	0.0100	22 FEB 2022
14361	PCB 137B23B ICP Pressure Sensor	0.0099	22 FEB 2022
14442	PCB 137B23B ICP Pressure Sensor	0.0101	22 FEB 2022
14443	PCB 137B23B ICP Pressure Sensor	0.0101	22 FEB 2022

Table 4: Data Acquisition Equipment Details

S/N	Description	Channels	Calibration
DB19001831	Dewesoft SIRIUSif-HD-16xACC	16	11 FEB 2022
DB21023080	Dewesoft SIRIUSif-HD-16xACC	16	24 MAR 2022

Further instrumentation variables are provided within each individual test results section; analog-to-digital (ADC) conversion of each range specified in the instrumentation configuration tables was 24 bit for blast pressure. ICP sensors were provided with a constant excitation current of 4 milliamps.

Note: Blast waves decrease in magnitude, decrease in velocity and increase in duration the further they are from the source. Recorded blast waveforms appear different from traditional blast waveforms when there are reflections or electrical interference/noise (faults in sensors, electrical components, electrical connections, external changes in electromagnetic environment, etc.). The following phenomena in blast waveforms are inconsistent with the behavior of waves and are considered suspect (erroneous; excluded from peak value reporting):

- *Phenomena in blast waveforms that are not seen traveling from one sensor to the next within the same line of sensors.*
- *Peaks that are observed instantaneously across multiple channels.*
- *Rapid, sudden changes from one value to another.*

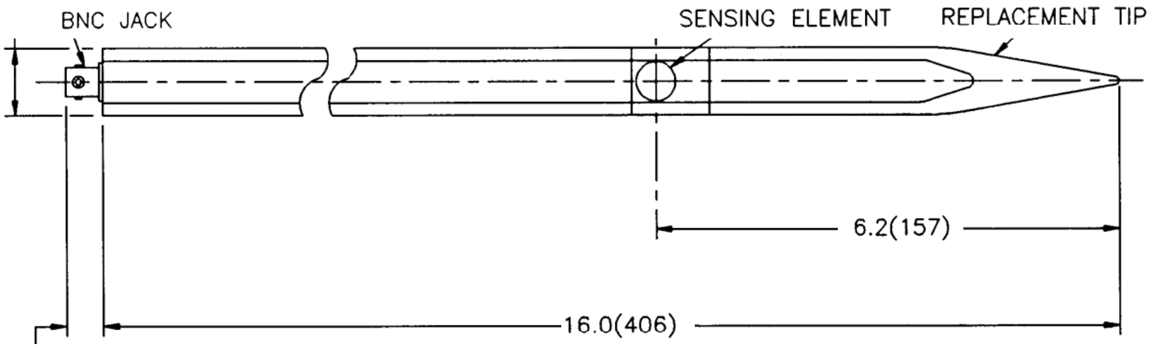


Figure 6: Blast Probe with Incident (Side-on) Pressure Transducer (typical)

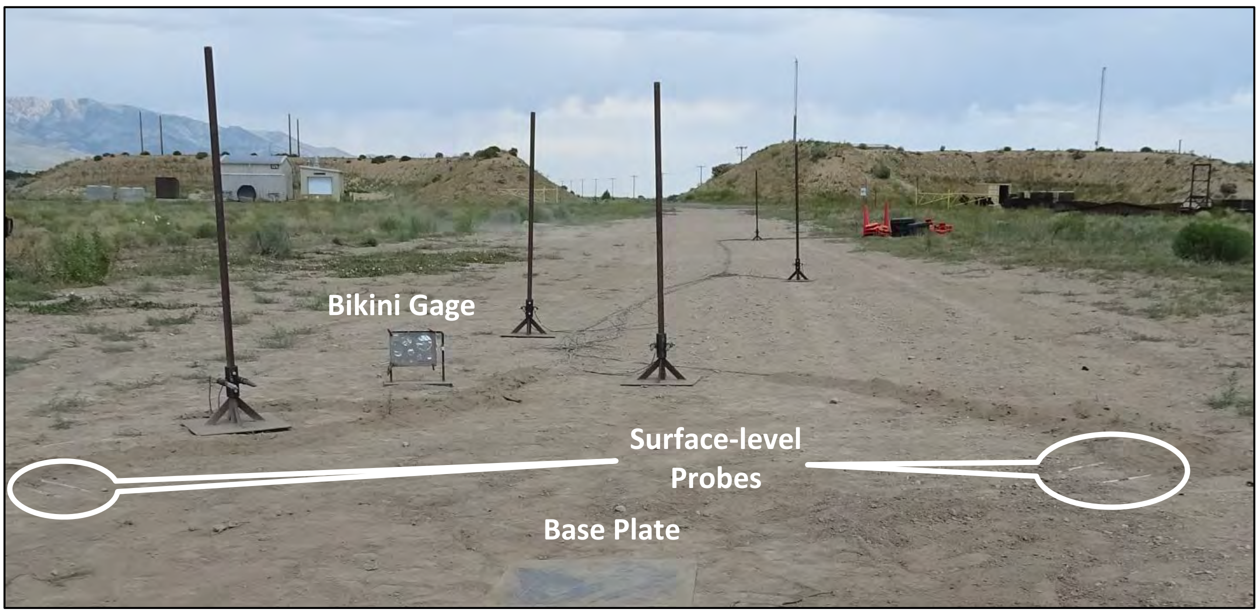


Photo 11: Instrumentation Line A

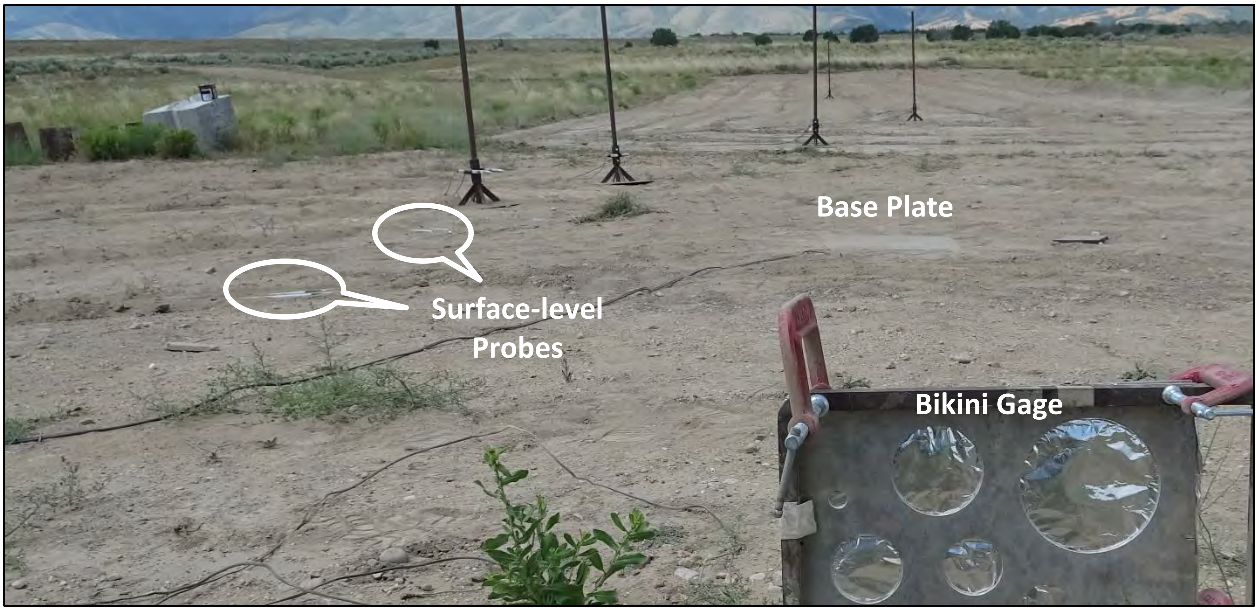


Photo 12: Instrumentation Line B

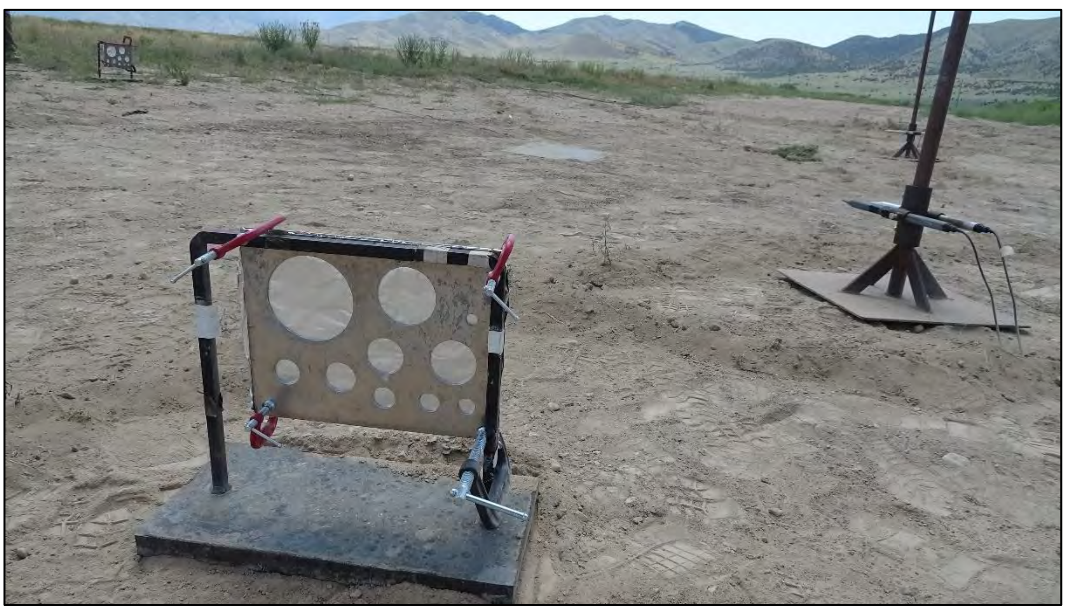


Photo 13: Ground Zero with Instrumentation Lines A and B

Blast overpressure was also measured using two Bikini gages facing the blast and positioned 90 degrees apart at Station 6 (48.9 feet from the center of the test arrangement) for TNT Trials 2 and 3 and Station 3 (10.9 feet) for all other trials. Standard hole diameters for Bikini gages, as shown in Figure 7, are 10 in (0.95 psi), 4-1/2 in (1.9 psi), 2-3/4 in (2.8 psi), 2 in (3.7 psi), 1-1/2 in (4.6 psi), 15/16 in (6.9 psi), 43/64 in (9.1 psi), 19/64 in (18 psi) and 11/64 in (28 psi) for holes covered with Reynolds aluminum foil that is 1-mil (0.001-inch) thick. Figure 8 is a plot of the gage hole size plotted against the rupture pressure; a power regression line provides a good linear fit through the data on a log-log plot.

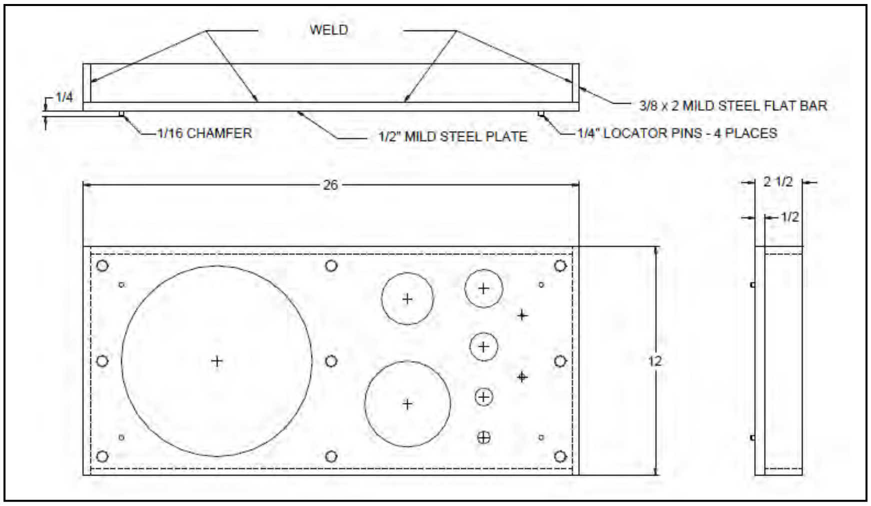
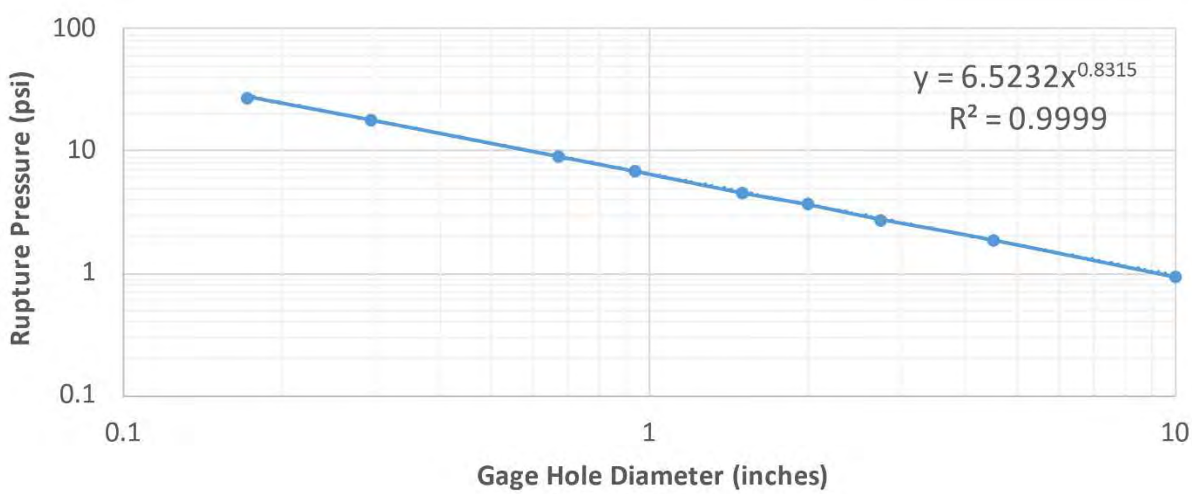


Figure 7: Standard Bikini Gages

Figure 8: Conversion of Bikini Gage Hole to Rupture Pressure



SMS's Bikini gages utilized Reynolds aluminum foil that was 1-mil (0.001-inch) thick with hole diameters different from that of the standard; utilizing the Figure 8 hole-to-pressure conversion, the gage hole diameters and corresponding rupture pressures were 3-3/4 inches (2.2 psi), 2-1/2 inches (3.0 psi), 2 inches (3.7 psi), 1-5/8 inches (4.4 psi), 1-3/8 inches (5.0 psi), 1-3/16 inches (5.7 psi), 1 inch (6.5 psi), 7/8 inch (7.3 psi), 3/4 inch (8.3 psi) and 1/2 inch (12 psi).

5.4 DAQ Channel and Sensor Function Tests

An electronic calibration pulse of similar frequency (for dynamic sensors) and amplitude to that anticipated during the test was provided to each data acquisition channel, confirming proper function and setup of all lines and channels. For each dynamic pressure channel, a PCB Model 492B ICP sensor simulator provided a 100 Hz sine wave with a magnitude of 10.0 volts peak-to-peak. Sensors were reconnected after providing the calibration signal and manually functioned, confirming proper function of all sensors and their location.

5.5 Thermite Test Configuration

For each thermite trial, a 20-pound thermite sample was placed inside a conductive plastic bag. The bag was placed on top of the insulation plate on a steel base plate and formed into a hemisphere. A small thermite igniter, comprised of an electric match and 10 grams of thermite starter mix, was placed in the thermite hemisphere. The depth of the igniter was dictated by the trial number. The igniter was placed approximately 0.25 inches into the top of the hemisphere for Trial 1 of each thermite. The igniter was placed at the center of the hemisphere for Trial 2 of each thermite. The igniter was centrally located at the bottom of the hemisphere for Trial 3 of each thermite. A diagram of the charge setup is given in Figure 9.

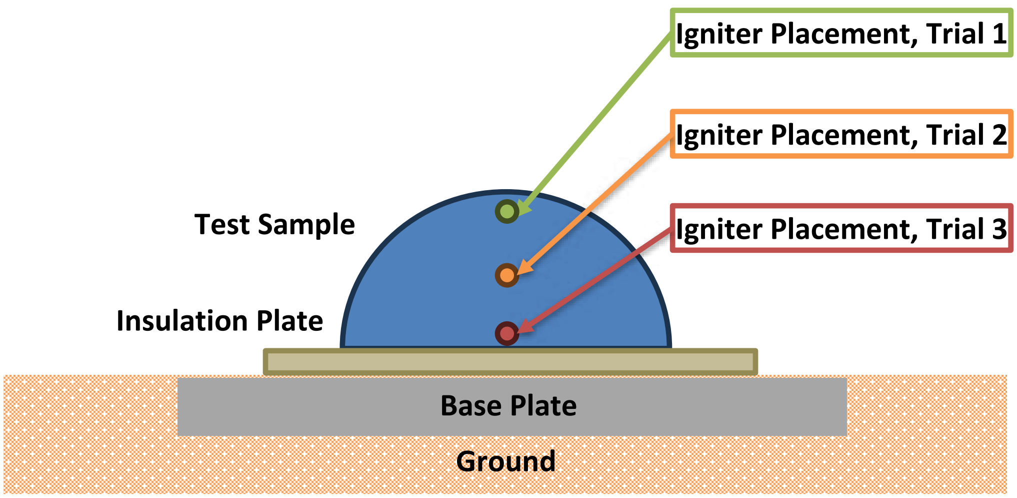


Figure 9: Test Setup for Thermite Surface Detonation Tests

5.6 TNT Test Configuration

For each TNT trial, the charge was placed on the base plate. A 1-inch by 1-inch Composition A-5 pellet was secured to the top of the hemisphere. A No. 8 strength detonator was then placed on top of the pellet. Setup for the TNT charges is shown in Figure 10.

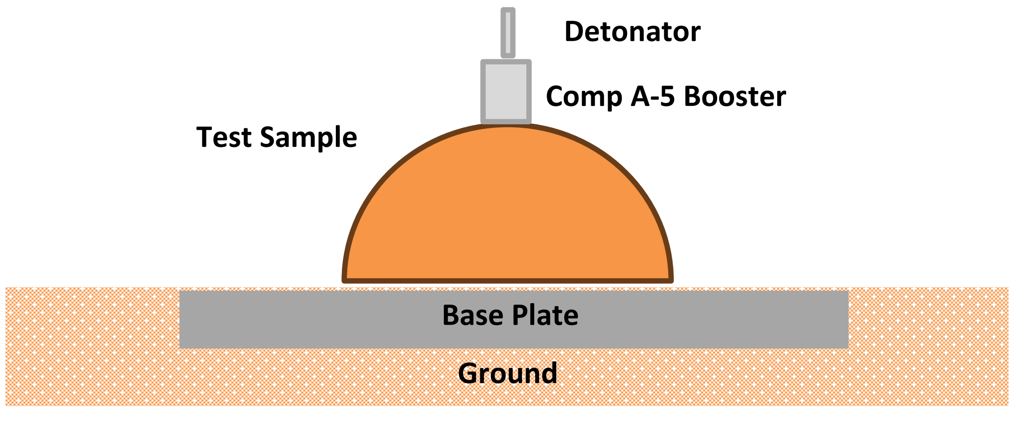


Figure 10: Test Setup for TNT Surface Detonation Tests

6.0 TEST RESULTS

6.1 General

The following sections are for each of the explosive samples. Each section contains:

- Table of test conditions listing trial number, atmospheric conditions, sample configuration, net explosive weight (N.E.W.), mass of explosive train and percentage of the test sample.
- Photos of the test setup.
- Data summary table for each trial listing the sensor position, peak pressure and positive impulse as measured at SMS's test site in Tooele, Utah (see individual waveforms in the Appendix), along with a few data acquisition variables (sensor serial number, span, sampling rate).
- Figures showing the peak pressure and scaled impulse versus scaled distance at sea level with a smoothed polynomial fit through the average values. The scaled values are based upon the total charge weight, i.e., the weight of the initiation train in equivalent pounds of the sample's weight has been added to the weight of the sample (refer to Section 3.6.3 for further details).

6.2 Fine Al-MnO_2 Thermite – Large-Scale Mix ID #7 (SMS mixed)

The tables, photos and figures in this section summarize the trials performed on Large-Scale Mix ID #7. For each trial, the thermite powder was mounded in the center of a 4-inch-thick, 24-inch-square A572 Grade 50 steel base plate covered with a thin layer of sand (thermal barrier, easier cleanup of slag). Each trial resulted in an explosion of the thermite that produced a small positive-pressure pulse immediately preceding the characteristic deflagration curve; no holes were ruptured on either of the Bikini gages at Station 3.

Table 5: Test Conditions for Large-Scale Mix ID #7

Trial	Atmospheric Conditions		Configuration	Sample N.E.W. (kg)	Comments
	(K)	(inHg)			
1	301	29.77	Top ignition of mounded powder	9.07	Explosion
2	303	29.77	Middle ignition of mounded powder	9.07	Explosion
3	303	29.77	Bottom ignition of mounded powder	9.07	Explosion

Photo 14: Test Setup and Results for Trial 1 of Large-Scale Mix ID #7

Photo 15: Test Setup and Results for Trial 2 of Large-Scale Mix ID #7

Photo 16: Test Setup and Results for Trial 3 of Large-Scale Mix ID #7

Table 6: Raw & Filtered Data Summary for Trial 1 of Large-Scale Mix ID #7

Sensor Group	Sensor Station	Sensor Position	Sensor S/N	Distance (ft)	Peak Pressure (psig)		Positive Impulse (psi-ms)	Span (V)	Sampling Rate (Hz)
					Raw	Filter			
A	1	Right	1930	8.10	0.360	0.370	2.40	±10	200,000
B	1	Left	1934	8.18	0.510	0.300	2.33	±10	200,000
B	1	Right	9814	8.21	0.290	0.290	2.47	±10	200,000
A	3	Left	1940	10.86	0.347	0.332	3.19	±10	200,000
A	3	Right	1936	10.86	0.370	0.380	4.83	±10	200,000
B	3	Left	1952	10.86	0.320	0.310	4.05	±10	200,000
B	3	Right	1949	10.86	0.375	0.357	6.12	±10	200,000
A	4	Left	1938	14.66	0.390	0.390	3.71	±10	200,000
A	4	Right	1937	14.66	0.280	0.280	1.83	±10	200,000
B	4	Left	1945	14.63	0.270	0.280	3.02	±10	200,000
B	4	Right	1933	14.63	0.240	0.240	2.60	±10	200,000
A	5	Left	14442	24.45	0.148	0.188	1.07	±10	200,000
A	5	Right	14443	24.45	0.163	0.198	1.36	±10	200,000
B	5	Left	1911	24.45	0.245	0.156	3.10	±10	200,000
B	5	Right	9880	24.45	0.255	0.211	3.19	±10	200,000
A	6	Left	13381	48.86	0.117	0.118	0.87	±10	200,000
A	6	Right	13380	48.86	0.110	0.107	0.71	±10	200,000
B	6	Left	13374	48.85	0.106	0.104	0.89	±10	200,000
B	6	Right	1913	48.85	0.087	0.085	0.71	±10	200,000
A	7	Left	14360	118.96	0.032	0.039	0.17	±10	200,000
A	7	Right	13268	118.96	0.033	0.036	0.14	±10	200,000
B	7	Left	9882	108.58	0.048	0.031	0.38	±10	200,000
B	7	Right	9883	108.58	0.050	0.029	0.42	±10	200,000

Table 7: Data Summary for Trial 2 of Large-Scale Mix ID #7

Sensor Group	Sensor Station	Sensor Position	Sensor S/N	Distance (ft)	Peak Pressure (psig)		Positive Impulse (psi-ms)	Span (V)	Sampling Rate (Hz)
					Raw	Filter			
B	1	Left	1934	8.18	0.690	0.680	9.37	±10	200,000
B	1	Right	9814	8.21	0.740	0.750	10.1	±10	200,000
A	2	Left	1908	8.09	0.700	0.630	10.7	±10	200,000
A	2	Right	1950	8.10	0.570	0.640	5.30	±10	200,000
B	2	Right	1944	8.13	0.460	0.470	8.14	±10	200,000
A	3	Left	1940	10.86	0.492	0.499	6.84	±10	200,000
A	3	Right	1936	10.86	0.470	0.470	5.80	±10	200,000
B	3	Left	1952	10.86	0.480	0.530	7.63	±10	200,000
B	3	Right	1949	10.86	0.463	0.471	5.10	±10	200,000
A	4	Left	1938	14.66	0.670	0.560	10.0	±10	200,000
A	4	Right	1937	14.66	0.550	0.560	7.90	±10	200,000
B	4	Left	1945	14.63	0.440	0.500	6.52	±10	200,000
B	4	Right	1933	14.63	0.480	0.350	8.68	±10	200,000
A	5	Left	14442	24.45	0.274	0.248	7.69	±10	200,000
A	5	Right	14443	24.45	0.275	0.251	1.96	±10	200,000
B	5	Left	1911	24.45	0.244	0.214	2.43	±10	200,000
B	5	Right	9880	24.45	0.251	0.229	2.99	±10	200,000
A	6	Left	13381	48.86	0.116	0.123	1.05	±10	200,000
A	6	Right	13380	48.86	0.132	0.133	1.48	±10	200,000
B	6	Left	13374	48.85	0.132	0.133	4.93	±10	200,000
B	6	Right	1913	48.85	0.110	0.130	2.27	±10	200,000
A	7	Left	14360	118.96	0.050	0.052	0.71	±10	200,000
A	7	Right	13268	118.96	0.052	0.053	0.42	±10	200,000
B	7	Left	9882	108.58	0.065	0.087	0.96	±10	200,000
B	7	Right	9883	108.58	0.059	0.081	0.62	±10	200,000

Table 8: Data Summary for Trial 3 of Large-Scale Mix ID #7

Sensor Group	Sensor Station	Sensor Position	Sensor S/N	Distance (ft)	Peak Pressure (psig)		Positive Impulse (psi-ms)	Span (V)	Sampling Rate (Hz)
					Raw	Filter			
A	1	Right	1930	8.10	1.19	0.910	8.46	±10	200,000
B	1	Left	1934	8.18	1.23	0.980	10.3	±10	200,000
B	1	Right	9814	8.21	1.25	1.080	11.7	±10	200,000
A	2	Right	1950	8.10	1.15	0.940	10.4	±10	200,000
A	3	Left	1940	10.86	0.708	0.690	7.55	±10	200,000
A	3	Right	1936	10.86	0.700	0.739	9.23	±10	200,000
B	3	Left	1952	10.86	0.750	0.790	8.80	±10	200,000
B	3	Right	1949	10.86	0.773	0.759	7.93	±10	200,000
A	4	Right	1937	14.66	0.400	0.480	6.68	±10	200,000
B	4	Left	1945	14.63	0.600	0.520	8.32	±10	200,000
B	4	Right	1933	14.63	0.600	0.500	9.21	±10	200,000
A	5	Left	14442	24.45	0.250	0.233	4.50	±10	200,000
A	5	Right	14443	24.45	0.260	0.242	3.51	±10	200,000
B	5	Left	1911	24.45	0.300	0.271	2.93	±10	200,000
B	5	Right	9880	24.45	0.400	0.291	2.49	±10	200,000
A	6	Left	13381	48.86	0.120	0.119	1.21	±10	200,000
A	6	Right	13380	48.86	0.150	0.117	1.24	±10	200,000
B	6	Left	13374	48.85	0.150	0.130	1.95	±10	200,000
B	6	Right	1913	48.85	0.130	0.117	3.49	±10	200,000
A	7	Left	14360	118.96	0.060	0.065	0.90	±10	200,000
A	7	Right	13268	118.96	0.067	0.090	1.01	±10	200,000
B	7	Left	9882	108.58	0.083	0.087	1.01	±10	200,000
B	7	Right	9883	108.58	0.090	0.090	1.10	±10	200,000

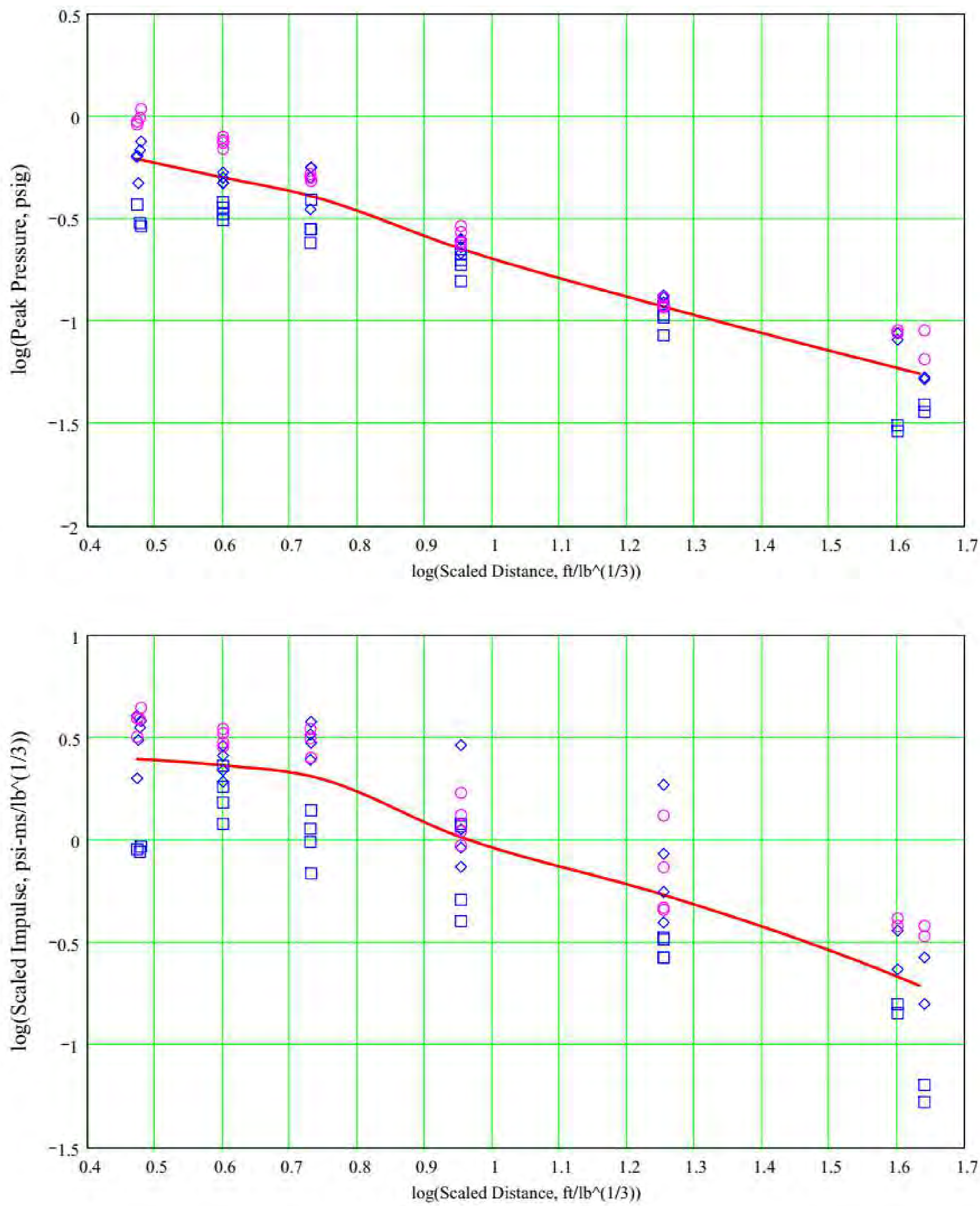


Figure 11: Filtered Peak Pressure (top) and Scaled Positive Impulse (bottom) versus Scaled Distance for Mounded Large-Scale Mix ID #7 on the Surface at Sea Level

6.3 Fine Mg&Al-MoO_3-CuO Thermite – Large-Scale Mix ID #8 (SMS mixed)

The tables, photos and figures in this section summarize the trials performed on Large-Scale Mix ID #8. For each trial, the thermite powder was mounded in the center of a 4-inch-thick, 24-inch-square A572 Grade 50 steel base plate covered with a thin layer of sand (thermal barrier, easier cleanup of slag). Each trial resulted in an explosion of the thermite that produced a small positive-pressure pulse immediately preceding the characteristic deflagration curve; no holes were ruptured on either of the Bikini gages at Station 3. For Trial 3, the wave transitioned at Station 5 from a positive-pressure pulse at Stations 1 - 4 to a shock wave at Stations 6 - 7, as shown in Figure 12.

Table 9: Test Conditions for Large-Scale Mix ID #8

Trial	Atmospheric Conditions		Configuration	Sample N.E.W. (kg)	Comments
	(K)	(inHg)			
1	305	29.74	Top ignition of mounded powder	9.07	Explosion
2	305	29.73	Middle ignition of mounded powder	9.07	Explosion
3	306	29.72	Bottom ignition of mounded powder	9.07	Explosion

Photo 17: Test Setup and Results for Trial 1 of Large-Scale Mix ID #8

Photo 18: Test Setup and Results for Trial 2 of Large-Scale Mix ID #8

Photo 19: Test Setup and Results for Trial 3 of Large-Scale Mix ID #8

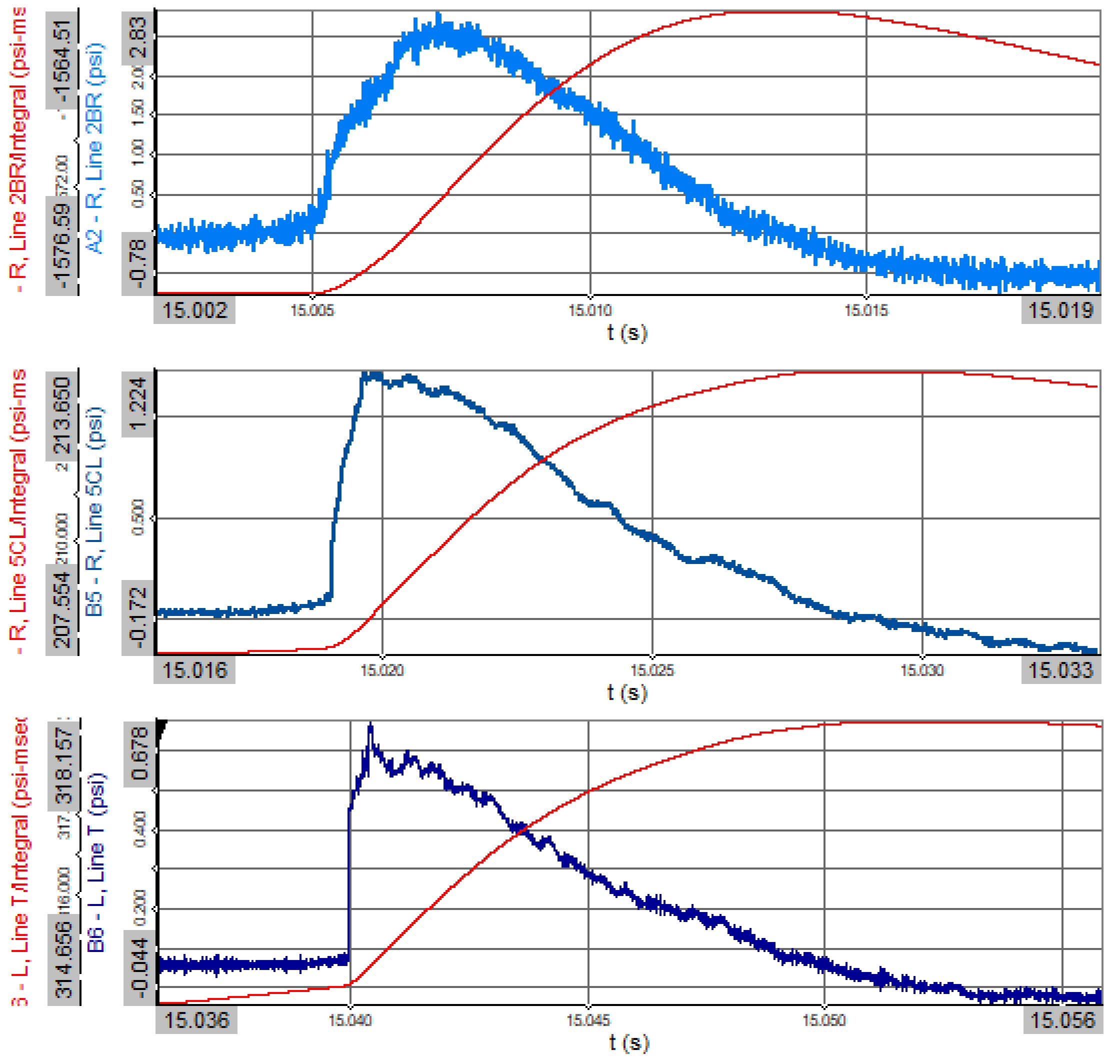


Figure 12: Positive Pressure Pulse at Stations 1 - 4 (top plot), Wave Transition at Station 5 (middle plot) and Shock Wave at Stations 6 - 7 (bottom plot)

Table 10: Data Summary for Trial 1 of Large-Scale Mix ID #8

Sensor Group	Sensor Station	Sensor Position	Sensor S/N	Distance (ft)	Peak Pressure (psig)		Positive Impulse (psi-ms)	Span (V)	Sampling Rate (Hz)
					Raw	Filter			
B	1	Left	1934	8.18	2.06	1.89	10.9	±10	200,000
B	1	Right	9814	8.21	2.33	2.16	12.7	±10	200,000
A	2	Right	1950	8.10	1.89	1.71	8.5	±10	200,000
A	3	Left	1940	10.86	1.56	1.55	10.6	±10	200,000
A	3	Right	1936	10.86	1.99	1.79	14.0	±10	200,000
B	3	Left	1952	10.86	1.98	1.74	11.3	±10	200,000
B	3	Right	1949	10.86	1.53	1.51	8.41	±10	200,000
A	4	Right	1937	14.66	1.57	1.42	11.4	±10	200,000
B	4	Left	1945	14.63	1.55	1.38	9.42	±10	200,000
B	4	Right	1933	14.63	1.45	1.21	8.15	±10	200,000
A	5	Left	14442	24.45	0.804	0.731	5.57	±10	200,000
A	5	Right	14443	24.45	0.844	0.746	5.81	±10	200,000
B	5	Left	1911	24.45	0.706	0.788	3.29	±10	200,000
B	5	Right	9880	24.45	0.817	0.727	4.28	±10	200,000
A	6	Left	13381	48.86	0.421	0.366	2.74	±10	200,000
A	6	Right	13380	48.86	0.380	0.316	1.96	±10	200,000
B	6	Left	13374	48.85	0.333	0.390	1.39	±10	200,000
B	6	Right	1913	48.85	0.237	0.363	0.76	±10	200,000
A	7	Left	14360	118.96	0.345	0.192	3.77	±10	200,000
A	7	Right	13268	118.96	0.247	0.195	1.68	±10	200,000
B	7	Left	9882	108.58	0.208	0.198	1.01	±10	200,000
B	7	Right	9883	108.58	0.236	0.202	1.41	±10	200,000

Table 11: Data Summary for Trial 2 of Large-Scale Mix ID #8

Sensor Group	Sensor Station	Sensor Position	Sensor S/N	Distance (ft)	Peak Pressure (psig)		Positive Impulse (psi-ms)	Span (V)	Sampling Rate (Hz)
					Raw	Filter			
B	1	Left	1934	8.18	2.07	1.69	12.2	±10	200,000
B	1	Right	9814	8.21	2.32	1.96	14.0	±10	200,000
A	2	Right	1950	8.10	1.72	1.80	7.5	±10	200,000
A	3	Left	1940	10.86	1.58	1.51	10.3	±10	200,000
A	3	Right	1936	10.86	1.89	1.58	10.6	±10	200,000
B	3	Left	1952	10.86	1.63	1.45	10.5	±10	200,000
B	3	Right	1949	10.86	1.31	1.41	7.94	±10	200,000
A	4	Right	1937	14.66	1.72	1.27	10.1	±10	200,000
B	4	Left	1945	14.63	1.53	1.17	9.61	±10	200,000
B	4	Right	1933	14.63	1.51	1.13	9.07	±10	200,000
A	5	Left	14442	24.45	0.964	0.802	5.98	±10	200,000
A	5	Right	14443	24.45	1.009	0.815	6.31	±10	200,000
B	5	Left	1911	24.45	0.775	0.752	4.74	±10	200,000
B	5	Right	9880	24.45	0.719	0.839	3.85	±10	200,000
A	6	Left	13381	48.86	0.474	0.388	3.59	±10	200,000
A	6	Right	13380	48.86	0.512	0.396	4.00	±10	200,000
B	6	Left	13374	48.85	0.426	0.380	2.90	±10	200,000
B	6	Right	1913	48.85	0.384	0.356	2.52	±10	200,000
A	7	Left	14360	118.96	0.273	0.186	2.31	±10	200,000
A	7	Right	13268	118.96	0.343	0.190	3.59	±10	200,000
B	7	Left	9882	108.58	0.153	0.189	0.66	±10	200,000
B	7	Right	9883	108.58	0.162	0.190	0.70	±10	200,000

Table 12: Data Summary for Trial 3 of Large-Scale Mix ID #8

Sensor Group	Sensor Station	Sensor Position	Sensor S/N	Distance (ft)	Peak Pressure (psig)		Positive Impulse (psi-ms)	Span (V)	Sampling Rate (Hz)
					Raw	Filter			
B	1	Left	1934	8.18	2.74	2.57	10.9	±10	200,000
B	1	Right	9814	8.21	3.06	2.85	12.2	±10	200,000
A	2	Right	1950	8.10	2.83	2.59	12.1	±10	200,000
A	3	Left	1940	10.86	2.41	2.23	11.4	±10	200,000
A	3	Right	1936	10.86	2.74	2.19	12.5	±10	200,000
B	3	Left	1952	10.86	2.30	2.05	9.62	±10	200,000
B	3	Right	1949	10.86	2.08	2.01	9.45	±10	200,000
A	4	Left	1938	14.66	2.46	2.07	10.9	±10	200,000
A	4	Right	1937	14.66	2.18	1.74	9.95	±10	200,000
B	4	Left	1945	14.63	2.02	1.68	7.99	±10	200,000
B	4	Right	1933	14.63	1.80	1.47	7.07	±10	200,000
A	5	Left	14442	24.45	1.19	1.12	5.45	±10	200,000
A	5	Right	14443	24.45	1.30	1.15	7.03	±10	200,000
B	5	Left	1911	24.45	1.01	1.09	4.21	±10	200,000
B	5	Right	9880	24.45	1.22	1.17	6.10	±10	200,000
A	6	Left	13381	48.86	0.761	0.613	3.81	±10	200,000
A	6	Right	13380	48.86	0.694	0.632	2.86	±10	200,000
B	6	Left	13374	48.85	0.678	0.541	3.50	±10	200,000
B	6	Right	1913	48.85	0.620	0.492	3.16	±10	200,000
A	7	Left	14360	118.96	0.407	0.284	2.00	±10	200,000
A	7	Right	13268	118.96	0.503	0.290	3.08	±10	200,000
B	7	Left	9882	108.58	0.316	0.273	1.32	±10	200,000
B	7	Right	9883	108.58	0.343	0.271	1.83	±10	200,000

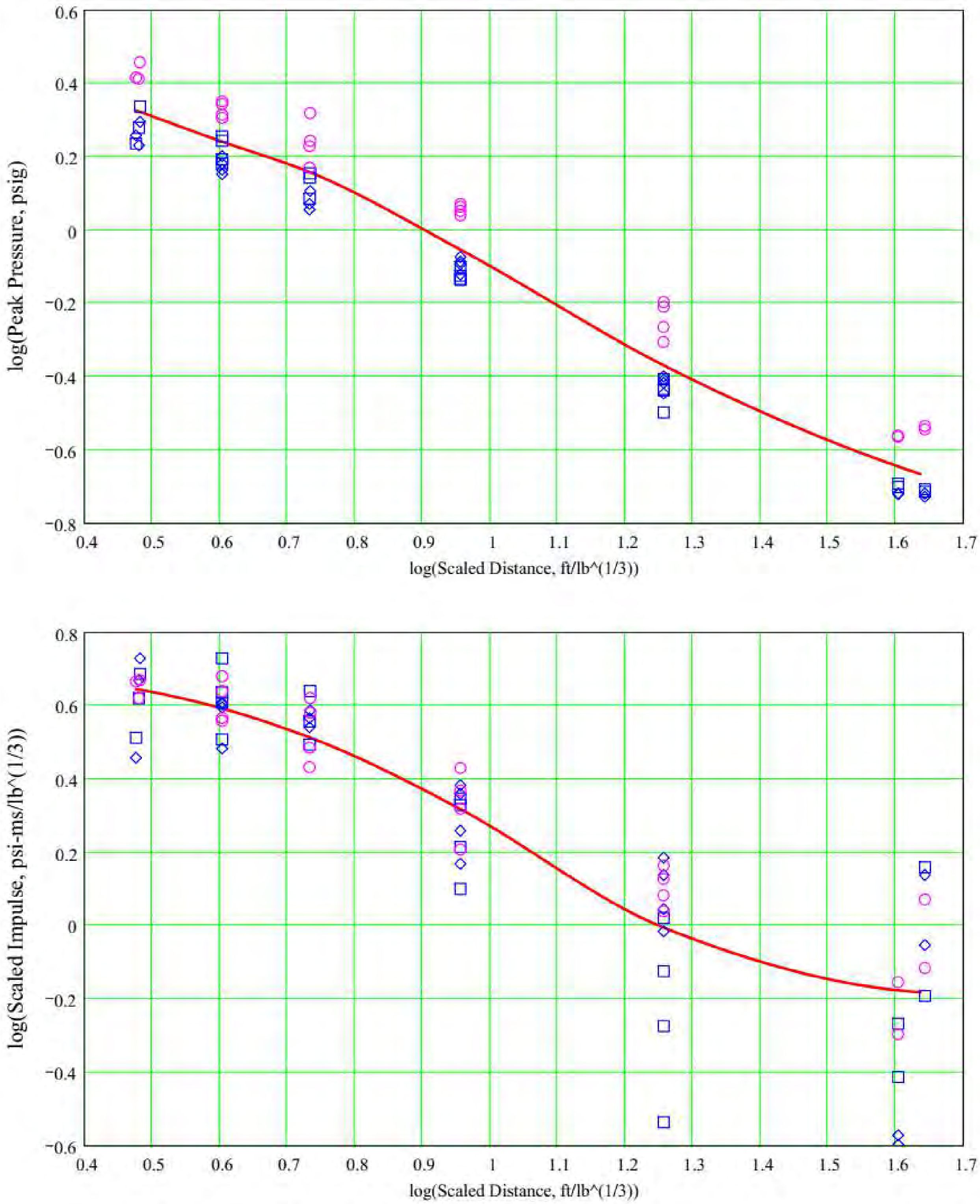


Figure 13: Filtered Peak Pressure (top) and Scaled Positive Impulse (bottom) versus Scaled Distance for Mounded Large-Scale Mix ID #8 on the Surface at Sea Level

6.4 Fine Mg-MnO_2 Thermite – Small-Scale Mix ID #4 (SMS mixed)

The tables, photos and figures in this section summarize the trials performed on Small-Scale Mix ID #4. For the first two trials, the thermite powder was mounded in the center of a 4-inch-thick, 24-inch-square A572 Grade 50 steel base plate covered with a thin layer of sand (thermal barrier, easier cleanup of slag). For the third trial, the thermite powder was mounded in the center of a 0.5-inch-thick ceramic fiber board on the steel base plate. The first and third trials resulted in an explosion of the thermite that produced a small positive-pressure pulse immediately preceding the characteristic deflagration curve; no holes were ruptured on either of the Bikini gages at Station 3 (pressure less than 2.2 psi).

Table 13: Test Conditions for Small-Scale Mix ID #4

Trial	Atmospheric Conditions		Configuration	Sample N.E.W. (kg)	Comments
	(K)	(inHg)			
1	302	29.77	Top ignition of mounded powder	9.07	Explosion
2	302	29.76	Middle ignition of mounded powder	9.07	Deflagration
3	306	29.92	Bottom ignition of mounded powder	9.07	Explosion

Photo 20: Test Setup and Results for Trial 1 of Small-Scale Mix ID #4

Photo 21: Test Setup and Results for Trial 2 of Small-Scale Mix ID #4

Photo 22: Test Setup and Results for Trial 3 of Small-Scale Mix ID #4

Table 14: Data Summary for Trial 1 of Small-Scale Mix ID #4

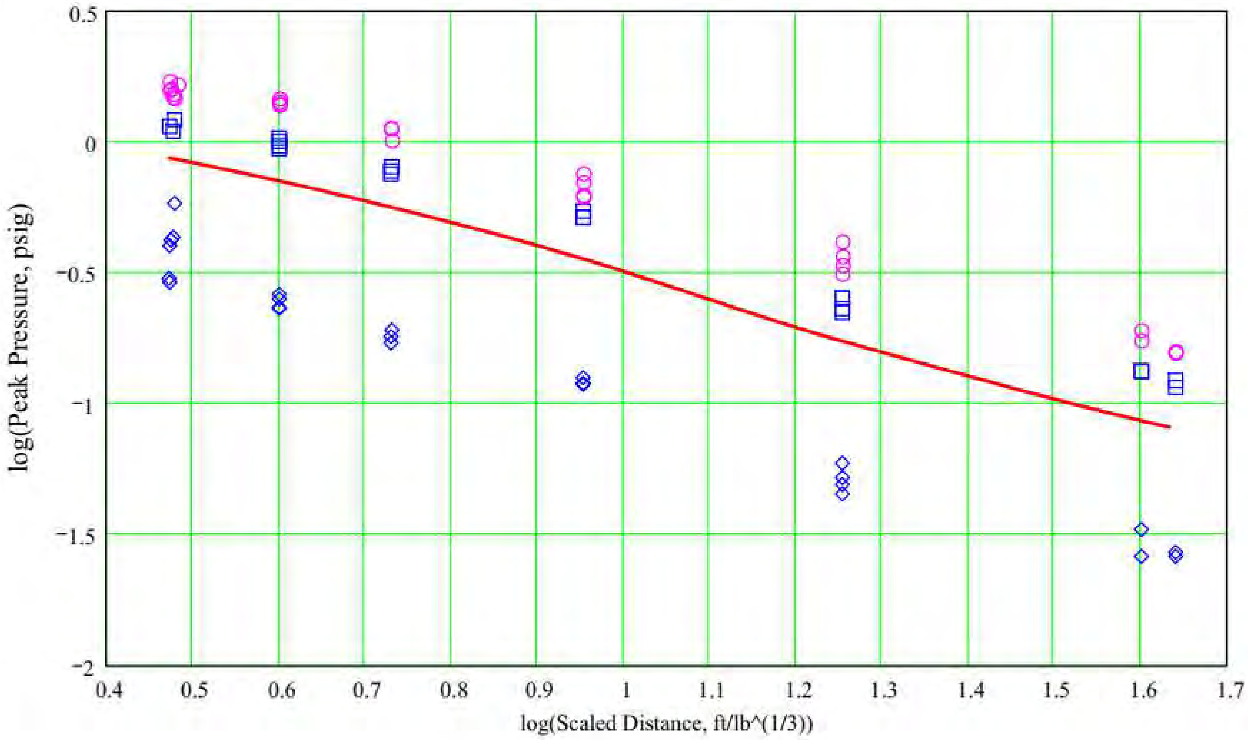
Sensor Group	Sensor Station	Sensor Position	Sensor S/N	Distance (ft)	Peak Pressure (psig)		Positive Impulse (psi-ms)	Span (V)	Sampling Rate (Hz)
					Raw	Filter			
B	1	Left	1934	8.18	1.29	1.09	8.38	±10	200,000
B	1	Right	9814	8.21	1.43	1.21	9.47	±10	200,000
A	2	Right	1950	8.10	1.30	1.14	6.51	±10	200,000
A	3	Left	1940	10.86	1.04	1.03	7.52	±10	200,000
A	3	Right	1936	10.86	1.43	1.00	10.2	±10	200,000
B	3	Left	1952	10.86	1.16	0.96	5.84	±10	200,000
B	3	Right	1949	10.86	0.948	0.937	4.52	±10	200,000
A	4	Right	1937	14.66	1.13	0.800	9.44	±10	200,000
B	4	Left	1945	14.63	0.970	0.770	6.47	±10	200,000
B	4	Right	1933	14.63	0.930	0.750	5.44	±10	200,000
A	5	Left	14442	24.45	0.531	0.513	1.68	±10	200,000
A	5	Right	14443	24.45	0.521	0.512	1.10	±10	200,000
B	5	Right	9880	24.45	0.580	0.542	4.51	±10	200,000
A	6	Left	13381	48.86	0.245	0.222	0.73	±10	200,000
A	6	Right	13380	48.86	0.276	0.253	0.88	±10	200,000
B	6	Left	13374	48.85	0.269	0.252	2.06	±10	200,000
B	6	Right	1913	48.85	0.320	0.230	3.75	±10	200,000
A	7	Left	14360	118.96	0.137	0.115	0.94	±10	200,000
A	7	Right	13268	118.96	0.140	0.122	1.03	±10	200,000
B	7	Left	9882	108.58	0.160	0.133	1.35	±10	200,000
B	7	Right	9883	108.58	0.165	0.132	1.35	±10	200,000

Table 15: Data Summary for Trial 2 of Small-Scale Mix ID #4

Sensor Group	Sensor Station	Sensor Position	Sensor S/N	Distance (ft)	Peak Pressure (psig)		Positive Impulse (psi-ms)	Span (V)	Sampling Rate (Hz)
					Raw	Filter			
A	1	Right	1930	8.10	0.580	0.400	2.63	±10	200,000
B	1	Left	1934	8.18	0.650	0.430	2.89	±10	200,000
B	1	Right	9814	8.21	0.810	0.580	4.40	±10	200,000
A	2	Left	1908	8.09	0.520	0.300	1.98	±10	200,000
A	2	Right	1950	8.10	0.590	0.290	4.13	±10	200,000
B	2	Right	1944	8.13	0.630	0.420	3.38	±10	200,000
A	3	Left	1940	10.86	0.283	0.261	2.62	±10	200,000
A	3	Right	1936	10.86	0.590	0.250	4.13	±10	200,000
B	3	Left	1952	10.86	0.530	0.230	4.08	±10	200,000
B	3	Right	1949	10.86	0.360	0.232	4.59	±10	200,000
A	4	Right	1937	14.66	0.540	0.190	3.79	±10	200,000
B	4	Left	1945	14.63	0.490	0.180	3.57	±10	200,000
B	4	Right	1933	14.63	0.660	0.170	4.72	±10	200,000
A	5	Left	14442	24.45	0.175	0.118	2.08	±10	200,000
A	5	Right	14443	24.45	0.141	0.119	0.41	±10	200,000
B	5	Right	9880	24.45	0.142	0.125	0.58	±10	200,000
A	6	Left	13381	48.86	0.066	0.049	0.91	±10	200,000
A	6	Right	13380	48.86	0.077	0.059	0.31	±10	200,000
B	6	Left	13374	48.85	0.088	0.052	0.67	±10	200,000
B	6	Right	1913	48.85	0.079	0.045	0.66	±10	200,000
A	7	Left	14360	118.96	0.049	0.026	0.23	±10	200,000
A	7	Right	13268	118.96	0.104	0.027	0.84	±10	200,000
B	7	Left	9882	108.58	0.156	0.026	1.67	±10	200,000
B	7	Right	9883	108.58	0.120	0.033	1.18	±10	200,000

Table 16: Data Summary for Trial 3 of Small-Scale Mix ID #4

Sensor Group	Sensor Station	Sensor Position	Sensor S/N	Distance (ft)	Peak Pressure (psig)		Positive Impulse (psi-ms)	Span (V)	Sampling Rate (Hz)
					Raw	Filter			
A	1	Left	1935	8.28	1.88	1.65	13.8	±10	200,000
A	1	Right	1930	8.10	1.77	1.57	12.1	±10	200,000
B	1	Left	1934	8.18	1.70	1.52	11.6	±10	200,000
B	1	Right	9814	8.21	1.62	1.46	9.74	±10	200,000
A	2	Right	1950	8.10	1.97	1.70	10.9	±10	200,000
B	2	Left	1921	8.17	1.81	1.48	10.7	±10	200,000
B	2	Right	1944	8.13	1.95	1.59	11.5	±10	200,000
A	3	Left	1940	10.86	1.48	1.46	9.35	±10	200,000
A	3	Right	1936	10.86	1.90	1.39	13.3	±10	200,000
B	3	Left	1952	10.86	1.64	1.42	10.0	±10	200,000
B	3	Right	1949	10.86	1.35	1.38	7.75	±10	200,000
A	4	Right	1937	14.66	1.30	1.01	8.58	±10	200,000
B	4	Left	1945	14.63	1.48	1.12	9.17	±10	200,000
B	4	Right	1933	14.63	1.48	1.13	9.02	±10	200,000
A	5	Left	14442	24.45	0.543	0.614	2.74	±10	200,000
A	5	Right	14443	24.45	0.516	0.623	2.47	±10	200,000
B	5	Left	1911	24.45	0.610	0.699	2.71	±10	200,000
B	5	Right	9880	24.45	0.685	0.754	3.20	±10	200,000
A	6	Left	13381	48.86	0.329	0.337	1.53	±10	200,000
A	6	Right	13380	48.86	0.342	0.364	2.43	±10	200,000
B	6	Left	13374	48.85	0.358	0.415	2.04	±10	200,000
B	6	Right	1913	48.85	0.315	0.313	1.71	±10	200,000
A	7	Left	14360	118.96	0.156	0.156	0.18	±10	200,000
A	7	Right	13268	118.96	0.155	0.158	0.19	±10	200,000
B	7	Left	9882	108.58	0.197	0.190	0.22	±10	200,000
B	7	Right	9883	108.58	0.165	0.174	0.28	±10	200,000



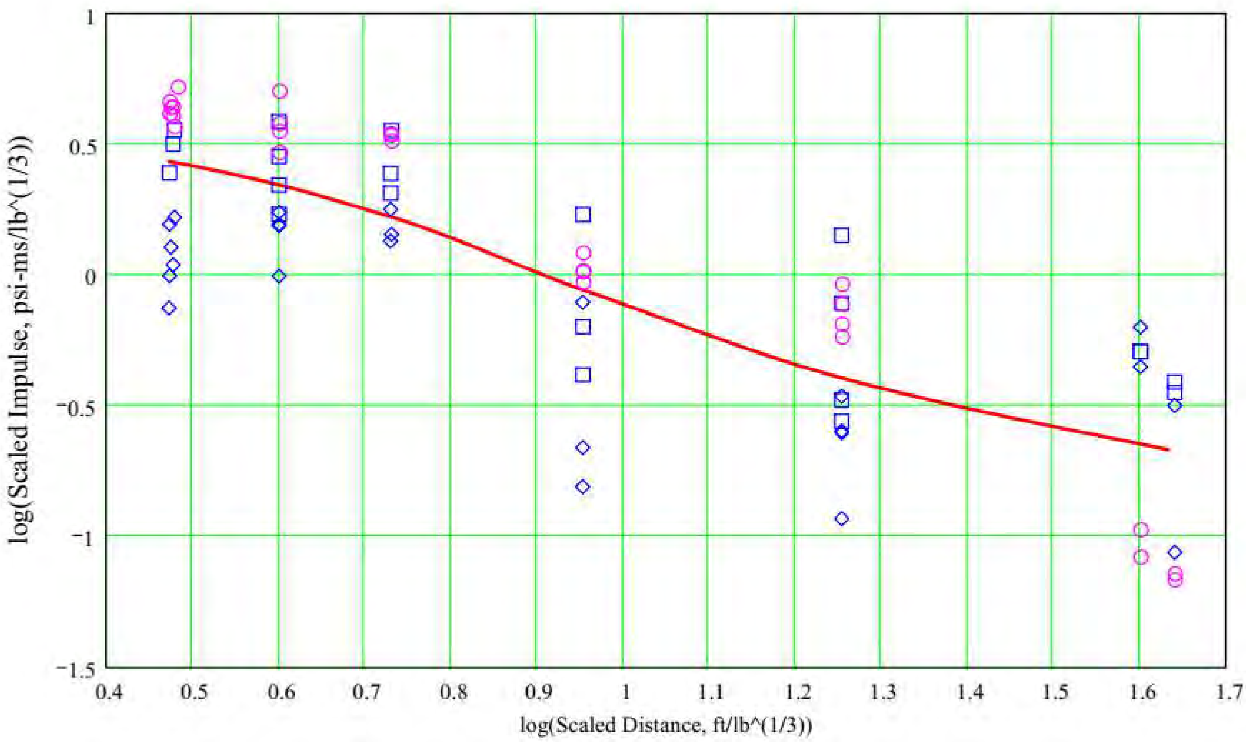


Figure 14: Filtered Peak Pressure (top) and Scaled Positive Impulse (bottom) versus Scaled Distance for Mounded Small-Scale Mix ID #4 on the Surface at Sea Level

6.5 Fine Al-SnO_2 Thermite – Small-Scale Mix ID #19 (SMS mixed)

The tables, photos and figures in this section summarize the trials performed on Small-Scale Mix ID #19. For each trial, the thermite powder was mounded in the center of a 0.5-inch-thick ceramic fiber board on a 4-inch-thick, 24-inch-square A572 Grade 50 steel base plate. Each trial resulted in a burning reaction.

Table 17: Test Conditions for Small-Scale Mix ID #19

Trial	Atmospheric Conditions		Configuration	Sample N.E.W. (kg)	Comments
	(K)	(inHg)			
1	304	29.70	Top ignition of mounded powder	9.07	Burning reaction.
2	305	29.70	Middle ignition of mounded powder	9.07	Burning reaction.
3	302	29.73	Bottom ignition of mounded powder	9.07	Burning reaction.

Photo 23: Test Setup and Results for Trial 1 of Small-Scale Mix ID #19

Photo 24: Test Setup and Results for Trial 2 of Small-Scale Mix ID #19

Photo 25: Test Setup and Results for Trial 3 of Small-Scale Mix ID #19

Table 18: Data Summary for Trial 1 of Small-Scale Mix ID #19

Sensor Group	Sensor Station	Sensor Position	Sensor S/N	Distance (ft)	Peak Pressure (psig)	Positive Impulse (psi-ms)	Span (V)	Sampling Rate (Hz)
A	1	Left	1935	8.28	-	-	±10	200,000
A	1	Right	1930	8.10	-	-	±10	200,000
B	1	Left	1934	8.18	-	-	±10	200,000
B	1	Right	9814	8.21	-	-	±10	200,000
A	2	Left	1908	8.09	-	-	±10	200,000
A	2	Right	1950	8.10	-	-	±10	200,000
B	2	Left	1921	8.17	-	-	±10	200,000
B	2	Right	1944	8.13	-	-	±10	200,000
A	3	Left	1940	10.86	-	-	±10	200,000
A	3	Right	1936	10.86	-	-	±10	200,000
B	3	Left	1952	10.86	-	-	±10	200,000
B	3	Right	1949	10.86	-	-	±10	200,000
A	4	Left	1938	14.66	-	-	±10	200,000
A	4	Right	1937	14.66	-	-	±10	200,000
B	4	Left	1945	14.63	-	-	±10	200,000
B	4	Right	1933	14.63	-	-	±10	200,000
A	5	Left	14442	24.45	-	-	±10	200,000
A	5	Right	14443	24.45	-	-	±10	200,000
B	5	Left	1911	24.45	-	-	±10	200,000
B	5	Right	9880	24.45	-	-	±10	200,000
A	6	Left	13381	48.86	-	-	±10	200,000
A	6	Right	13380	48.86	-	-	±10	200,000
B	6	Left	13374	48.85	-	-	±10	200,000
B	6	Right	1913	48.85	-	-	±10	200,000
A	7	Left	14360	118.96	-	-	±10	200,000
A	7	Right	13268	118.96	-	-	±10	200,000
B	7	Left	9882	108.58	-	-	±10	200,000
B	7	Right	9883	108.58	-	-	±10	200,000

Table 19: Data Summary for Trial 2 of Small-Scale Mix ID #19

Sensor Group	Sensor Station	Sensor Position	Sensor S/N	Distance (ft)	Peak Pressure (psig)	Positive Impulse (psi-ms)	Span (V)	Sampling Rate (Hz)
A	1	Left	1935	8.28	-	-	±10	200,000
A	1	Right	1930	8.10	-	-	±10	200,000
B	1	Left	1934	8.18	-	-	±10	200,000
B	1	Right	9814	8.21	-	-	±10	200,000
A	2	Left	1908	8.09	-	-	±10	200,000
A	2	Right	1950	8.10	-	-	±10	200,000
B	2	Left	1921	8.17	-	-	±10	200,000
B	2	Right	1944	8.13	-	-	±10	200,000
A	3	Left	1940	10.86	-	-	±10	200,000
A	3	Right	1936	10.86	-	-	±10	200,000
B	3	Left	1952	10.86	-	-	±10	200,000
B	3	Right	1949	10.86	-	-	±10	200,000
A	4	Left	1938	14.66	-	-	±10	200,000
A	4	Right	1937	14.66	-	-	±10	200,000
B	4	Left	1945	14.63	-	-	±10	200,000
B	4	Right	1933	14.63	-	-	±10	200,000
A	5	Left	14442	24.45	-	-	±10	200,000
A	5	Right	14443	24.45	-	-	±10	200,000
B	5	Left	1911	24.45	-	-	±10	200,000
B	5	Right	9880	24.45	-	-	±10	200,000
A	6	Left	13381	48.86	-	-	±10	200,000
A	6	Right	13380	48.86	-	-	±10	200,000
B	6	Left	13374	48.85	-	-	±10	200,000
B	6	Right	1913	48.85	-	-	±10	200,000
A	7	Left	14360	118.96	-	-	±10	200,000
A	7	Right	13268	118.96	-	-	±10	200,000
B	7	Left	9882	108.58	-	-	±10	200,000
B	7	Right	9883	108.58	-	-	±10	200,000

Table 20: Data Summary for Trial 3 of Small-Scale Mix ID #19

Sensor Group	Sensor Station	Sensor Position	Sensor S/N	Distance (ft)	Peak Pressure (psig)	Positive Impulse (psi-ms)	Span (V)	Sampling Rate (Hz)
A	1	Left	1935	8.28	-	-	±10	200,000
A	1	Right	1930	8.10	-	-	±10	200,000
B	1	Left	1934	8.18	-	-	±10	200,000
B	1	Right	9814	8.21	-	-	±10	200,000
A	2	Left	1908	8.09	-	-	±10	200,000
A	2	Right	1950	8.10	-	-	±10	200,000
B	2	Left	1921	8.17	-	-	±10	200,000
B	2	Right	1944	8.13	-	-	±10	200,000
A	3	Left	1940	10.86	-	-	±10	200,000
A	3	Right	1936	10.86	-	-	±10	200,000
B	3	Left	1952	10.86	-	-	±10	200,000
B	3	Right	1949	10.86	-	-	±10	200,000
A	4	Left	1938	14.66	-	-	±10	200,000
A	4	Right	1937	14.66	-	-	±10	200,000
B	4	Left	1945	14.63	-	-	±10	200,000
B	4	Right	1933	14.63	-	-	±10	200,000
A	5	Left	14442	24.45	-	-	±10	200,000
A	5	Right	14443	24.45	-	-	±10	200,000
B	5	Left	1911	24.45	-	-	±10	200,000
B	5	Right	9880	24.45	-	-	±10	200,000
A	6	Left	13381	48.86	-	-	±10	200,000
A	6	Right	13380	48.86	-	-	±10	200,000
B	6	Left	13374	48.85	-	-	±10	200,000
B	6	Right	1913	48.85	-	-	±10	200,000
A	7	Left	14360	118.96	-	-	±10	200,000
A	7	Right	13268	118.96	-	-	±10	200,000
B	7	Left	9882	108.58	-	-	±10	200,000
B	7	Right	9883	108.58	-	-	±10	200,000

6.6 Fine Al-Bi_2O_3 Thermite – Small-Scale Mix ID #24 (SMS mixed)

The tables, photos and figures in this section summarize the trials performed on Small-Scale Mix ID #24. For each trial, the thermite powder was mounded in the center of a 0.5-inch-thick ceramic fiber board on a 4-inch-thick, 24-inch-square A572 Grade 50 steel base plate. Each trial resulted in a detonation of the thermite that produced a shock wave. Holes were ruptured in the Bikini gages at Station 3 (10.86 feet) as follows:

- Trial 1: eight largest holes at A3 (7.3 - 8.3 psig); four largest holes at B3 (4.4 - 5.0 psig).

- Trial 2: nine largest holes at A3 (8.3 - 12 psig); seven largest holes at B3 (6.5 - 7.3 psig).
- Trial 3: four largest holes at A3 (4.4 - 5.0 psig); eight largest holes at B3 (7.3 - 8.3 psig).

Table 21: Test Conditions for Small-Scale Mix ID #24

Trial	Atmospheric Conditions		Configuration	Sample N.E.W. (kg)	Comments
	(K)	(inHg)			
1	302	29.74	Top ignition of mounded powder	9.07	Detonation (shock wave)
2	303	29.75	Middle ignition of mounded powder	9.07	Detonation (shock wave)
3	303	29.75	Bottom ignition of mounded powder	9.07	Detonation (shock wave)

Photo 26: Test Setup and Results for Trial 1 of Small-Scale Mix ID #24

Photo 27: Test Setup and Results for Trial 2 of Small-Scale Mix ID #24

Photo 28: Test Setup and Results for Trial 3 of Small-Scale Mix ID #24

Table 22: Data Summary for Trial 1 of Small-Scale Mix ID #24

Sensor Group	Sensor Station	Sensor Position	Sensor S/N	Distance (ft)	Peak Pressure (psig)		Positive Impulse (psi-ms)	Span (V)	Sampling Rate (Hz)
					Raw	Filter			
B	1	Left	1934	8.18	6.21	5.94	14.5	±10	200,000
B	1	Right	9814	8.21	7.21	6.04	16.0	±10	200,000
A	3	Left	1940	10.86	5.00	4.52	10.3	±10	200,000
A	3	Right	1936	10.86	5.26	4.61	13.3	±10	200,000
B	3	Right	1949	10.86	5.77	5.51	9.91	±10	200,000
A	4	Right	1937	14.66	2.43	2.14	10.4	±10	200,000
B	4	Left	1945	14.63	3.58	2.95	10.2	±10	200,000
B	4	Right	1933	14.63	3.15	2.55	9.61	±10	200,000
A	5	Left	14442	24.45	1.66	1.34	5.80	±10	200,000
A	5	Right	14443	24.45	1.54	1.35	5.21	±10	200,000
B	5	Left	1911	24.45	1.88	1.46	3.99	±10	200,000
B	5	Right	9880	24.45	1.97	1.67	5.03	±10	200,000
A	6	Left	13381	48.86	0.618	0.531	2.01	±10	200,000
A	6	Right	13380	48.86	0.608	0.531	2.28	±10	200,000
B	6	Left	13374	48.85	0.757	0.590	2.94	±10	200,000
B	6	Right	1913	48.85	0.694	0.531	2.22	±10	200,000
A	7	Left	14360	118.96	0.403	0.243	2.78	±10	200,000
A	7	Right	13268	118.96	0.375	0.257	1.72	±10	200,000
B	7	Left	9882	108.58	0.312	0.234	1.72	±10	200,000
B	7	Right	9883	108.58	0.327	0.253	2.27	±10	200,000

Table 23: Data Summary for Trial 2 of Small-Scale Mix ID #24

Sensor Group	Sensor Station	Sensor Position	Sensor S/N	Distance (ft)	Peak Pressure (psig)		Positive Impulse (psi-ms)	Span (V)	Sampling Rate (Hz)
					Raw	Filter			
A	1	Left	1935	8.28	19.7	16.4	16.5	±10	200,000
B	1	Left	1934	8.18	11.9	11.2	17.4	±10	200,000
B	1	Right	9814	8.21	14.0	11.1	20.1	±10	200,000
A	2	Right	1950	8.10	22.6	20.7	21.2	±10	200,000
A	3	Left	1940	10.86	20.2	18.1	15.9	±10	200,000
B	3	Right	1949	10.86	12.1	10.9	15.3	±10	200,000
A	4	Right	1937	14.66	11.4	9.8	12.4	±10	200,000
B	4	Left	1945	14.63	8.71	7.74	12.1	±10	200,000
A	5	Left	14442	24.45	4.45	3.63	6.93	±10	200,000
A	5	Right	14443	24.45	4.18	3.74	7.09	±10	200,000
B	5	Left	1911	24.45	4.34	3.50	6.90	±10	200,000
B	5	Right	9880	24.45	4.46	3.68	7.36	±10	200,000
A	6	Left	13381	48.86	1.56	1.31	2.70	±10	200,000
A	6	Right	13380	48.86	1.78	1.44	3.72	±10	200,000
B	6	Left	13374	48.85	1.52	1.22	3.21	±10	200,000
B	6	Right	1913	48.85	1.51	1.16	3.42	±10	200,000
A	7	Left	14360	118.96	0.861	0.539	2.94	±10	200,000
A	7	Right	13268	118.96	0.899	0.591	3.20	±10	200,000
B	7	Left	9882	108.58	0.507	0.455	1.34	±10	200,000
B	7	Right	9883	108.58	0.469	0.457	1.30	±10	200,000

Table 24: Data Summary for Trial 3 of Small-Scale Mix ID #24

Sensor Group	Sensor Station	Sensor Position	Sensor S/N	Distance (ft)	Peak Pressure (psig)		Positive Impulse (psi-ms)	Span (V)	Sampling Rate (Hz)
					Raw	Filter			
B	1	Left	1934	8.18	7.43	4.80	10.1	±10	200,000
B	1	Right	9814	8.21	6.89	6.02	12.8	±10	200,000
A	2	Right	1950	8.10	7.08	6.33	10.4	±10	200,000
A	3	Left	1940	10.86	4.93	4.50	8.33	±10	200,000
A	3	Right	1936	10.86	5.35	4.65	8.53	±10	200,000
B	3	Left	1952	10.86	3.01	2.73	6.22	±10	200,000
B	3	Right	1949	10.86	3.37	2.98	9.07	±10	200,000
A	4	Right	1937	14.66	3.36	2.83	7.44	±10	200,000
B	4	Left	1945	14.63	2.32	2.01	9.47	±10	200,000
B	4	Right	1933	14.63	2.05	1.56	8.98	±10	200,000
A	5	Left	14442	24.45	1.44	1.19	4.38	±10	200,000
A	5	Right	14443	24.45	1.35	1.24	4.17	±10	200,000
B	5	Left	1911	24.45	1.15	0.97	3.62	±10	200,000
B	5	Right	9880	24.45	1.27	1.10	5.18	±10	200,000
A	6	Left	13381	48.86	0.742	0.650	3.03	±10	200,000
A	6	Right	13380	48.86	0.777	0.664	3.52	±10	200,000
B	6	Left	13374	48.85	0.540	0.443	2.86	±10	200,000
B	6	Right	1913	48.85	0.495	0.390	2.54	±10	200,000
A	7	Left	14360	118.96	0.326	0.176	2.51	±10	200,000
A	7	Right	13268	118.96	0.325	0.122	1.67	±10	200,000
B	7	Left	9882	108.58	0.217	0.095	1.68	±10	200,000
B	7	Right	9883	108.58	0.235	0.123	2.18	±10	200,000

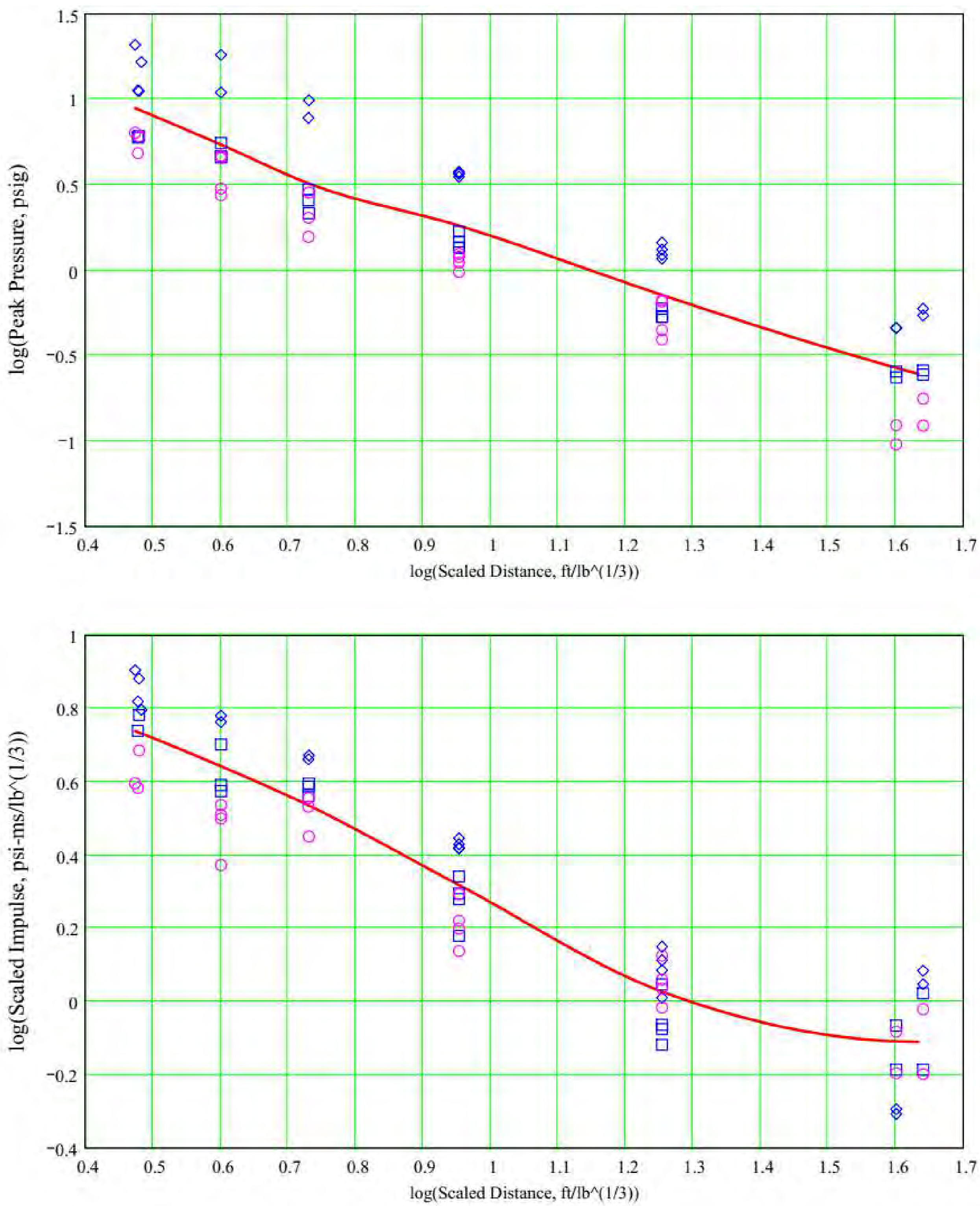


Figure 15: Filtered Peak Pressure (top) and Scaled Positive Impulse (bottom) versus Scaled Distance for Mounded Small-Scale Mix ID #24 on the Surface at Sea Level

6.7 Fine Al-Fe_3O_4 – Small-Scale Mix ID #27 (SMS Mixed)

The tables, photos and figures in this section summarize the trials performed on Small-Scale Mix ID #27. For each trial, the thermite powder was mounded in the center of a 0.5-inch-thick ceramic fiber board on a 4-inch-thick, 24-inch-square A572 Grade 50 steel base plate. Each trial resulted in burning of the thermite.

Table 25: Test Conditions for Small-Scale Mix ID #27

Trial	Atmospheric Conditions		Configuration	Sample N.E.W. (kg)	Comments
	(K)	(inHg)			
1	302	29.69	Top ignition of mounded powder	9.07	Burning reaction
2	305	29.96	Middle ignition of mounded powder	9.07	Burning reaction
3	302	29.71	Bottom ignition of mounded powder	9.07	Burning reaction

Photo 29: Test Setup and Results for Trial 1 of Small-Scale Mix ID #27

Photo 30: Test Setup and Results for Trial 2 of Small-Scale Mix ID #27

Photo 31: Test Setup and Results for Trial 3 of Small-Scale Mix ID #27

Table 26: Data Summary for Trial 1 of Small-Scale Mix ID #27

Sensor Group	Sensor Station	Sensor Position	Sensor S/N	Distance (ft)	Peak Pressure (psig)	Positive Impulse (psi-ms)	Span (V)	Sampling Rate (Hz)
A	1	Left	1935	8.28	-	-	±10	200,000
A	1	Right	1930	8.10	-	-	±10	200,000
B	1	Left	1934	8.18	-	-	±10	200,000
B	1	Right	9814	8.21	-	-	±10	200,000
A	2	Left	1908	8.09	-	-	±10	200,000
A	2	Right	1950	8.10	-	-	±10	200,000
B	2	Left	1921	8.17	-	-	±10	200,000
B	2	Right	1944	8.13	-	-	±10	200,000
A	3	Left	1940	10.86	-	-	±10	200,000
A	3	Right	1936	10.86	-	-	±10	200,000
B	3	Left	1952	10.86	-	-	±10	200,000
B	3	Right	1949	10.86	-	-	±10	200,000
A	4	Left	1938	14.66	-	-	±10	200,000
A	4	Right	1937	14.66	-	-	±10	200,000
B	4	Left	1945	14.63	-	-	±10	200,000
B	4	Right	1933	14.63	-	-	±10	200,000
A	5	Left	14442	24.45	-	-	±10	200,000
A	5	Right	14443	24.45	-	-	±10	200,000
B	5	Left	1911	24.45	-	-	±10	200,000
B	5	Right	9880	24.45	-	-	±10	200,000
A	6	Left	13381	48.86	-	-	±10	200,000
A	6	Right	13380	48.86	-	-	±10	200,000
B	6	Left	13374	48.85	-	-	±10	200,000
B	6	Right	1913	48.85	-	-	±10	200,000
A	7	Left	14360	118.96	-	-	±10	200,000
A	7	Right	13268	118.96	-	-	±10	200,000
B	7	Left	9882	108.58	-	-	±10	200,000
B	7	Right	9883	108.58	-	-	±10	200,000

Table 27: Data Summary for Trial 2 of Small-Scale Mix ID #27

Sensor Group	Sensor Station	Sensor Position	Sensor S/N	Distance (ft)	Peak Pressure (psig)	Positive Impulse (psi-ms)	Span (V)	Sampling Rate (Hz)
A	1	Left	1935	8.28	-	-	±10	200,000
A	1	Right	1930	8.10	-	-	±10	200,000
B	1	Left	1934	8.18	-	-	±10	200,000
B	1	Right	9814	8.21	-	-	±10	200,000
A	2	Left	1908	8.09	-	-	±10	200,000
A	2	Right	1950	8.10	-	-	±10	200,000
B	2	Left	1921	8.17	-	-	±10	200,000
B	2	Right	1944	8.13	-	-	±10	200,000
A	3	Left	1940	10.86	-	-	±10	200,000
A	3	Right	1936	10.86	-	-	±10	200,000
B	3	Left	1952	10.86	-	-	±10	200,000
B	3	Right	1949	10.86	-	-	±10	200,000
A	4	Left	1938	14.66	-	-	±10	200,000
A	4	Right	1937	14.66	-	-	±10	200,000
B	4	Left	1945	14.63	-	-	±10	200,000
B	4	Right	1933	14.63	-	-	±10	200,000
A	5	Left	14442	24.45	-	-	±10	200,000
A	5	Right	14443	24.45	-	-	±10	200,000
B	5	Left	1911	24.45	-	-	±10	200,000
B	5	Right	9880	24.45	-	-	±10	200,000
A	6	Left	13381	48.86	-	-	±10	200,000
A	6	Right	13380	48.86	-	-	±10	200,000
B	6	Left	13374	48.85	-	-	±10	200,000
B	6	Right	1913	48.85	-	-	±10	200,000
A	7	Left	14360	118.96	-	-	±10	200,000
A	7	Right	13268	118.96	-	-	±10	200,000
B	7	Left	9882	108.58	-	-	±10	200,000
B	7	Right	9883	108.58	-	-	±10	200,000

Table 28: Data Summary for Trial 3 of Small-Scale Mix ID #27

Sensor Group	Sensor Station	Sensor Position	Sensor S/N	Distance (ft)	Peak Pressure (psig)	Positive Impulse (psi-ms)	Span (V)	Sampling Rate (Hz)
A	1	Left	1935	8.28	-	-	±10	200,000
A	1	Right	1930	8.10	-	-	±10	200,000
B	1	Left	1934	8.18	-	-	±10	200,000
B	1	Right	9814	8.21	-	-	±10	200,000
A	2	Left	1908	8.09	-	-	±10	200,000
A	2	Right	1950	8.10	-	-	±10	200,000
B	2	Left	1921	8.17	-	-	±10	200,000
B	2	Right	1944	8.13	-	-	±10	200,000
A	3	Left	1940	10.86	-	-	±10	200,000
A	3	Right	1936	10.86	-	-	±10	200,000
B	3	Left	1952	10.86	-	-	±10	200,000
B	3	Right	1949	10.86	-	-	±10	200,000
A	4	Left	1938	14.66	-	-	±10	200,000
A	4	Right	1937	14.66	-	-	±10	200,000
B	4	Left	1945	14.63	-	-	±10	200,000
B	4	Right	1933	14.63	-	-	±10	200,000
A	5	Left	14442	24.45	-	-	±10	200,000
A	5	Right	14443	24.45	-	-	±10	200,000
B	5	Left	1911	24.45	-	-	±10	200,000
B	5	Right	9880	24.45	-	-	±10	200,000
A	6	Left	13381	48.86	-	-	±10	200,000
A	6	Right	13380	48.86	-	-	±10	200,000
B	6	Left	13374	48.85	-	-	±10	200,000
B	6	Right	1913	48.85	-	-	±10	200,000
A	7	Left	14360	118.96	-	-	±10	200,000
A	7	Right	13268	118.96	-	-	±10	200,000
B	7	Left	9882	108.58	-	-	±10	200,000
B	7	Right	9883	108.58	-	-	±10	200,000

6.8 Fine Al-NiO – Small-Scale Mix ID #30 (SMS Mixed)

The tables, photos and figures in this section summarize the trials performed on Small-Scale Mix ID #30. For each trial, the thermite powder was mounded in the center of a 0.5-inch-thick ceramic fiber board on a 4-inch-thick, 24-inch-square A572 Grade 50 steel base plate. Each trial resulted in deflagration of the thermite.

Table 29: Test Conditions for Small-Scale Mix ID #30

Trial	Atmospheric Conditions (K)	Atmospheric Conditions (inHg)	Configuration	Sample N.E.W. (kg)	Comments
1	302	29.72	Top ignition of mounded powder	9.07	Deflagration
2	303	29.71	Middle ignition of mounded powder	9.07	Deflagration
3	303	29.71	Bottom ignition of mounded powder	9.07	Deflagration

Photo 32: Test Setup and Results for Trial 1 of Small-Scale Mix ID #30

Photo 33: Test Setup and Results for Trial 2 of Small-Scale Mix ID #30

Photo 34: Test Setup and Results for Trial 3 of Small-Scale Mix ID #30

Table 30: Data Summary for Trial 1 of Small-Scale Mix ID #30

Sensor Group	Sensor Station	Sensor Position	Sensor S/N	Distance (ft)	Peak Pressure (psig)	Positive Impulse (psi-ms)	Span (V)	Sampling Rate (Hz)
A	1	Left	1935	8.28	-	-	±10	200,000
A	1	Right	1930	8.10	-	-	±10	200,000
B	1	Left	1934	8.18	-	-	±10	200,000
B	1	Right	9814	8.21	-	-	±10	200,000
A	2	Left	1908	8.09	-	-	±10	200,000
A	2	Right	1950	8.10	-	-	±10	200,000
B	2	Left	1921	8.17	-	-	±10	200,000
B	2	Right	1944	8.13	-	-	±10	200,000
A	3	Left	1940	10.86	-	-	±10	200,000
A	3	Right	1936	10.86	-	-	±10	200,000
B	3	Left	1952	10.86	-	-	±10	200,000
B	3	Right	1949	10.86	-	-	±10	200,000
A	4	Left	1938	14.66	-	-	±10	200,000
A	4	Right	1937	14.66	-	-	±10	200,000
B	4	Left	1945	14.63	-	-	±10	200,000
B	4	Right	1933	14.63	-	-	±10	200,000
A	5	Left	14442	24.45	-	-	±10	200,000
A	5	Right	14443	24.45	-	-	±10	200,000
B	5	Left	1911	24.45	-	-	±10	200,000
B	5	Right	9880	24.45	-	-	±10	200,000
A	6	Left	13381	48.86	-	-	±10	200,000
A	6	Right	13380	48.86	-	-	±10	200,000
B	6	Left	13374	48.85	-	-	±10	200,000
B	6	Right	1913	48.85	-	-	±10	200,000
A	7	Left	14360	118.96	-	-	±10	200,000
A	7	Right	13268	118.96	-	-	±10	200,000
B	7	Left	9882	108.58	-	-	±10	200,000
B	7	Right	9883	108.58	-	-	±10	200,000

Table 31: Data Summary for Trial 2 of Small-Scale Mix ID #30

Sensor Group	Sensor Station	Sensor Position	Sensor S/N	Distance (ft)	Peak Pressure (psig)	Positive Impulse (psi-ms)	Span (V)	Sampling Rate (Hz)
A	1	Left	1935	8.28	-	-	±10	200,000
A	1	Right	1930	8.10	-	-	±10	200,000
B	1	Left	1934	8.18	-	-	±10	200,000
B	1	Right	9814	8.21	-	-	±10	200,000
A	2	Left	1908	8.09	-	-	±10	200,000
A	2	Right	1950	8.10	-	-	±10	200,000
B	2	Left	1921	8.17	-	-	±10	200,000
B	2	Right	1944	8.13	-	-	±10	200,000
A	3	Left	1940	10.86	-	-	±10	200,000
A	3	Right	1936	10.86	-	-	±10	200,000
B	3	Left	1952	10.86	-	-	±10	200,000
B	3	Right	1949	10.86	-	-	±10	200,000
A	4	Left	1938	14.66	-	-	±10	200,000
A	4	Right	1937	14.66	-	-	±10	200,000
B	4	Left	1945	14.63	-	-	±10	200,000
B	4	Right	1933	14.63	-	-	±10	200,000
A	5	Left	14442	24.45	-	-	±10	200,000
A	5	Right	14443	24.45	-	-	±10	200,000
B	5	Left	1911	24.45	-	-	±10	200,000
B	5	Right	9880	24.45	-	-	±10	200,000
A	6	Left	13381	48.86	-	-	±10	200,000
A	6	Right	13380	48.86	-	-	±10	200,000
B	6	Left	13374	48.85	-	-	±10	200,000
B	6	Right	1913	48.85	-	-	±10	200,000
A	7	Left	14360	118.96	-	-	±10	200,000
A	7	Right	13268	118.96	-	-	±10	200,000
B	7	Left	9882	108.58	-	-	±10	200,000
B	7	Right	9883	108.58	-	-	±10	200,000

Table 32: Data Summary for Trial 3 of Small-Scale Mix ID #30

Sensor Group	Sensor Station	Sensor Position	Sensor S/N	Distance (ft)	Peak Pressure (psig)	Positive Impulse (psi-ms)	Span (V)	Sampling Rate (Hz)
A	1	Left	1935	8.28	-	-	±10	200,000
A	1	Right	1930	8.10	-	-	±10	200,000
B	1	Left	1934	8.18	-	-	±10	200,000
B	1	Right	9814	8.21	-	-	±10	200,000
A	2	Left	1908	8.09	-	-	±10	200,000
A	2	Right	1950	8.10	-	-	±10	200,000
B	2	Left	1921	8.17	-	-	±10	200,000
B	2	Right	1944	8.13	-	-	±10	200,000
A	3	Left	1940	10.86	-	-	±10	200,000
A	3	Right	1936	10.86	-	-	±10	200,000
B	3	Left	1952	10.86	-	-	±10	200,000
B	3	Right	1949	10.86	-	-	±10	200,000
A	4	Left	1938	14.66	-	-	±10	200,000
A	4	Right	1937	14.66	-	-	±10	200,000
B	4	Left	1945	14.63	-	-	±10	200,000
B	4	Right	1933	14.63	-	-	±10	200,000
A	5	Left	14442	24.45	-	-	±10	200,000
A	5	Right	14443	24.45	-	-	±10	200,000
B	5	Left	1911	24.45	-	-	±10	200,000
B	5	Right	9880	24.45	-	-	±10	200,000
A	6	Left	13381	48.86	-	-	±10	200,000
A	6	Right	13380	48.86	-	-	±10	200,000
B	6	Left	13374	48.85	-	-	±10	200,000
B	6	Right	1913	48.85	-	-	±10	200,000
A	7	Left	14360	118.96	-	-	±10	200,000
A	7	Right	13268	118.96	-	-	±10	200,000
B	7	Left	9882	108.58	-	-	±10	200,000
B	7	Right	9883	108.58	-	-	±10	200,000

6.9 Fine Ti-Bi_2O_3 – Small-Scale Mix ID #48 (SMS Mixed)

The tables, photos and figures in this section summarize the trials performed on Small-Scale Mix ID #48. For each trial, the thermite powder was mounded in the center of a 0.5-inch-thick ceramic fiber board on a 4-inch-thick, 24-inch-square A572 Grade 50 steel base plate. Each trial resulted in a detonation of the thermite that produced a shock wave. Holes were ruptured in the Bikini gages at Station 3 (10.86 feet) as follows:

- Trial 1: five largest holes at A3 (5.0 - 5.7 psig); two largest holes at B3 (3.0 - 3.7 psig).
- Trial 2: three largest holes at A3 (3.7 - 4.4 psig); the largest hole at B3 (2.2 - 3.0 psig).
- Trial 3: the largest hole at A3 (2.2 - 3.0 psig); the largest hole at B3 (2.2 - 3.0 psig).

Table 33: Test Conditions for Small-Scale Mix ID #48

Trial	Atmospheric Conditions		Configuration	Sample N.E.W. (kg)	Comments
	(K)	(inHg)			
1	302	29.78	Top ignition of mounded powder	9.07	Detonation (shock wave)
2	302	29.78	Middle ignition of mounded powder	9.07	Detonation (shock wave)
3	302	29.78	Bottom ignition of mounded powder	9.07	Detonation (shock wave)

Photo 35: Test Setup and Results for Trial 1 of Small-Scale Mix ID #48

Photo 36: Test Setup and Results for Trial 2 of Small-Scale Mix ID #48

Photo 37: Test Setup and Results for Trial 3 of Small-Scale Mix ID #48

Table 34: Data Summary for Trial 1 of Small-Scale Mix ID #48

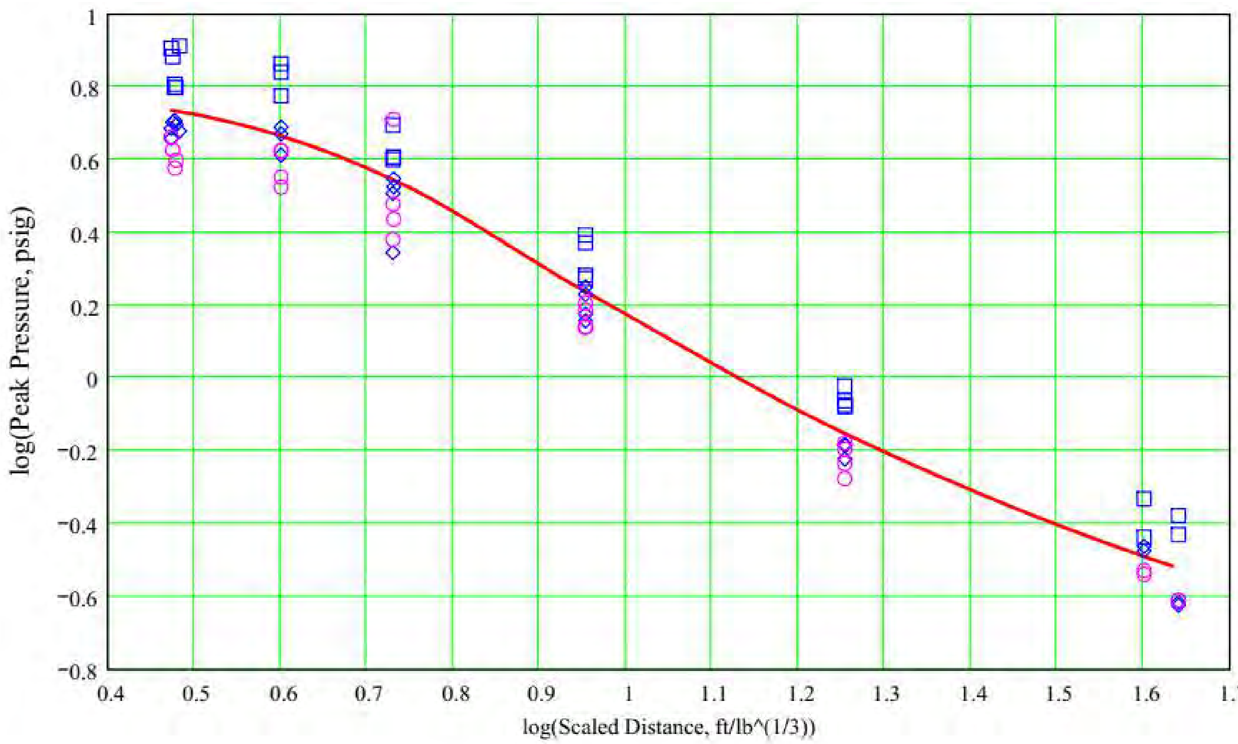
Sensor Group	Sensor Station	Sensor Position	Sensor S/N	Distance (ft)	Peak Pressure (psig)		Positive Impulse (psi-ms)	Span (V)	Sampling Rate (Hz)
					Raw	Filter			
A	1	Left	1935	8.28	8.14	8.14	9.62	±10	200,000
B	1	Left	1934	8.18	6.60	6.39	10.6	±10	200,000
B	1	Right	9814	8.21	6.74	6.27	11.98	±10	200,000
A	2	Right	1950	8.10	8.58	8.01	10.93	±10	200,000
B	2	Left	1921	8.17	7.66	6.25	13.51	±10	200,000
B	2	Right	1944	8.13	7.95	7.60	10.93	±10	200,000
A	3	Left	12359	10.86	7.80	6.89	9.34	±10	200,000
A	3	Right	1936	10.86	7.90	7.26	9.68	±10	200,000
B	3	Right	14361	10.86	6.77	5.93	8.65	±10	200,000
A	4	Left	1938	14.66	4.67	4.02	8.03	±10	200,000
A	4	Right	1937	14.66	4.67	4.03	7.17	±10	200,000
B	4	Left	1945	14.63	5.66	4.93	7.27	±10	200,000
B	4	Right	1933	14.63	4.31	3.96	3.94	±10	200,000
A	5	Left	14442	24.45	2.29	1.87	4.02	±10	200,000
A	5	Right	14443	24.45	2.18	1.91	4.20	±10	200,000
B	5	Left	1911	24.45	2.96	2.34	4.54	±10	200,000
B	5	Right	9880	24.45	2.98	2.46	4.50	±10	200,000
A	6	Left	13381	48.86	0.978	0.840	1.97	±10	200,000
A	6	Right	13380	48.86	1.03	0.832	2.20	±10	200,000
B	6	Left	13374	48.85	1.14	0.948	2.40	±10	200,000
B	6	Right	1913	48.85	1.12	0.861	2.17	±10	200,000
A	7	Left	14360	118.96	0.510	0.417	1.78	±10	200,000
A	7	Right	13268	118.96	0.449	0.370	1.43	±10	200,000
B	7	Left	9882	108.58	0.468	0.364	0.44	±10	200,000
B	7	Right	9883	108.58	0.466	0.464	0.33	±10	200,000

Table 35: Data Summary for Trial 2 of Small-Scale Mix ID #48

Sensor Group	Sensor Station	Sensor Position	Sensor S/N	Distance (ft)	Peak Pressure (psig)		Positive Impulse (psi-ms)	Span (V)	Sampling Rate (Hz)
					Raw	Filter			
A	1	Left	1935	8.28	5.46	4.75	9.19	±10	200,000
A	1	Right	1930	8.10	4.65	4.53	6.79	±10	200,000
B	1	Left	1934	8.18	5.42	5.07	9.03	±10	200,000
B	1	Right	9814	8.21	5.37	4.95	10.1	±10	200,000
A	2	Right	1950	8.10	4.99	4.83	8.47	±10	200,000
B	2	Right	1944	8.13	5.19	5.03	8.92	±10	200,000
A	3	Left	1940	10.86	5.33	4.67	6.46	±10	200,000
A	3	Right	1936	10.86	5.32	4.87	6.70	±10	200,000
B	3	Right	14361	10.86	4.53	4.08	7.10	±10	200,000
A	4	Left	1938	14.66	4.14	3.51	7.00	±10	200,000
A	4	Right	1937	14.66	3.86	3.34	5.56	±10	200,000
B	4	Left	1945	14.63	3.60	3.20	5.53	±10	200,000
B	4	Right	1933	14.63	2.45	2.20	3.24	±10	200,000
A	5	Left	14442	24.45	1.72	1.43	3.03	±10	200,000
A	5	Right	14443	24.45	1.64	1.49	3.18	±10	200,000
B	5	Left	1911	24.45	2.23	1.69	4.03	±10	200,000
B	5	Right	9880	24.45	2.24	1.77	4.08	±10	200,000
A	6	Left	13381	48.86	0.502	0.651	0.52	±10	200,000
A	6	Right	13380	48.86	0.706	0.651	1.27	±10	200,000
B	6	Left	13374	48.85	0.762	0.654	1.45	±10	200,000
B	6	Right	1913	48.85	0.645	0.597	0.86	±10	200,000
A	7	Left	14360	118.96	0.240	0.237	0.41	±10	200,000
A	7	Right	13268	118.96	0.215	0.241	0.30	±10	200,000
B	7	Left	9882	108.58	0.369	0.334	0.41	±10	200,000
B	7	Right	9883	108.58	0.353	0.344	0.31	±10	200,000

Table 36: Data Summary for Trial 3 of Small-Scale Mix ID #48

Sensor Group	Sensor Station	Sensor Position	Sensor S/N	Distance (ft)	Peak Pressure (psig)		Positive Impulse (psi-ms)	Span (V)	Sampling Rate (Hz)
					Raw	Filter			
B	1	Left	1934	8.18	3.73	3.76	8.33	±10	200,000
B	1	Right	9814	8.21	3.95	3.95	9.71	±10	200,000
A	2	Right	1950	8.10	4.81	4.58	7.73	±10	200,000
B	2	Right	1944	8.13	4.32	4.21	8.65	±10	200,000
A	3	Left	1940	10.86	4.44	4.19	7.00	±10	200,000
A	3	Right	1936	10.86	4.59	4.19	12.2	±10	200,000
B	3	Left	1947	10.86	4.03	3.33	8.72	±10	200,000
B	3	Right	1949	10.86	3.97	3.55	6.26	±10	200,000
A	4	Left	1938	14.66	5.73	5.11	6.84	±10	200,000
A	4	Right	1937	14.66	3.10	2.72	5.24	±10	200,000
B	4	Left	1945	14.63	3.46	2.99	5.17	±10	200,000
B	4	Right	1933	14.63	2.67	2.39	1.90	±10	200,000
A	5	Left	14442	24.45	1.64	1.38	3.43	±10	200,000
A	5	Right	14443	24.45	1.53	1.37	3.44	±10	200,000
B	5	Left	1911	24.45	2.14	1.53	4.61	±10	200,000
B	5	Right	9880	24.45	2.13	1.60	4.49	±10	200,000
A	6	Left	13381	48.86	0.747	0.661	1.80	±10	200,000
A	6	Right	13380	48.86	0.764	0.635	1.79	±10	200,000
B	6	Left	13374	48.85	0.677	0.579	1.07	±10	200,000
B	6	Right	1913	48.85	0.556	0.528	0.56	±10	200,000
A	7	Left	14360	118.96	0.271	0.244	0.59	±10	200,000
A	7	Right	13268	118.96	0.318	0.244	0.94	±10	200,000
B	7	Left	9882	108.58	0.282	0.295	0.43	±10	200,000
B	7	Right	9883	108.58	0.288	0.288	0.51	±10	200,000



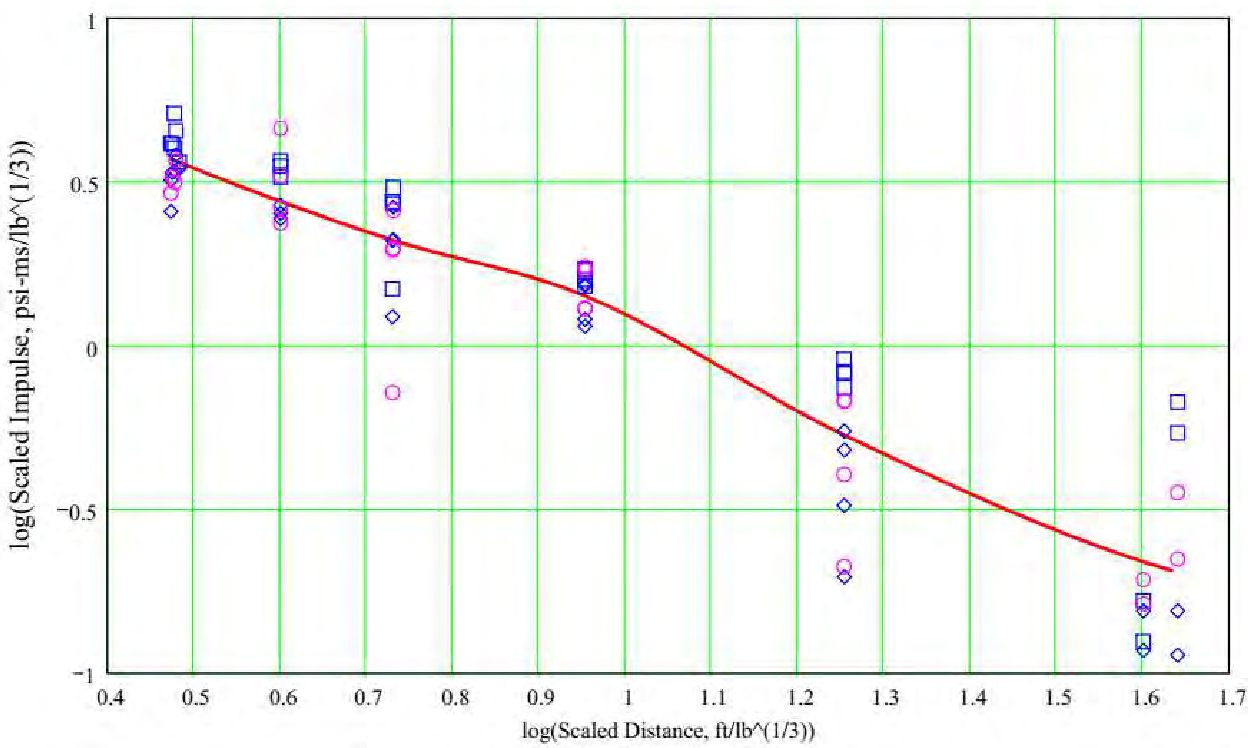


Figure 16: Filtered Peak Pressure (top) and Scaled Positive Impulse (bottom) versus Scaled Distance for Mounded Small-Scale Mix ID #48 on the Surface at Sea Level

6.10 Hemispherical Cast TNT

The tables, photos and figures in this section summarize the trials performed on hemispherical charges of cast TNT. For each trial, the hemispherical charge was placed at the center of ground zero on a steel plate. The first trial was performed in the center of a 0.5-inch-thick ceramic fiber board on a 1.5-inch-thick, 20-inch square ASTM 1020 steel plate; the plate was on a 4-inch-thick, 24-inch-square A572 Grade 50 steel base plate with the top at ground level. The second trial was performed on a 4-inch-thick, 24-inch-square A572 Grade 50 steel plate with the top at ground level. The third trial was performed on a 1.5-inch-thick, 32.5-inch x 37.75-inch A572 Grade 50 steel plate that was resting on the ground. Each trial resulted in a detonation of the TNT that produced a shock wave. The steel plate was damaged in Trials 1 and 2 and holed (perforated) in Trial 3 with a crater. For Trial 1, all holes were ruptured in the Bikini gages at Station 3 (> 12 psig). For Trials 2 and 3, the Bikini gages were moved to Station 6 (48.86 feet) for Trials 2 and 3; the largest hole was ruptured at stations A6 and B6 (2.2 - 3.0 psig).

Table 37: Test Conditions for Cast TNT

Trial	Atmospheric Conditions		Configuration	Sample N.E.W.	Initiation Train		Comments
	(K)	(inHg)		(kg)	(gm)	(%)	
1	303	29.87	Top ignition of mounded powder	8.627	21.8	0.3	Detonated
2	305	29.80	Middle ignition of mounded powder	8.645	21.8	0.3	Detonated
3	305	29.76	Bottom ignition of mounded powder	8.596	21.8	0.3	Detonated

Photo 38: Test Setup and Results for Trial 1 of Cast TNT

Photo 39: Test Setup and Results for Trial 2 of Cast TNT

Photo 40: Test Setup and Results for Trial 3 of Cast TNT

Table 38: Raw & Filtered Data Summary for Trial 1 of Hemispherical Cast TNT

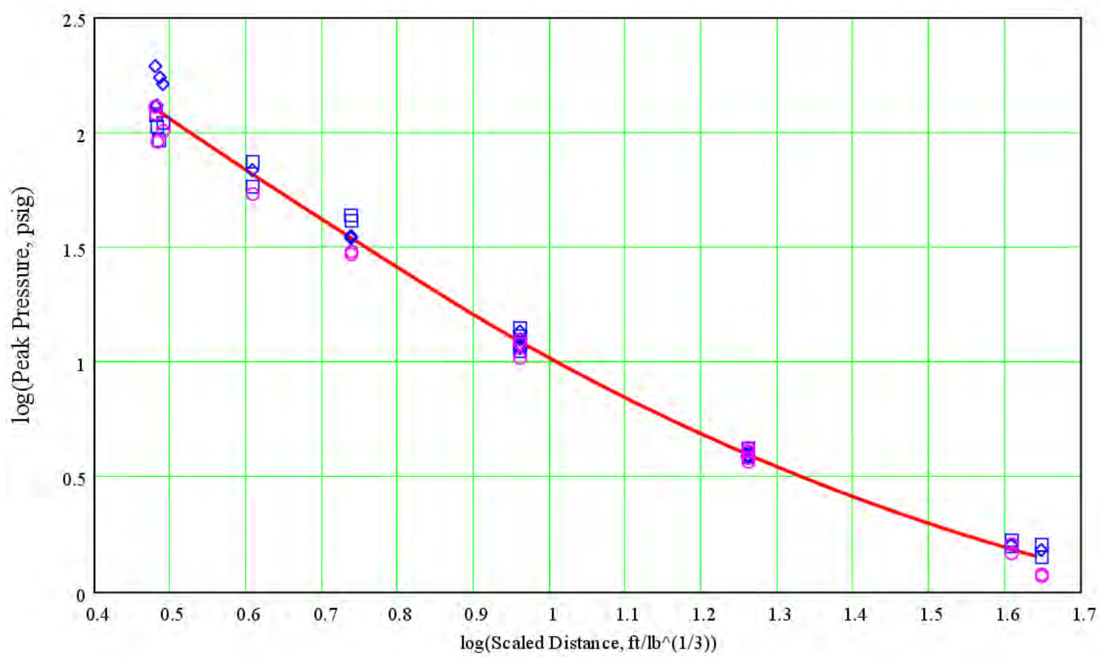
Sensor Group	Sensor Station	Sensor Position	Sensor S/N	Distance (ft)	Peak Pressure (psig)		Positive Impulse (psi-ms)	Span (V)	Sampling Rate (Hz)
					Raw	Filter			
A	1	Left	1935	8.28	110	80.5	57.2	±10	200,000
B	1	Left	1934	8.18	92.3	65.5	32.9	±10	200,000
A	2	Right	1950	8.10	119	99.3	60.7	±10	200,000
B	2	Right	1944	8.13	106	80.2	50.8	±10	200,000
A	3	Left	1940	10.86	74.5	60.5	44.3	±10	200,000
B	3	Left	1952	10.86	58.1	46.7	40.9	±10	200,000
A	4	Left	1938	14.66	41.3	32.6	33.2	±10	200,000
B	4	Left	1945	14.63	43.6	25.6	20.6	±10	200,000
A	5	Left	14442	24.45	11.8	10.0	21.2	±10	200,000
A	5	Right	14443	24.45	11.2	10.2	21.6	±10	200,000
B	5	Left	1911	24.45	13.0	11.2	20.5	±10	200,000
B	5	Right	9880	24.45	14.1	12.3	23.3	±10	200,000
A	6	Left	13381	48.86	3.91	3.25	9.00	±10	200,000
A	6	Right	13380	48.86	3.86	3.33	11.2	±10	200,000
B	6	Left	13374	48.85	4.20	3.35	10.7	±10	200,000
B	6	Right	1913	48.85	3.97	3.13	9.88	±10	200,000
A	7	Left	14360	118.96	1.42	1.12	5.37	±10	200,000
A	7	Right	13268	118.96	1.61	1.32	8.58	±10	200,000
B	7	Left	9882	108.58	1.58	1.25	5.88	±10	200,000
B	7	Right	9883	108.58	1.68	1.41	9.50	±10	200,000

Table 39: Raw & Filtered Data Summary for Trial 2 of Hemispherical Cast TNT

Sensor Group	Sensor Station	Sensor Position	Sensor S/N	Distance (ft)	Peak Pressure (psig)		Positive Impulse (psi-ms)	Span (V)	Sampling Rate (Hz)
					Raw	Filter			
A	1	Left	1935	8.28	162	127	66.7	±10	200,000
B	1	Right	9814	8.21	173	123	74.2	±10	200,000
A	2	Left	1908	8.09	194	131	74.6	±10	200,000
A	2	Right	1950	8.10	130	92.7	60.0	±10	200,000
B	2	Right	1944	8.13	131	83.3	58.4	±10	200,000
A	3	Left	1940	10.86	68.4	60.1	48.4	±10	200,000
A	4	Left	1938	14.66	34.6	31.7	33.6	±10	200,000
A	4	Right	1937	14.66	35.4	30.9	30.8	±10	200,000
A	5	Left	14442	24.45	11.9	9.94	20.0	±10	200,000
A	5	Right	14443	24.45	11.5	10.4	20.6	±10	200,000
B	5	Left	1911	24.45	12.6	10.6	20.2	±10	200,000
B	5	Right	9880	24.45	13.6	11.7	22.7	±10	200,000
A	6	Left	13381	48.86	3.92	3.20	8.42	±10	200,000
A	6	Right	13380	48.86	3.88	3.31	10.4	±10	200,000
B	6	Left	13374	48.85	4.11	3.28	11.2	±10	200,000
B	6	Right	1913	48.85	3.83	3.05	11.0	±10	200,000
A	7	Right	13268	118.96	1.52	1.21	5.28	±10	200,000
B	7	Right	9883	108.58	1.60	1.33	7.41	±10	200,000

Table 40: Raw & Filtered Data Summary for Trial 3 of Hemispherical Cast TNT

Sensor Group	Sensor Station	Sensor Position	Sensor S/N	Distance (ft)	Peak Pressure (psig)		Positive Impulse (psi-ms)	Span (V)	Sampling Rate (Hz)
					Raw	Filter			
A	1	Left	1935	8.28	101	84.8	70.4	±10	200,000
A	2	Left	1908	8.09	129	71.6	46.4	±10	200,000
A	2	Right	1950	8.10	120	74.9	47.4	±10	200,000
B	2	Right	1944	8.13	90.8	76.0	33.5	±10	200,000
A	3	Right	1936	10.86	53.8	46.1	28.4	±10	200,000
A	4	Left	1938	14.66	30.2	26.5	31.4	±10	200,000
A	4	Right	1937	14.66	29.4	25.5	28.1	±10	200,000
A	5	Right	14443	24.45	10.4	9.59	20.4	±10	200,000
B	5	Left	1911	24.45	12.0	10.4	21.0	±10	200,000
B	5	Right	9880	24.45	12.5	11.0	23.2	±10	200,000
A	6	Left	13381	48.86	3.68	3.03	8.63	±10	200,000
A	6	Right	13380	48.86	3.83	3.18	12.4	±10	200,000
B	6	Left	13374	48.85	4.23	3.32	11.4	±10	200,000
B	6	Right	1913	48.85	4.07	3.15	10.7	±10	200,000
A	7	Left	14360	118.96	1.19	1.03	4.13	±10	200,000
A	7	Right	13268	118.96	1.17	1.07	3.55	±10	200,000
B	7	Left	9882	108.58	1.61	1.18	7.11	±10	200,000
B	7	Right	9883	108.58	1.47	1.13	6.78	±10	200,000



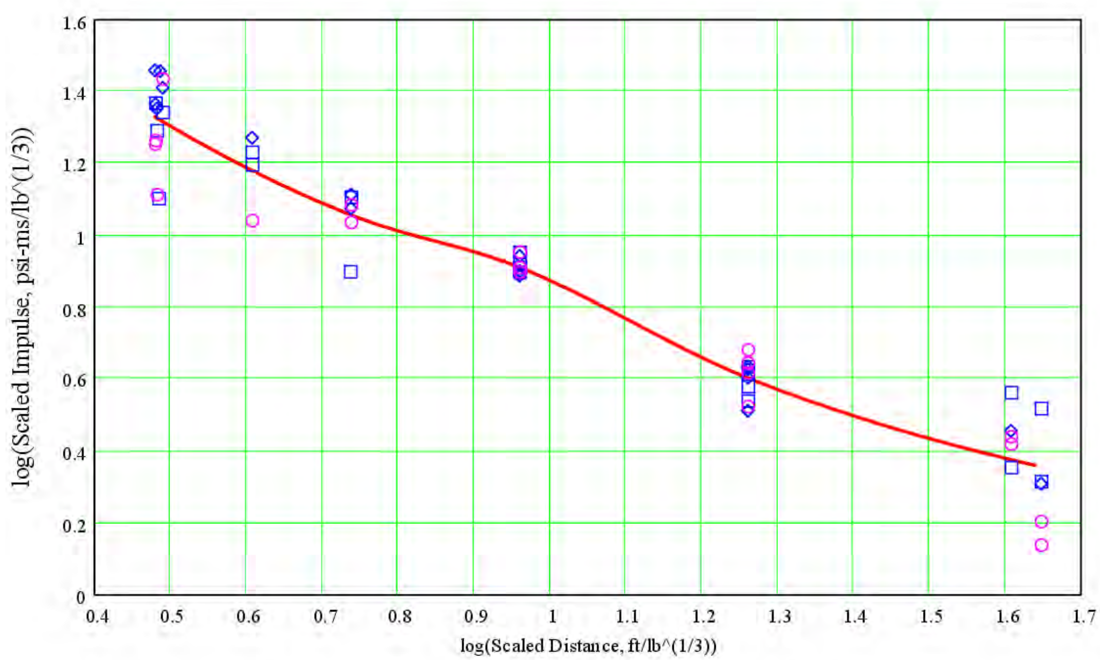


Figure 17: Raw Peak Pressure (top) and Scaled Positive Impulse (bottom) versus Scaled Distance for Hemispherical Cast TNT on the Surface at Sea Level

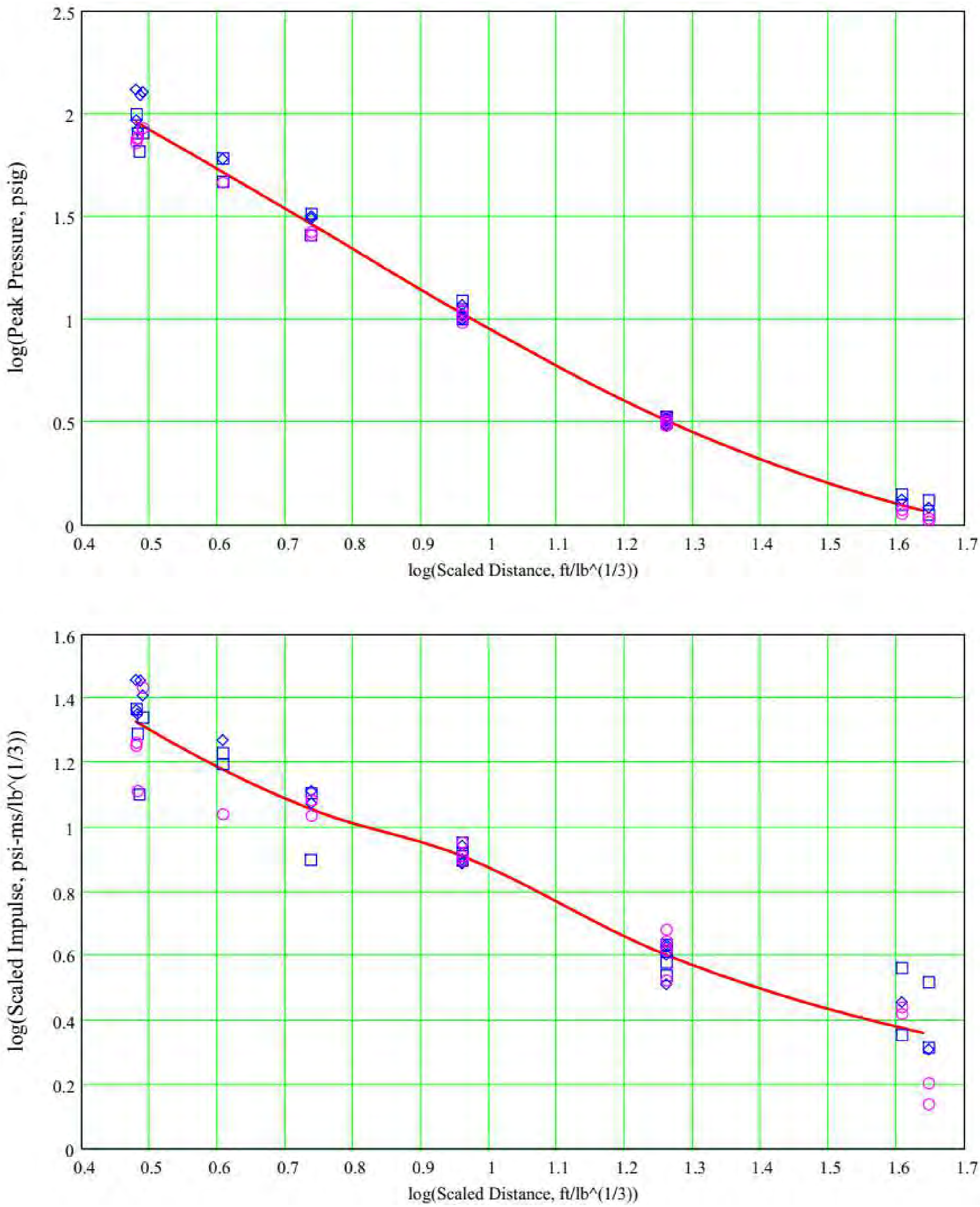


Figure 18: Filtered Peak Pressure (top) and Scaled Positive Impulse (bottom) versus Scaled Distance for Hemispherical Cast TNT on the Surface at Sea Level

7.0 REFERENCES

(1) Unified Facilities Criteria (UFC) 3-340-02, *Structures to Resist the Effects of Accidental Explosions*, 5 December 2008.

(2) Kingery, C. N. and Bulmash, G., *Airblast Parameters from TNT Spherical Air Burst and Hemispherical Burst*, ARBRL-TR-02555, April 1984 (AD B082713) Defense Technical Information Center, Fort Belvoir, VA.

(3) Joint Technical Bulletin (TB) 700-2, NAVSEAINST 8020.8C, TO 11A-1-47, *Department of Defense Ammunition and Explosives Hazard Classification Procedures*, 30 July 2012.

(4) Swatosh, J.J., et al., *Blast Parameters of Lead Styphnate, Lead Azide, and Tetracene*, Technical Report 4900, IIT Research Institute, December 1975.

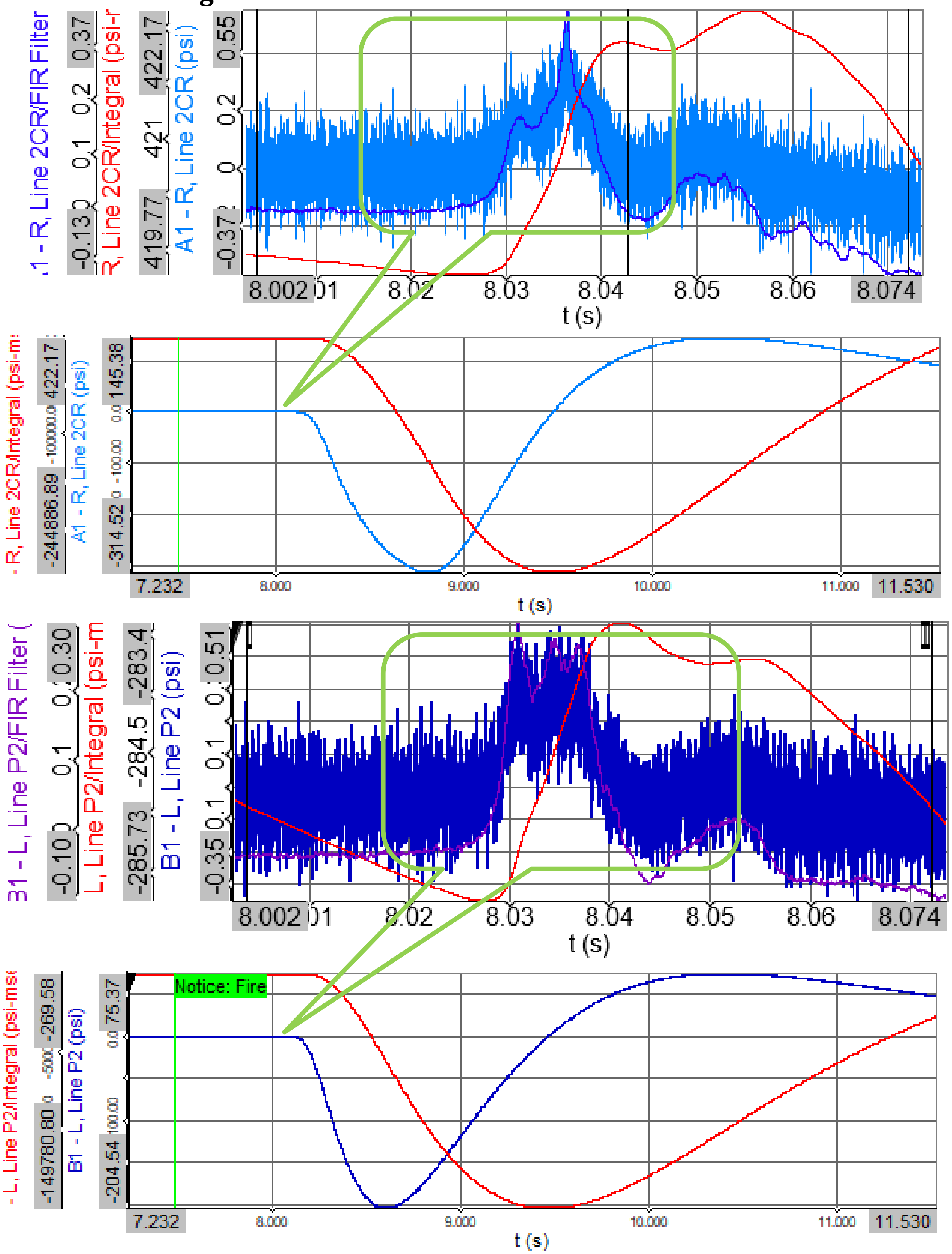
(5) McIntyre, F.L., *Compilation of Blast Parameters of Selected High Explosives, Propellants, and Pyrotechnics in Surface Burst Configurations*, U.S. Army Armament Research Development and Engineering Command (AMCCOM) Contractor Report for Contract No. NAS 13-290, January 1987.

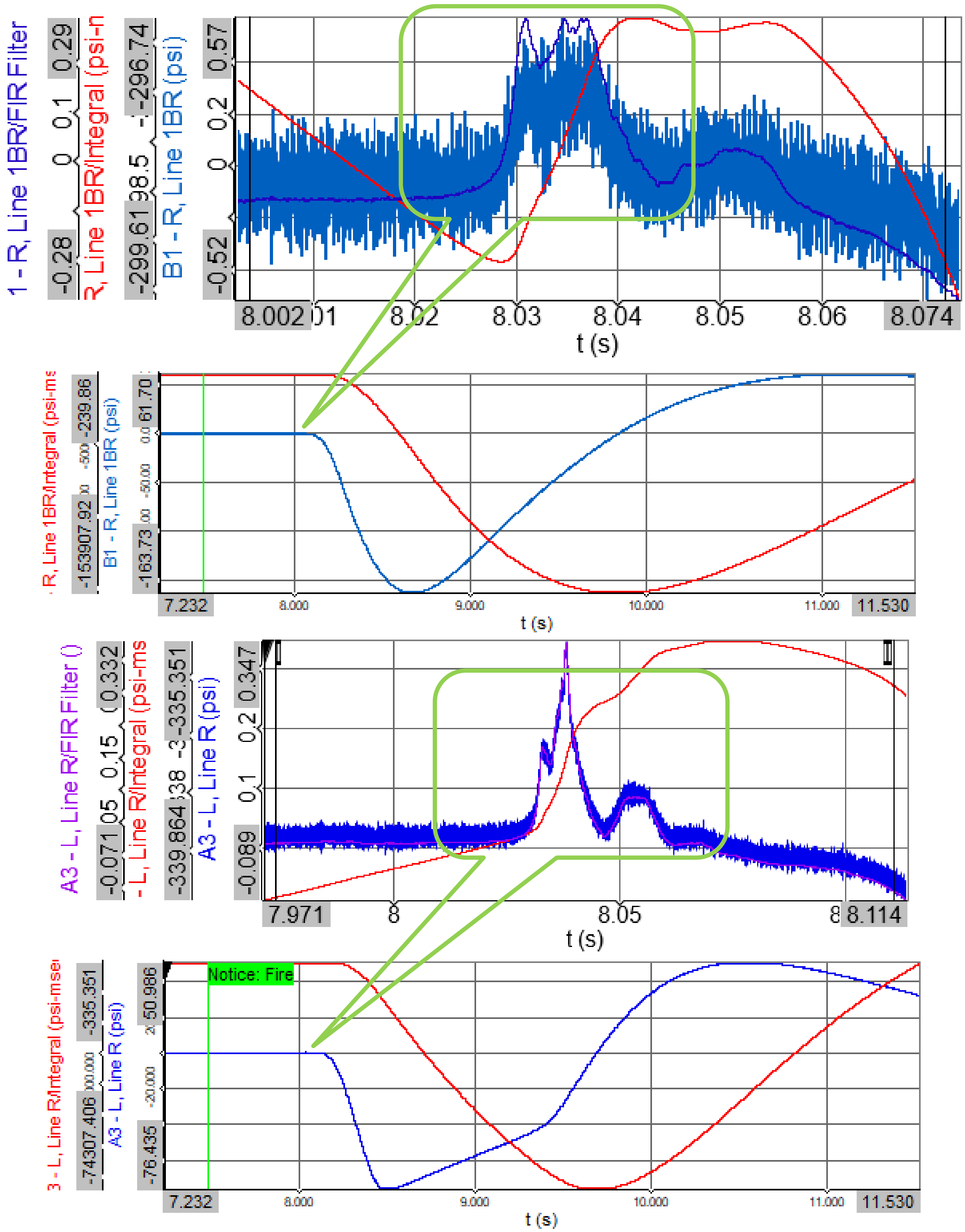
APPENDIX

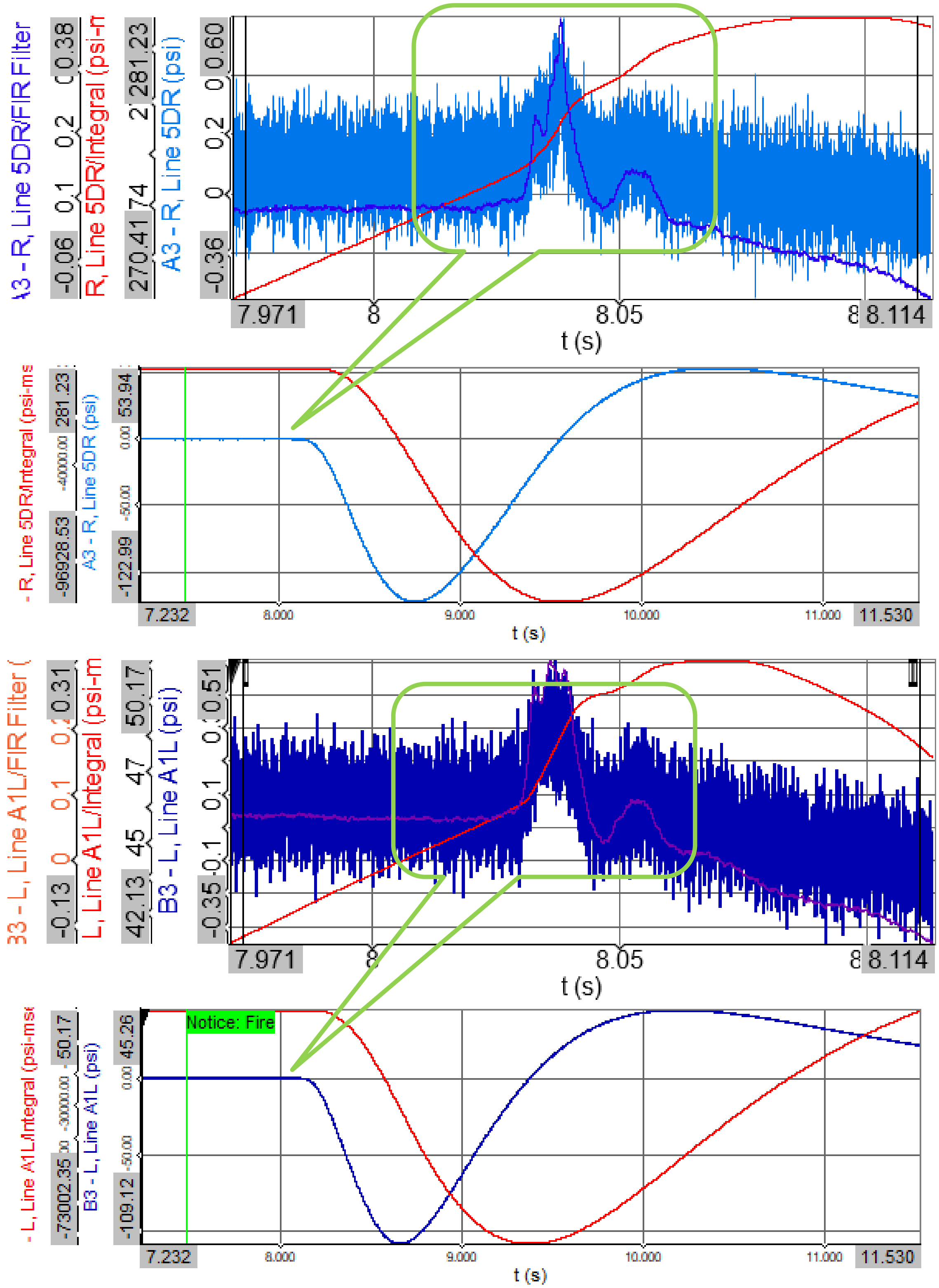
8.0 BLAST WAVEFORMS

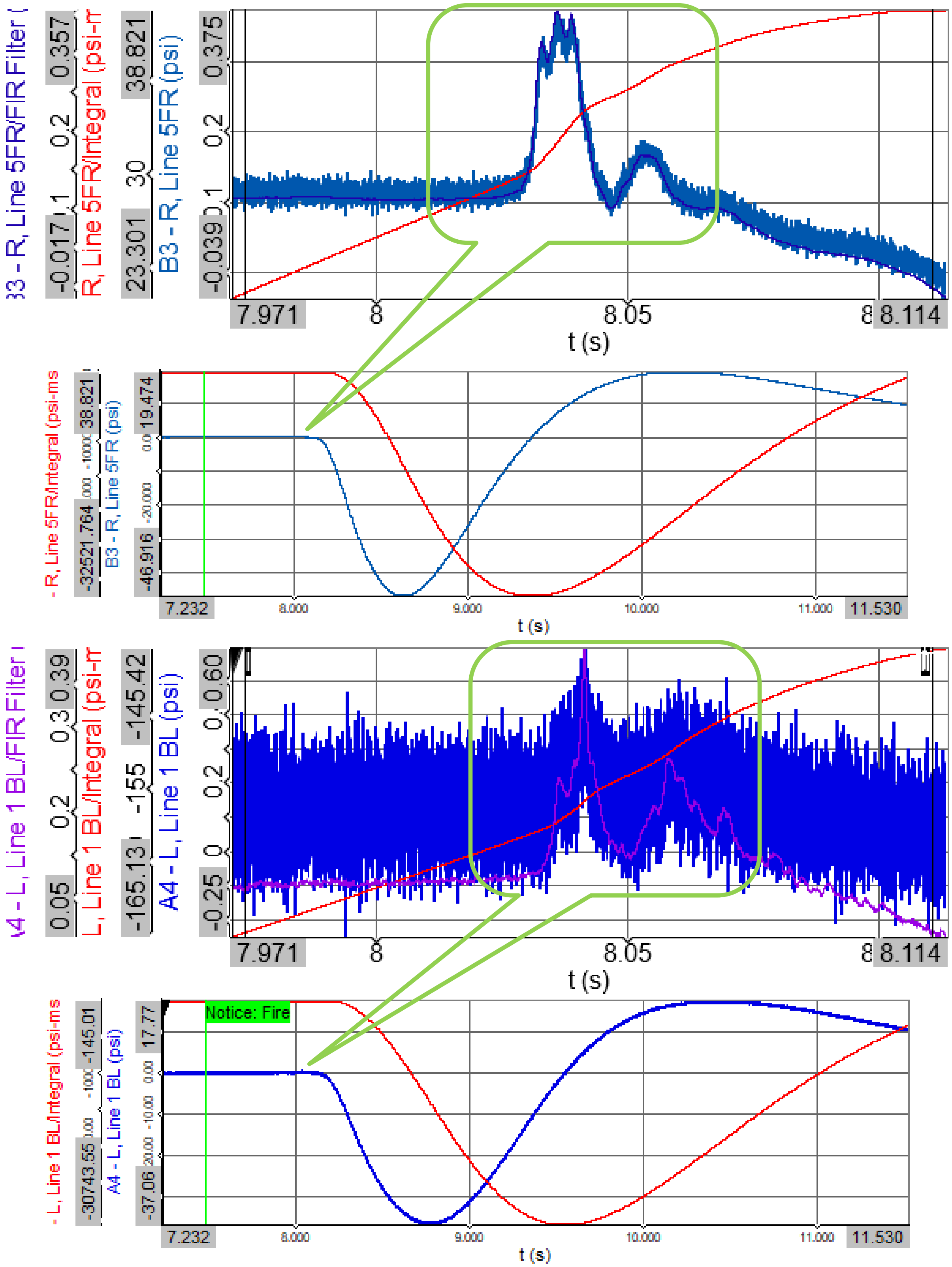
8.1 Fine Al-MnO_2 Thermite – Large-Scale Mix ID #7 (SMS mixed)

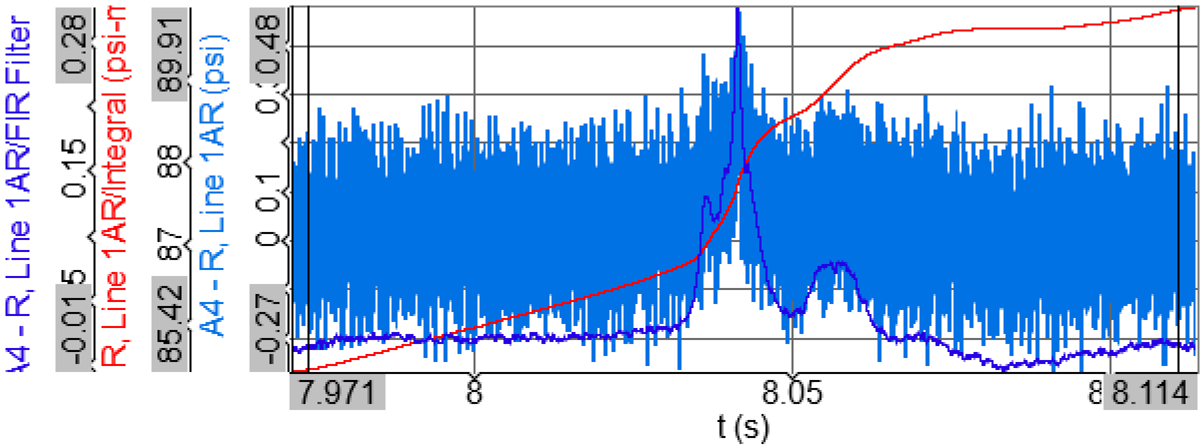
8.1.1 Trial 1 for Large-Scale Mix ID #7

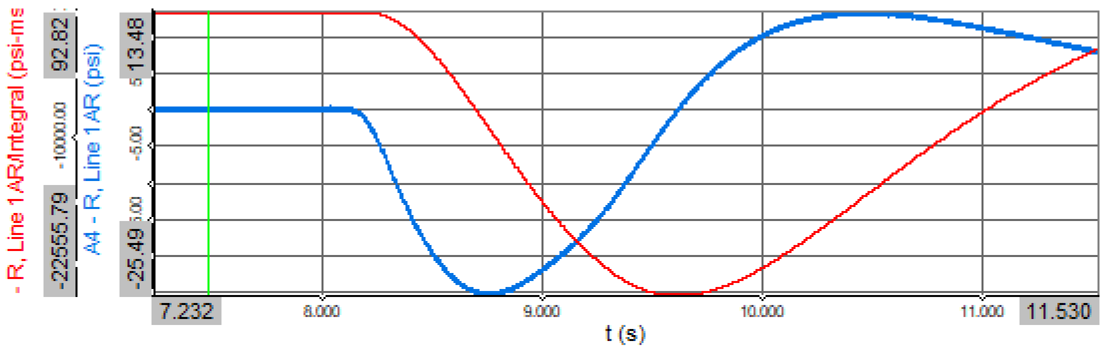


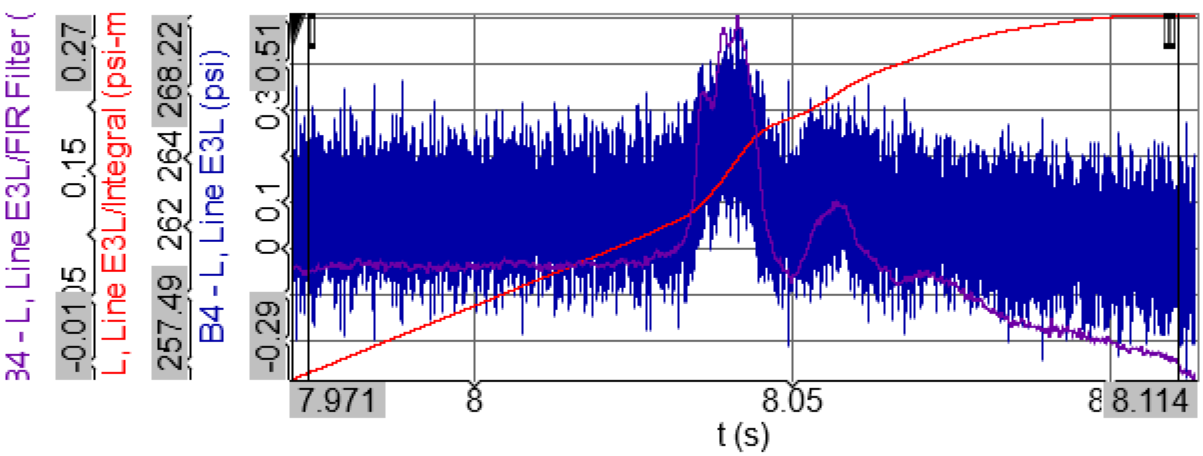

1 - R, Line 1BR/FIR Filter
R, Line 1BR/Integral (psi-n
B1 - R, Line 1BR (psi)
0.29
0.1
0
-0.28
-296.74
98.5
-299.61
0.57
0.2
0
-0.52
8.002
8.02
8.03
8.04
8.05
8.06
8.074
t (s)
R, Line 1BR/Integral (psi-ms
B1 - R, Line 1BR (psi)
-239.86
-153907.92
61.70
-163.73
7.232
8.000
9.000
10.000
11.000
11.530
t (s)
A3 - L, Line R/FIR Filter ()
L, Line R/Integral (psi-ms
A3 - L, Line R (psi)
0.332
0.15
-0.071
-335.351
-339.864
0.347
0.2
0.1
-0.089
7.971
8
8.05
8.114
t (s)
3 - L, Line R/Integral (psi-mse
A3 - L, Line R (psi)
-335.351
-74307.406
50.986
-76.435
Notice: Fire
7.232
8.000
9.000
10.000
11.000
11.530
t (s)

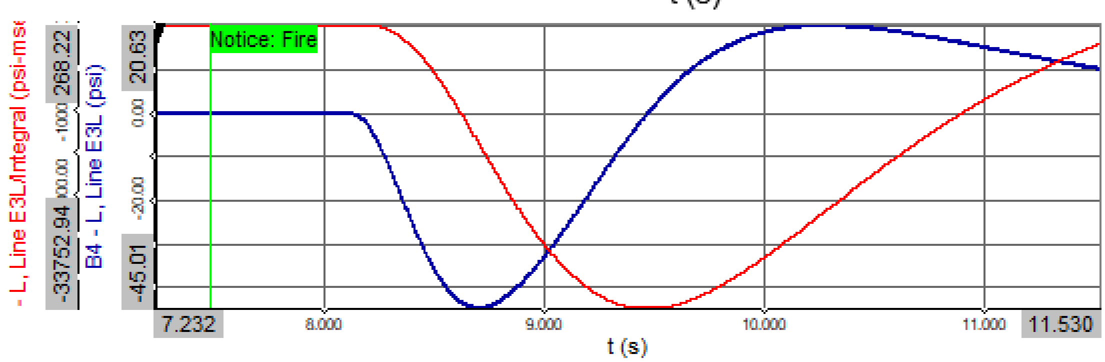

A3 - R, Line 5DR/FIR Filter
R, Line 5DR/Integral (psi-m
A3 - R, Line 5DR (psi)
7.971
8
8.05
8.114
t (s)
- R, Line 5DR/Integral (psi-ms
A3 - R, Line 5DR (psi)
7.232
8.000
9.000
10.000
11.000
11.530
t (s)
B3 - L, Line A1L/FIR Filter (
L, Line A1L/Integral (psi-m
B3 - L, Line A1L (psi)
7.971
8
8.05
8.114
t (s)
- L, Line A1L/Integral (psi-ms
B3 - L, Line A1L (psi)
Notice: Fire
7.232
8.000
9.000
10.000
11.000
11.530
t (s)

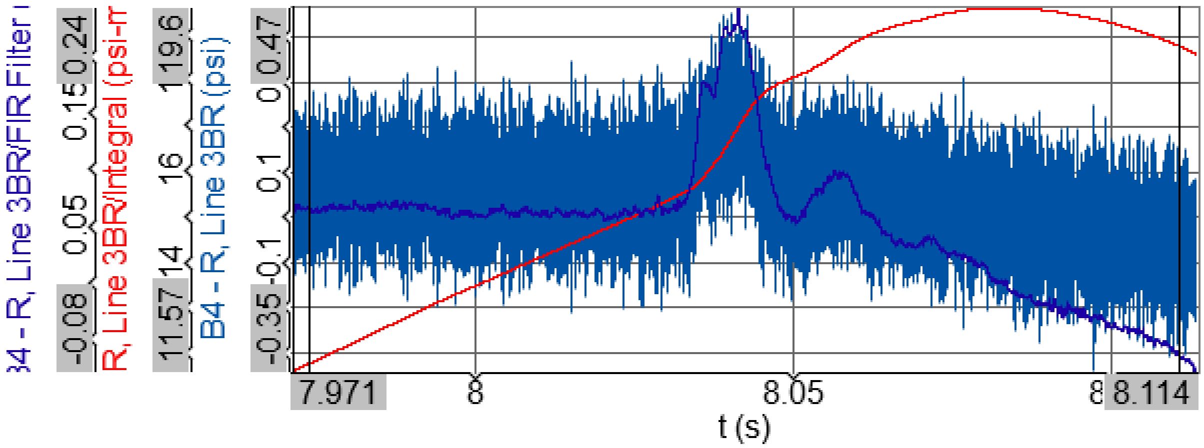

B3 - R, Line 5FR/FIR Filter (
R, Line 5FR/Integral (psi-m
B3 - R, Line 5FR (psi)
7.971
8
8.05
8.114
t (s)
- R, Line 5FR/Integral (psi-ms
B3 - R, Line 5FR (psi)
7.232
8.000
9.000
10.000
11.000
11.530
t (s)
A4 - L, Line 1 BL/FIR Filter (
L, Line 1 BL/Integral (psi-m
A4 - L, Line 1 BL (psi)
7.971
8
8.05
8.114
t (s)
- L, Line 1 BL/Integral (psi-ms
A4 - L, Line 1 BL (psi)
Notice: Fire
7.232
8.000
9.000
10.000
11.000
11.530
t (s)

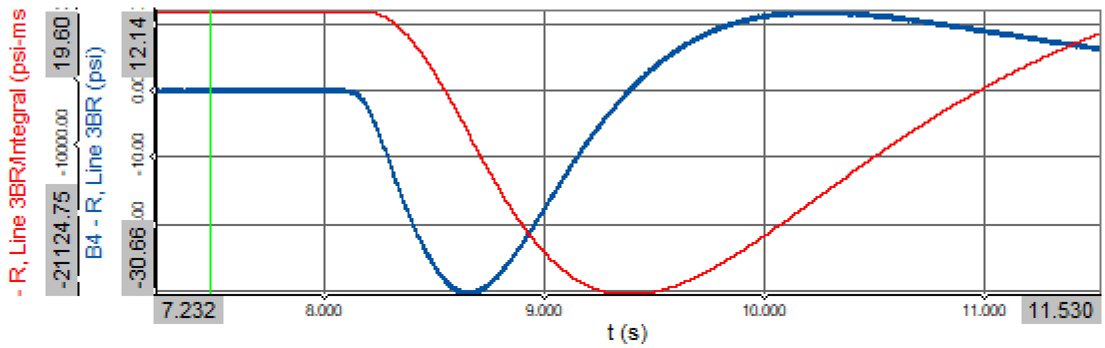

A4 - R, Line 1AR/FIR Filter
R, Line 1AR/Integral (psi-m
A4 - R, Line 1AR (psi)
7.971
8
8.05
8.114
t (s)

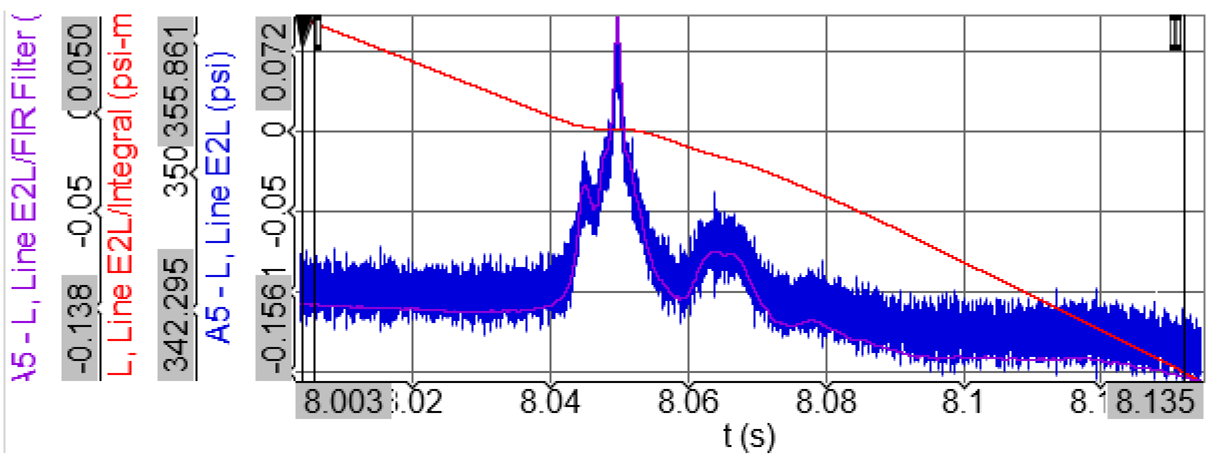

- R, Line 1AR/Integral (psi-ms
A4 - R, Line 1AR (psi)
7.232
8.000
9.000
10.000
11.000
11.530
t (s)

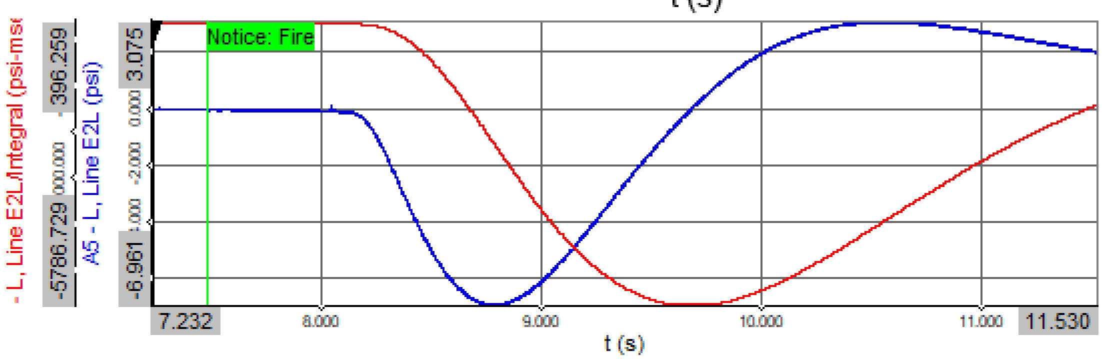

B4 - L, Line E3L/FIR Filter (
L, Line E3L/Integral (psi-m
B4 - L, Line E3L (psi)
7.971
8
8.05
8.114
t (s)

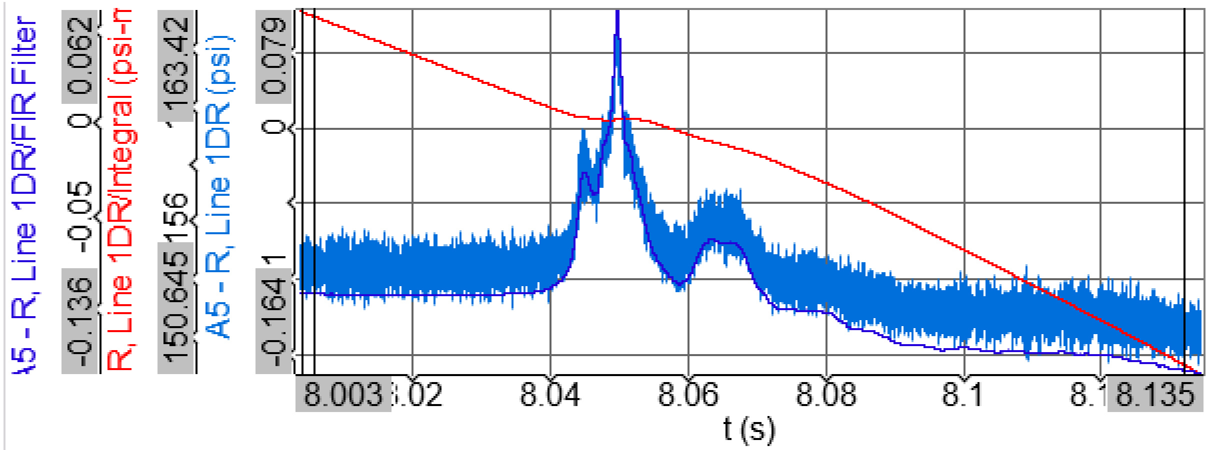

- L, Line E3L/Integral (psi-ms
B4 - L, Line E3L (psi)
Notice: Fire
7.232
8.000
9.000
10.000
11.000
11.530
t (s)

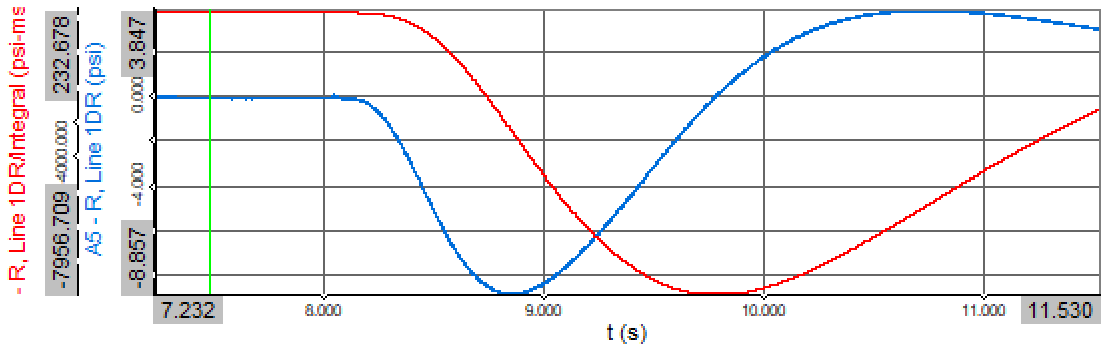

B4 - R, Line 3BR/FIR Filter
R, Line 3BR/Integral (psi-m
B4 - R, Line 3BR (psi)
7.971
8
8.05
8.114
t (s)

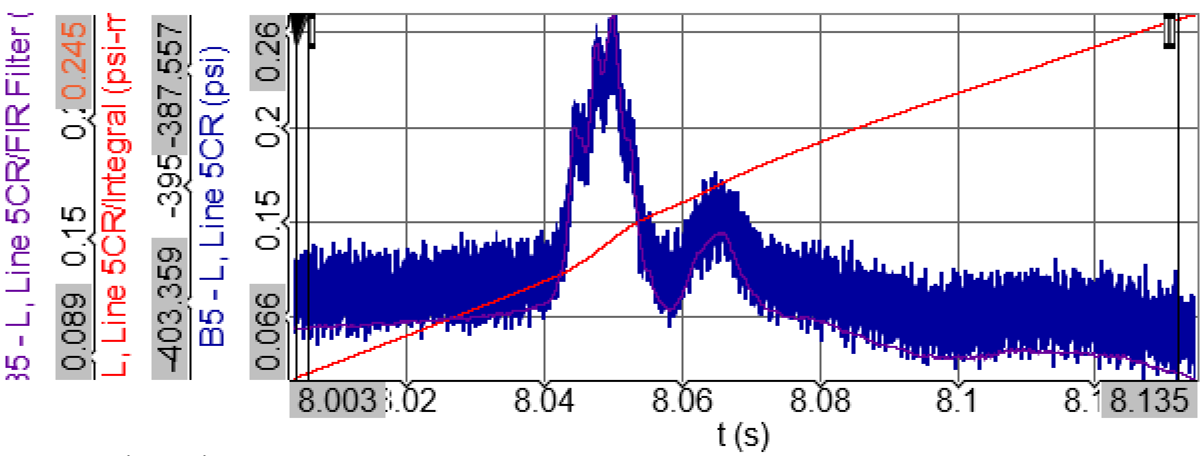

- R, Line 3BR/Integral (psi-ms
B4 - R, Line 3BR (psi)
7.232
8.000
9.000
10.000
11.000
11.530
t (s)

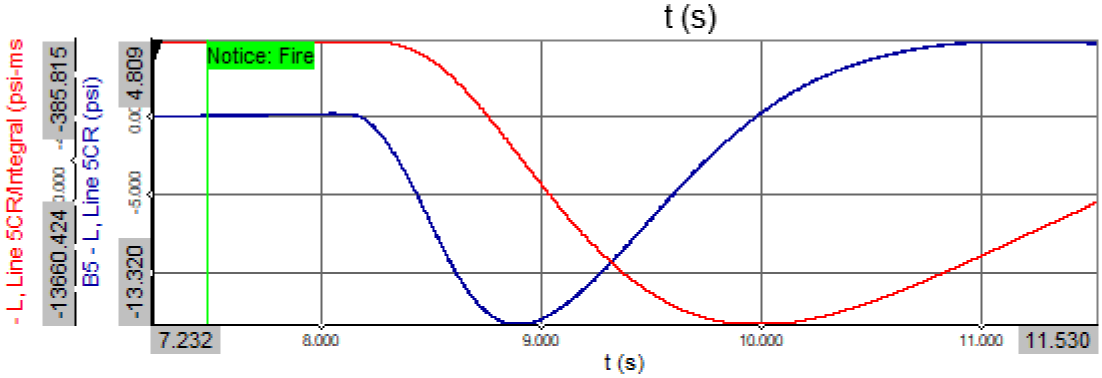

A5 - L, Line E2L/FIR Filter
L, Line E2L/Integral (psi-m
A5 - L, Line E2L (psi)
8.003
8.04
8.06
8.08
8.1
8.135
t (s)

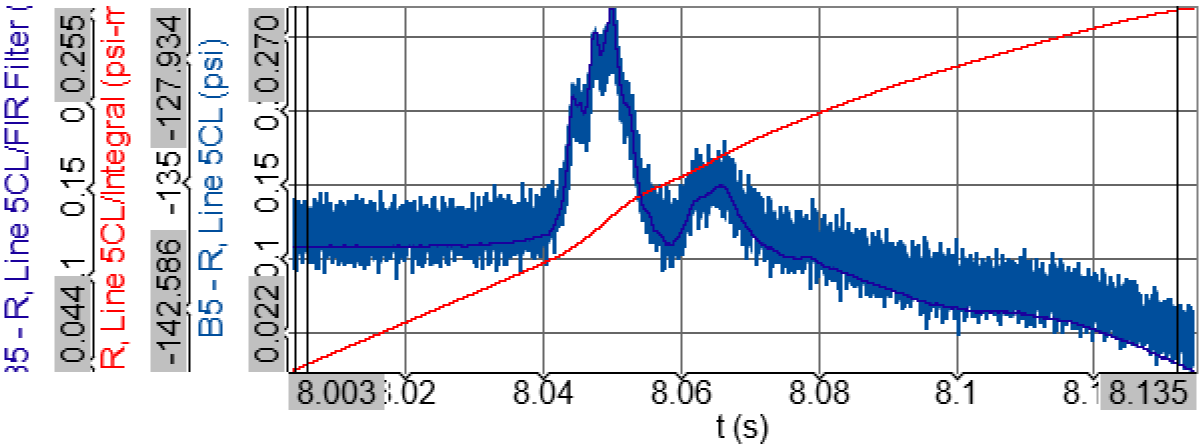

Notice: Fire
- L, Line E2L/Integral (psi-ms
A5 - L, Line E2L (psi)
7.232
8.000
9.000
10.000
11.000
11.530
t (s)

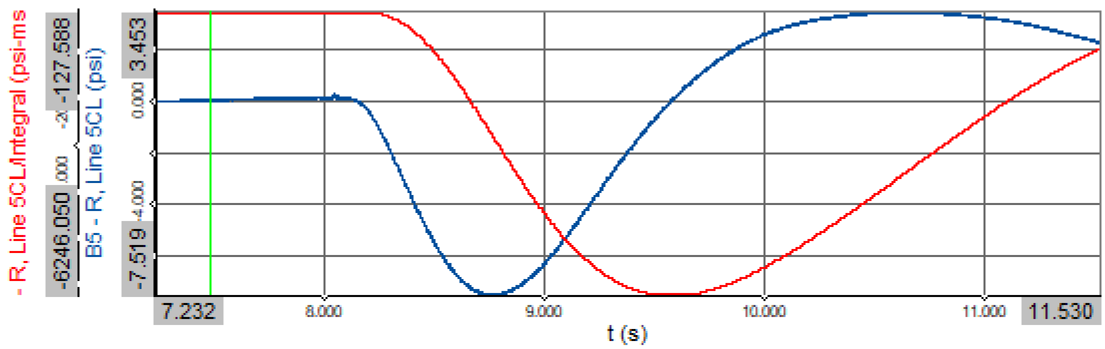

A5 - R, Line 1DR/FIR Filter
R, Line 1DR/Integral (psi-m
A5 - R, Line 1DR (psi)
-0.136 -0.05 0 0.062
150.645 156 163.42
-0.164 0 0.079
8.003 8.04 8.06 8.08 8.1 8.135
t (s)

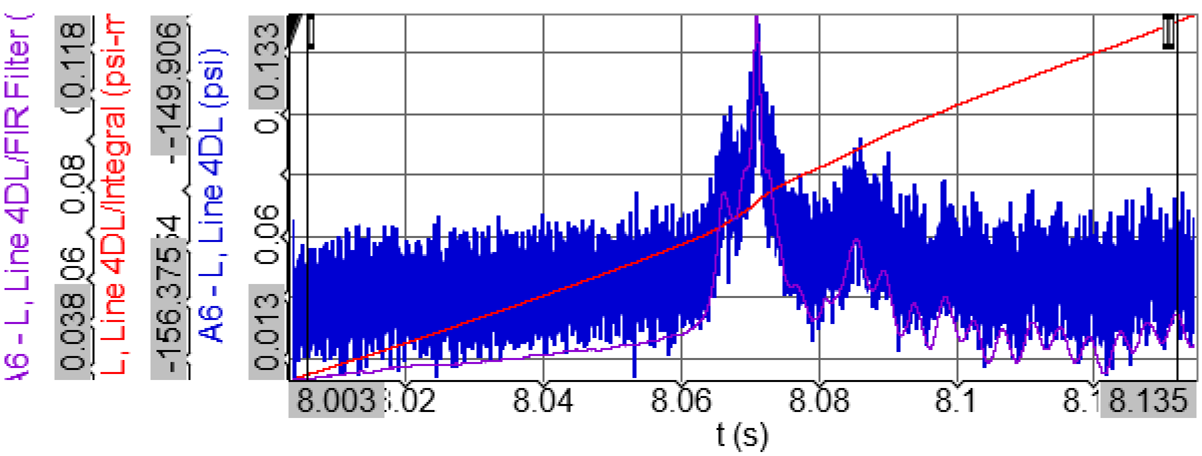

- R, Line 1DR/Integral (psi-ms
A5 - R, Line 1DR (psi)
-7956.709 232.678
-8.857 3.847
7.232 8.000 9.000 10.000 11.000 11.530
t (s)

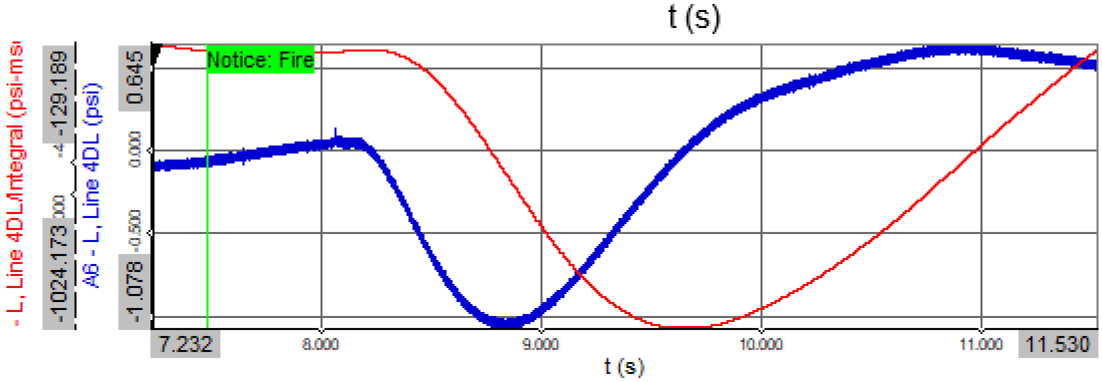

B5 - L, Line 5CR/FIR Filter (
L, Line 5CR/Integral (psi-m
B5 - L, Line 5CR (psi)
0.089 0.15 0.245
-403.359 -395 -387.557
0.066 0.15 0.2 0.26
8.003 8.04 8.06 8.08 8.1 8.135
t (s)

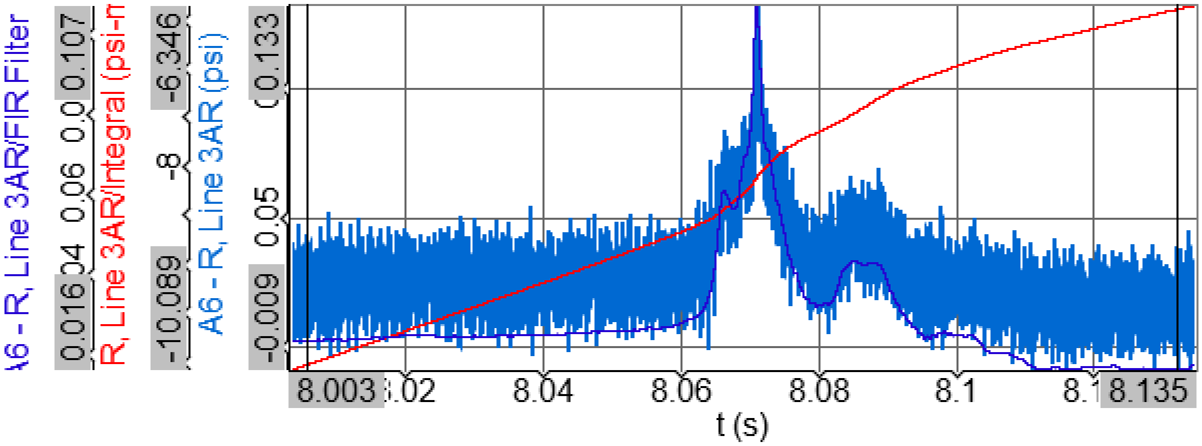

Notice: Fire
- L, Line 5CR/Integral (psi-ms
B5 - L, Line 5CR (psi)
-13660.424 -385.815
-13.320 -5.000 4.809
7.232 8.000 9.000 10.000 11.000 11.530
t (s)

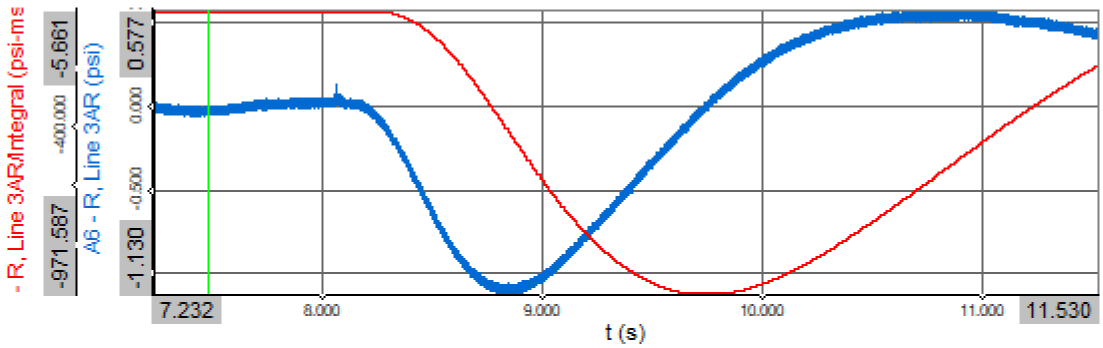

B5 - R, Line 5CL (psi)
R, Line 5CL/Integral (psi-m
B5 - R, Line 5CL/FIR Filter (
8.003
8.04
8.06
8.08
8.1
8.135
t (s)

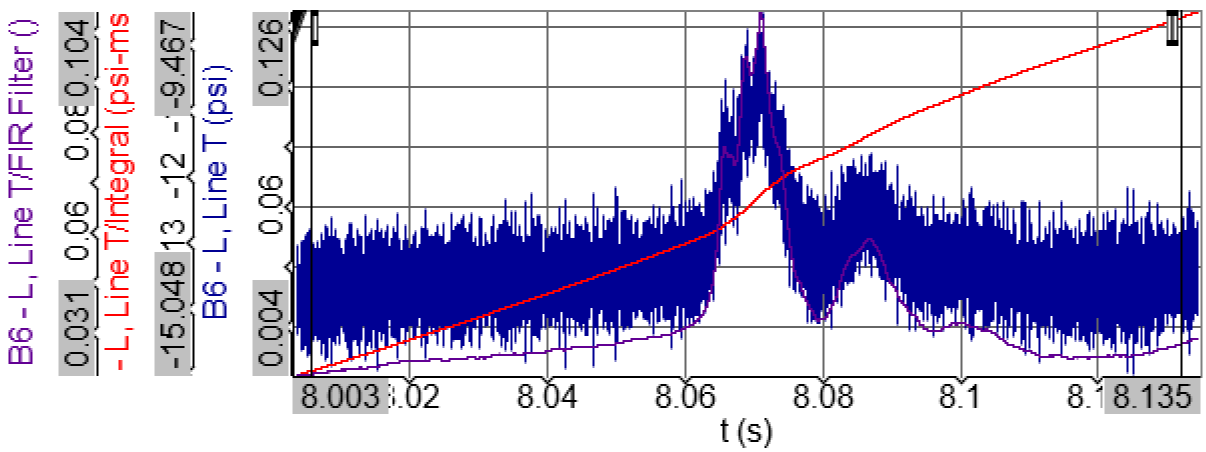

B5 - R, Line 5CL (psi)
- R, Line 5CL/Integral (psi-ms
3.453
-7.519
-127.588
-6246.050
7.232
8.000
9.000
10.000
11.000
11.530
t (s)

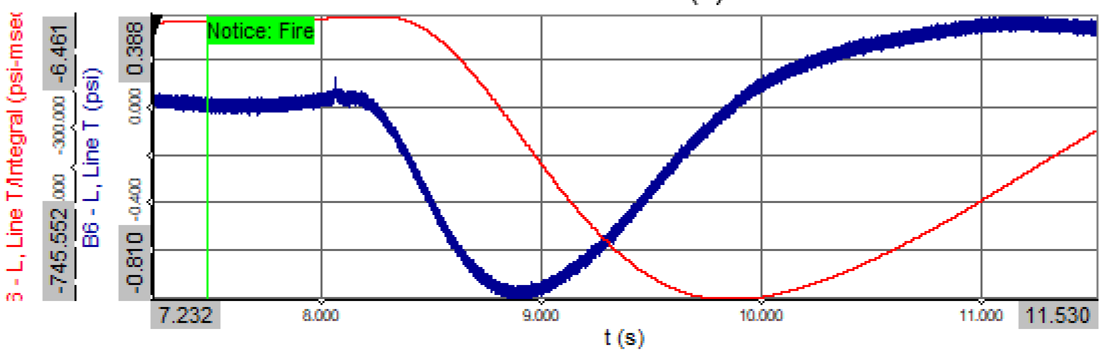

A6 - L, Line 4DL (psi)
L, Line 4DL/Integral (psi-m
A6 - L, Line 4DL/FIR Filter (
8.003
8.04
8.06
8.08
8.1
8.135
t (s)

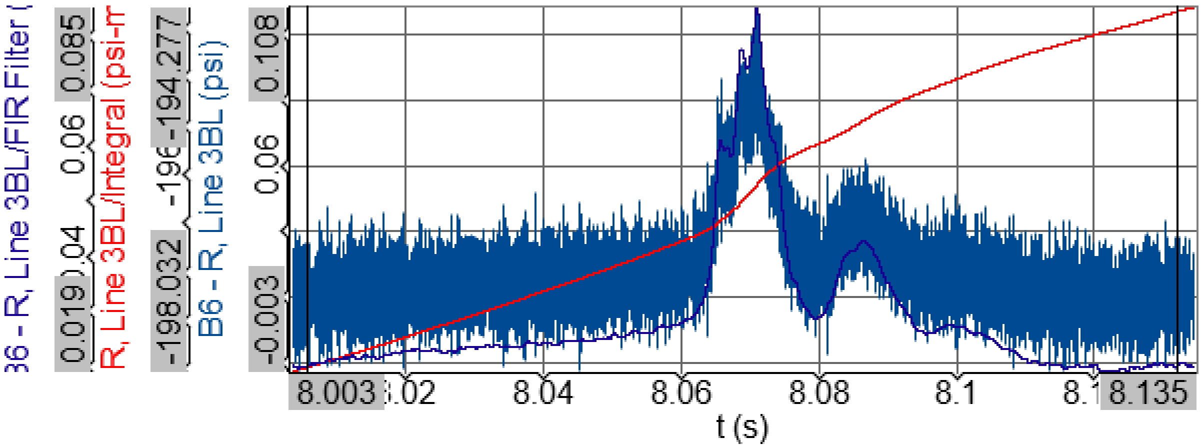

Notice: Fire
A6 - L, Line 4DL (psi)
- L, Line 4DL/Integral (psi-ms
0.645
-1.078
-129.189
-1024.173
7.232
8.000
9.000
10.000
11.000
11.530
t (s)

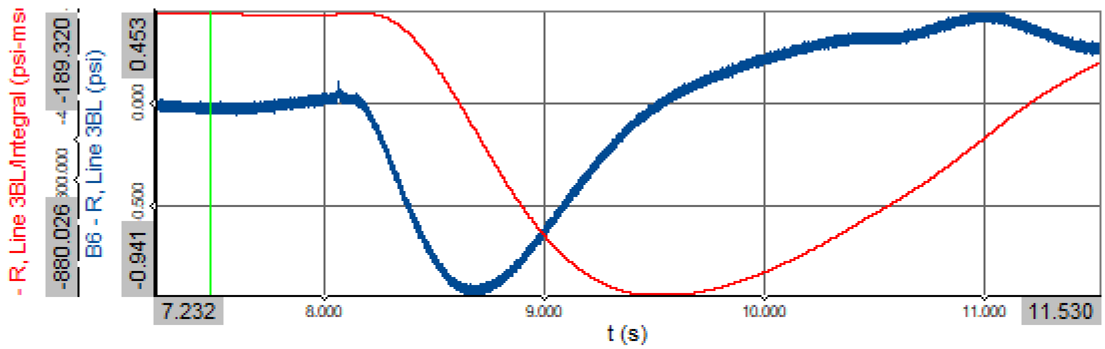

A6 - R, Line 3AR/FIR Filter
R, Line 3AR/Integral (psi-m
A6 - R, Line 3AR (psi)
t (s)

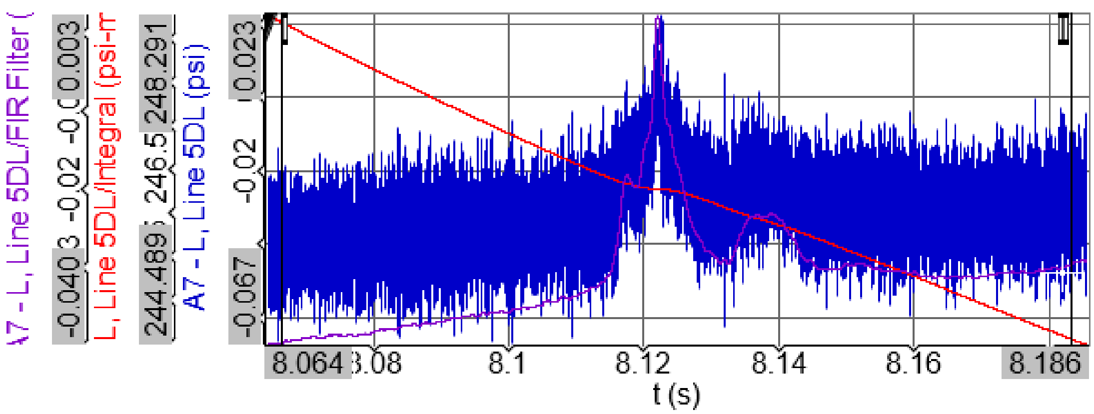

- R, Line 3AR/Integral (psi-ms
A6 - R, Line 3AR (psi)
t (s)

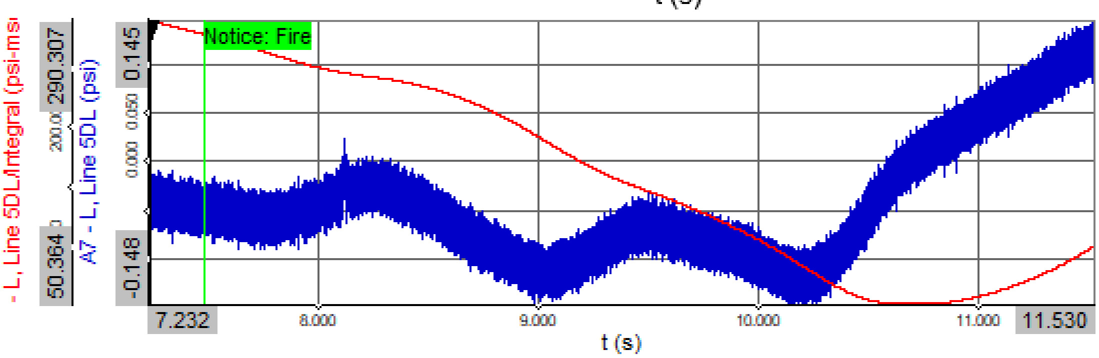

B6 - L, Line T/FIR Filter ()
- L, Line T/Integral (psi-ms
B6 - L, Line T (psi)
t (s)

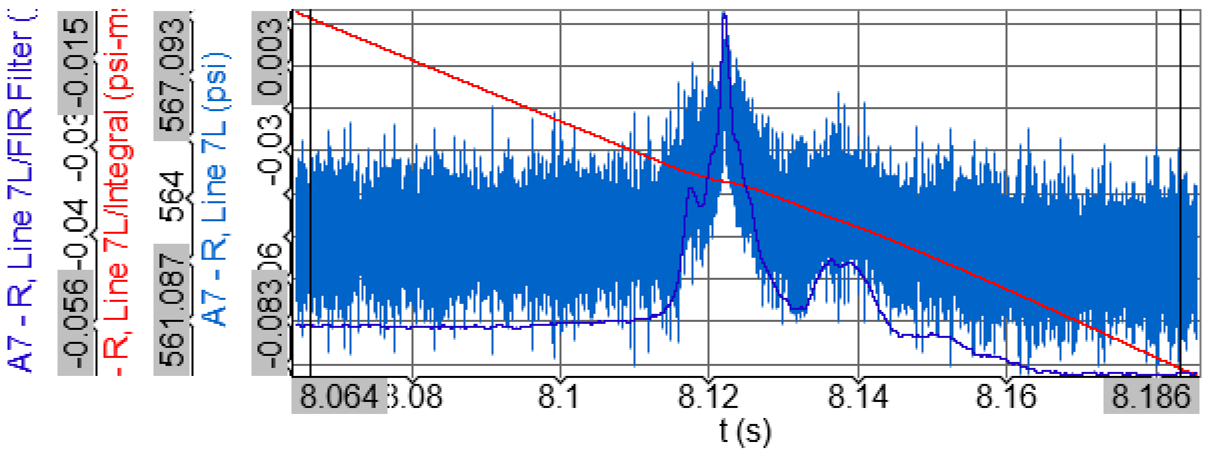

- L, Line T/Integral (psi-msec
B6 - L, Line T (psi)
Notice: Fire
t (s)

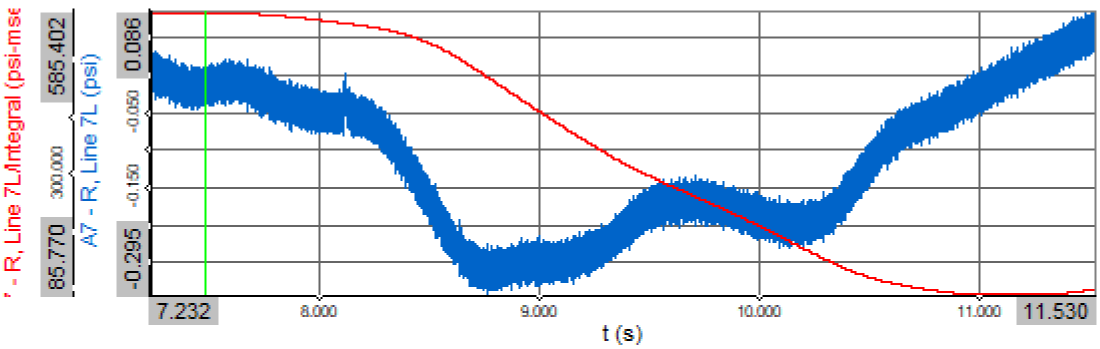

B6 - R, Line 3BL (psi)
R, Line 3BL/Integral (psi-m
t (s)
8.003
8.04
8.06
8.08
8.1
8.135

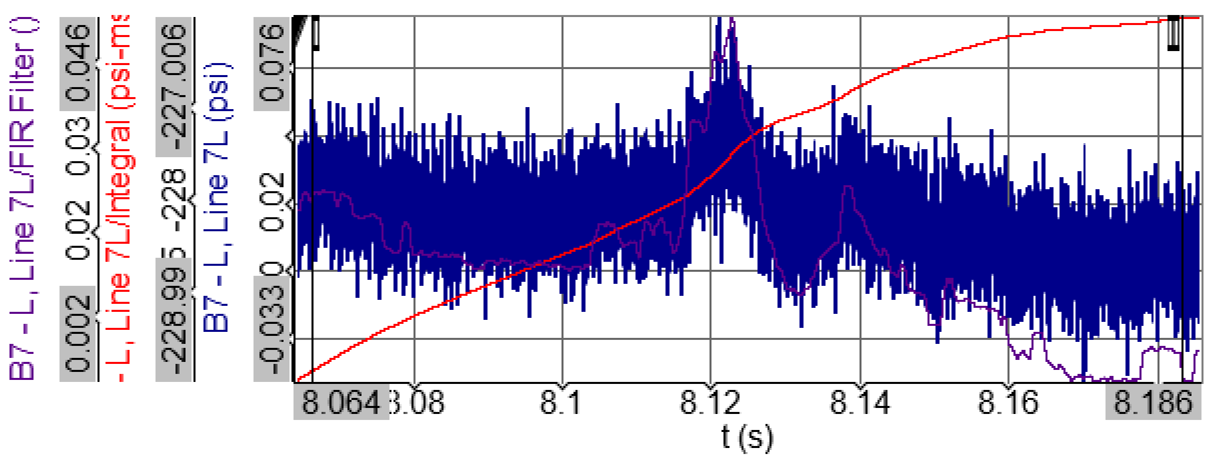

B6 - R, Line 3BL (psi)
R, Line 3BL/Integral (psi-ms
t (s)
7.232
8.000
9.000
10.000
11.000
11.530

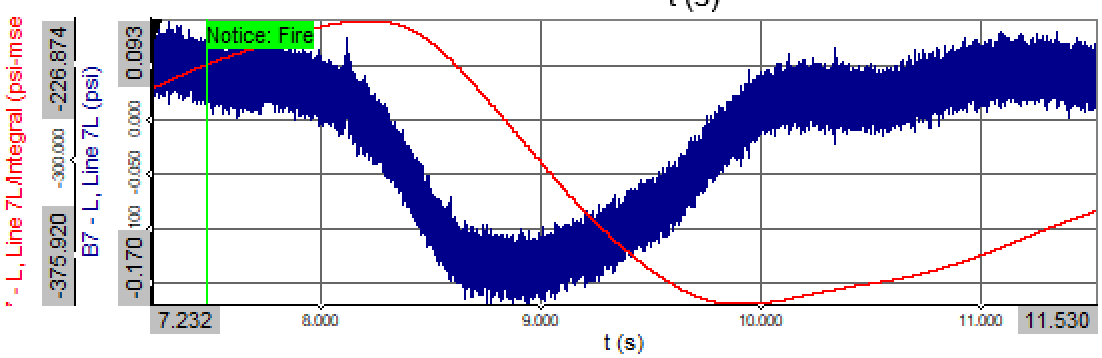

A7 - L, Line 5DL (psi)
L, Line 5DL/Integral (psi-m
A7 - L, Line 5DL/FIR Filter (
t (s)
8.064
8.1
8.12
8.14
8.16
8.186

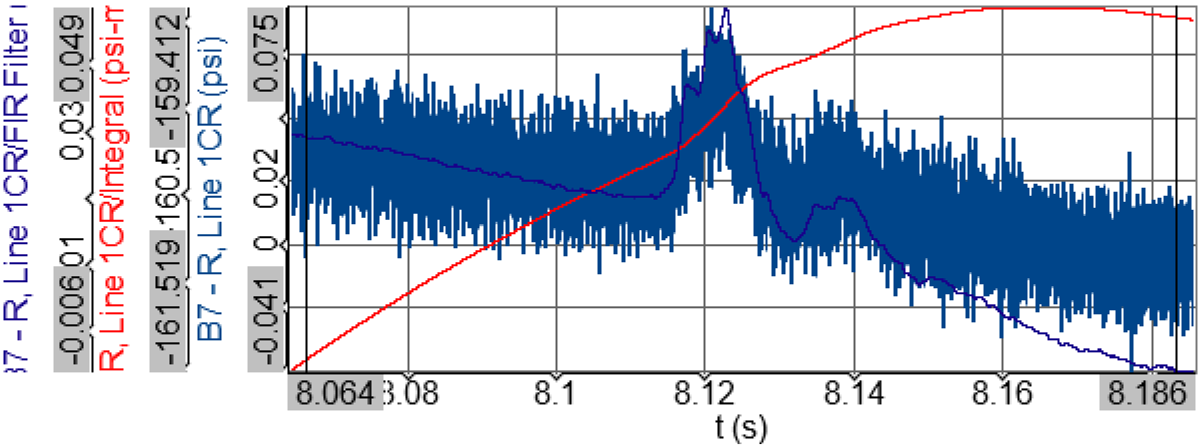

Notice: Fire
A7 - L, Line 5DL (psi)
L, Line 5DL/Integral (psi-ms
t (s)
7.232
8.000
9.000
10.000
11.000
11.530

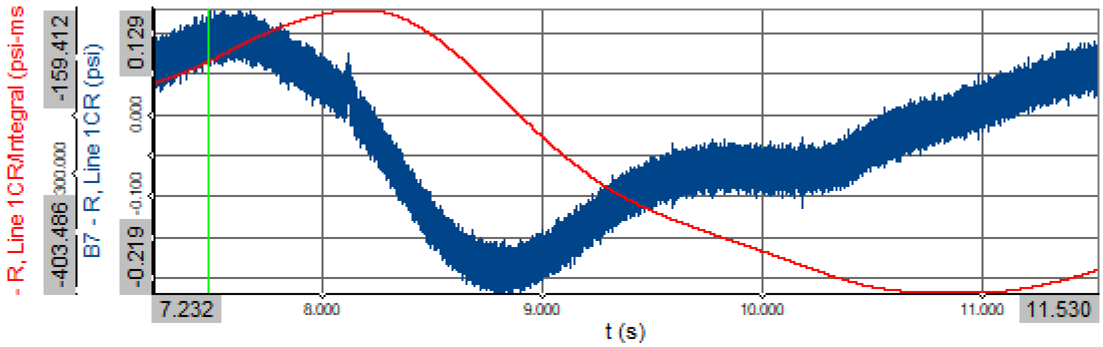

A7 - R, Line 7L/FIR Filter (
-0.056 -0.04 -0.03 -0.015
- R, Line 7L/Integral (psi-m
561.087 564 567.093
A7 - R, Line 7L (psi)
-0.083 0.003
8.064 8.08 8.1 8.12 8.14 8.16 8.186
t (s)

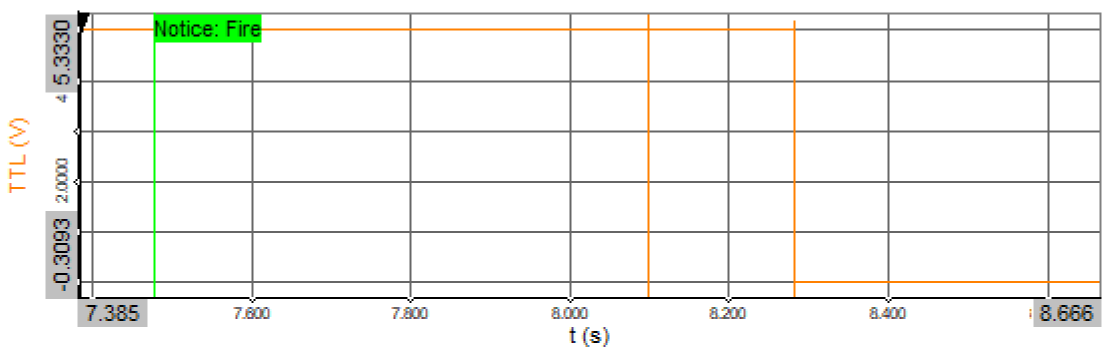

- R, Line 7L/Integral (psi-ms
85.770 300.000 585.402
A7 - R, Line 7L (psi)
-0.295 -0.150 -0.050 0.086
7.232 8.000 9.000 10.000 11.000 11.530
t (s)


B7 - L, Line 7L/FIR Filter ()
0.002 0.02 0.03 0.046
- L, Line 7L/Integral (psi-ms
-228.995 -228 -227.006
B7 - L, Line 7L (psi)
-0.033 0.02 0.076
8.064 8.08 8.1 8.12 8.14 8.16 8.186
t (s)

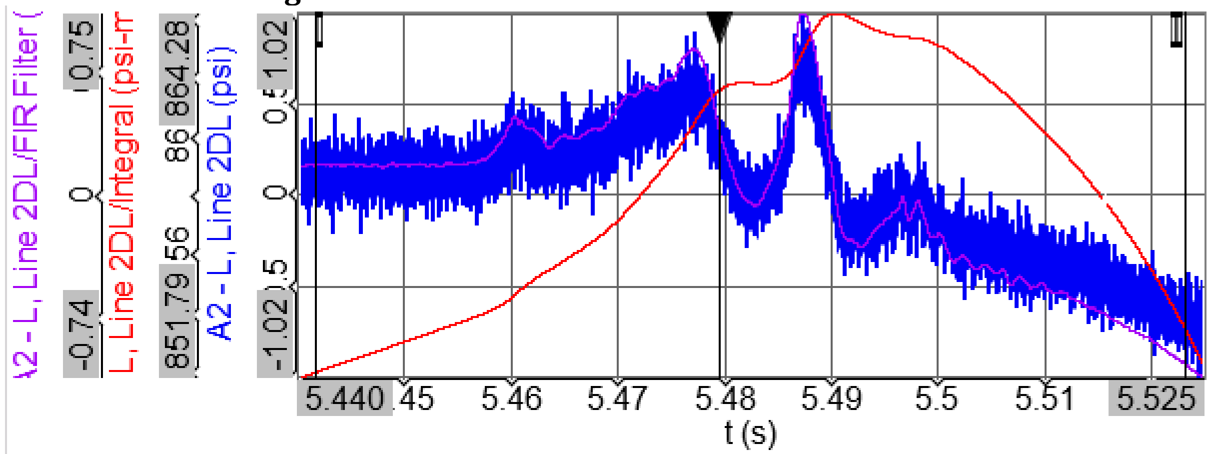

Notice: Fire
- L, Line 7L/Integral (psi-mse
-375.920 -300.000 -226.874
B7 - L, Line 7L (psi)
-0.170 -0.050 0.000 0.093
7.232 8.000 9.000 10.000 11.000 11.530
t (s)

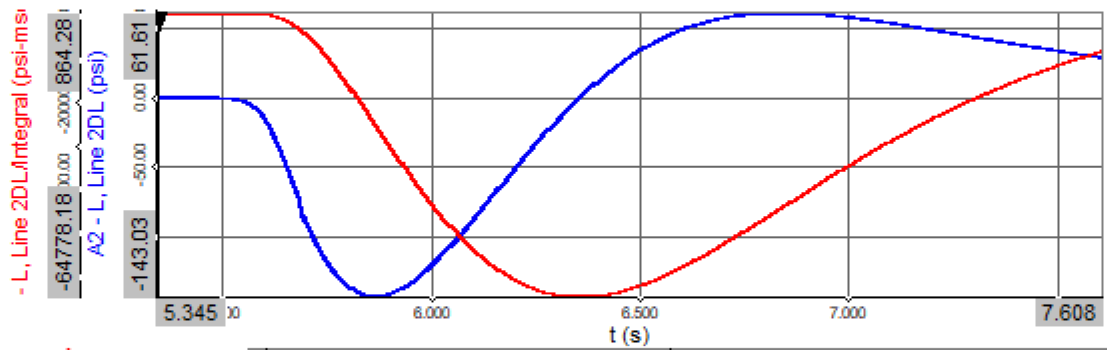

B7 - R, Line 1CR/FIR Filter
R, Line 1CR/Integral (psi-m
B7 - R, Line 1CR (psi)
8.064
8.186
t (s)

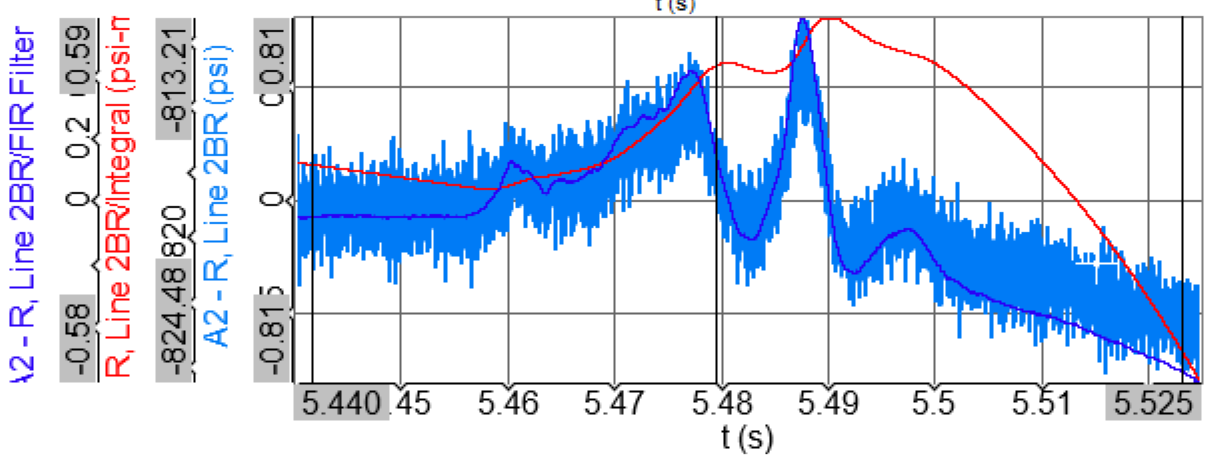

- R, Line 1CR/Integral (psi-ms
B7 - R, Line 1CR (psi)
7.232
11.530
t (s)

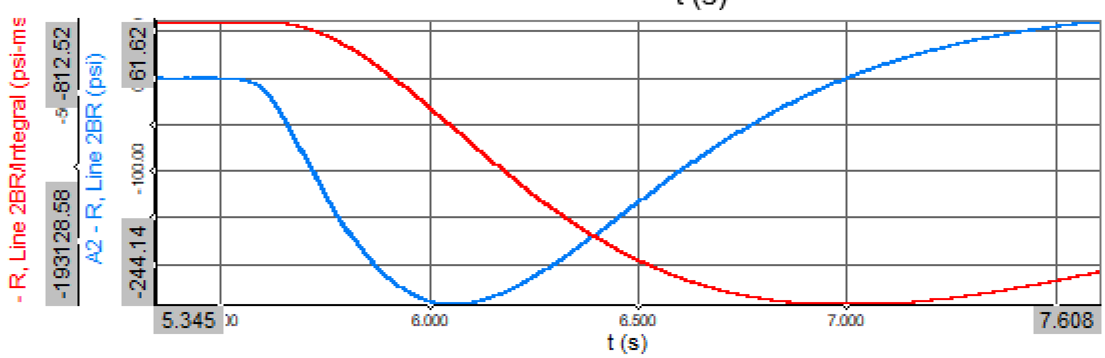

Notice: Fire
TTL (V)
7.385
8.666
t (s)

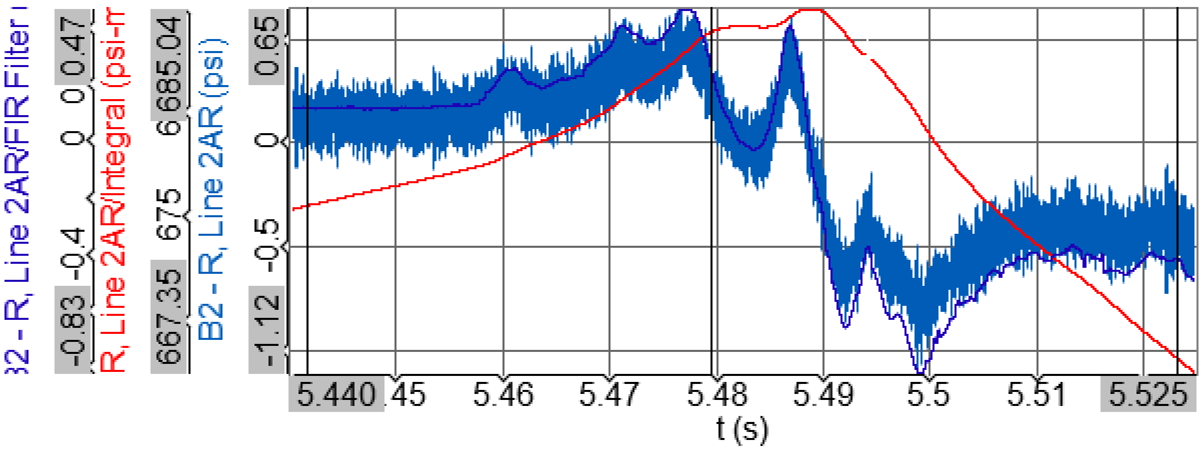
8.1.2 Trial 2 for Large-Scale Mix ID #7

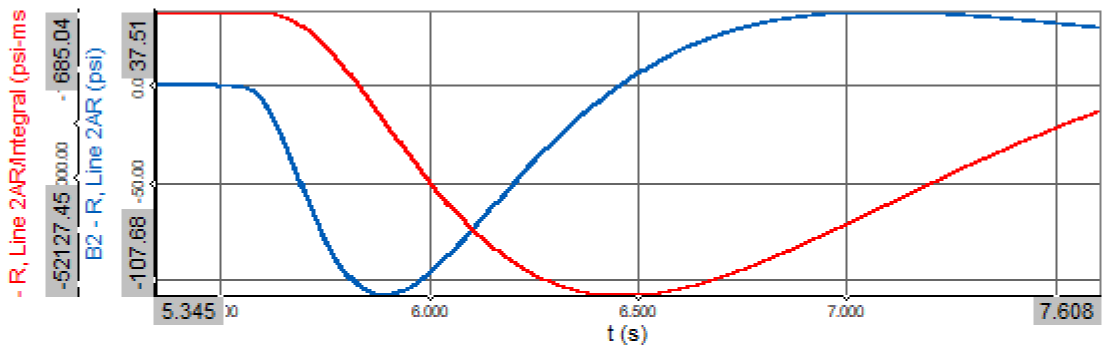


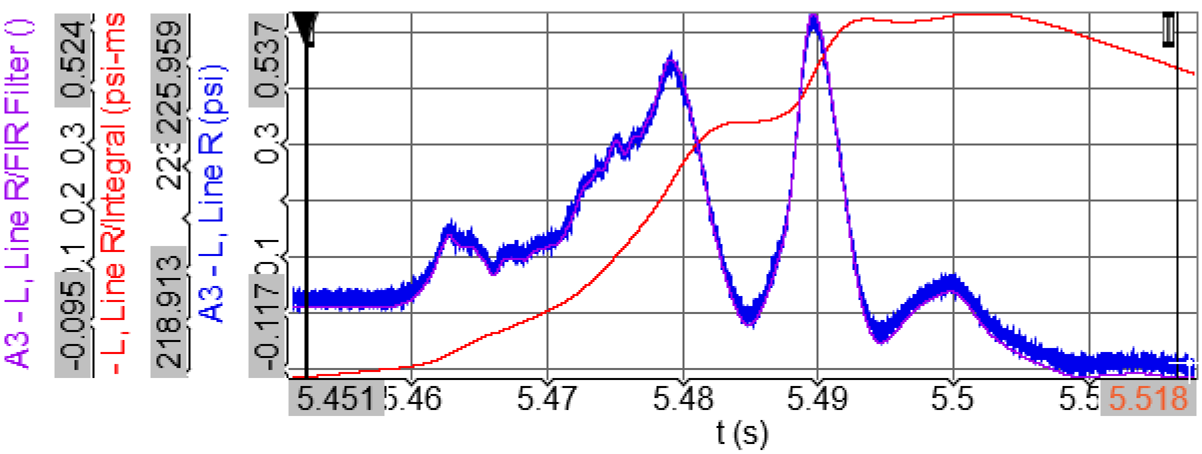


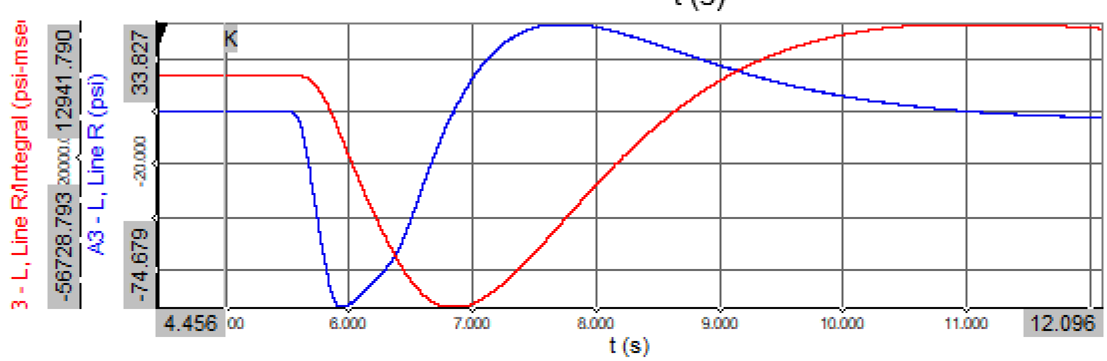


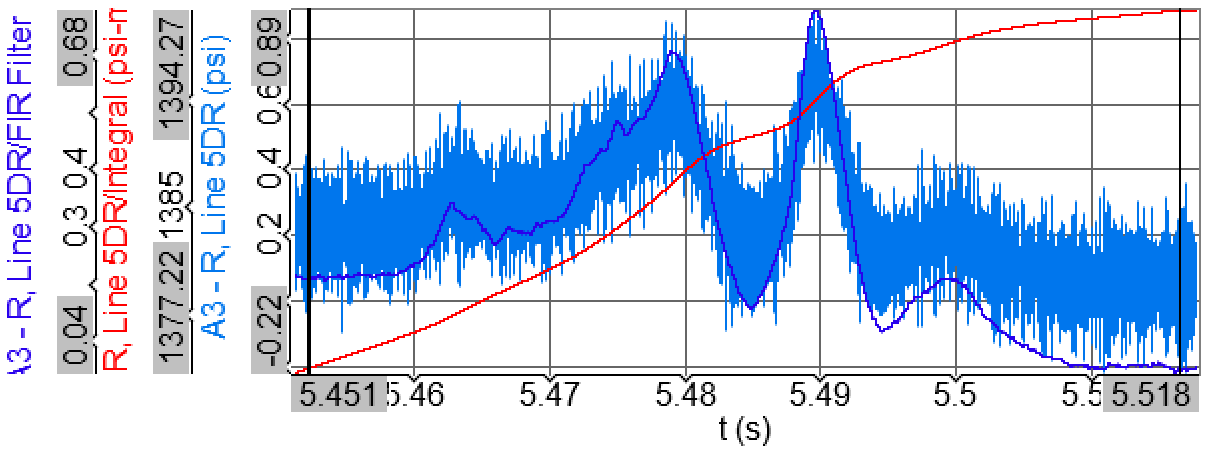


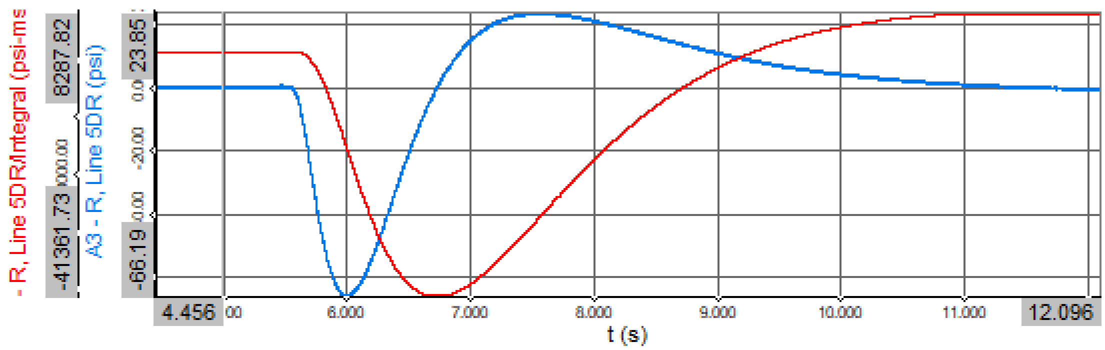

B2 - R, Line 2AR/FIR Filter
R, Line 2AR/Integral (psi-ms)
B2 - R, Line 2AR (psi)
5.440
5.525
t (s)

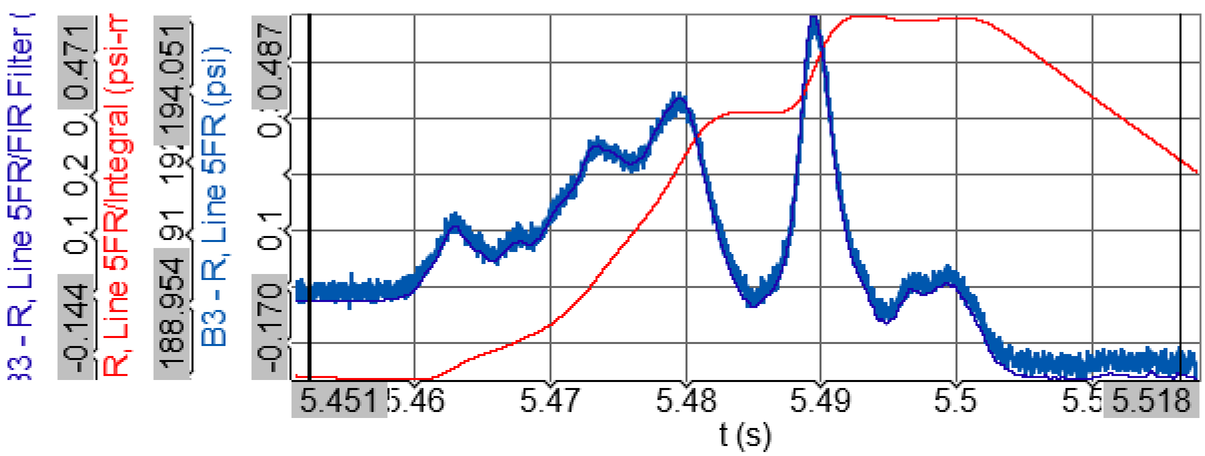

R, Line 2AR/Integral (psi-ms)
B2 - R, Line 2AR (psi)
5.345
7.608
t (s)

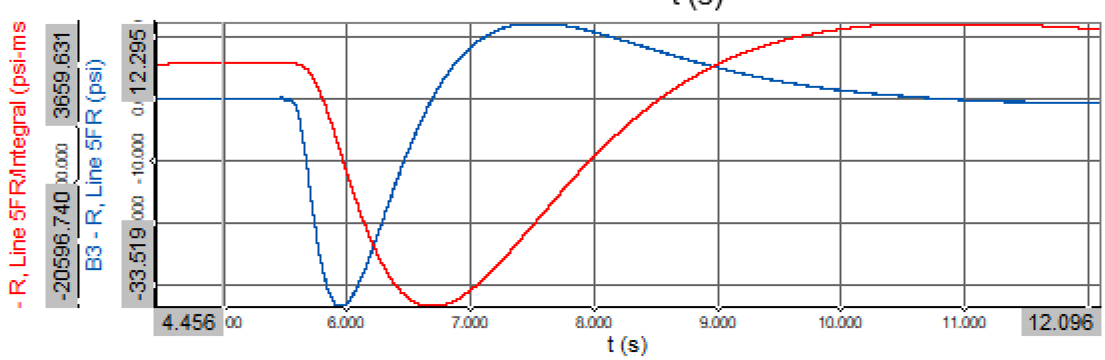

A3 - L, Line R/FIR Filter ()
L, Line R/Integral (psi-ms)
A3 - L, Line R (psi)
5.451
5.518
t (s)

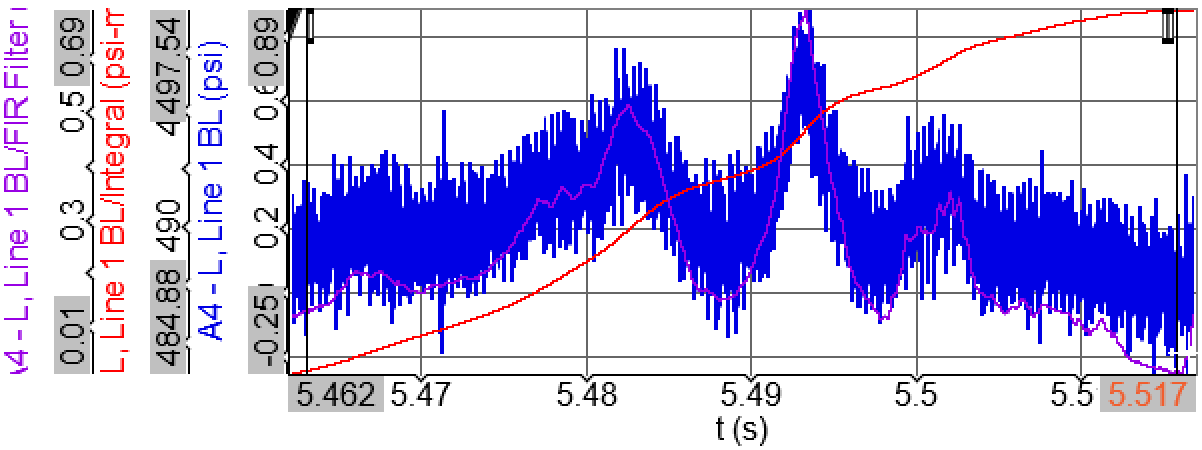

L, Line R/Integral (psi-ms)
A3 - L, Line R (psi)
4.456
12.096
t (s)

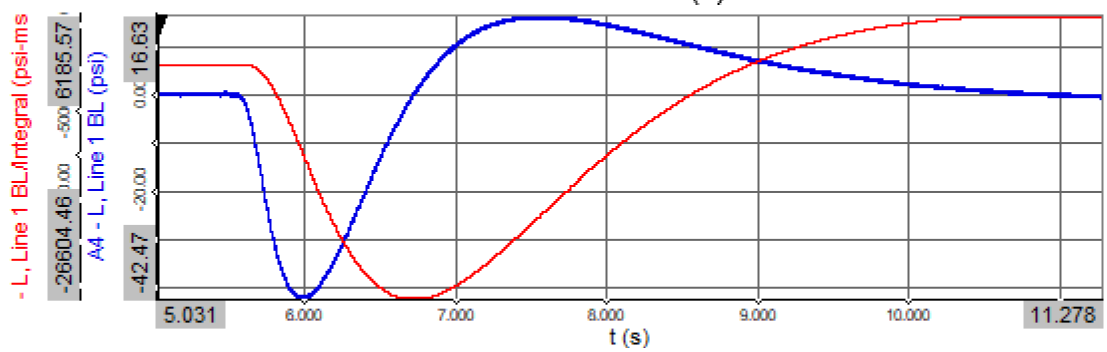

R, Line 5DR/FIR Filter
R, Line 5DR/Integral (psi-m
A3 - R, Line 5DR (psi)
0.04
0.3 0.4
0.68
1377.22 1385
1394.27
-0.22
0.2
0.4
0.6 0.89
5.451
5.46
5.47
5.48
5.49
5.5
5.518
t (s)

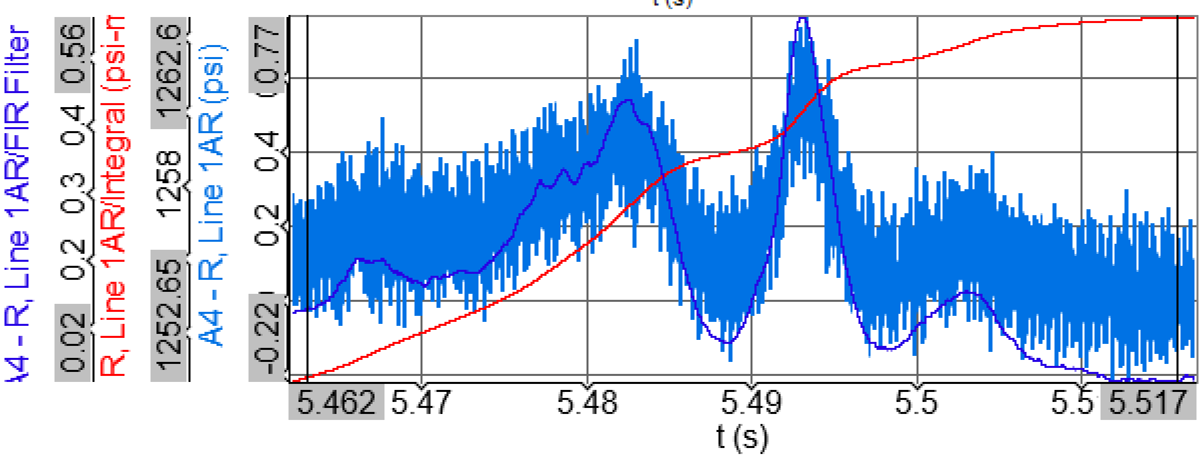

- R, Line 5DR/Integral (psi-ms
-41361.73
8287.82
A3 - R, Line 5DR (psi)
-66.19
-20.00
23.85
4.456
6.000
7.000
8.000
9.000
10.000
11.000
12.096
t (s)

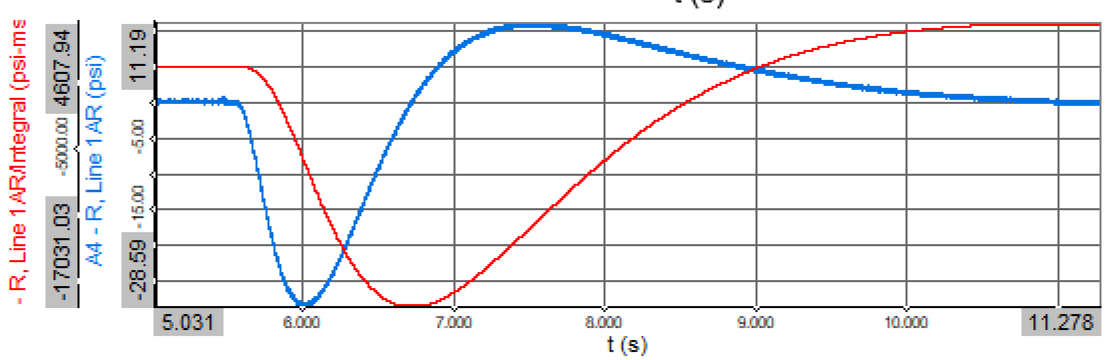

R, Line 5FR/FIR Filter (
R, Line 5FR/Integral (psi-m
B3 - R, Line 5FR (psi)
-0.144
0.1 0.2
0.471
188.954
194.051
-0.170
0.1
0.487
5.451
5.46
5.47
5.48
5.49
5.5
5.518
t (s)

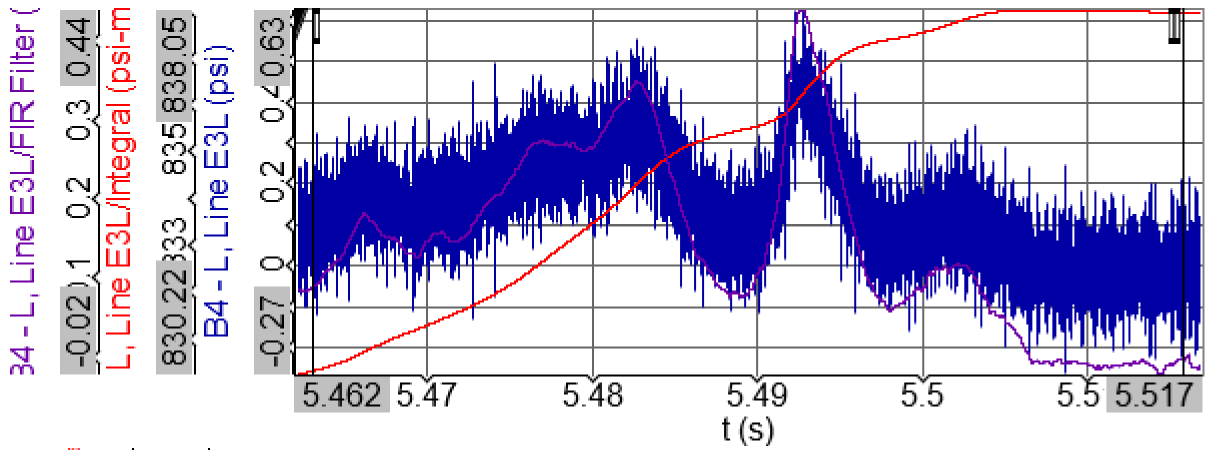

- R, Line 5FR/Integral (psi-ms
-20596.740
3659.631
B3 - R, Line 5FR (psi)
-33.519
-10.000
12.295
4.456
6.000
7.000
8.000
9.000
10.000
11.000
12.096
t (s)

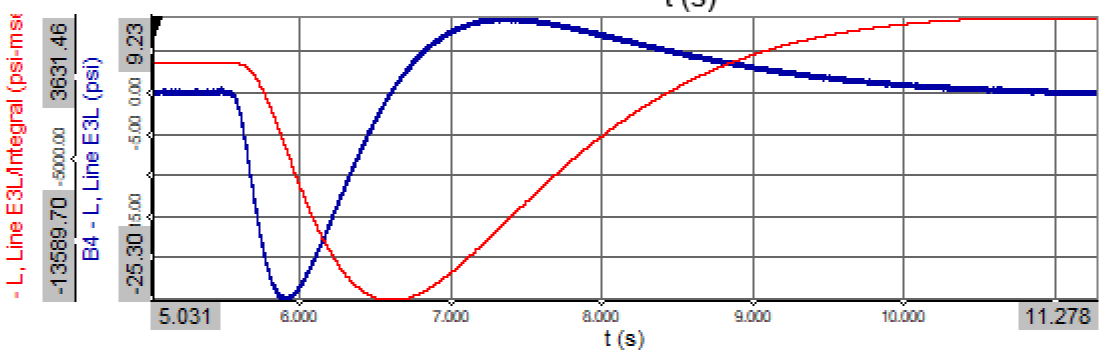

A4 - L, Line 1 BL (psi)
L, Line 1 BL/Integral (psi-m
A4 - L, Line 1 BL/FIR Filter
t (s)
5.462
5.47
5.48
5.49
5.5
5.517

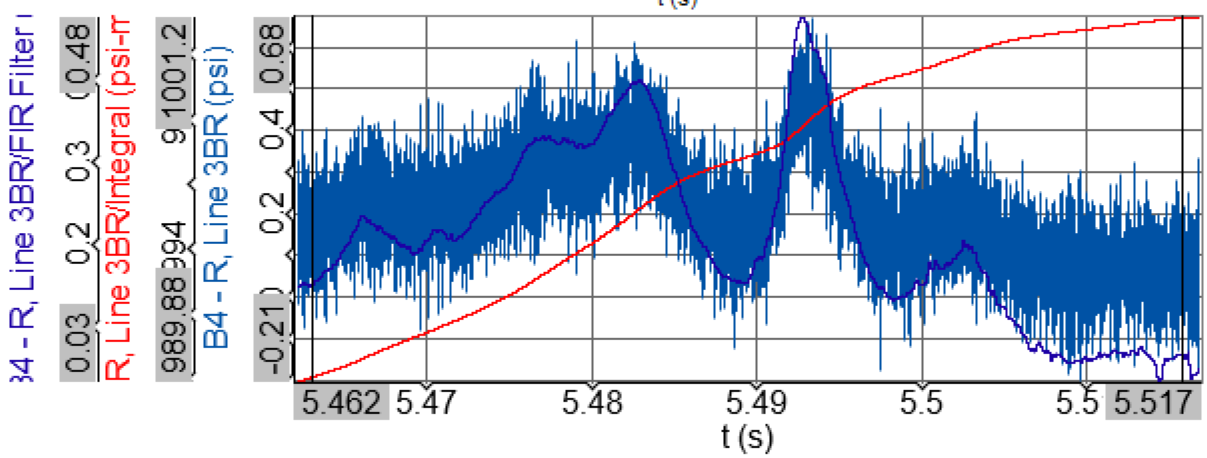

A4 - L, Line 1 BL (psi)
- L, Line 1 BL/Integral (psi-ms
t (s)
5.031
6.000
7.000
8.000
9.000
10.000
11.278

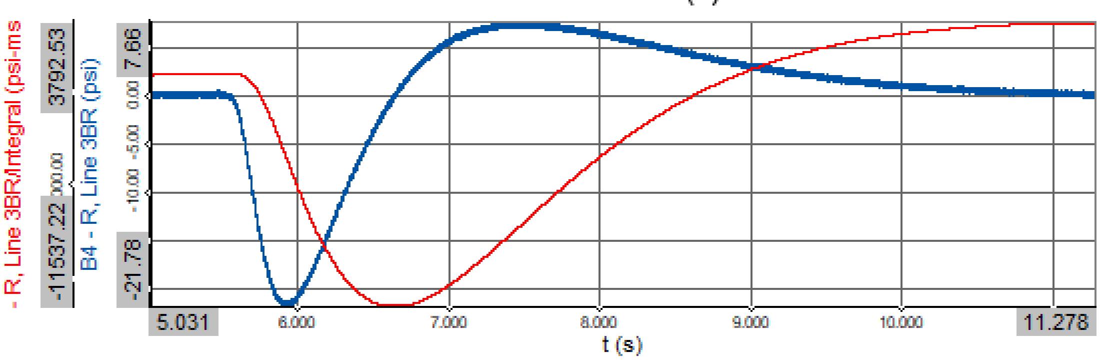

A4 - R, Line 1AR (psi)
R, Line 1AR/Integral (psi-m
A4 - R, Line 1AR/FIR Filter
t (s)
5.462
5.47
5.48
5.49
5.5
5.517

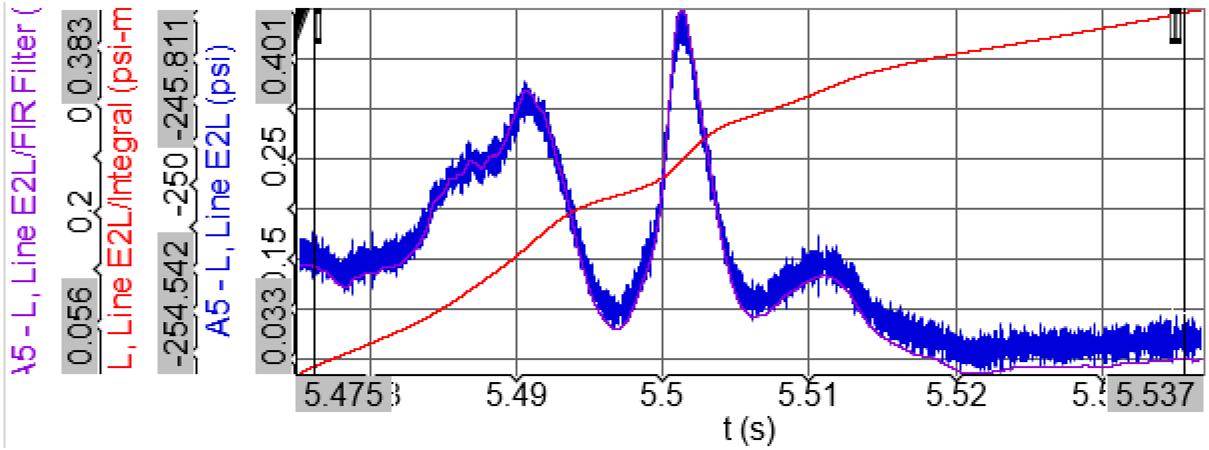

A4 - R, Line 1AR (psi)
- R, Line 1AR/Integral (psi-ms
t (s)
5.031
6.000
7.000
8.000
9.000
10.000
11.278

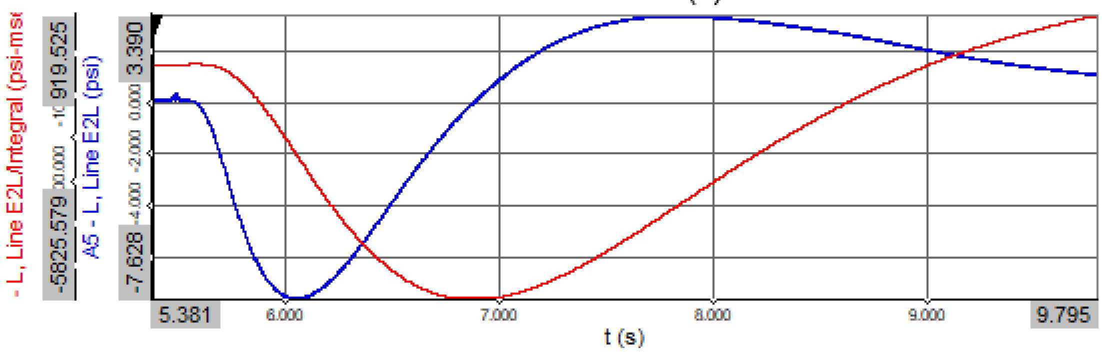

B4 - L, Line E3L (psi)
L, Line E3L/Integral (psi-m
34 - L, Line E3L/FIR Filter (
t (s)
5.462
5.47
5.48
5.49
5.5
5.517

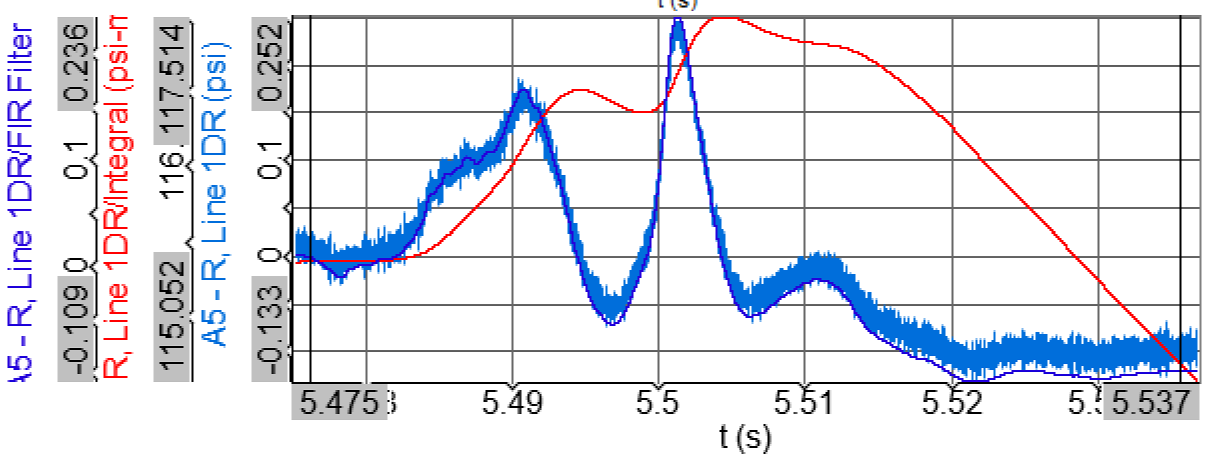

B4 - L, Line E3L (psi)
- L, Line E3L/Integral (psi-ms
t (s)
5.031
11.278

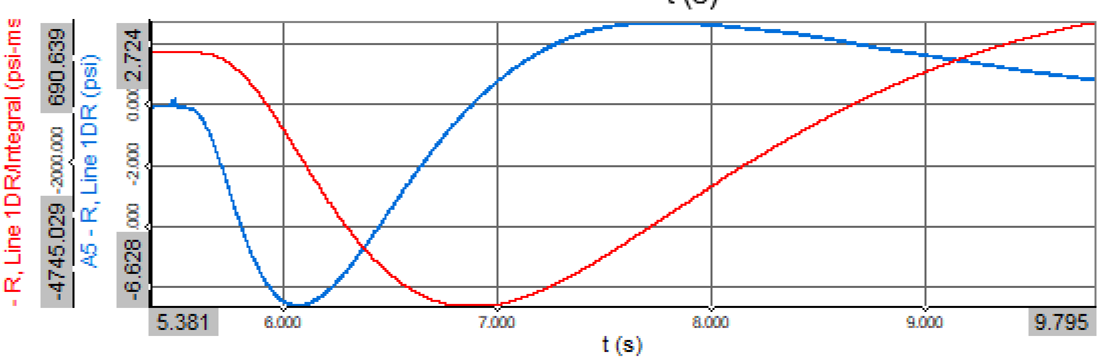

B4 - R, Line 3BR (psi)
R, Line 3BR/Integral (psi-m
34 - R, Line 3BR/FIR Filter
t (s)
5.462
5.47
5.48
5.49
5.5
5.517

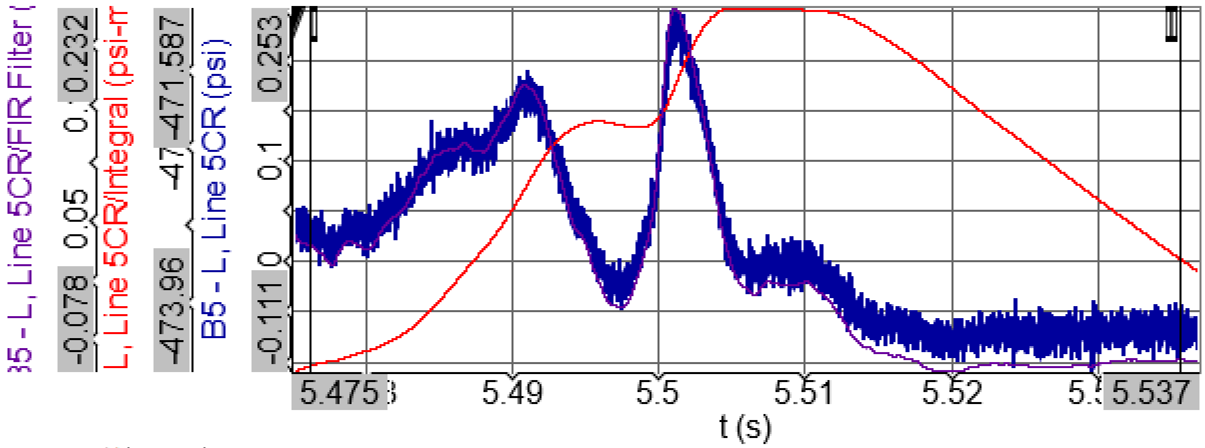

B4 - R, Line 3BR (psi)
- R, Line 3BR/Integral (psi-ms
t (s)
5.031
11.278

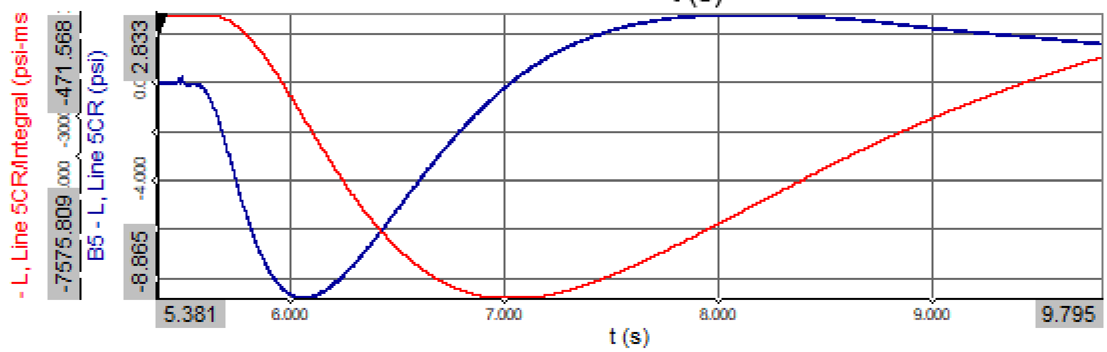

A5 - L, Line E2L (psi)
t (s)
5.475
5.49
5.5
5.51
5.52
5.537

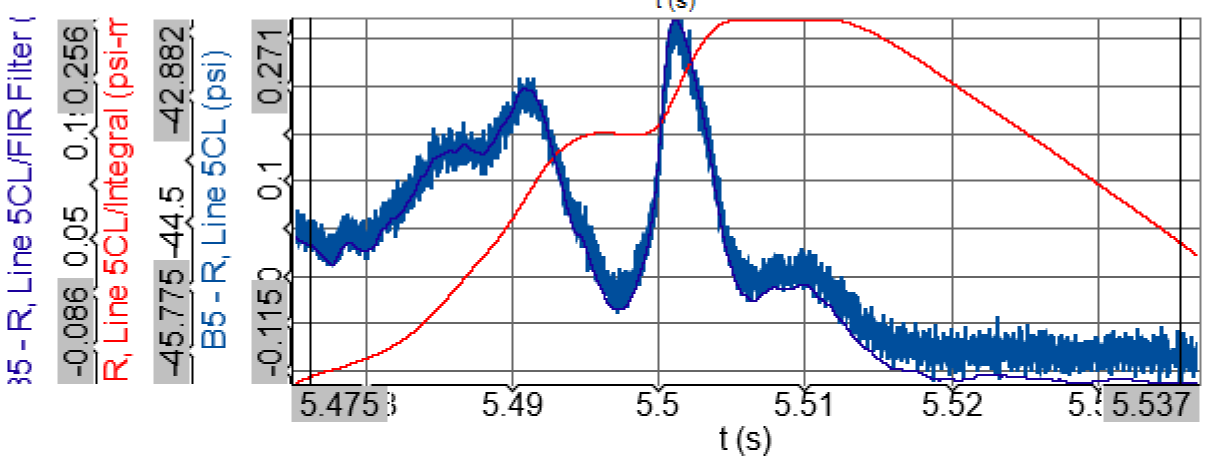

A5 - L, Line E2L (psi)
t (s)
5.381
6.000
7.000
8.000
9.000
9.795

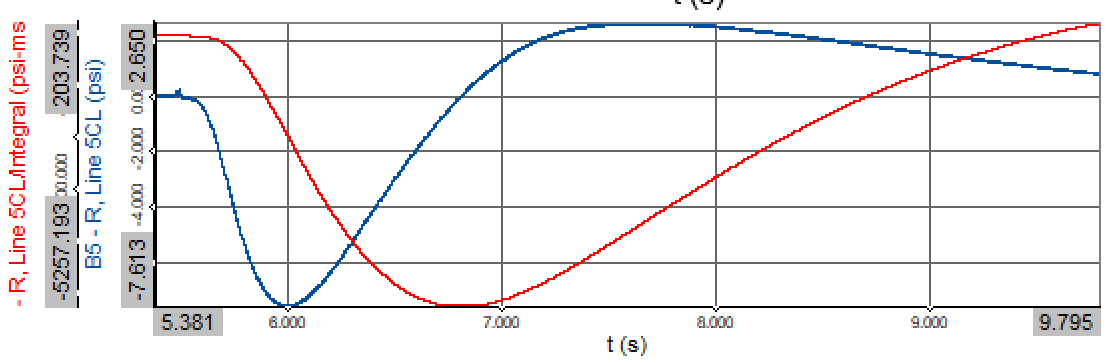

A5 - R, Line 1DR (psi)
t (s)
5.475
5.49
5.5
5.51
5.52
5.537

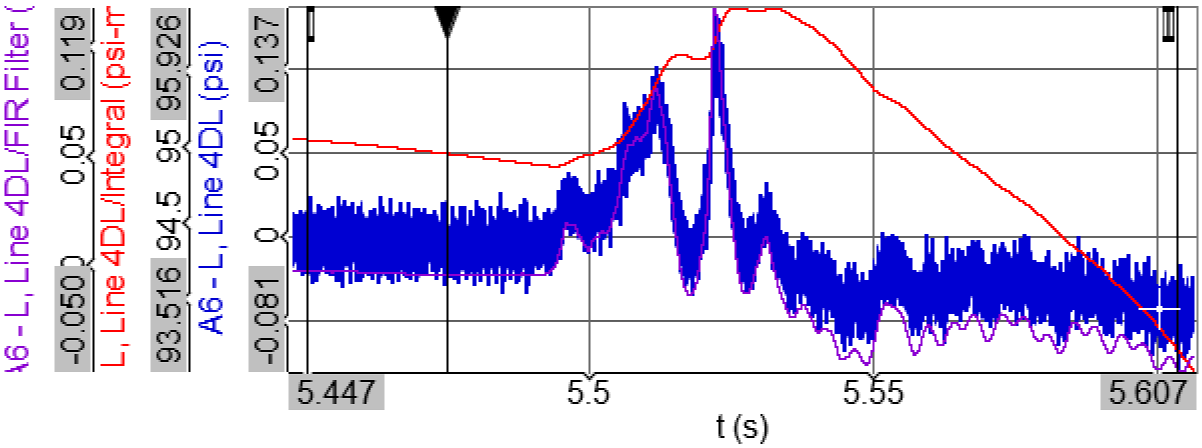

A5 - R, Line 1DR (psi)
t (s)
5.381
6.000
7.000
8.000
9.000
9.795

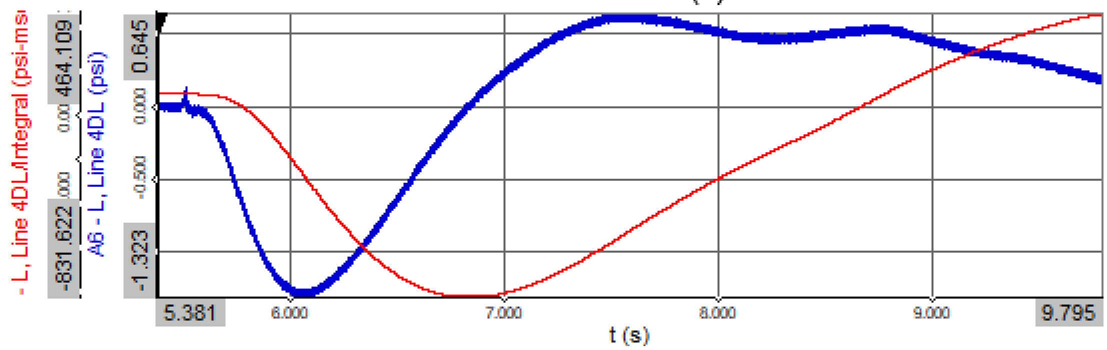

B5 - L, Line 5CR (psi)
t (s)
5.475
5.49
5.5
5.51
5.52
5.537

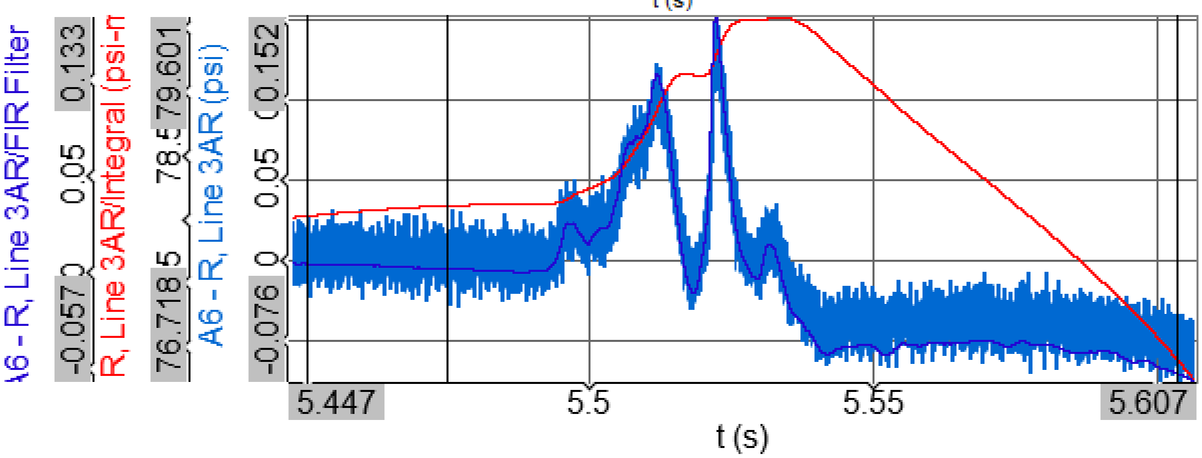

- L, Line 5CR/Integral (psi-ms
B5 - L, Line 5CR (psi)
t (s)
5.381
6.000
7.000
8.000
9.000
9.795

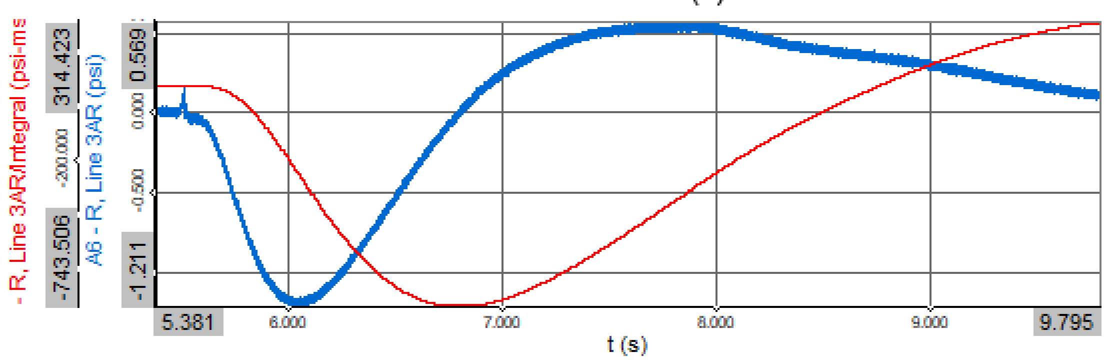

B5 - R, Line 5CL (psi)
t (s)
5.475
5.49
5.5
5.51
5.52
5.537

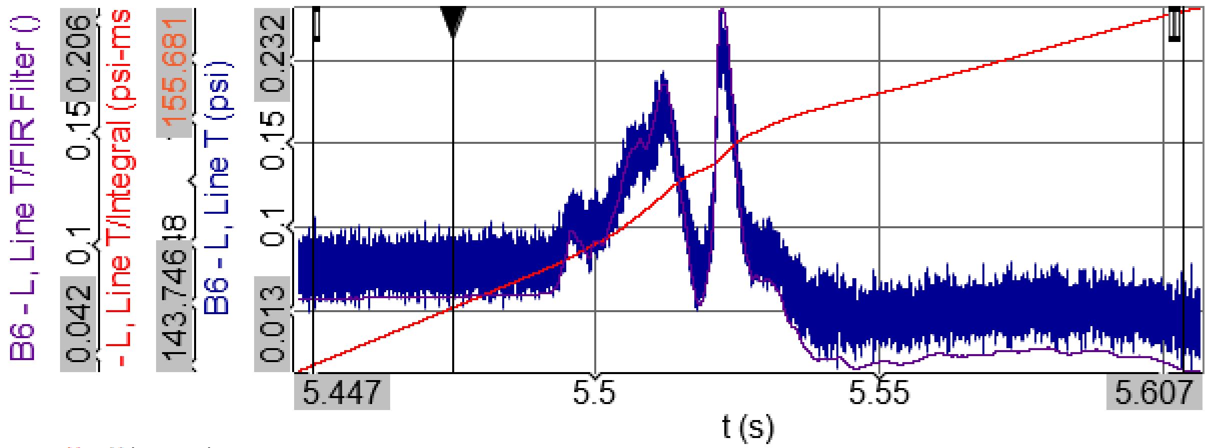

- R, Line 5CL/Integral (psi-ms
B5 - R, Line 5CL (psi)
t (s)
5.381
6.000
7.000
8.000
9.000
9.795

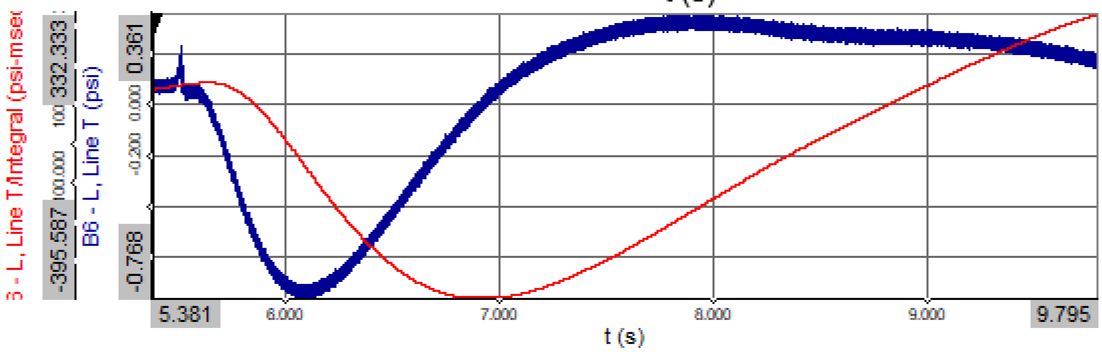

A6 - L, Line 4DL (psi)
0.137
0.05
0
-0.081
93.516
94.5
95
95.926
-0.050
0.05
0.119
5.447
5.5
5.55
5.607
t (s)

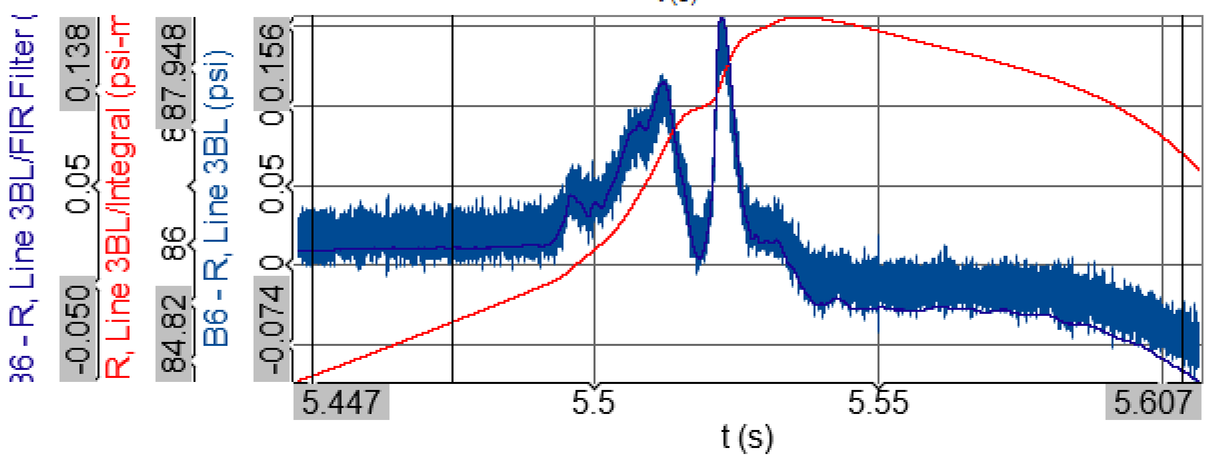

A6 - L, Line 4DL (psi)
0.645
0.000
-0.500
-1.323
464.109
-831.622
5.381
6.000
7.000
8.000
9.000
9.795
t (s)

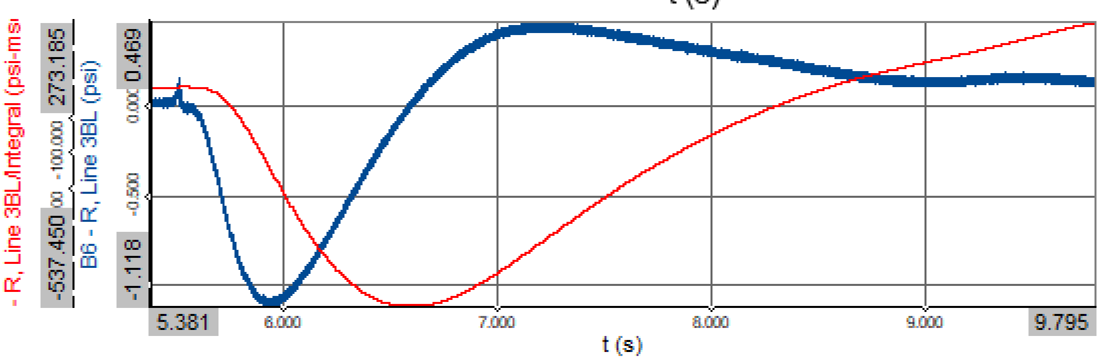

A6 - R, Line 3AR (psi)
0.05
0
-0.076
76.718
79.601
-0.057
0.05
0.133
5.447
5.5
5.55
5.607
t (s)

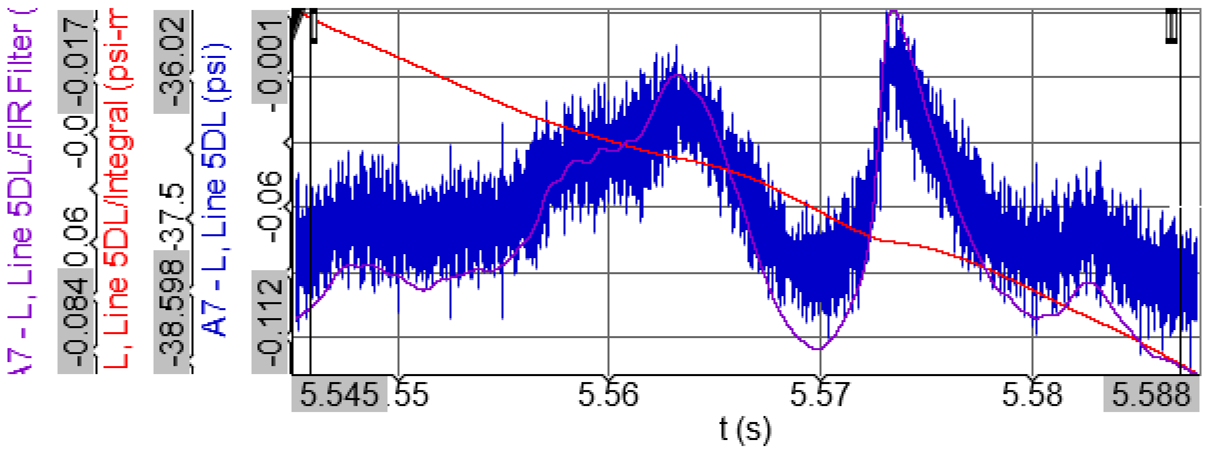

A6 - R, Line 3AR (psi)
0.569
0.000
-0.500
-1.211
314.423
-200.000
-743.506
5.381
6.000
7.000
8.000
9.000
9.795
t (s)

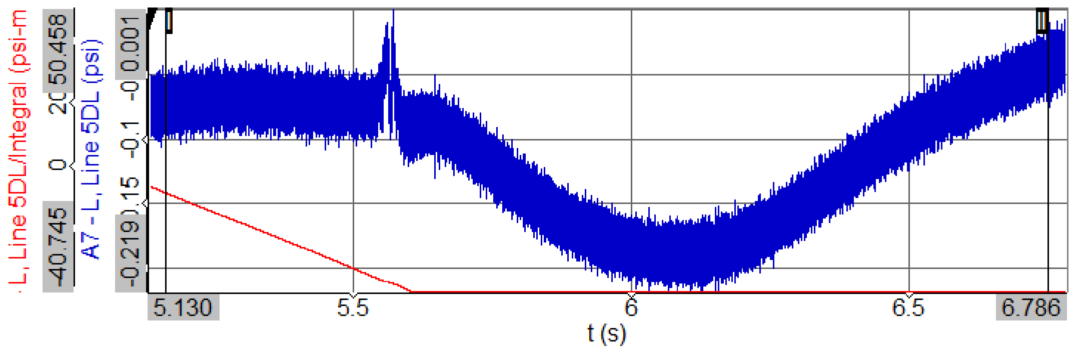

B6 - L, Line T/FIR Filter ()
0.042
0.1
0.15
0.206
- L, Line T/Integral (psi-ms
143.746
155.681
B6 - L, Line T (psi)
0.013
0.1
0.15
0.232
5.447
5.5
5.55
5.607
t (s)

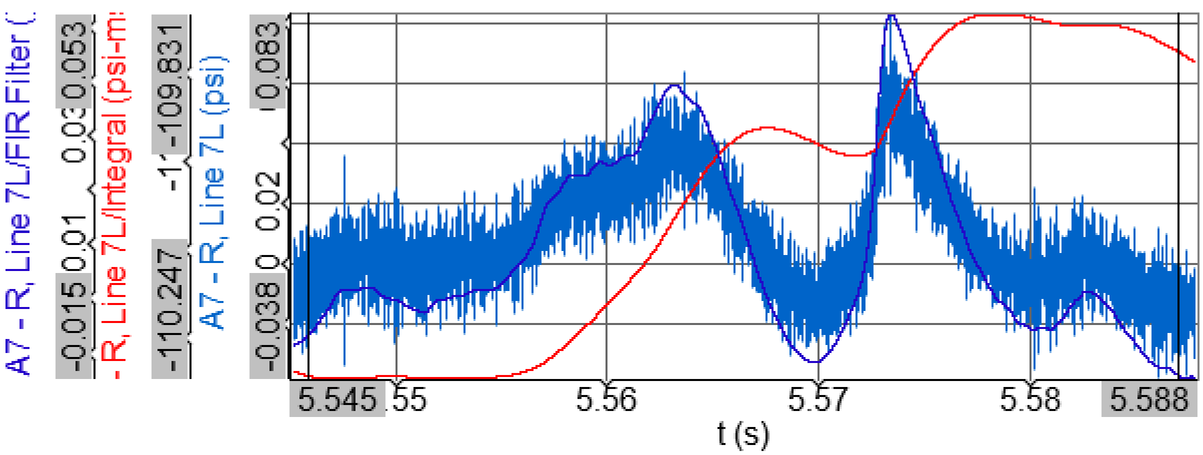

-395.587
332.333
B6 - L, Line T (psi)
-0.768
0.361
5.381
6.000
7.000
8.000
9.000
9.795
t (s)

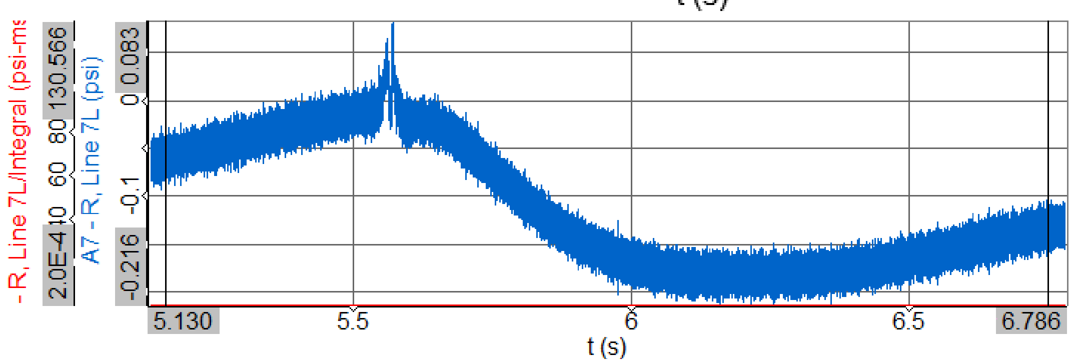

B6 - R, Line 3BL/FIR Filter (
-0.050
0.05
0.138
R, Line 3BL/Integral (psi-m
84.82
86
87.948
B6 - R, Line 3BL (psi)
-0.074
0
0.05
0.156
5.447
5.5
5.55
5.607
t (s)

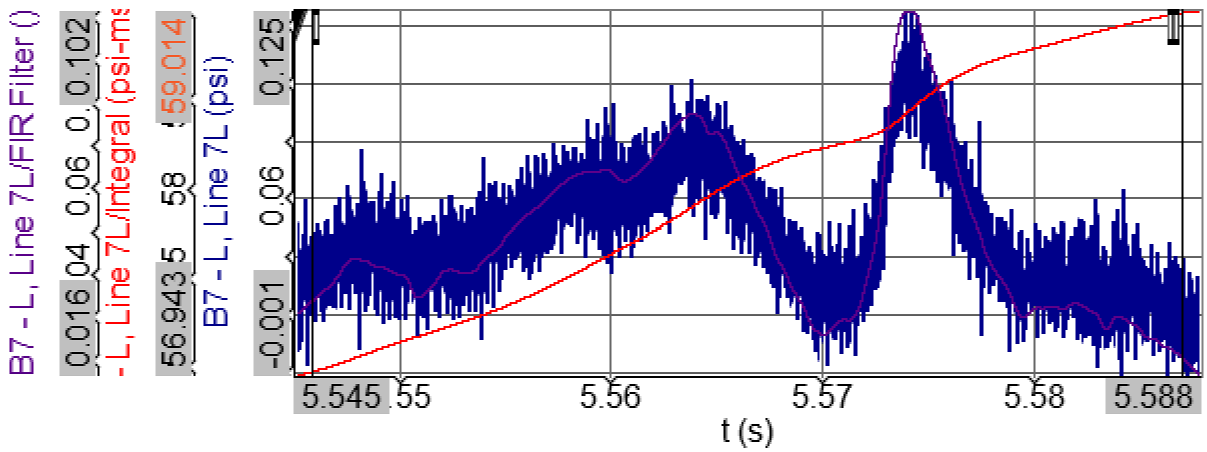

- R, Line 3BL/Integral (psi-ms
-537.450
273.185
B6 - R, Line 3BL (psi)
-1.118
0.469
5.381
6.000
7.000
8.000
9.000
9.795
t (s)

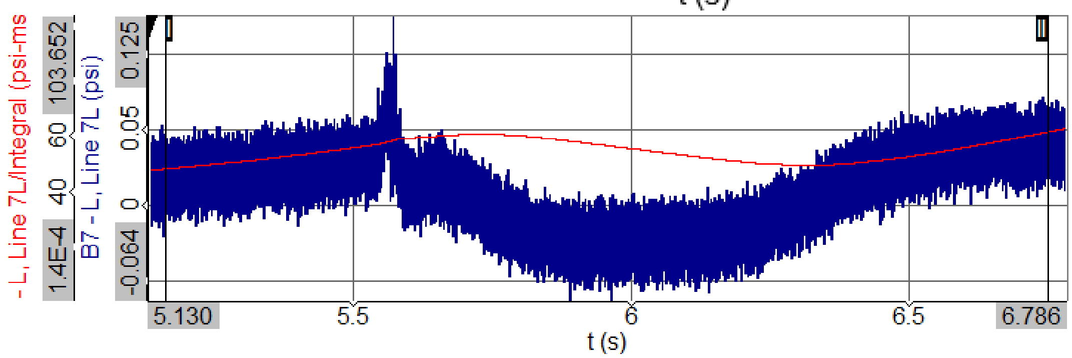

A7 - L, Line 5DL/FIR Filter (
L, Line 5DL/Integral (psi-m
A7 - L, Line 5DL (psi)
5.545
5.55
5.56
5.57
5.58
5.588
t (s)

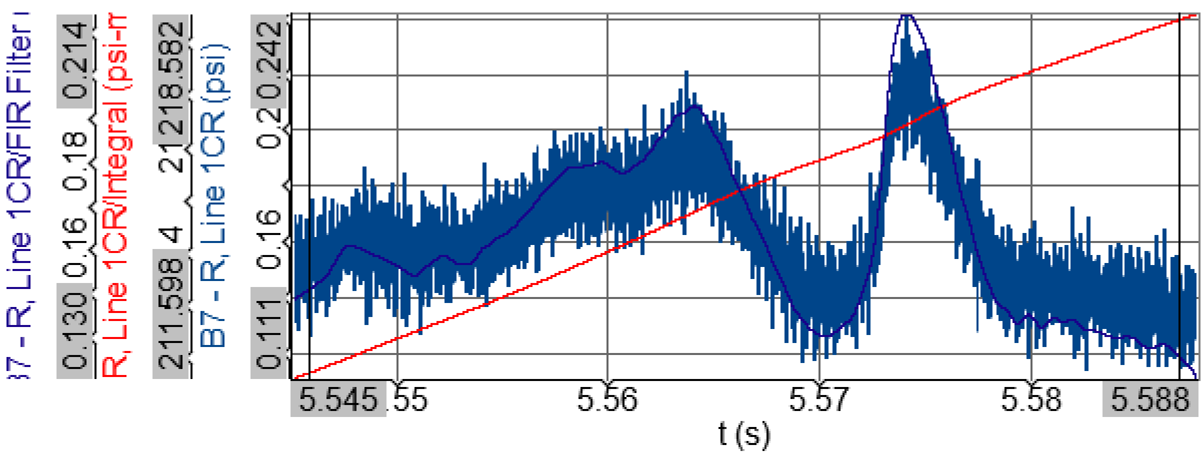

L, Line 5DL/Integral (psi-m
A7 - L, Line 5DL (psi)
5.130
5.5
6
6.5
6.786
t (s)

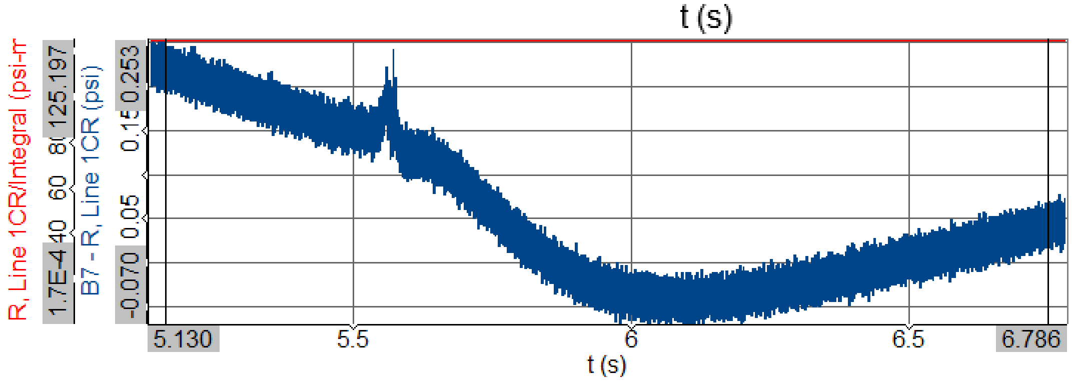

A7 - R, Line 7L/FIR Filter (
-R, Line 7L/Integral (psi-m
A7 - R, Line 7L (psi)
5.545
5.55
5.56
5.57
5.58
5.588
t (s)

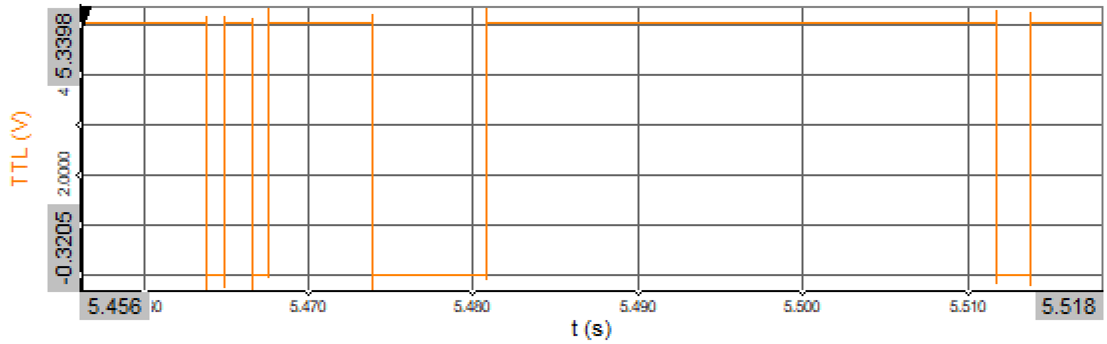

-R, Line 7L/Integral (psi-m
A7 - R, Line 7L (psi)
5.130
5.5
6
6.5
6.786
t (s)


B7 - L, Line 7L/FIR Filter ()
B7 - L, Line 7L (psi)
t (s)
5.545
5.55
5.56
5.57
5.58
5.588

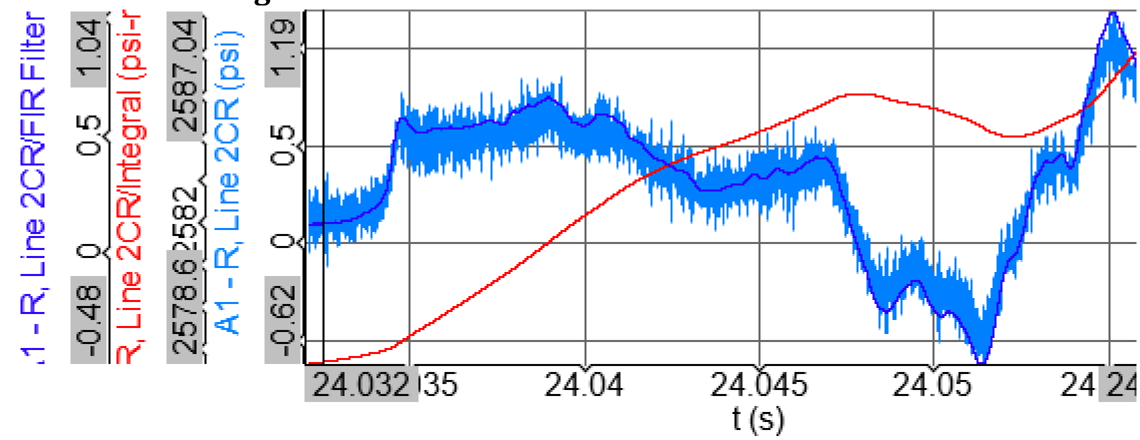

-L, Line 7L/Integral (psi-ms
B7 - L, Line 7L (psi)
t (s)
5.130
5.5
6
6.5
6.786

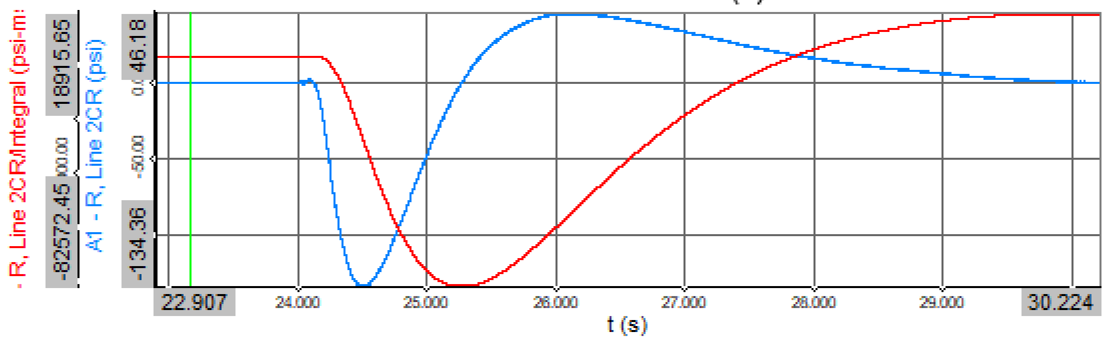

B7 - R, Line 1CR (psi)
t (s)
5.545
5.55
5.56
5.57
5.58
5.588

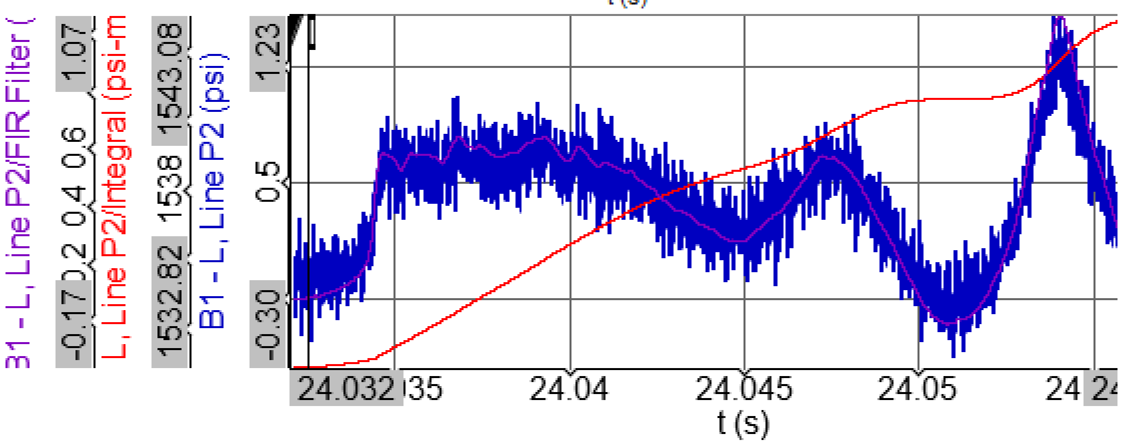

B7 - R, Line 1CR (psi)
t (s)
5.130
5.5
6
6.5
6.786

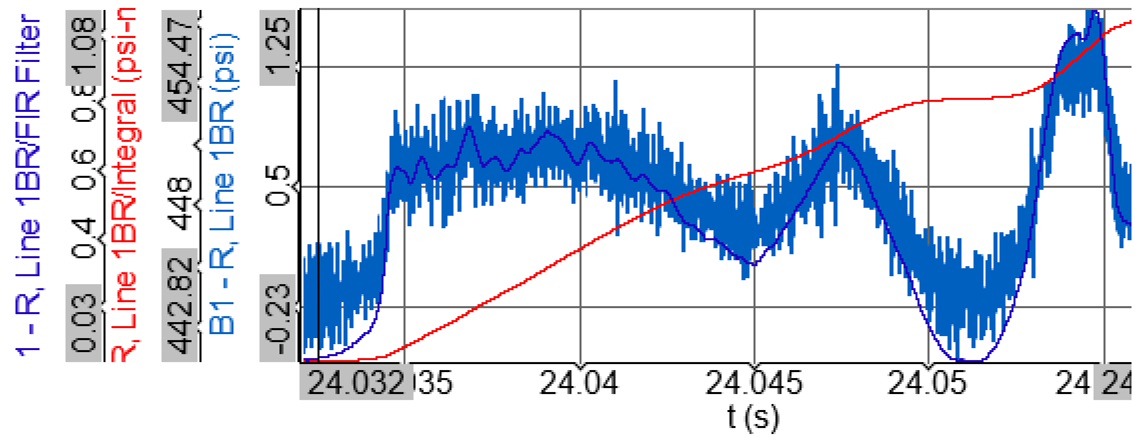

5.3398
TTL (V)
2.0000
-0.3205
5.456
5.470
5.480
5.490
5.500
5.510
5.518
t (s)

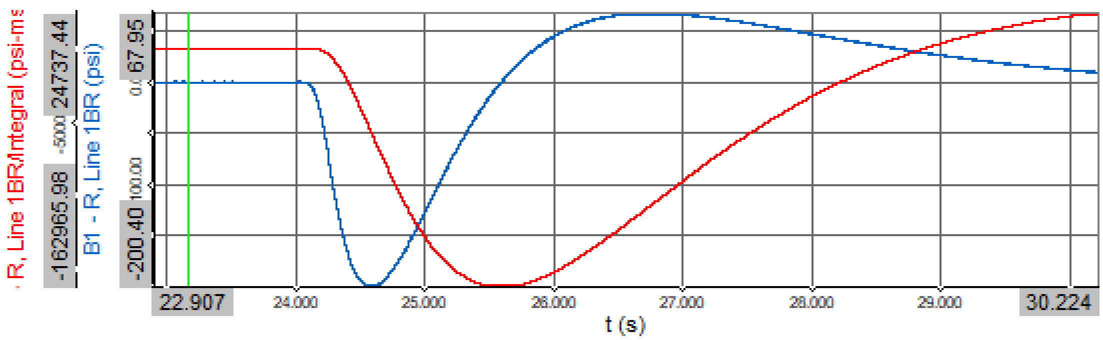
8.1.3 Trial 3 for Large-Scale Mix ID #7

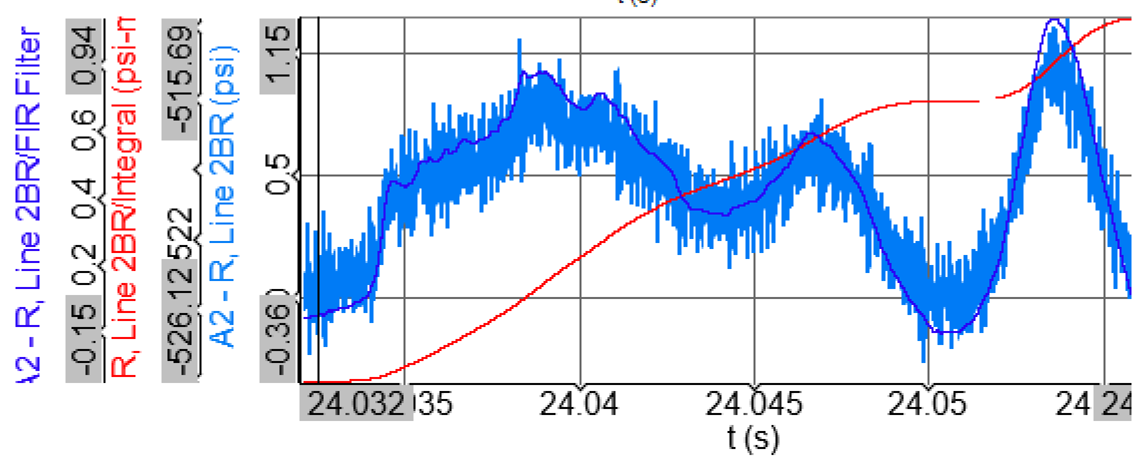


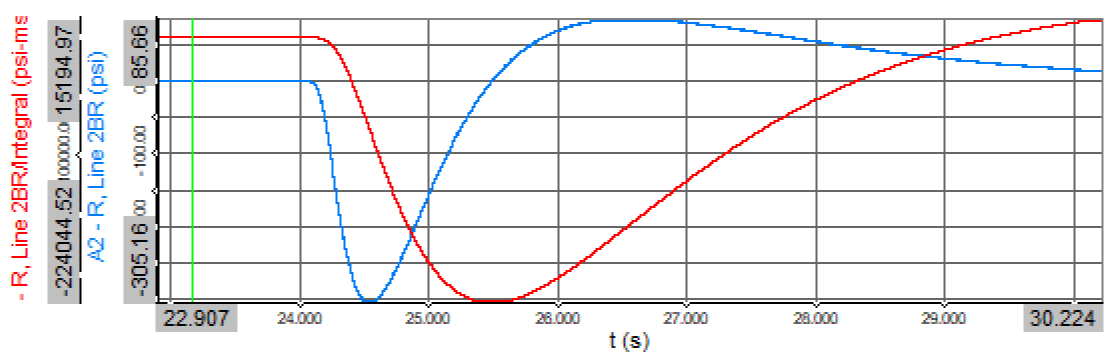


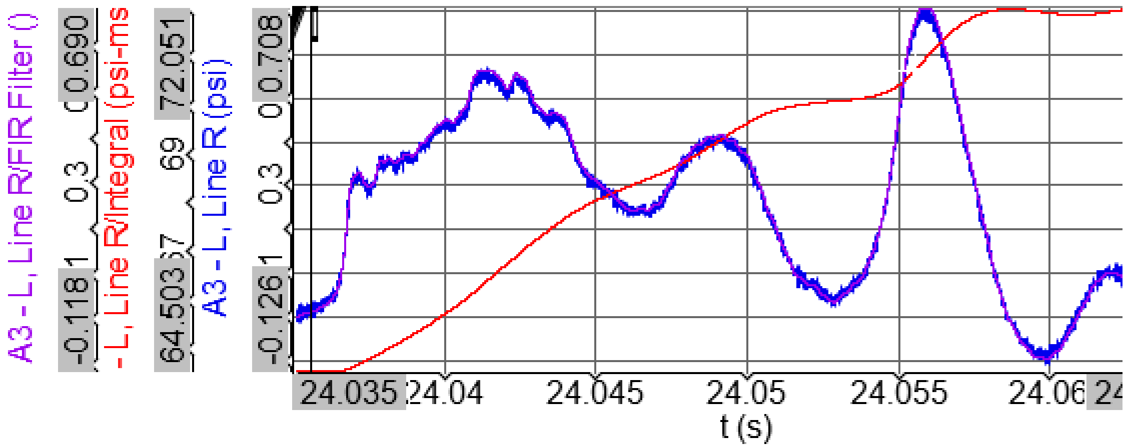


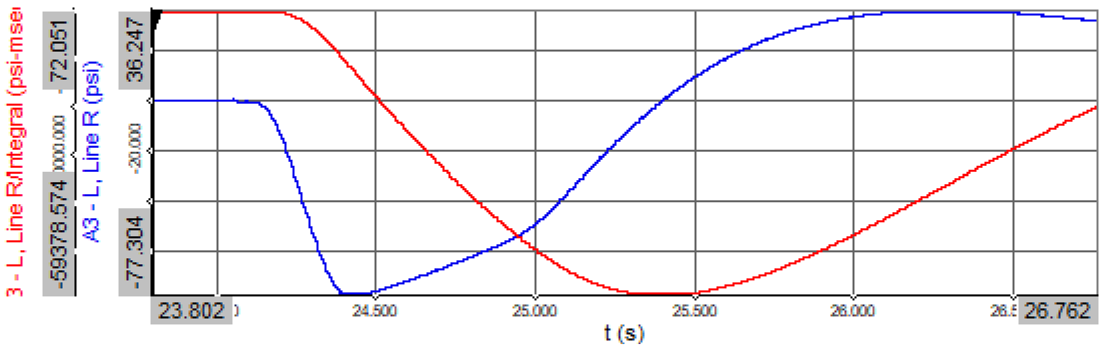

B1 - R, Line 1BR (psi)
t (s)
24.032
24.04
24.045
24.05

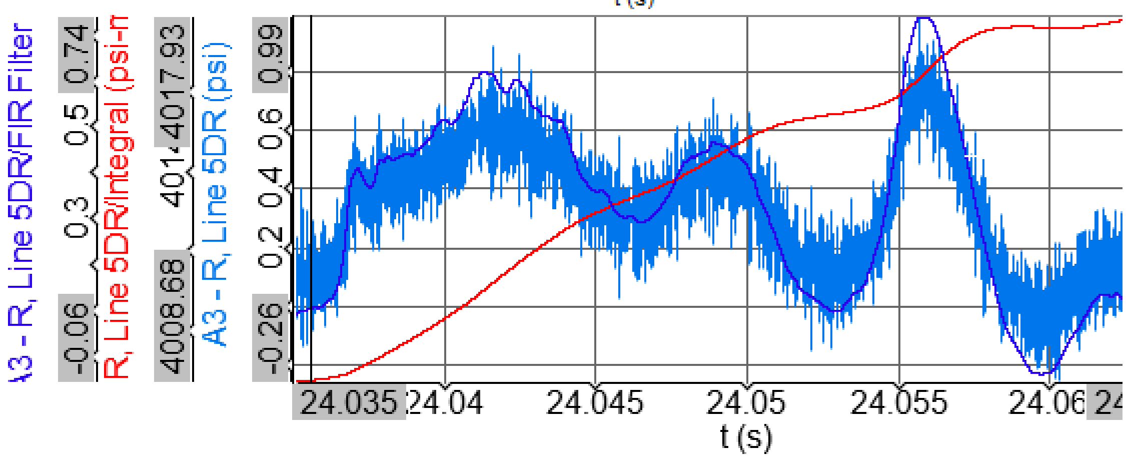

B1 - R, Line 1BR (psi)
22.907
24.000
25.000
26.000
27.000
28.000
29.000
30.224
t (s)

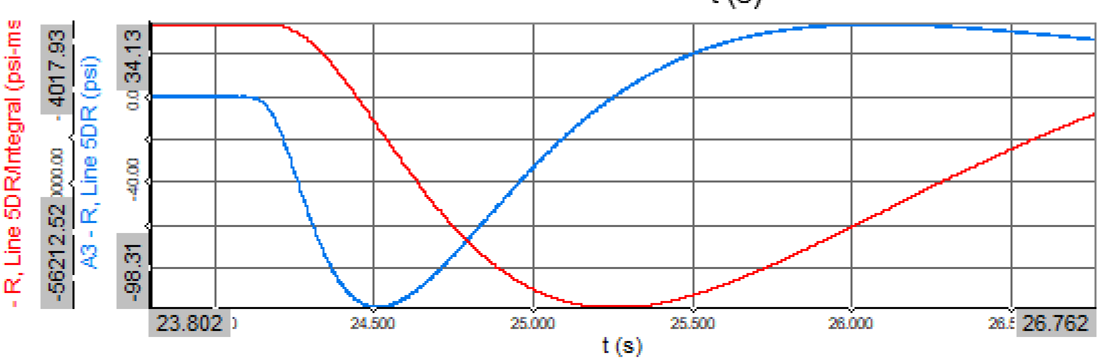

A2 - R, Line 2BR (psi)
t (s)
24.032
24.04
24.045
24.05

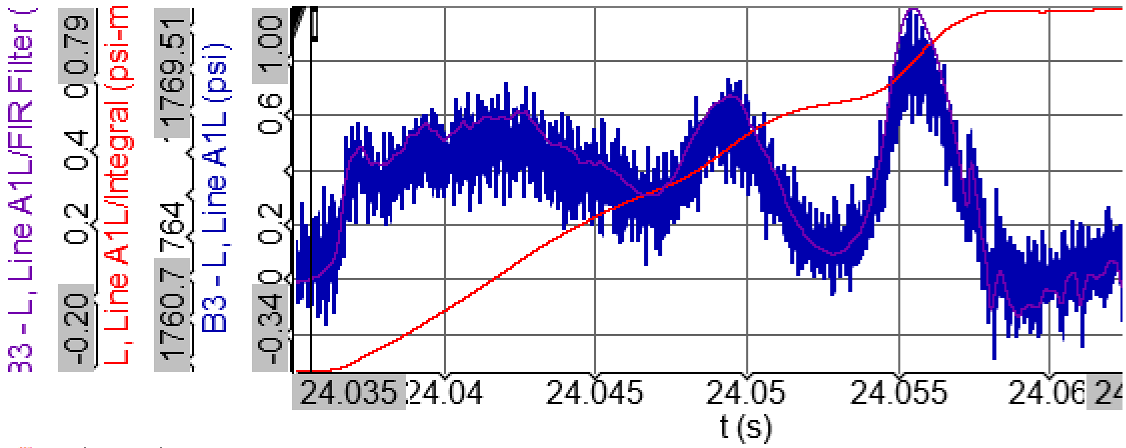

A2 - R, Line 2BR (psi)
22.907
24.000
25.000
26.000
27.000
28.000
29.000
30.224
t (s)

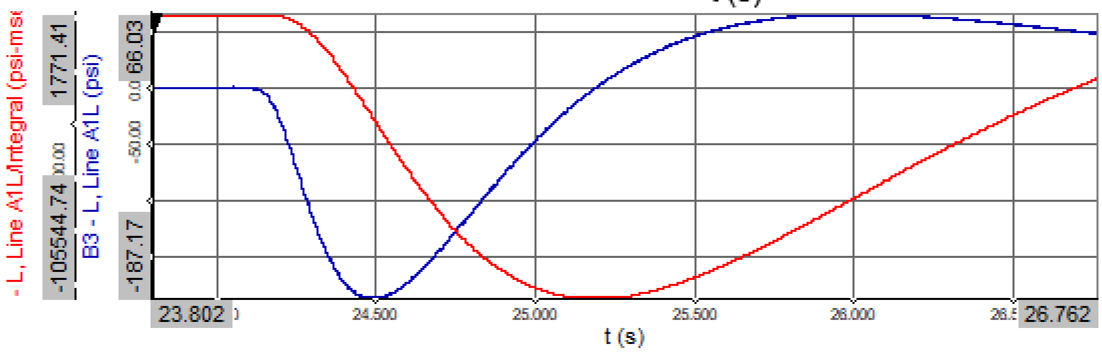

A3 - L, Line R/FIR Filter ()
-L, Line R/Integral (psi-ms
A3 - L, Line R (psi)
24.035
24.04
24.045
24.05
24.055
24.06
t (s)

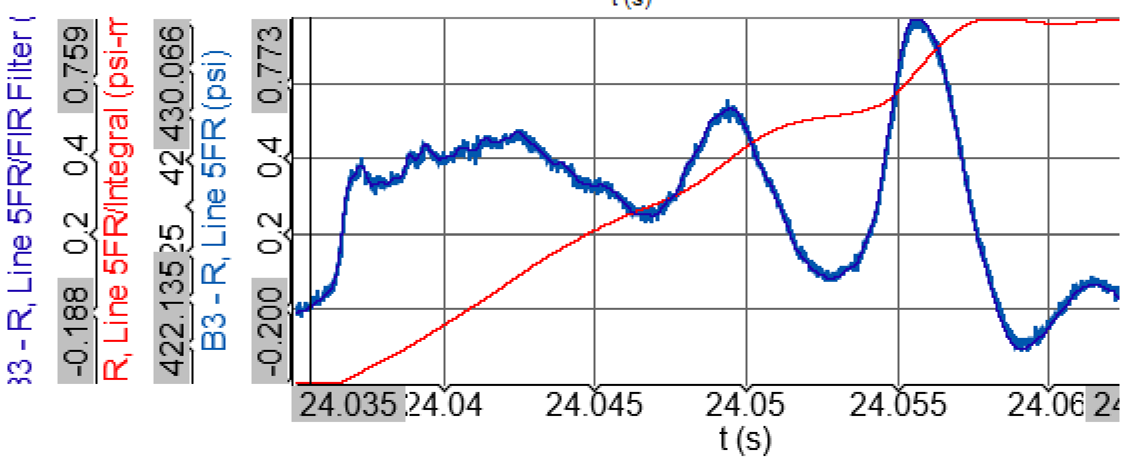

3 - L, Line R/Integral (psi-mse
A3 - L, Line R (psi)
23.802
24.500
25.000
25.500
26.000
26.762
t (s)

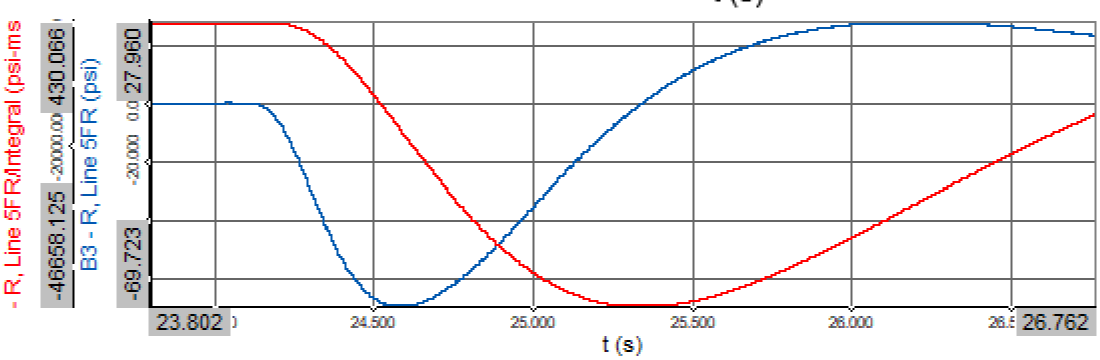

A3 - R, Line 5DR/FIR Filter
R, Line 5DR/Integral (psi-m
A3 - R, Line 5DR (psi)
24.035
24.04
24.045
24.05
24.055
24.06
t (s)

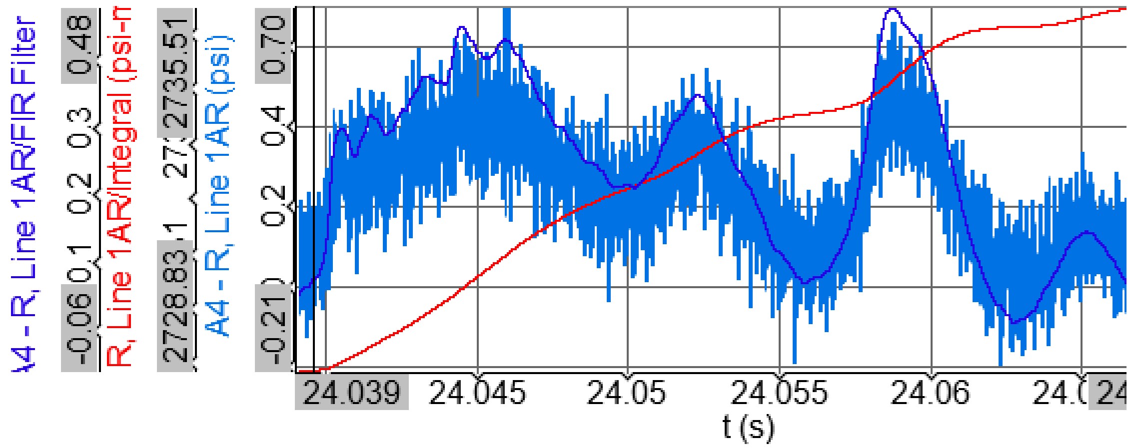

- R, Line 5DR/Integral (psi-ms
A3 - R, Line 5DR (psi)
23.802
24.500
25.000
25.500
26.000
26.762
t (s)

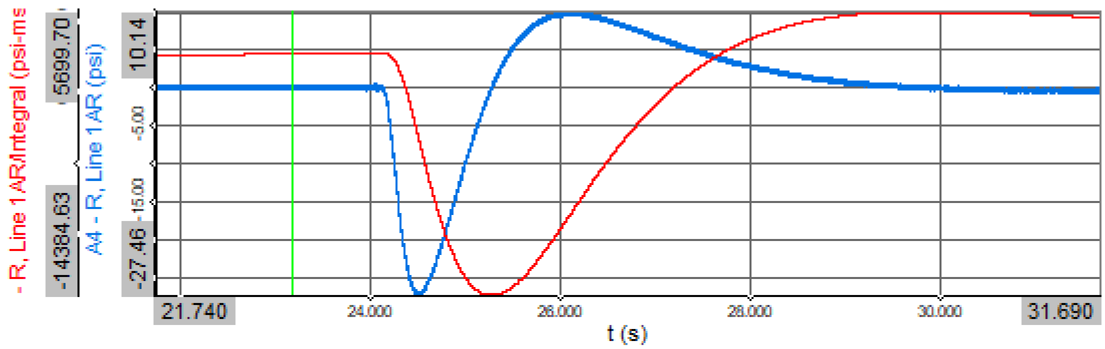

B3 - L, Line A1L (psi)
t (s)

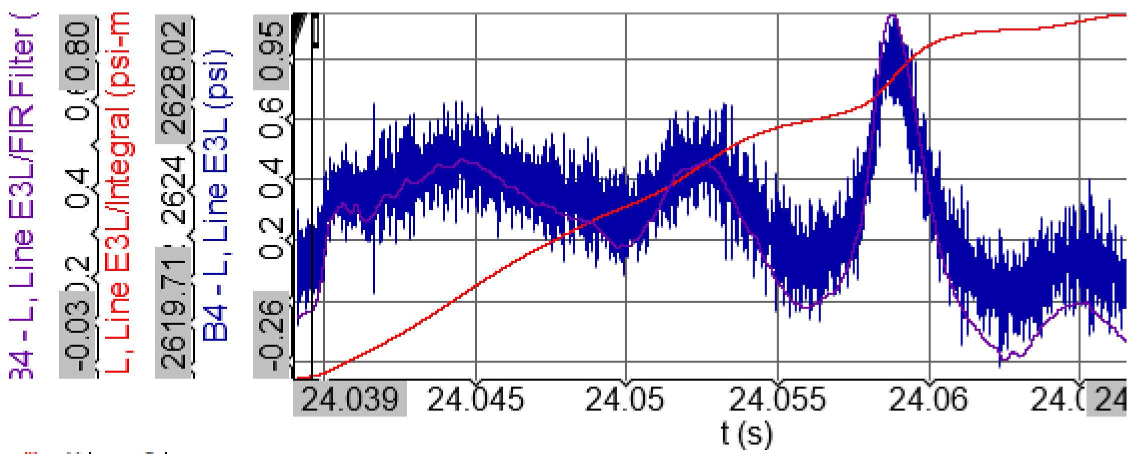

B3 - L, Line A1L (psi)
t (s)

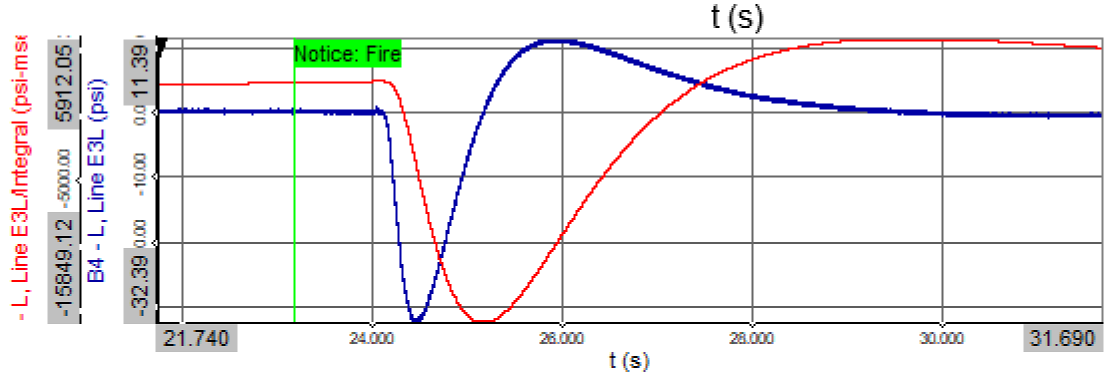

B3 - R, Line 5FR (psi)
t (s)

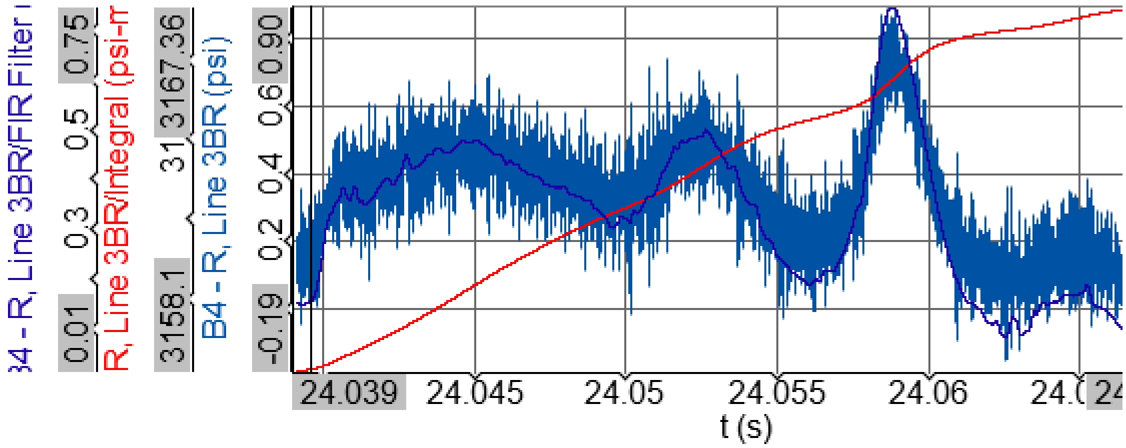

B3 - R, Line 5FR (psi)
t (s)

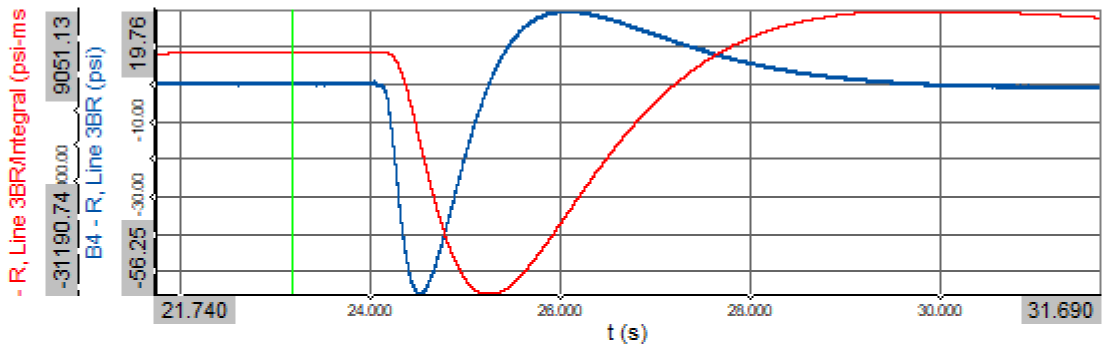

A4 - R, Line 1AR/FIR Filter
R, Line 1AR/Integral (psi-m
A4 - R, Line 1AR (psi)
t (s)
24.039
24.045
24.05
24.055
24.06

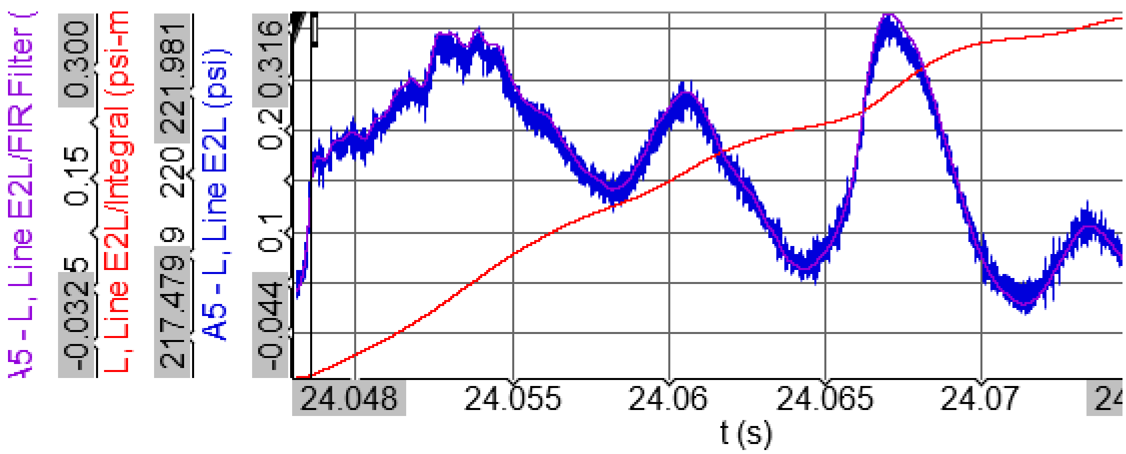

- R, Line 1AR/Integral (psi-ms
A4 - R, Line 1AR (psi)
t (s)
21.740
31.690

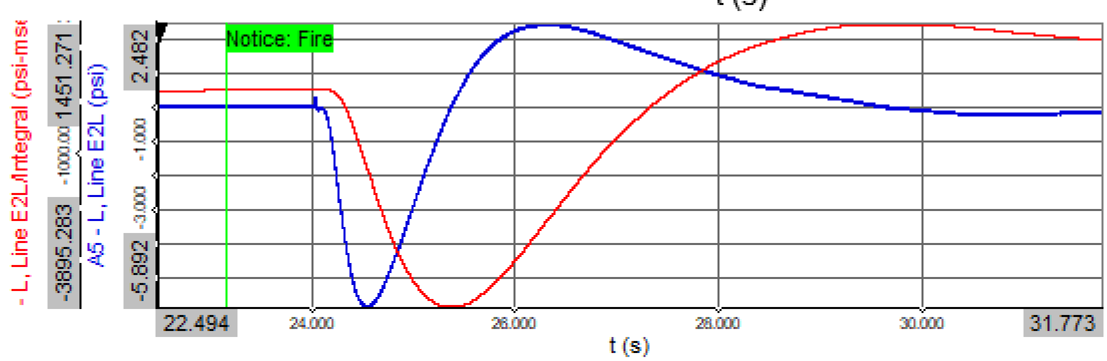

B4 - L, Line E3L/FIR Filter (
L, Line E3L/Integral (psi-m
B4 - L, Line E3L (psi)
t (s)
24.039
24.045
24.05
24.055
24.06

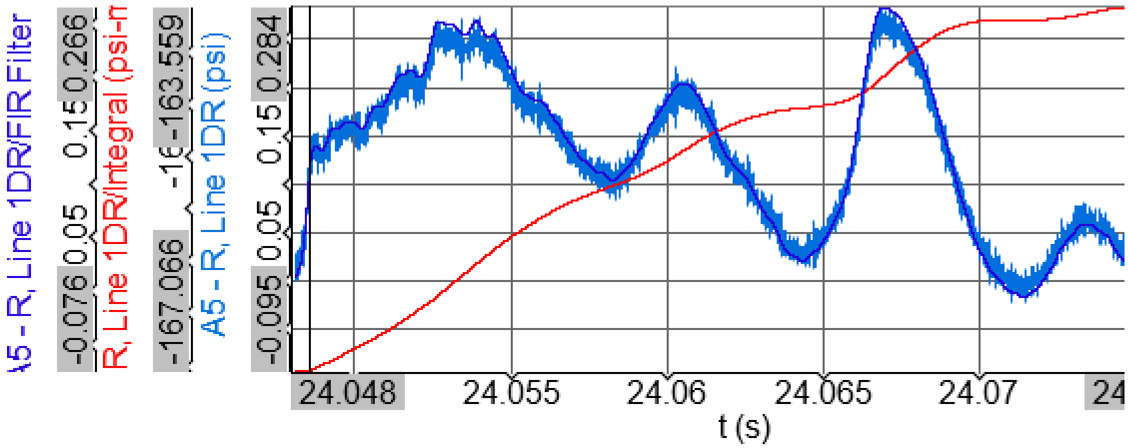

Notice: Fire
- L, Line E3L/Integral (psi-ms
B4 - L, Line E3L (psi)
t (s)
21.740
31.690

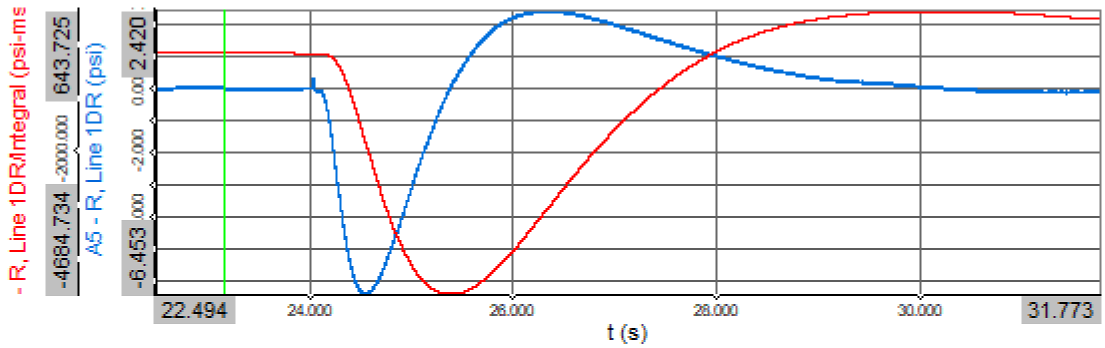

B4 - R, Line 3BR (psi)
R, Line 3BR/Integral (psi-m
24.039
24.045
24.05
24.055
24.06
t (s)

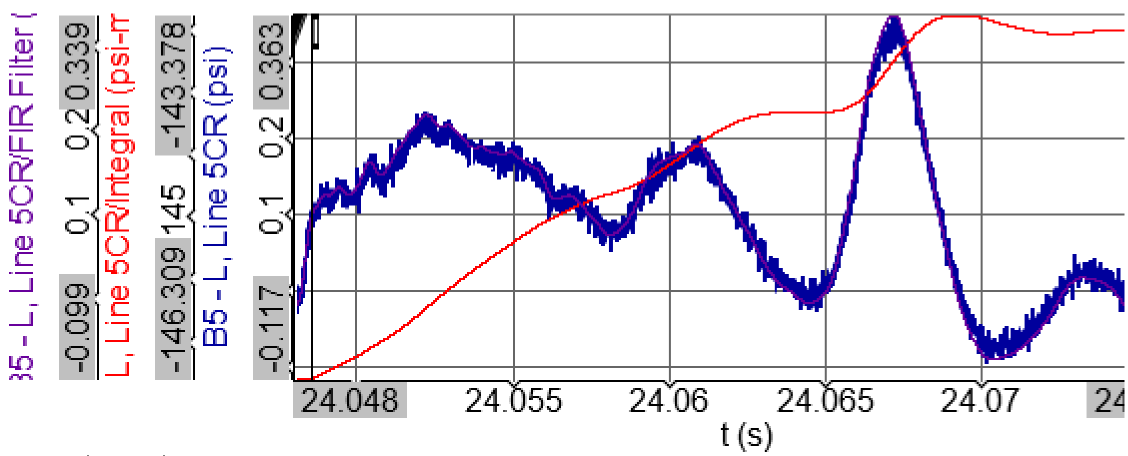

- R, Line 3BR/Integral (psi-ms
B4 - R, Line 3BR (psi)
21.740
24.000
26.000
28.000
30.000
31.690
t (s)

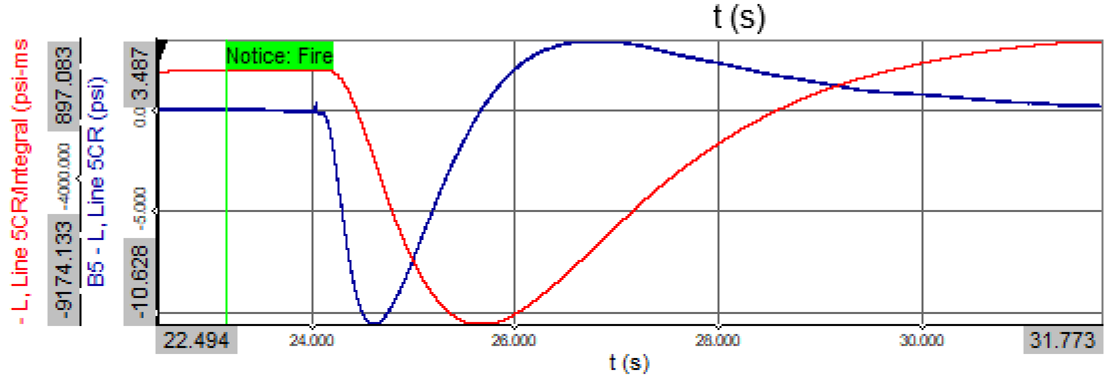

A5 - L, Line E2L (psi)
L, Line E2L/Integral (psi-m
24.048
24.055
24.06
24.065
24.07
t (s)

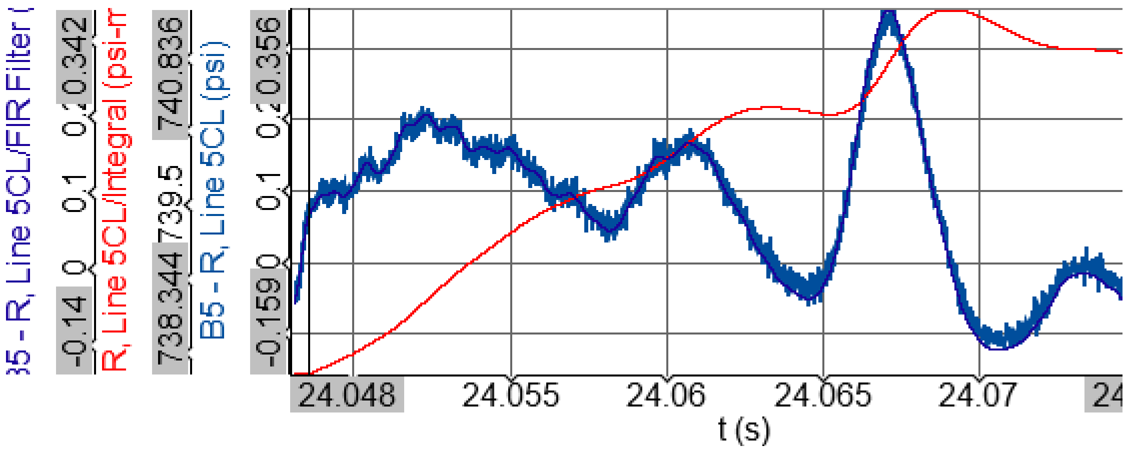

Notice: Fire
- L, Line E2L/Integral (psi-ms
A5 - L, Line E2L (psi)
22.494
24.000
26.000
28.000
30.000
31.773
t (s)

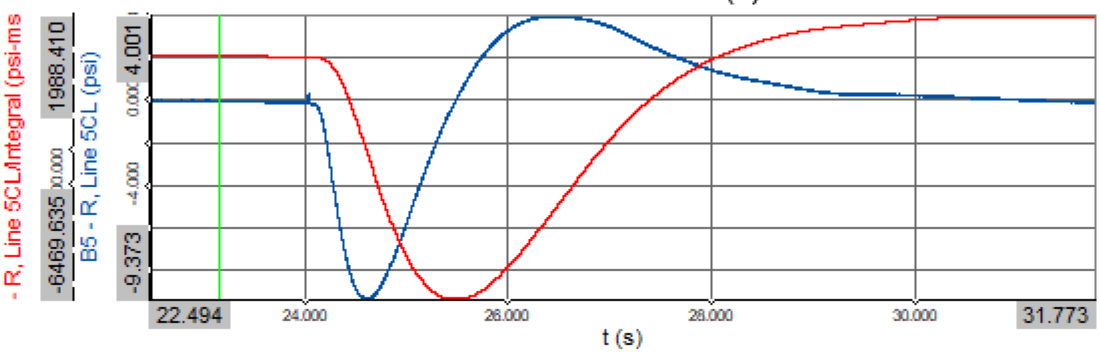

A5 - R, Line 1DR/FIR Filter
R, Line 1DR/Integral (psi-m
A5 - R, Line 1DR (psi)
-0.076 0.05 0.15 0.266
-167.066 -163.559
-0.095 0.05 0.15 0.284
24.048
24.055
24.06
24.065
24.07
t (s)

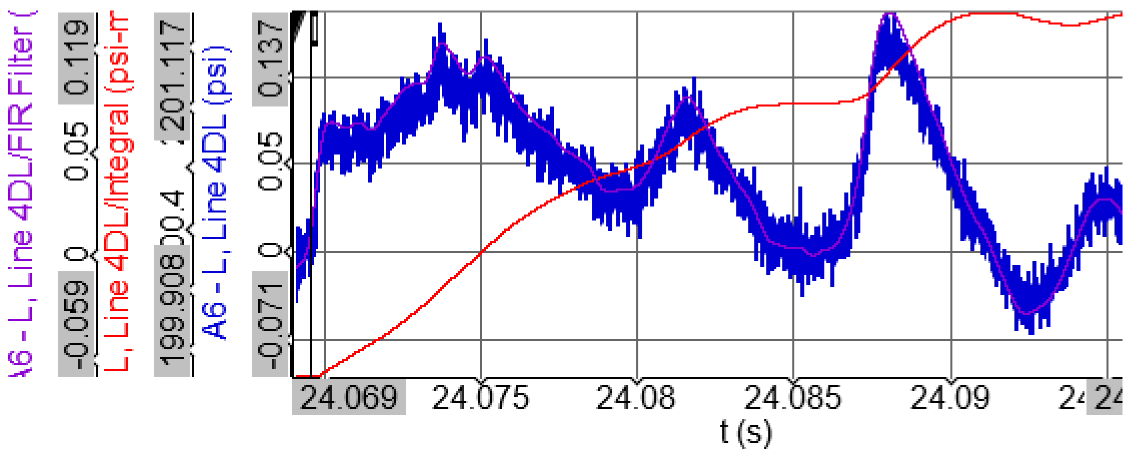

- R, Line 1DR/Integral (psi-ms
-4684.734 -2000.000 643.725
A5 - R, Line 1DR (psi)
-6.453 -2.000 0.00 2.420
22.494
24.000
26.000
28.000
30.000
31.773
t (s)

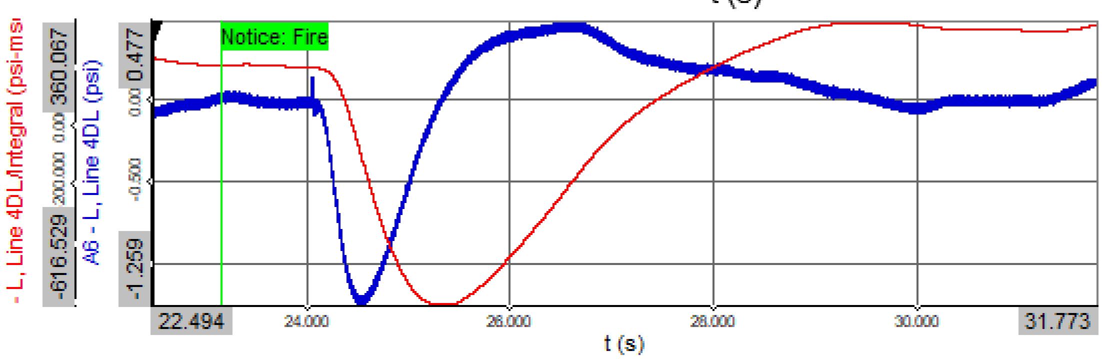

B5 - L, Line 5CR/FIR Filter
L, Line 5CR/Integral (psi-m
B5 - L, Line 5CR (psi)
-0.099 0.1 0.2 0.339
-146.309 145 -143.378
-0.117 0.1 0.2 0.363
24.048
24.055
24.06
24.065
24.07
t (s)

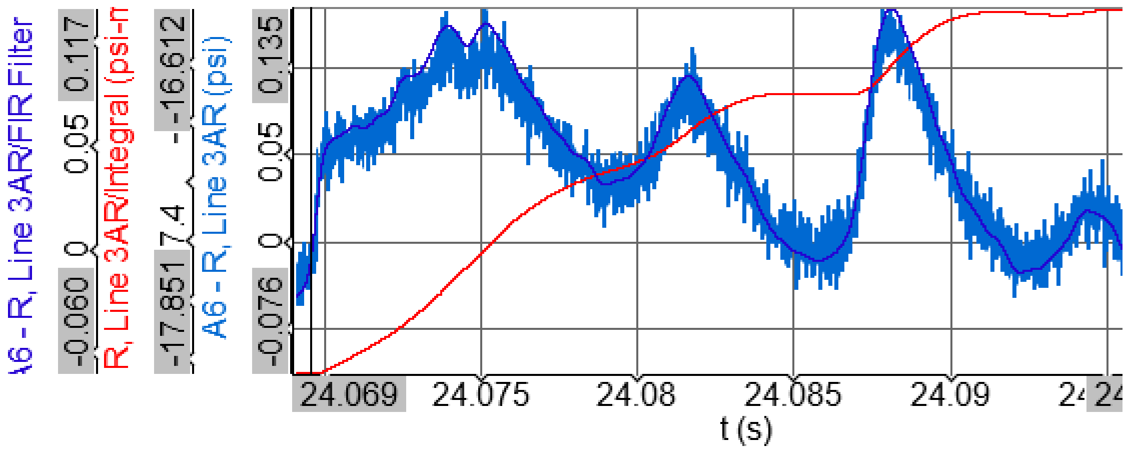

- L, Line 5CR/Integral (psi-ms
-9174.133 -4000.000 897.083
B5 - L, Line 5CR (psi)
-10.628 -5.000 0.0 3.487
Notice: Fire
22.494
24.000
26.000
28.000
30.000
31.773
t (s)

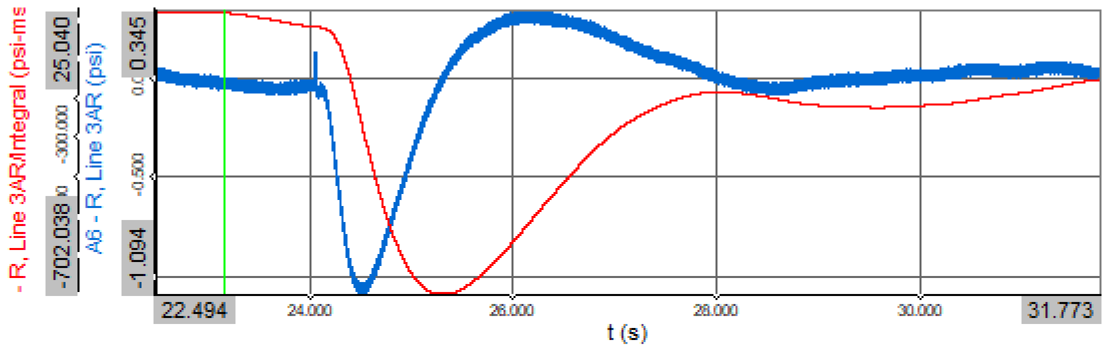

B5 - R, Line 5CL/FIR Filter (
R, Line 5CL/Integral (psi-m
B5 - R, Line 5CL (psi)
24.048
24.055
24.06
24.065
24.07
t (s)

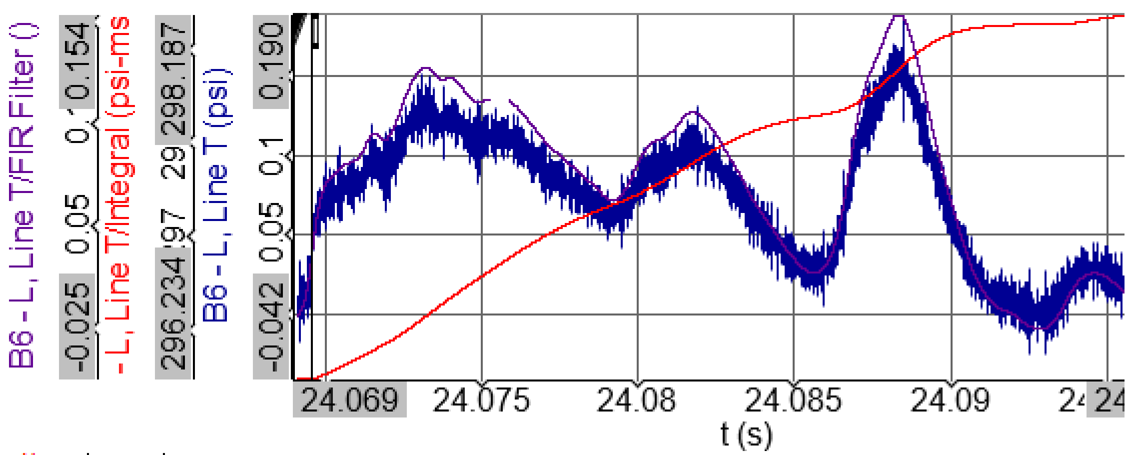

- R, Line 5CL/Integral (psi-ms
B5 - R, Line 5CL (psi)
22.494
24.000
26.000
28.000
30.000
31.773
t (s)

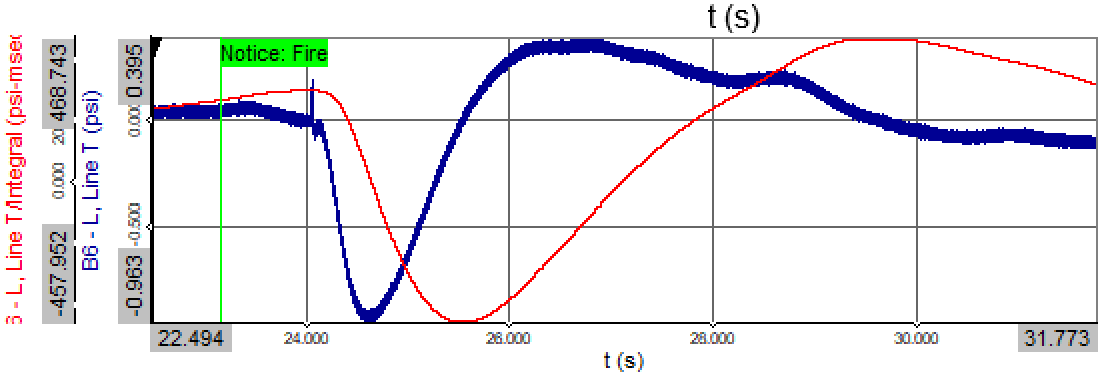

A6 - L, Line 4DL/FIR Filter (
L, Line 4DL/Integral (psi-m
A6 - L, Line 4DL (psi)
24.069
24.075
24.08
24.085
24.09
t (s)

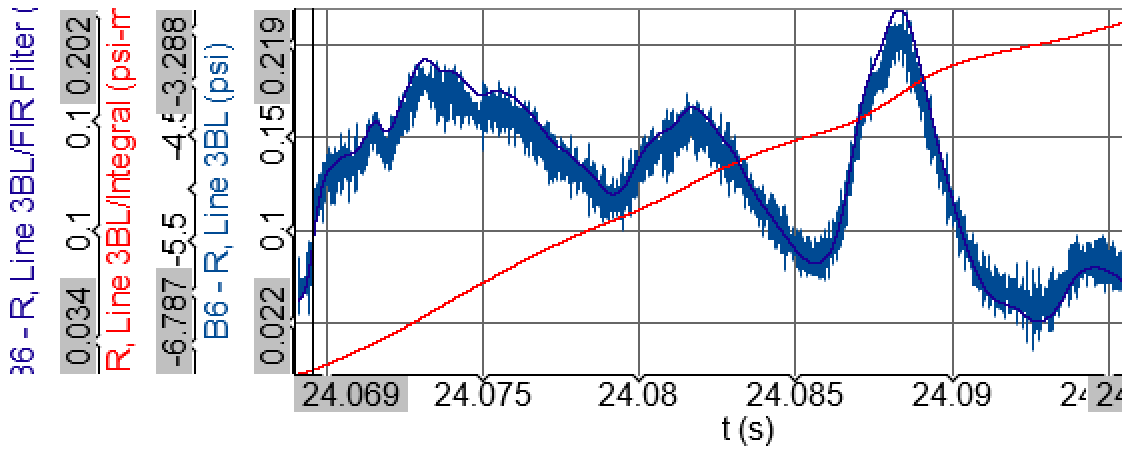

- L, Line 4DL/Integral (psi-ms
A6 - L, Line 4DL (psi)
Notice: Fire
22.494
24.000
26.000
28.000
30.000
31.773
t (s)

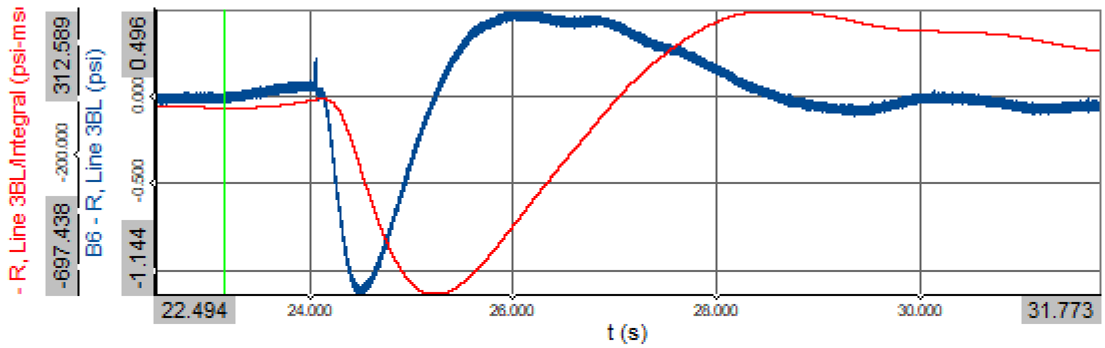

A6 - R, Line 3AR/FIR Filter
R, Line 3AR/Integral (psi-m
A6 - R, Line 3AR (psi)
-0.060
0
0.05
0.117
-17.851
7.4
-16.612
-0.076
0
0.05
0.135
24.069
24.075
24.08
24.085
24.09
t (s)

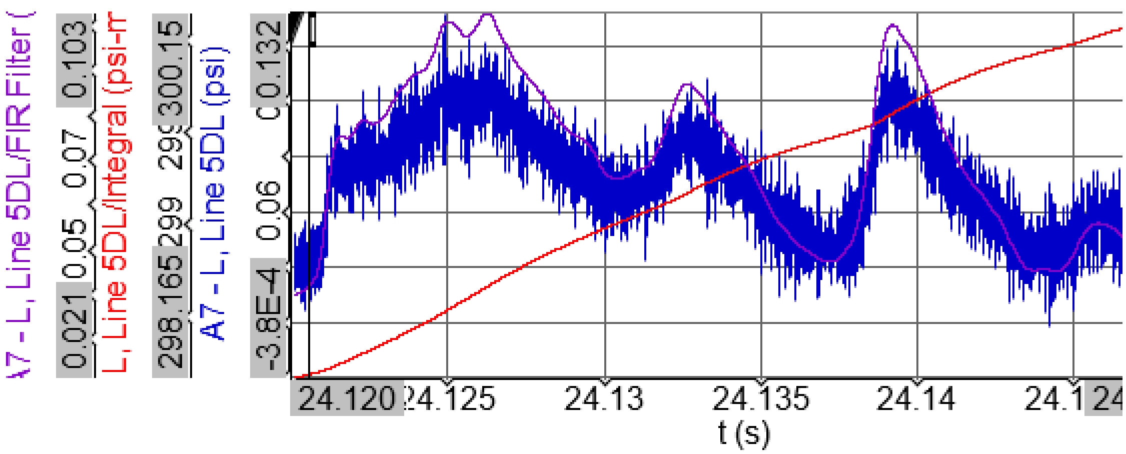

- R, Line 3AR/Integral (psi-ms
A6 - R, Line 3AR (psi)
-702.038
-300.000
25.040
-1.094
-0.500
0.345
22.494
24.000
26.000
28.000
30.000
31.773
t (s)

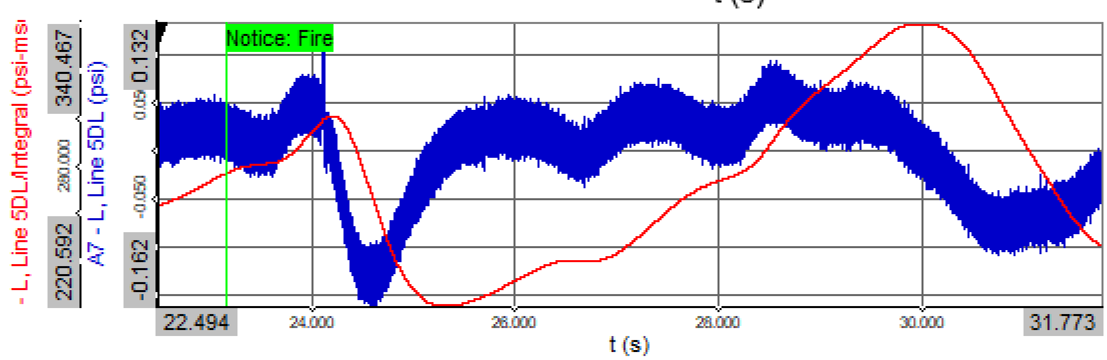

B6 - L, Line T/FIR Filter ()
- L, Line T/Integral (psi-ms
B6 - L, Line T (psi)
-0.025
0.05
0.154
296.234
298.187
-0.042
0.05
0.1
0.190
24.069
24.075
24.08
24.085
24.09
t (s)

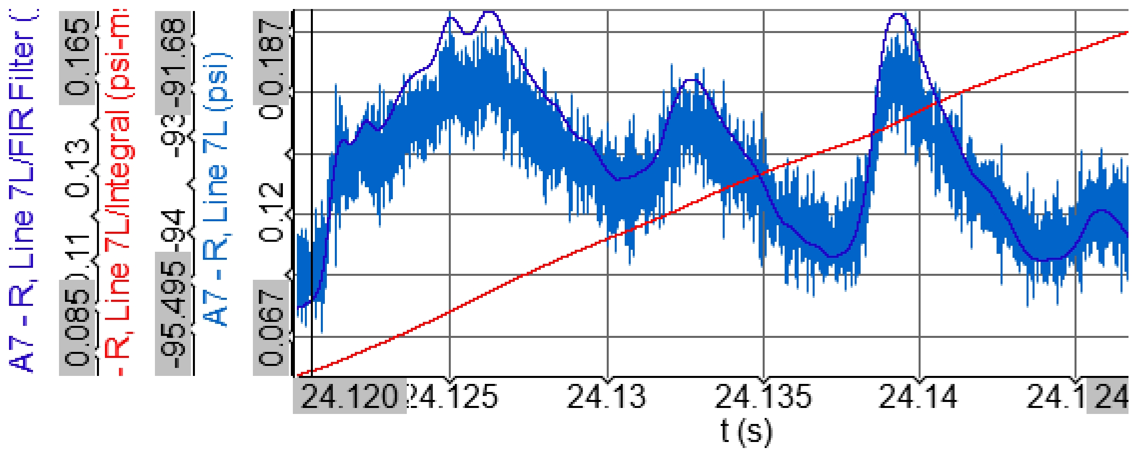

Notice: Fire
- L, Line T/Integral (psi-msec
B6 - L, Line T (psi)
-457.952
0.000
468.743
-0.963
-0.500
0.395
22.494
24.000
26.000
28.000
30.000
31.773
t (s)

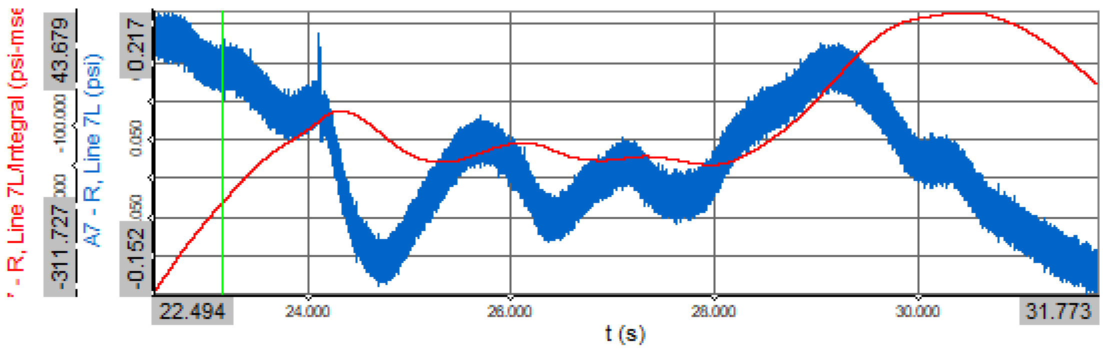

B6 - R, Line 3BL/FIR Filter (
R, Line 3BL/Integral (psi-m
B6 - R, Line 3BL (psi)
t (s)

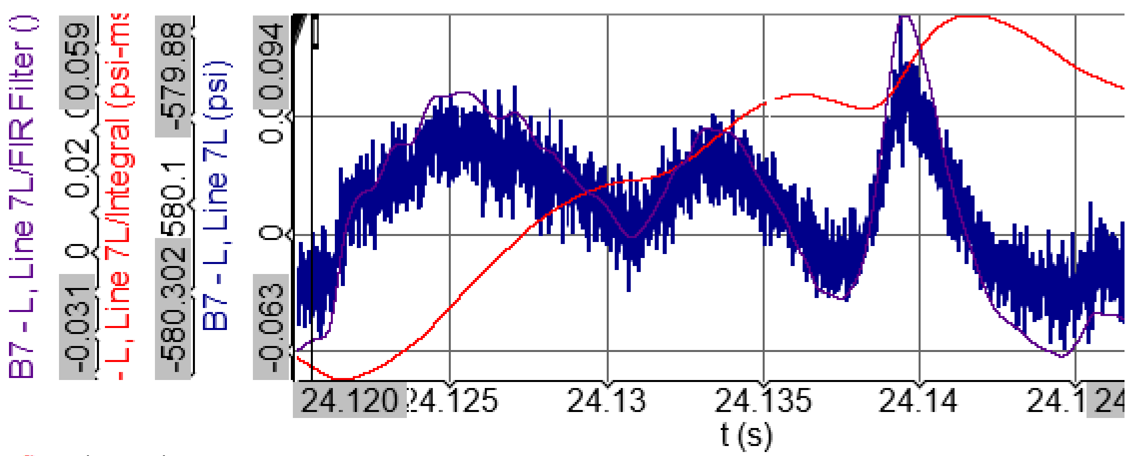

- R, Line 3BL/Integral (psi-ms
B6 - R, Line 3BL (psi)
t (s)

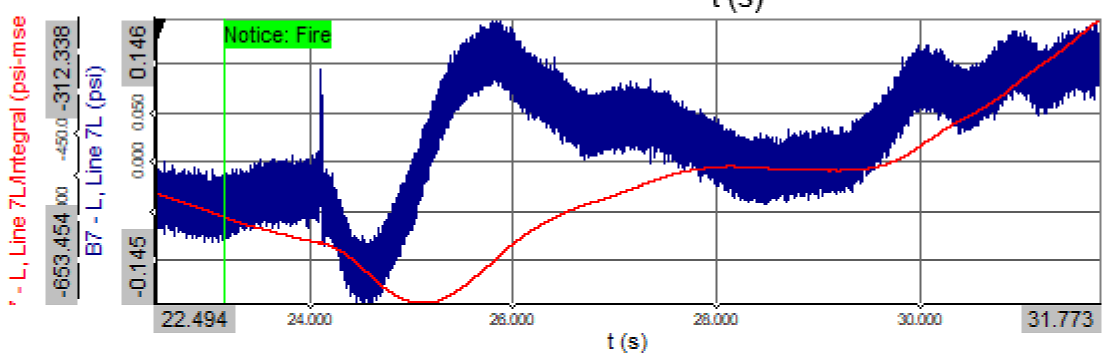

A7 - L, Line 5DL/FIR Filter (
L, Line 5DL/Integral (psi-m
A7 - L, Line 5DL (psi)
t (s)

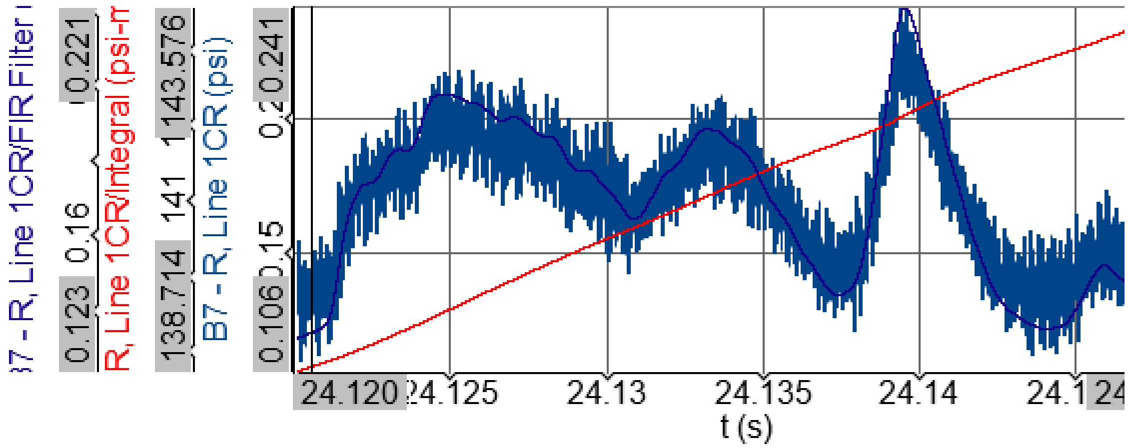

Notice: Fire
- L, Line 5DL/Integral (psi-ms
A7 - L, Line 5DL (psi)
t (s)

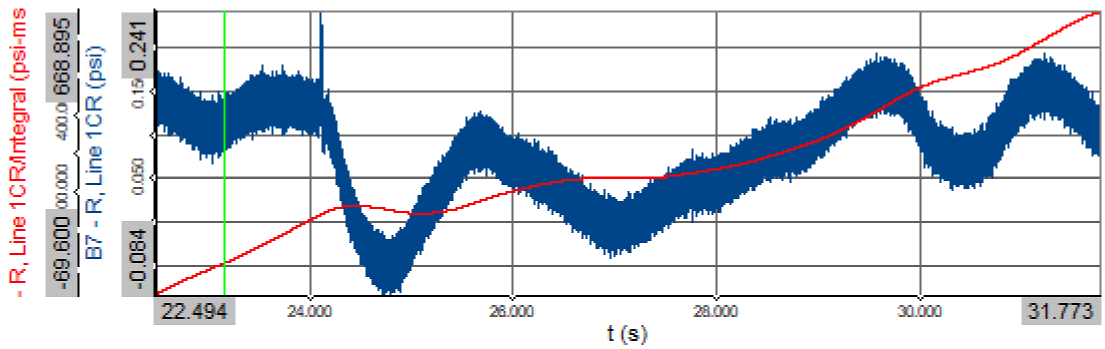

A7 - R, Line 7L/FIR Filter (
-R, Line 7L/Integral (psi-m
A7 - R, Line 7L (psi)
t (s)

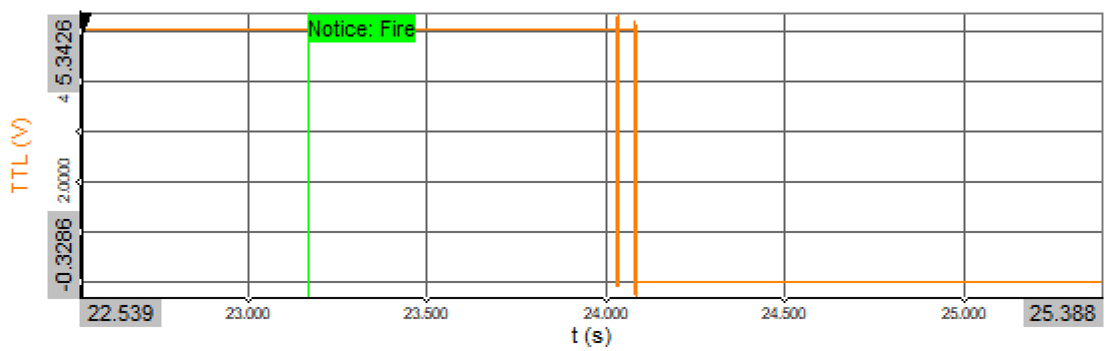

- R, Line 7L/Integral (psi-mse
A7 - R, Line 7L (psi)
t (s)


B7 - L, Line 7L/FIR Filter ()
- L, Line 7L/Integral (psi-ms
B7 - L, Line 7L (psi)
t (s)


- L, Line 7L/Integral (psi-mse
B7 - L, Line 7L (psi)
Notice: Fire
t (s)

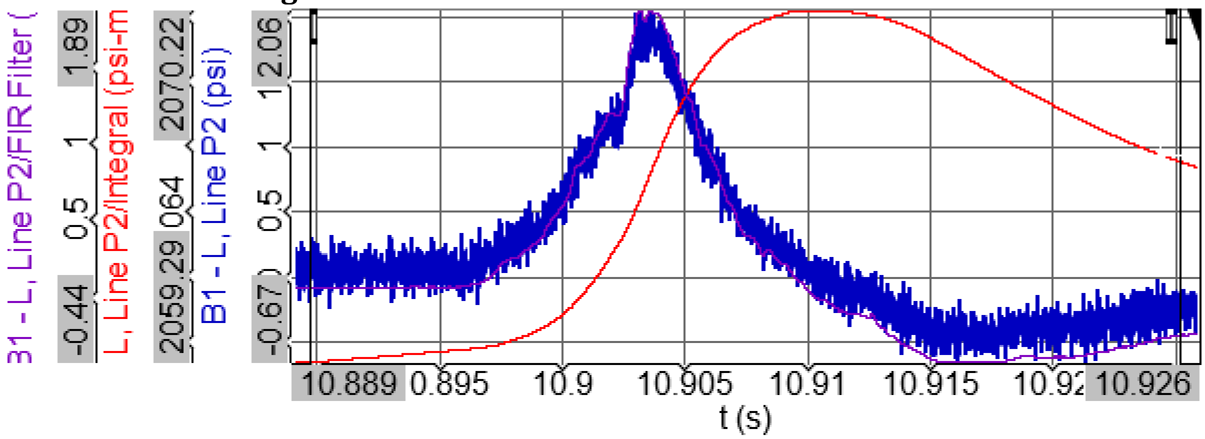

B7 - R, Line 1CR/FIR Filter
R, Line 1CR/Integral (psi-m
B7 - R, Line 1CR (psi)
0.123
0.16
0.221
138.714
141
143.576
0.106
0.15
0.20
0.241
24.120
24.125
24.13
24.135
24.14
24.1
t (s)

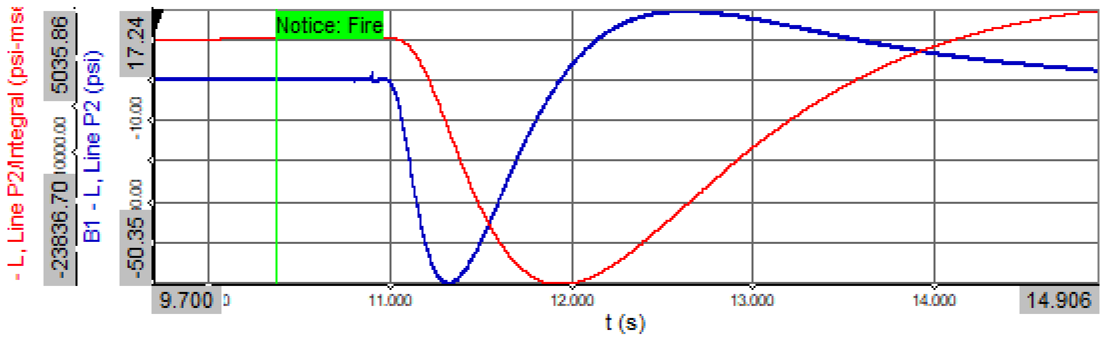

R, Line 1CR/Integral (psi-ms
B7 - R, Line 1CR (psi)
-69.600
668.895
-0.084
0.241
22.494
24.000
26.000
28.000
30.000
31.773
t (s)

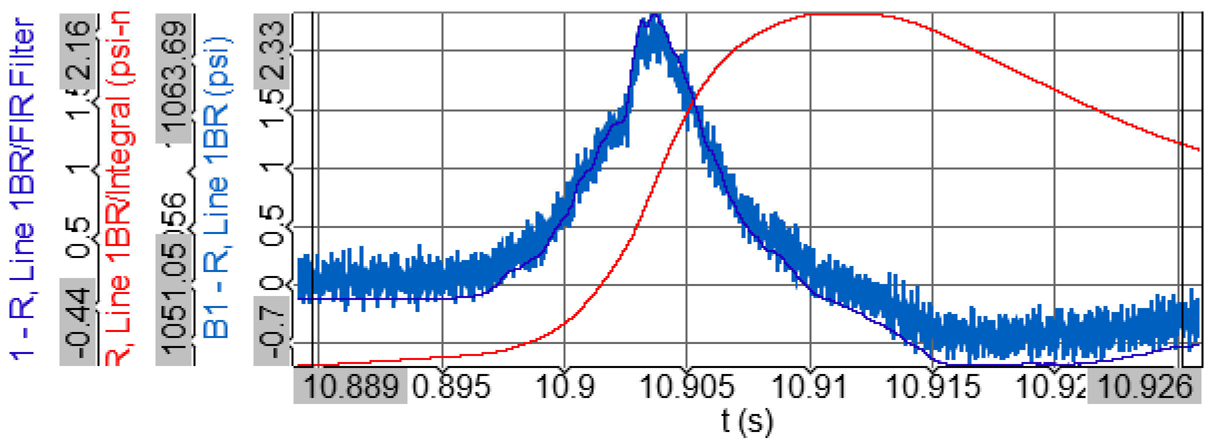

TTL (V)
-0.3286
2.0000
5.3426
Notice: Fire
22.539
23.000
23.500
24.000
24.500
25.000
25.388
t (s)

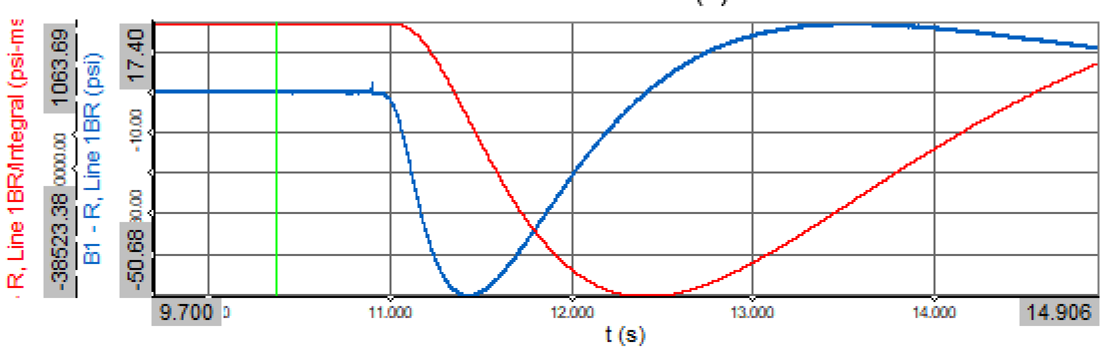
8.2 Fine Mg&Al-MoO_3-CuO Thermite – Large-Scale Mix ID #8 (SMS mixed)

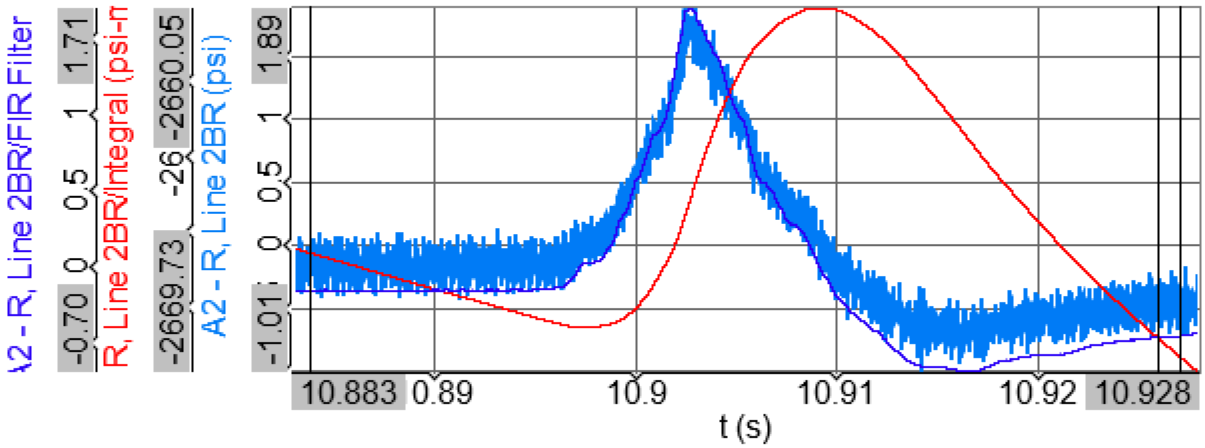
8.2.1 Trial 1 for Large-Scale Mix ID #8

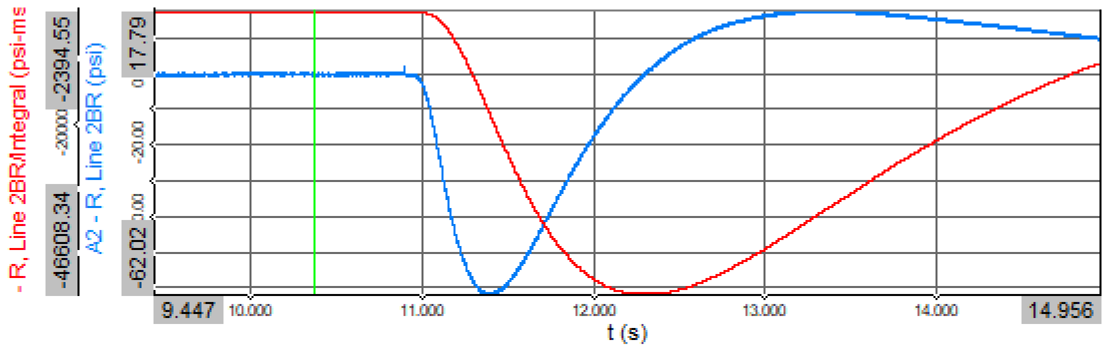


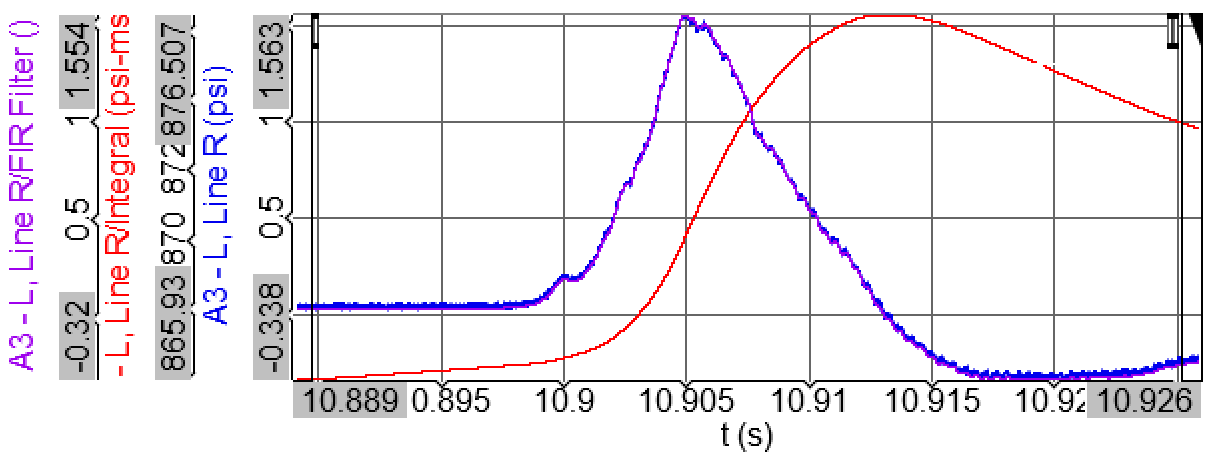


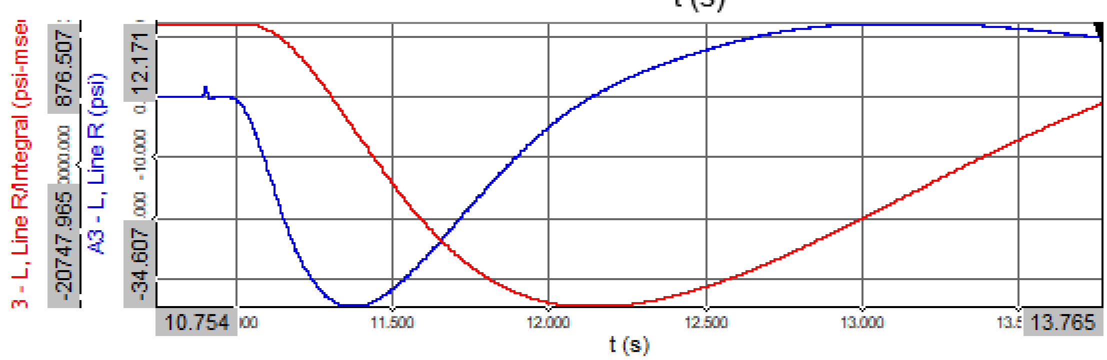


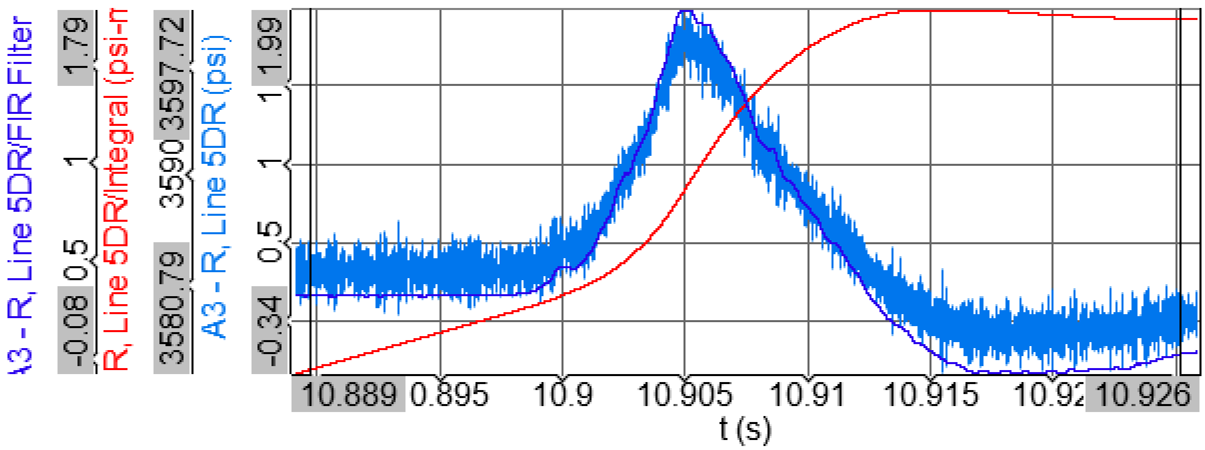


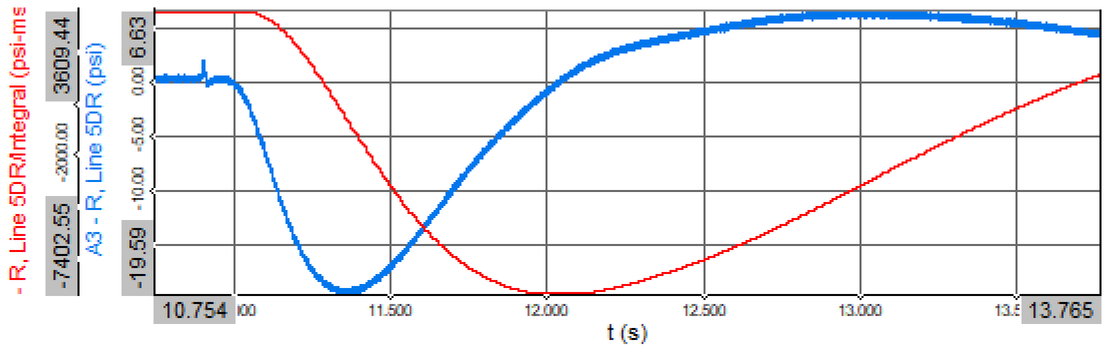

A2 - R, Line 2BR/FIR Filter
R, Line 2BR/Integral (psi-m
A2 - R, Line 2BR (psi)
10.883
10.89
10.9
10.91
10.92
10.928
t (s)

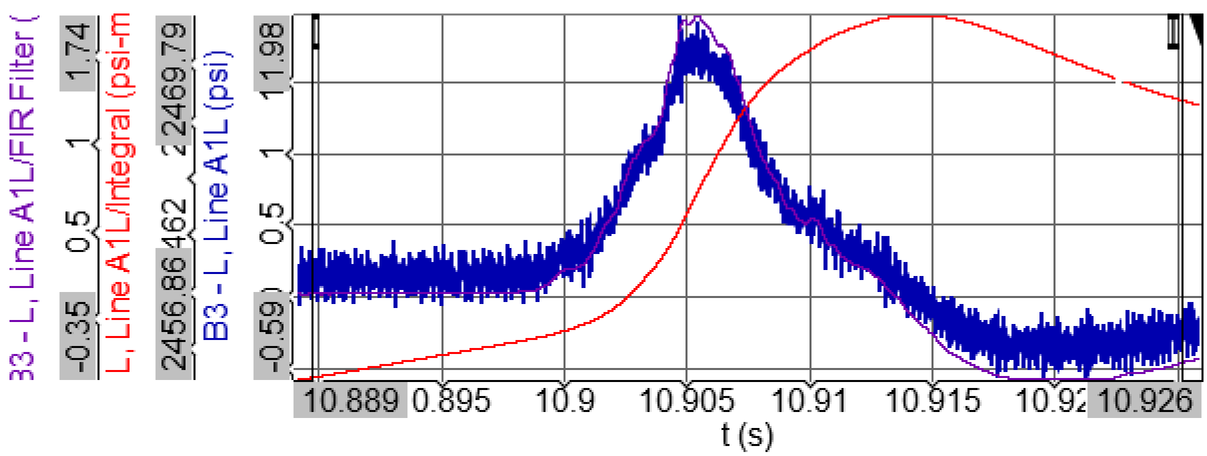

- R, Line 2BR/Integral (psi-ms
A2 - R, Line 2BR (psi)
9.447
10.000
11.000
12.000
13.000
14.000
14.956
t (s)

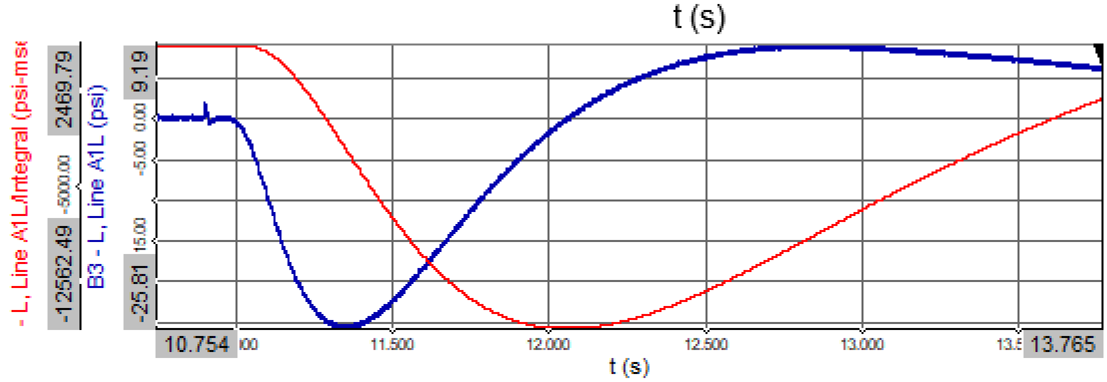

A3 - L, Line R/FIR Filter ()
- L, Line R/Integral (psi-ms
A3 - L, Line R (psi)
10.889
0.895
10.9
10.905
10.91
10.915
10.926
t (s)

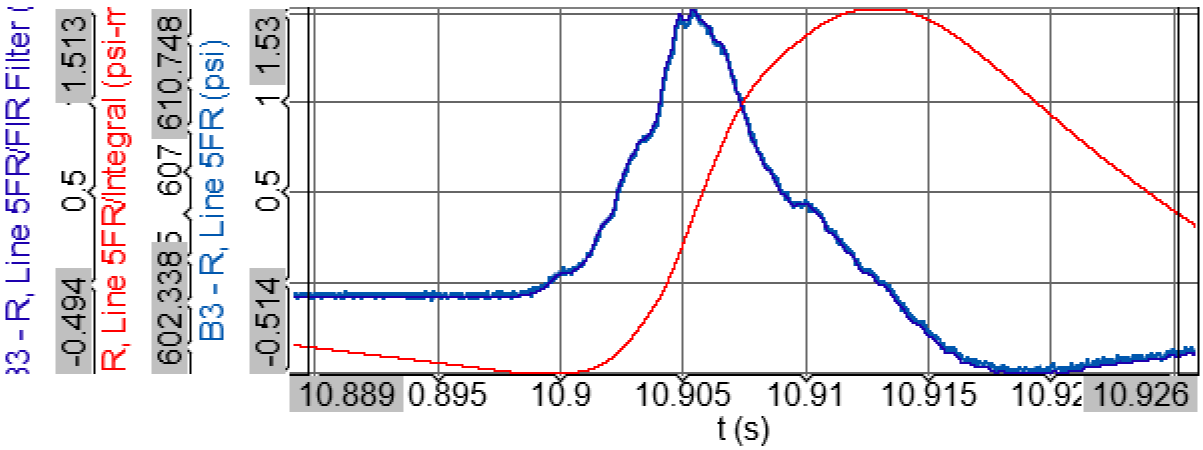

3 - L, Line R/Integral (psi-mse
A3 - L, Line R (psi)
10.754
11.500
12.000
12.500
13.000
13.765
t (s)

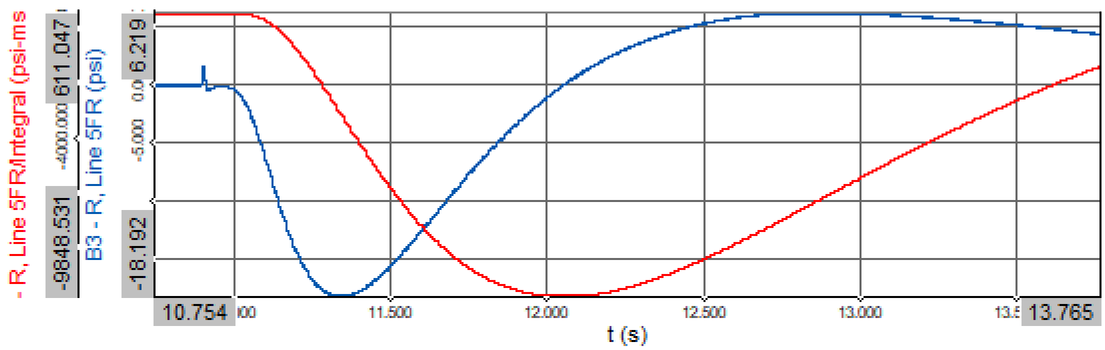

R, Line 5DR/FIR Filter
R, Line 5DR/Integral (psi-m
A3 - R, Line 5DR (psi)
t (s)
10.889
10.926

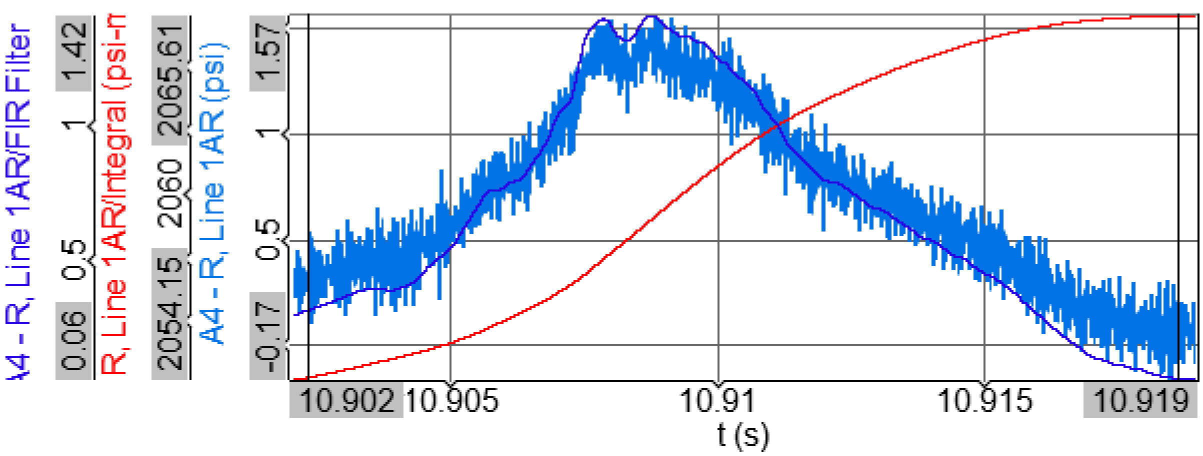

R, Line 5DR/Integral (psi-ms
A3 - R, Line 5DR (psi)
t (s)
10.754
13.765

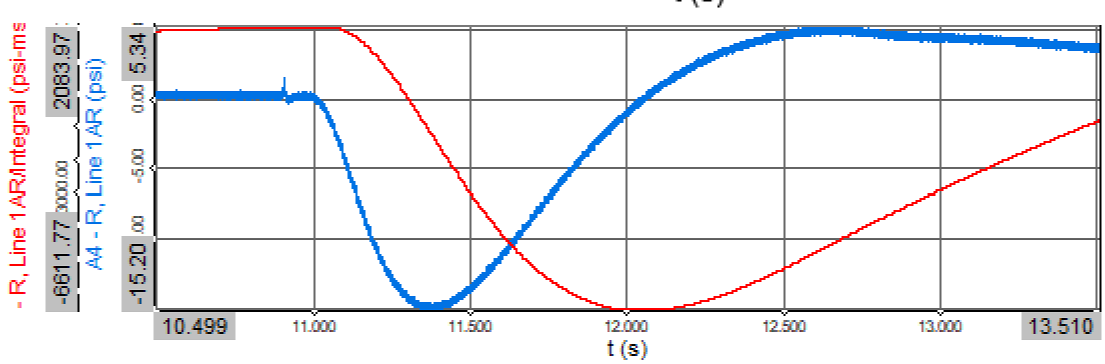

L, Line A1L/FIR Filter
L, Line A1L/Integral (psi-m
B3 - L, Line A1L (psi)
t (s)
10.889
10.926

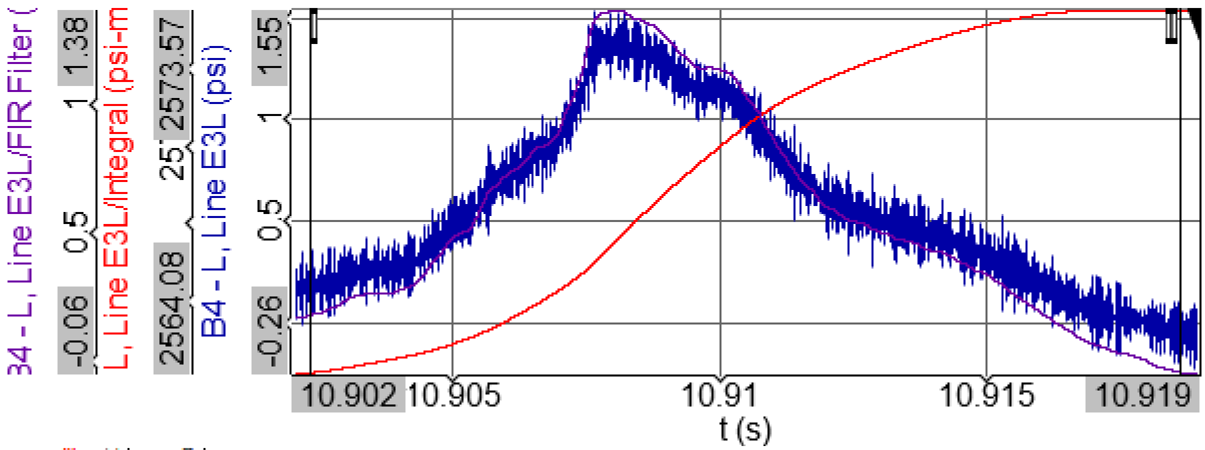

L, Line A1L/Integral (psi-ms
B3 - L, Line A1L (psi)
t (s)
10.754
13.765

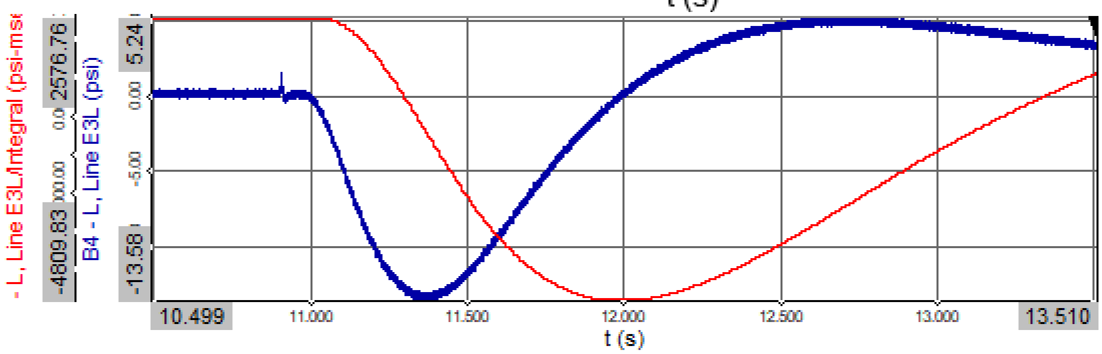

B3 - R, Line 5FR/FIR Filter (
R, Line 5FR/Integral (psi-m
B3 - R, Line 5FR (psi)
-0.494
0.5
1.513
602.338
607
610.748
-0.514
0.5
1
1.53
10.889
0.895
10.9
10.905
10.91
10.915
10.92
10.926
t (s)

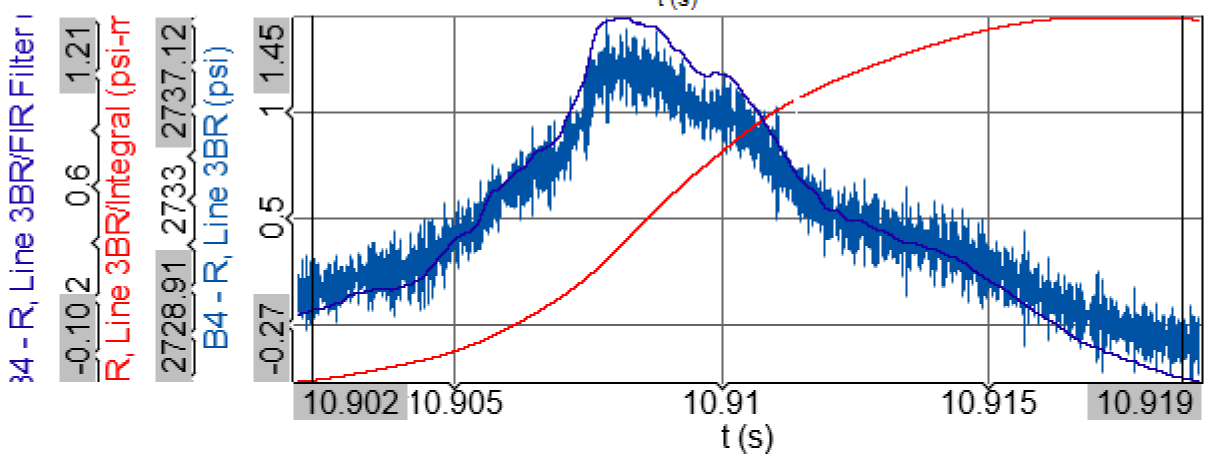

- R, Line 5FR/Integral (psi-ms
B3 - R, Line 5FR (psi)
-9848.531
611.047
-18.192
6.219
10.754
11.500
12.000
12.500
13.000
13.765
t (s)

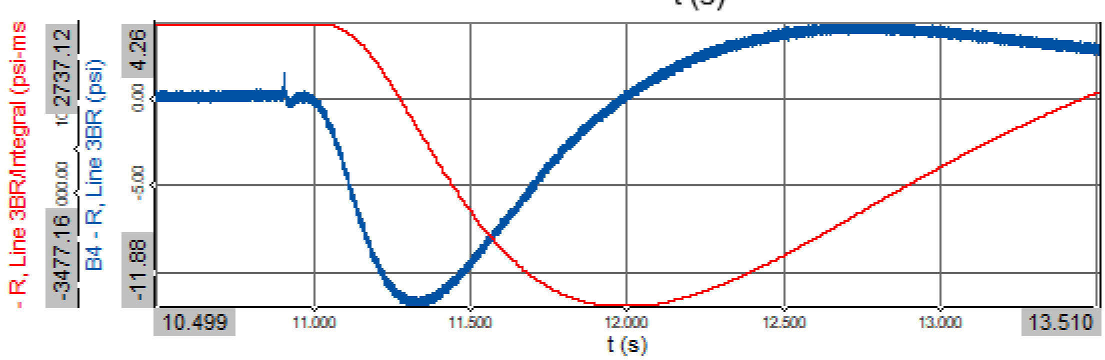

A4 - R, Line 1AR/FIR Filter
R, Line 1AR/Integral (psi-m
A4 - R, Line 1AR (psi)
0.06
0.5
1
1.42
2054.15
2060
2065.61
-0.17
0.5
1
1.57
10.902
10.905
10.91
10.915
10.919
t (s)

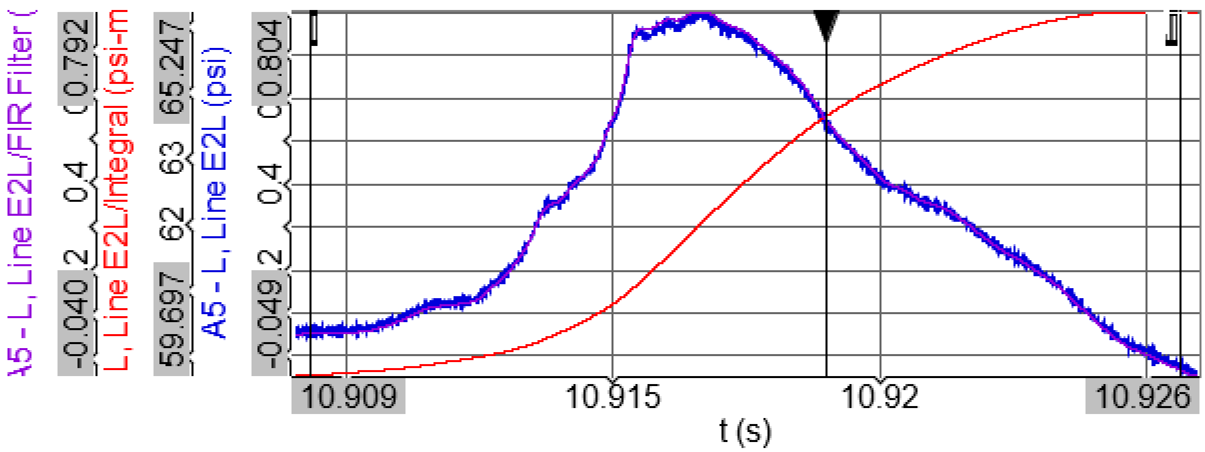

- R, Line 1AR/Integral (psi-ms
A4 - R, Line 1AR (psi)
-6611.77
2083.97
-15.20
5.34
10.499
11.000
11.500
12.000
12.500
13.000
13.510
t (s)

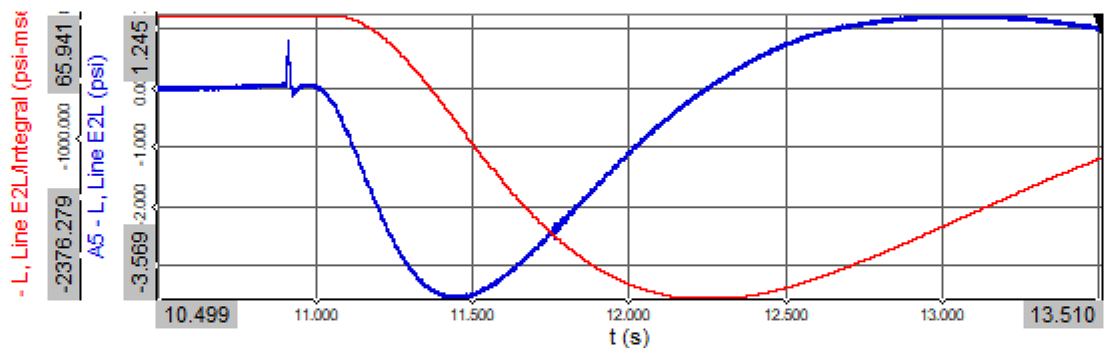

B4 - L, Line E3L (psi)
t (s)
10.902
10.905
10.91
10.915
10.919
-0.26
0.5
1
1.55
2564.08
2573.57
-0.06
0.5
1
1.38

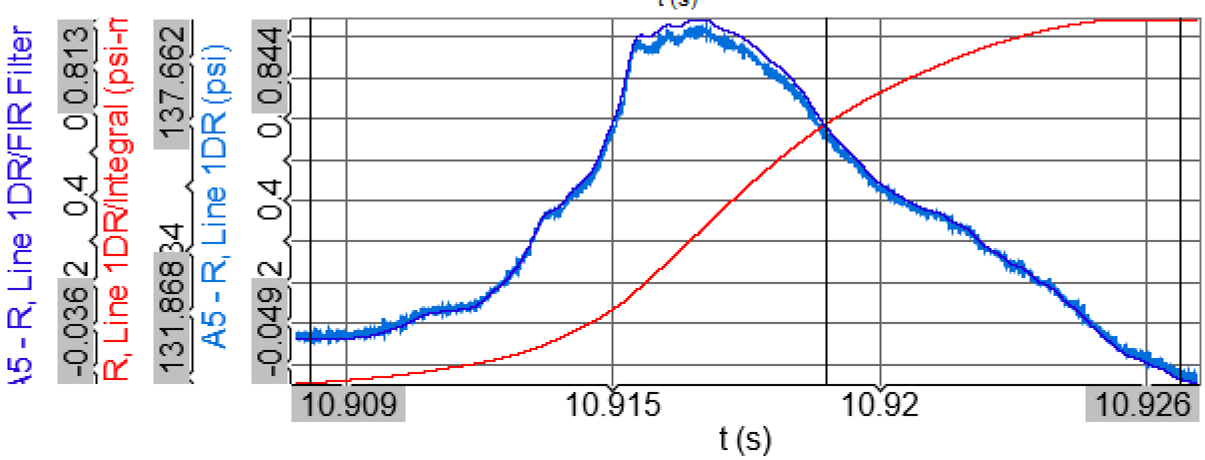

B4 - L, Line E3L (psi)
t (s)
10.499
11.000
11.500
12.000
12.500
13.000
13.510
-13.58
-5.00
0.00
5.24
-4809.83
2576.76

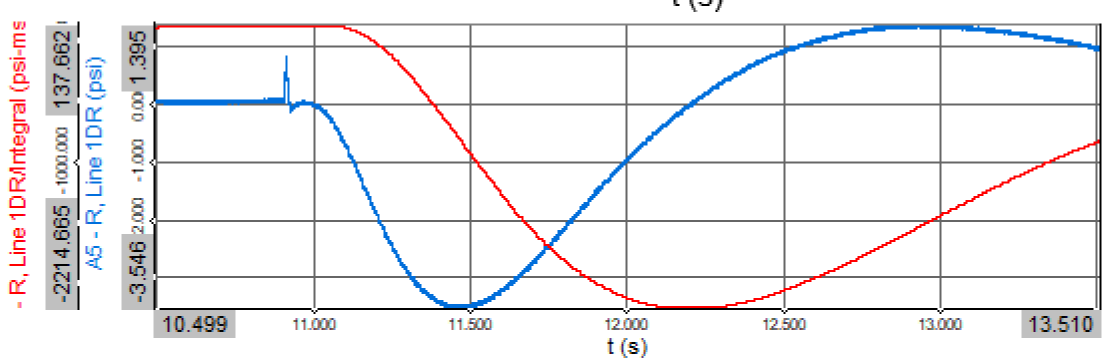

B4 - R, Line 3BR (psi)
t (s)
10.902
10.905
10.91
10.915
10.919
-0.27
0.5
1
1.45
2728.91
2733
2737.12
-0.10
0.6
1.21

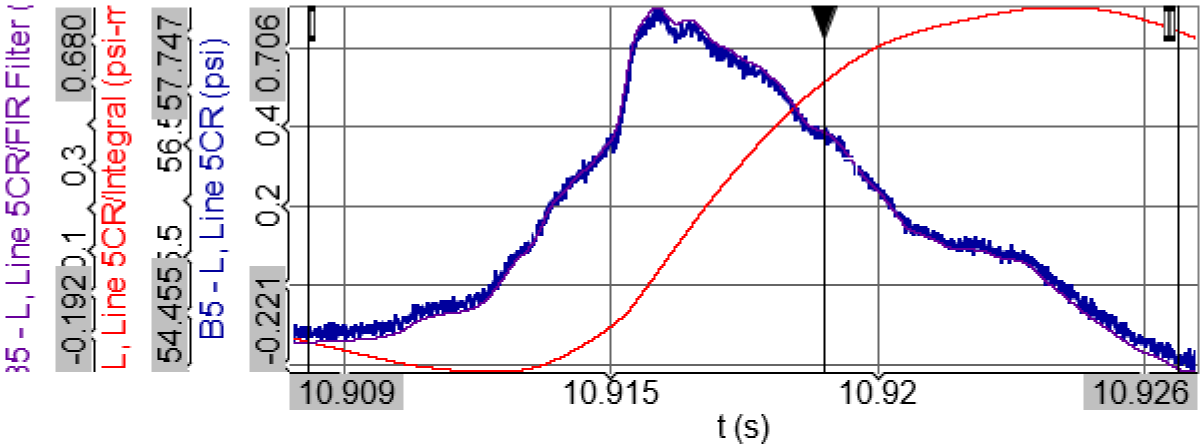

B4 - R, Line 3BR (psi)
t (s)
10.499
11.000
11.500
12.000
12.500
13.000
13.510
-11.88
-5.00
0.00
4.26
-3477.16
2737.12

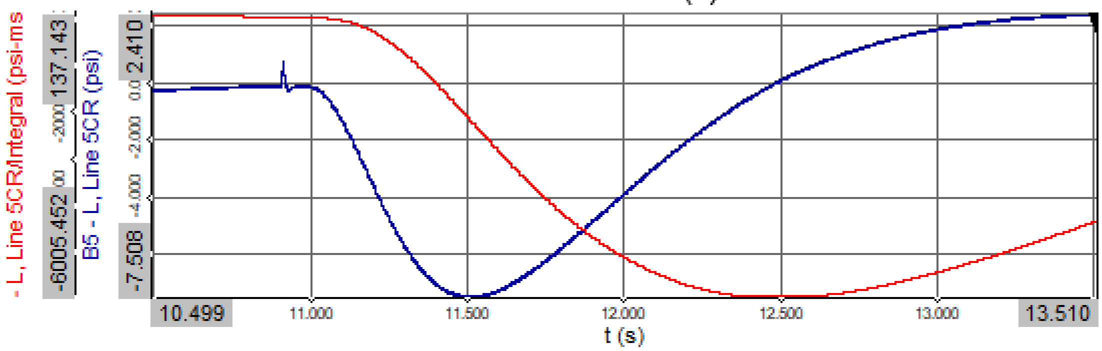

A5 - L, Line E2L (psi)
10.909
10.915
10.92
10.926
t (s)

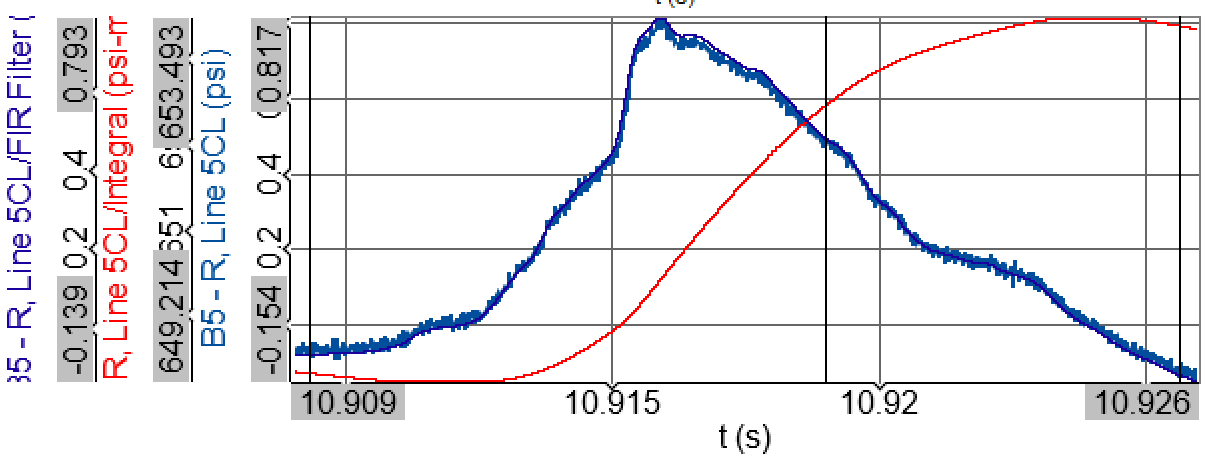

A5 - L, Line E2L (psi)
10.499
11.000
11.500
12.000
12.500
13.000
13.510
t (s)

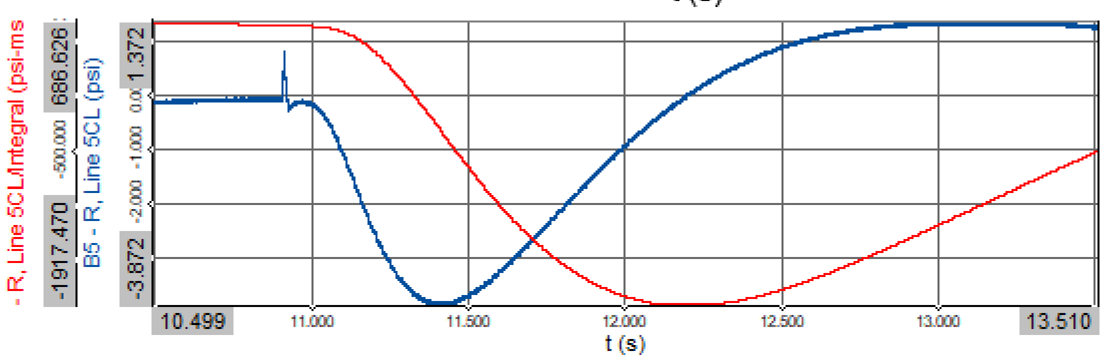

A5 - R, Line 1DR (psi)
10.909
10.915
10.92
10.926
t (s)

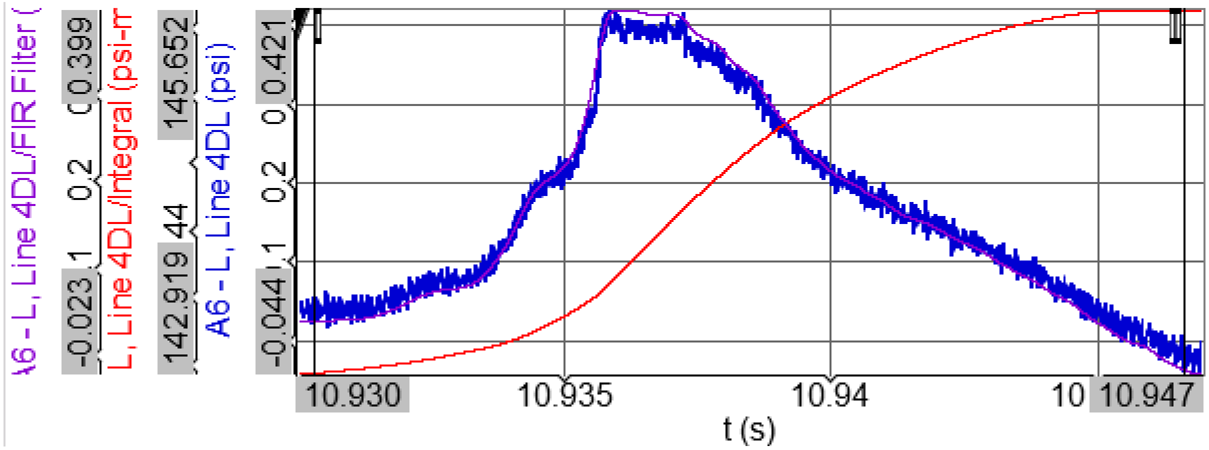

A5 - R, Line 1DR (psi)
10.499
11.000
11.500
12.000
12.500
13.000
13.510
t (s)

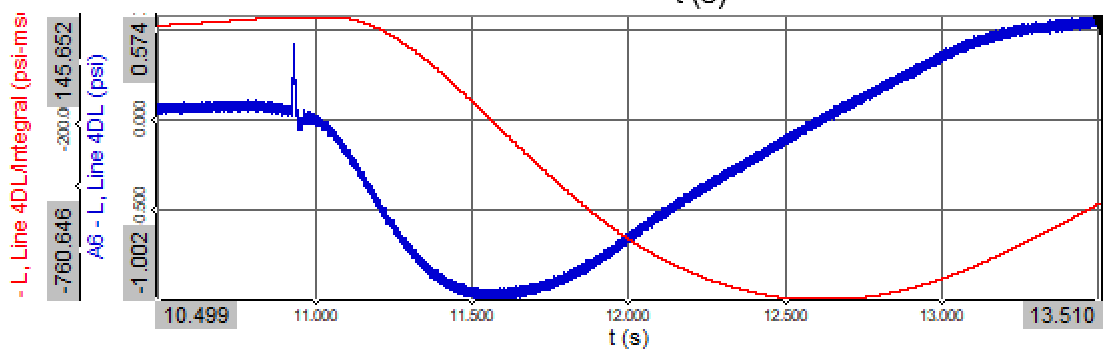

B5 - L, Line 5CR (psi)
10.909
10.915
10.92
10.926
t (s)

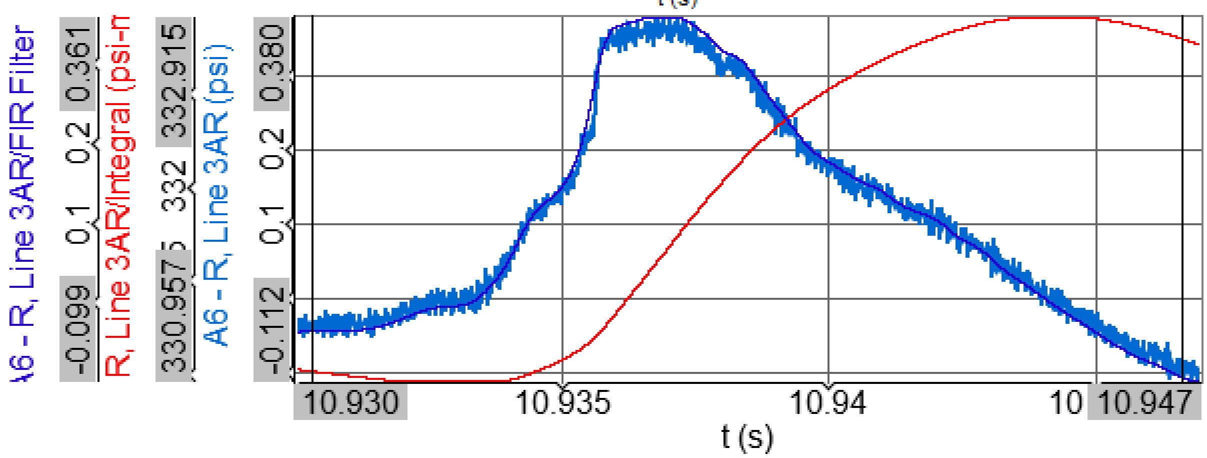

B5 - L, Line 5CR (psi)
10.499
11.000
11.500
12.000
12.500
13.000
13.510
t (s)

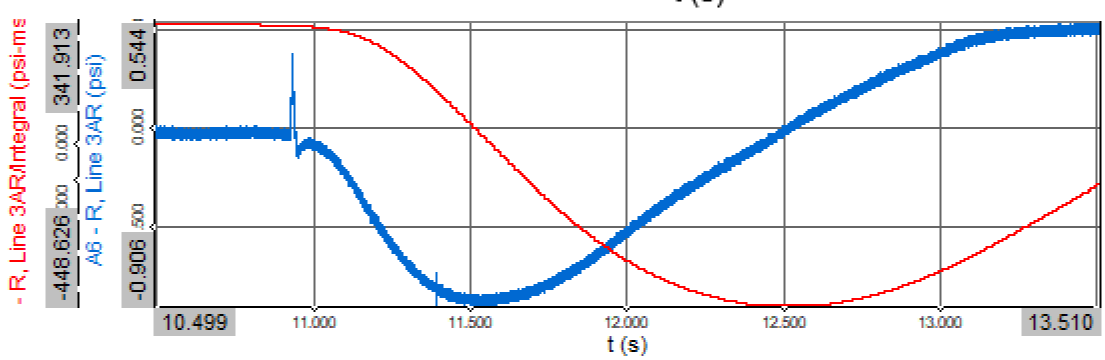

B5 - R, Line 5CL (psi)
10.909
10.915
10.92
10.926
t (s)

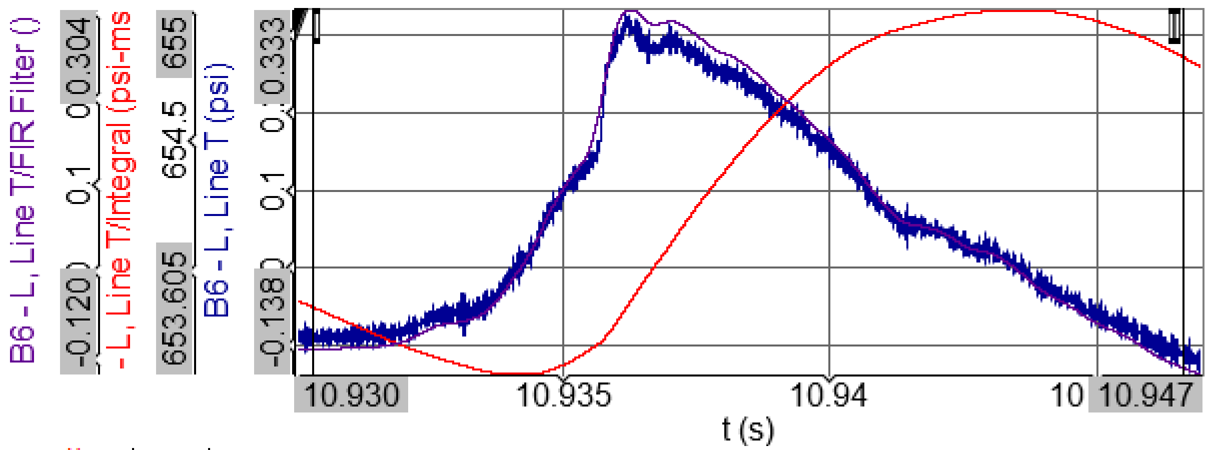

B5 - R, Line 5CL (psi)
10.499
11.000
11.500
12.000
12.500
13.000
13.510
t (s)

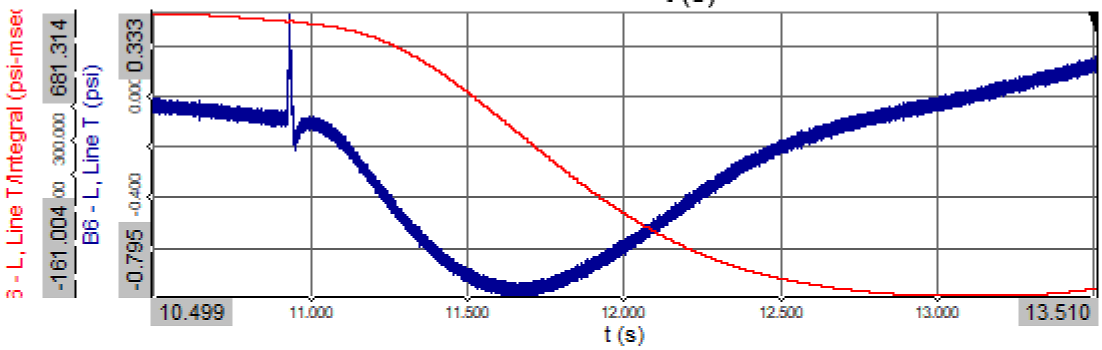

A6 - L, Line 4DL/FIR Filter (
L, Line 4DL/Integral (psi-m
A6 - L, Line 4DL (psi)
0.399
-0.023
145.652
142.919
0.421
-0.044
10.930
10.935
10.94
10.947
t (s)

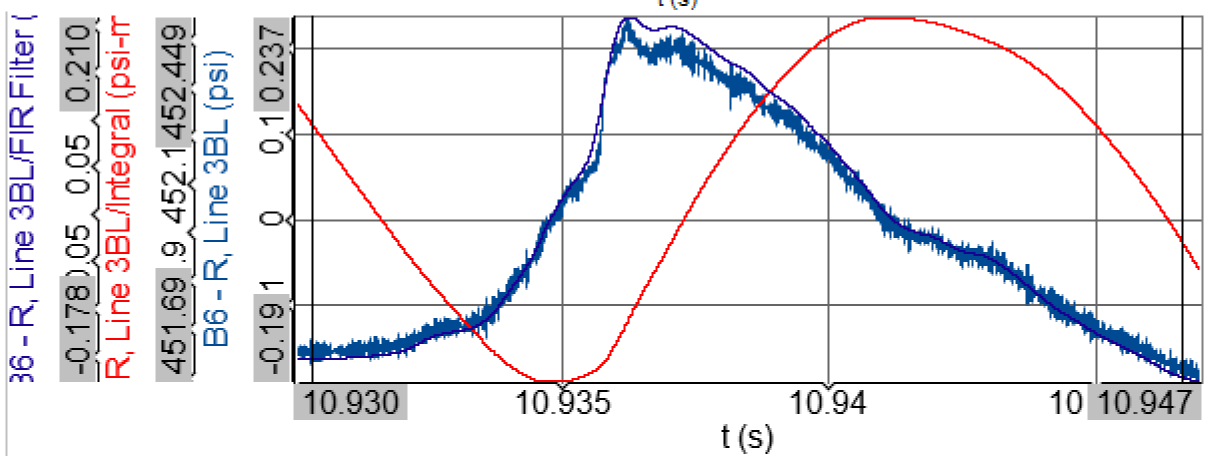

- L, Line 4DL/Integral (psi-ms
A6 - L, Line 4DL (psi)
145.652
-760.646
0.574
-1.002
10.499
11.000
11.500
12.000
12.500
13.000
13.510
t (s)

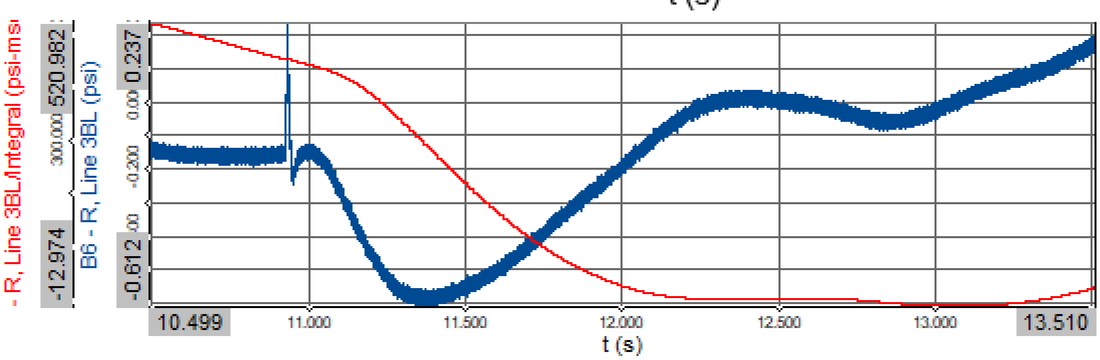

A6 - R, Line 3AR/FIR Filter
R, Line 3AR/Integral (psi-m
A6 - R, Line 3AR (psi)
0.361
-0.099
332.915
330.957
0.380
-0.112
10.930
10.935
10.94
10.947
t (s)

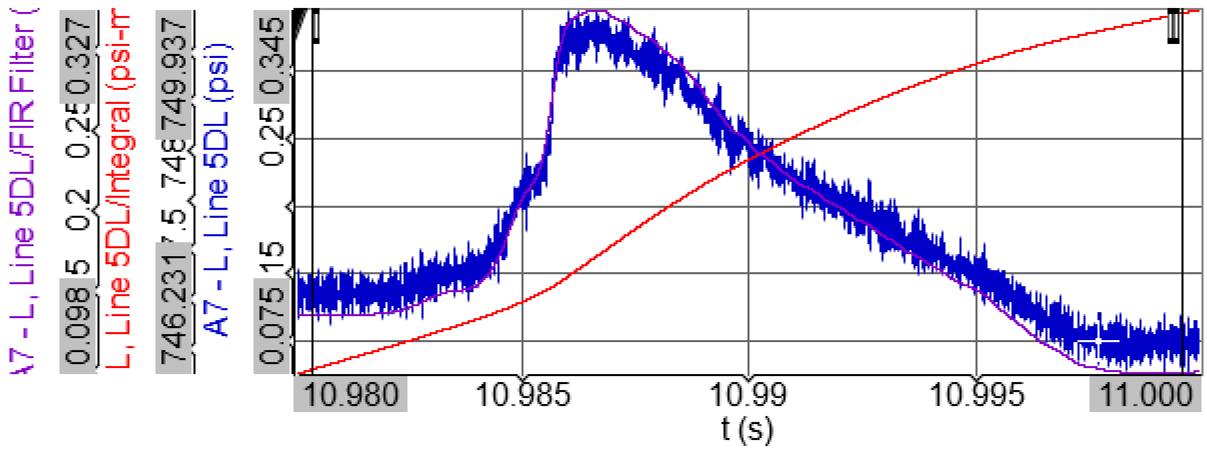

- R, Line 3AR/Integral (psi-ms
A6 - R, Line 3AR (psi)
341.913
-448.626
0.544
-0.906
10.499
11.000
11.500
12.000
12.500
13.000
13.510
t (s)

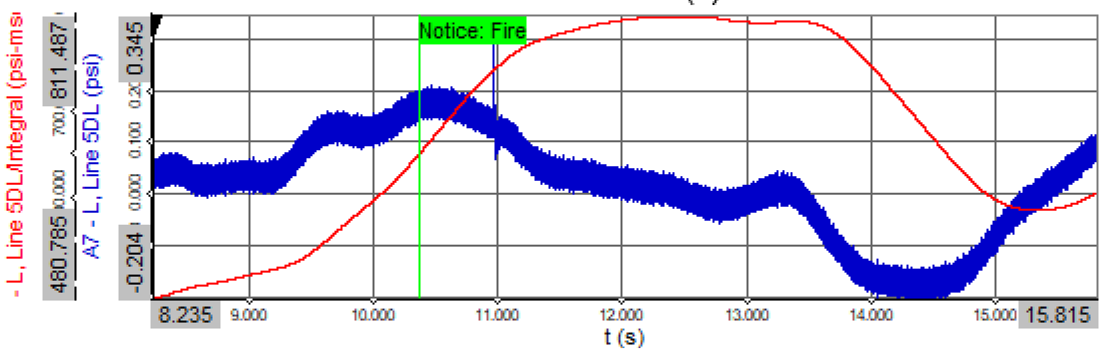

B6 - L, Line T/FIR Filter ()
- L, Line T/Integral (psi-ms
B6 - L, Line T (psi)
-0.120
0.1
0.304
653.605
654.5
655
-0.138
0.333
10.930
10.935
10.94
10.947
t (s)

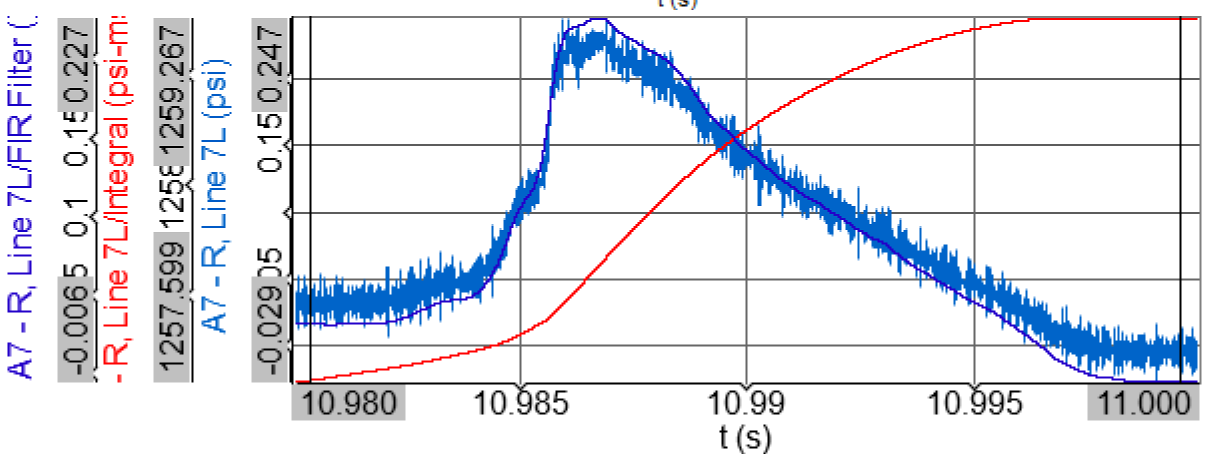

- L, Line T/Integral (psi-msec
B6 - L, Line T (psi)
-161.004
681.314
-0.795
0.333
10.499
11.000
11.500
12.000
12.500
13.000
13.510
t (s)

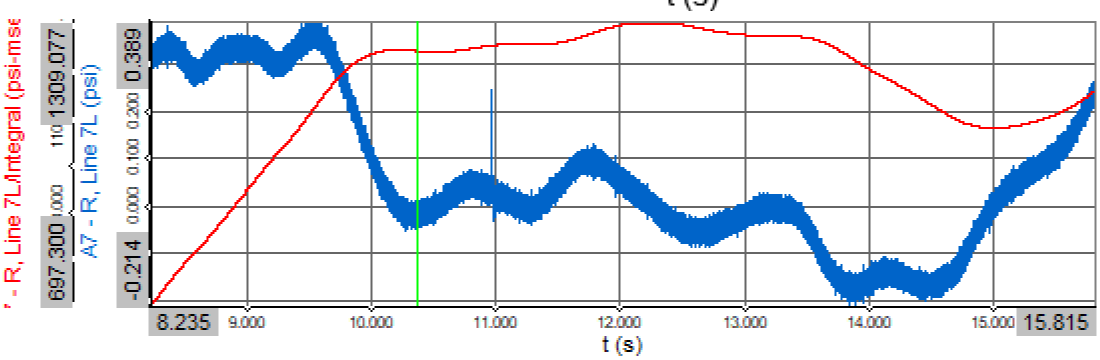

B6 - R, Line 3BL/FIR Filter (
R, Line 3BL/Integral (psi-m
B6 - R, Line 3BL (psi)
-0.178
0.05
0.210
451.69
452.449
-0.191
0.237
10.930
10.935
10.94
10.947
t (s)

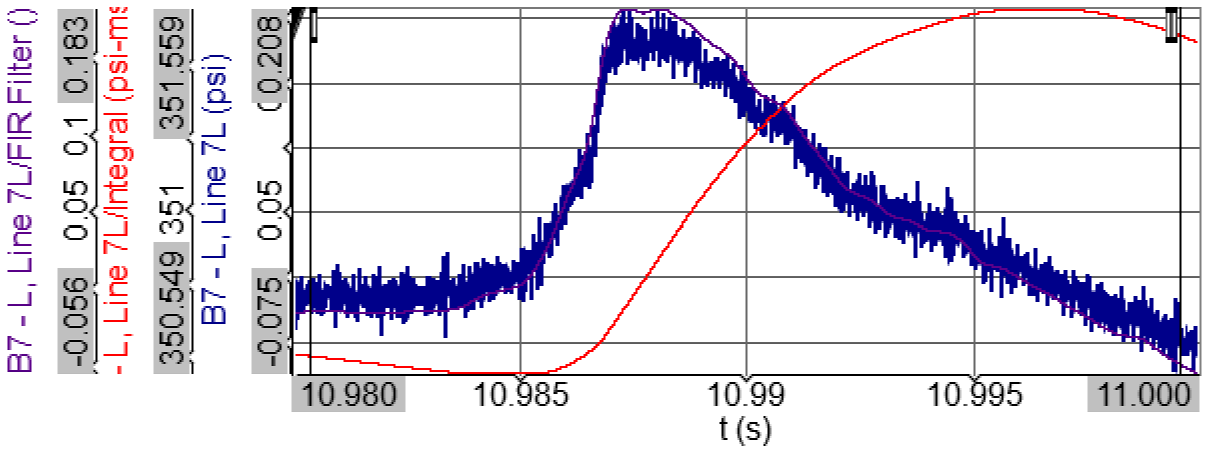

- R, Line 3BL/Integral (psi-ms
B6 - R, Line 3BL (psi)
-12.974
520.982
-0.612
0.237
10.499
11.000
11.500
12.000
12.500
13.000
13.510
t (s)

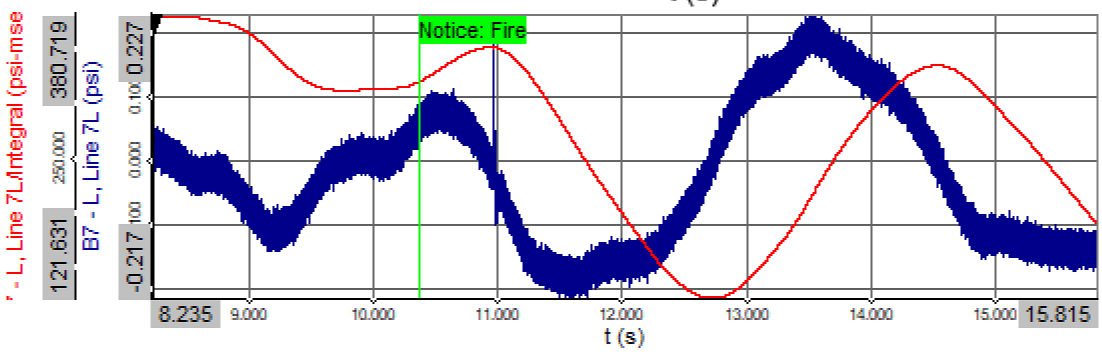

A7 - L, Line 5DL (psi)
10.980
10.985
10.99
10.995
11.000
t (s)

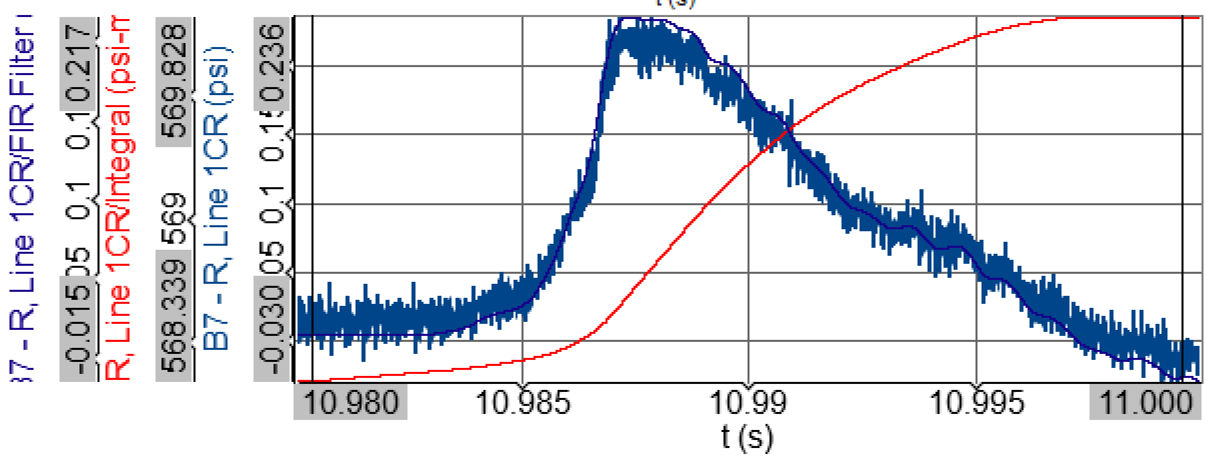

Notice: Fire
A7 - L, Line 5DL (psi)
8.235
15.815
t (s)

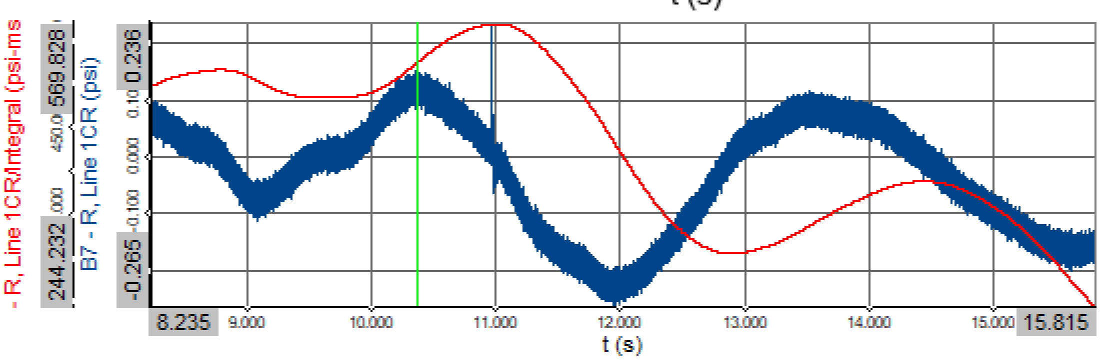

A7 - R, Line 7L/FIR Filter (
A7 - R, Line 7L (psi)
10.980
10.985
10.99
10.995
11.000
t (s)

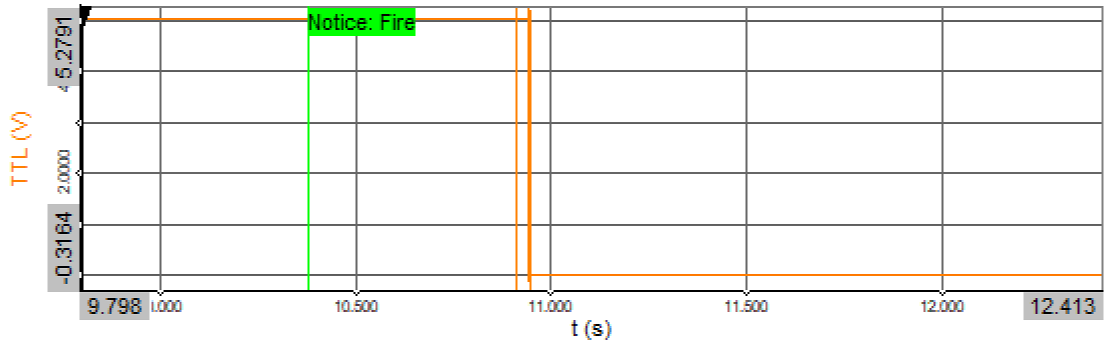

A7 - R, Line 7L (psi)
8.235
15.815
t (s)


B7 - L, Line 7L/FIR Filter ()
-L, Line 7L/Integral (psi-ms
B7 - L, Line 7L (psi)
10.980
10.985
10.99
10.995
11.000
t (s)

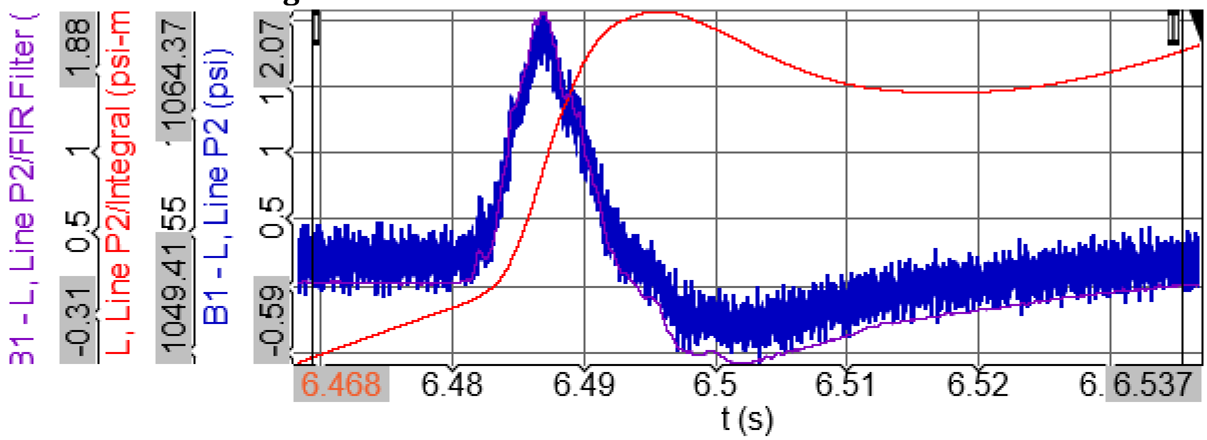

- L, Line 7L/Integral (psi-mse
B7 - L, Line 7L (psi)
Notice: Fire
8.235
9.000
10.000
11.000
12.000
13.000
14.000
15.000
15.815
t (s)

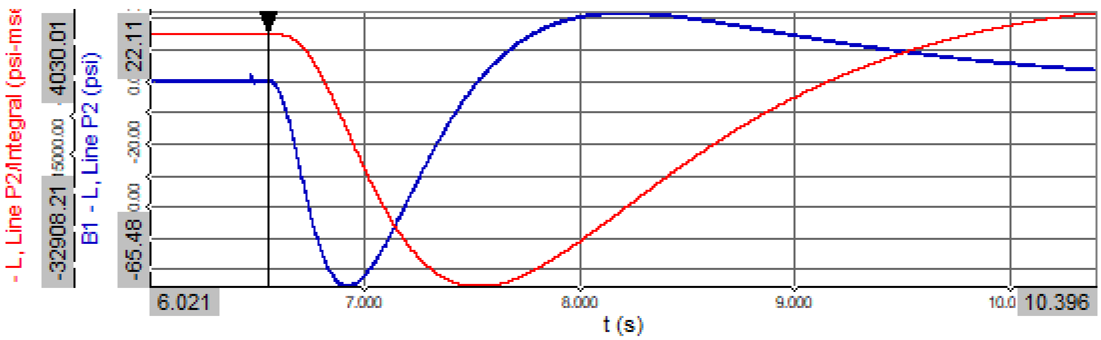

B7 - R, Line 1CR/FIR Filter
R, Line 1CR/Integral (psi-m
B7 - R, Line 1CR (psi)
10.980
10.985
10.99
10.995
11.000
t (s)

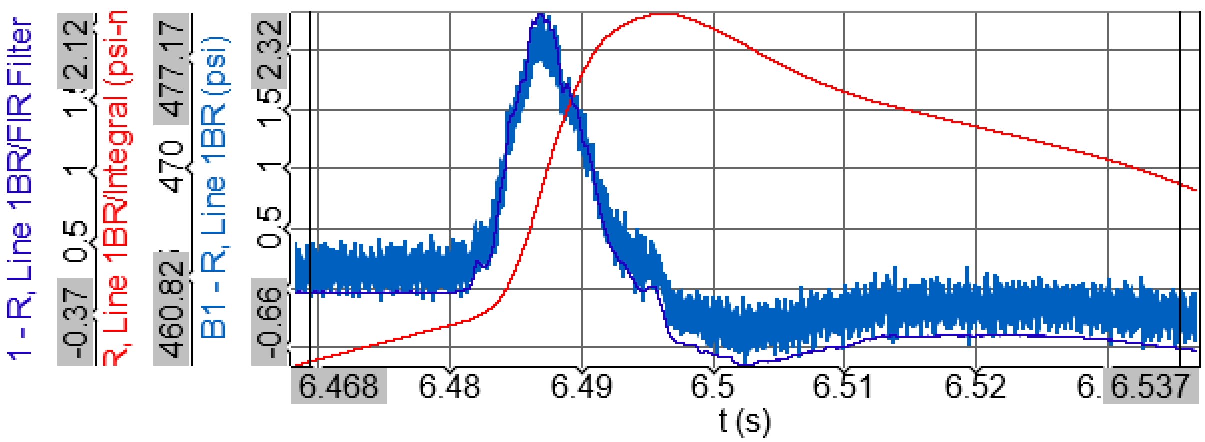

- R, Line 1CR/Integral (psi-ms
B7 - R, Line 1CR (psi)
8.235
9.000
10.000
11.000
12.000
13.000
14.000
15.000
15.815
t (s)

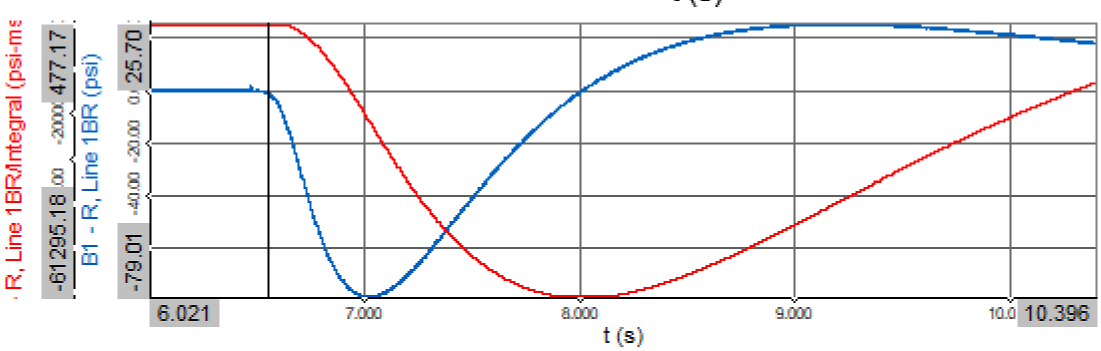

Notice: Fire
TTL (V)
5.2791
2.0000
-0.3164
9.798
10.500
11.000
11.500
12.000
12.413
t (s)

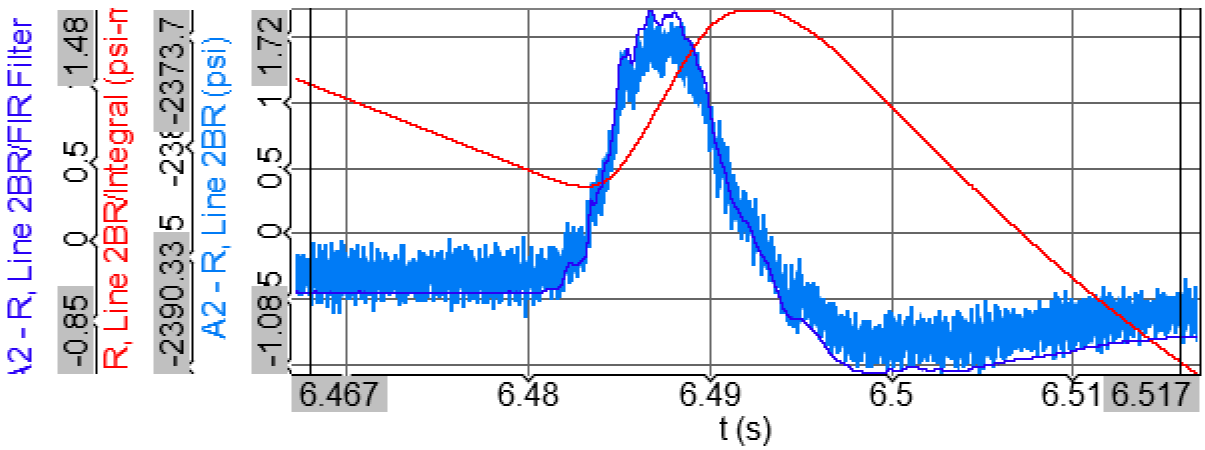
8.2.2 Trial 2 for Large-Scale Mix ID #8

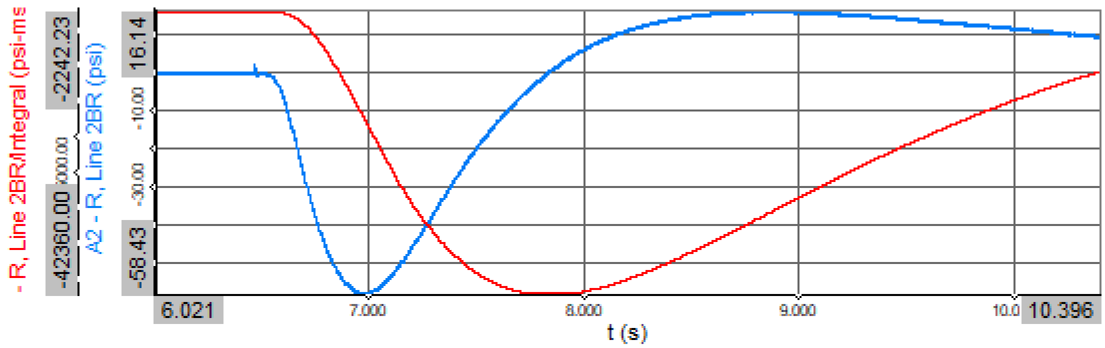


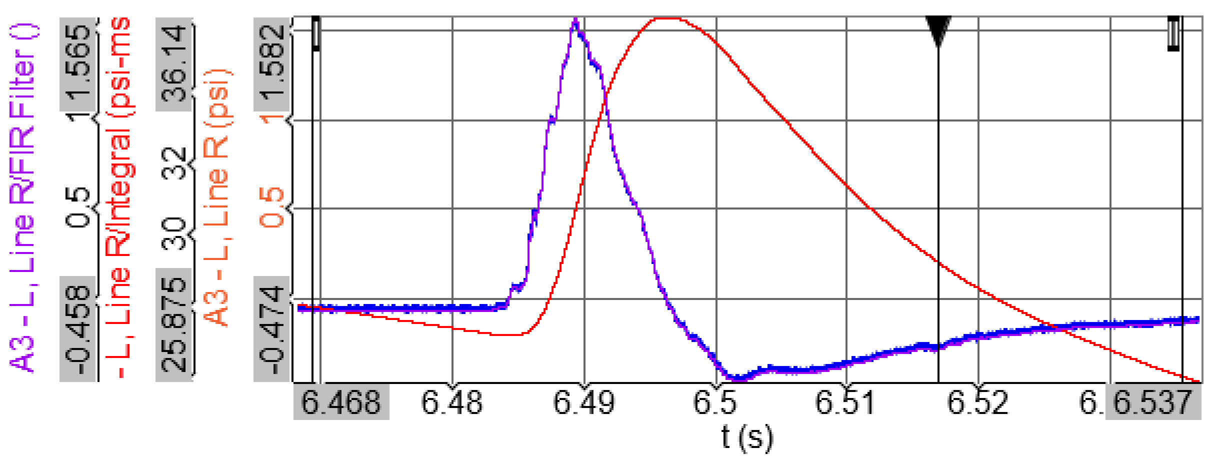


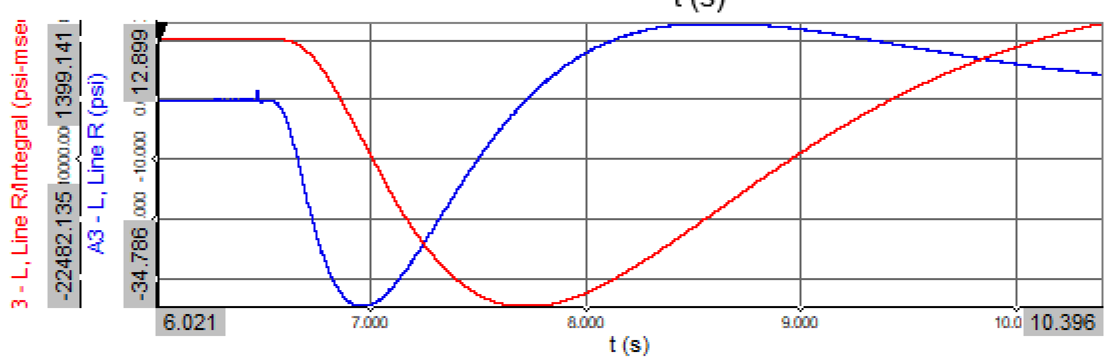


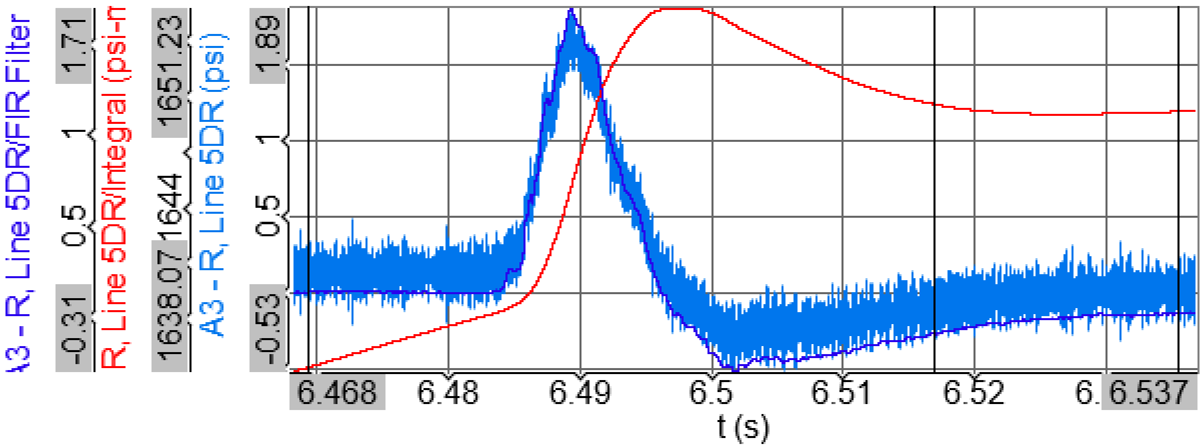


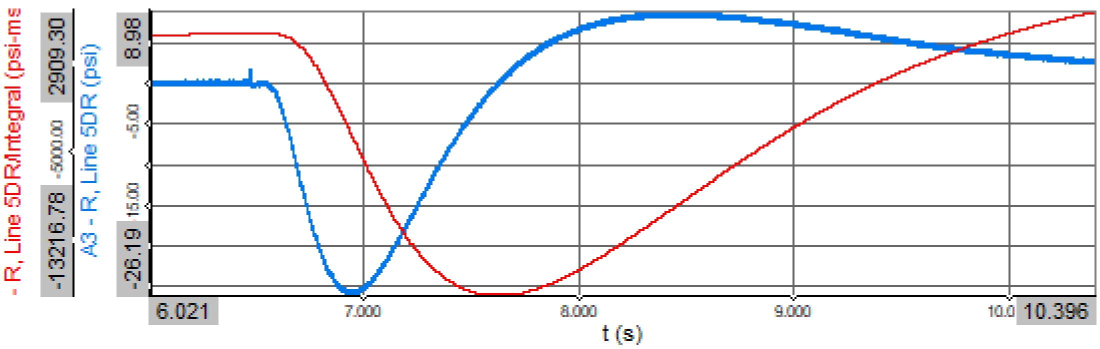

A2 - R, Line 2BR/FIR Filter
R, Line 2BR/Integral (psi-m
A2 - R, Line 2BR (psi)
t (s)
6.467
6.48
6.49
6.5
6.51
6.517

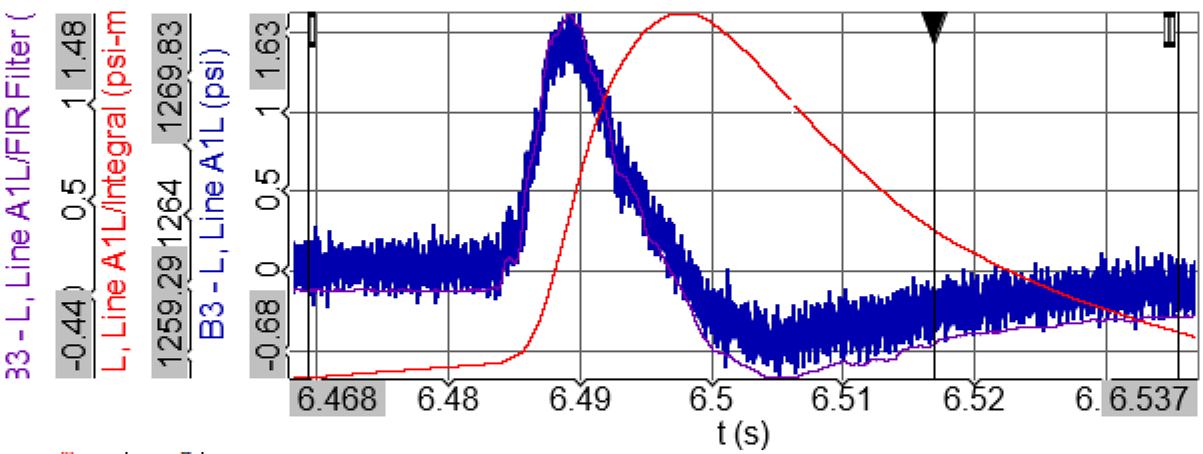

- R, Line 2BR/Integral (psi-ms
A2 - R, Line 2BR (psi)
t (s)
6.021
7.000
8.000
9.000
10.396

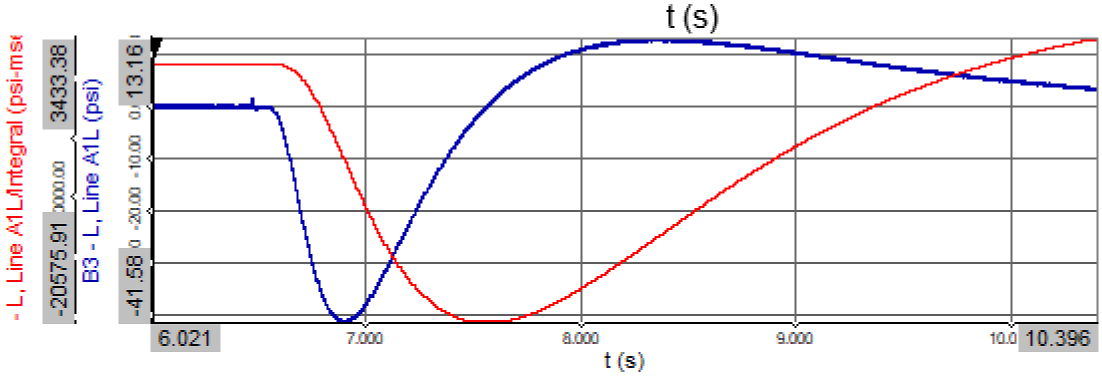

A3 - L, Line R/FIR Filter ()
- L, Line R/Integral (psi-ms
A3 - L, Line R (psi)
t (s)
6.468
6.48
6.49
6.5
6.51
6.52
6.537

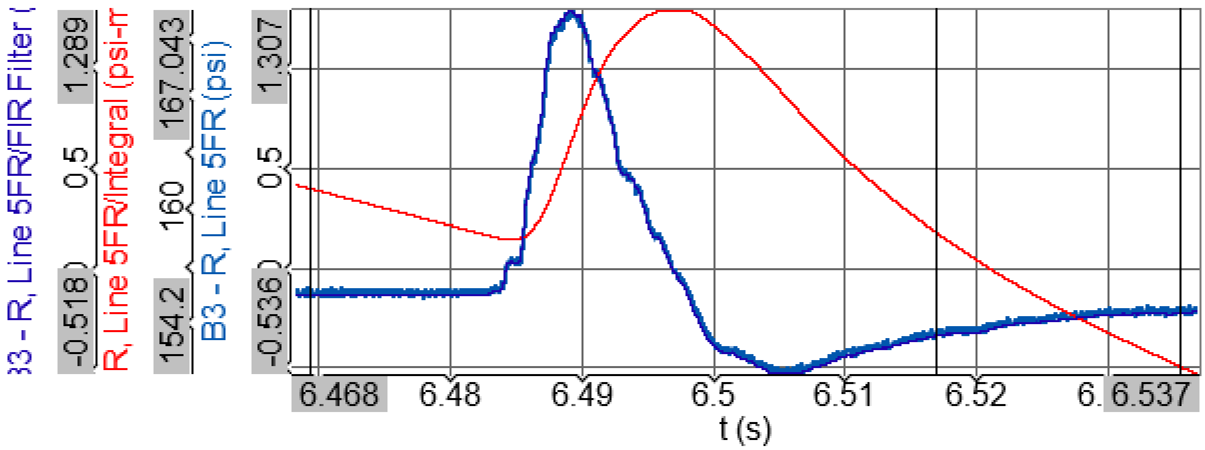

3 - L, Line R/Integral (psi-mse
A3 - L, Line R (psi)
t (s)
6.021
7.000
8.000
9.000
10.396

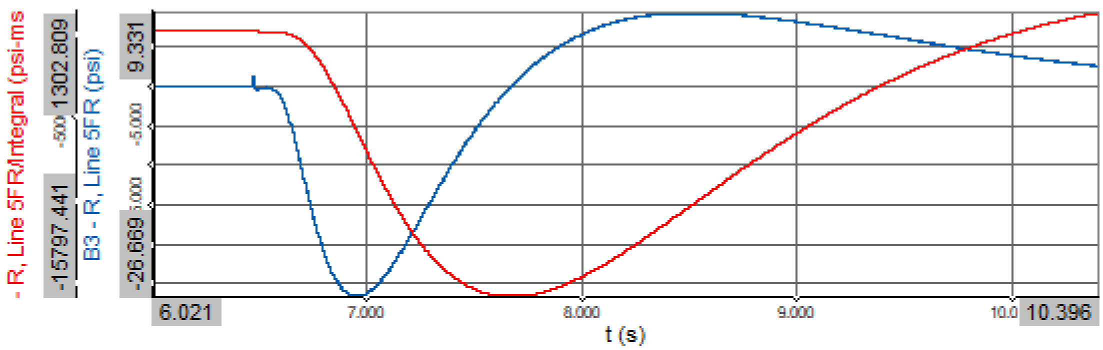

A3 - R, Line 5DR/FIR Filter
R, Line 5DR/Integral (psi-m
A3 - R, Line 5DR (psi)
-0.31
0.5
1
1.71
1638.07
1644
1651.23
-0.53
0.5
1
1.89
6.468
6.48
6.49
6.5
6.51
6.52
6.537
t (s)

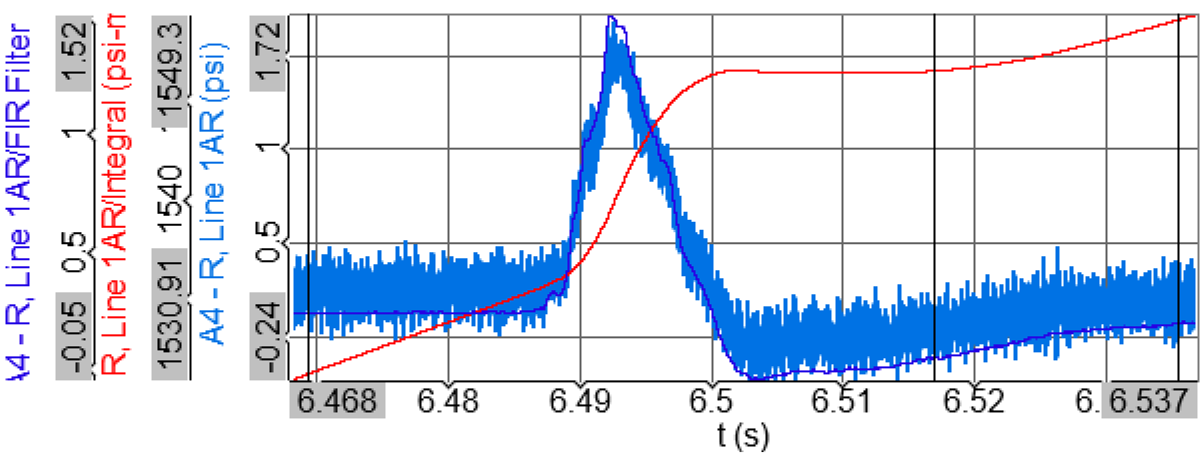

- R, Line 5DR/Integral (psi-ms
A3 - R, Line 5DR (psi)
-13216.78
-5000.00
2909.30
-26.19
15.00
-5.00
8.98
6.021
7.000
8.000
9.000
10.396
t (s)

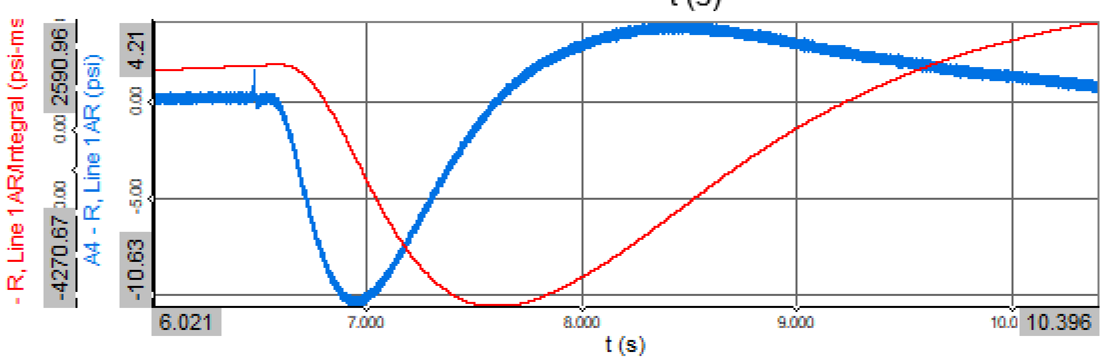

B3 - L, Line A1L/FIR Filter (
L, Line A1L/Integral (psi-m
B3 - L, Line A1L (psi)
-0.44
0.5
1
1.48
1259.29
1264
1269.83
-0.68
0
0.5
1
1.63
6.468
6.48
6.49
6.5
6.51
6.52
6.537
t (s)

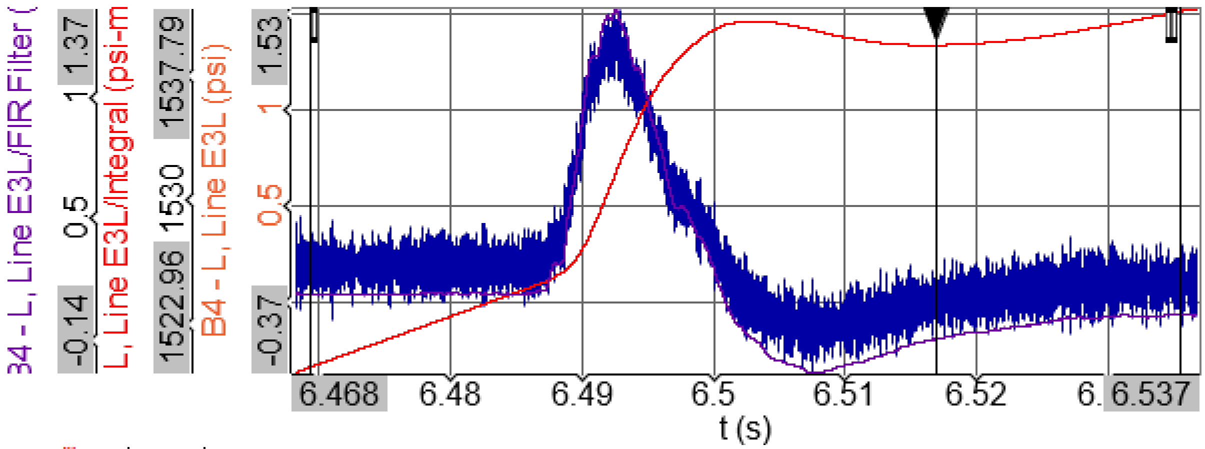

- L, Line A1L/Integral (psi-ms
B3 - L, Line A1L (psi)
-20575.91
3433.38
-41.58
-20.00
-10.00
13.16
6.021
7.000
8.000
9.000
10.396
t (s)

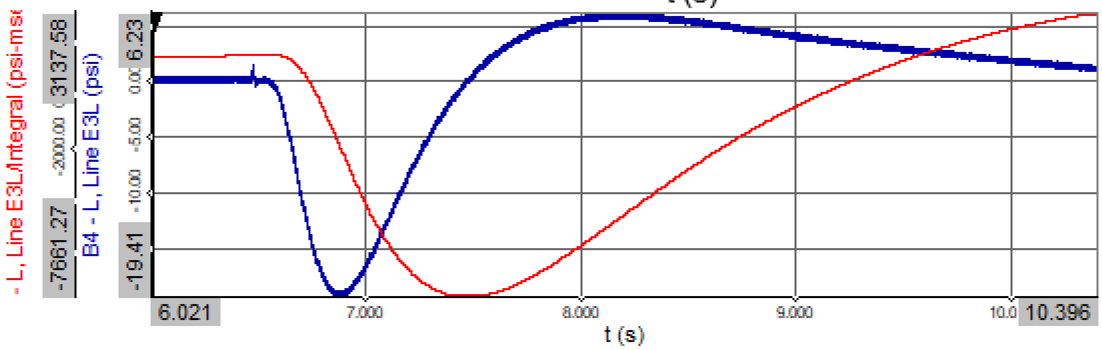

B3 - R, Line 5FR (psi)
R, Line 5FR/Integral (psi-m
t (s)
6.468
6.48
6.49
6.5
6.51
6.52
6.537

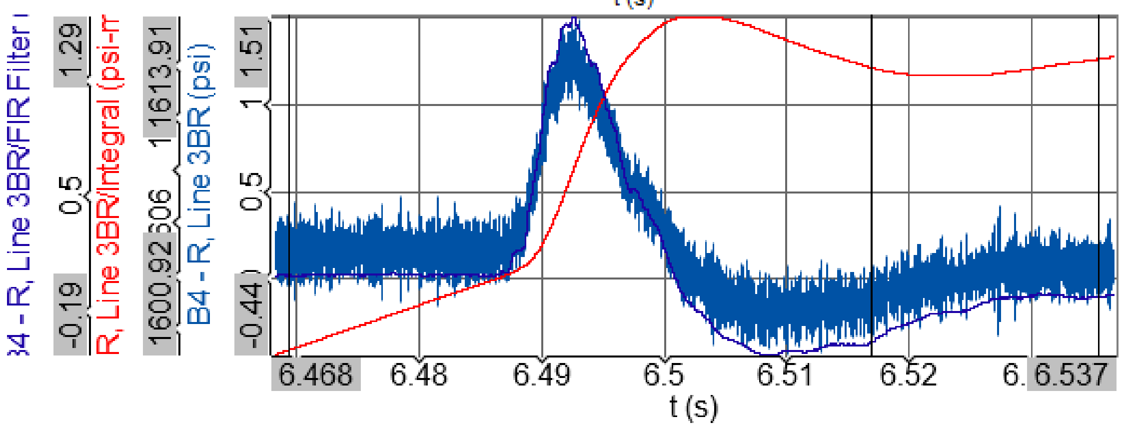

- R, Line 5FR/Integral (psi-ms
B3 - R, Line 5FR (psi)
t (s)
6.021
7.000
8.000
9.000
10.396

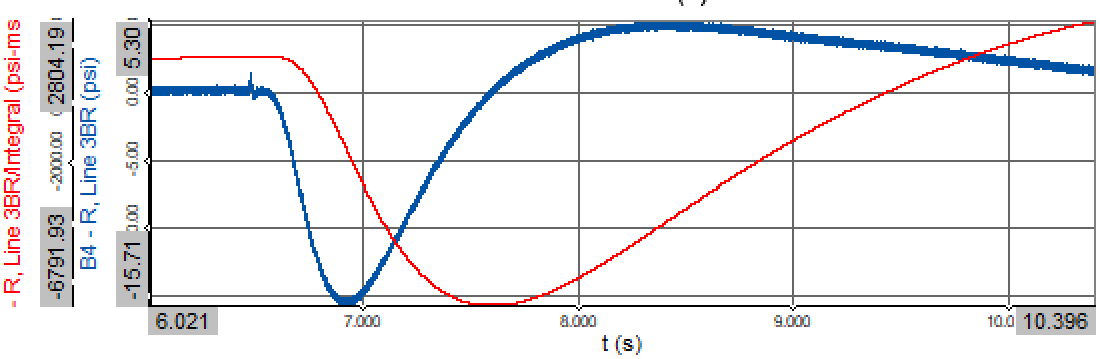

A4 - R, Line 1AR/FIR Filter
R, Line 1AR/Integral (psi-m
A4 - R, Line 1AR (psi)
t (s)
6.468
6.48
6.49
6.5
6.51
6.52
6.537

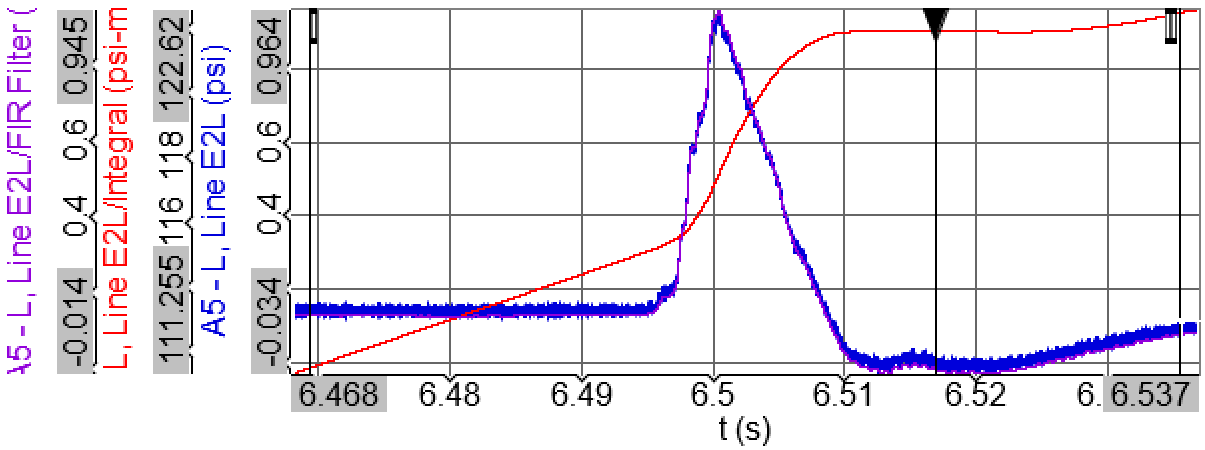

- R, Line 1AR/Integral (psi-ms
A4 - R, Line 1AR (psi)
t (s)
6.021
7.000
8.000
9.000
10.396

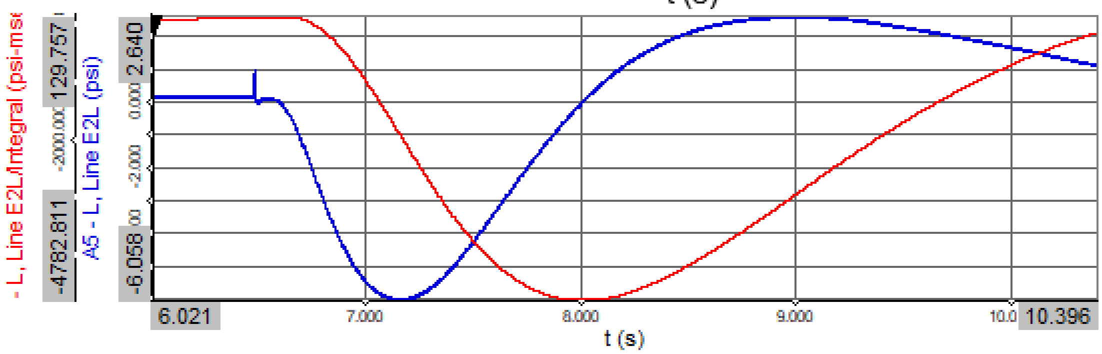

34 - L, Line E3L/FIR Filter (
L, Line E3L/Integral (psi-m
B4 - L, Line E3L (psi)
6.468
6.48
6.49
6.5
6.51
6.52
6.537
t (s)

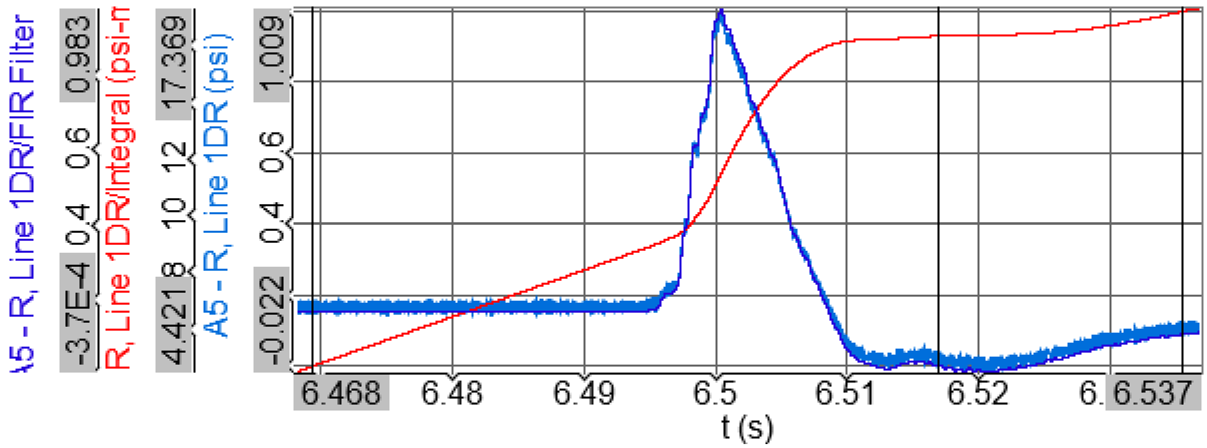

- L, Line E3L/Integral (psi-ms
B4 - L, Line E3L (psi)
6.021
7.000
8.000
9.000
10.396
t (s)

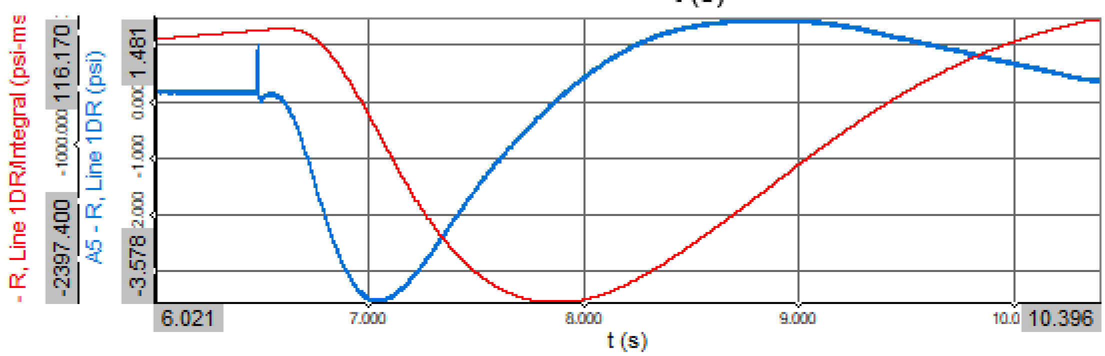

34 - R, Line 3BR/FIR Filter
R, Line 3BR/Integral (psi-m
B4 - R, Line 3BR (psi)
6.468
6.48
6.49
6.5
6.51
6.52
6.537
t (s)

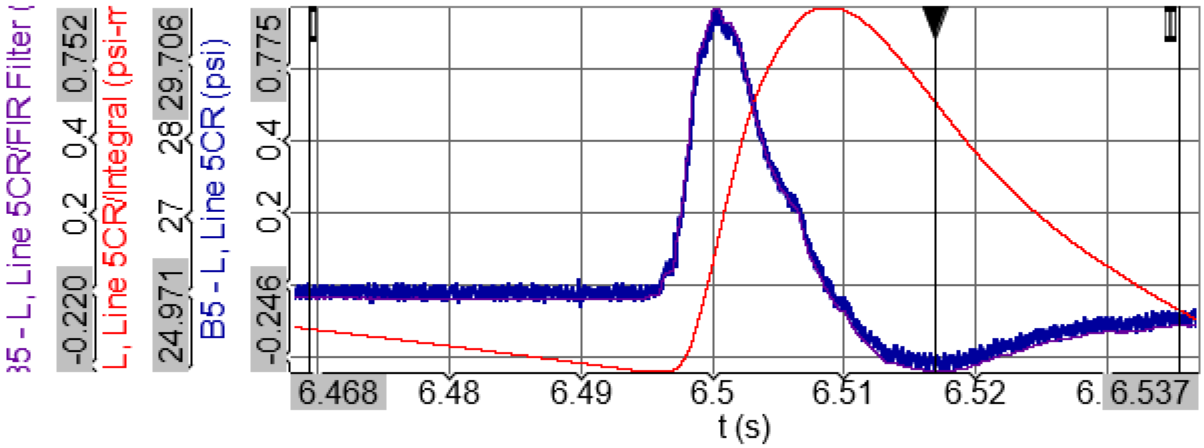

- R, Line 3BR/Integral (psi-ms
B4 - R, Line 3BR (psi)
6.021
7.000
8.000
9.000
10.396
t (s)

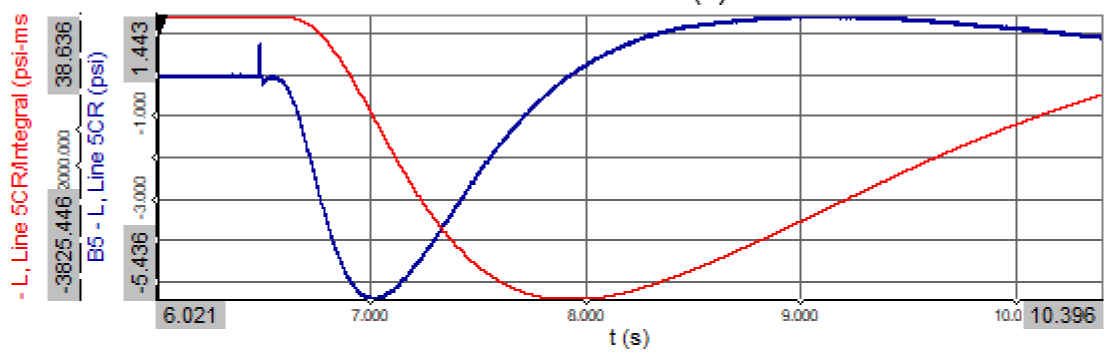

A5 - L, Line E2L/FIR Filter (
L, Line E2L/Integral (psi-m
A5 - L, Line E2L (psi)
t (s)

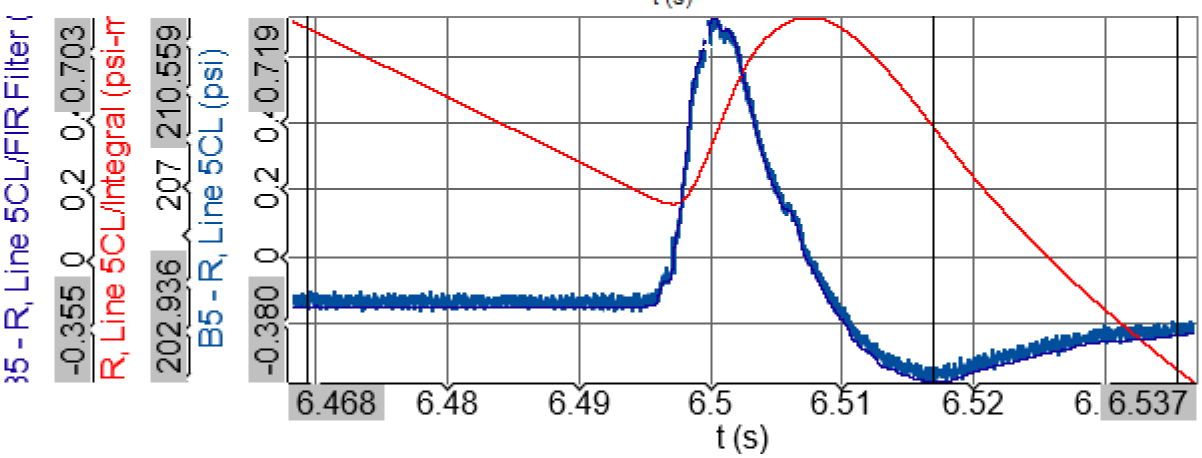

- L, Line E2L/Integral (psi-ms
A5 - L, Line E2L (psi)
t (s)

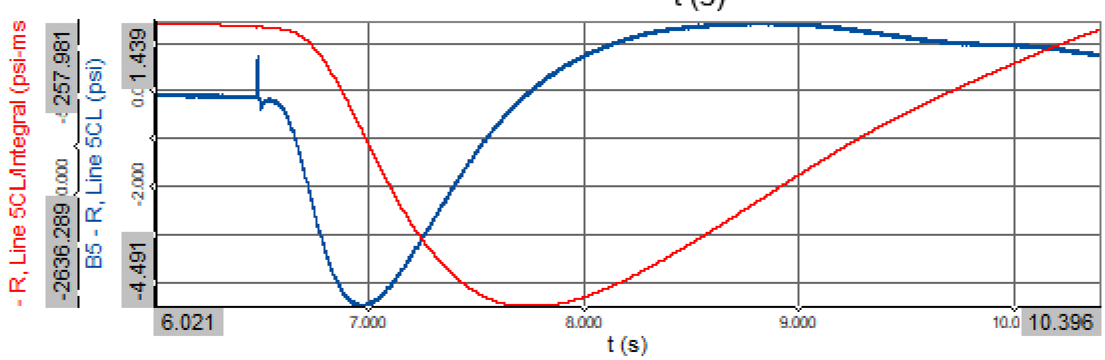

A5 - R, Line 1DR/FIR Filter
R, Line 1DR/Integral (psi-m
A5 - R, Line 1DR (psi)
t (s)

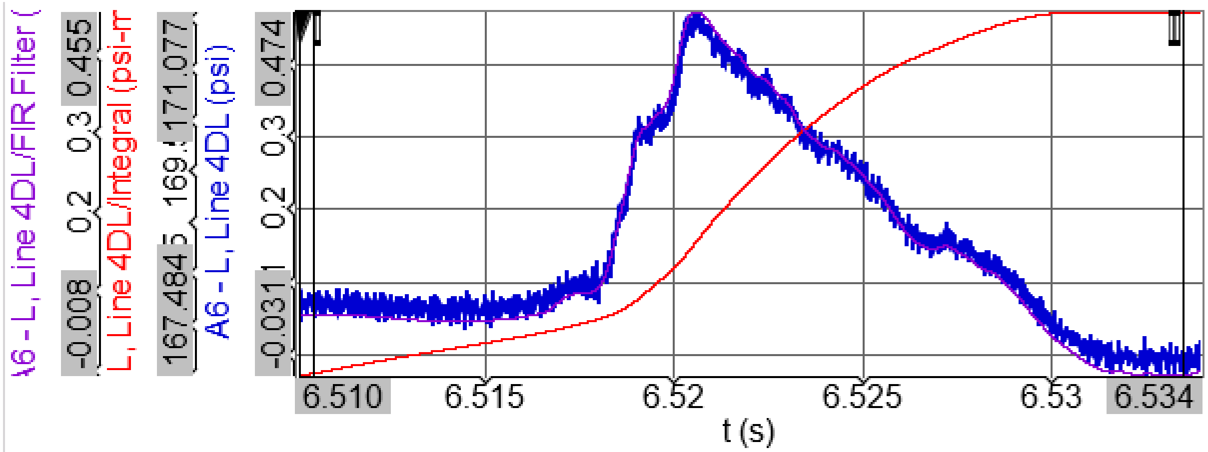

- R, Line 1DR/Integral (psi-ms
A5 - R, Line 1DR (psi)
t (s)

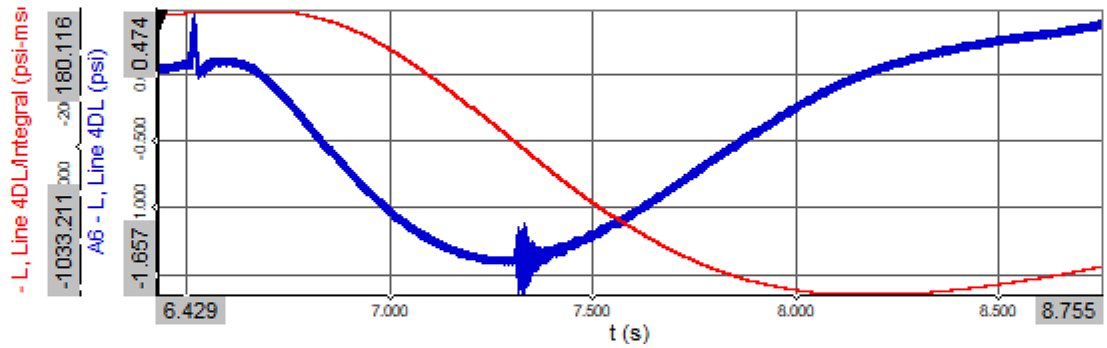

B5 - L, Line 5CR (psi)
L, Line 5CR/Integral (psi-m
35 - L, Line 5CR/FIR Filter (
-0.246
0.775
24.971
29.706
-0.220
0.752
6.468
6.48
6.49
6.5
6.51
6.52
6.537
t (s)

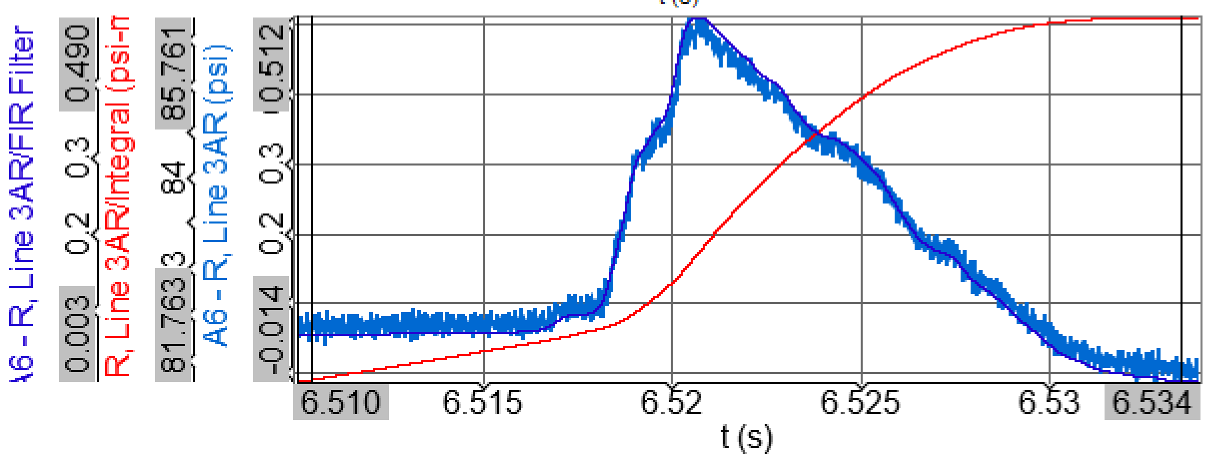

B5 - L, Line 5CR (psi)
- L, Line 5CR/Integral (psi-ms
-5.436
1.443
-3825.446
38.636
6.021
7.000
8.000
9.000
10.396
t (s)

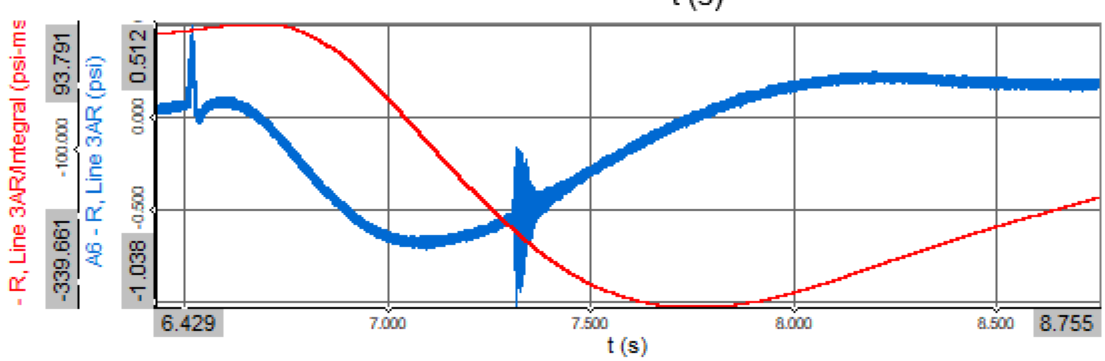

B5 - R, Line 5CL (psi)
R, Line 5CL/Integral (psi-m
35 - R, Line 5CL/FIR Filter (
-0.380
0.719
202.936
210.559
-0.355
0.703
6.468
6.48
6.49
6.5
6.51
6.52
6.537
t (s)

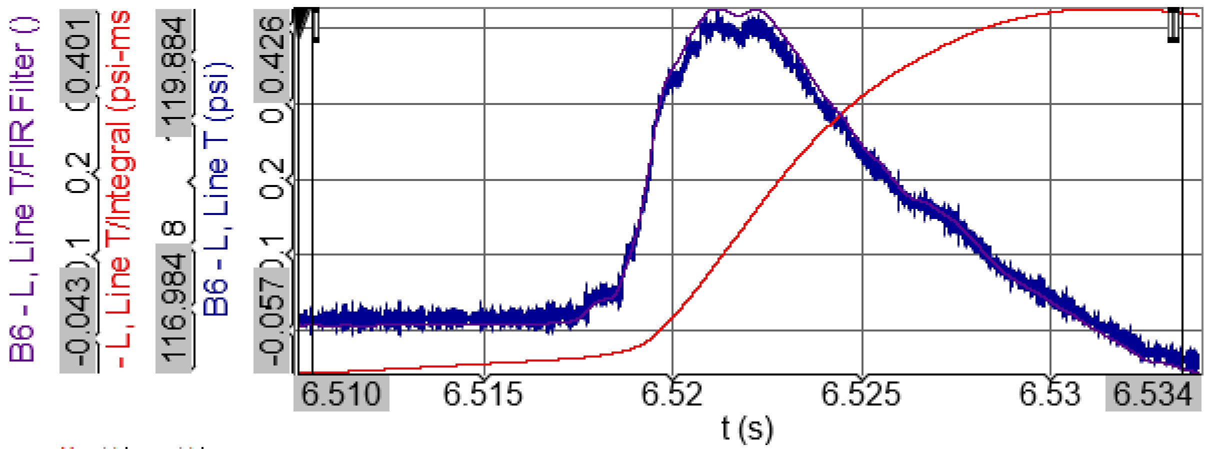

B5 - R, Line 5CL (psi)
- R, Line 5CL/Integral (psi-ms
-4.491
1.439
-2636.289
257.981
6.021
7.000
8.000
9.000
10.396
t (s)

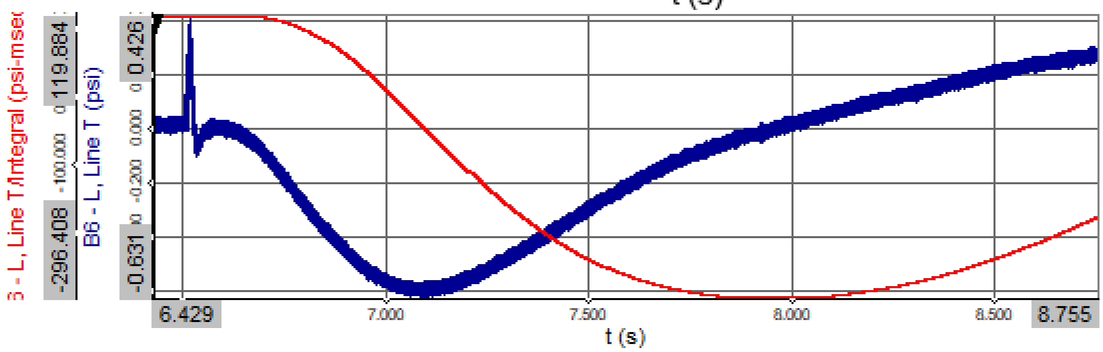

A6 - L, Line 4DL/FIR Filter (
-0.008
0.2
0.3
0.455
L, Line 4DL/Integral (psi-m
167.484
171.077
A6 - L, Line 4DL (psi)
-0.031
0.2
0.3
0.474
6.510
6.515
6.52
6.525
6.53
6.534
t (s)

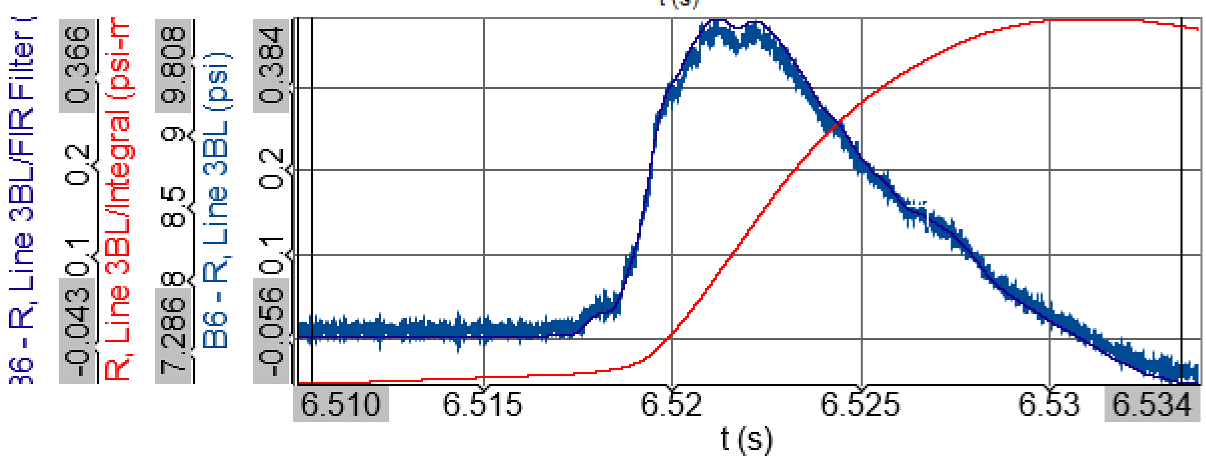

- L, Line 4DL/Integral (psi-ms
-1033.211
180.116
A6 - L, Line 4DL (psi)
-1.657
0.474
6.429
7.000
7.500
8.000
8.500
8.755
t (s)

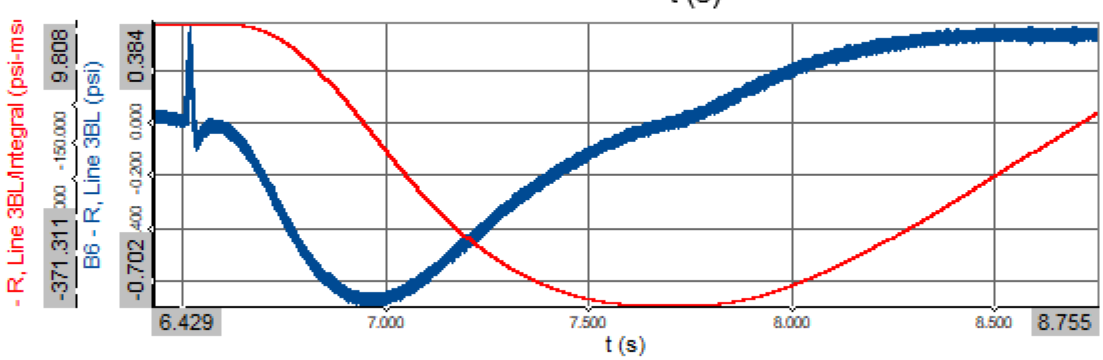

A6 - R, Line 3AR/FIR Filter
0.003
0.2
0.3
0.490
R, Line 3AR/Integral (psi-m
81.763
84
85.761
A6 - R, Line 3AR (psi)
-0.014
0.2
0.3
0.512
6.510
6.515
6.52
6.525
6.53
6.534
t (s)

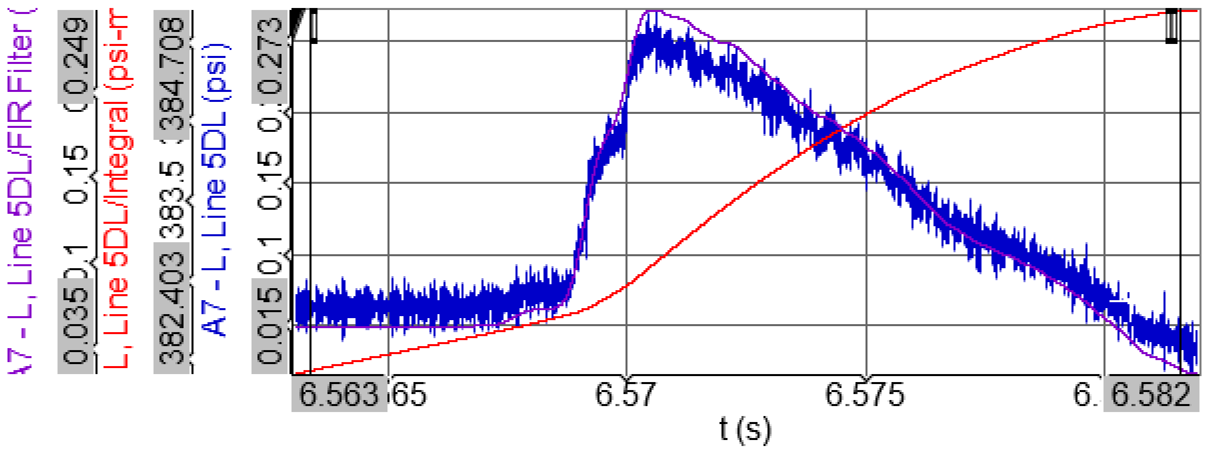

- R, Line 3AR/Integral (psi-ms
-339.661
-100.000
93.791
A6 - R, Line 3AR (psi)
-1.038
-0.500
0.000
0.512
6.429
7.000
7.500
8.000
8.500
8.755
t (s)

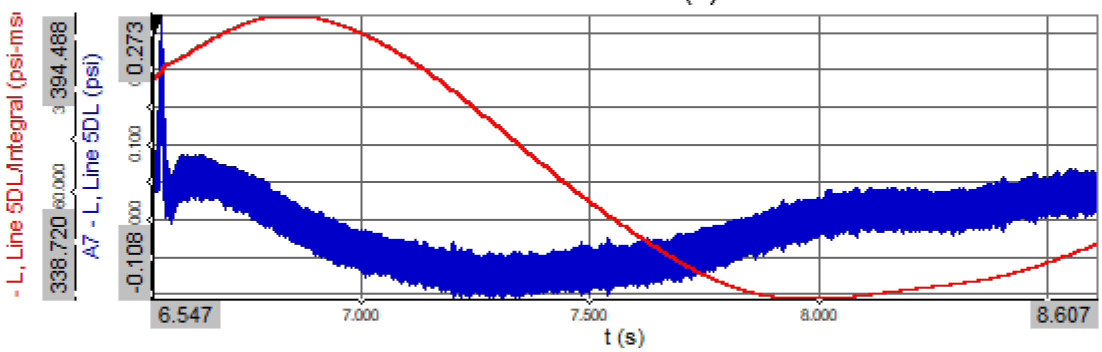

B6 - L, Line T/FIR Filter ()
- L, Line T/Integral (psi-ms
B6 - L, Line T (psi)
t (s)

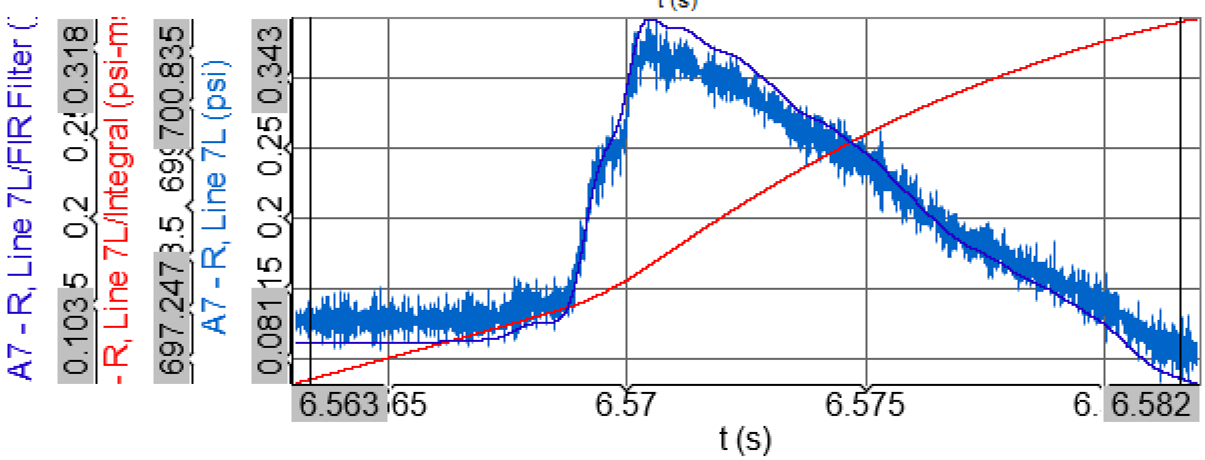

B6 - L, Line T (psi)
t (s)

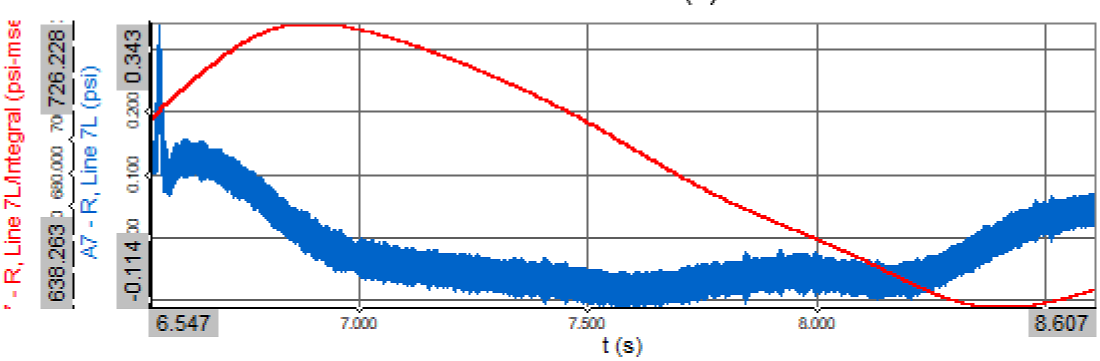

36 - R, Line 3BL/FIR Filter (
R, Line 3BL/Integral (psi-m
B6 - R, Line 3BL (psi)
t (s)

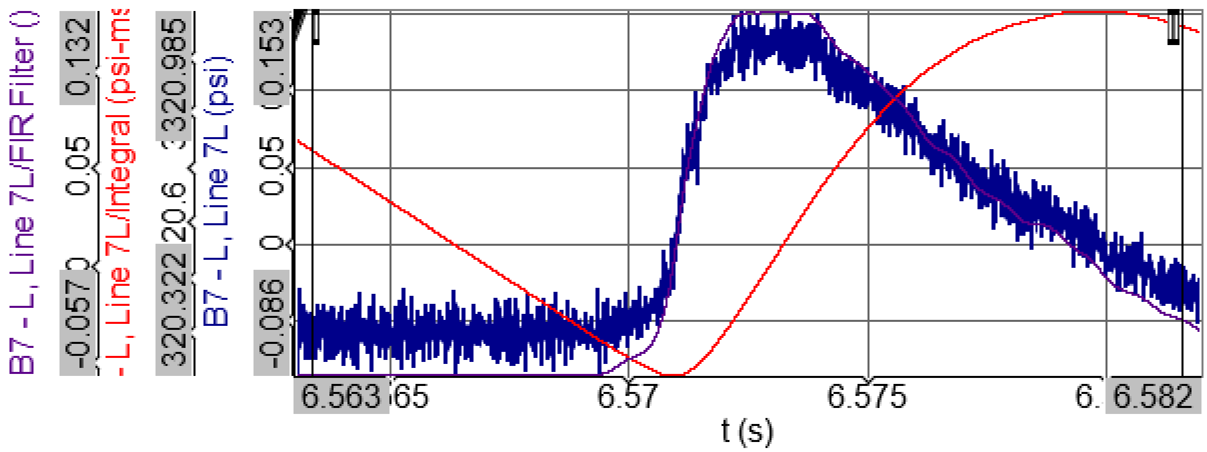

- R, Line 3BL/Integral (psi-ms
B6 - R, Line 3BL (psi)
t (s)

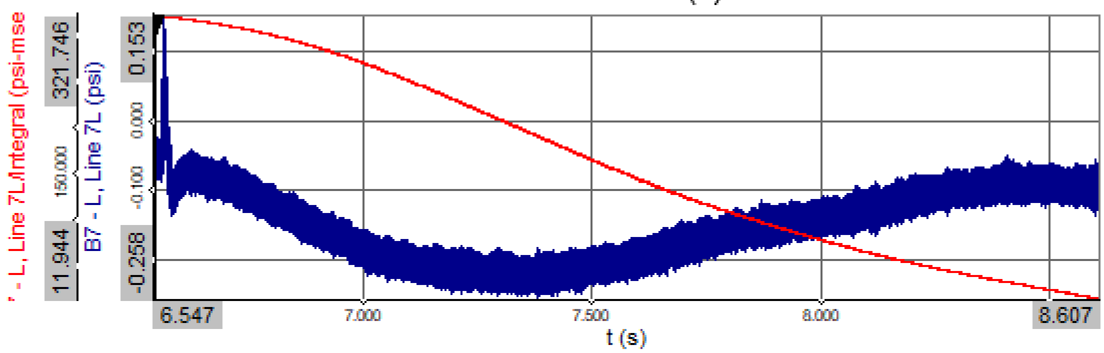

A7 - L, Line 5DL (psi)
6.563
6.57
6.575
6.582
t (s)

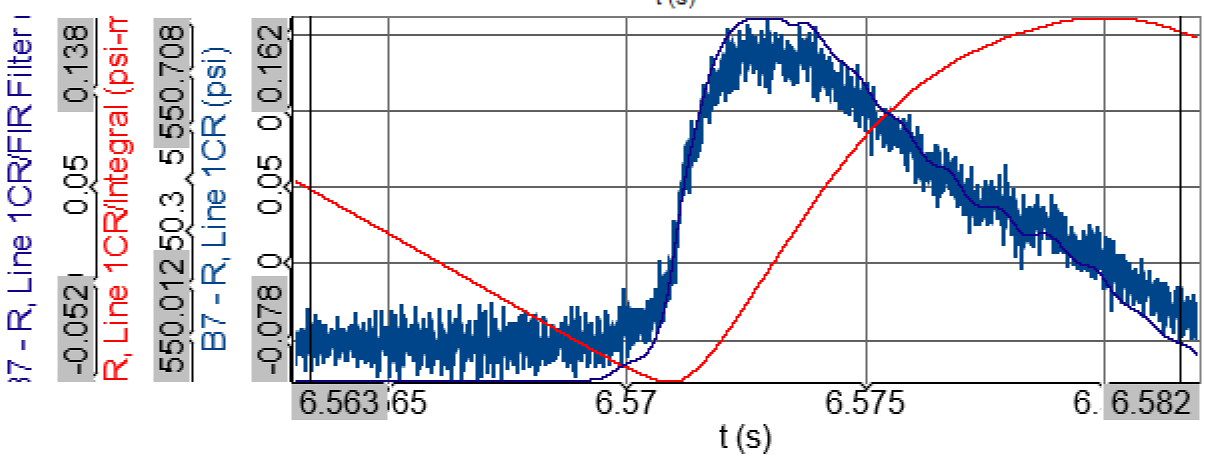

A7 - L, Line 5DL (psi)
6.547
7.000
7.500
8.000
8.607
t (s)

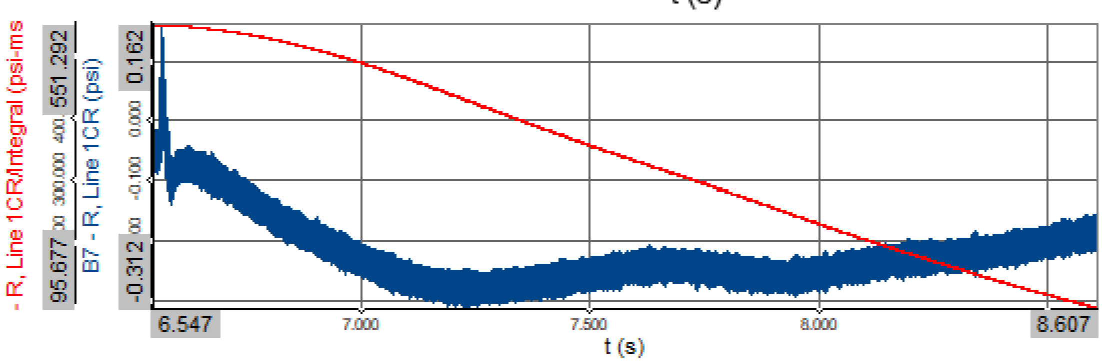

A7 - R, Line 7L (psi)
6.563
6.57
6.575
6.582
t (s)

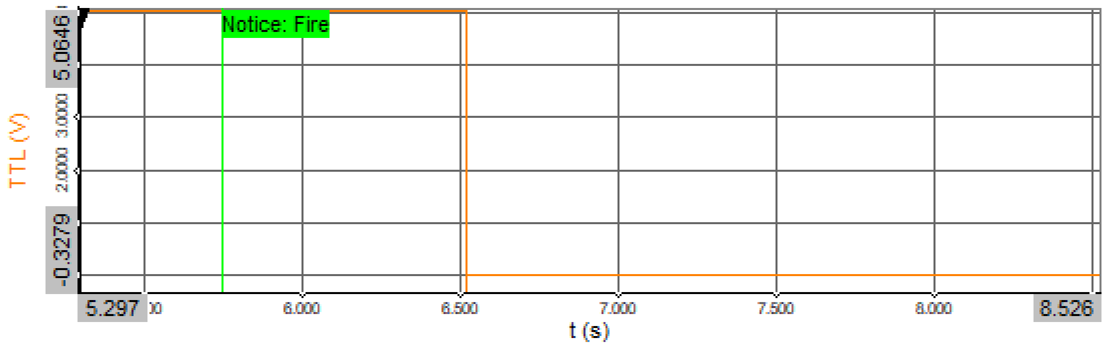

A7 - R, Line 7L (psi)
6.547
7.000
7.500
8.000
8.607
t (s)


B7 - L, Line 7L/FIR Filter ()
-L, Line 7L/Integral (psi-ms
B7 - L, Line 7L (psi)
t (s)
6.563
6.57
6.575
6.582

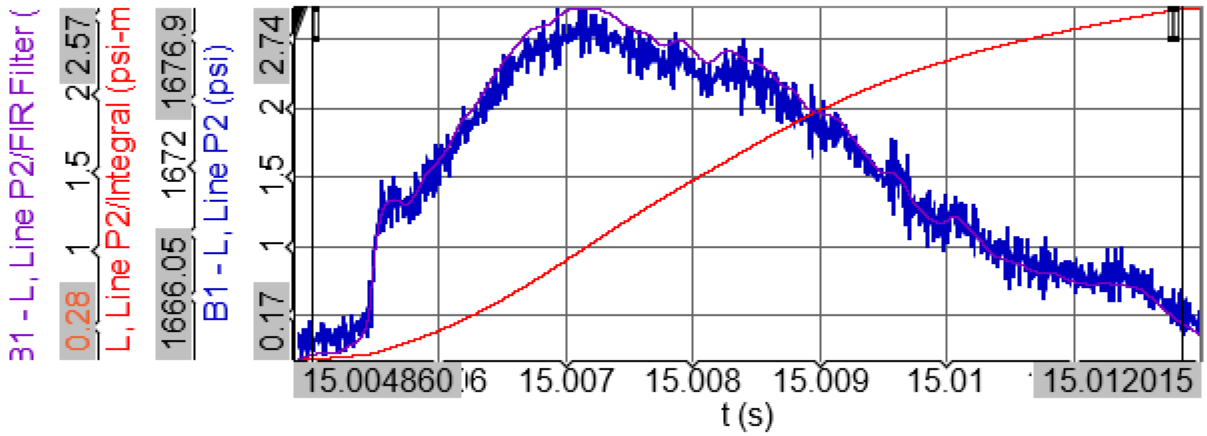

- L, Line 7L/Integral (psi-mse
B7 - L, Line 7L (psi)
t (s)
6.547
7.000
7.500
8.000
8.607

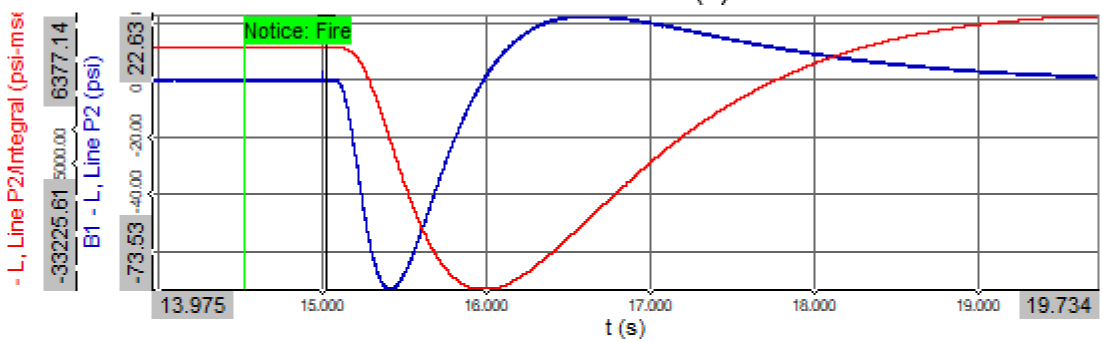

B7 - R, Line 1CR/FIR Filter
R, Line 1CR/Integral (psi-m
B7 - R, Line 1CR (psi)
t (s)
6.563
6.57
6.575
6.582

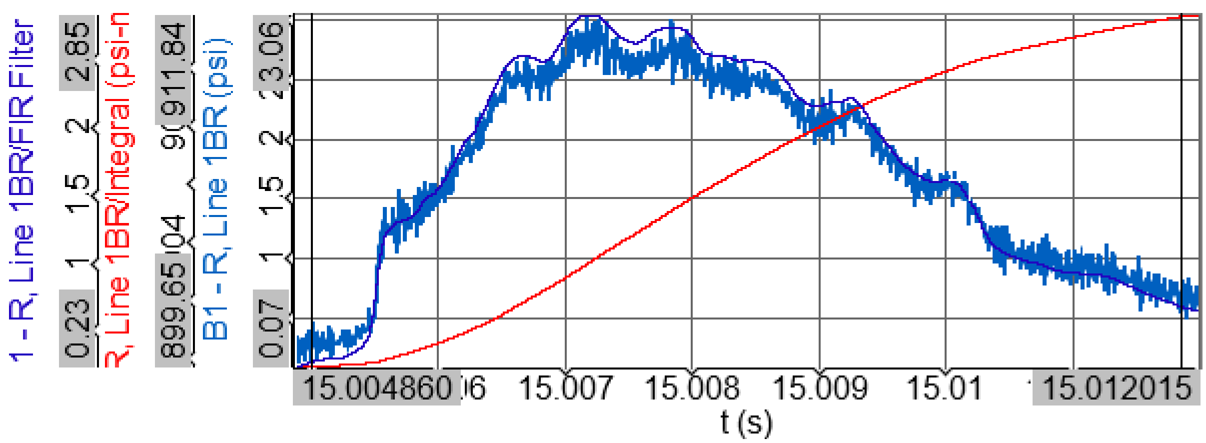

- R, Line 1CR/Integral (psi-ms
B7 - R, Line 1CR (psi)
t (s)
6.547
7.000
7.500
8.000
8.607

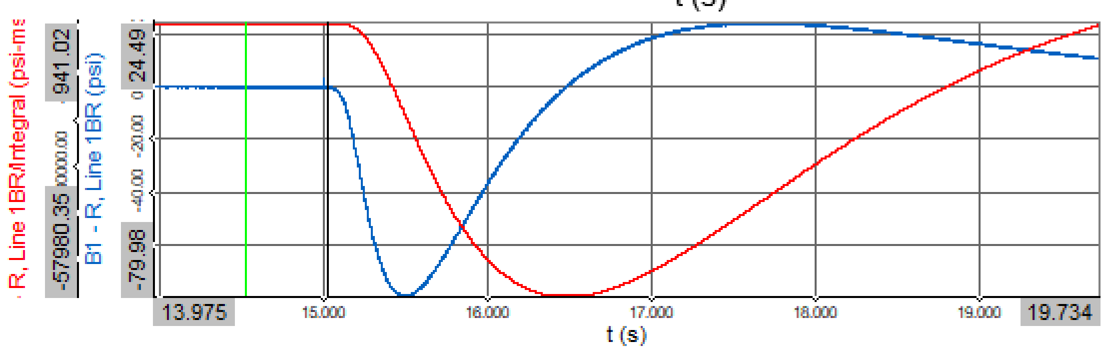

Notice: Fire
TTL (V)
5.0646
3.0000
2.0000
-0.3279
5.297
6.000
6.500
7.000
7.500
8.000
8.526
t (s)

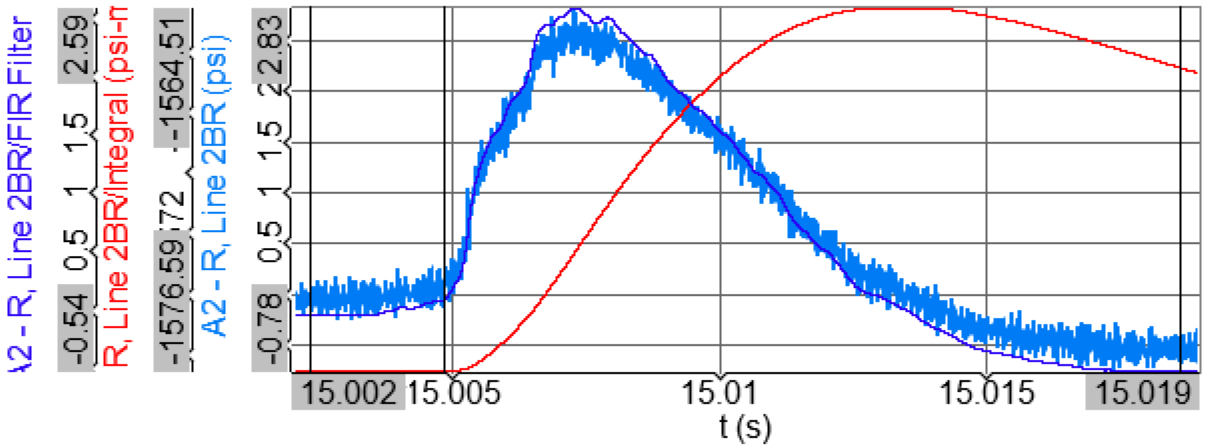
8.2.3 Trial 3 for Large-Scale Mix ID #8

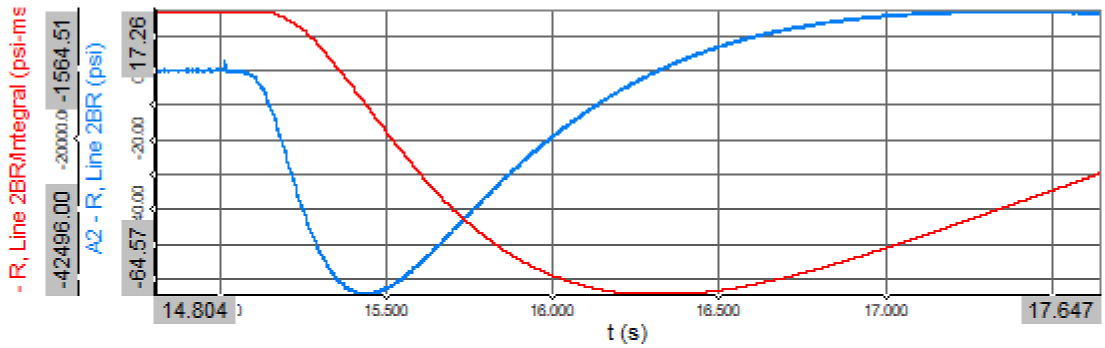


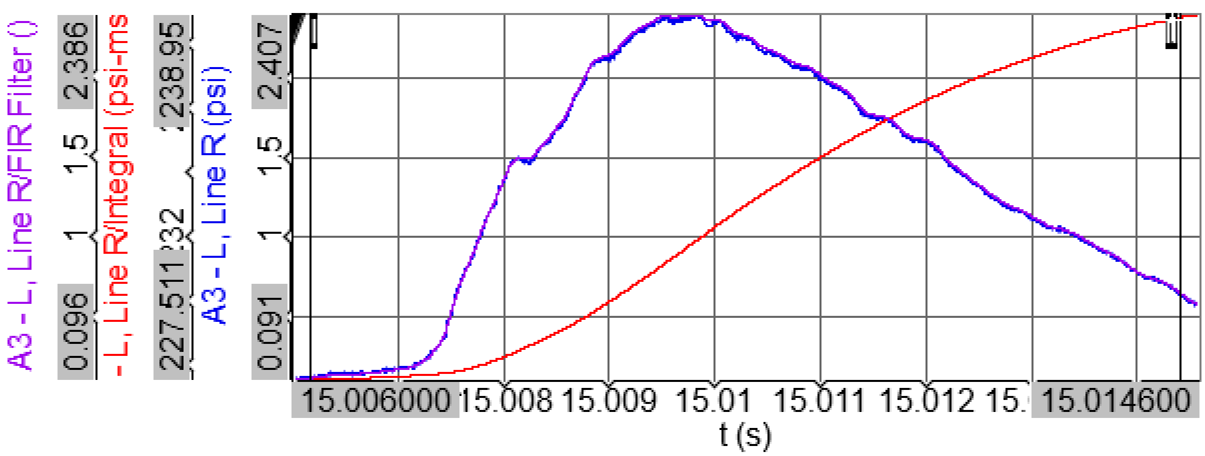


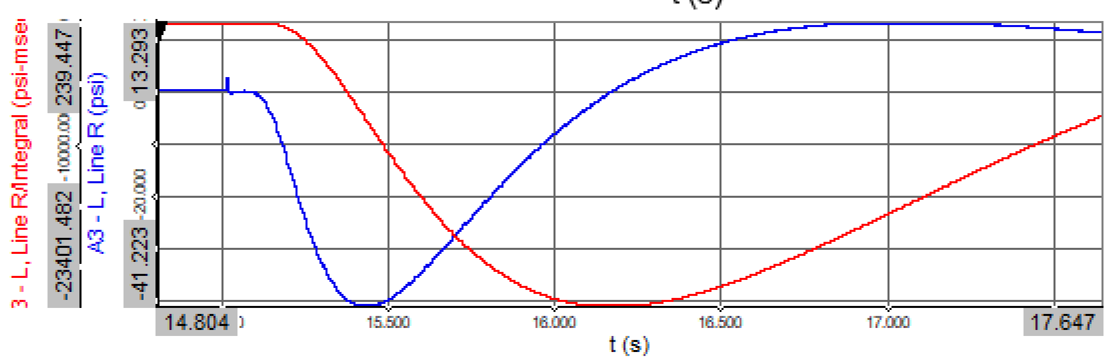


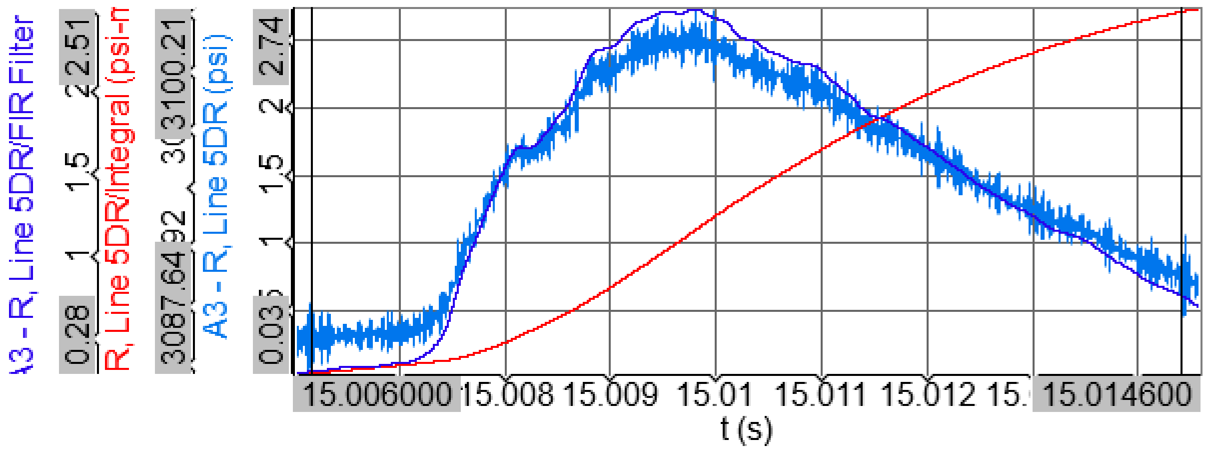


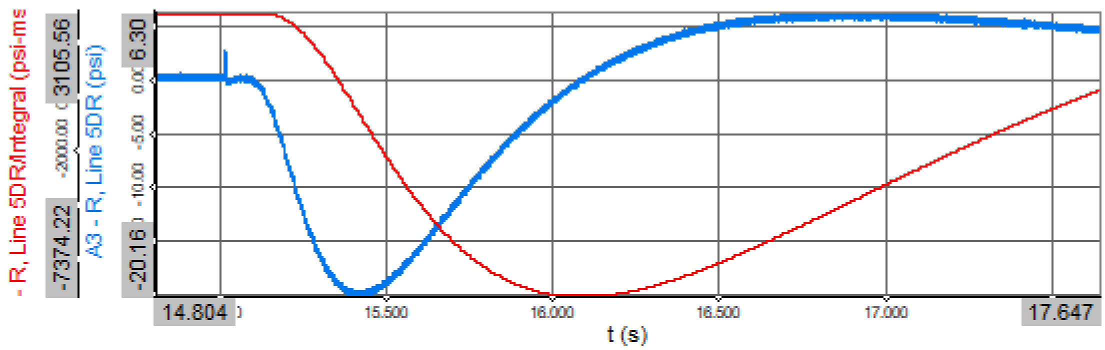

A2 - R, Line 2BR/FIR Filter
R, Line 2BR/Integral (psi-m
A2 - R, Line 2BR (psi)
-0.54
0.5
1
1.5
2.59
-1576.59
-1564.51
-0.78
0.5
1
1.5
2.83
15.002
15.005
15.01
15.015
15.019
t (s)

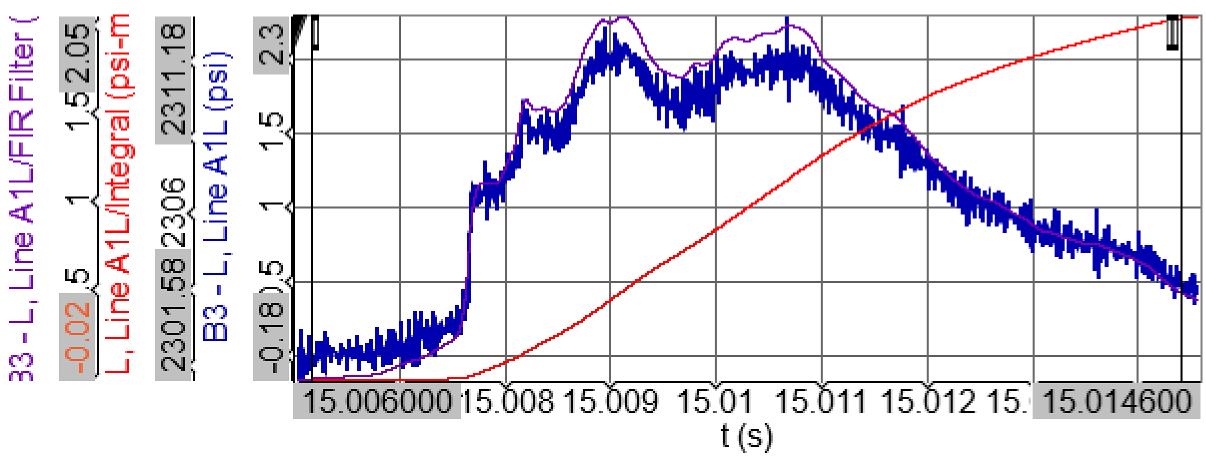

- R, Line 2BR/Integral (psi-ms
-42496.00
-20000.0
-1564.51
A2 - R, Line 2BR (psi)
-64.57
-40.00
-20.00
17.26
14.804
15.500
16.000
16.500
17.000
17.647
t (s)

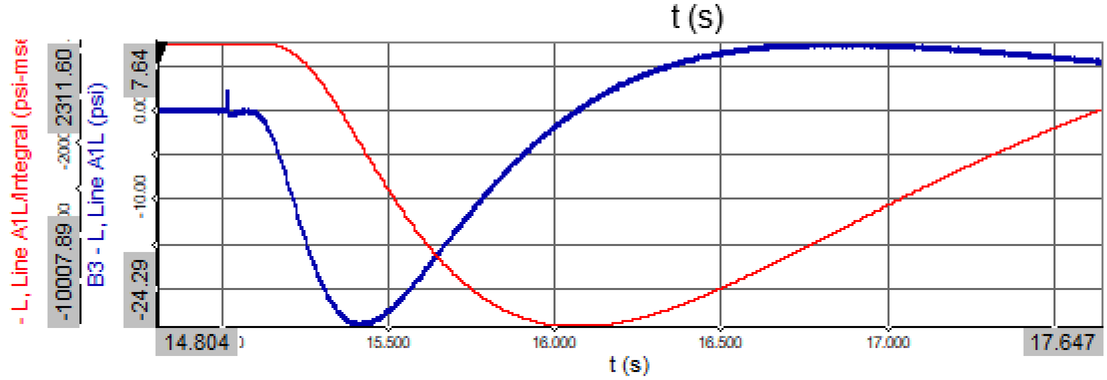

A3 - L, Line R/FIR Filter ()
- L, Line R/Integral (psi-ms
A3 - L, Line R (psi)
0.096
1
1.5
2.386
227.511
238.95
0.091
1
1.5
2.407
15.006000
15.008
15.009
15.01
15.011
15.012
15.014600
t (s)

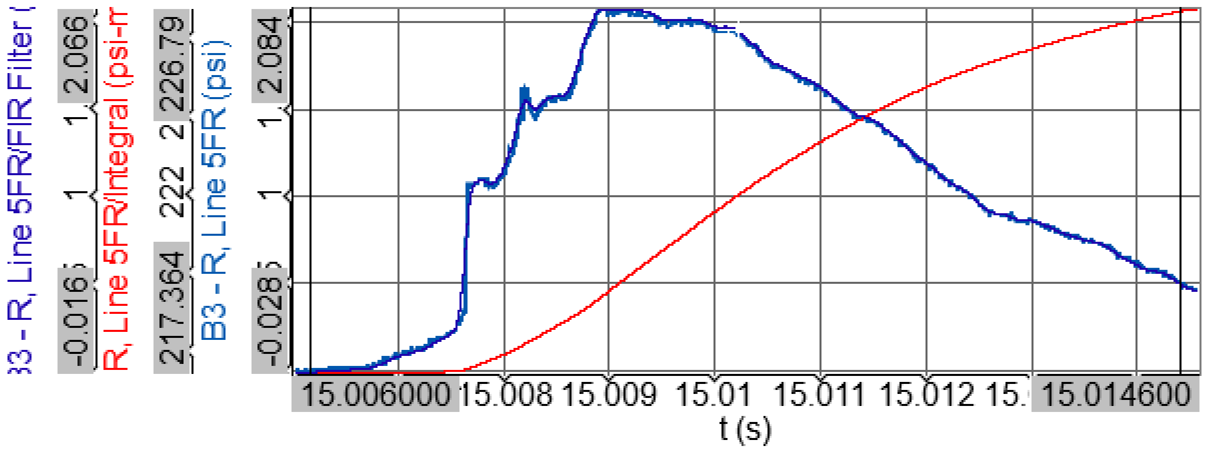

3 - L, Line R/Integral (psi-mse
-23401.482
-10000.00
239.447
A3 - L, Line R (psi)
-41.223
-20.000
13.293
14.804
15.500
16.000
16.500
17.000
17.647
t (s)

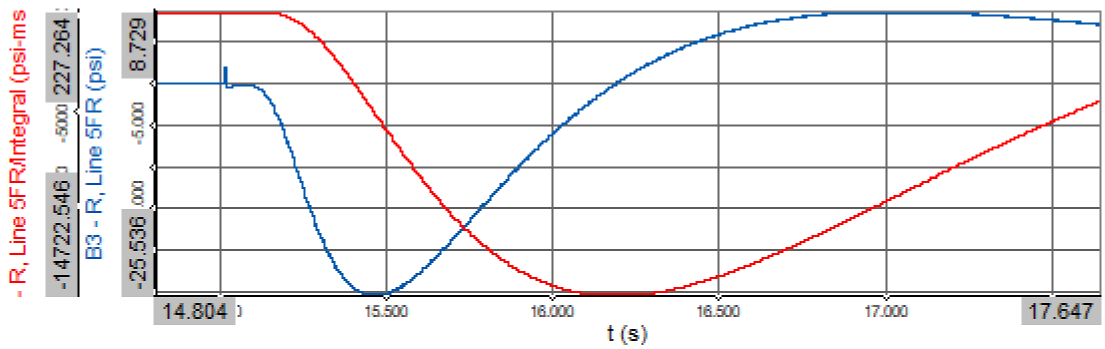

A3 - R, Line 5DR/FIR Filter
R, Line 5DR/Integral (psi-m
A3 - R, Line 5DR (psi)
15.006000
15.014600
t (s)

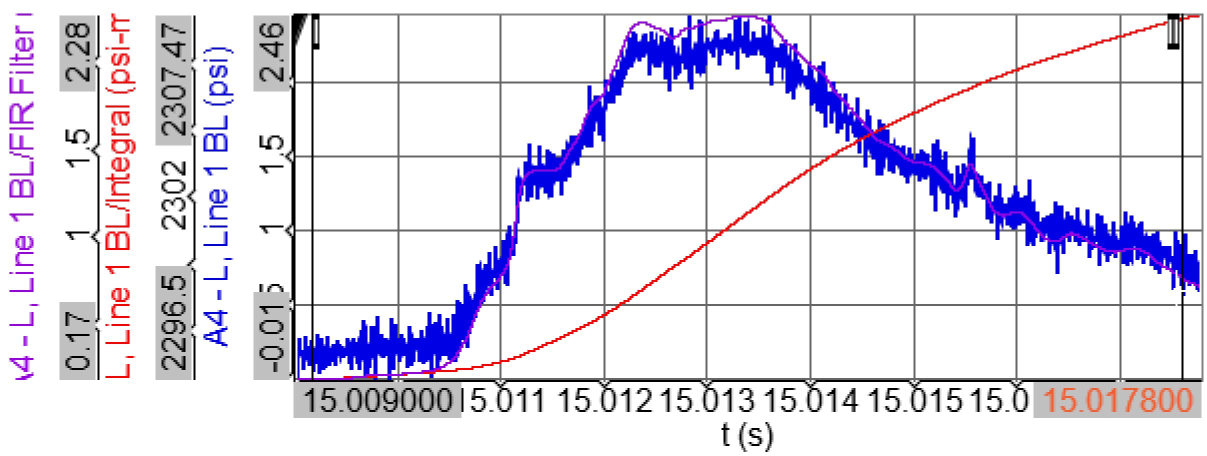

R, Line 5DR/Integral (psi-ms
A3 - R, Line 5DR (psi)
14.804
15.500
16.000
16.500
17.000
17.647
t (s)

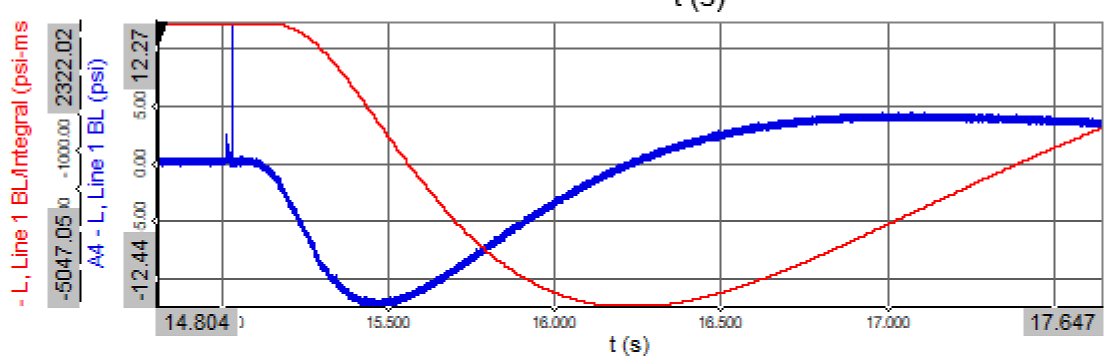

B3 - L, Line A1L/FIR Filter
L, Line A1L/Integral (psi-m
B3 - L, Line A1L (psi)
15.006000
15.014600
t (s)

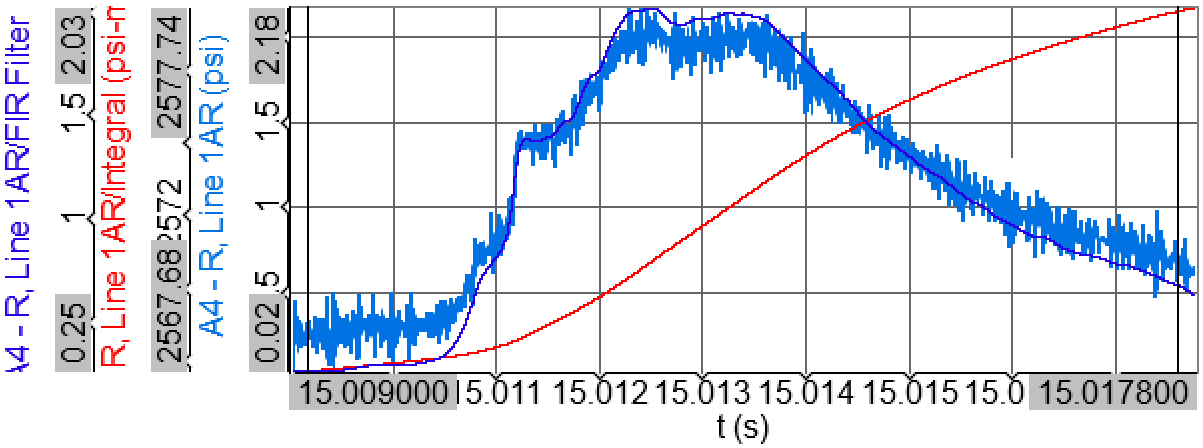

- L, Line A1L/Integral (psi-ms
B3 - L, Line A1L (psi)
14.804
15.500
16.000
16.500
17.000
17.647
t (s)

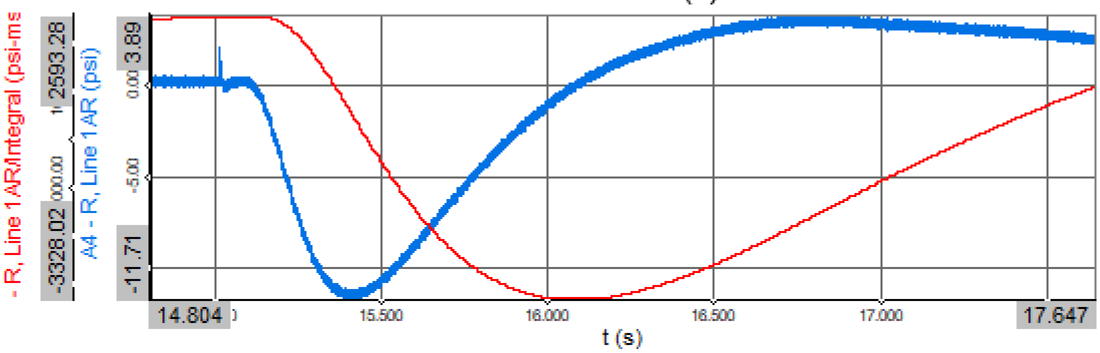

B3 - R, Line 5FR/FIR Filter (
R, Line 5FR/Integral (psi-m
B3 - R, Line 5FR (psi)
2.066
-0.016
226.79
217.364
2.084
-0.028
15.006000
15.014600
t (s)

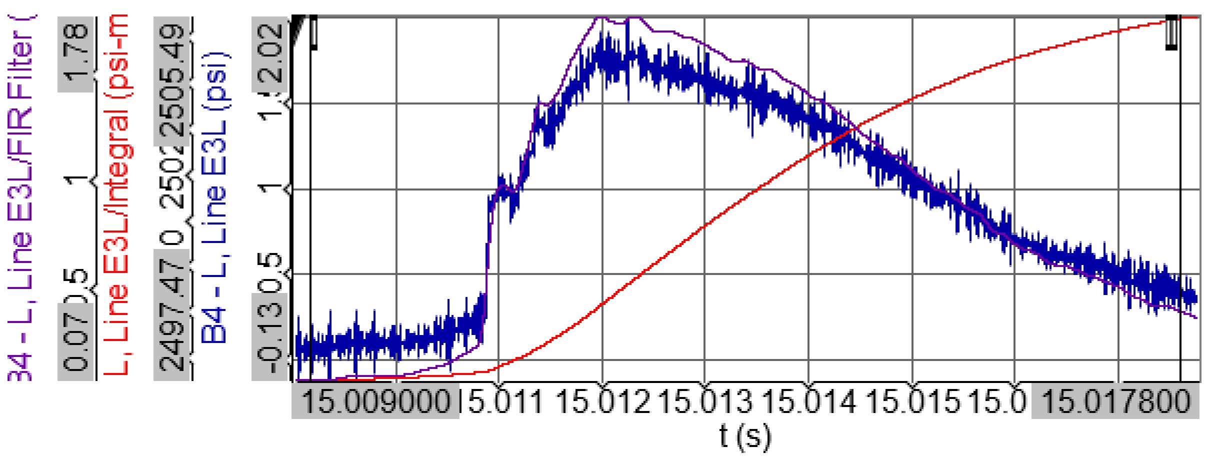

- R, Line 5FR/Integral (psi-ms
B3 - R, Line 5FR (psi)
227.264
-14722.546
8.729
-25.536
14.804
15.500
16.000
16.500
17.000
17.647
t (s)

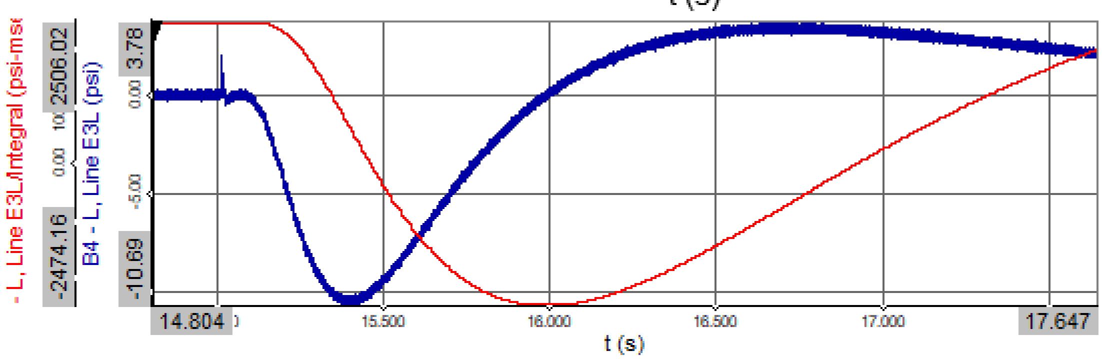

A4 - L, Line 1 BL/FIR Filter
L, Line 1 BL/Integral (psi-m
A4 - L, Line 1 BL (psi)
2.28
0.17
2307.47
2296.5
2.46
-0.01
15.009000
15.017800
t (s)

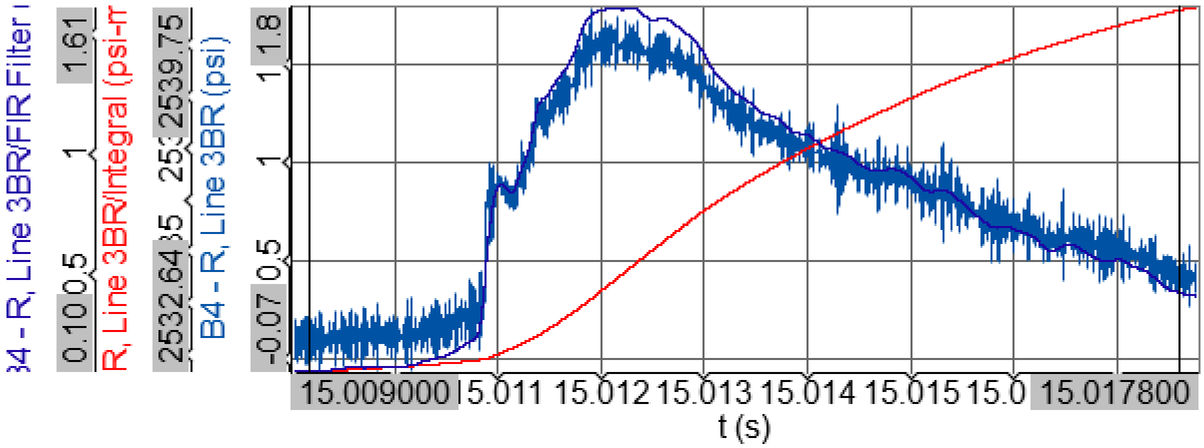

- L, Line 1 BL/Integral (psi-ms
A4 - L, Line 1 BL (psi)
2322.02
-5047.05
12.27
-12.44
14.804
15.500
16.000
16.500
17.000
17.647
t (s)

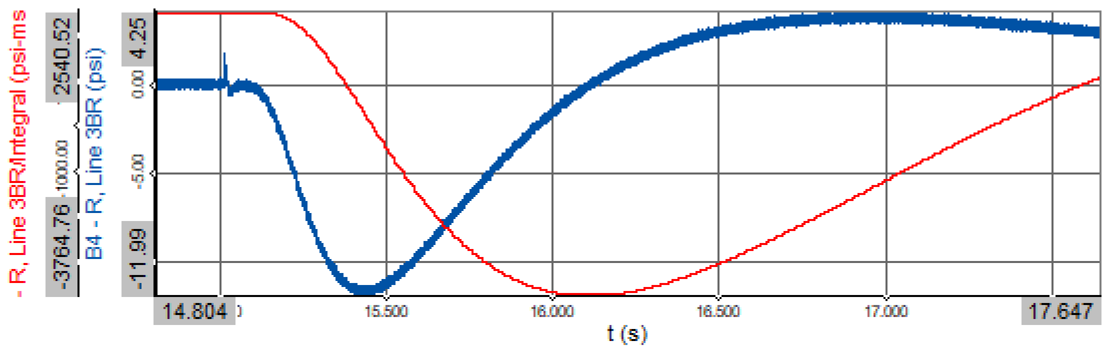

A4 - R, Line 1AR/FIR Filter
R, Line 1AR/Integral (psi-m
A4 - R, Line 1AR (psi)
15.009000
15.017800
t (s)

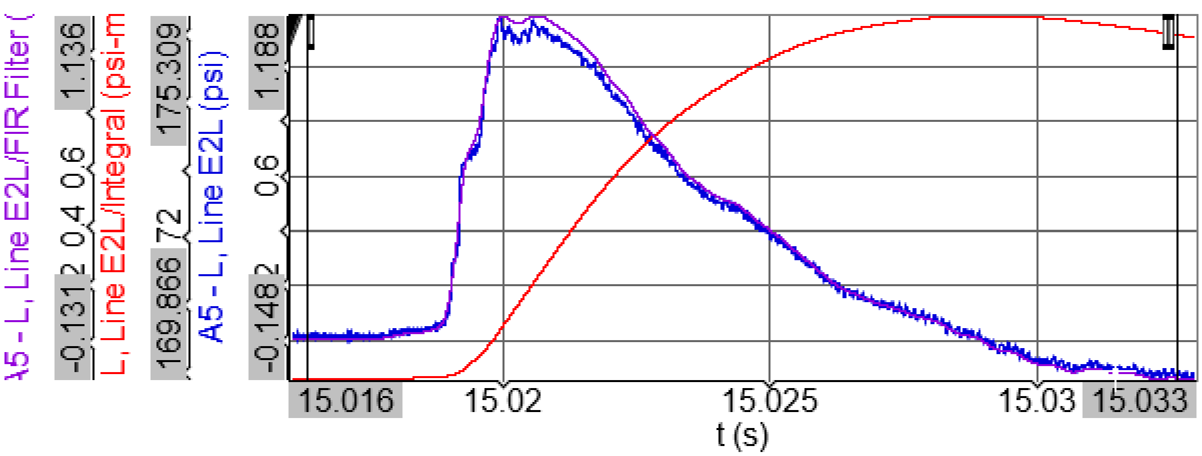

- R, Line 1AR/Integral (psi-ms
A4 - R, Line 1AR (psi)
14.804
17.647
t (s)

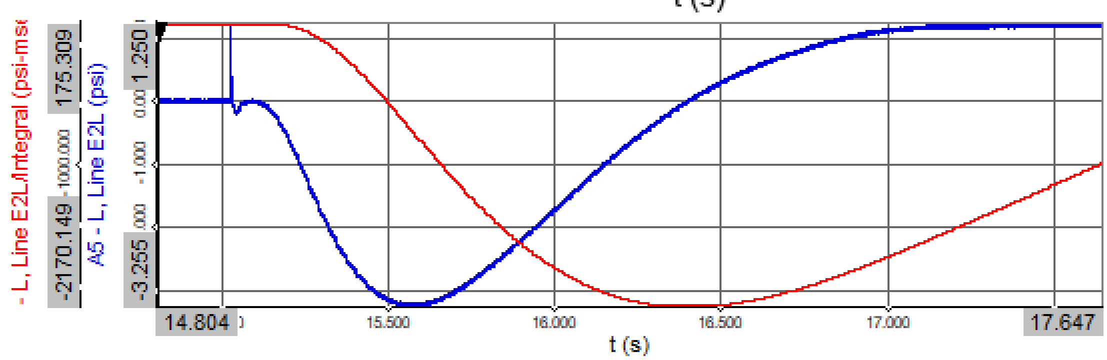

B4 - L, Line E3L/FIR Filter (
L, Line E3L/Integral (psi-m
B4 - L, Line E3L (psi)
15.009000
15.017800
t (s)

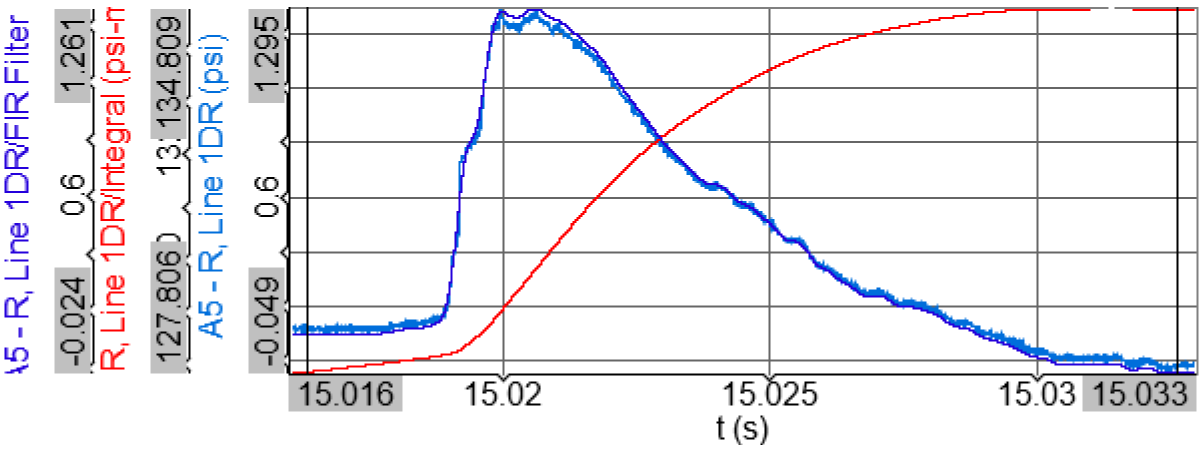

- L, Line E3L/Integral (psi-ms
B4 - L, Line E3L (psi)
14.804
17.647
t (s)

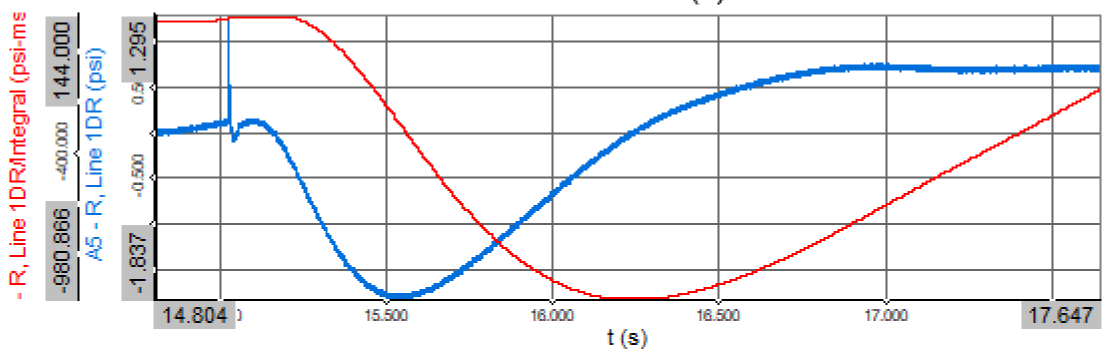

B4 - R, Line 3BR/FIR Filter
R, Line 3BR/Integral (psi-m
B4 - R, Line 3BR (psi)
15.009000
15.011
15.012
15.013
15.014
15.015
15.017800
t (s)

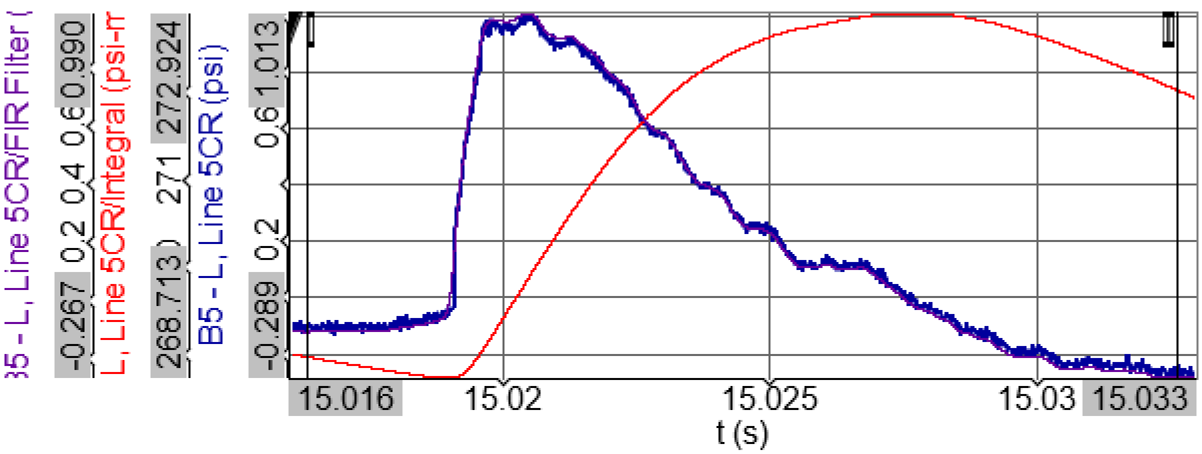

- R, Line 3BR/Integral (psi-ms
B4 - R, Line 3BR (psi)
2540.52
-3764.76
4.25
-11.99
14.804
15.500
16.000
16.500
17.000
17.647
t (s)

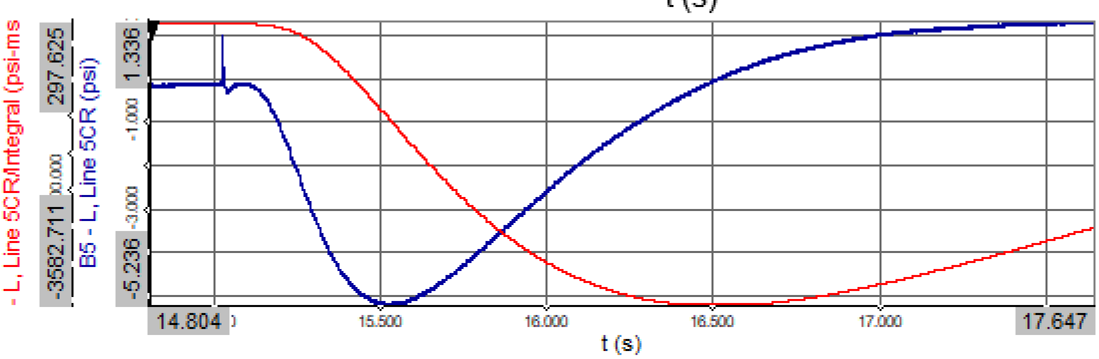

A5 - L, Line E2L/FIR Filter
L, Line E2L/Integral (psi-m
A5 - L, Line E2L (psi)
1.136
-0.131
175.309
169.866
1.188
-0.148
15.016
15.02
15.025
15.03
15.033
t (s)

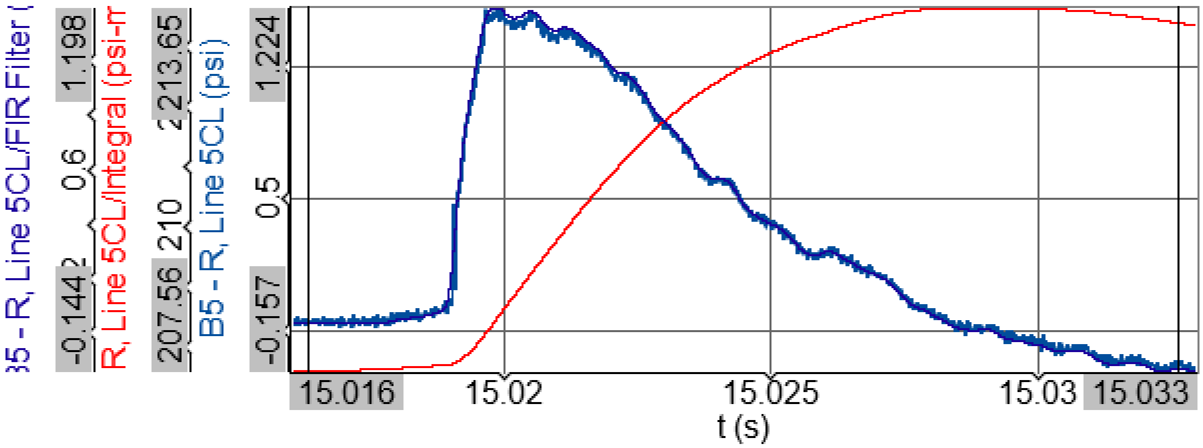

- L, Line E2L/Integral (psi-ms
A5 - L, Line E2L (psi)
175.309
-2170.149
1.250
-3.255
14.804
15.500
16.000
16.500
17.000
17.647
t (s)

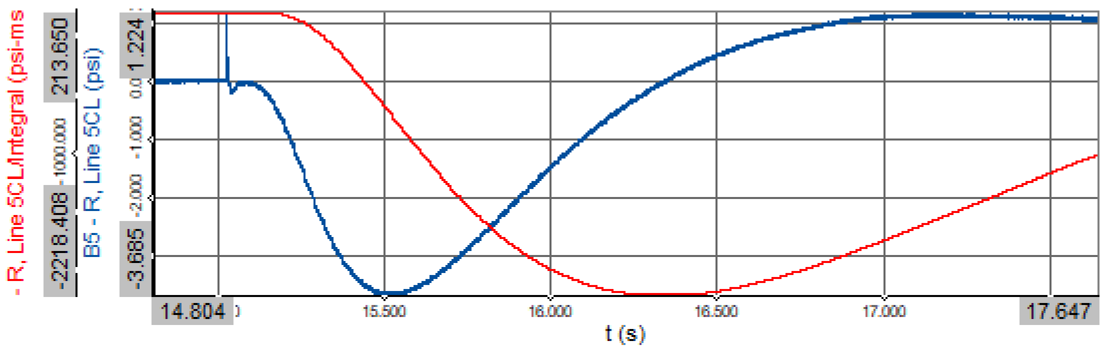

A5 - R, Line 1DR/FIR Filter
R, Line 1DR/Integral (psi-m
A5 - R, Line 1DR (psi)
1.261
0.6
-0.024
134.809
127.806
1.295
0.6
-0.049
15.016
15.02
15.025
15.03
15.033
t (s)

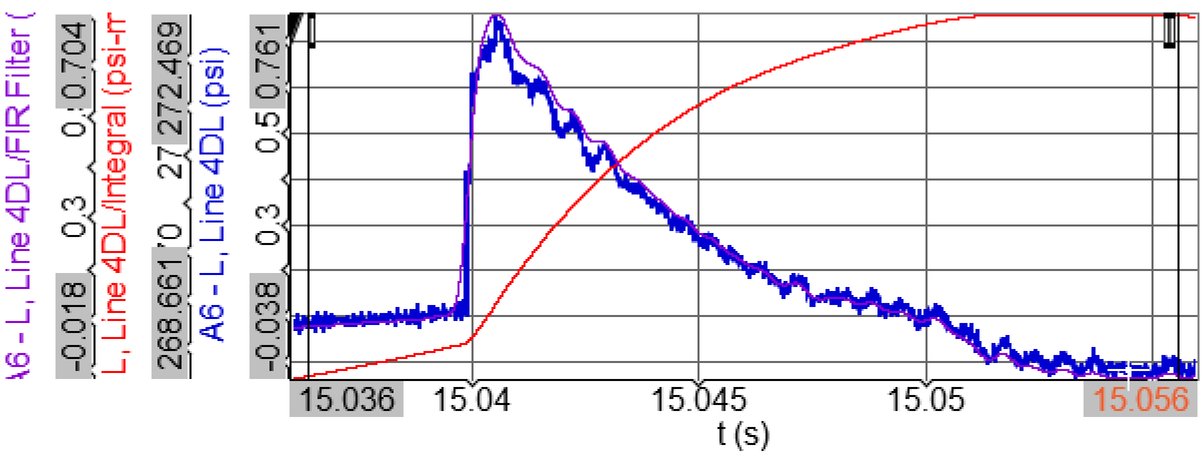

- R, Line 1DR/Integral (psi-ms
A5 - R, Line 1DR (psi)
144.000
-400.000
-980.866
1.295
0.5
-0.500
-1.837
14.804
15.500
16.000
16.500
17.000
17.647
t (s)

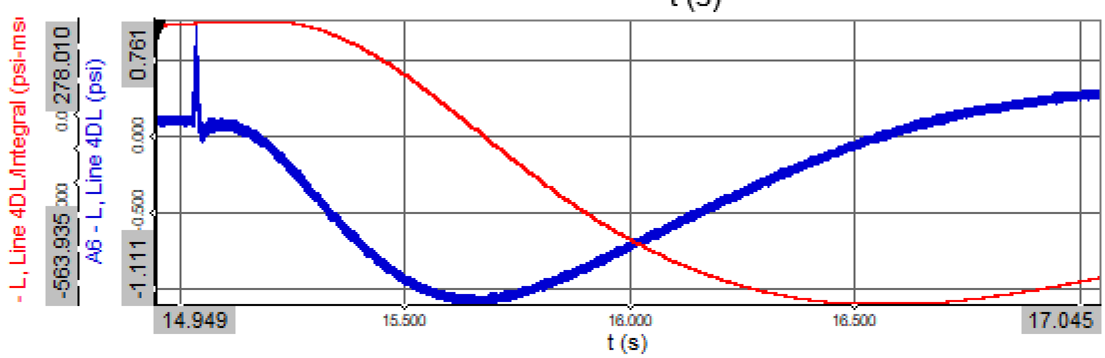

B5 - L, Line 5CR/FIR Filter (
L, Line 5CR/Integral (psi-m
B5 - L, Line 5CR (psi)
0.990
0.6
0.4
0.2
-0.267
272.924
271
268.713
1.013
0.6
0.2
-0.289
15.016
15.02
15.025
15.03
15.033
t (s)

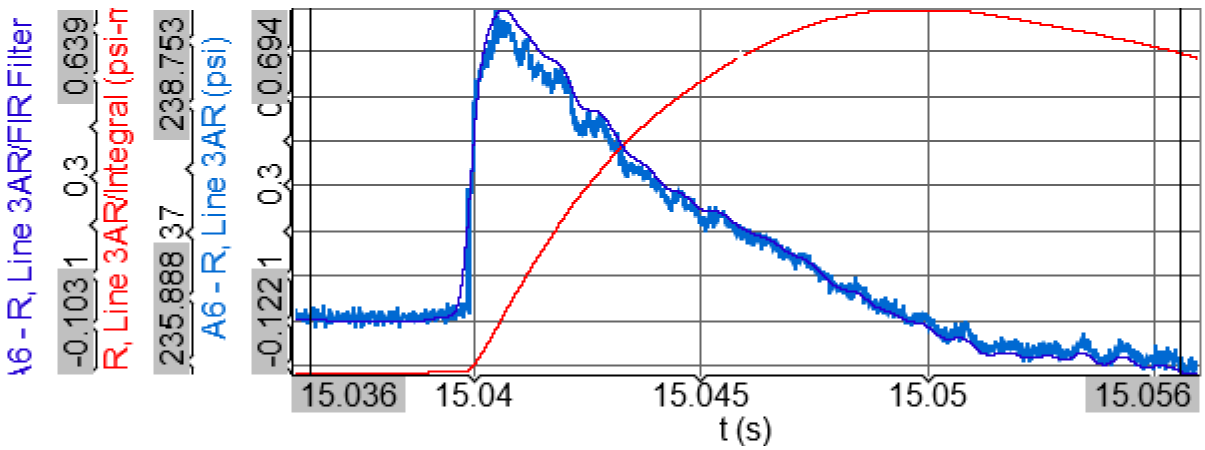

- L, Line 5CR/Integral (psi-ms
B5 - L, Line 5CR (psi)
297.625
-3582.711
1.336
-1.000
-3.000
-5.236
14.804
15.500
16.000
16.500
17.000
17.647
t (s)

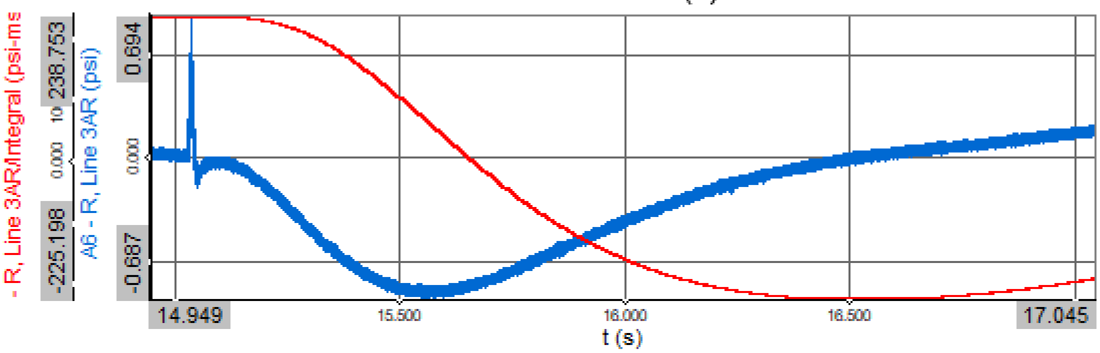

R, Line 5CL/Integral (psi-m
B5 - R, Line 5CL (psi)
1.198
0.6
-0.144
213.65
210
207.56
1.224
0.5
-0.157
15.016
15.02
15.025
15.03
15.033
t (s)

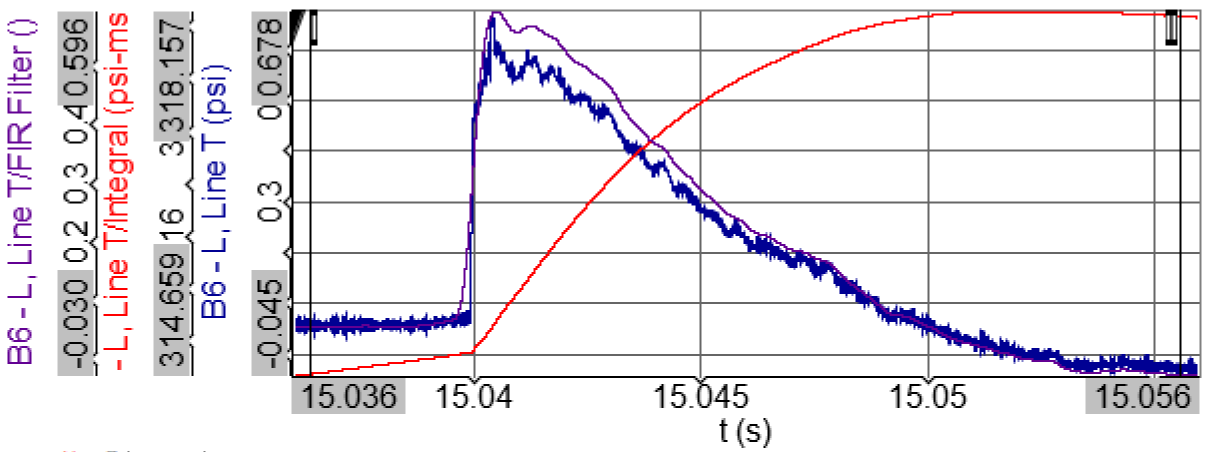

- R, Line 5CL/Integral (psi-ms
B5 - R, Line 5CL (psi)
213.650
-2218.408
1.224
-3.685
14.804
15.500
16.000
16.500
17.000
17.647
t (s)

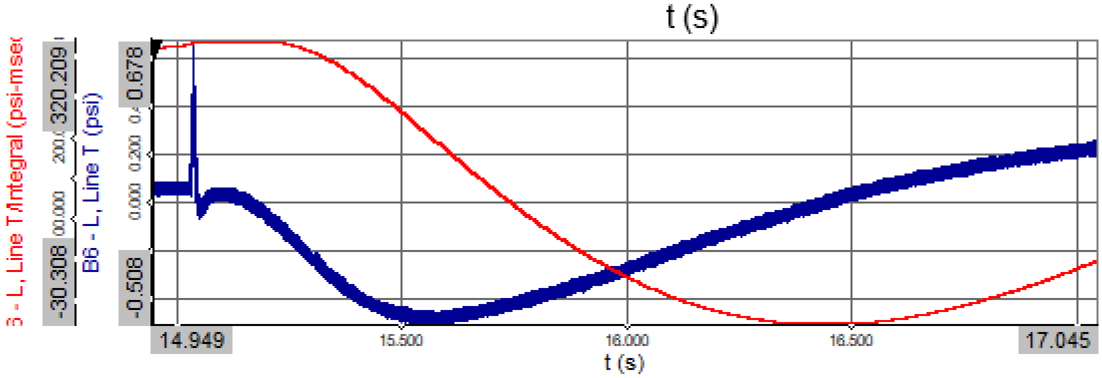

L, Line 4DL/Integral (psi-m
A6 - L, Line 4DL (psi)
0.704
0.3
-0.018
272.469
268.661
0.761
0.5
0.3
-0.038
15.036
15.04
15.045
15.05
15.056
t (s)

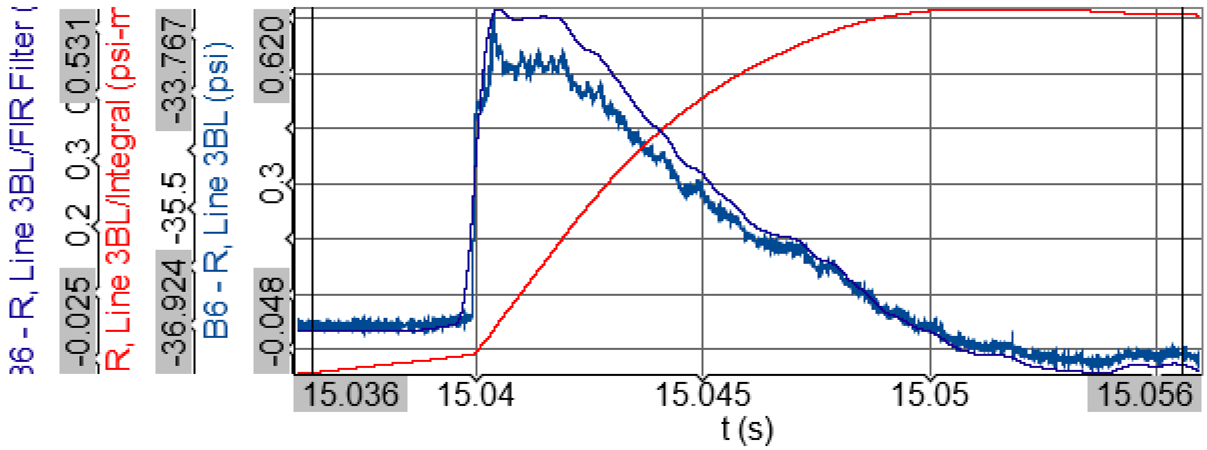

- L, Line 4DL/Integral (psi-ms
A6 - L, Line 4DL (psi)
278.010
-563.935
0.761
-1.111
14.949
15.500
16.000
16.500
17.045
t (s)

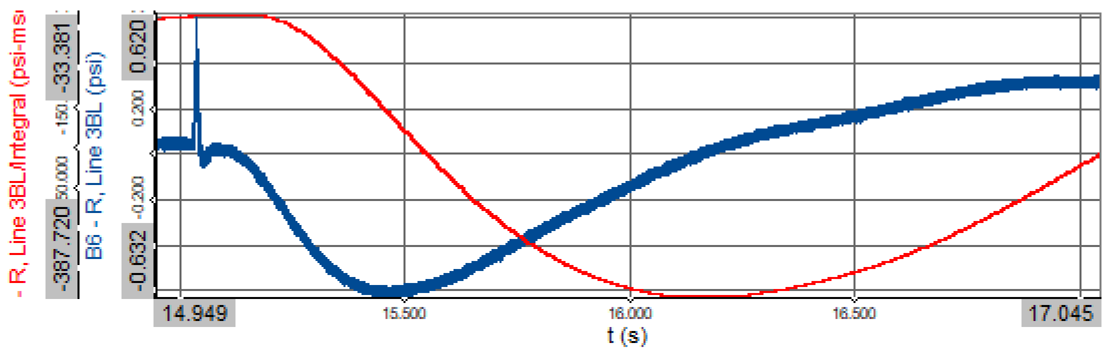

A6 - R, Line 3AR/FIR Filter
R, Line 3AR/Integral (psi-m
A6 - R, Line 3AR (psi)
-0.103
0.639
235.888
238.753
-0.122
0.694
15.036
15.04
15.045
15.05
15.056
t (s)

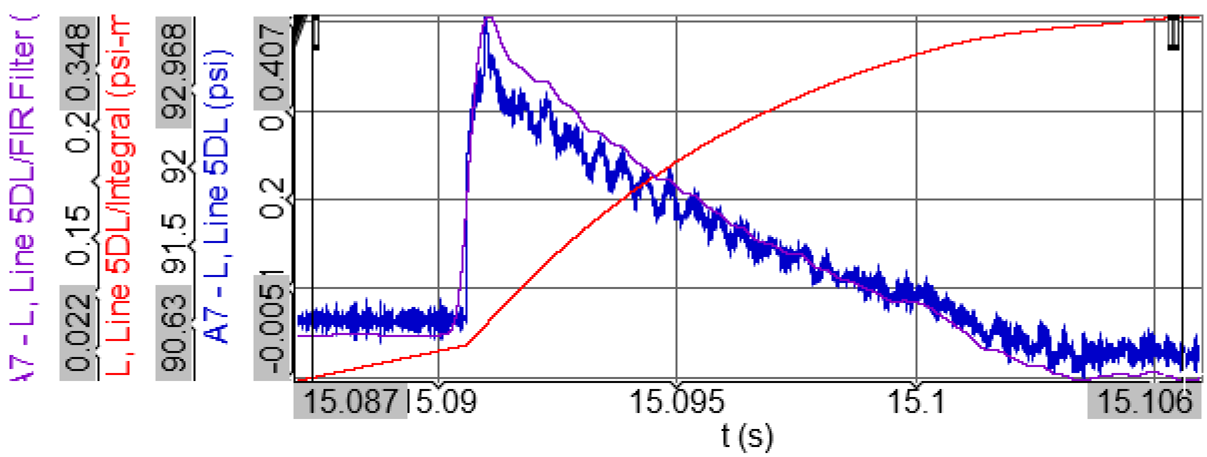

- R, Line 3AR/Integral (psi-ms
A6 - R, Line 3AR (psi)
-225.198
238.753
-0.687
0.694
14.949
15.500
16.000
16.500
17.045
t (s)

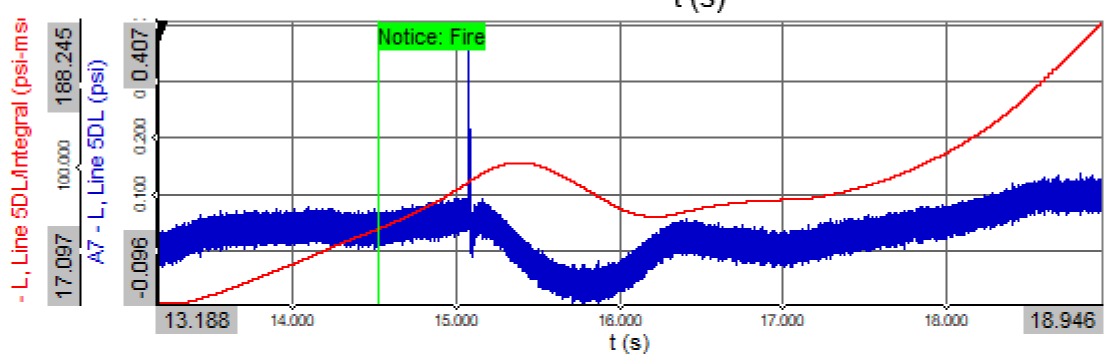

B6 - L, Line T/FIR Filter ()
- L, Line T/Integral (psi-ms
B6 - L, Line T (psi)
-0.030
0.596
314.659
318.157
-0.045
0.678
15.036
15.04
15.045
15.05
15.056
t (s)

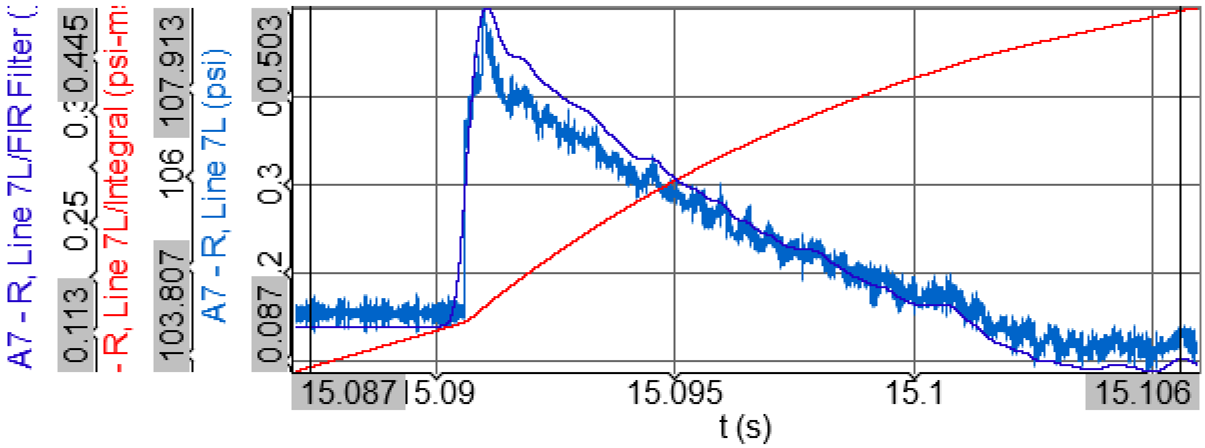

- L, Line T/Integral (psi-msec
B6 - L, Line T (psi)
-30.308
320.209
-0.508
0.678
14.949
15.500
16.000
16.500
17.045
t (s)

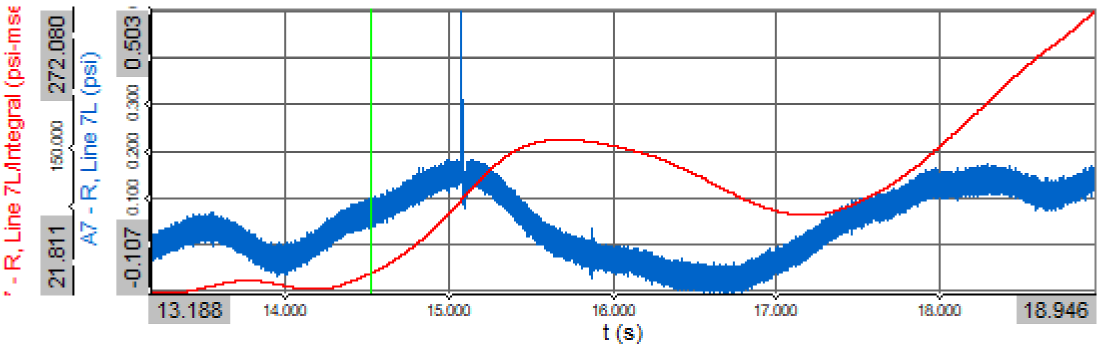

B6 - R, Line 3BL (psi)
R, Line 3BL/Integral (psi-m
t (s)
15.036
15.04
15.045
15.05
15.056

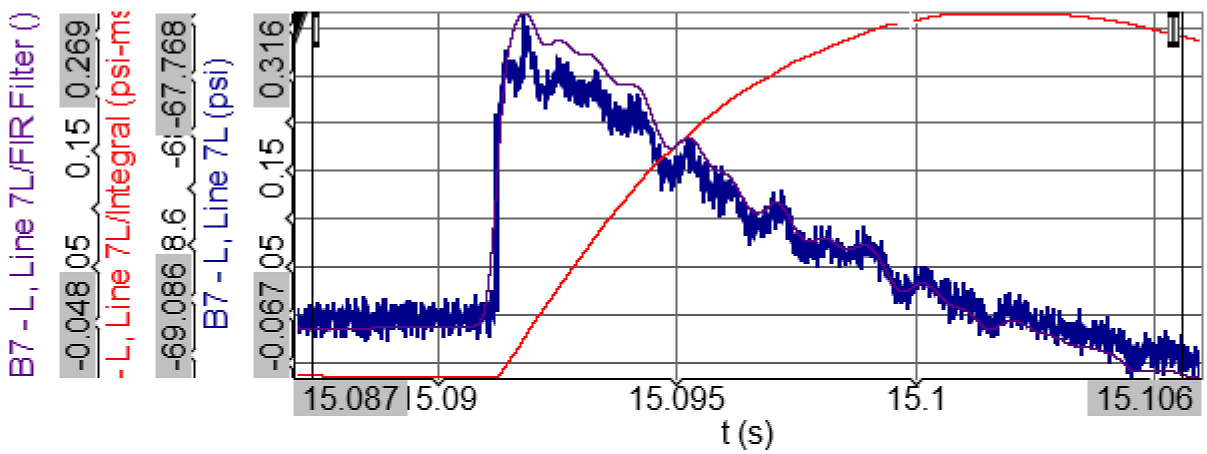

B6 - R, Line 3BL (psi)
- R, Line 3BL/Integral (psi-ms
t (s)
14.949
15.500
16.000
16.500
17.045

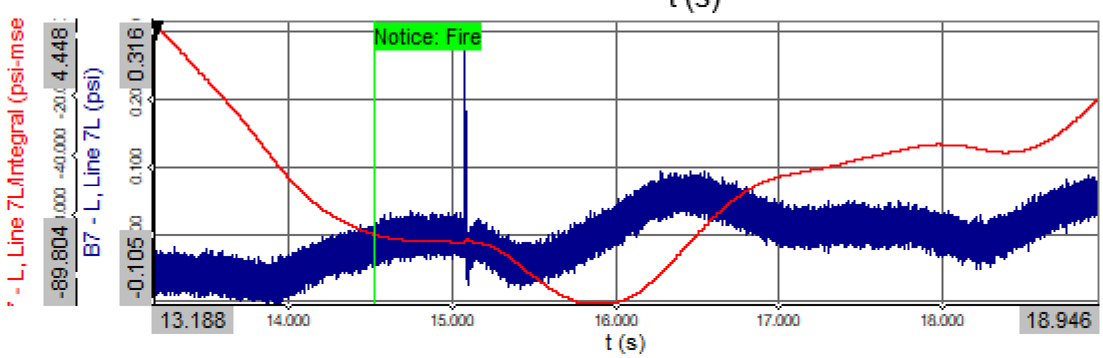

A7 - L, Line 5DL (psi)
L, Line 5DL/Integral (psi-m
t (s)
15.087
15.09
15.095
15.1
15.106

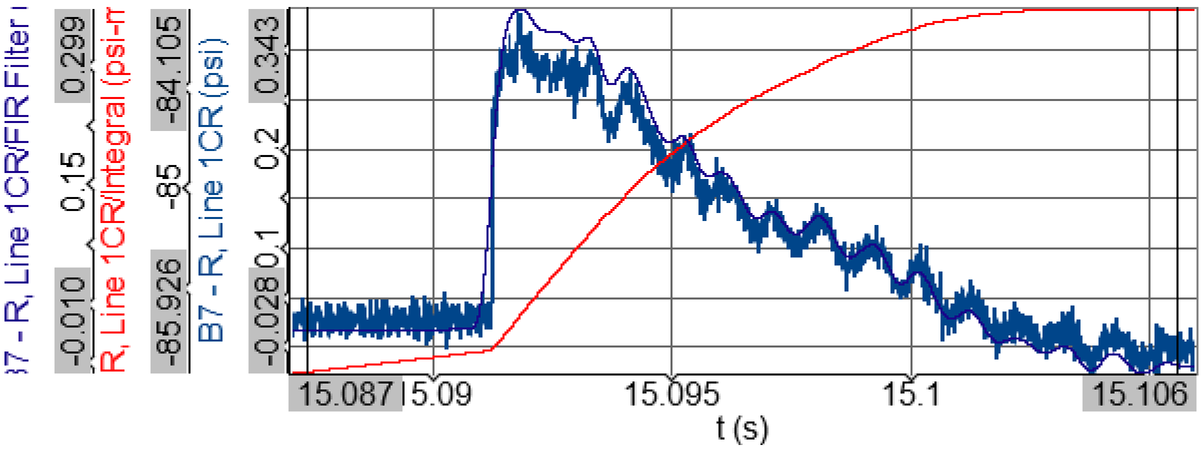

Notice: Fire
A7 - L, Line 5DL (psi)
- L, Line 5DL/Integral (psi-ms
t (s)
13.188
14.000
15.000
16.000
17.000
18.000
18.946

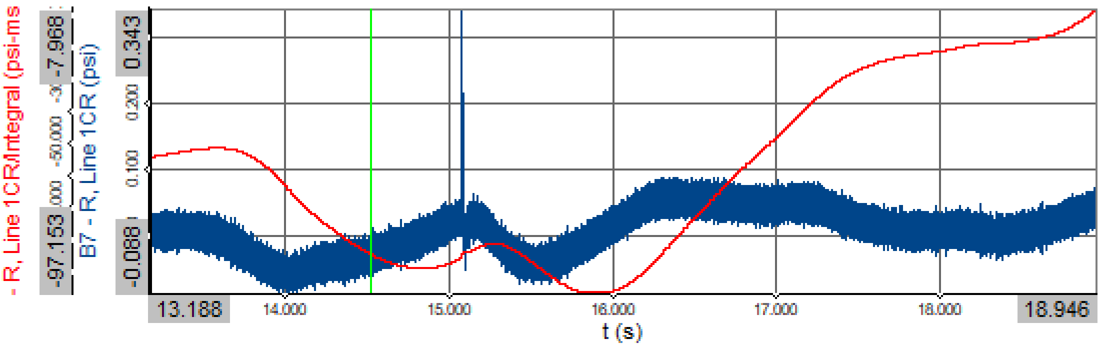

A7 - R, Line 7L/FIR Filter
R, Line 7L/Integral (psi-m
A7 - R, Line 7L (psi)
0.113
0.25
0.445
103.807
106
107.913
0.087
0.503
15.087
15.09
15.095
15.1
15.106
t (s)

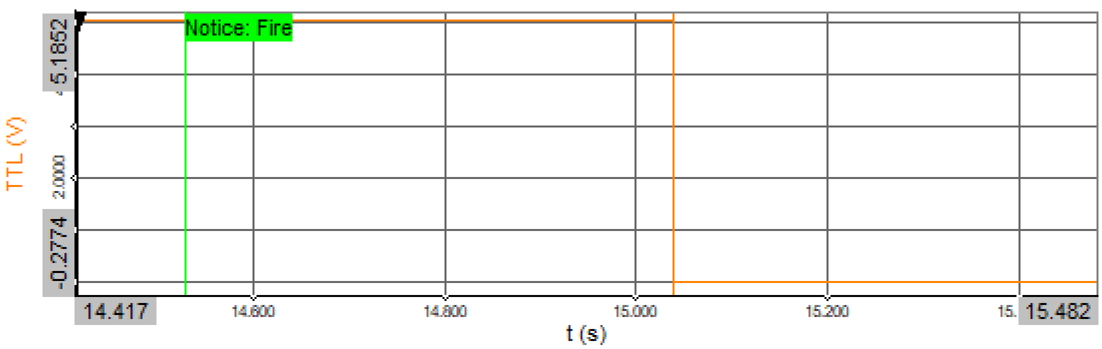

- R, Line 7L/Integral (psi-mse
A7 - R, Line 7L (psi)
21.811
272.080
-0.107
0.503
13.188
14.000
15.000
16.000
17.000
18.000
18.946
t (s)


B7 - L, Line 7L/FIR Filter ()
- L, Line 7L/Integral (psi-ms
B7 - L, Line 7L (psi)
-0.048
0.15
0.269
-69.086
-67.768
-0.067
0.15
0.316
15.087
15.09
15.095
15.1
15.106
t (s)


Notice: Fire
- L, Line 7L/Integral (psi-mse
B7 - L, Line 7L (psi)
-89.804
4.448
-0.105
0.316
13.188
14.000
15.000
16.000
17.000
18.000
18.946
t (s)

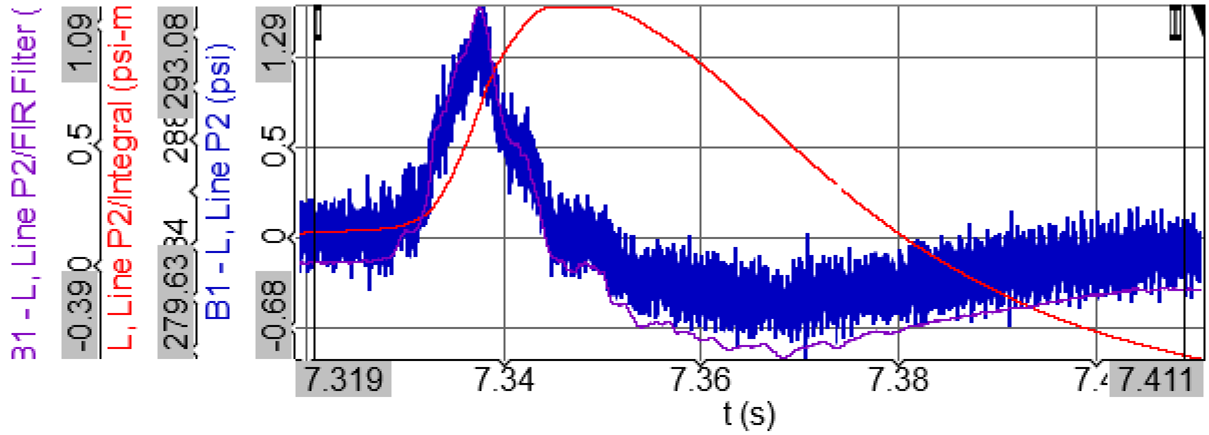

B7 - R, Line 1CR/FIR Filter
R, Line 1CR/Integral (psi-m
B7 - R, Line 1CR (psi)
-0.010
0.15
0.299
-85.926
-85
-84.105
-0.028
0.1
0.2
0.343
15.087
15.09
15.095
15.1
15.106
t (s)

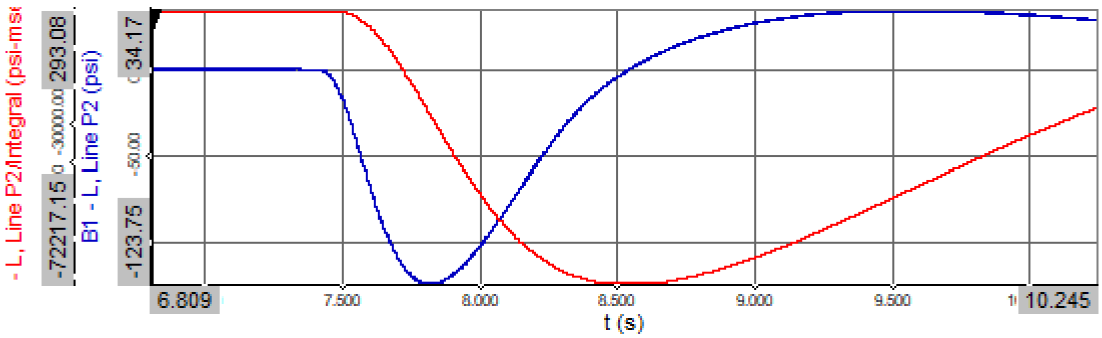

- R, Line 1CR/Integral (psi-ms
B7 - R, Line 1CR (psi)
-97.153
-7.968
-0.088
0.100
0.200
0.343
13.188
14.000
15.000
16.000
17.000
18.000
18.946
t (s)

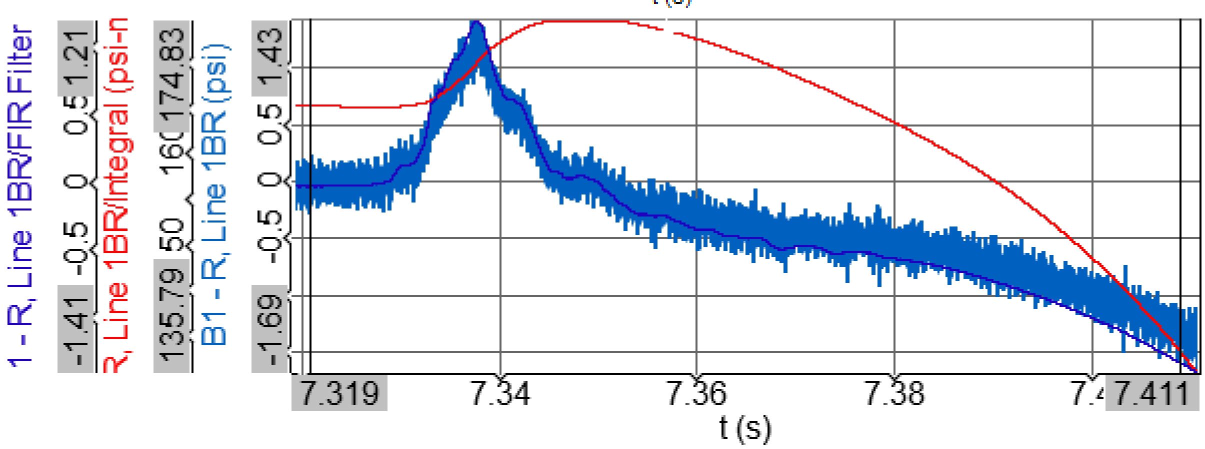

TTL (V)
-0.2774
2.0000
5.1852
Notice: Fire
14.417
14.600
14.800
15.000
15.200
15.482
t (s)

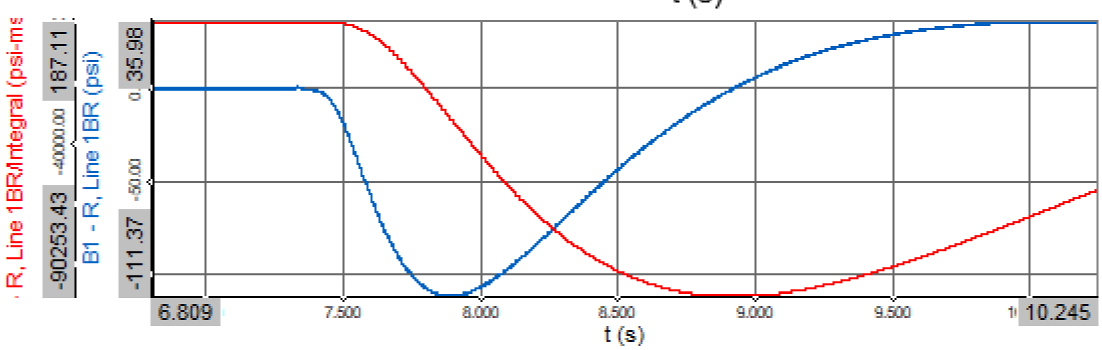
8.3 Fine Mg-MnO_2 Thermite – Small-Scale Mix ID #4 (SMS mixed)

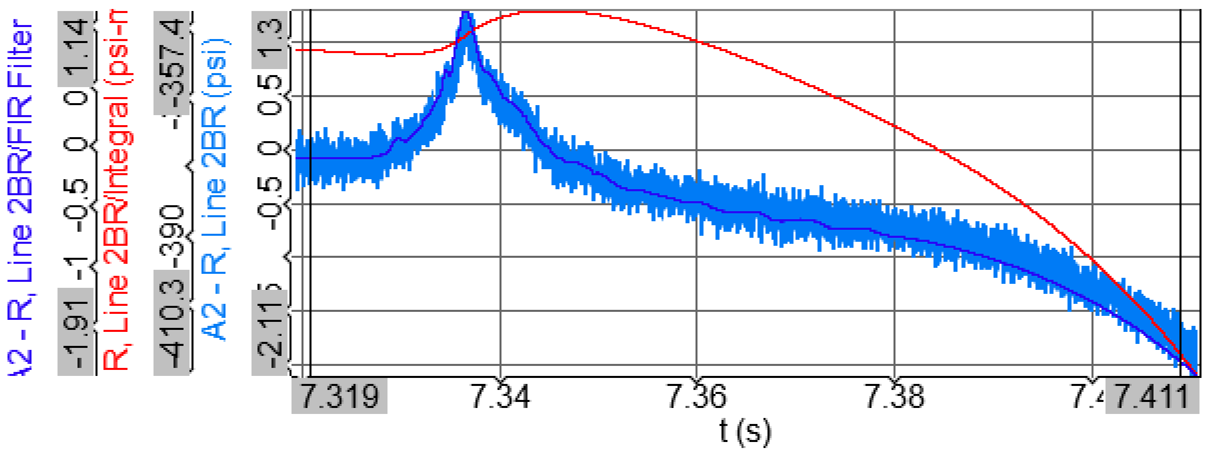
8.3.1 Trial 1 for Small-Scale Mix ID #4

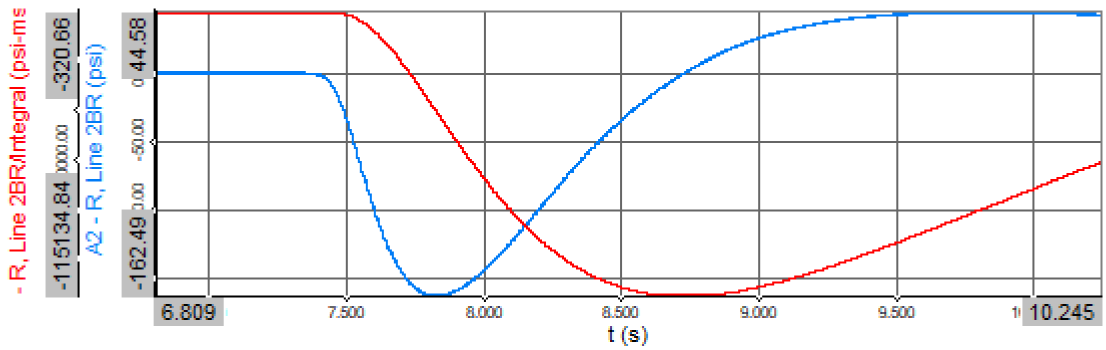


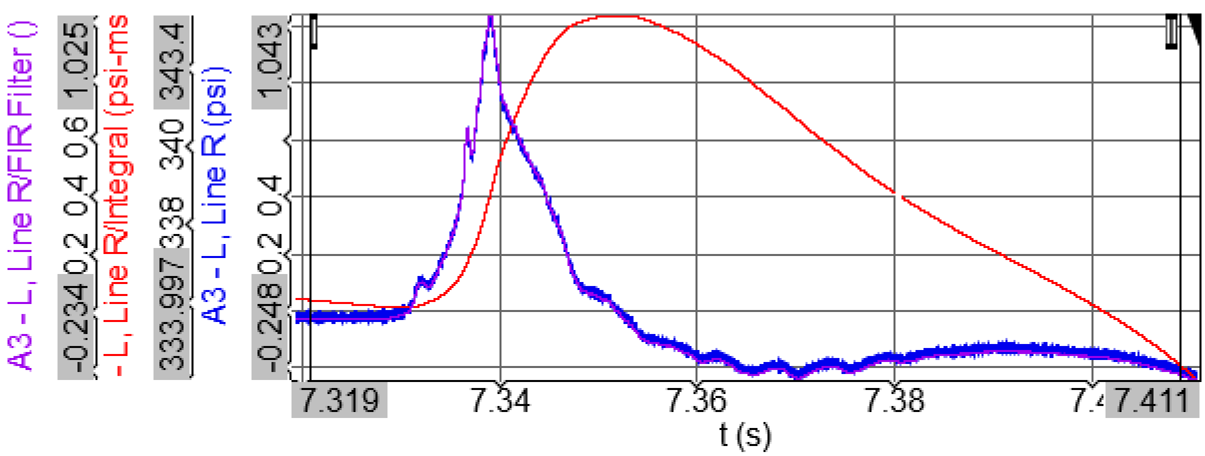


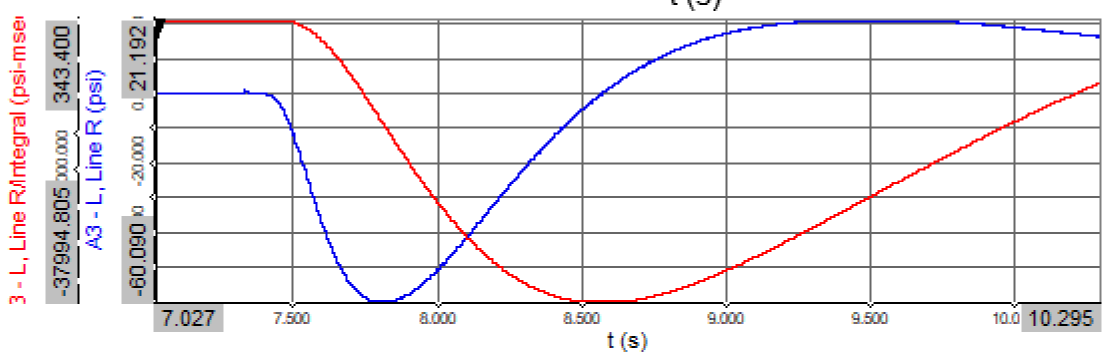


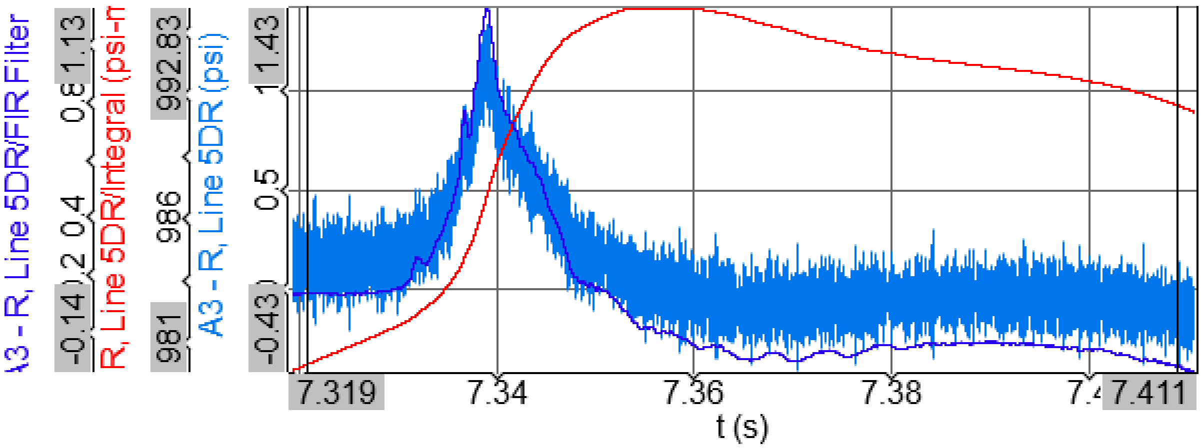


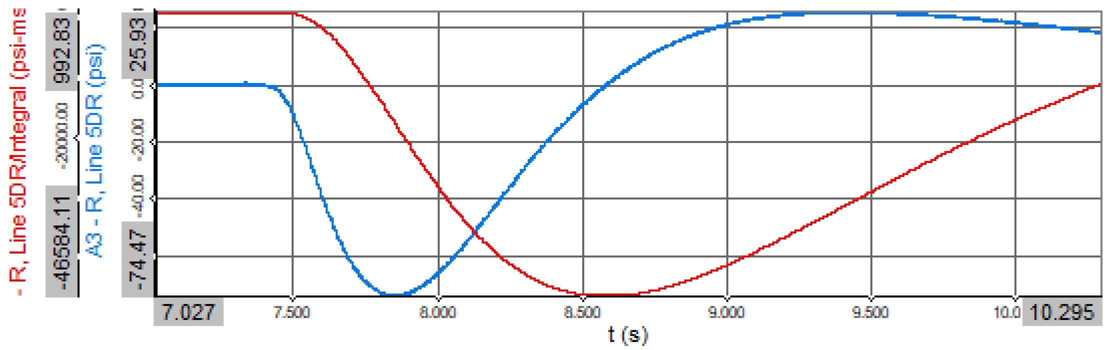

A2 - R, Line 2BR/FIR Filter
R, Line 2BR/Integral (psi-m
A2 - R, Line 2BR (psi)
-1.91 -1 -0.5 0 0.5 0 1.14
-410.3 -390 -357.4
-2.11 -0.5 0 0.5 1.3
7.319 7.34 7.36 7.38 7.411
t (s)

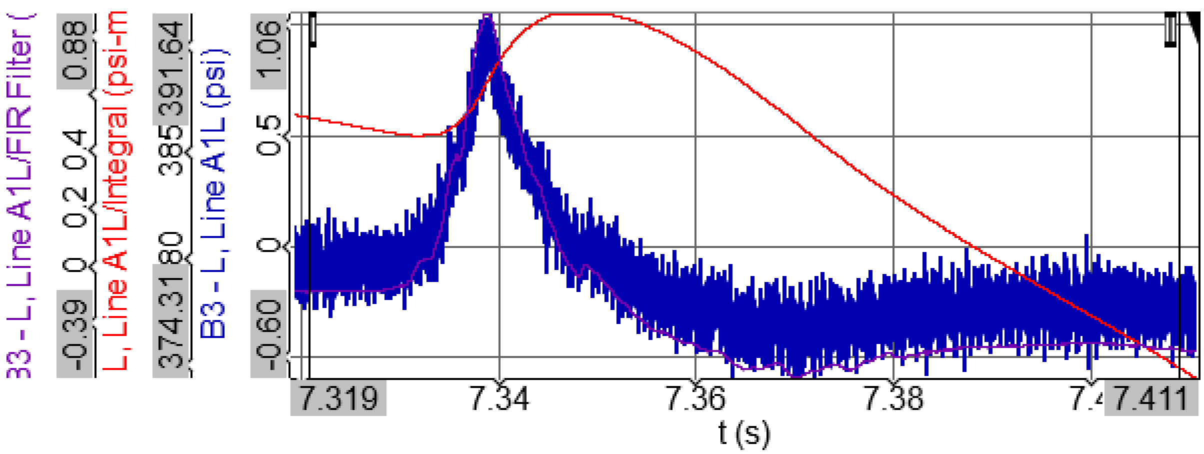

- R, Line 2BR/Integral (psi-ms
-115134.84 -320.66
A2 - R, Line 2BR (psi)
-162.49 -50.00 44.58
6.809 7.500 8.000 8.500 9.000 9.500 10.245
t (s)

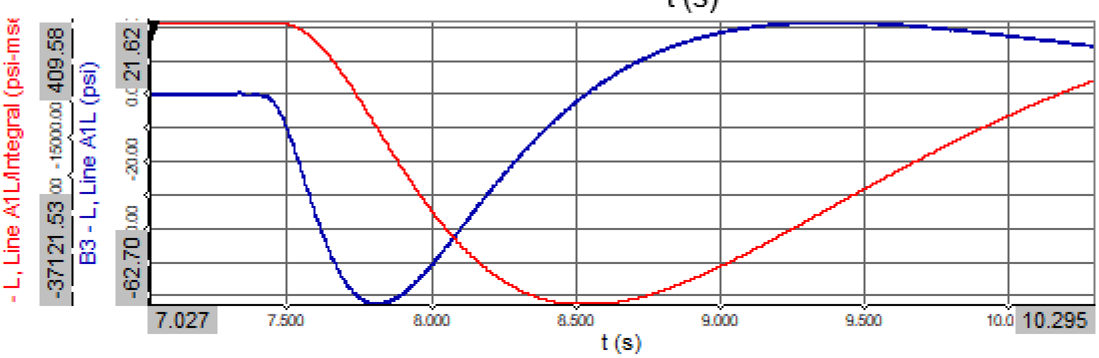

A3 - L, Line R/FIR Filter ()
- L, Line R/Integral (psi-ms
A3 - L, Line R (psi)
-0.234 0.2 0.4 0.6 1.025
333.997 338 340 343.4
-0.248 0.2 0.4 1.043
7.319 7.34 7.36 7.38 7.411
t (s)

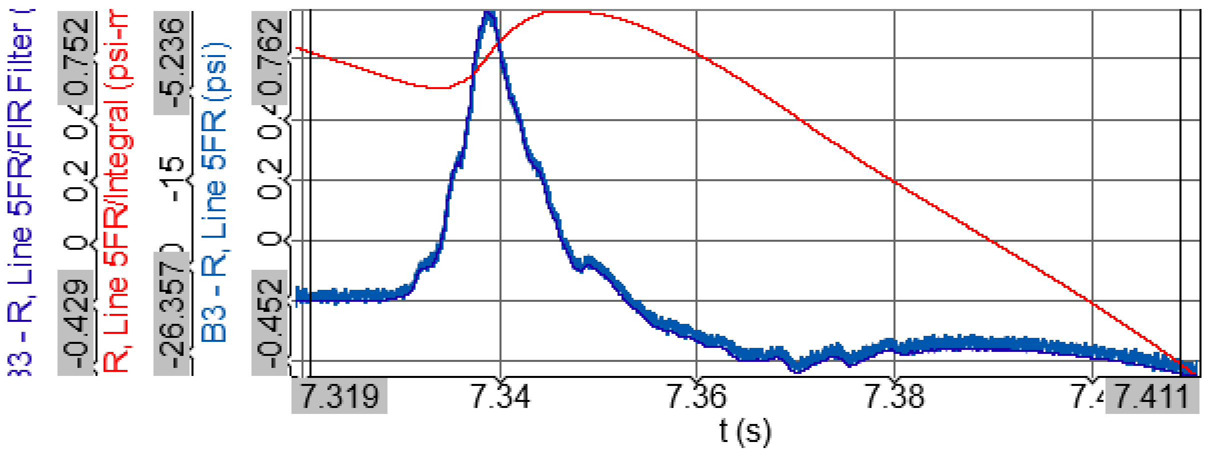

3 - L, Line R/Integral (psi-msec
-37994.805 343.400
A3 - L, Line R (psi)
-60.090 -20.000 21.192
7.027 7.500 8.000 8.500 9.000 9.500 10.295
t (s)

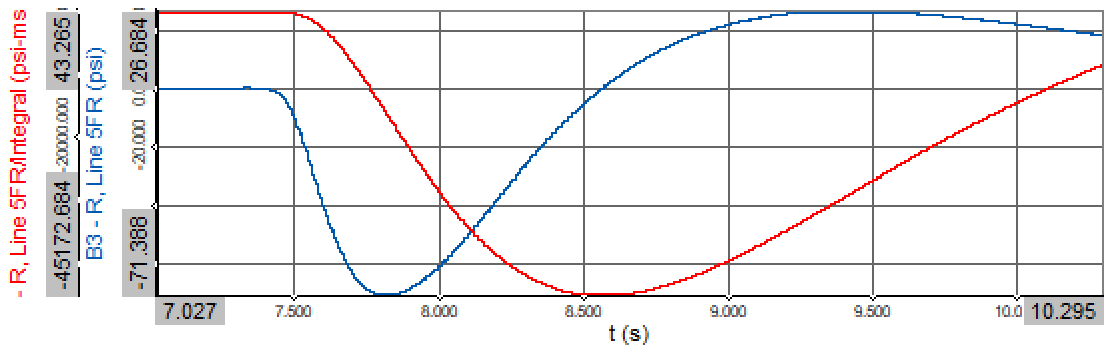

A3 - R, Line 5DR/FIR Filter
R, Line 5DR/Integral (psi-m
A3 - R, Line 5DR (psi)
7.319
7.34
7.36
7.38
7.411
t (s)

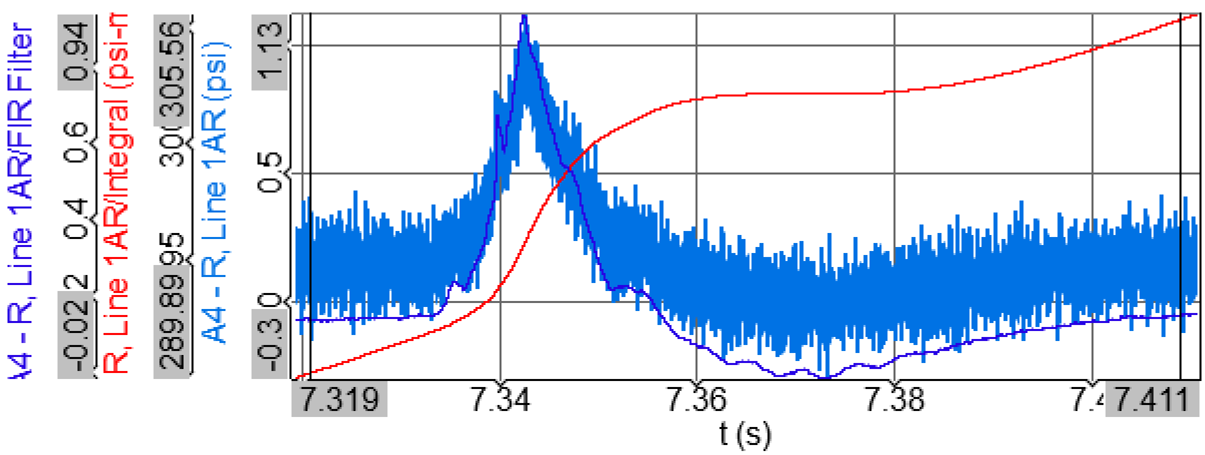

- R, Line 5DR/Integral (psi-ms
A3 - R, Line 5DR (psi)
7.027
10.295
t (s)

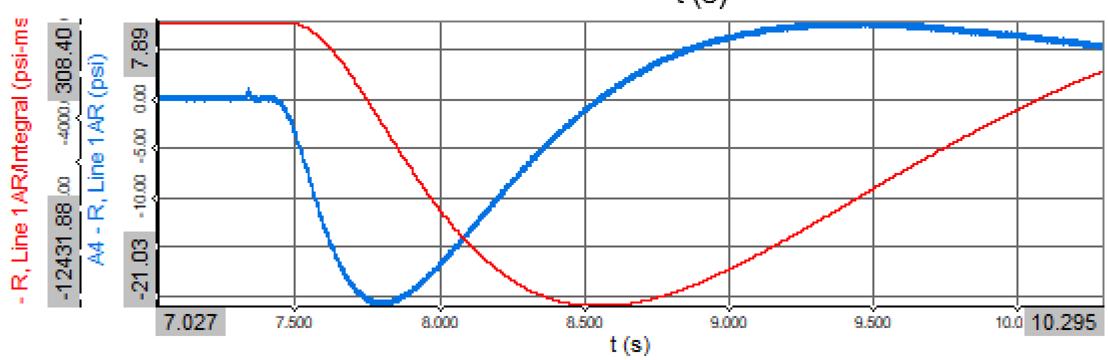

B3 - L, Line A1L/FIR Filter (
L, Line A1L/Integral (psi-m
B3 - L, Line A1L (psi)
7.319
7.34
7.36
7.38
7.411
t (s)

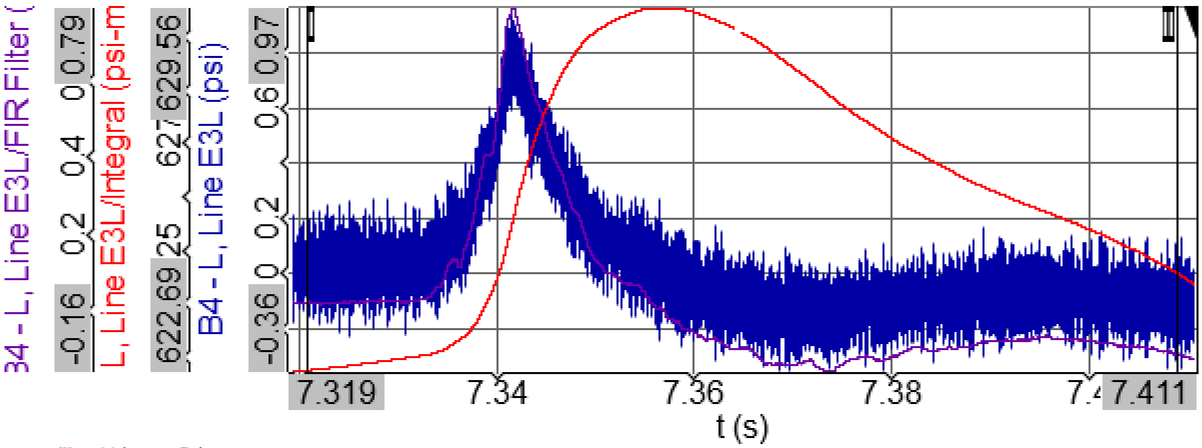

- L, Line A1L/Integral (psi-ms
B3 - L, Line A1L (psi)
7.027
10.295
t (s)

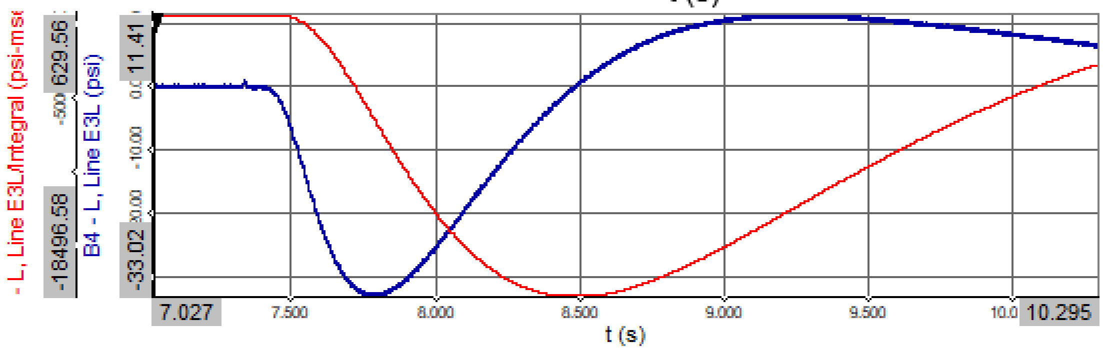

B3 - R, Line 5FR/FIR Filter (
-0.429 0 0.2 0.4 0.752
R, Line 5FR/Integral (psi-m
-26.357 -15 -5.236
B3 - R, Line 5FR (psi)
-0.452 0 0.2 0.4 0.762
7.319 7.34 7.36 7.38 7.4 7.411
t (s)

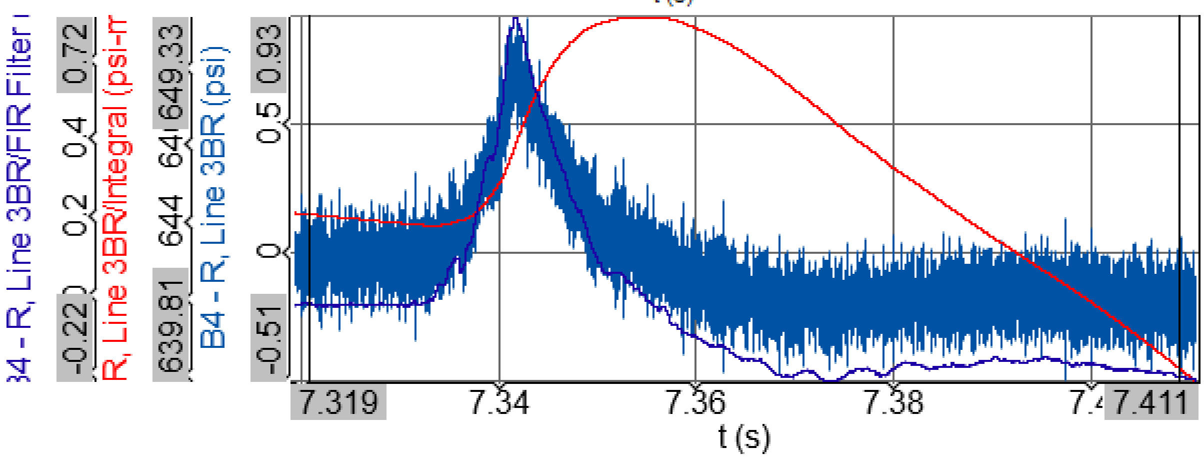

- R, Line 5FR/Integral (psi-ms
-45172.684 -20000.000 43.265
B3 - R, Line 5FR (psi)
-71.388 -20.000 0.0 26.684
7.027 7.500 8.000 8.500 9.000 9.500 10.0 10.295
t (s)

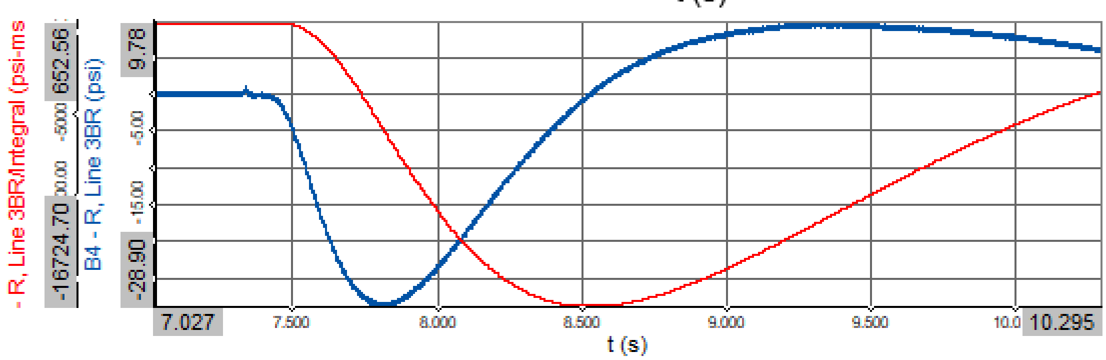

A4 - R, Line 1AR/FIR Filter
-0.02 0.2 0.4 0.6 0.94
R, Line 1AR/Integral (psi-m
289.89 295 300 305.56
A4 - R, Line 1AR (psi)
-0.3 0 0.5 1.13
7.319 7.34 7.36 7.38 7.4 7.411
t (s)

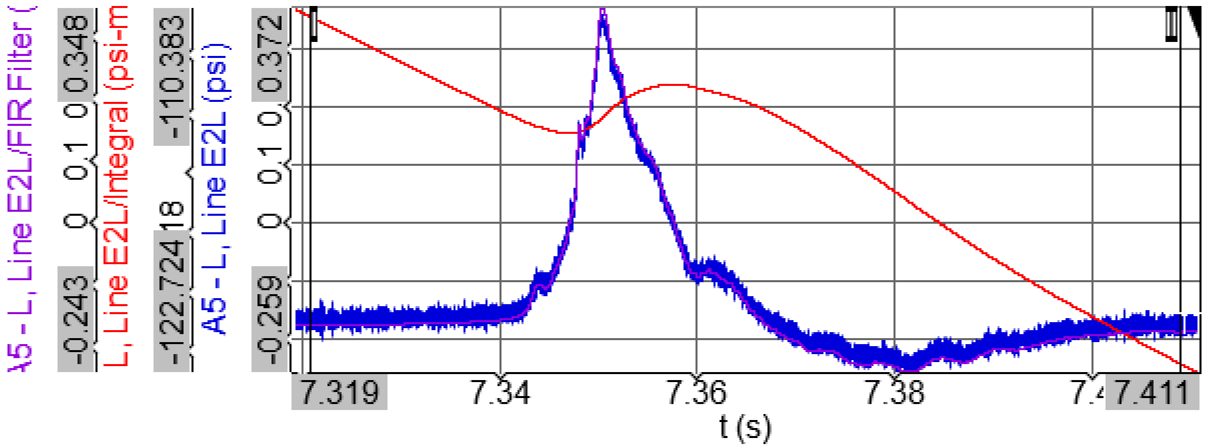

- R, Line 1AR/Integral (psi-ms
-12431.88 -4000.00 308.40
A4 - R, Line 1AR (psi)
-21.03 -10.00 -5.00 0.00 7.89
7.027 7.500 8.000 8.500 9.000 9.500 10.0 10.295
t (s)

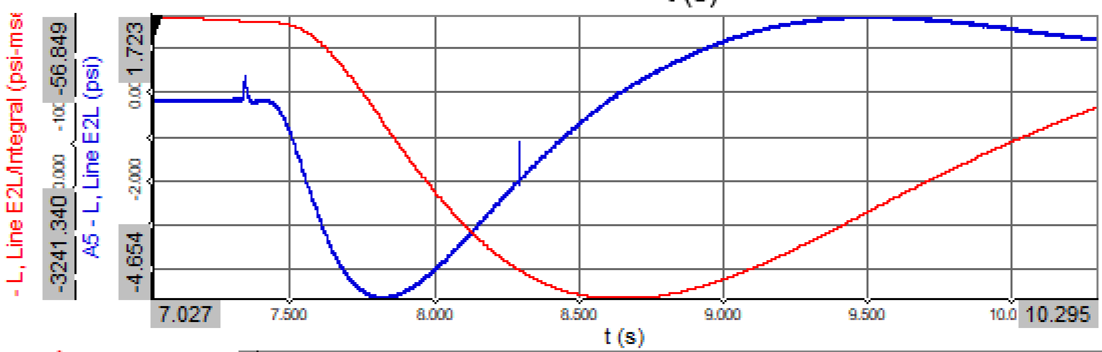

B4 - L, Line E3L (psi)
t (s)
7.319
7.34
7.36
7.38
7.411

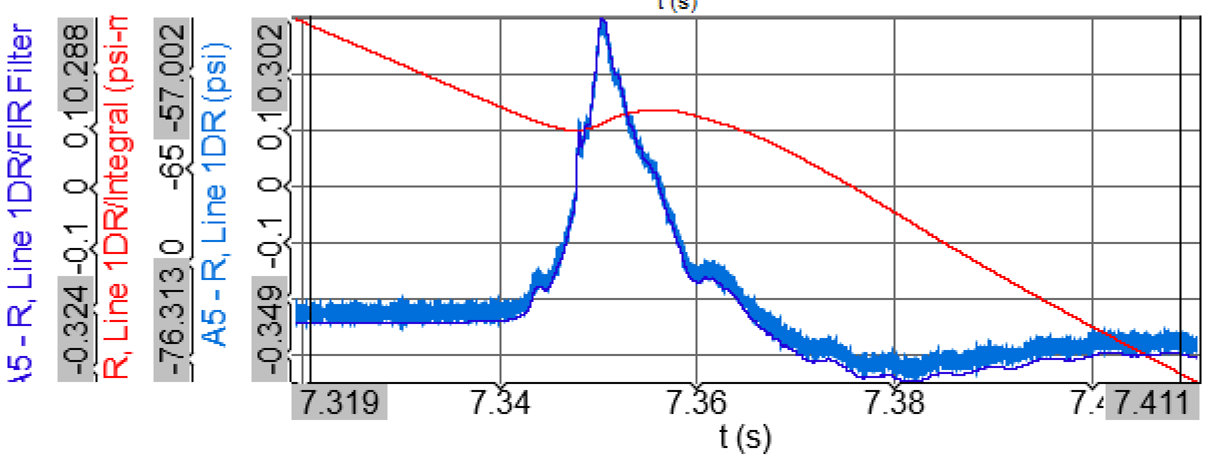

B4 - L, Line E3L (psi)
t (s)
7.027
7.500
8.000
8.500
9.000
9.500
10.295

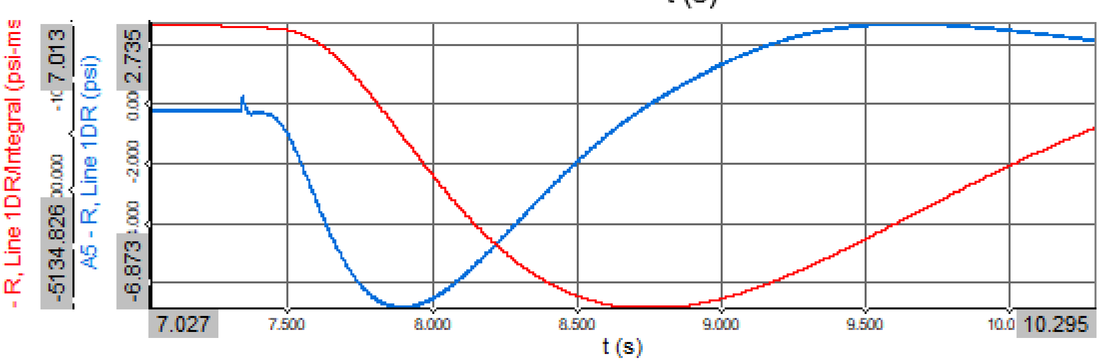

B4 - R, Line 3BR (psi)
t (s)
7.319
7.34
7.36
7.38
7.411

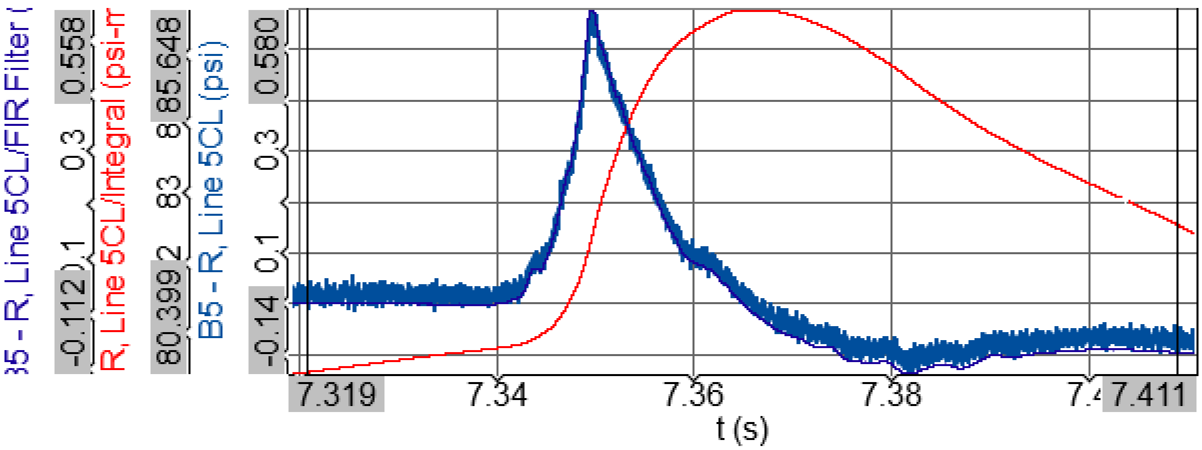

B4 - R, Line 3BR (psi)
t (s)
7.027
7.500
8.000
8.500
9.000
9.500
10.295

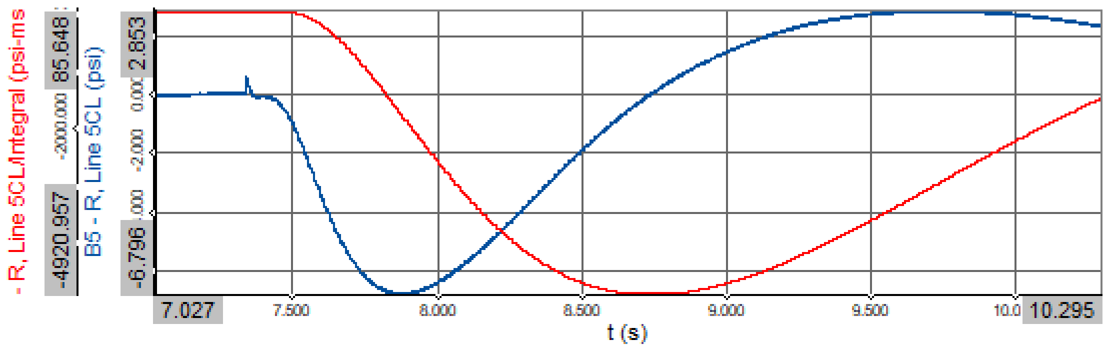

L, Line E2L/FIR Filter
L, Line E2L/Integral (psi-m
A5 - L, Line E2L (psi)
7.319
7.34
7.36
7.38
7.411
t (s)

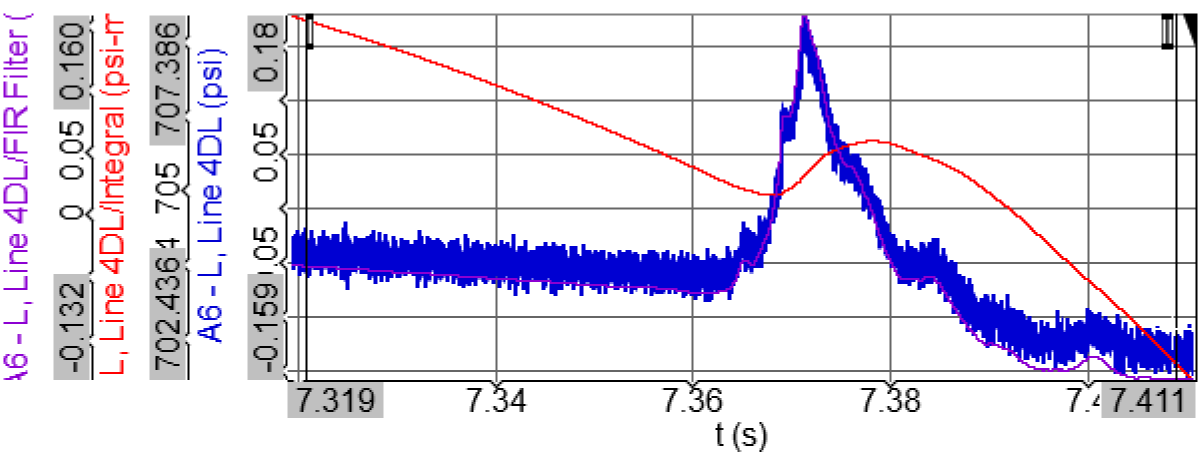

- L, Line E2L/Integral (psi-ms
A5 - L, Line E2L (psi)
7.027
7.500
8.000
8.500
9.000
9.500
10.295
t (s)

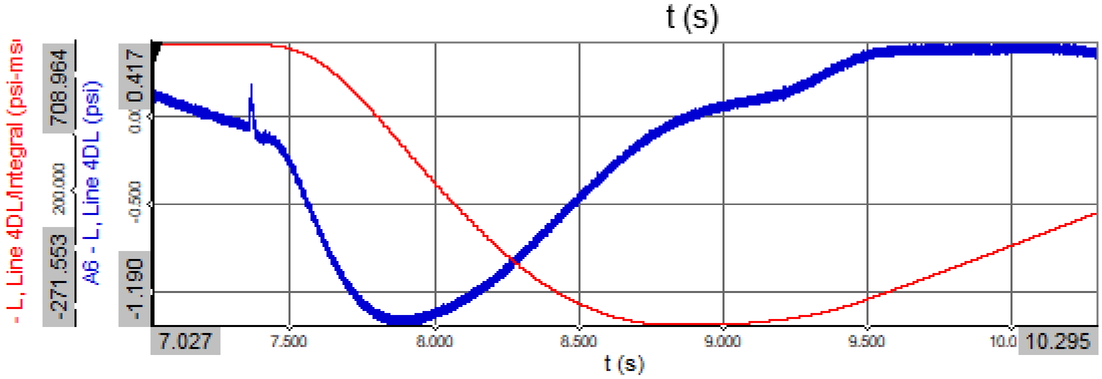

R, Line 1DR/FIR Filter
R, Line 1DR/Integral (psi-m
A5 - R, Line 1DR (psi)
7.319
7.34
7.36
7.38
7.411
t (s)

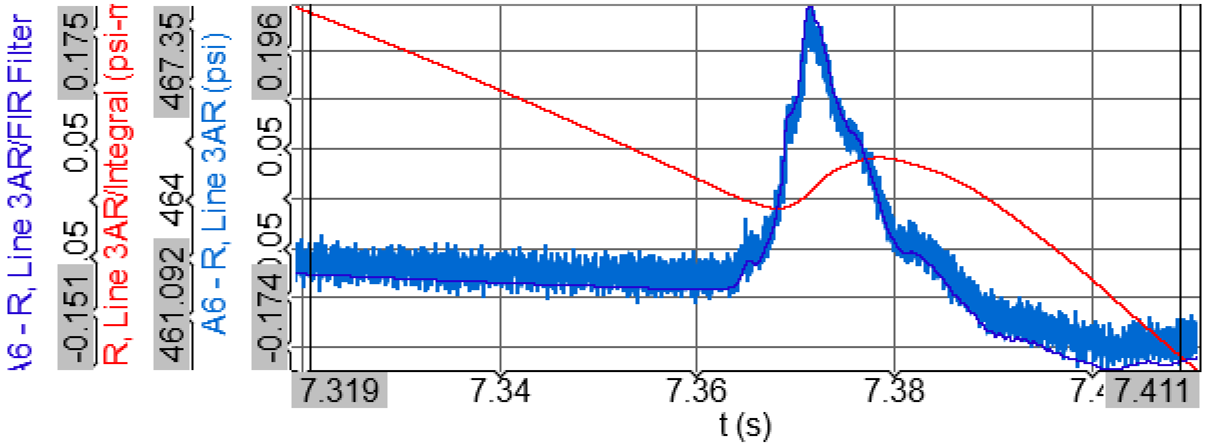

- R, Line 1DR/Integral (psi-ms
A5 - R, Line 1DR (psi)
7.027
7.500
8.000
8.500
9.000
9.500
10.295
t (s)

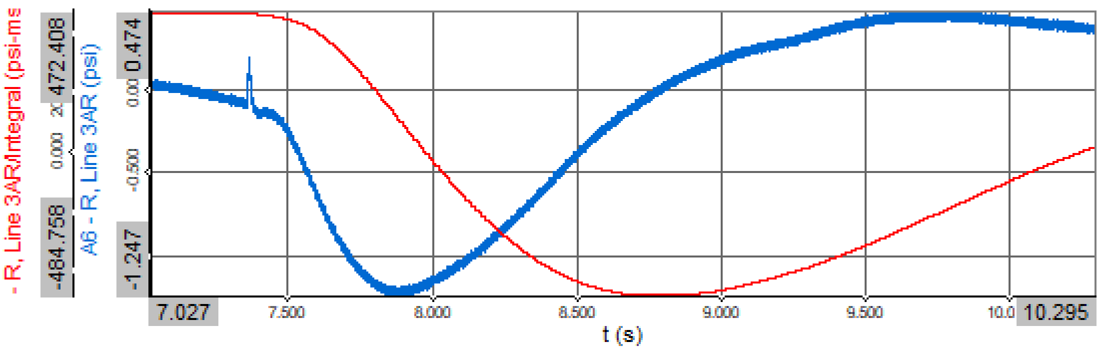

B5 - R, Line 5CL/FIR Filter (
R, Line 5CL/Integral (psi-m
B5 - R, Line 5CL (psi)
0.558
-0.112
85.648
80.399
0.580
-0.14
7.319
7.34
7.36
7.38
7.411
t (s)

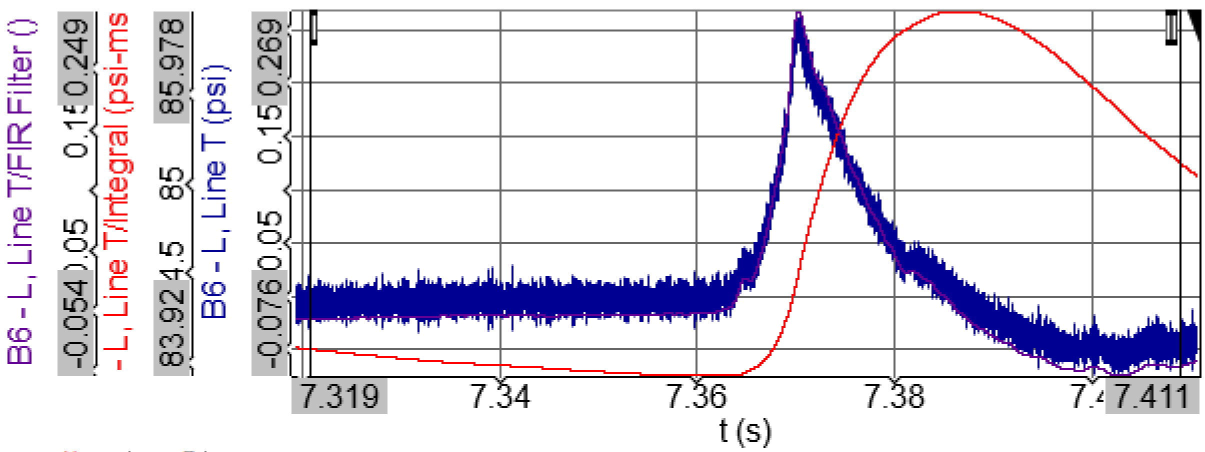

- R, Line 5CL/Integral (psi-ms
B5 - R, Line 5CL (psi)
85.648
-4920.957
2.853
-6.796
7.027
7.500
8.000
8.500
9.000
9.500
10.295
t (s)

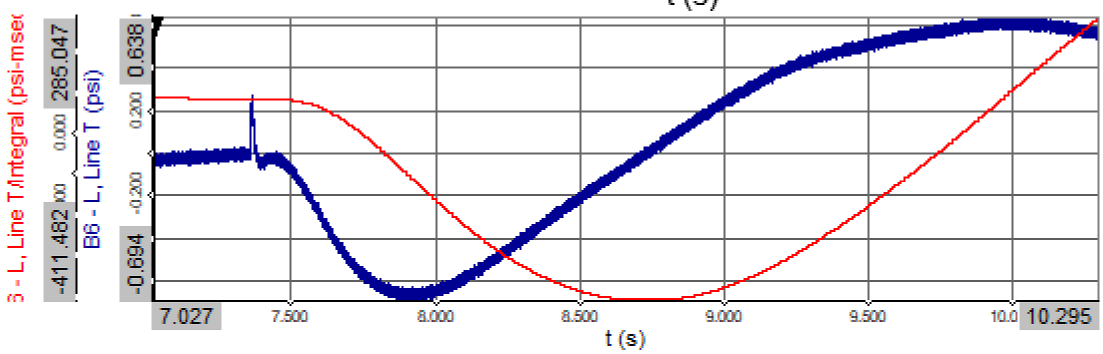

A6 - L, Line 4DL/FIR Filter (
L, Line 4DL/Integral (psi-m
A6 - L, Line 4DL (psi)
0.160
-0.132
707.386
702.436
0.18
-0.159
7.319
7.34
7.36
7.38
7.411
t (s)

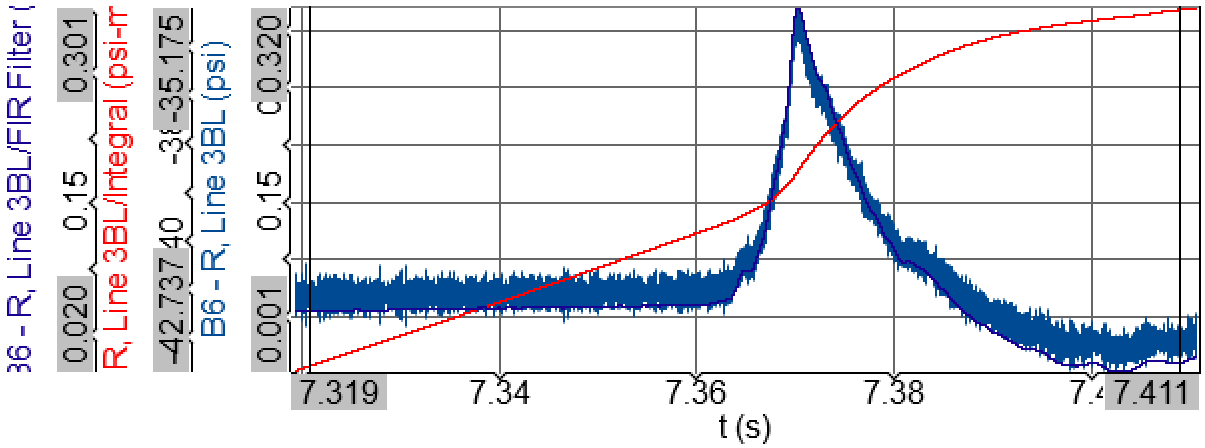

- L, Line 4DL/Integral (psi-ms
A6 - L, Line 4DL (psi)
708.964
-271.553
0.417
-1.190
7.027
7.500
8.000
8.500
9.000
9.500
10.295
t (s)

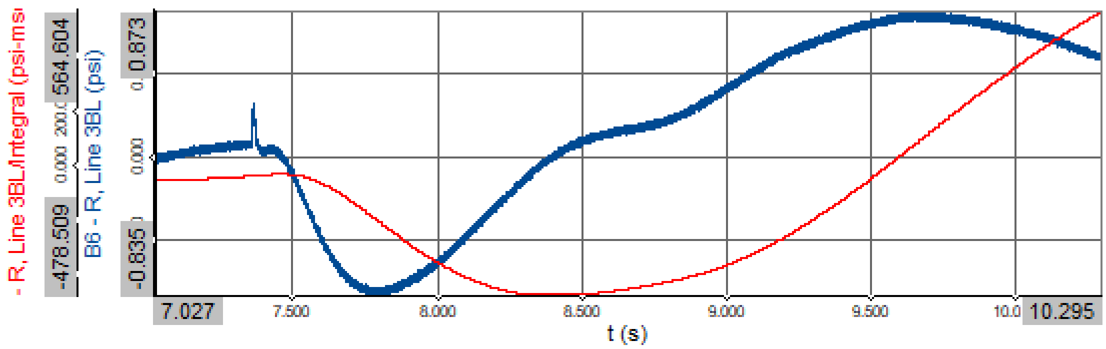

A6 - R, Line 3AR/FIR Filter
R, Line 3AR/Integral (psi-m
A6 - R, Line 3AR (psi)
7.319
7.34
7.36
7.38
7.411
t (s)

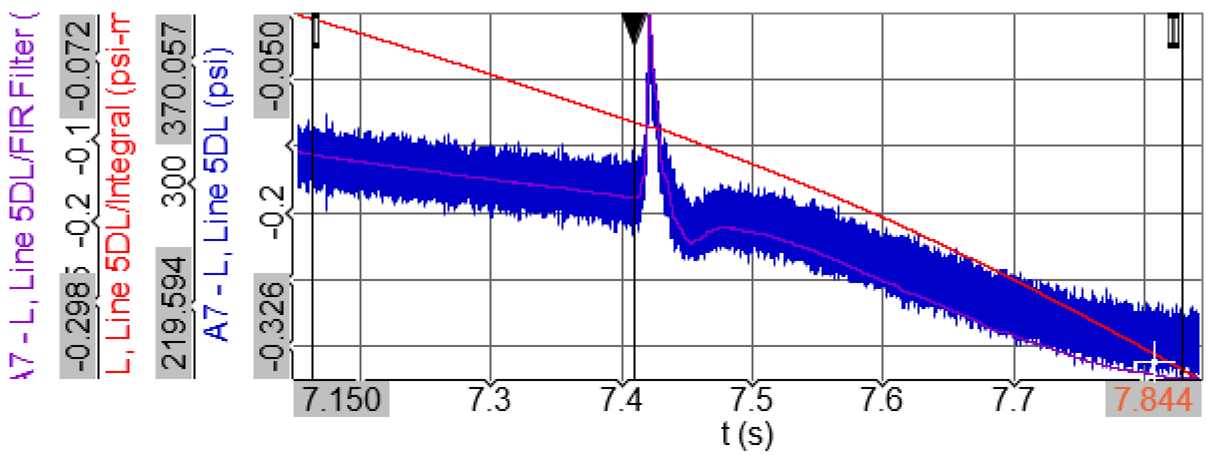

- R, Line 3AR/Integral (psi-ms
A6 - R, Line 3AR (psi)
7.027
7.500
8.000
8.500
9.000
9.500
10.295
t (s)

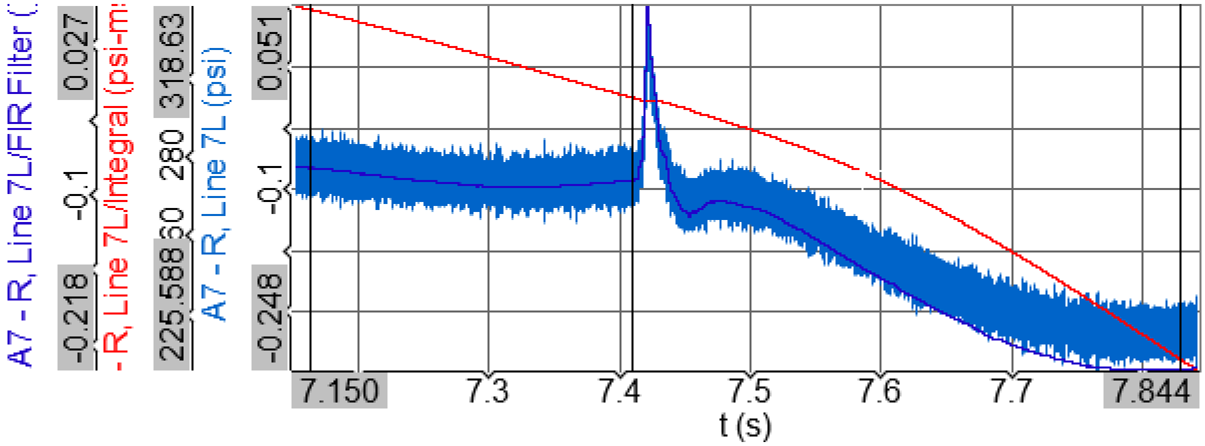

B6 - L, Line T/FIR Filter ()
- L, Line T/Integral (psi-ms
B6 - L, Line T (psi)
7.319
7.34
7.36
7.38
7.411
t (s)

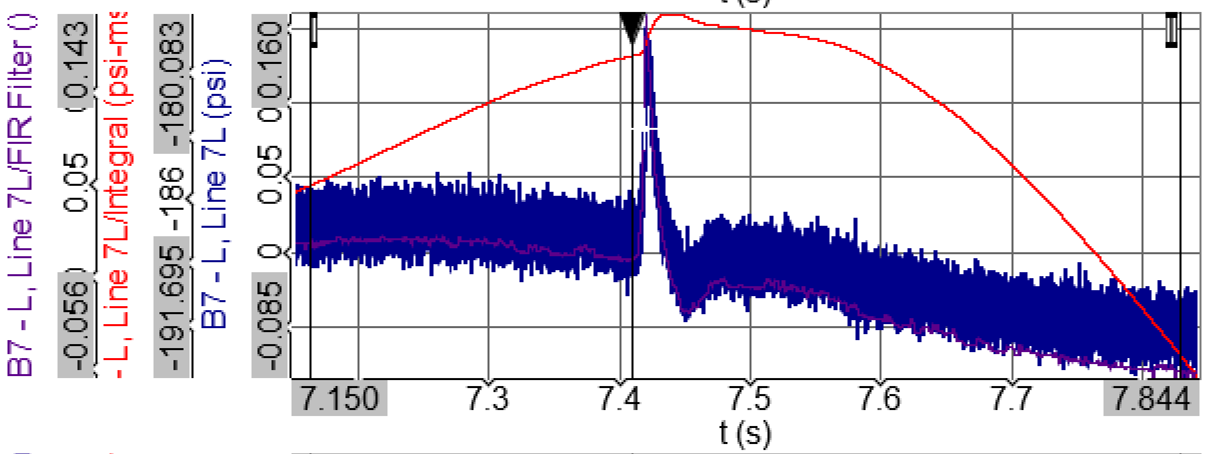

3 - L, Line T/Integral (psi-msec
B6 - L, Line T (psi)
7.027
7.500
8.000
8.500
9.000
9.500
10.295
t (s)

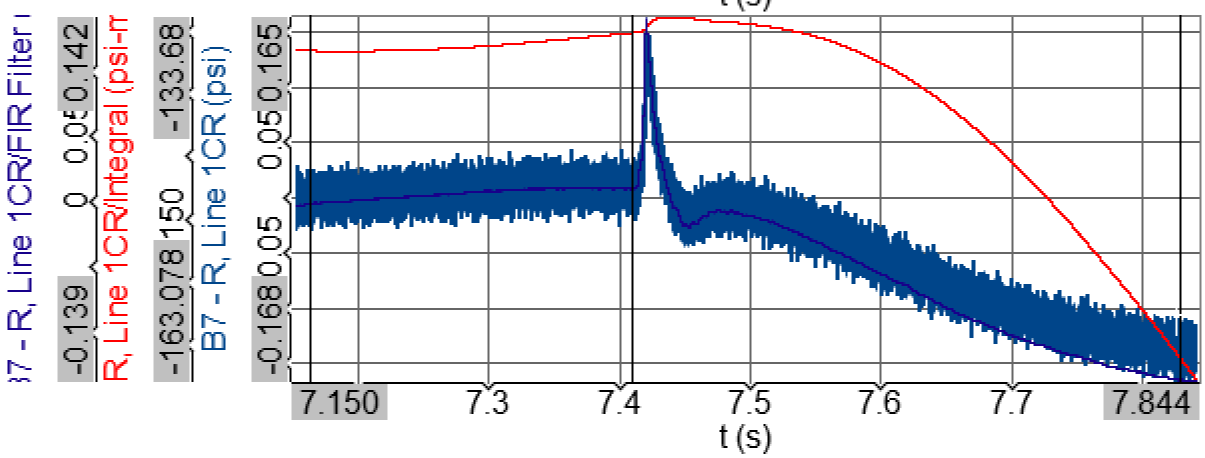

B6 - R, Line 3BL (psi)
R, Line 3BL/Integral (psi-m
t (s)
7.319
7.34
7.36
7.38
7.411

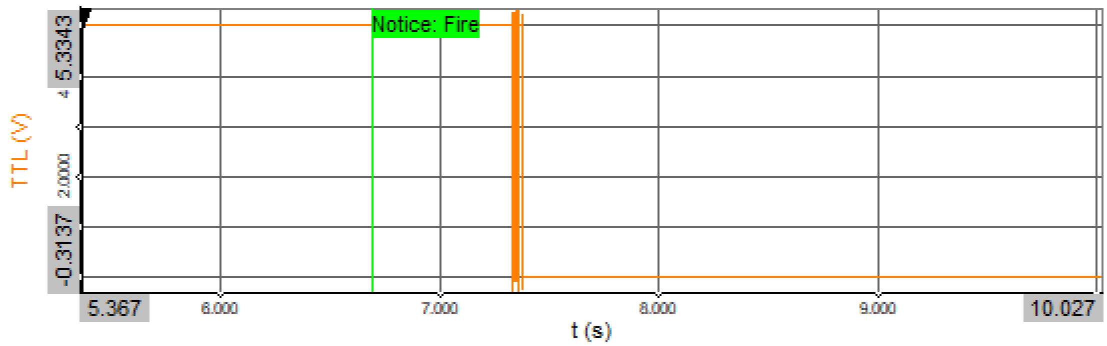

B6 - R, Line 3BL (psi)
- R, Line 3BL/Integral (psi-ms
t (s)
7.027
7.500
8.000
8.500
9.000
9.500
10.295


A7 - L, Line 5DL/FIR Filter (
L, Line 5DL/Integral (psi-m
A7 - L, Line 5DL (psi)
t (s)
7.150
7.3
7.4
7.5
7.6
7.7
7.844

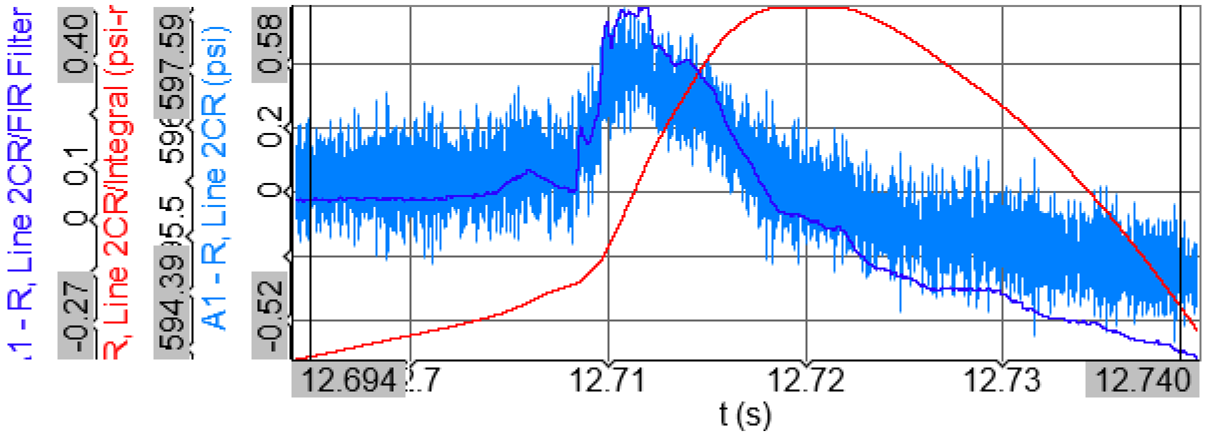

A7 - R, Line 7L/FIR Filter (
-R, Line 7L/Integral (psi-m
A7 - R, Line 7L (psi)
0.027
-0.1
-0.218
318.63
280
225.588
0.051
-0.1
-0.248
7.150
7.3
7.4
7.5
7.6
7.7
7.844
t (s)

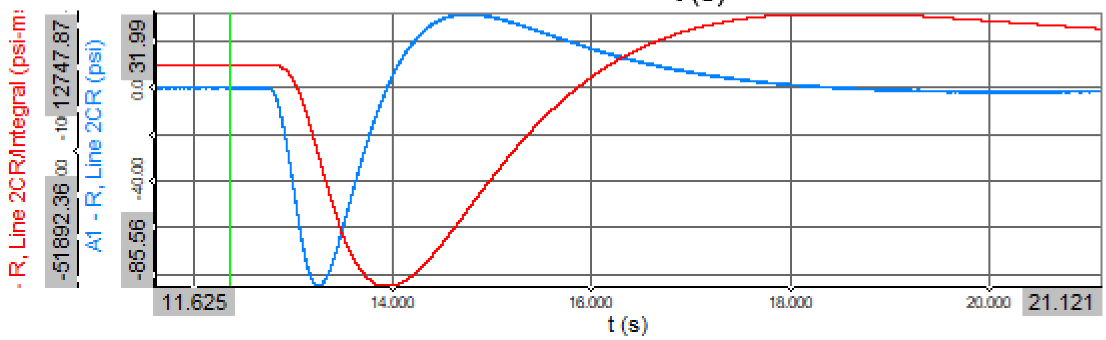

B7 - L, Line 7L/FIR Filter ()
- L, Line 7L/Integral (psi-m
B7 - L, Line 7L (psi)
0.143
0.05
-0.056
-180.083
-186
-191.695
0.160
0.05
0
-0.085
7.150
7.3
7.4
7.5
7.6
7.7
7.844
t (s)

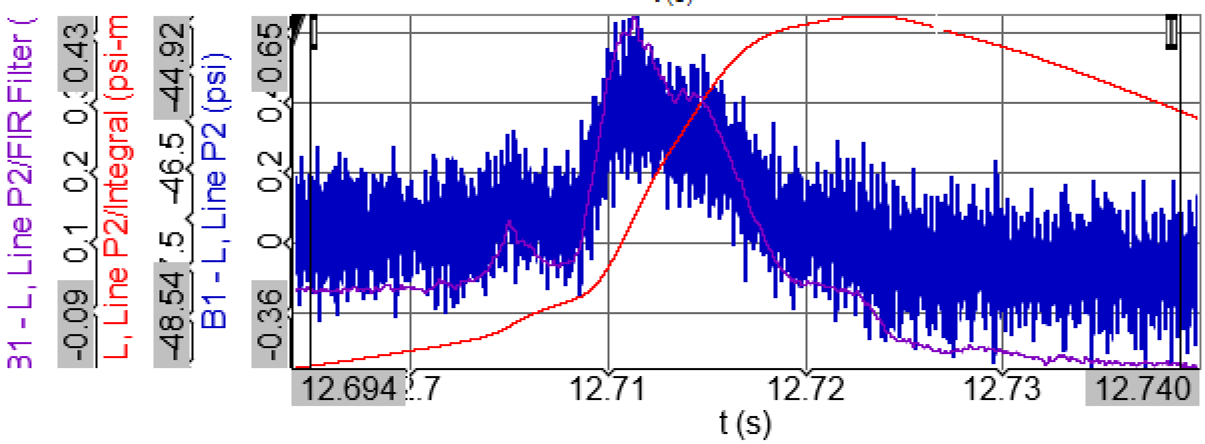

B7 - R, Line 1CR/FIR Filter
R, Line 1CR/Integral (psi-m
B7 - R, Line 1CR (psi)
0.142
0
-0.139
-133.68
150
-163.078
0.165
0.05
-0.168
7.150
7.3
7.4
7.5
7.6
7.7
7.844
t (s)

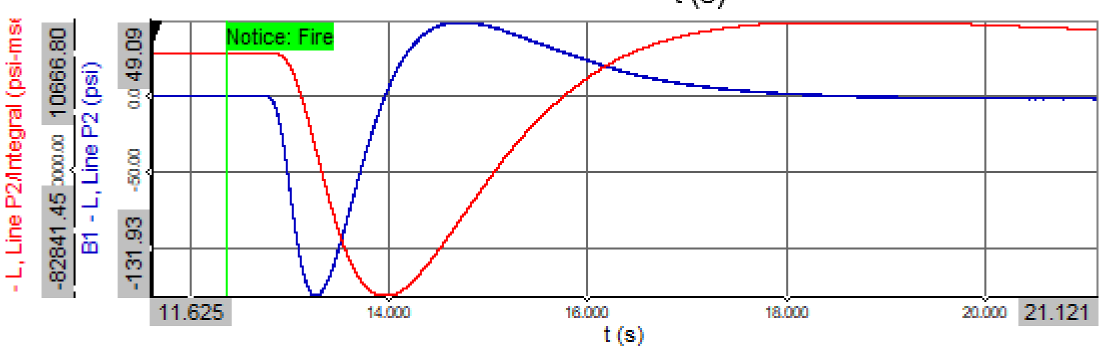

Notice: Fire
TTL (V)
5.3343
2.0000
-0.3137
5.367
6.000
7.000
8.000
9.000
10.027
t (s)

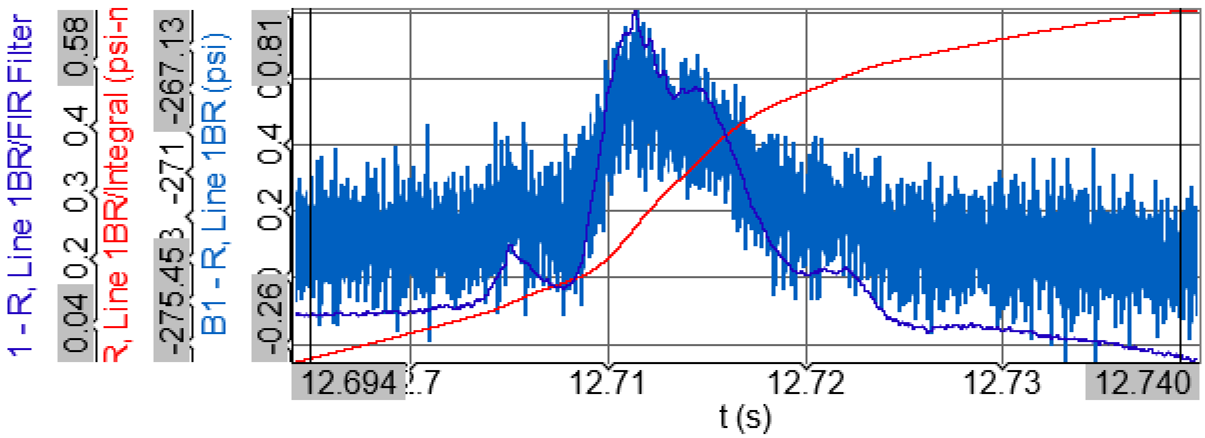
8.3.2 Trial 2 for Small-Scale Mix ID #4

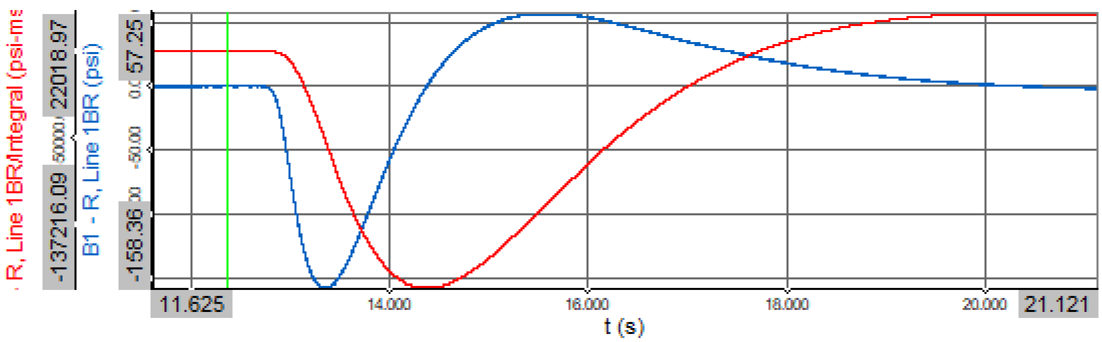


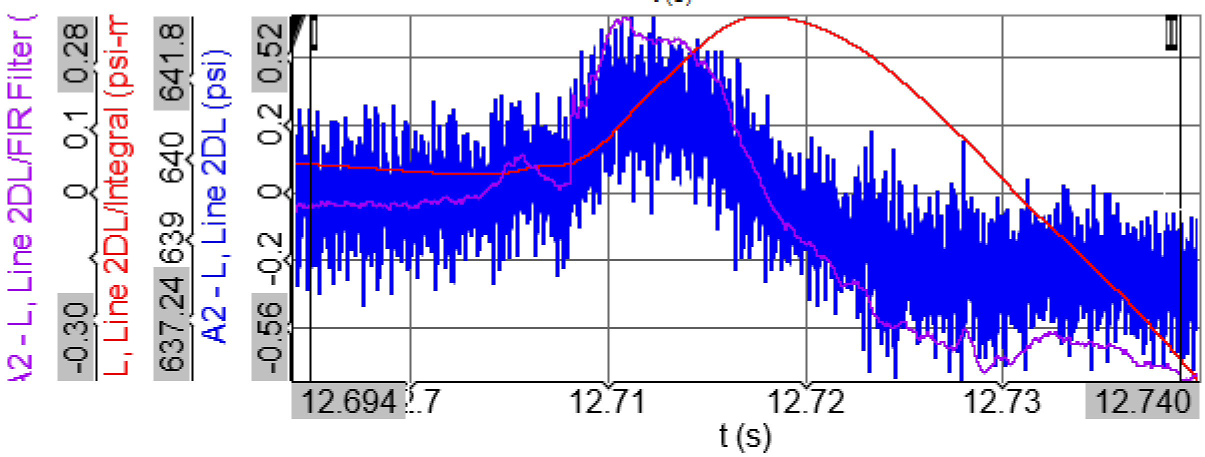


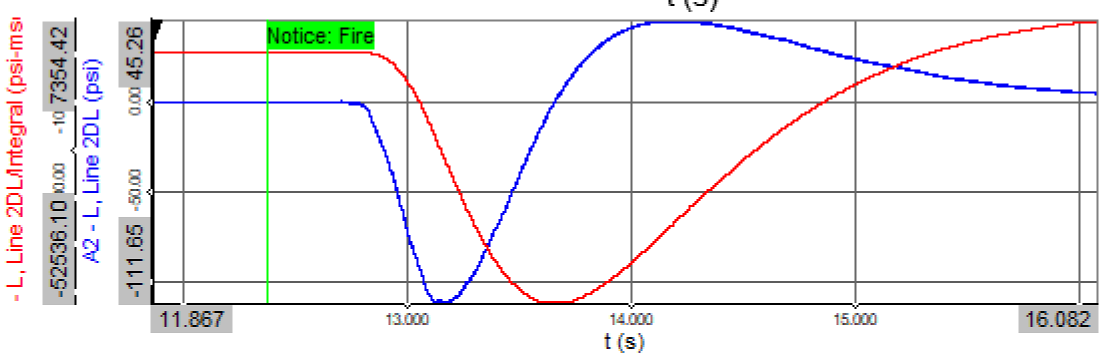


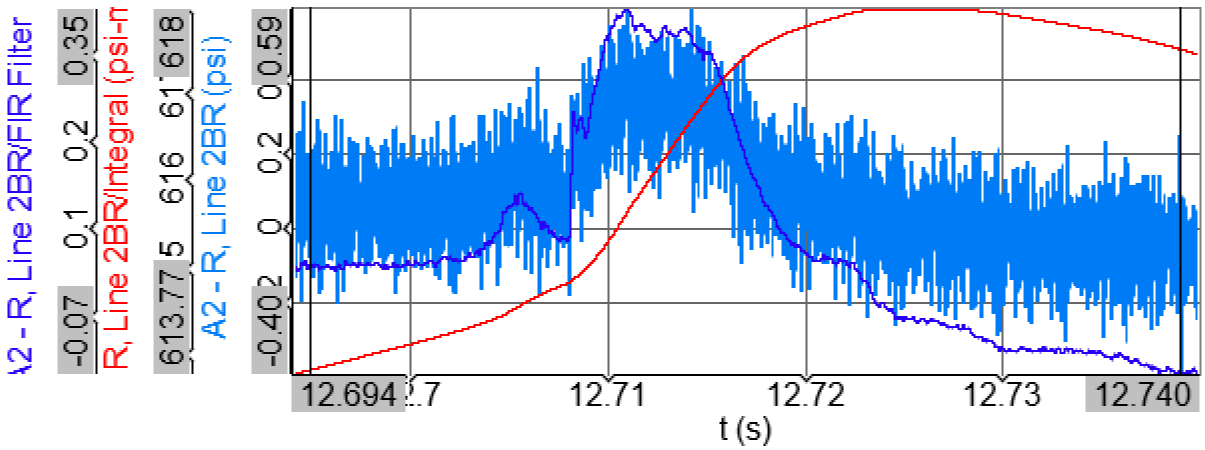


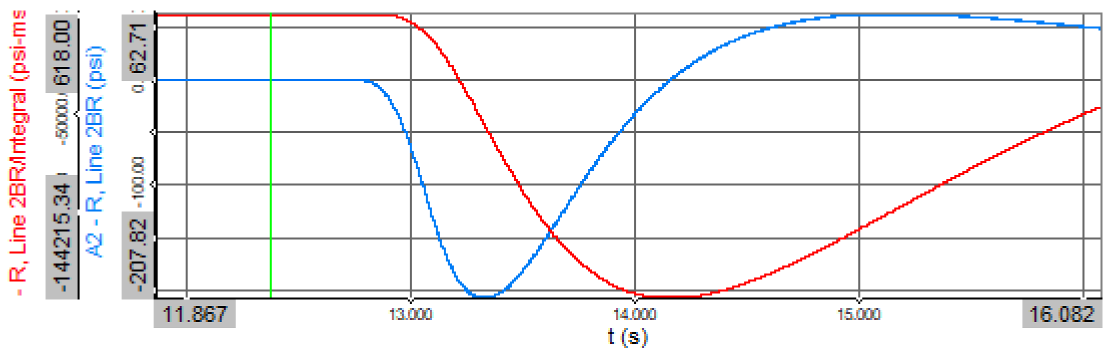

1 - R, Line 1BR/FIR Filter
R, Line 1BR/Integral (psi-m
B1 - R, Line 1BR (psi)
12.694
12.71
12.72
12.73
12.740
t (s)

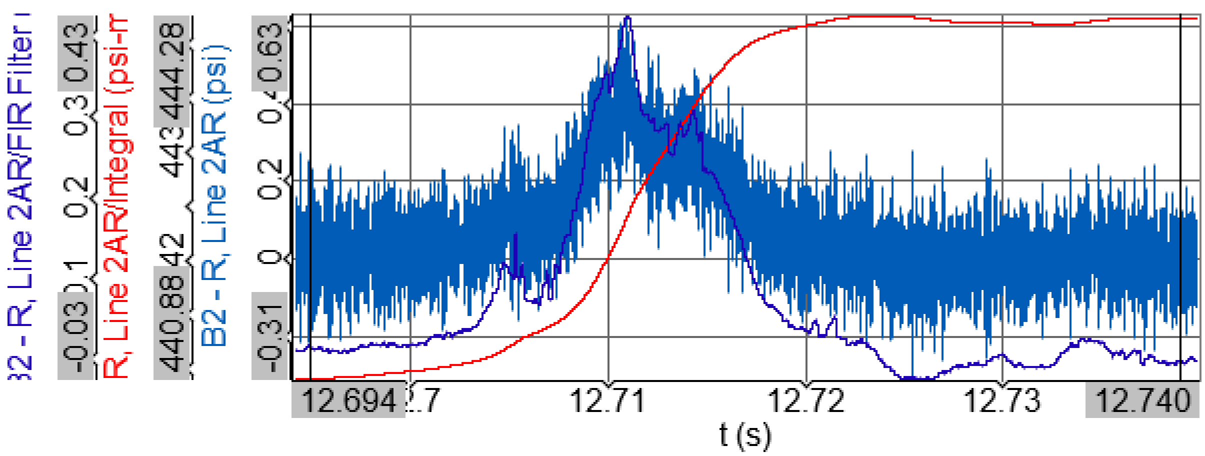

R, Line 1BR/Integral (psi-ms
B1 - R, Line 1BR (psi)
11.625
14.000
16.000
18.000
20.000
21.121
t (s)

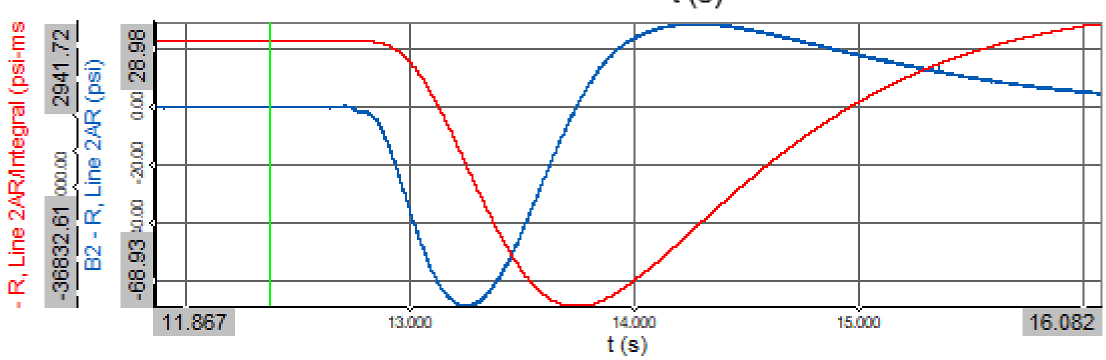

A2 - L, Line 2DL/FIR Filter (
L, Line 2DL/Integral (psi-m
A2 - L, Line 2DL (psi)
12.694
12.71
12.72
12.73
12.740
t (s)

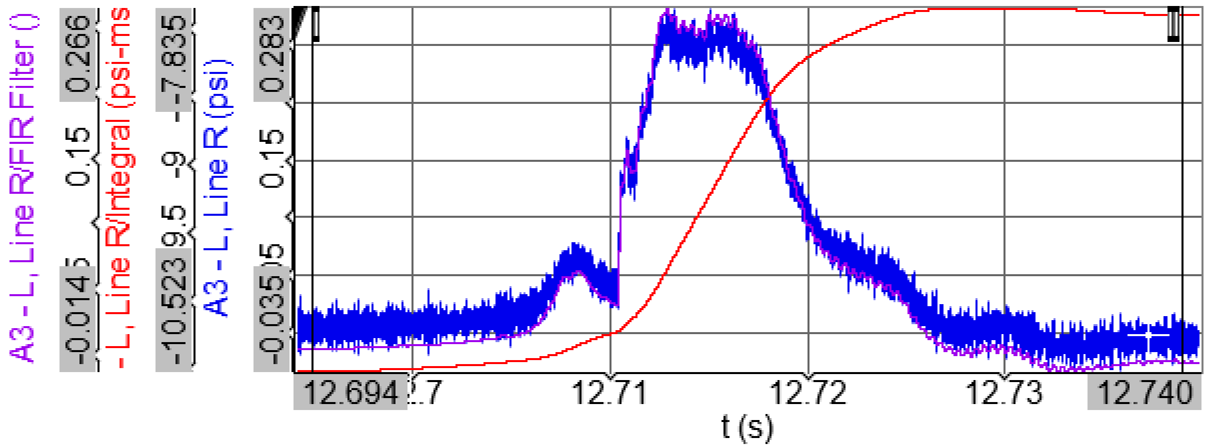

Notice: Fire
L, Line 2DL/Integral (psi-ms
A2 - L, Line 2DL (psi)
11.867
13.000
14.000
15.000
16.082
t (s)

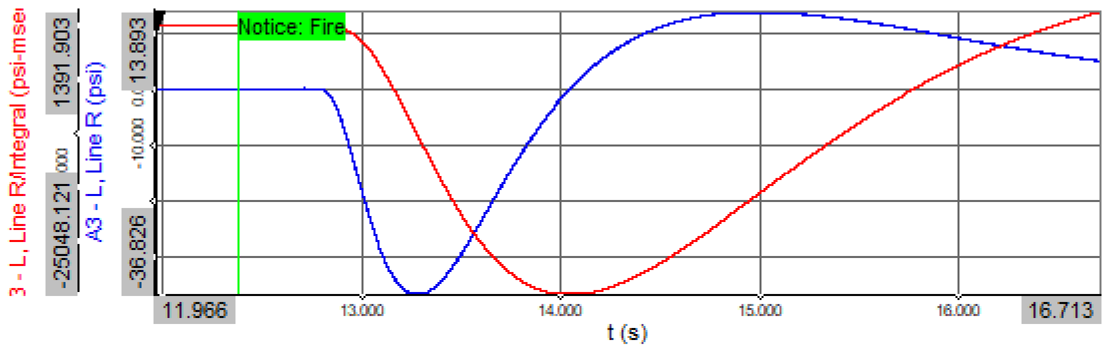

A2 - R, Line 2BR/FIR Filter
R, Line 2BR/Integral (psi-m
A2 - R, Line 2BR (psi)
-0.07
0.1
0.2
0.35
613.77
616
618
-0.40
0
0.2
0.59
12.694
12.71
12.72
12.73
12.740
t (s)

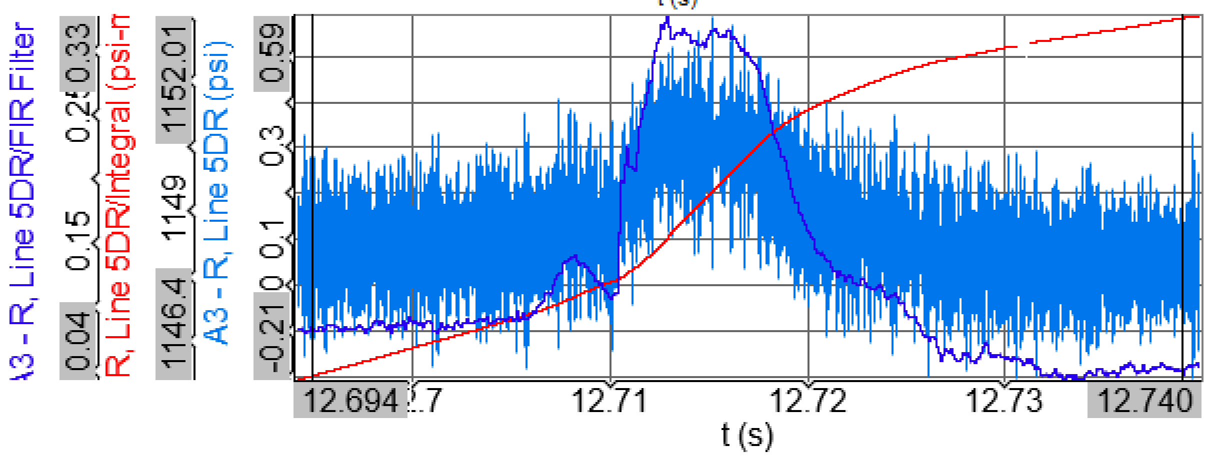

- R, Line 2BR/Integral (psi-ms
-144215.34
618.00
A2 - R, Line 2BR (psi)
-207.82
62.71
11.867
13.000
14.000
15.000
16.082
t (s)

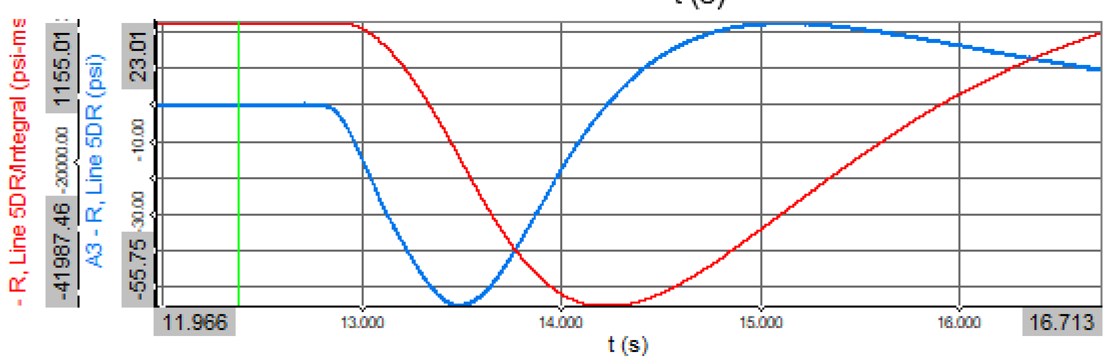

B2 - R, Line 2AR/FIR Filter
R, Line 2AR/Integral (psi-m
B2 - R, Line 2AR (psi)
-0.03
0.2
0.3
0.43
440.88
442
443
444.28
-0.31
0
0.2
0.63
12.694
12.71
12.72
12.73
12.740
t (s)

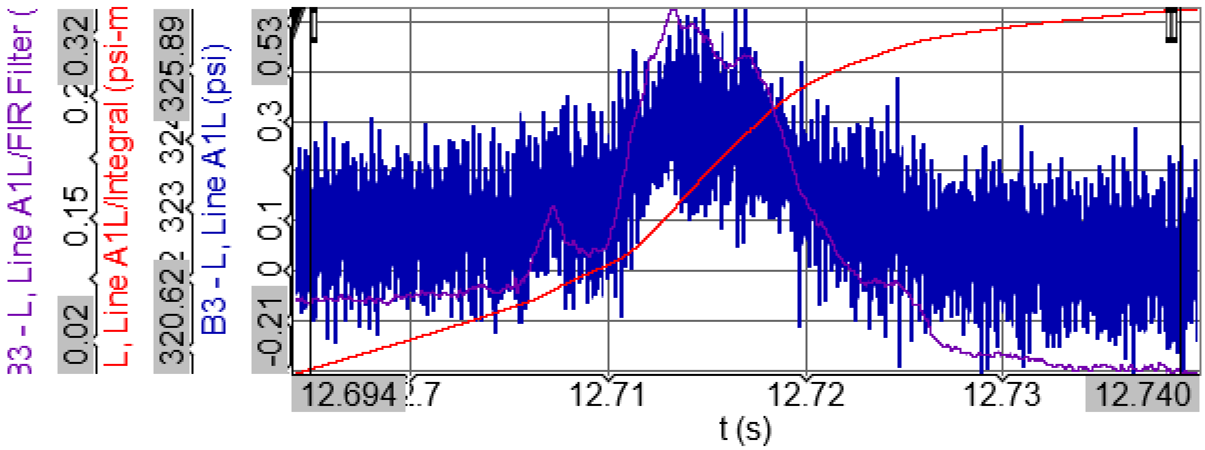

- R, Line 2AR/Integral (psi-ms
-36832.61
2941.72
B2 - R, Line 2AR (psi)
-68.93
0.00
-20.00
28.98
11.867
13.000
14.000
15.000
16.082
t (s)

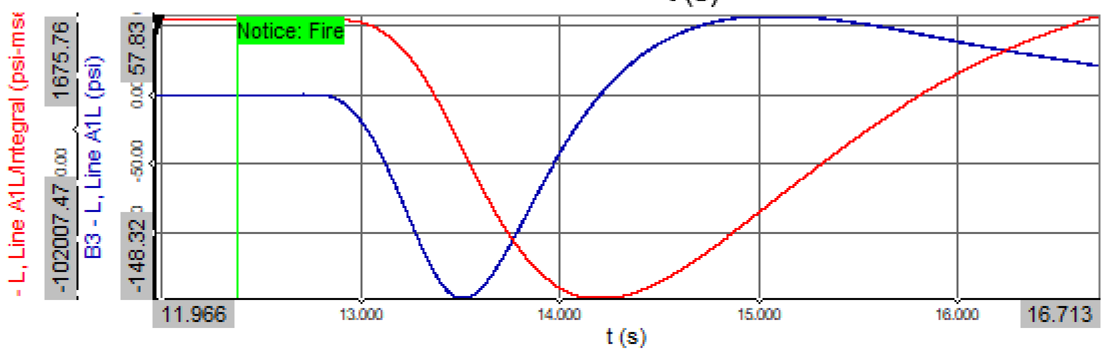

A3 - L, Line R/FIR Filter ()
-0.014
0.15
0.266
- L, Line R/Integral (psi-ms
-10.523
-9
-7.835
A3 - L, Line R (psi)
-0.035
0.15
0.283
12.694
12.71
12.72
12.73
12.740
t (s)

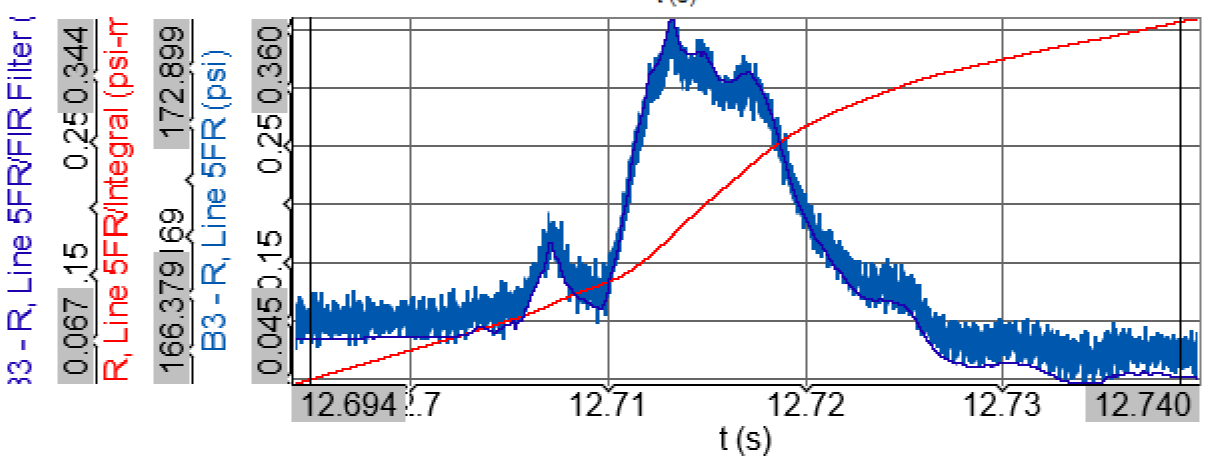

Notice: Fire
3 - L, Line R/Integral (psi-msec
-25048.121
1391.903
A3 - L, Line R (psi)
-36.826
-10.000
13.893
11.966
13.000
14.000
15.000
16.000
16.713
t (s)

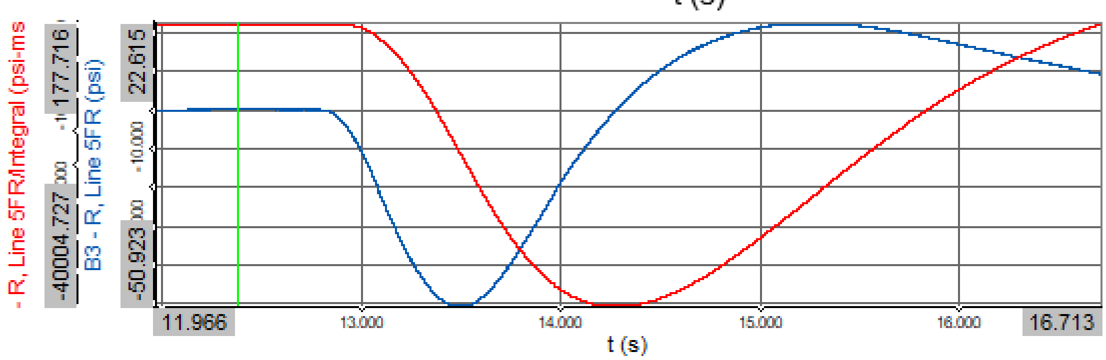

A3 - R, Line 5DR/FIR Filter
0.04
0.15
0.33
R, Line 5DR/Integral (psi-m
1146.4
1149
1152.01
A3 - R, Line 5DR (psi)
-0.21
0.3
0.59
12.694
12.71
12.72
12.73
12.740
t (s)

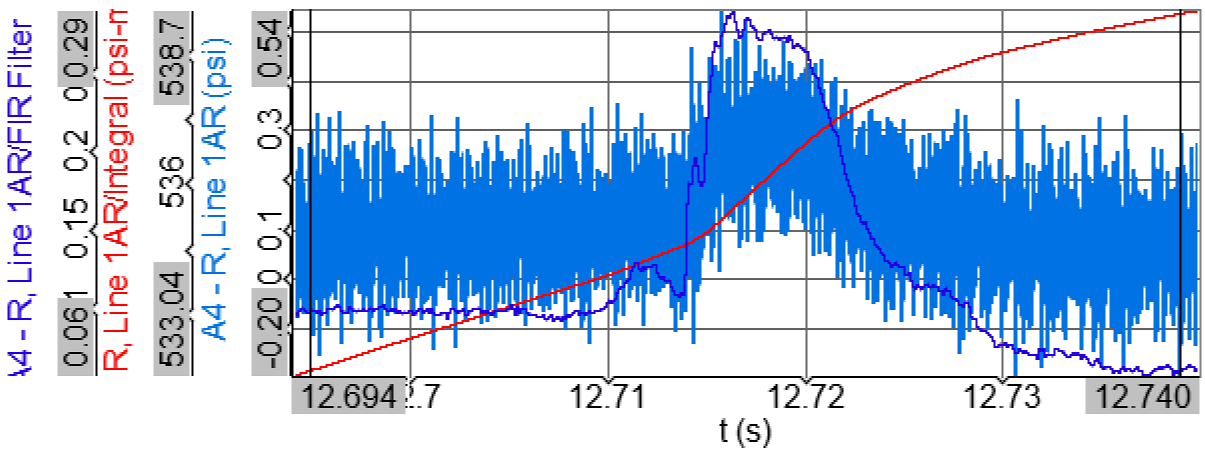

- R, Line 5DR/Integral (psi-ms
-41987.46
-20000.00
1155.01
A3 - R, Line 5DR (psi)
-55.75
-30.00
-10.00
23.01
11.966
13.000
14.000
15.000
16.000
16.713
t (s)

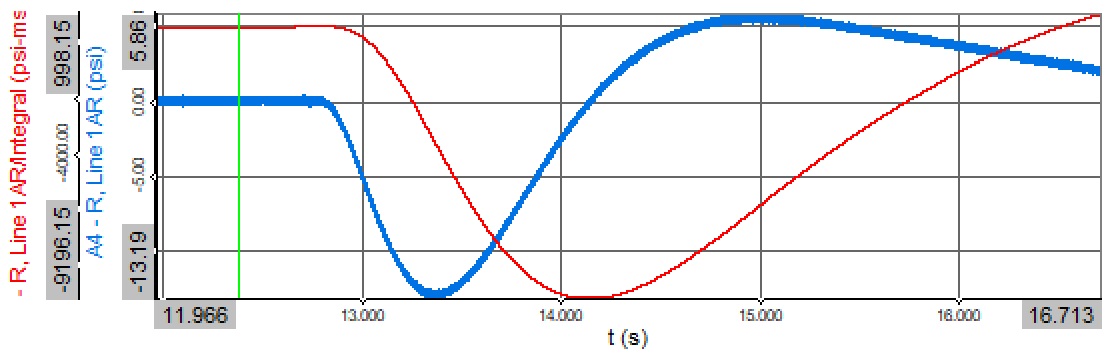

B3 - L, Line A1L (psi)
t (s)
12.694
12.71
12.72
12.73
12.740

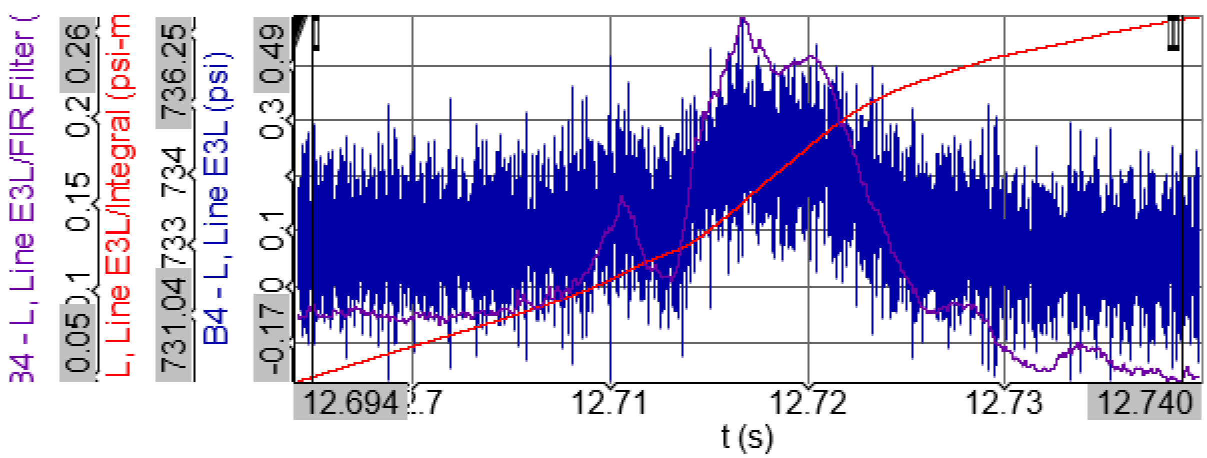

Notice: Fire
B3 - L, Line A1L (psi)
t (s)
11.966
13.000
14.000
15.000
16.000
16.713

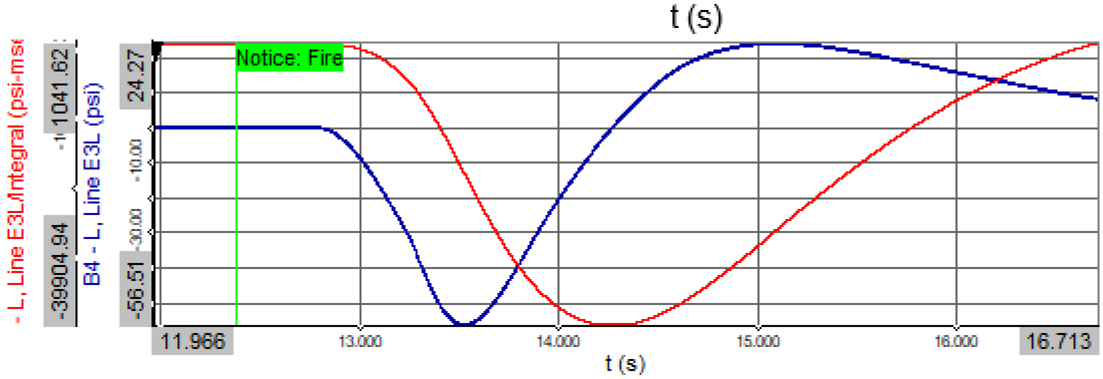

B3 - R, Line 5FR (psi)
t (s)
12.694
12.71
12.72
12.73
12.740

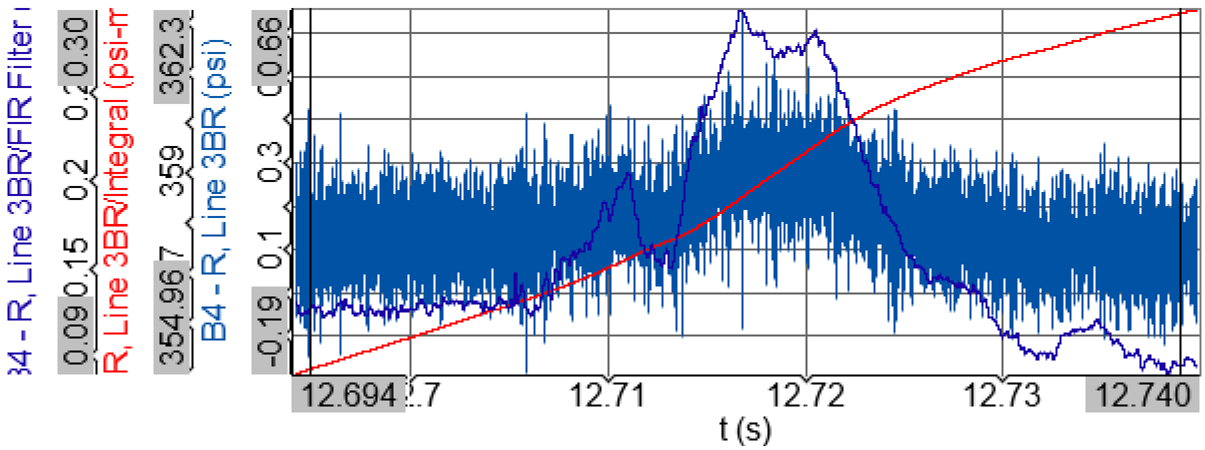

B3 - R, Line 5FR (psi)
t (s)
11.966
13.000
14.000
15.000
16.000
16.713

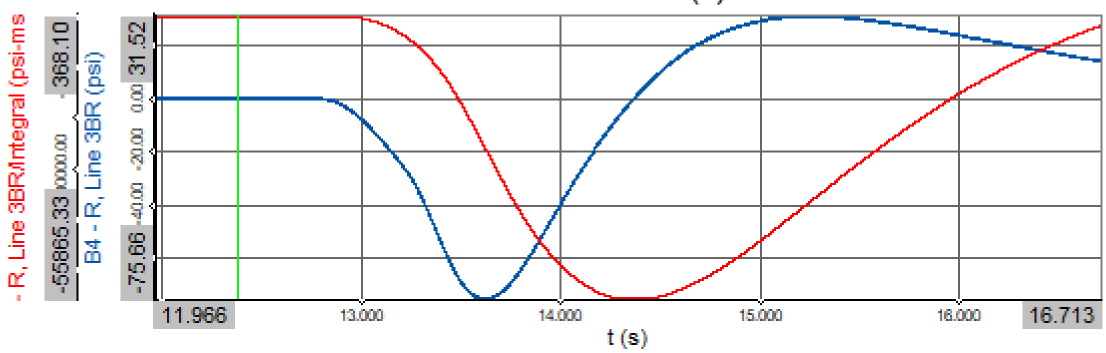

A4 - R, Line 1AR/FIR Filter
R, Line 1AR/Integral (psi-m
A4 - R, Line 1AR (psi)
12.694
12.71
12.72
12.73
12.740
t (s)

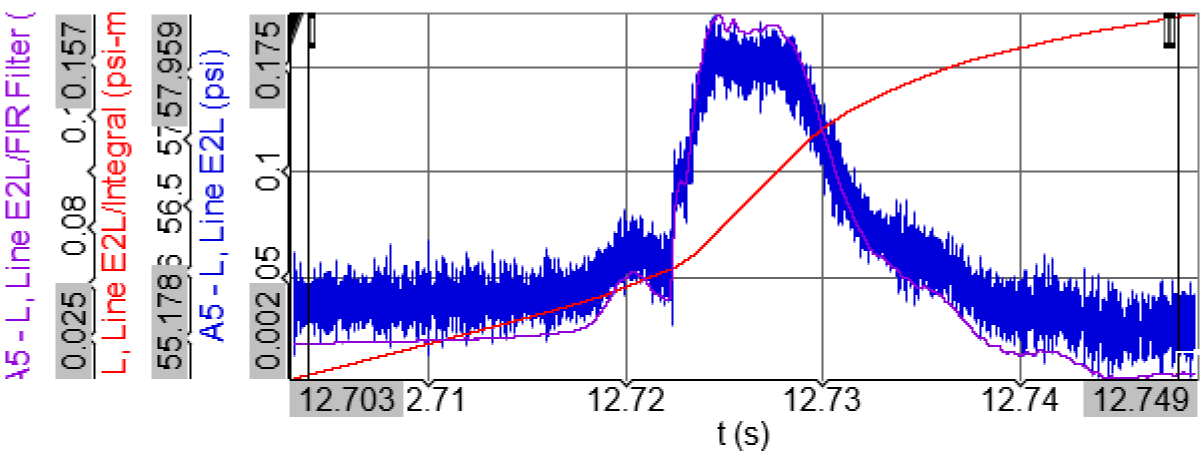

- R, Line 1AR/Integral (psi-ms
A4 - R, Line 1AR (psi)
11.966
13.000
14.000
15.000
16.000
16.713
t (s)

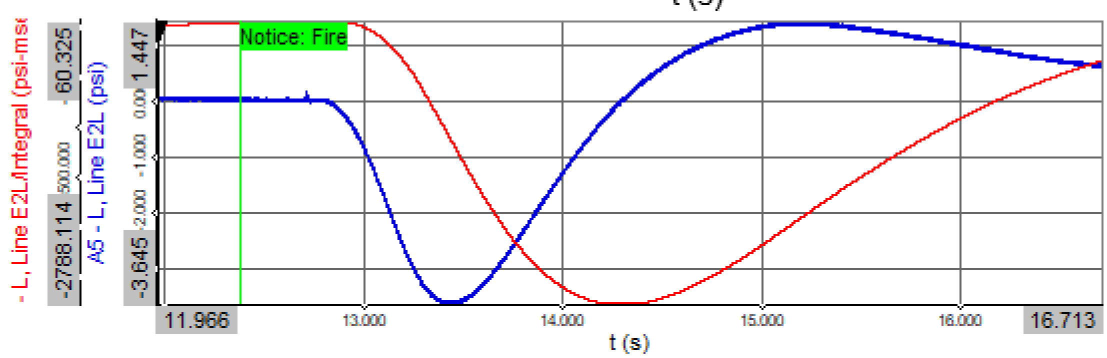

B4 - L, Line E3L/FIR Filter (
L, Line E3L/Integral (psi-m
B4 - L, Line E3L (psi)
12.694
12.71
12.72
12.73
12.740
t (s)

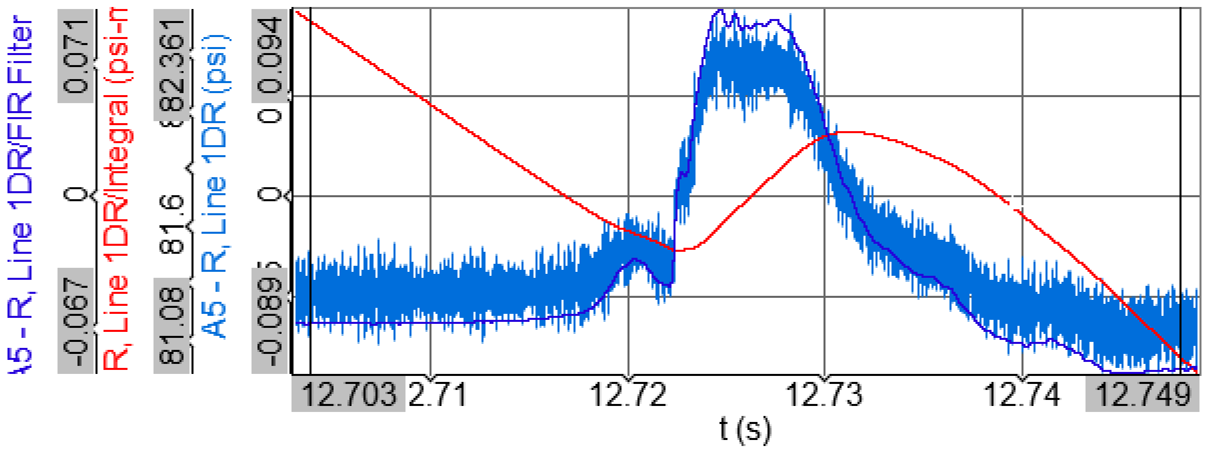

- L, Line E3L/Integral (psi-ms
B4 - L, Line E3L (psi)
Notice: Fire
11.966
13.000
14.000
15.000
16.000
16.713
t (s)

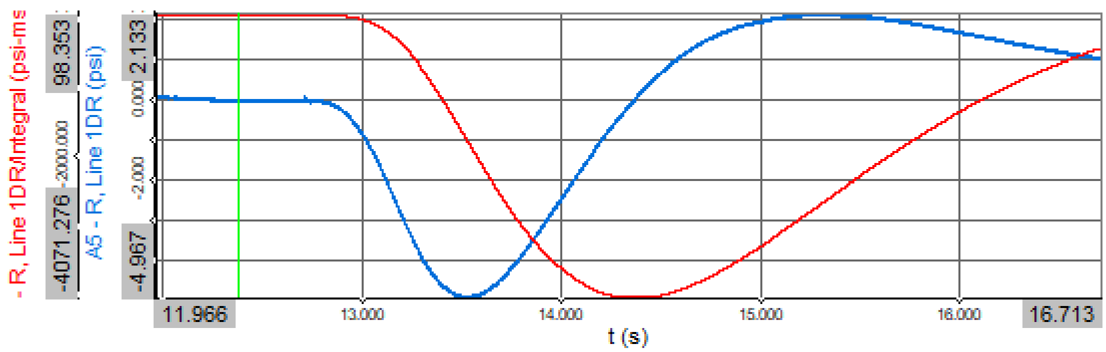

B4 - R, Line 3BR (psi)
R, Line 3BR/Integral (psi-m
t (s)
12.694
12.71
12.72
12.73
12.740

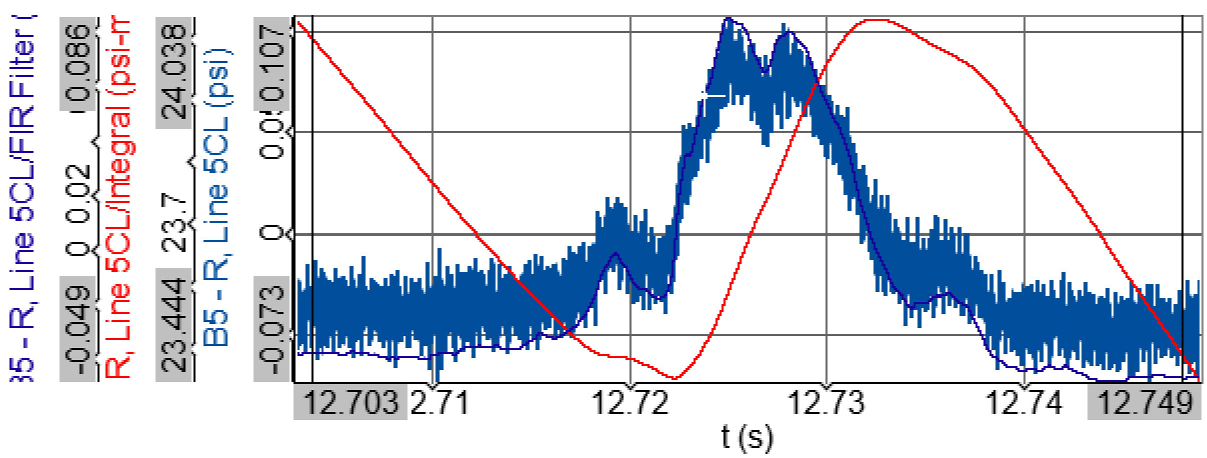

R, Line 3BR/Integral (psi-ms
B4 - R, Line 3BR (psi)
t (s)
11.966
13.000
14.000
15.000
16.000
16.713

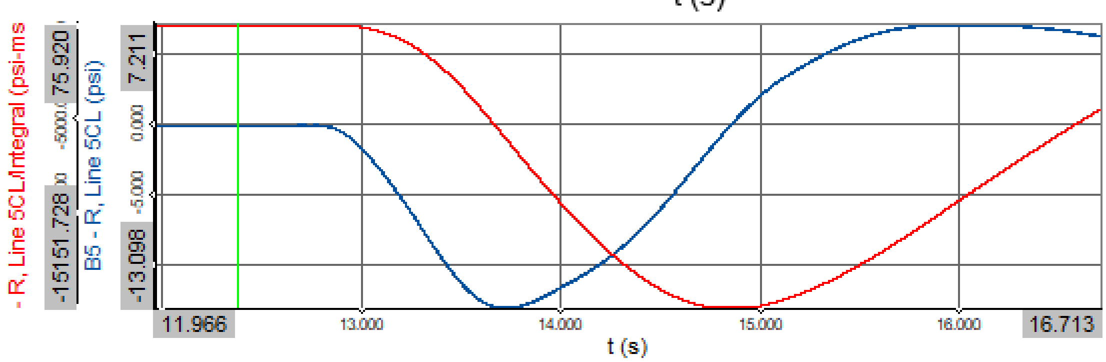

A5 - L, Line E2L (psi)
L, Line E2L/Integral (psi-m
t (s)
12.703
12.72
12.73
12.74
12.749

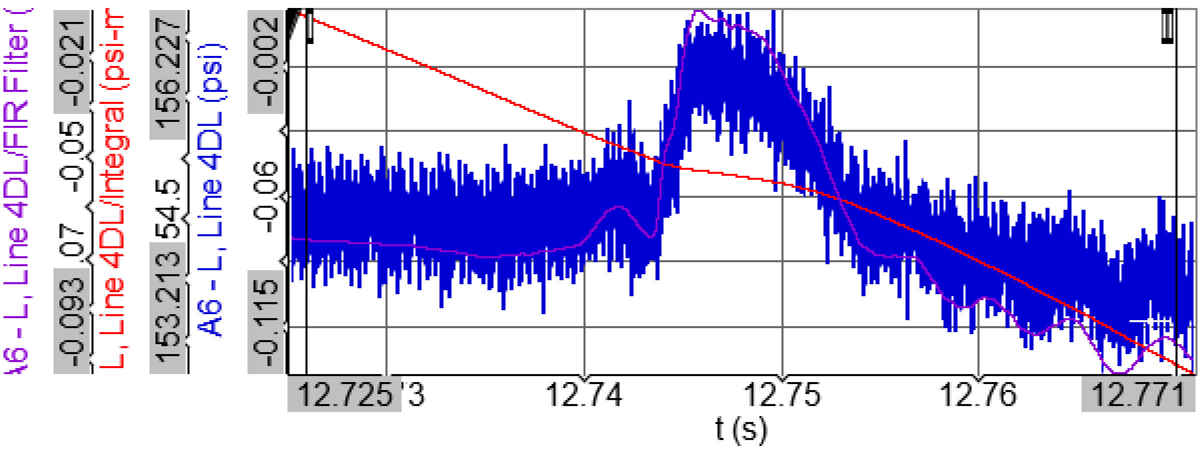

Notice: Fire
L, Line E2L/Integral (psi-ms
A5 - L, Line E2L (psi)
t (s)
11.966
13.000
14.000
15.000
16.000
16.713

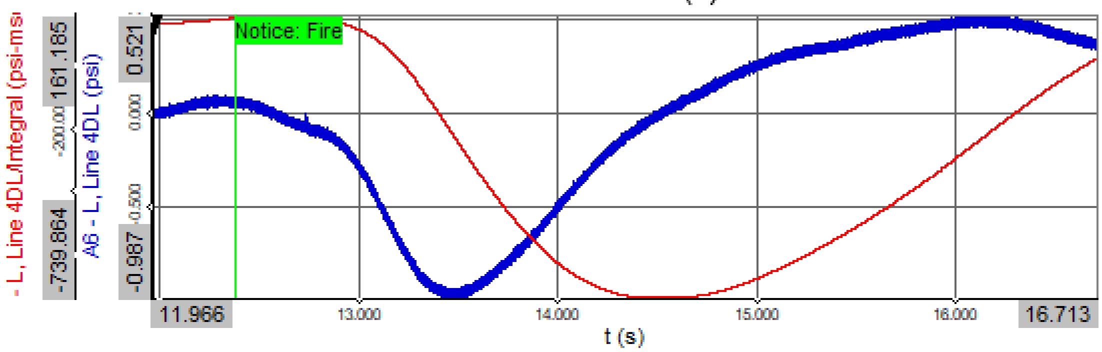

A5 - R, Line 1DR/FIR Filter
0.071
0
-0.067
R, Line 1DR/Integral (psi-m
82.361
81.6
81.08
A5 - R, Line 1DR (psi)
0.094
0
-0.089
12.703
12.71
12.72
12.73
12.74
12.749
t (s)

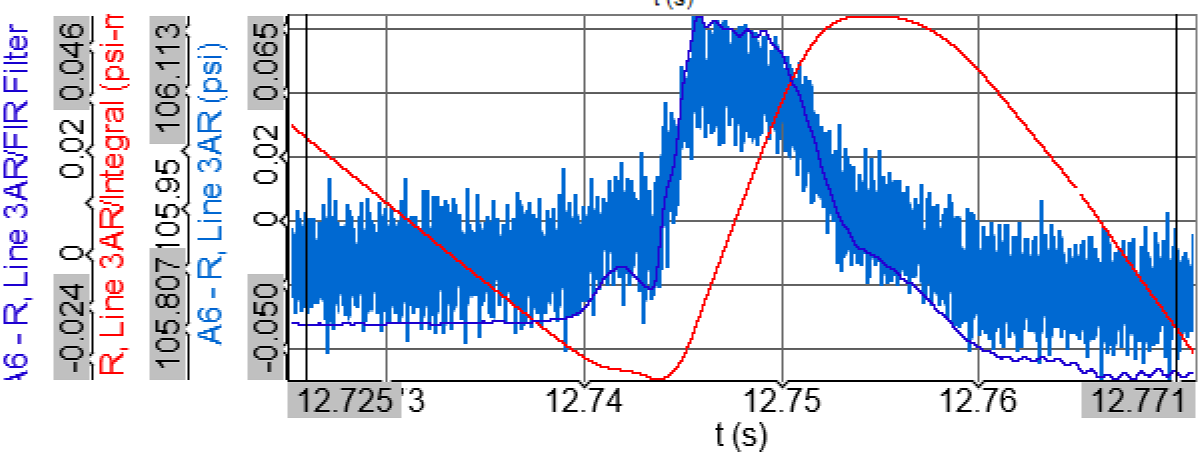

- R, Line 1DR/Integral (psi-ms
98.353
-2000.000
-4071.276
A5 - R, Line 1DR (psi)
2.133
0.000
-2.000
-4.967
11.966
13.000
14.000
15.000
16.000
16.713
t (s)

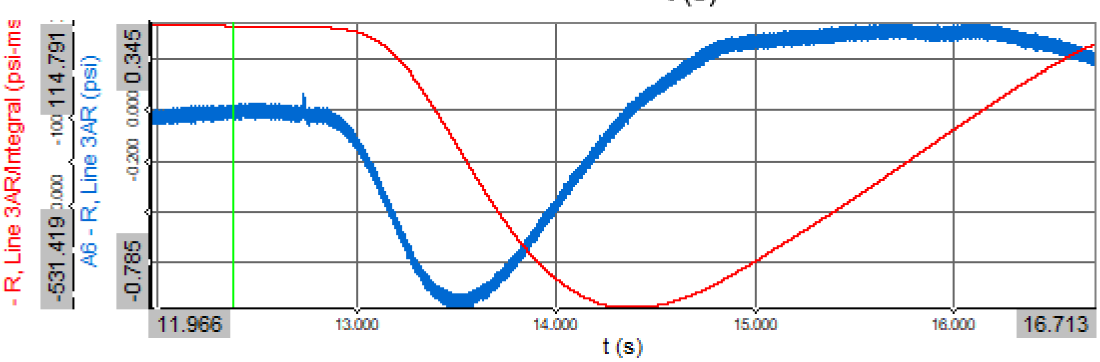

B5 - R, Line 5CL/FIR Filter (
0.086
0.02
0
-0.049
R, Line 5CL/Integral (psi-m
24.038
23.7
23.444
B5 - R, Line 5CL (psi)
0.107
0
-0.073
12.703
12.71
12.72
12.73
12.74
12.749
t (s)

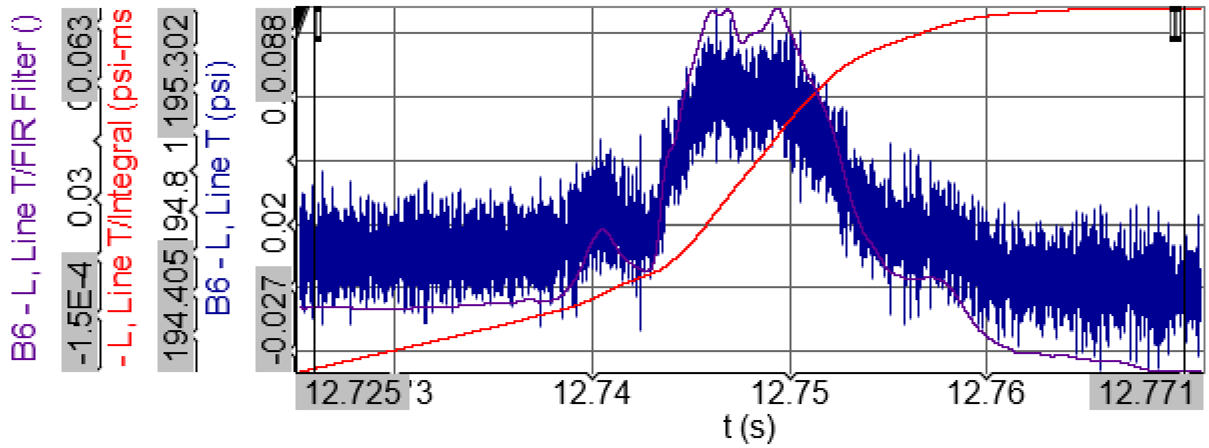

- R, Line 5CL/Integral (psi-ms
75.920
-15151.728
B5 - R, Line 5CL (psi)
7.211
0.000
-5.000
-13.098
11.966
13.000
14.000
15.000
16.000
16.713
t (s)

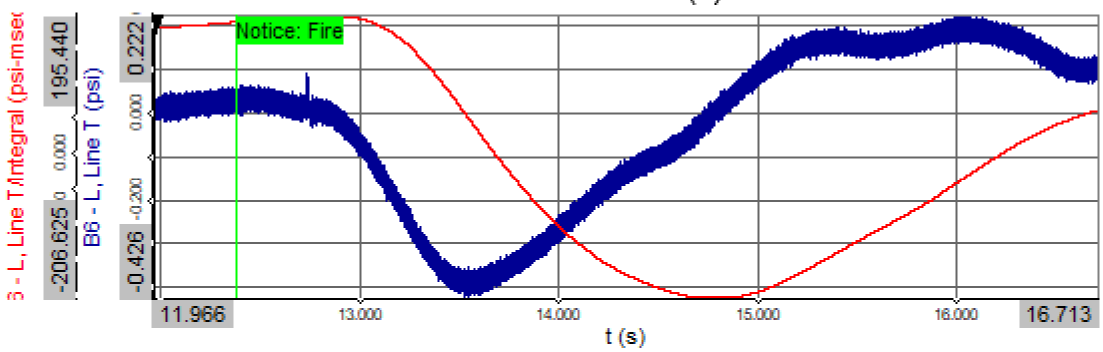

A6 - L, Line 4DL/FIR Filter (
L, Line 4DL/Integral (psi-m
A6 - L, Line 4DL (psi)
-0.093 .07 -0.05 -0.021
153.213 54.5 156.227
-0.115 -0.06 -0.002
12.725 12.74 12.75 12.76 12.771
t (s)

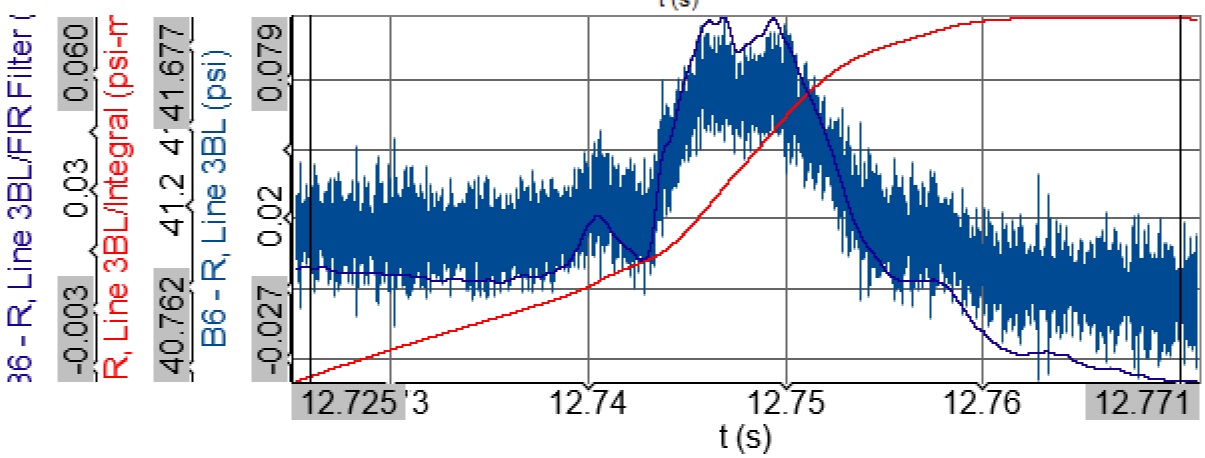

- L, Line 4DL/Integral (psi-ms
A6 - L, Line 4DL (psi)
-739.864 -200.0 161.185
-0.987 -0.500 0.000 0.521
Notice: Fire
11.966 13.000 14.000 15.000 16.000 16.713
t (s)

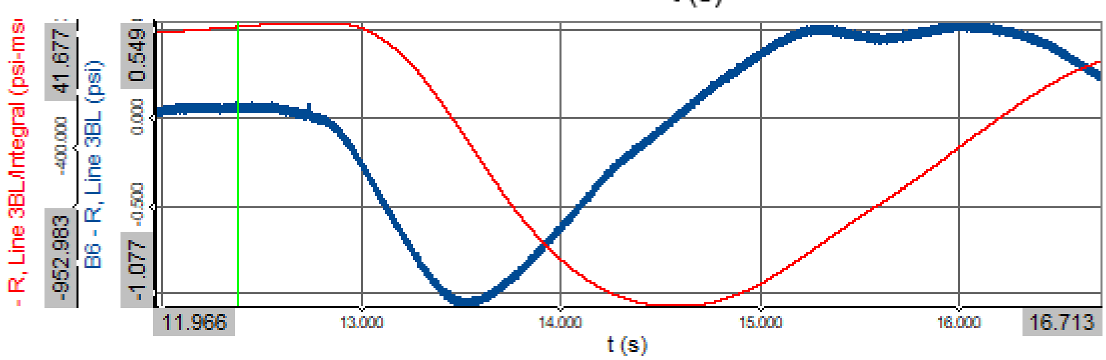

A6 - R, Line 3AR/FIR Filter
R, Line 3AR/Integral (psi-m
A6 - R, Line 3AR (psi)
-0.024 0 0.02 0.046
105.807 105.95 106.113
-0.050 0 0.02 0.065
12.725 12.74 12.75 12.76 12.771
t (s)

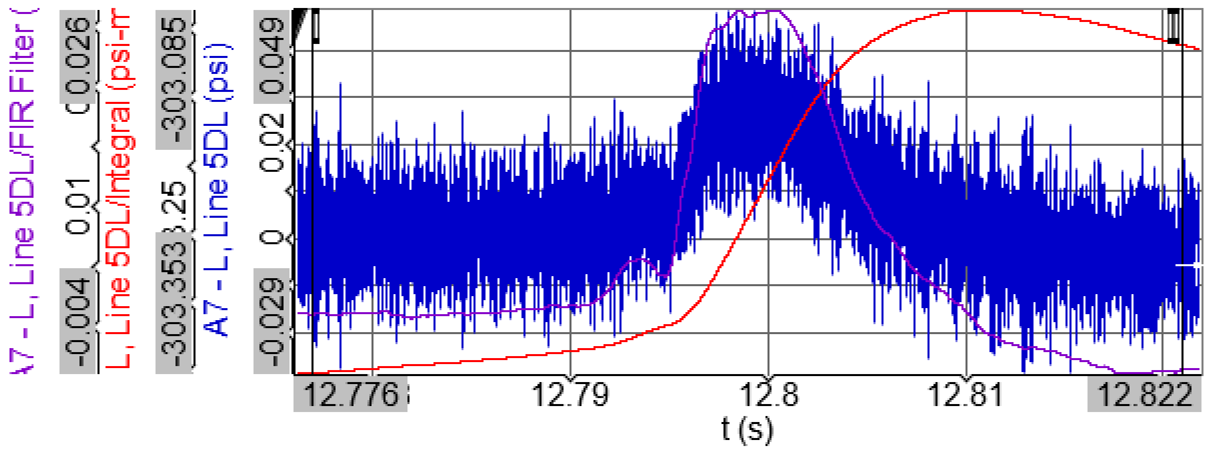

- R, Line 3AR/Integral (psi-ms
A6 - R, Line 3AR (psi)
-531.419 0.000 -100 114.791
-0.785 -0.200 0.000 0.345
11.966 13.000 14.000 15.000 16.000 16.713
t (s)

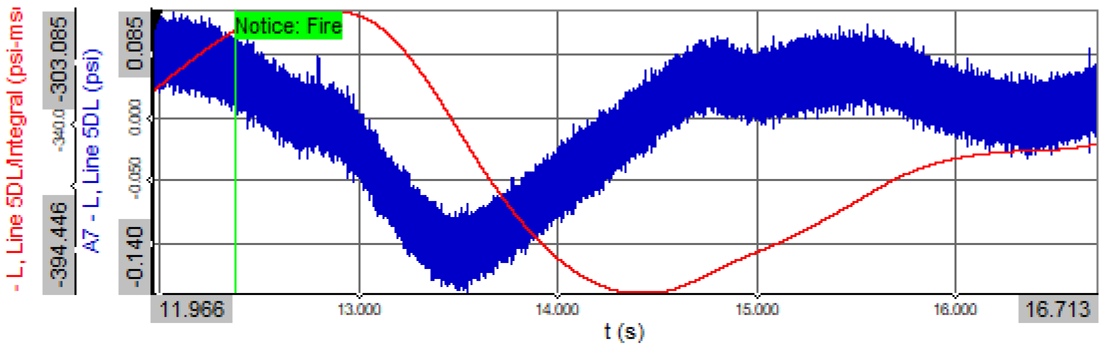

B6 - L, Line T/FIR Filter ()
-1.5E-4 0.03 0.063
- L, Line T/Integral (psi-ms
194.405 194.8 195.302
B6 - L, Line T (psi)
-0.027 0.02 0.088
12.725
12.74
12.75
12.76
12.771
t (s)

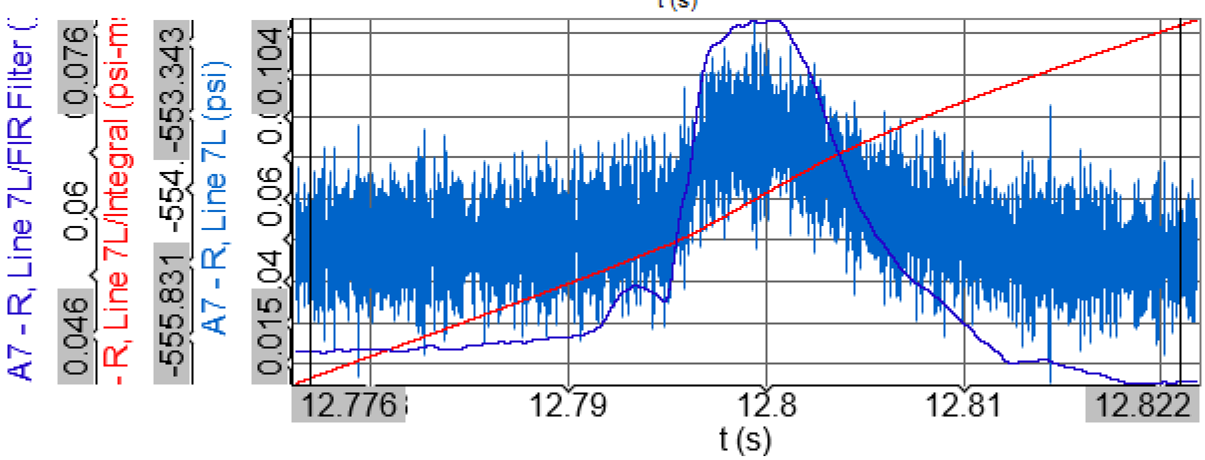

Notice: Fire
3 - L, Line T/Integral (psi-msec
-206.625 0.000 195.440
B6 - L, Line T (psi)
-0.426 -0.200 0.000 0.222
11.966
13.000
14.000
15.000
16.000
16.713
t (s)

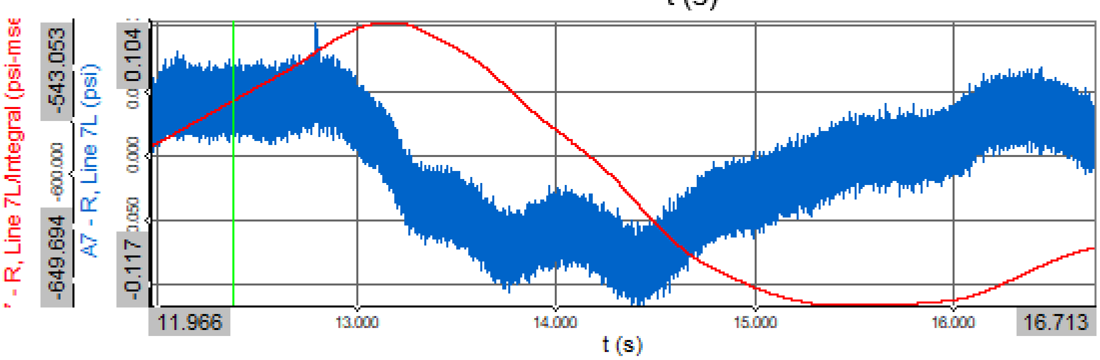

36 - R, Line 3BL/FIR Filter (
-0.003 0.03 0.060
R, Line 3BL/Integral (psi-m
40.762 41.2 41.677
B6 - R, Line 3BL (psi)
-0.027 0.02 0.079
12.725
12.74
12.75
12.76
12.771
t (s)

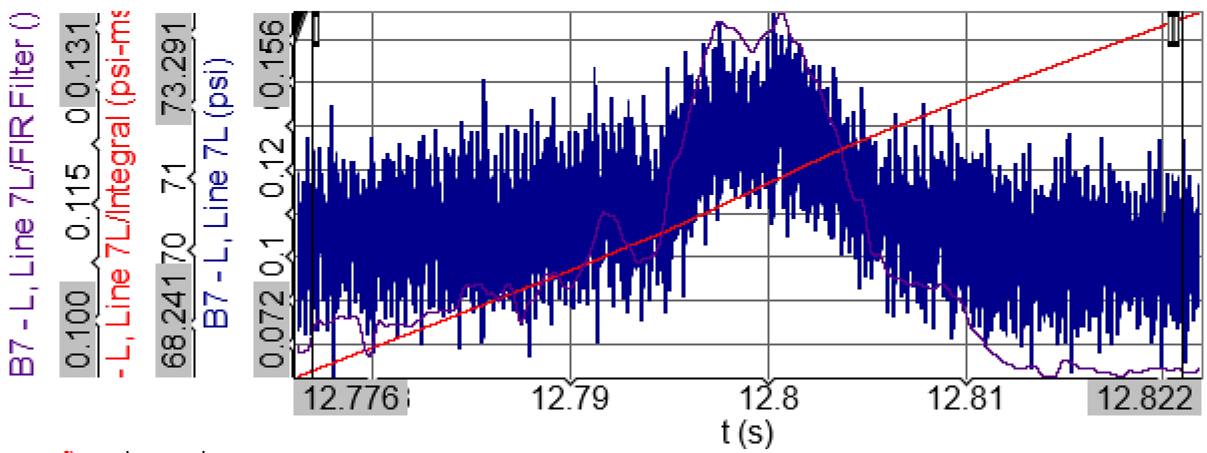

- R, Line 3BL/Integral (psi-ms
-952.983 -400.000 41.677
B6 - R, Line 3BL (psi)
-1.077 -0.500 0.000 0.549
11.966
13.000
14.000
15.000
16.000
16.713
t (s)

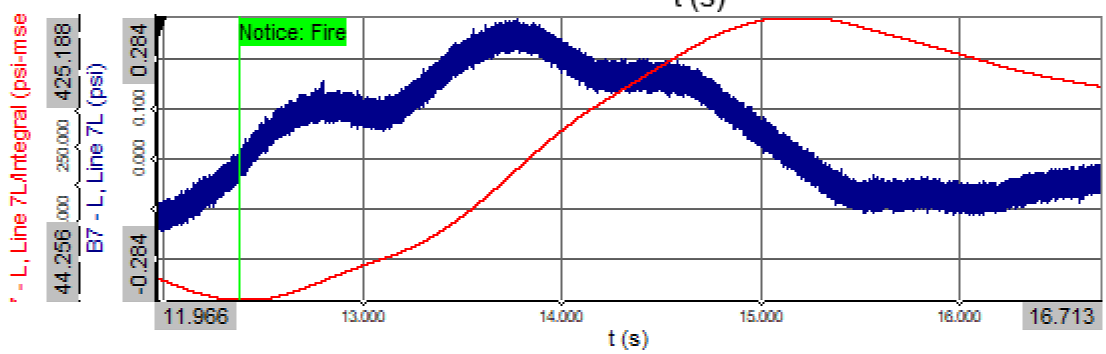

A7 - L, Line 5DL (psi)
12.776
12.79
12.8
12.81
12.822
t (s)

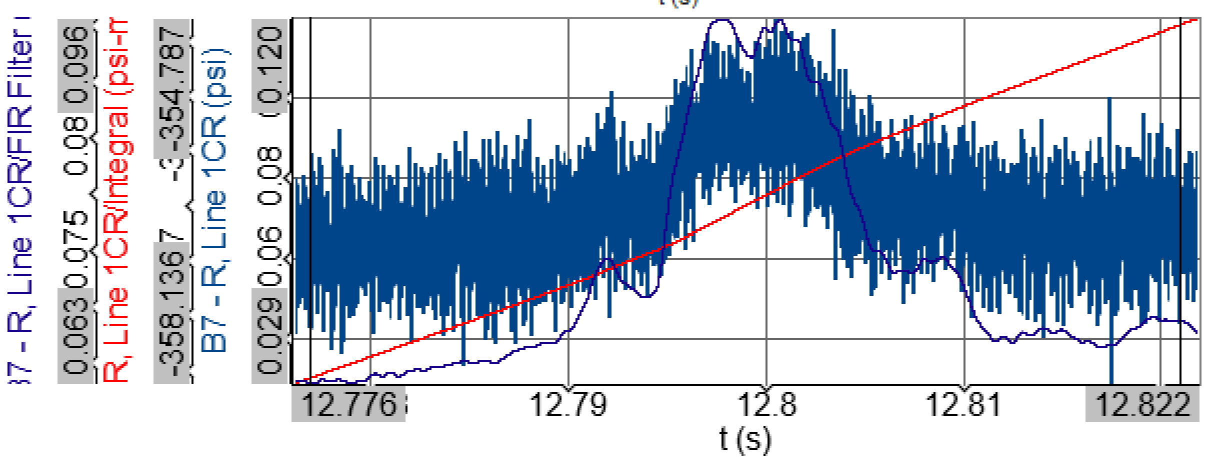

Notice: Fire
A7 - L, Line 5DL (psi)
11.966
13.000
14.000
15.000
16.000
16.713
t (s)

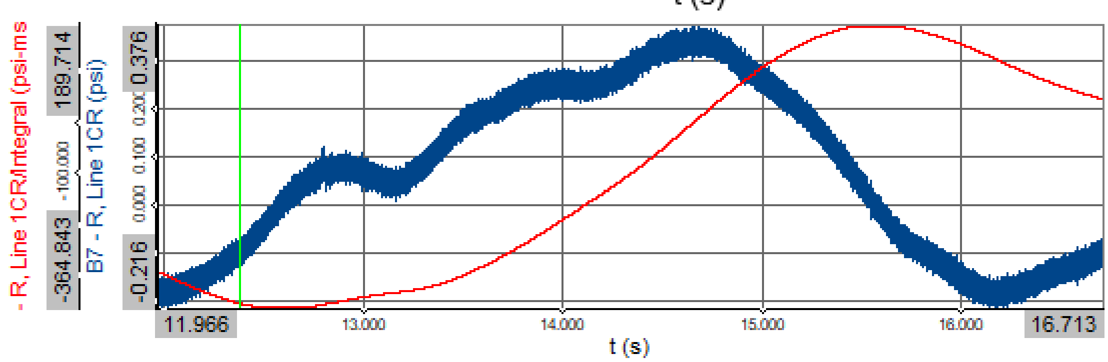

A7 - R, Line 7L (psi)
12.776
12.79
12.8
12.81
12.822
t (s)

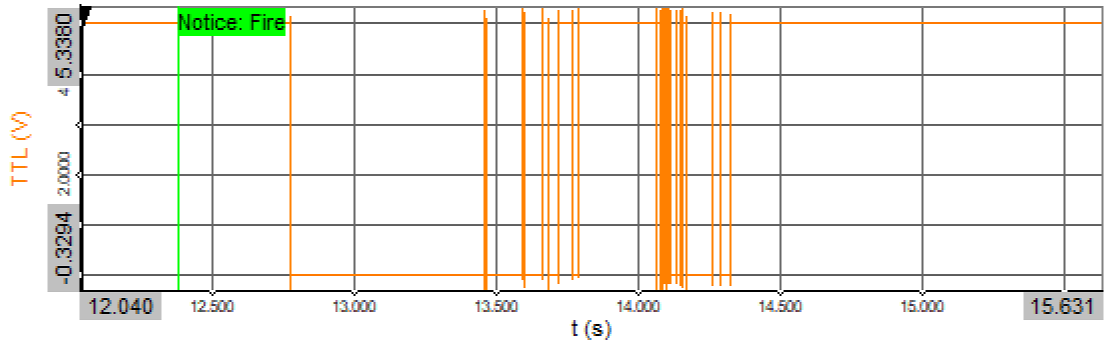

A7 - R, Line 7L (psi)
11.966
13.000
14.000
15.000
16.000
16.713
t (s)


B7 - L, Line 7L/FIR Filter ()
- L, Line 7L/Integral (psi-ms
B7 - L, Line 7L (psi)
12.776
12.79
12.8
12.81
12.822
t (s)

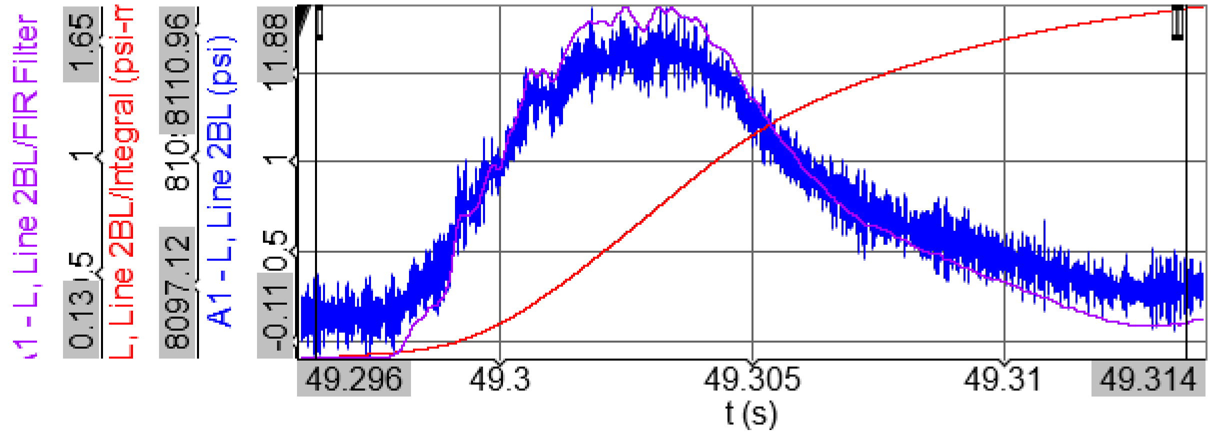

Notice: Fire
- L, Line 7L/Integral (psi-mse
B7 - L, Line 7L (psi)
11.966
13.000
14.000
15.000
16.000
16.713
t (s)

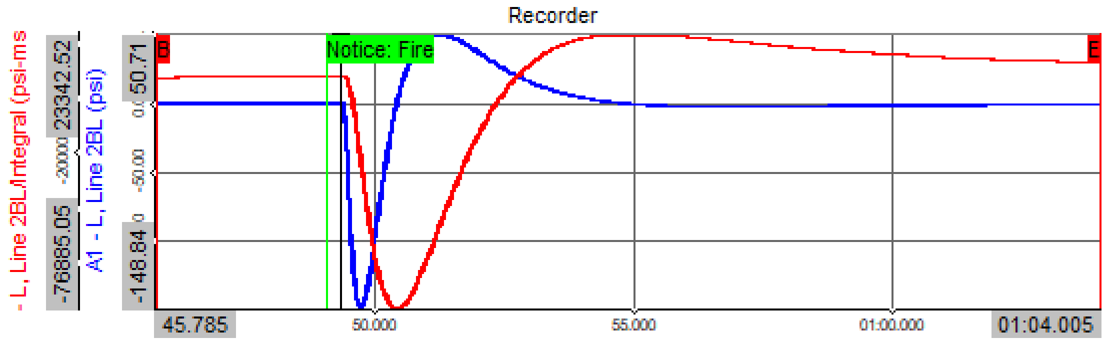

B7 - R, Line 1CR/FIR Filter
R, Line 1CR/Integral (psi-m
B7 - R, Line 1CR (psi)
12.776
12.79
12.8
12.81
12.822
t (s)

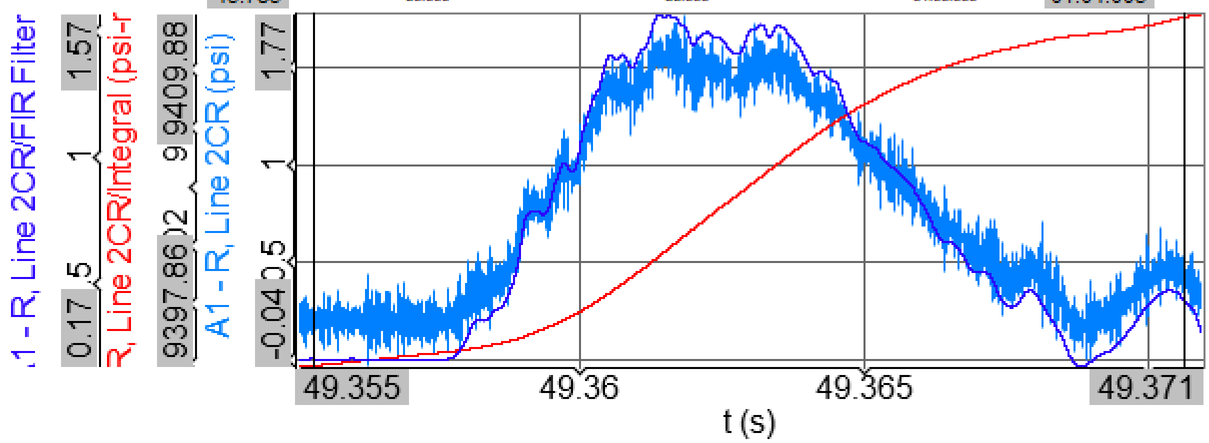

- R, Line 1CR/Integral (psi-ms
B7 - R, Line 1CR (psi)
11.966
13.000
14.000
15.000
16.000
16.713
t (s)

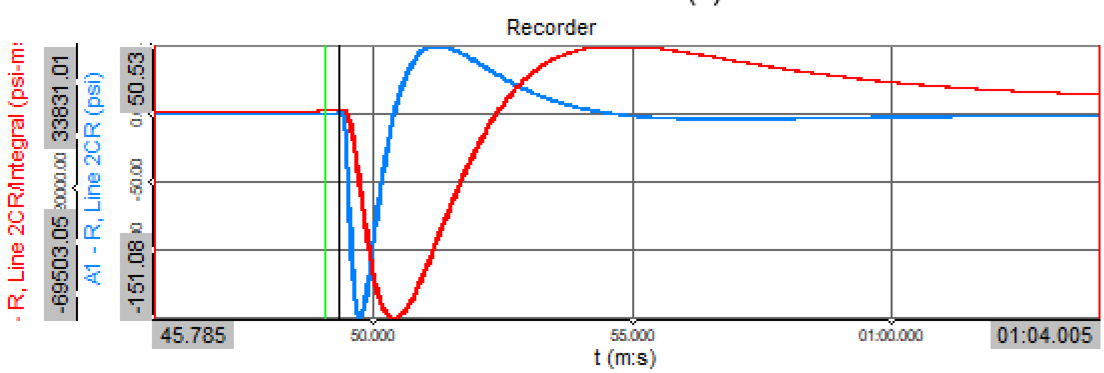

Notice: Fire
TTL (V)
5.3380
2.0000
-0.3294
12.040
12.500
13.000
13.500
14.000
14.500
15.000
15.631
t (s)

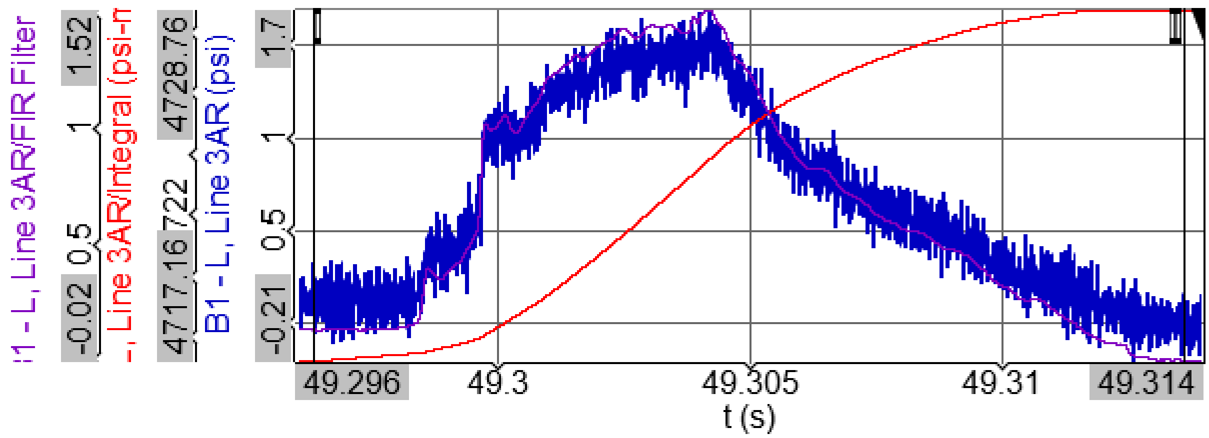
8.3.3 Trial 3 for Small-Scale Mix ID #4

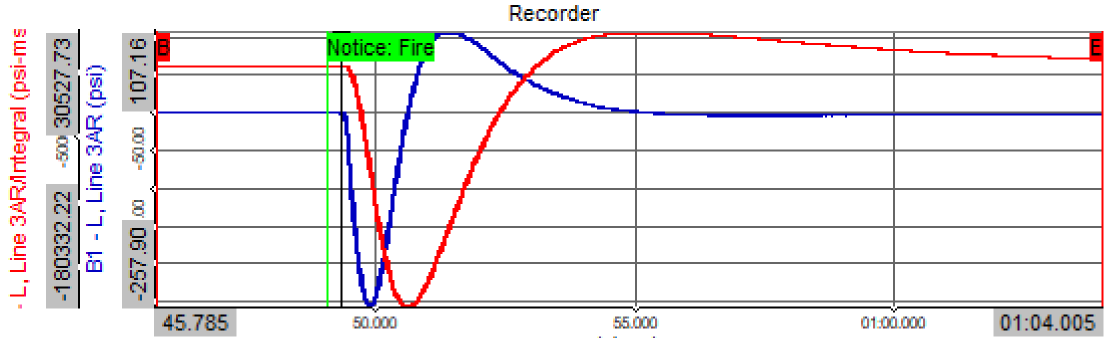


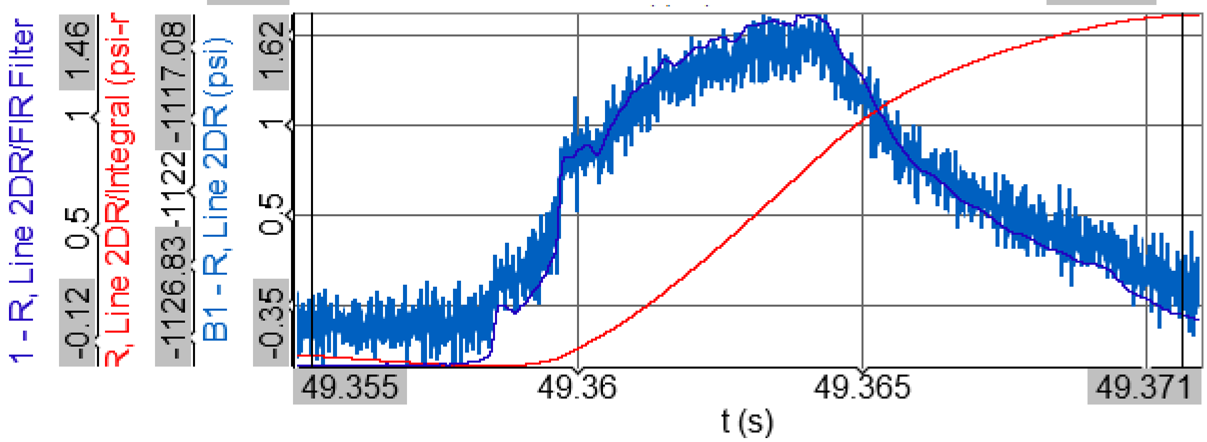


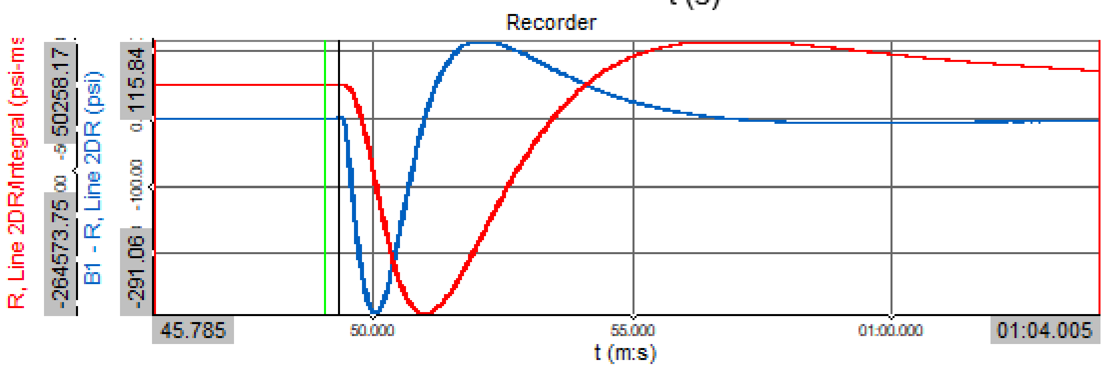


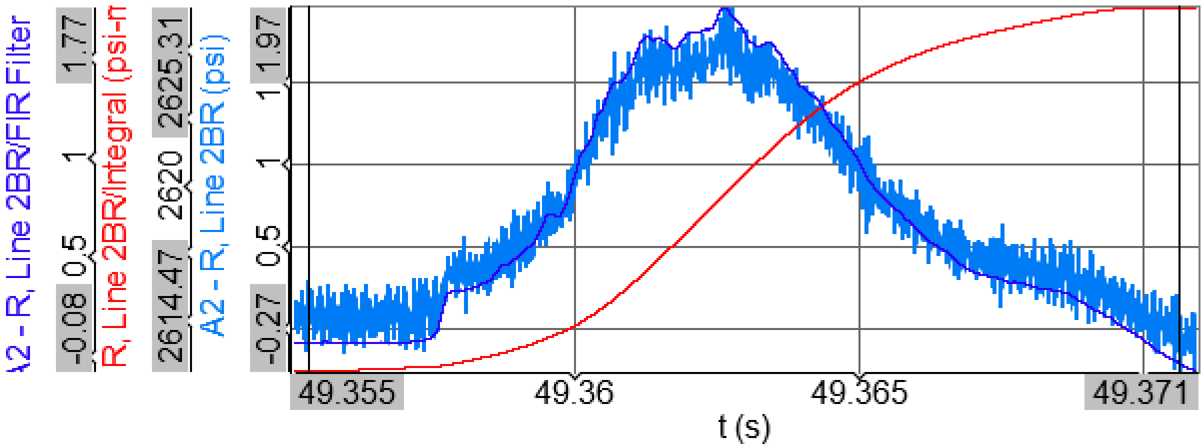


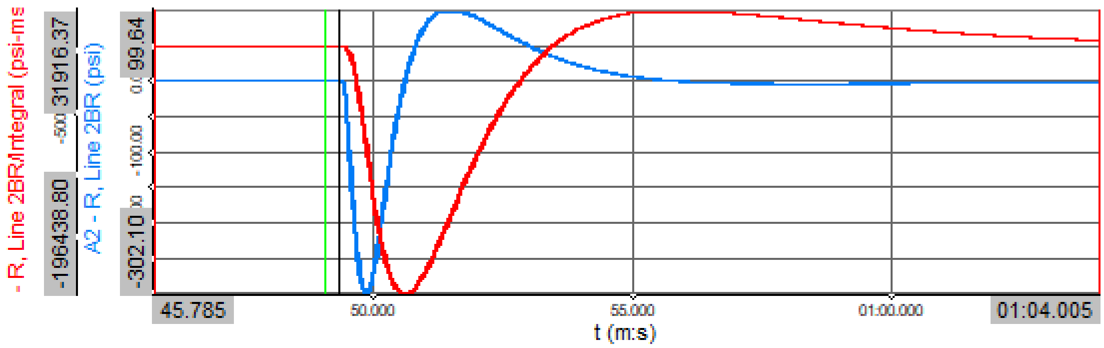

B1 - L, Line 3AR (psi)
t (s)
49.296
49.3
49.305
49.31
49.314

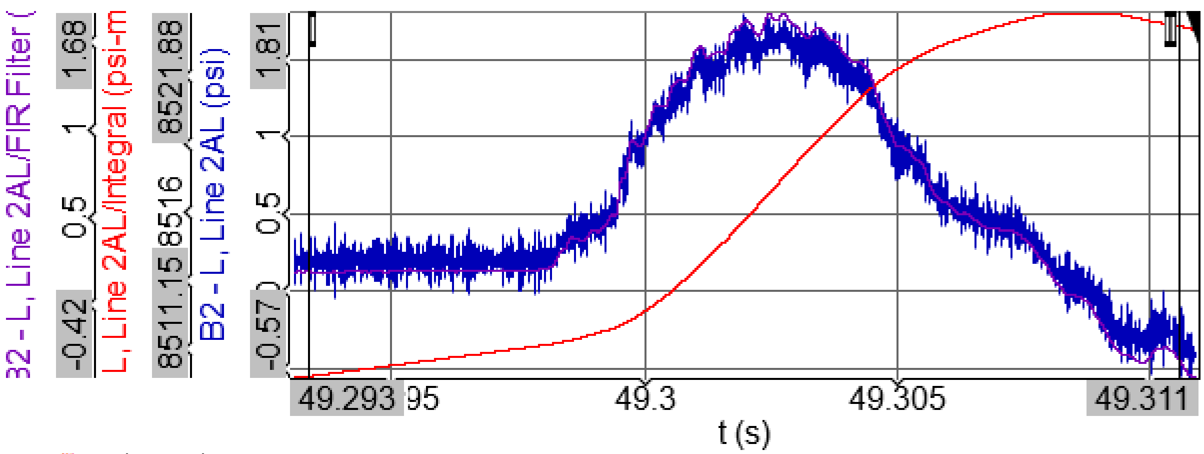

Recorder
Notice: Fire
B1 - L, Line 3AR (psi)
45.785
50.000
55.000
01:00.000
01:04.005

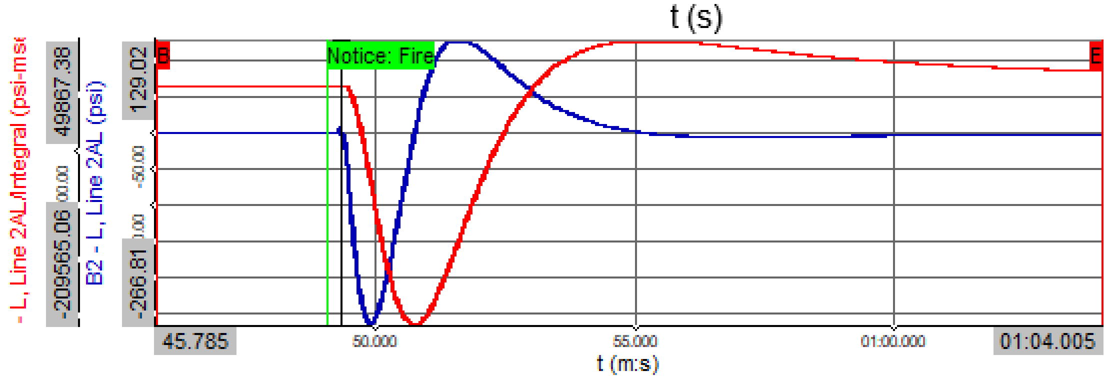

B1 - R, Line 2DR (psi)
t (s)
49.355
49.36
49.365
49.371

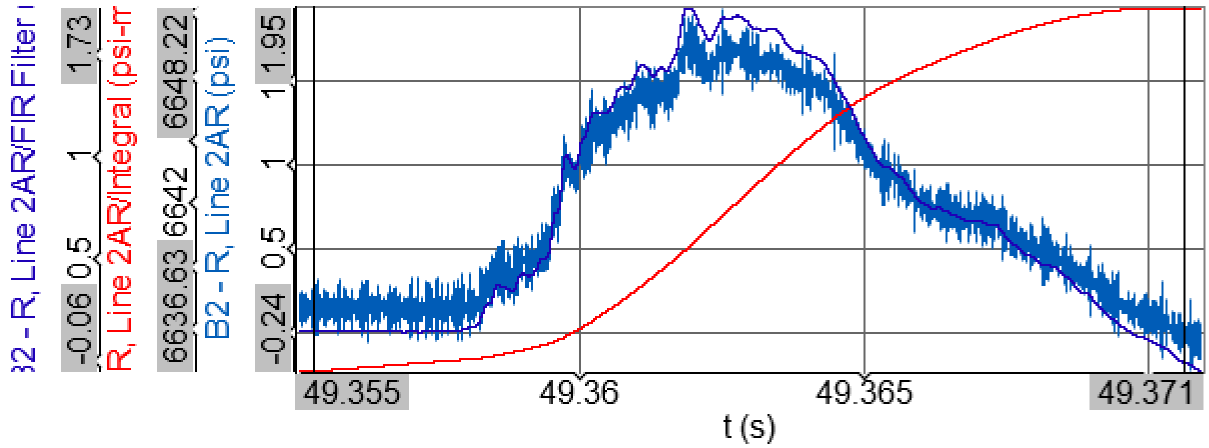

Recorder
B1 - R, Line 2DR (psi)
45.785
50.000
55.000
01:00.000
01:04.005
t (m:s)

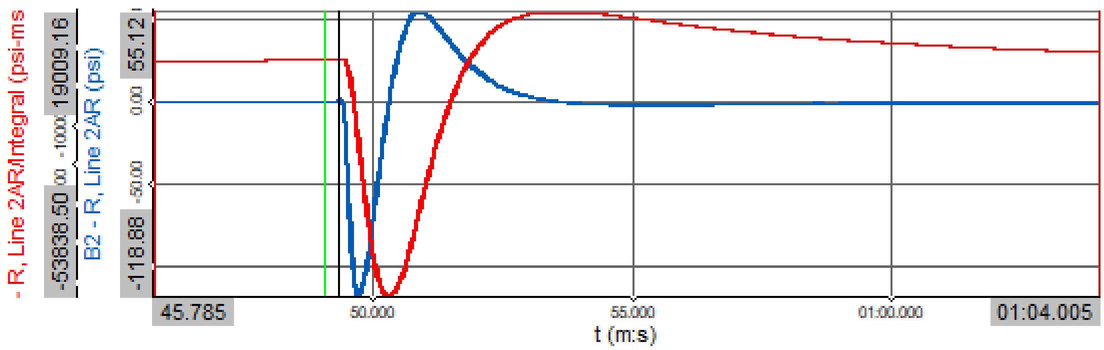

A2 - R, Line 2BR/FIR Filter
R, Line 2BR/Integral (psi-m
A2 - R, Line 2BR (psi)
49.355
49.36
49.365
49.371
t (s)

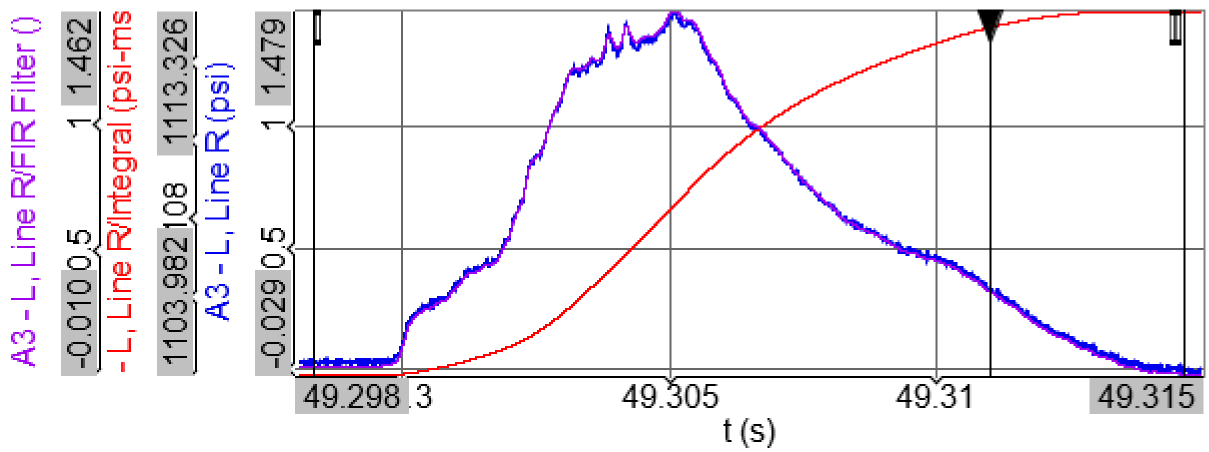

- R, Line 2BR/Integral (psi-ms
A2 - R, Line 2BR (psi)
45.785
50.000
55.000
01:00.000
01:04.005
t (m:s)

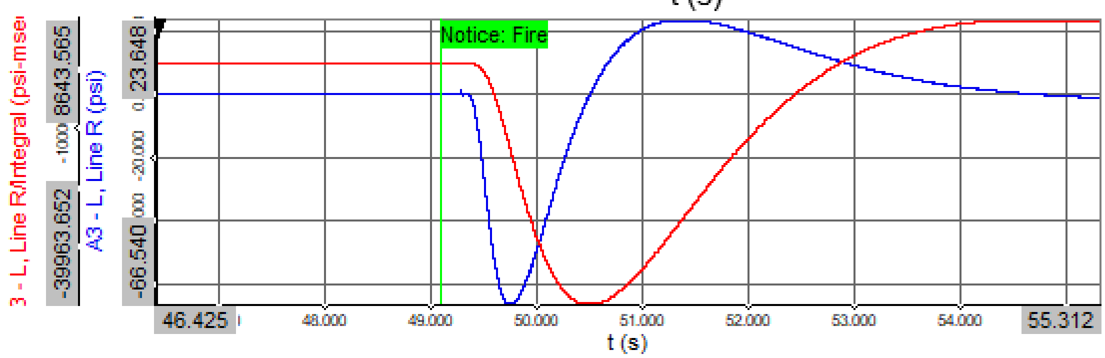

B2 - L, Line 2AL/FIR Filter (
L, Line 2AL/Integral (psi-m
B2 - L, Line 2AL (psi)
49.293
49.3
49.305
49.311
t (s)

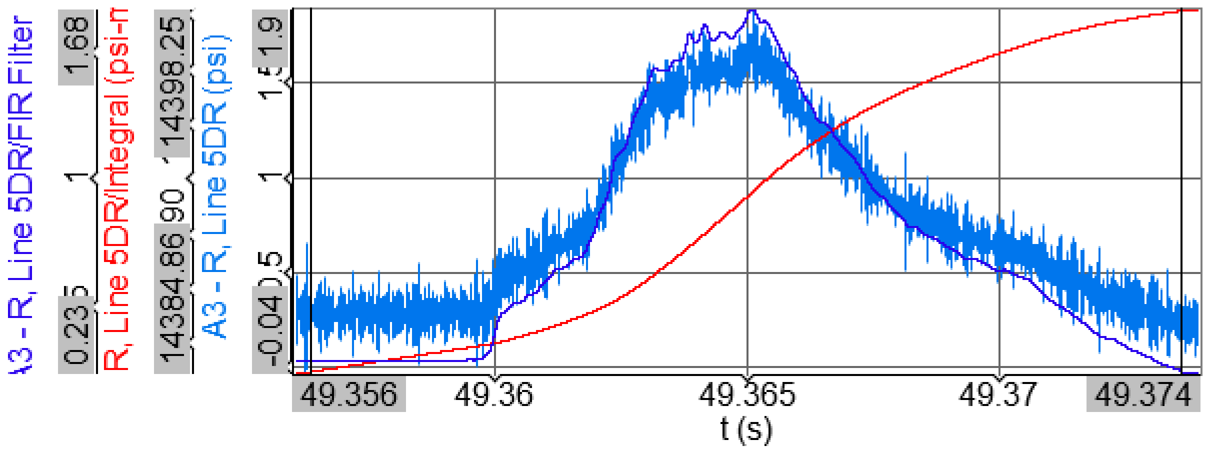

Notice: Fire
- L, Line 2AL/Integral (psi-ms
B2 - L, Line 2AL (psi)
45.785
50.000
55.000
01:00.000
01:04.005
t (m:s)

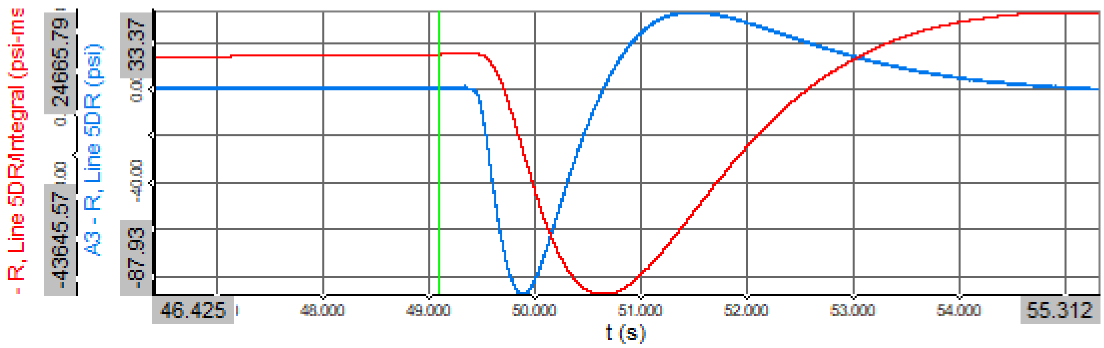

B2 - R, Line 2AR (psi)
R, Line 2AR/Integral (psi-m
49.355
49.36
49.365
49.371
t (s)

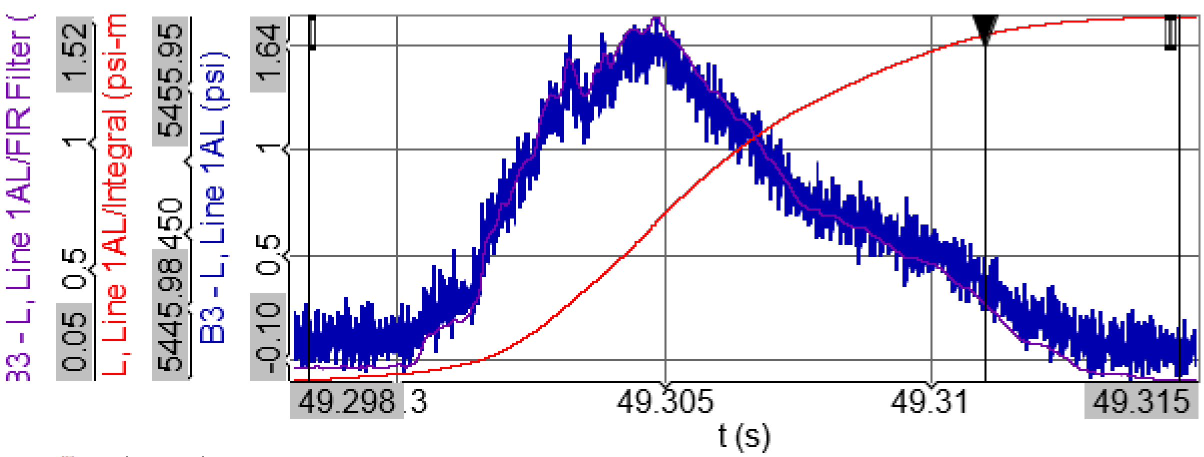

- R, Line 2AR/Integral (psi-ms
B2 - R, Line 2AR (psi)
45.785
50.000
55.000
01:00.000
01:04.005
t (m:s)

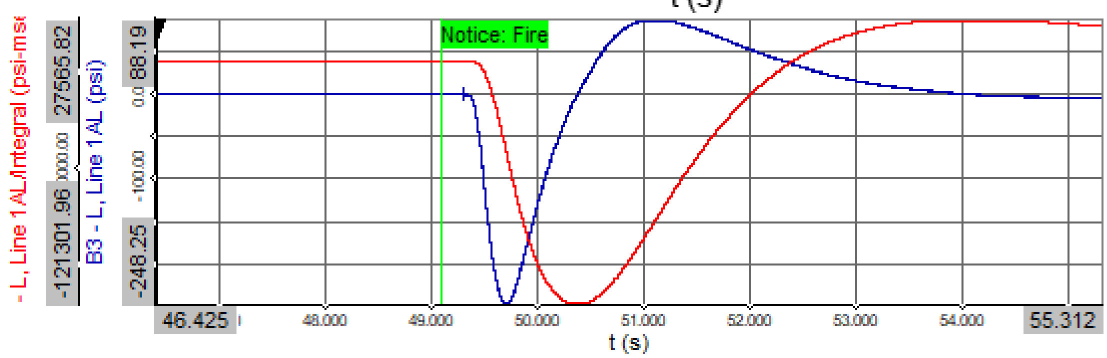

A3 - L, Line R/FIR Filter ()
- L, Line R/Integral (psi-ms
A3 - L, Line R (psi)
49.298
49.305
49.31
49.315
t (s)

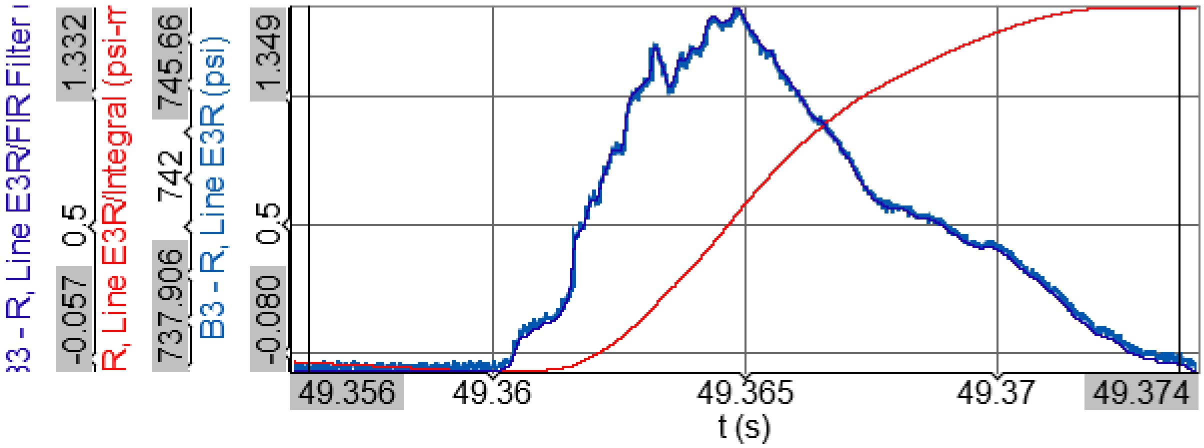

Notice: Fire
3 - L, Line R/Integral (psi-mse
A3 - L, Line R (psi)
46.425
48.000
49.000
50.000
51.000
52.000
53.000
54.000
55.312
t (s)

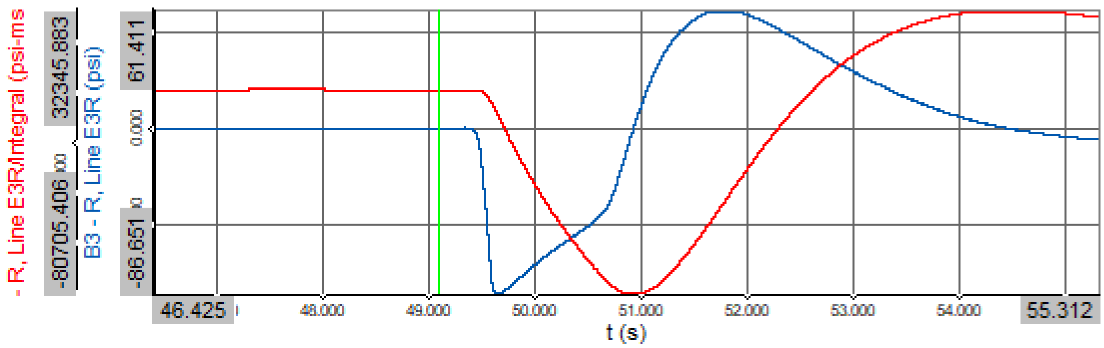

A3 - R, Line 5DR/FIR Filter
R, Line 5DR/Integral (psi-m
A3 - R, Line 5DR (psi)
49.356
49.36
49.365
49.37
49.374
t (s)

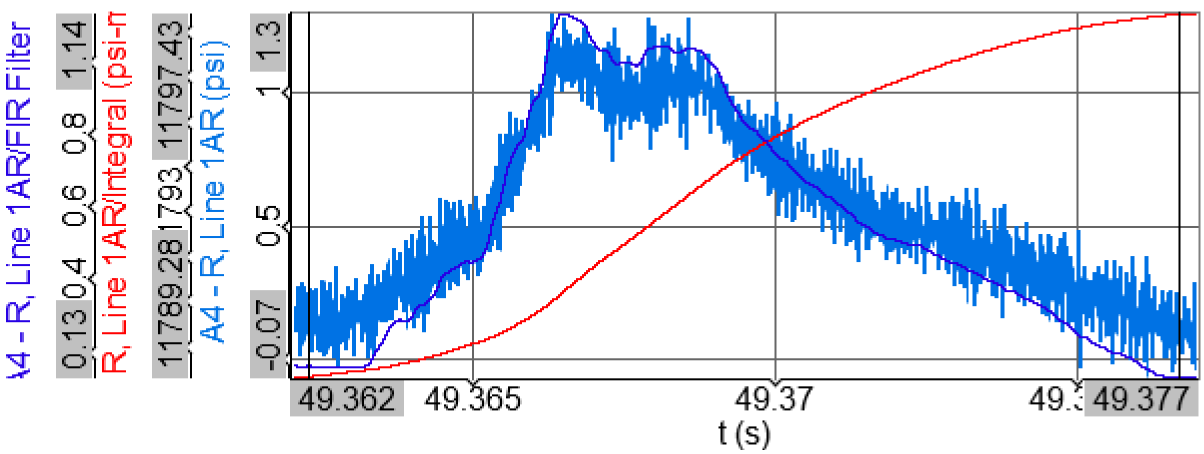

- R, Line 5DR/Integral (psi-ms
A3 - R, Line 5DR (psi)
46.425
55.312
t (s)

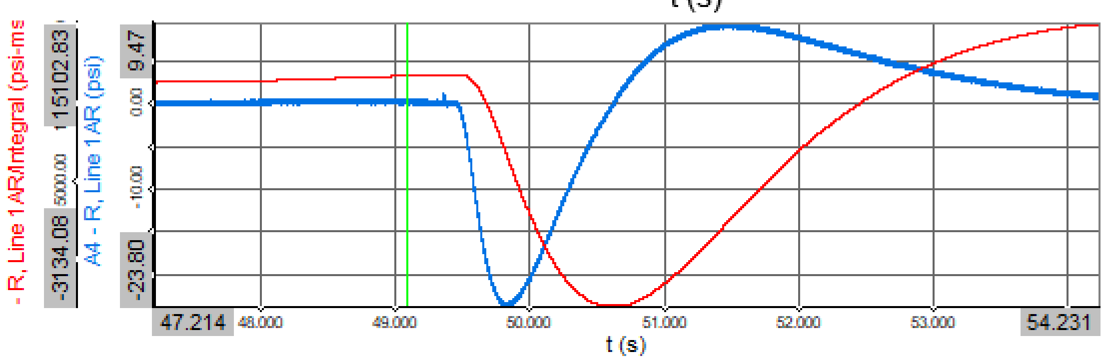

B3 - L, Line 1AL/FIR Filter (
L, Line 1AL/Integral (psi-m
B3 - L, Line 1AL (psi)
49.298
49.305
49.31
49.315
t (s)

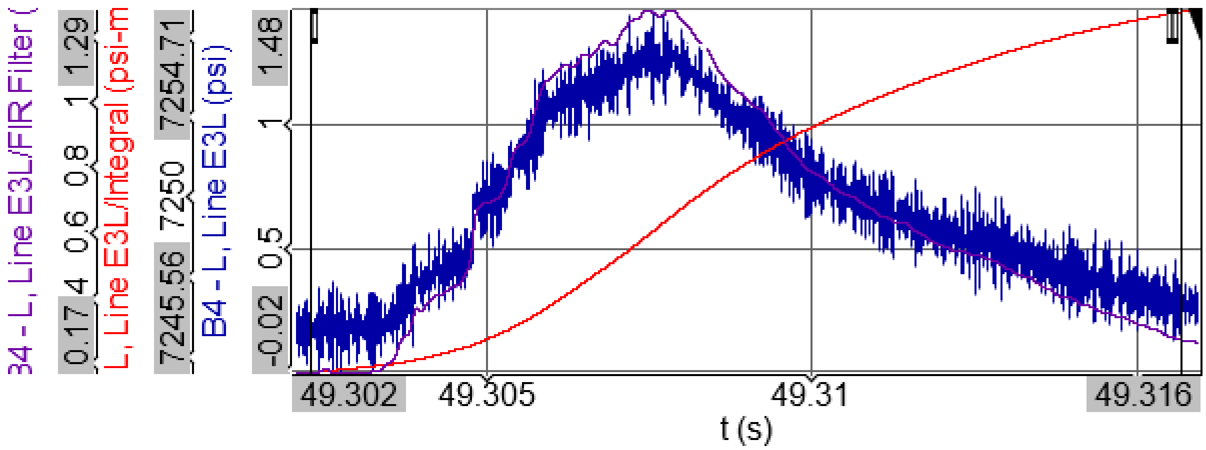

Notice: Fire
- L, Line 1AL/Integral (psi-ms
B3 - L, Line 1AL (psi)
46.425
55.312
t (s)

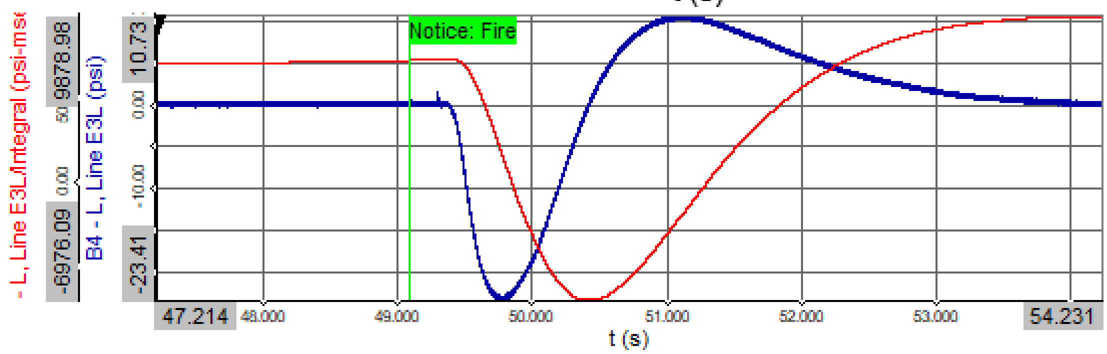

B3 - R, Line E3R/FIR Filter
R, Line E3R/Integral (psi-m
B3 - R, Line E3R (psi)
49.356
49.36
49.365
49.37
49.374
t (s)

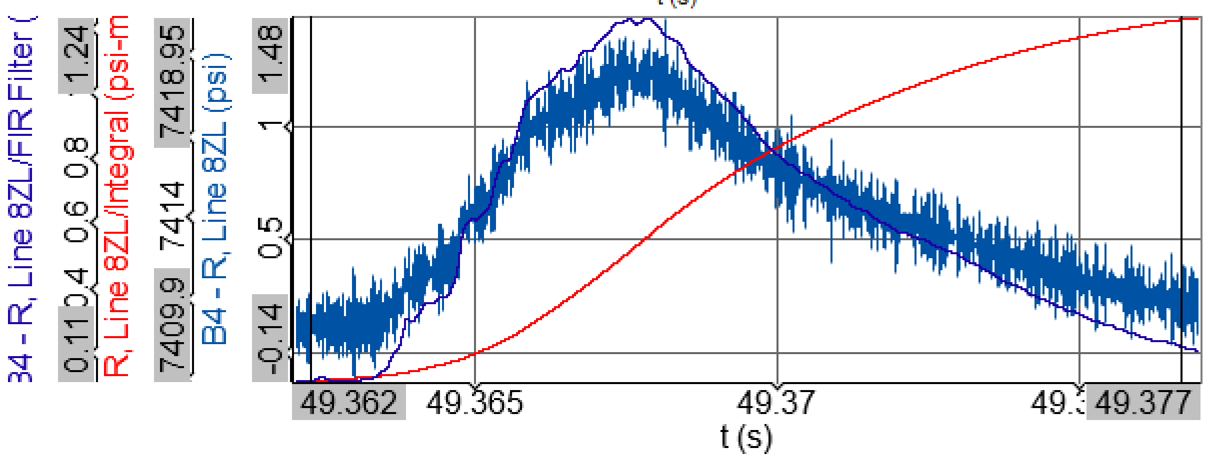

- R, Line E3R/Integral (psi-ms
B3 - R, Line E3R (psi)
46.425
55.312
t (s)

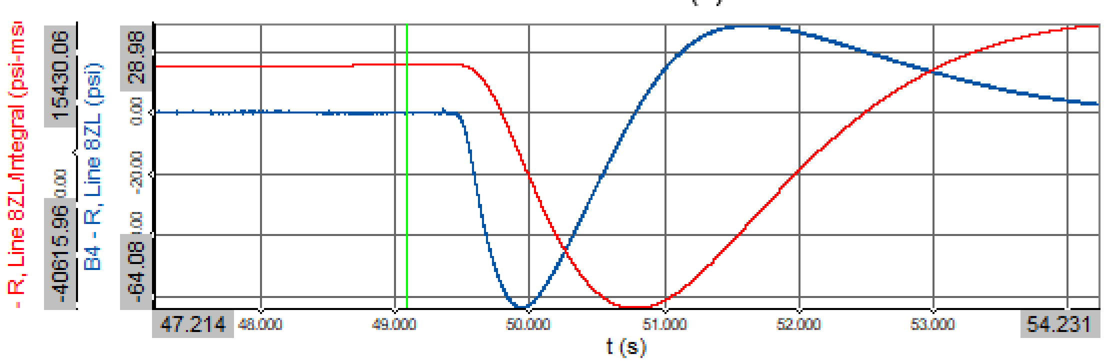

A4 - R, Line 1AR/FIR Filter
R, Line 1AR/Integral (psi-m
A4 - R, Line 1AR (psi)
49.362
49.365
49.37
49.377
t (s)

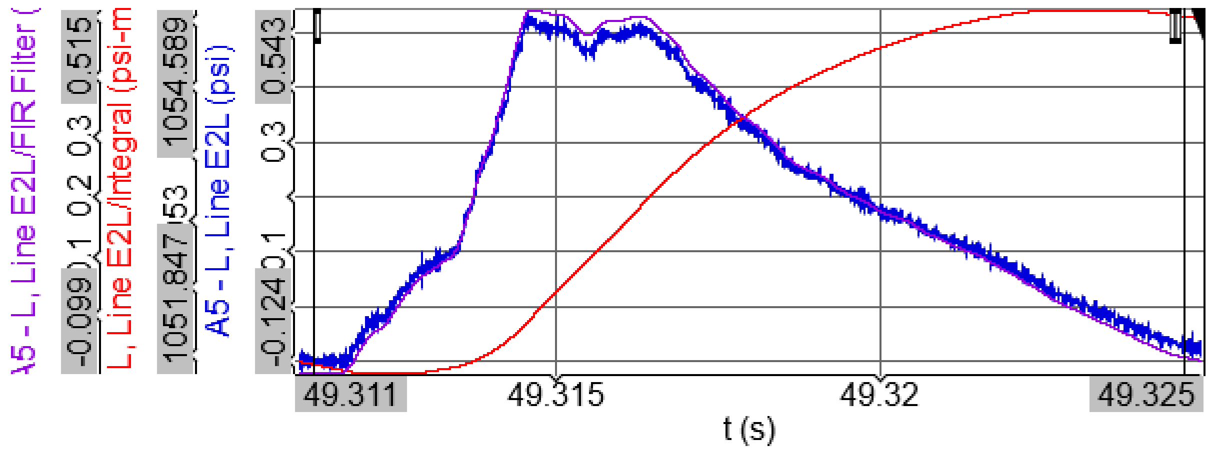

- R, Line 1AR/Integral (psi-ms
A4 - R, Line 1AR (psi)
47.214
54.231
t (s)

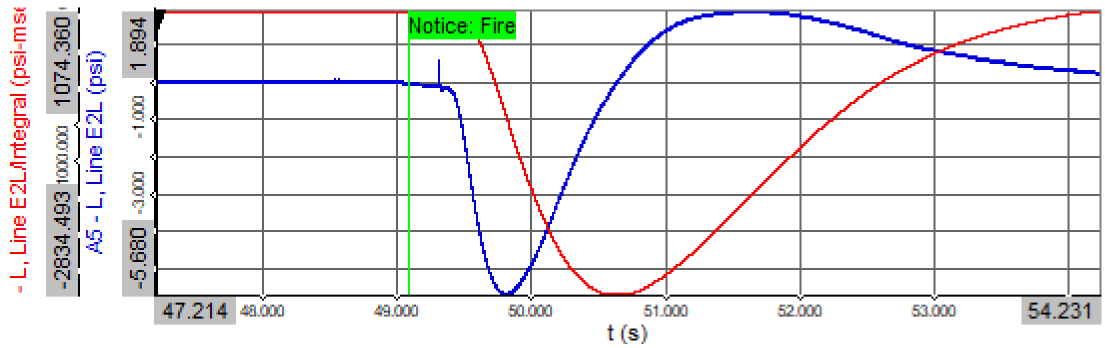

34 - L, Line E3L/FIR Filter (
L, Line E3L/Integral (psi-m
B4 - L, Line E3L (psi)
0.17
1.29
7245.56
7250
7254.71
-0.02
0.5
1
1.48
49.302
49.305
49.31
49.316
t (s)

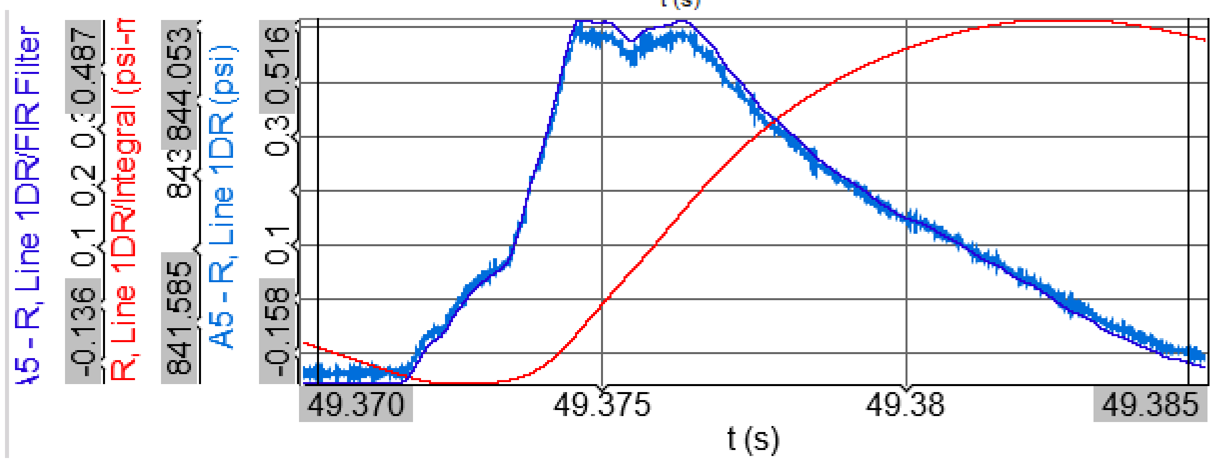

- L, Line E3L/Integral (psi-ms
B4 - L, Line E3L (psi)
-6976.09
9878.98
-23.41
-10.00
0.00
10.73
Notice: Fire
47.214
48.000
49.000
50.000
51.000
52.000
53.000
54.231
t (s)

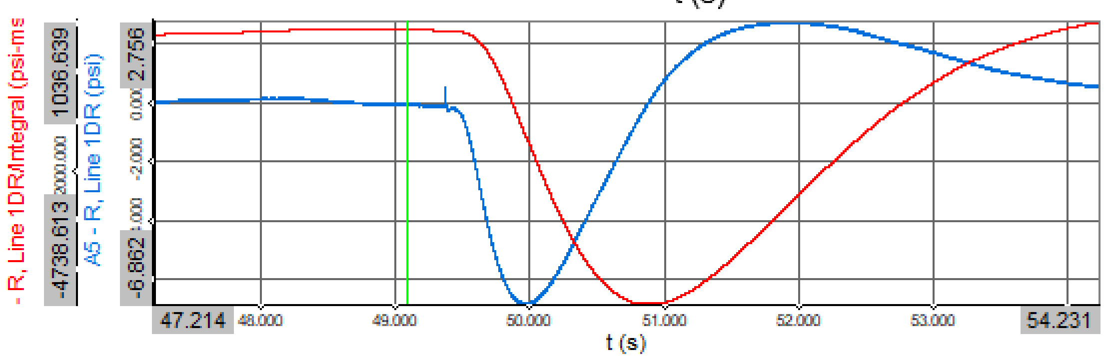

34 - R, Line 8ZL/FIR Filter (
R, Line 8ZL/Integral (psi-m
B4 - R, Line 8ZL (psi)
0.11
1.24
7409.9
7414
7418.95
-0.14
0.5
1
1.48
49.362
49.365
49.37
49.377
t (s)

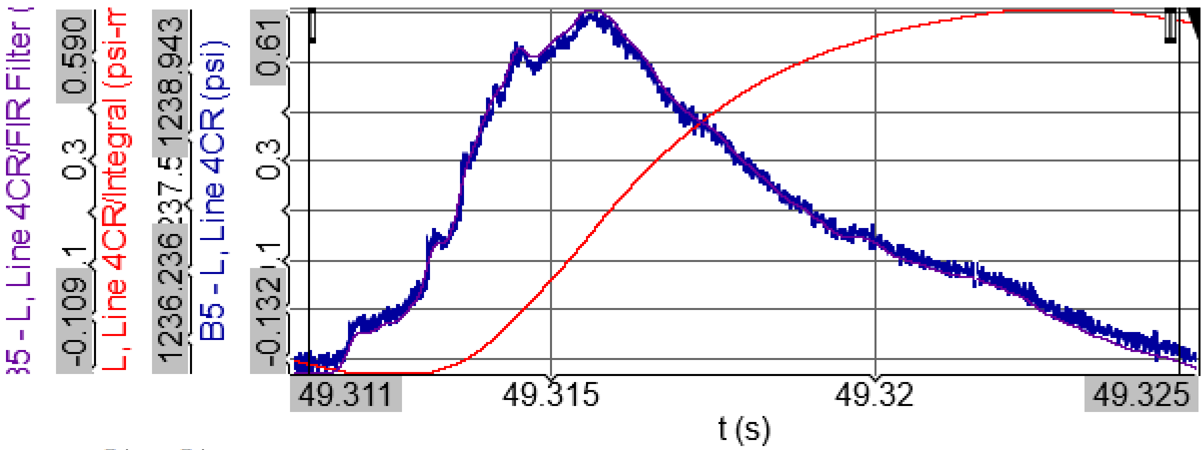

- R, Line 8ZL/Integral (psi-ms
B4 - R, Line 8ZL (psi)
-40615.96
15430.06
-64.08
-20.00
0.00
28.98
47.214
48.000
49.000
50.000
51.000
52.000
53.000
54.231
t (s)

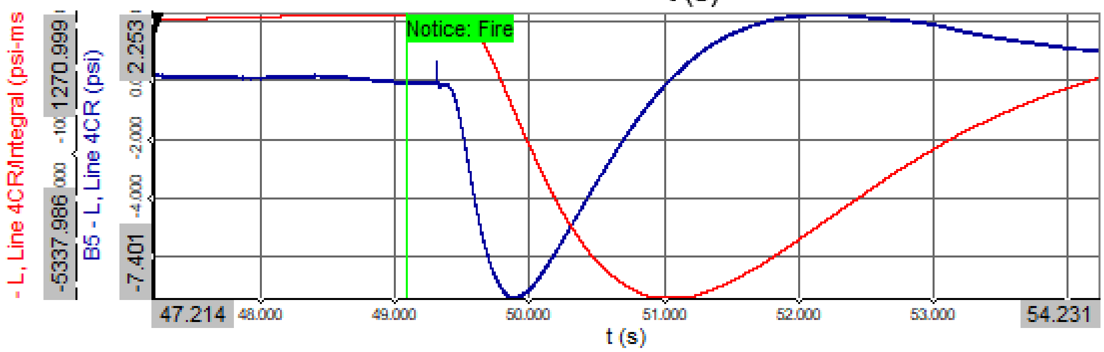

A5 - L, Line E2L/FIR Filter (
-0.099 0.1 0.2 0.3 0.515
L, Line E2L/Integral (psi-m
1051.847 53 1054.589
A5 - L, Line E2L (psi)
-0.124 0.1 0.3 0.543
49.311
49.315
49.32
49.325
t (s)

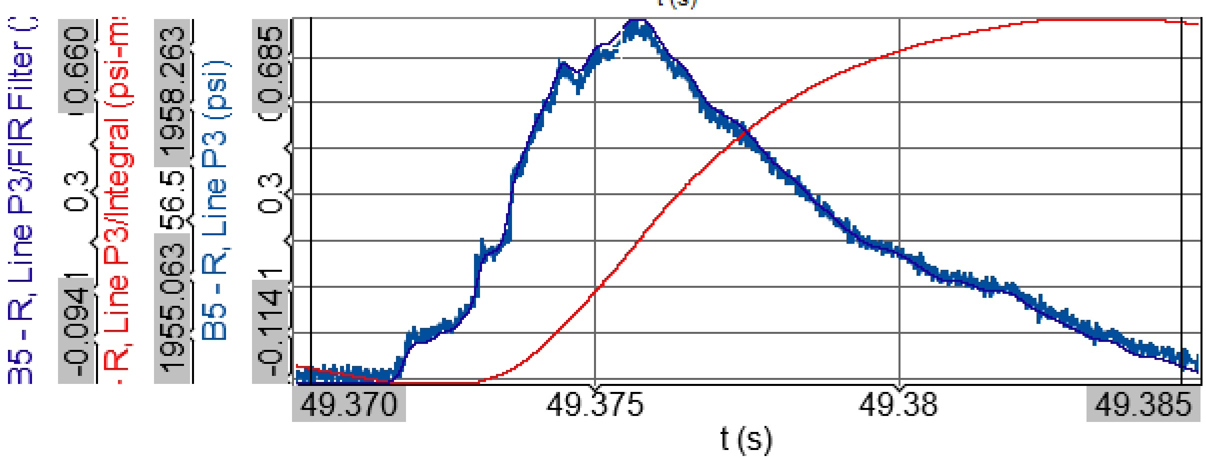

- L, Line E2L/Integral (psi-ms
-2834.493 1000.000 1074.360
A5 - L, Line E2L (psi)
-5.680 -3.000 -1.000 1.894
Notice: Fire
47.214 48.000 49.000 50.000 51.000 52.000 53.000 54.231
t (s)

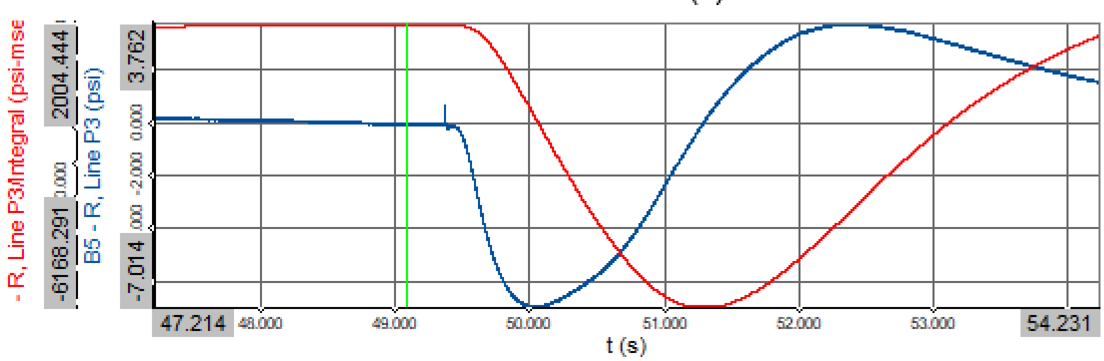

A5 - R, Line 1DR/FIR Filter
-0.136 0.1 0.2 0.3 0.487
R, Line 1DR/Integral (psi-m
841.585 843 844.053
A5 - R, Line 1DR (psi)
-0.158 0.1 0.3 0.516
49.370
49.375
49.38
49.385
t (s)

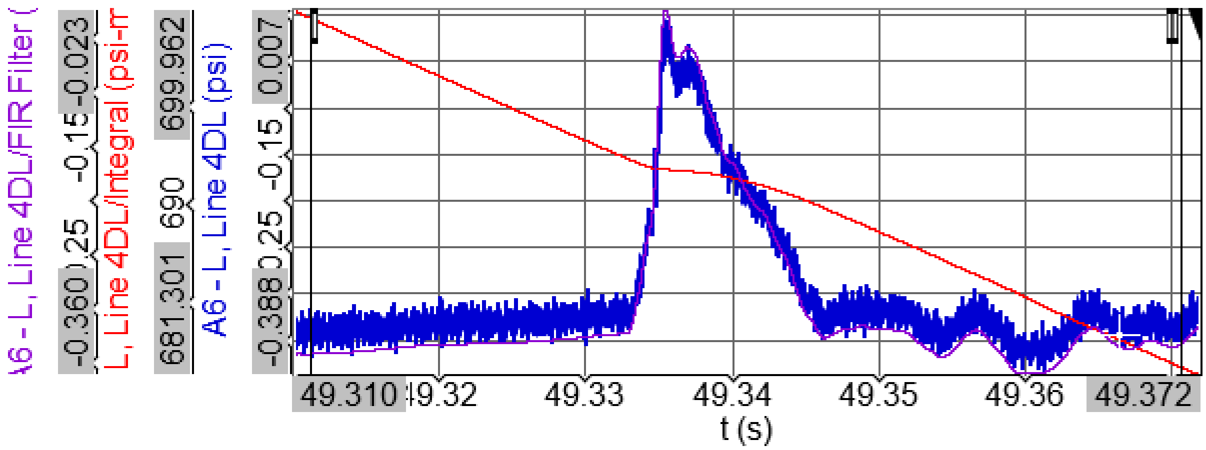

- R, Line 1DR/Integral (psi-ms
-4738.613 2000.000 1036.639
A5 - R, Line 1DR (psi)
-6.862 -4.000 -2.000 0.000 2.756
47.214 48.000 49.000 50.000 51.000 52.000 53.000 54.231
t (s)

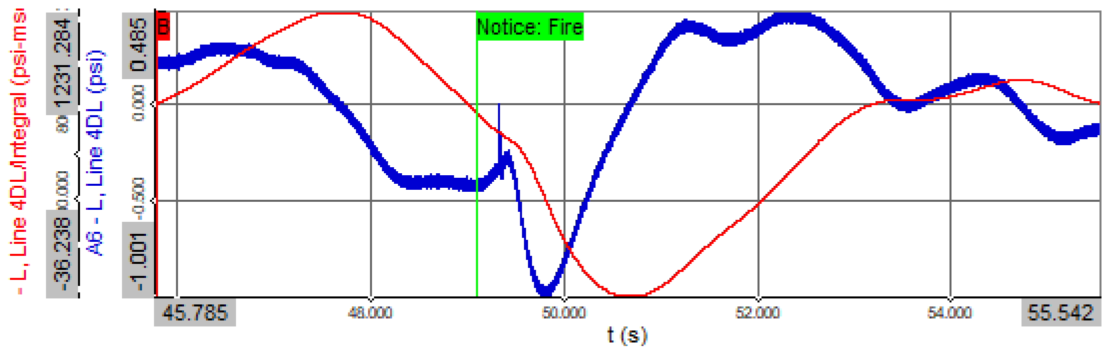

B5 - L, Line 4CR (psi)
0.61
0.3
-0.132
0.590
-0.109
1238.943
1236.236
49.311
49.315
49.32
49.325
t (s)

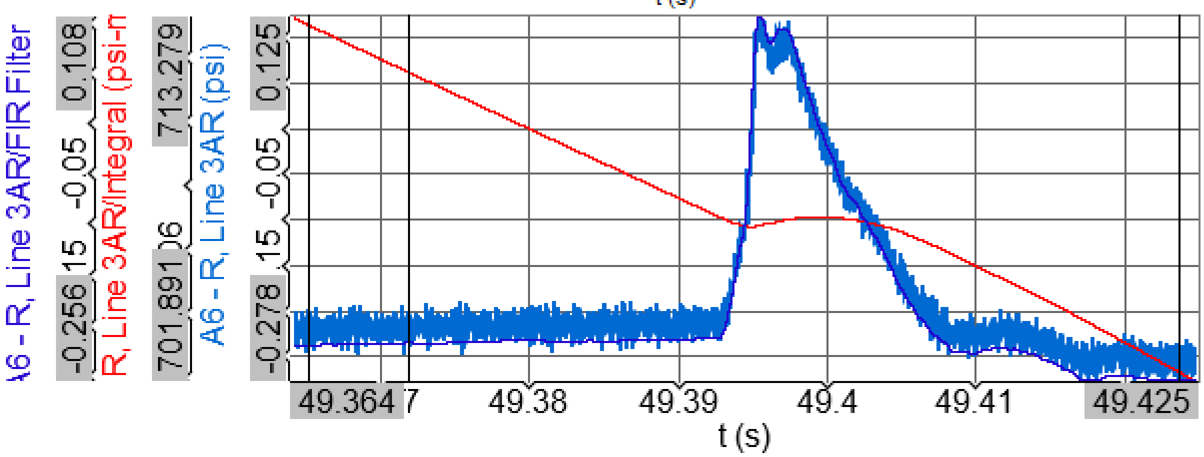

Notice: Fire
B5 - L, Line 4CR (psi)
2.253
-7.401
1270.999
-5337.986
47.214
48.000
49.000
50.000
51.000
52.000
53.000
54.231
t (s)

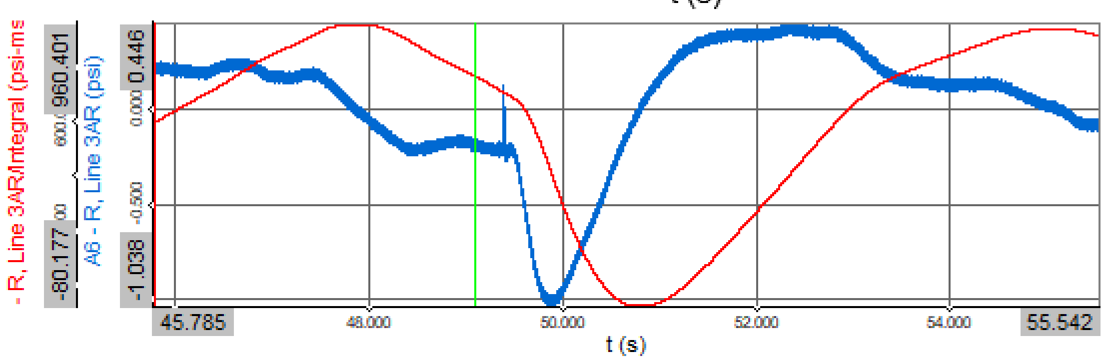

B5 - R, Line P3 (psi)
0.685
0.3
-0.114
0.660
-0.094
1958.263
1955.063
49.370
49.375
49.38
49.385
t (s)

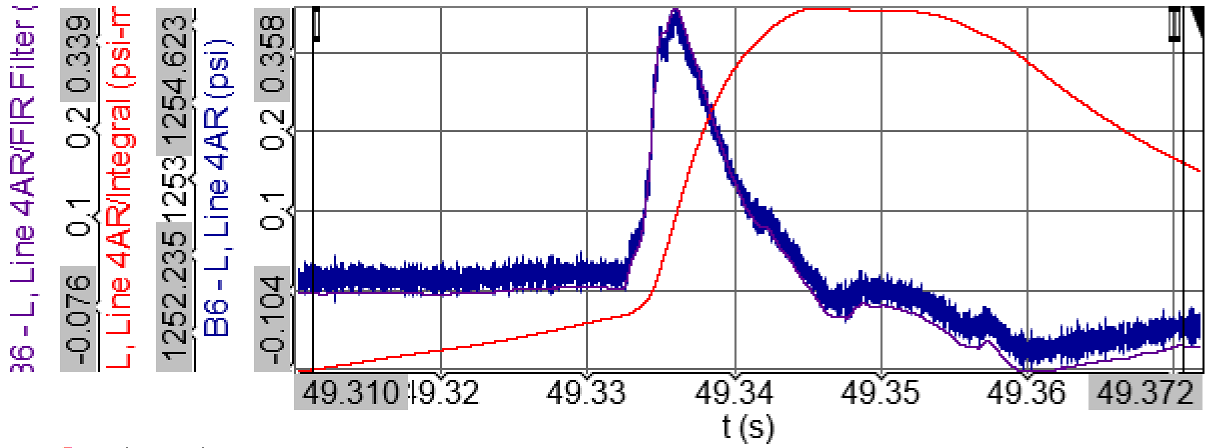

B5 - R, Line P3 (psi)
3.762
-7.014
2004.444
-6168.291
47.214
48.000
49.000
50.000
51.000
52.000
53.000
54.231
t (s)

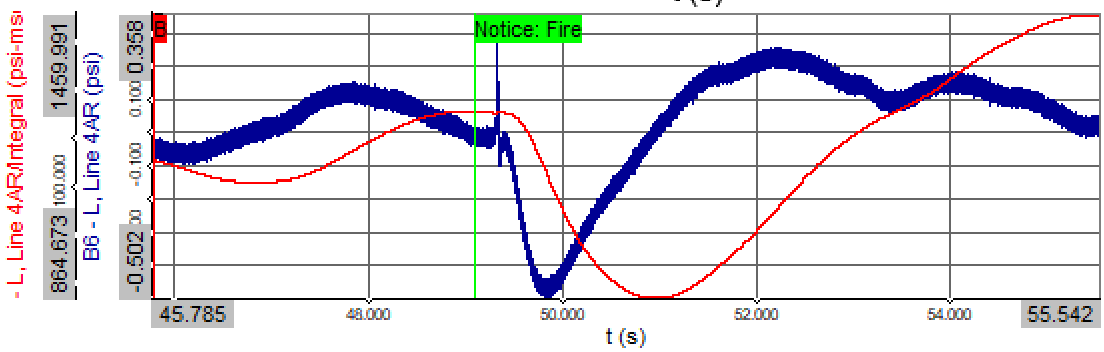

A6 - L, Line 4DL/FIR Filter
L, Line 4DL/Integral (psi-m
A6 - L, Line 4DL (psi)
49.310
49.32
49.33
49.34
49.35
49.36
49.372
t (s)

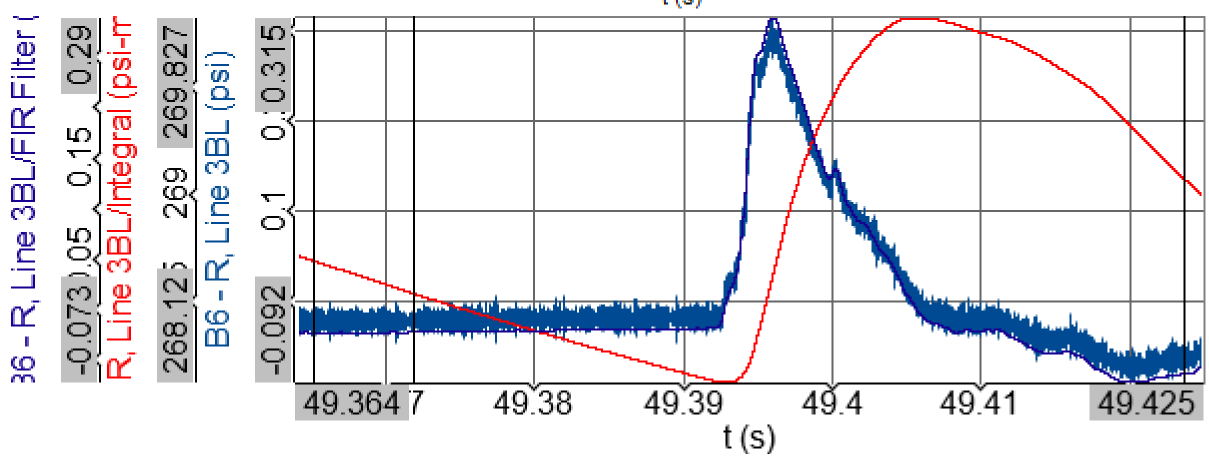

Notice: Fire
- L, Line 4DL/Integral (psi-ms
A6 - L, Line 4DL (psi)
45.785
48.000
50.000
52.000
54.000
55.542
t (s)

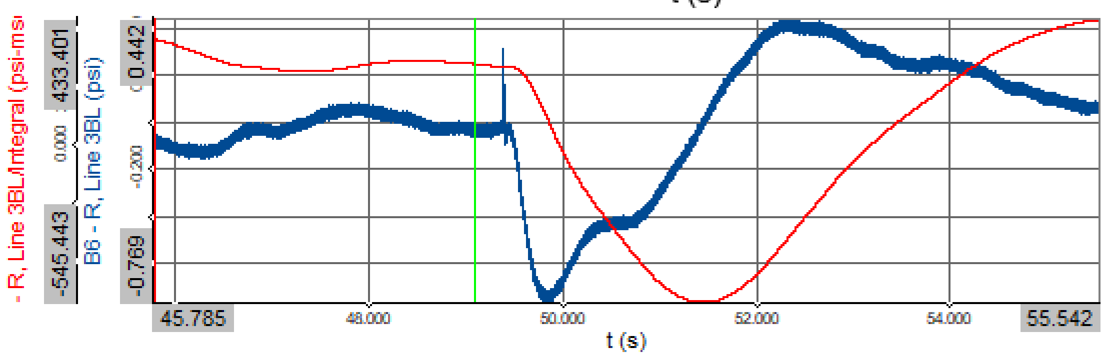

A6 - R, Line 3AR/FIR Filter
R, Line 3AR/Integral (psi-m
A6 - R, Line 3AR (psi)
49.364
49.38
49.39
49.4
49.41
49.425
t (s)

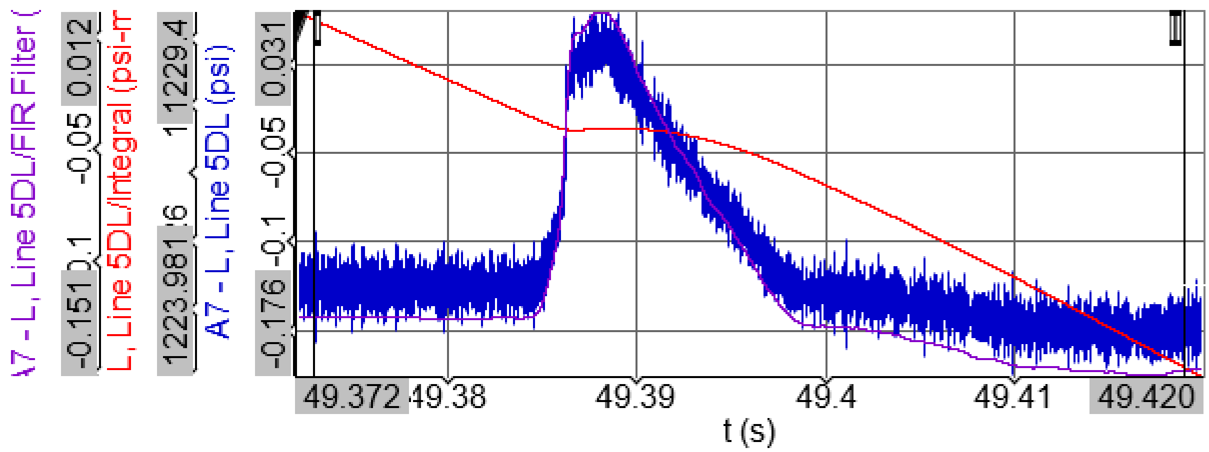

- R, Line 3AR/Integral (psi-ms
A6 - R, Line 3AR (psi)
45.785
48.000
50.000
52.000
54.000
55.542
t (s)

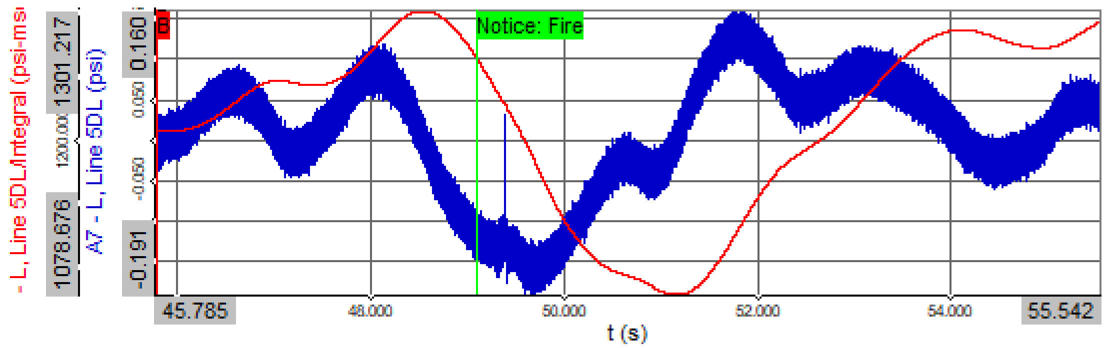

36 - L, Line 4AR/FIR Filter (
L, Line 4AR/Integral (psi-m
B6 - L, Line 4AR (psi)
-0.076
0.1
0.2
0.339
1252.235
1253
1254.623
-0.104
0.358
49.310
49.33
49.34
49.35
49.36
49.372
t (s)

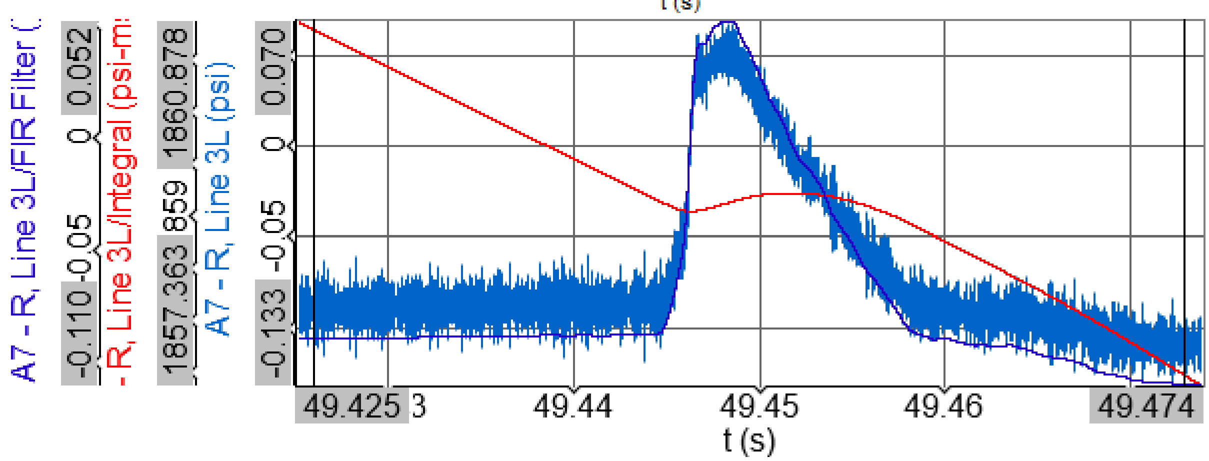

- L, Line 4AR/Integral (psi-ms
B6 - L, Line 4AR (psi)
864.673
1459.991
-0.502
0.358
Notice: Fire
45.785
48.000
50.000
52.000
54.000
55.542
t (s)

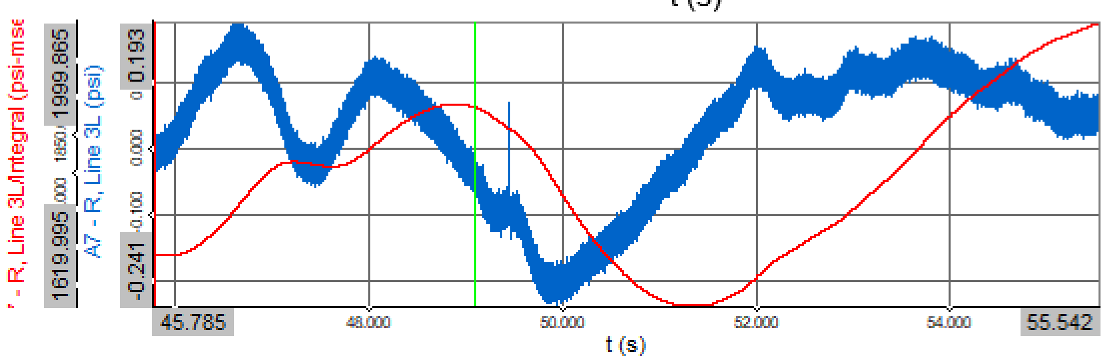

36 - R, Line 3BL/FIR Filter (
R, Line 3BL/Integral (psi-m
B6 - R, Line 3BL (psi)
-0.073
0.15
0.29
269
269.827
-0.092
0.1
0.315
49.364
49.38
49.39
49.4
49.41
49.425
t (s)

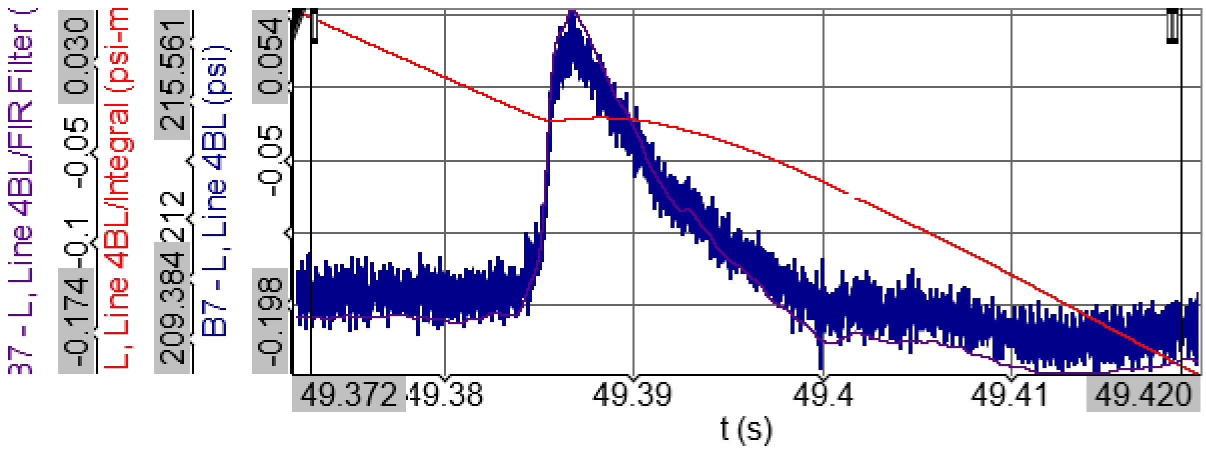

- R, Line 3BL/Integral (psi-ms
B6 - R, Line 3BL (psi)
-545.443
0.000
433.401
-0.769
-0.200
0.442
45.785
48.000
50.000
52.000
54.000
55.542
t (s)

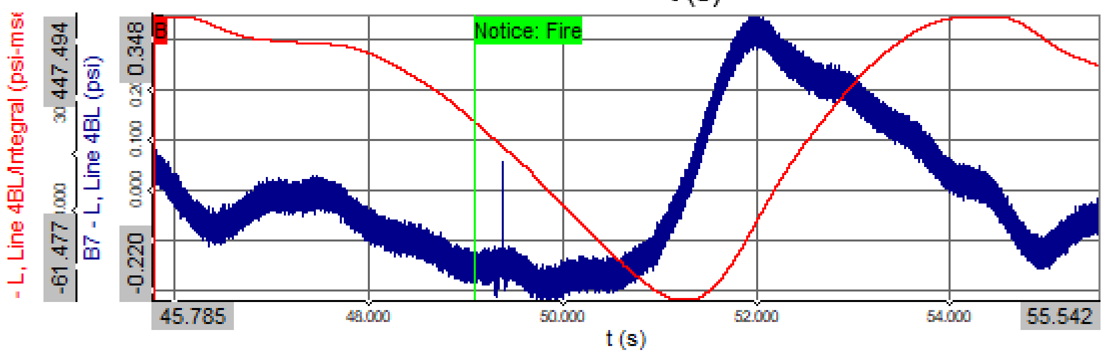

A7 - L, Line 5DL/FIR Filter (
L, Line 5DL/Integral (psi-m
A7 - L, Line 5DL (psi)
49.372
49.38
49.39
49.4
49.41
49.420
t (s)

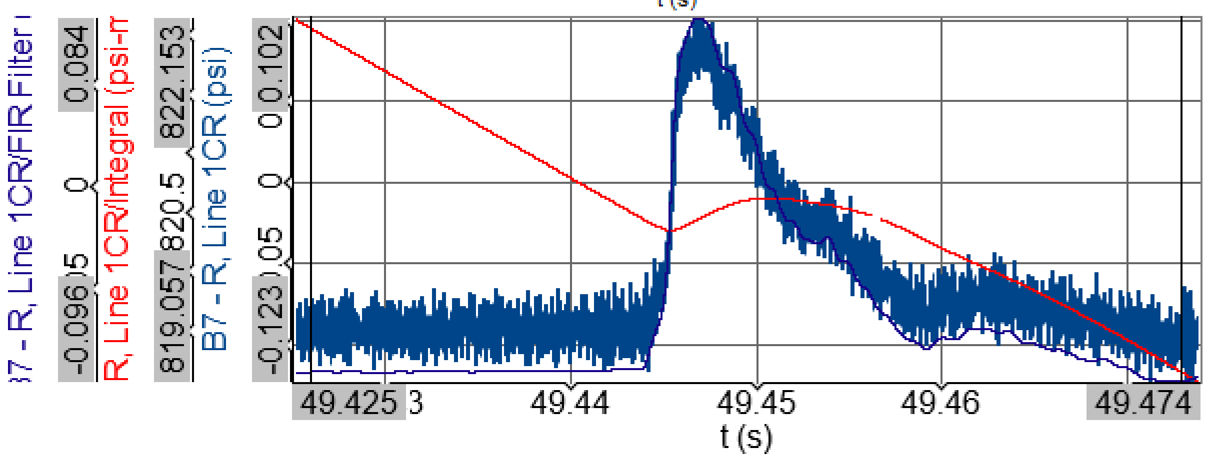

- L, Line 5DL/Integral (psi-ms
A7 - L, Line 5DL (psi)
Notice: Fire
45.785
48.000
50.000
52.000
54.000
55.542
t (s)

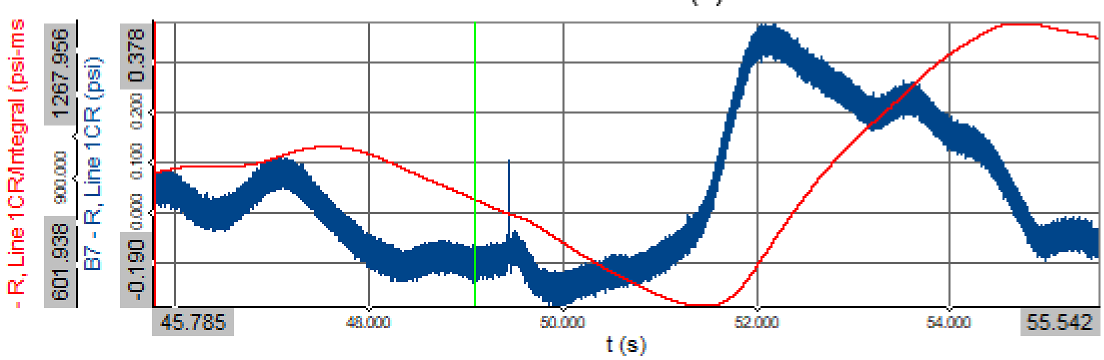

A7 - R, Line 3L/FIR Filter (
- R, Line 3L/Integral (psi-m
A7 - R, Line 3L (psi)
49.425
49.44
49.45
49.46
49.474
t (s)

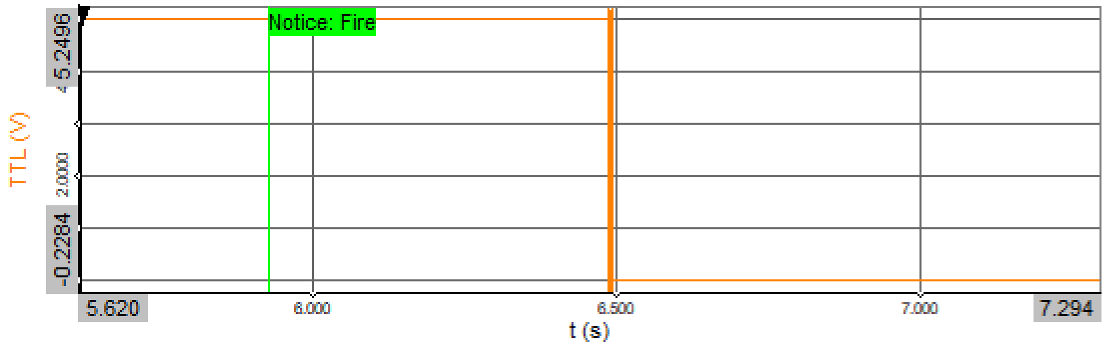

- R, Line 3L/Integral (psi-ms
A7 - R, Line 3L (psi)
45.785
48.000
50.000
52.000
54.000
55.542
t (s)


B7 - L, Line 4BL (psi)
49.372
49.38
49.39
49.4
49.41
49.420
t (s)


Notice: Fire
B7 - L, Line 4BL (psi)
45.785
48.000
50.000
52.000
54.000
55.542
t (s)

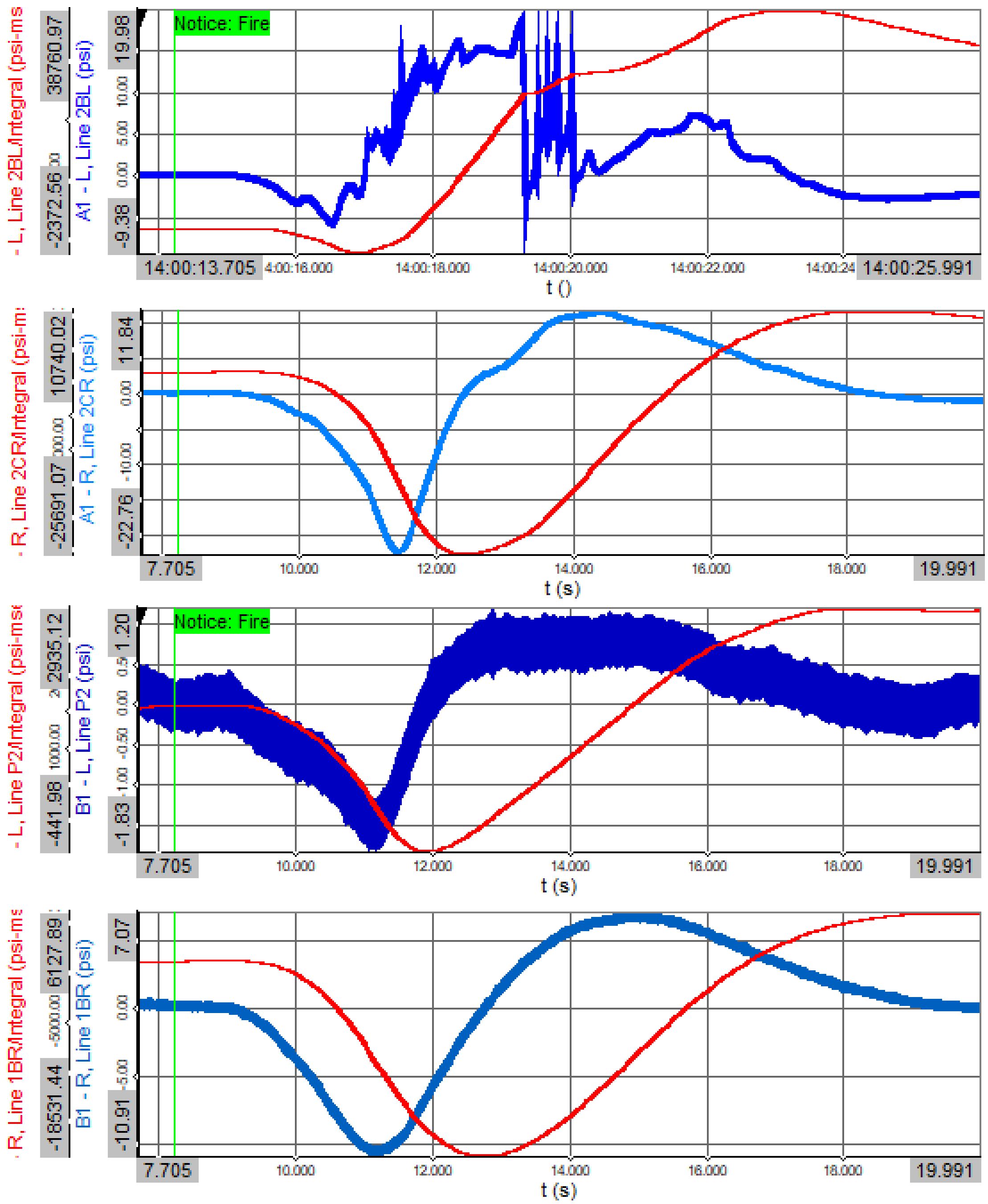

B7 - R, Line 1CR (psi)
49.425
49.44
49.45
49.46
49.474
t (s)

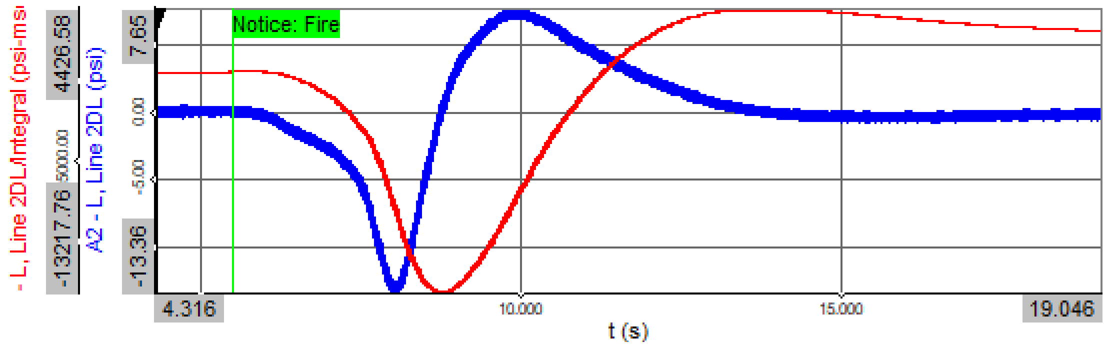

B7 - R, Line 1CR (psi)
45.785
48.000
50.000
52.000
54.000
55.542
t (s)

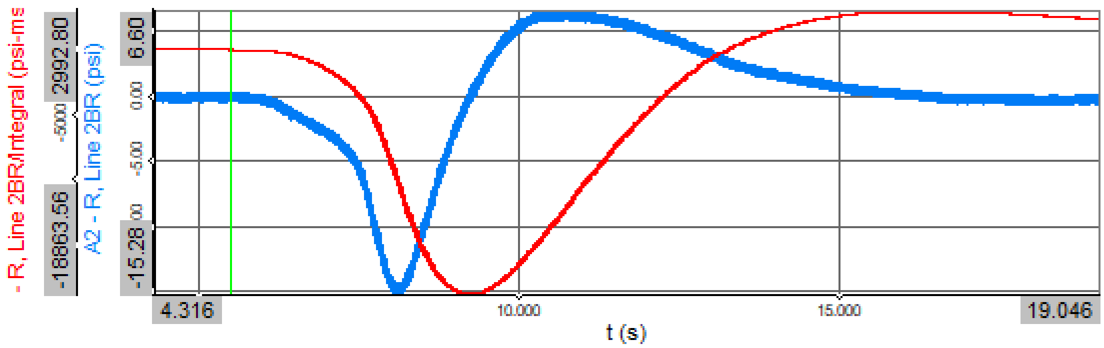

Notice: Fire
TTL (V)
5.2496
2.0000
-0.2284
5.620
6.000
6.500
7.000
7.294
t (s)

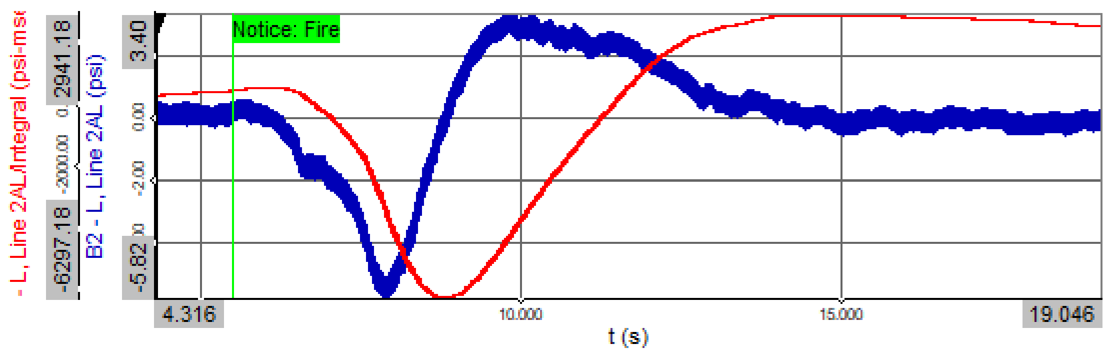
8.4 Fine Al-SnO_2 Thermite – Small-Scale Mix ID #19 (SMS mixed)

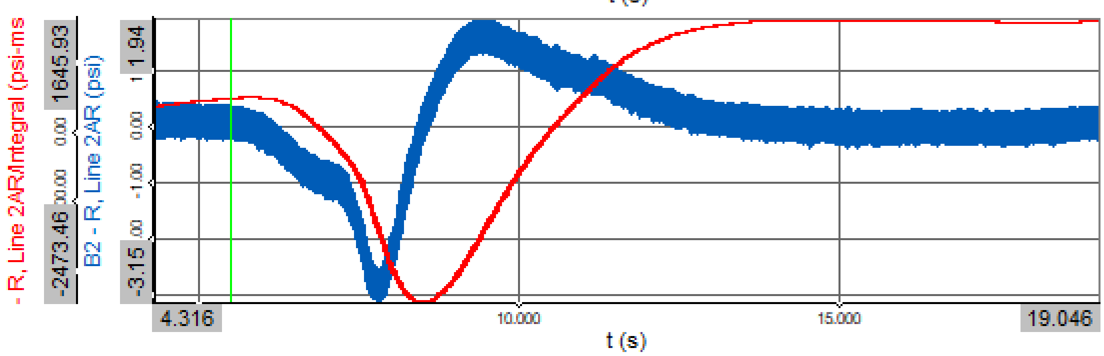
8.4.1 Trial 1 for Small-Scale Mix ID #19

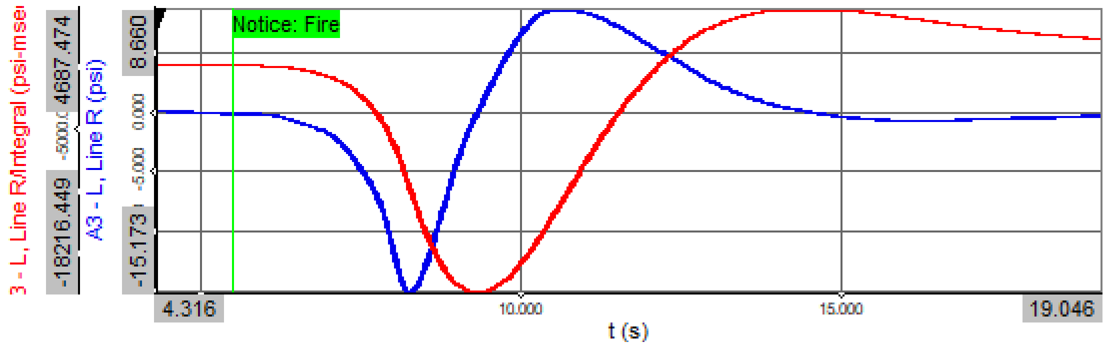


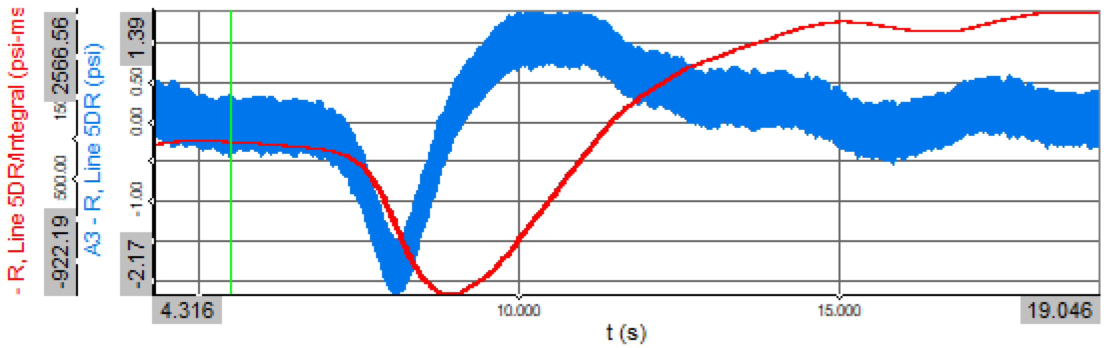

- L, Line 2DL/Integral (psi-ms
4426.58
-13217.76
A2 - L, Line 2DL (psi)
7.65
0.00
-5.00
-13.36
Notice: Fire
4.316
10.000
15.000
19.046
t (s)

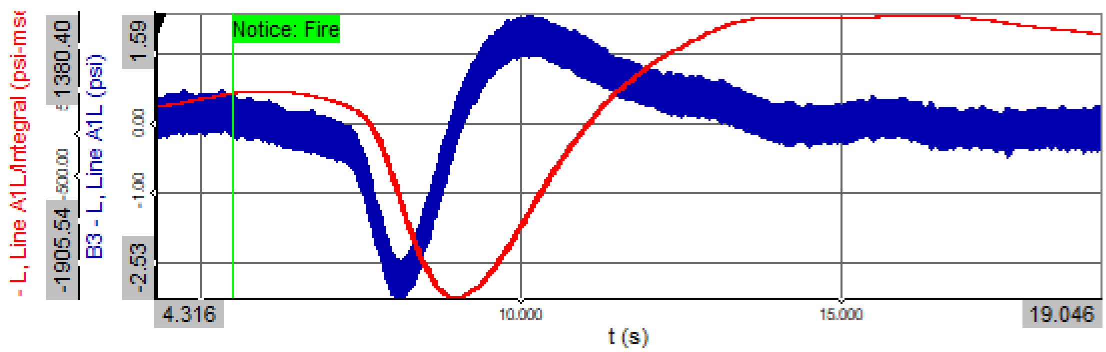

- R, Line 2BR/Integral (psi-ms
2992.80
-18863.56
A2 - R, Line 2BR (psi)
6.60
0.00
-5.00
-15.28
4.316
10.000
15.000
19.046
t (s)

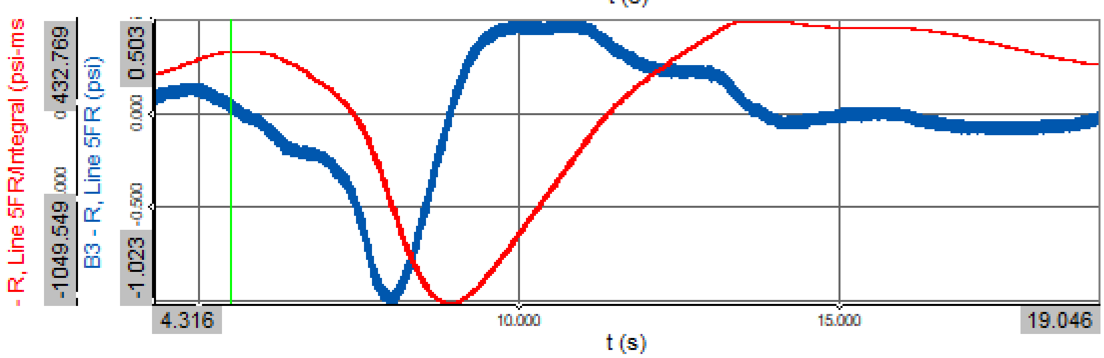

- L, Line 2AL/Integral (psi-ms
2941.18
-6297.18
B2 - L, Line 2AL (psi)
3.40
0.00
-2.00
-5.82
Notice: Fire
4.316
10.000
15.000
19.046
t (s)

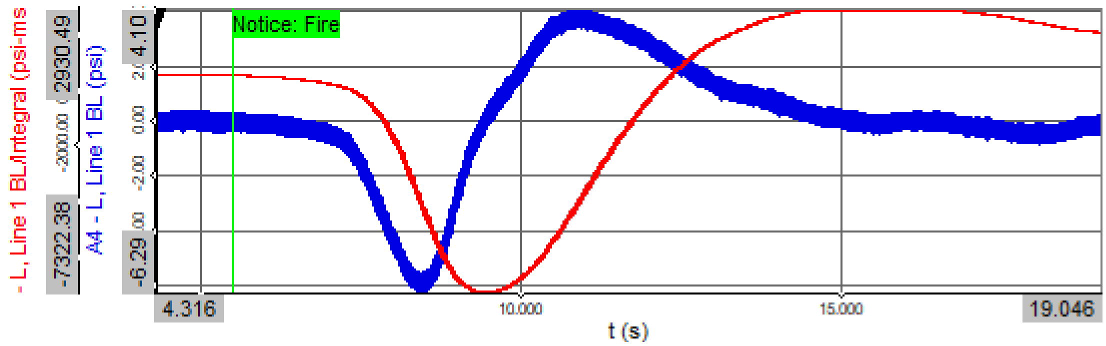

- R, Line 2AR/Integral (psi-ms
1645.93
-2473.46
B2 - R, Line 2AR (psi)
1.94
0.00
-1.00
-3.15
4.316
10.000
15.000
19.046
t (s)

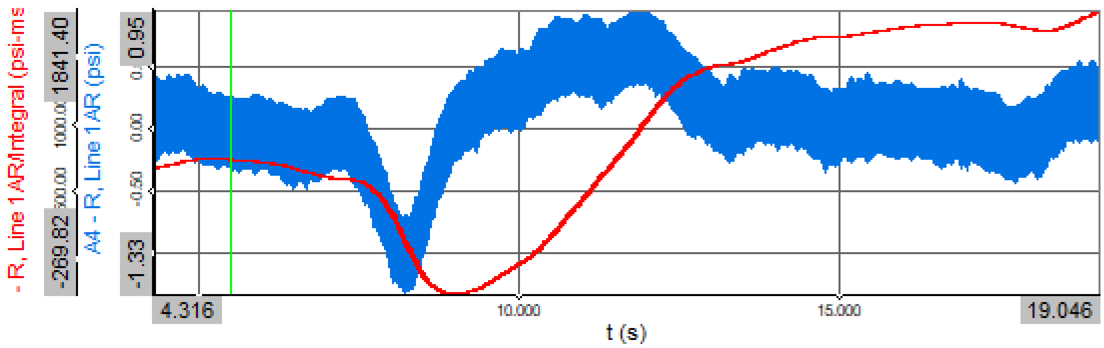

3 - L, Line R/Integral (psi-mse
A3 - L, Line R (psi)
Notice: Fire
8.660
4687.474
0.000
-5.000
-15.173
-18216.449
4.316
10.000
15.000
19.046
t (s)

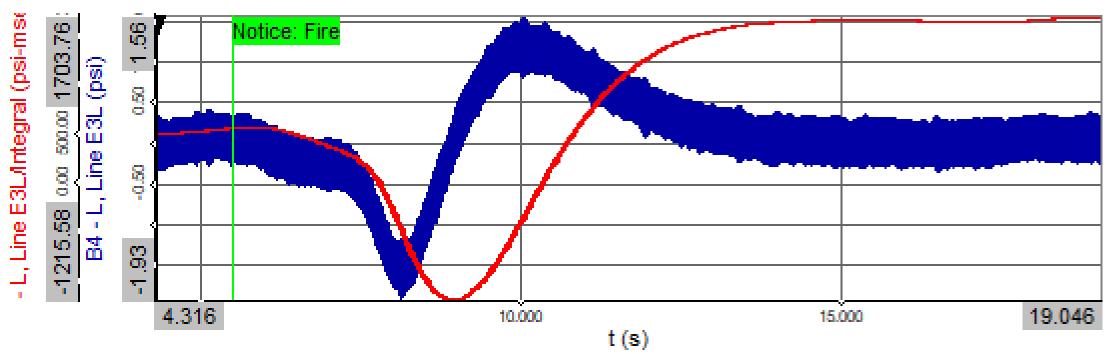

- R, Line 5DR/Integral (psi-ms
A3 - R, Line 5DR (psi)
1.39
2566.56
0.50
0.00
500.00
-1.00
-2.17
-922.19
4.316
10.000
15.000
19.046
t (s)

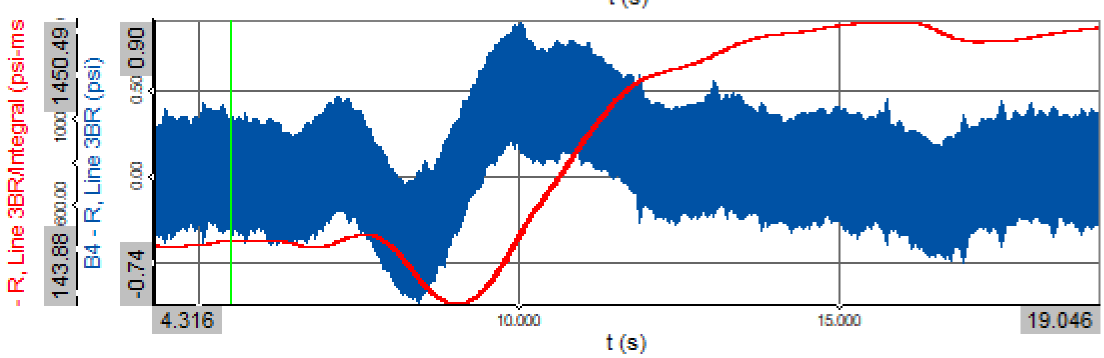

- L, Line A1L/Integral (psi-ms
B3 - L, Line A1L (psi)
Notice: Fire
1.59
1380.40
0.00
-500.00
-1.00
-2.53
-1905.54
4.316
10.000
15.000
19.046
t (s)

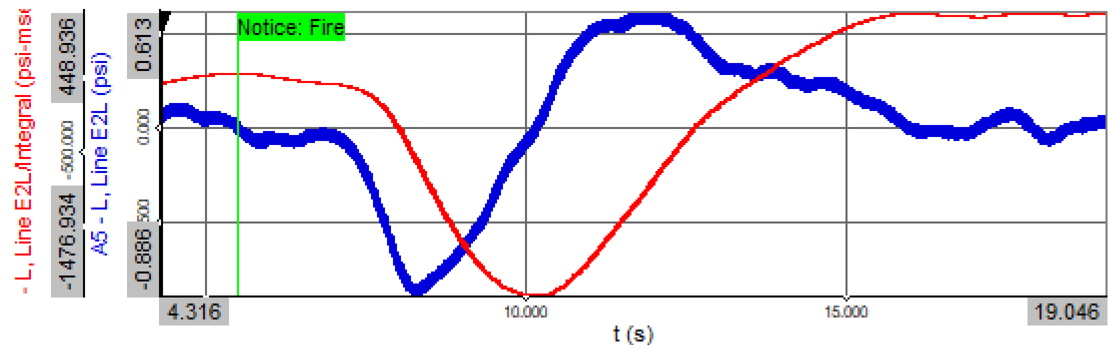

- R, Line 5FR/Integral (psi-ms
B3 - R, Line 5FR (psi)
0.503
432.769
0.000
-0.500
-1.023
-1049.549
4.316
10.000
15.000
19.046
t (s)

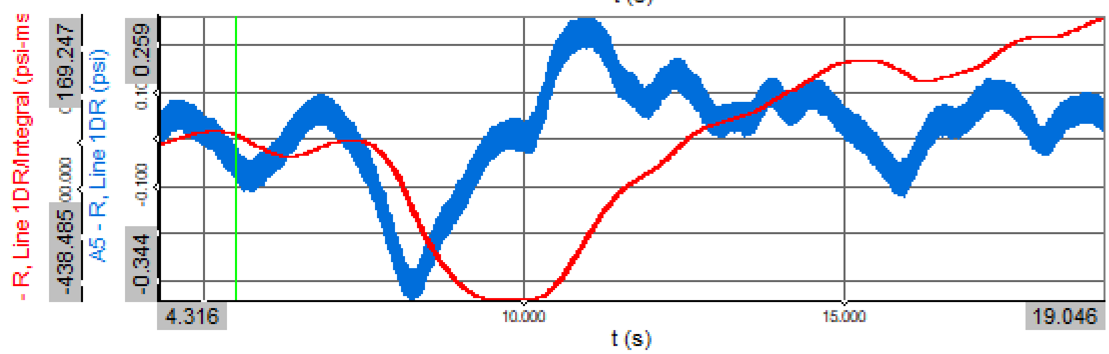

- L, Line 1 BL/Integral (psi-ms
A4 - L, Line 1 BL (psi)
2930.49
-7322.38
4.10
-6.29
Notice: Fire
4.316
10.000
15.000
19.046
t (s)

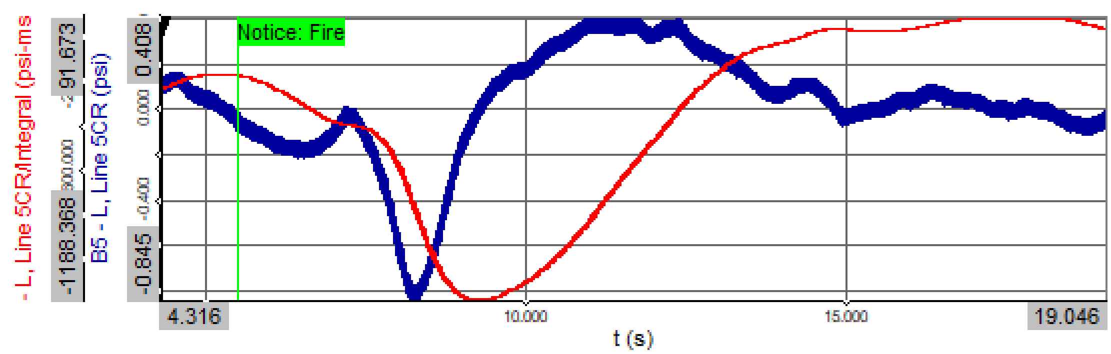

- R, Line 1 AR/Integral (psi-ms
A4 - R, Line 1 AR (psi)
1841.40
-269.82
0.95
-1.33
4.316
10.000
15.000
19.046
t (s)

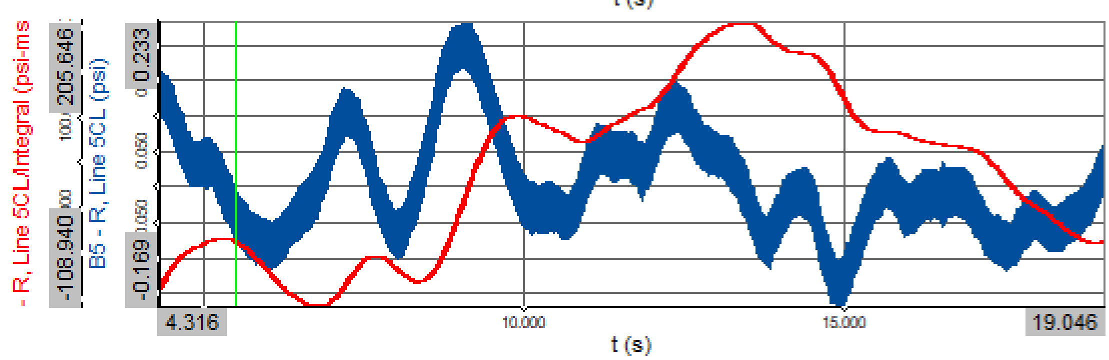

- L, Line E3L/Integral (psi-ms
B4 - L, Line E3L (psi)
1703.76
-1215.58
1.56
-1.93
Notice: Fire
4.316
10.000
15.000
19.046
t (s)

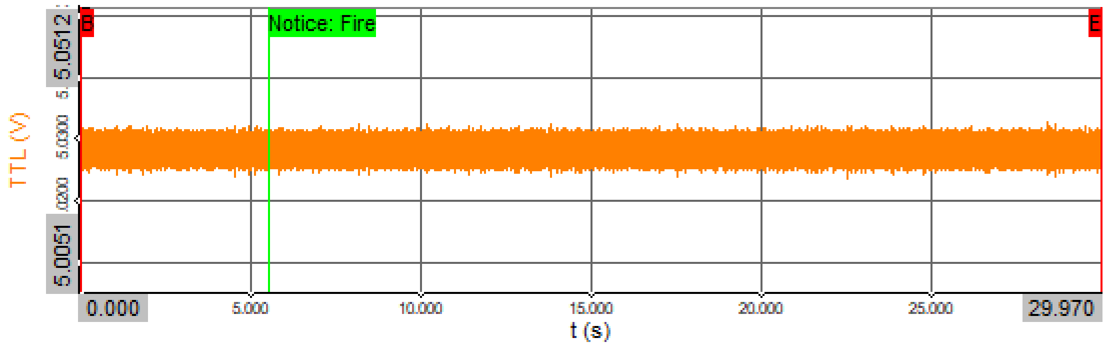

- R, Line 3BR/Integral (psi-ms
B4 - R, Line 3BR (psi)
1450.49
143.88
0.90
-0.74
4.316
10.000
15.000
19.046
t (s)


Notice: Fire
A5 - L, Line E2L (psi)
0.613
-0.886
448.936
-1476.934
4.316
10.000
15.000
19.046
t (s)

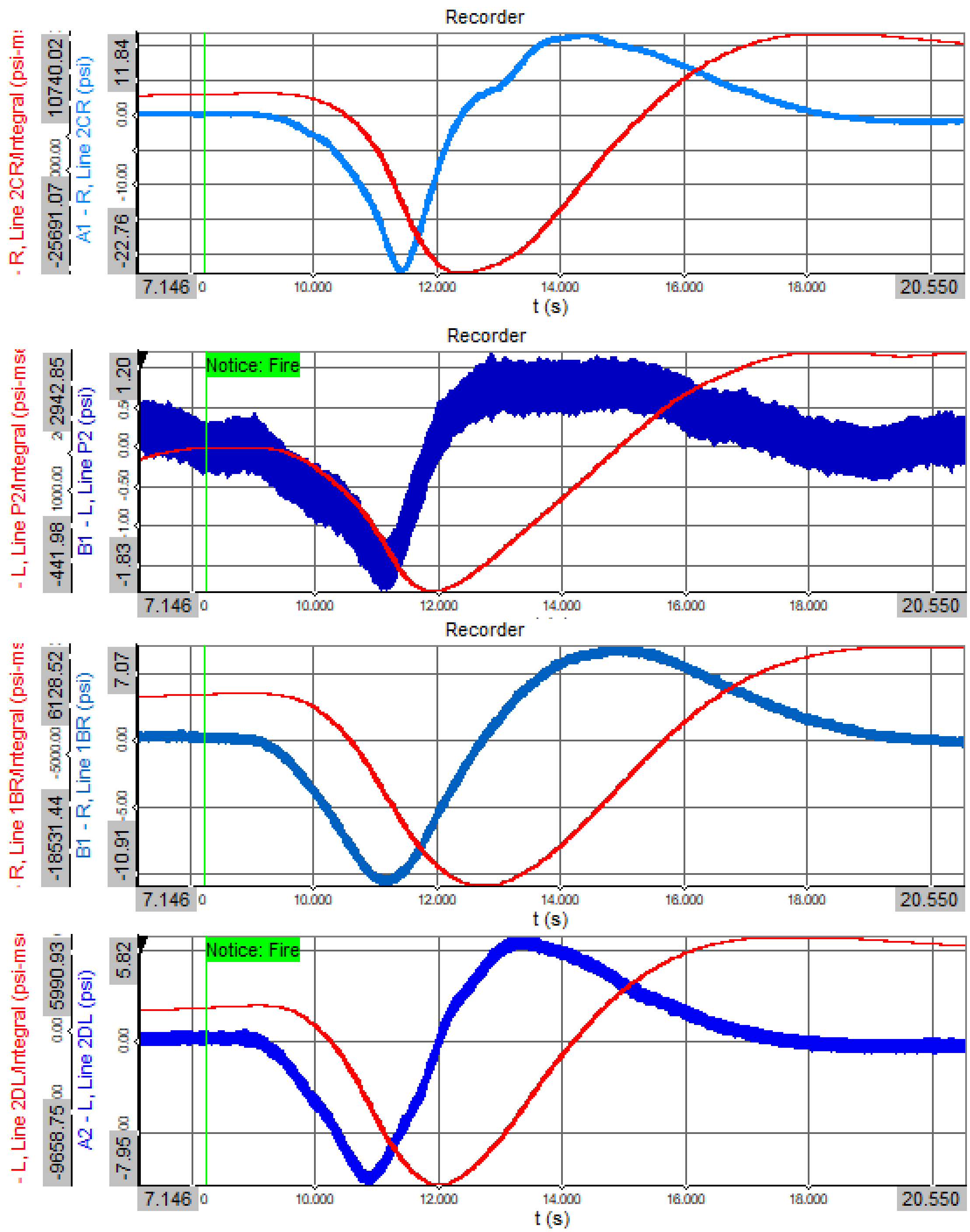

- R, Line 1DR/Integral (psi-ms
A5 - R, Line 1DR (psi)
0.259
-0.344
169.247
-438.485
4.316
10.000
15.000
19.046
t (s)

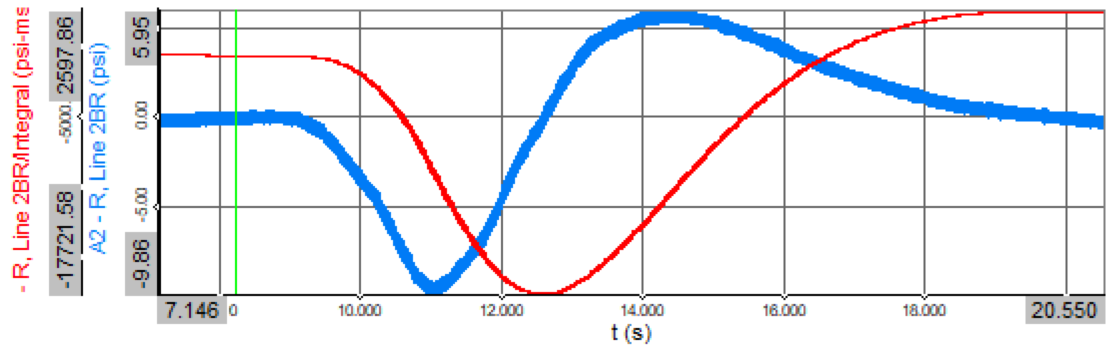

Notice: Fire
- L, Line 5CR/Integral (psi-ms
B5 - L, Line 5CR (psi)
0.408
-0.845
91.673
-1188.368
4.316
10.000
15.000
19.046
t (s)

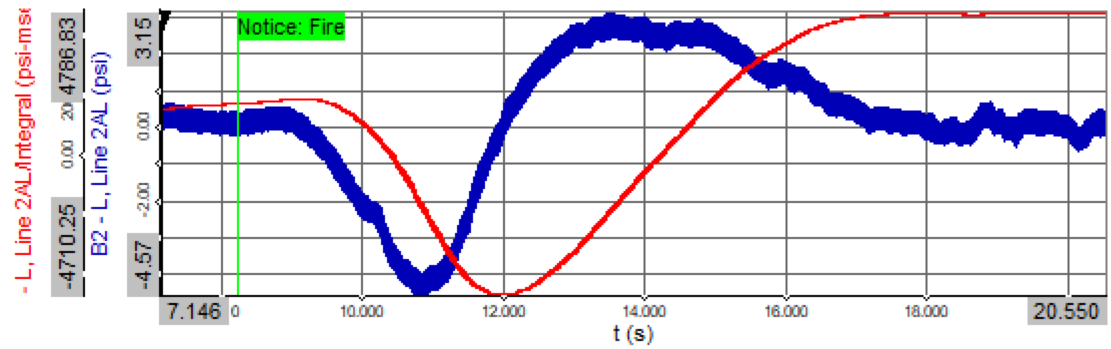

- R, Line 5CL/Integral (psi-ms
B5 - R, Line 5CL (psi)
0.233
-0.169
205.646
-108.940
4.316
10.000
15.000
19.046
t (s)

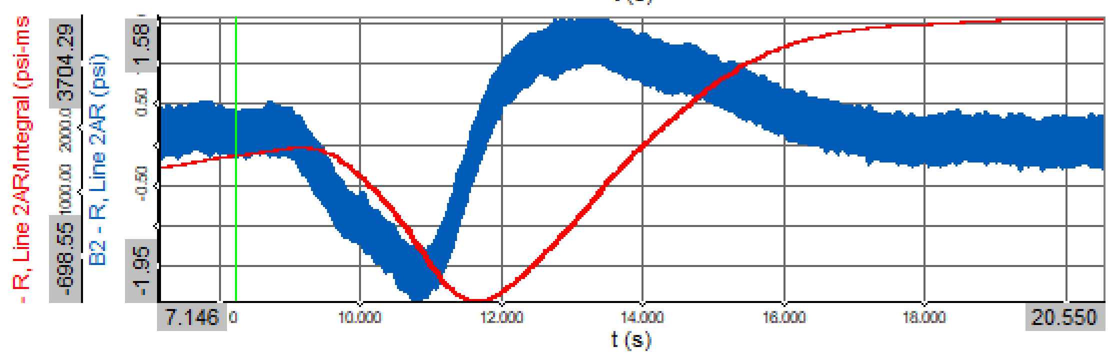

Notice: Fire
B
E
TTL (V)
5.0512
5.0051
0.000
5.000
10.000
15.000
20.000
25.000
29.970
t (s)

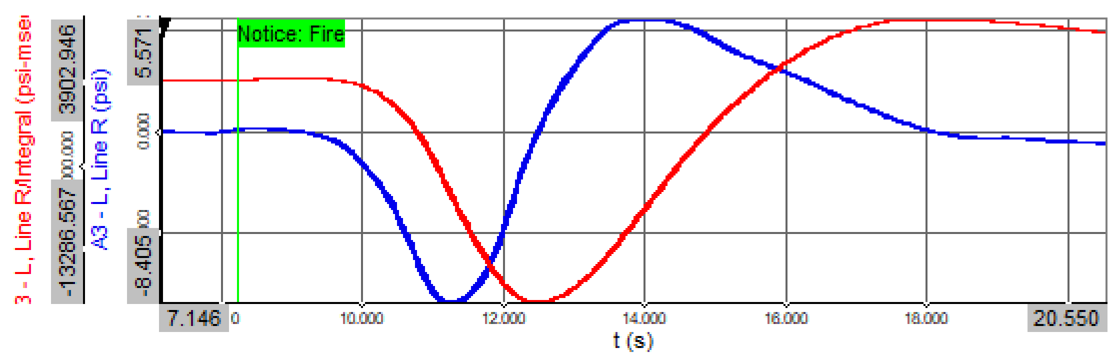
8.4.2 Trial 2 for Small-Scale Mix ID #19

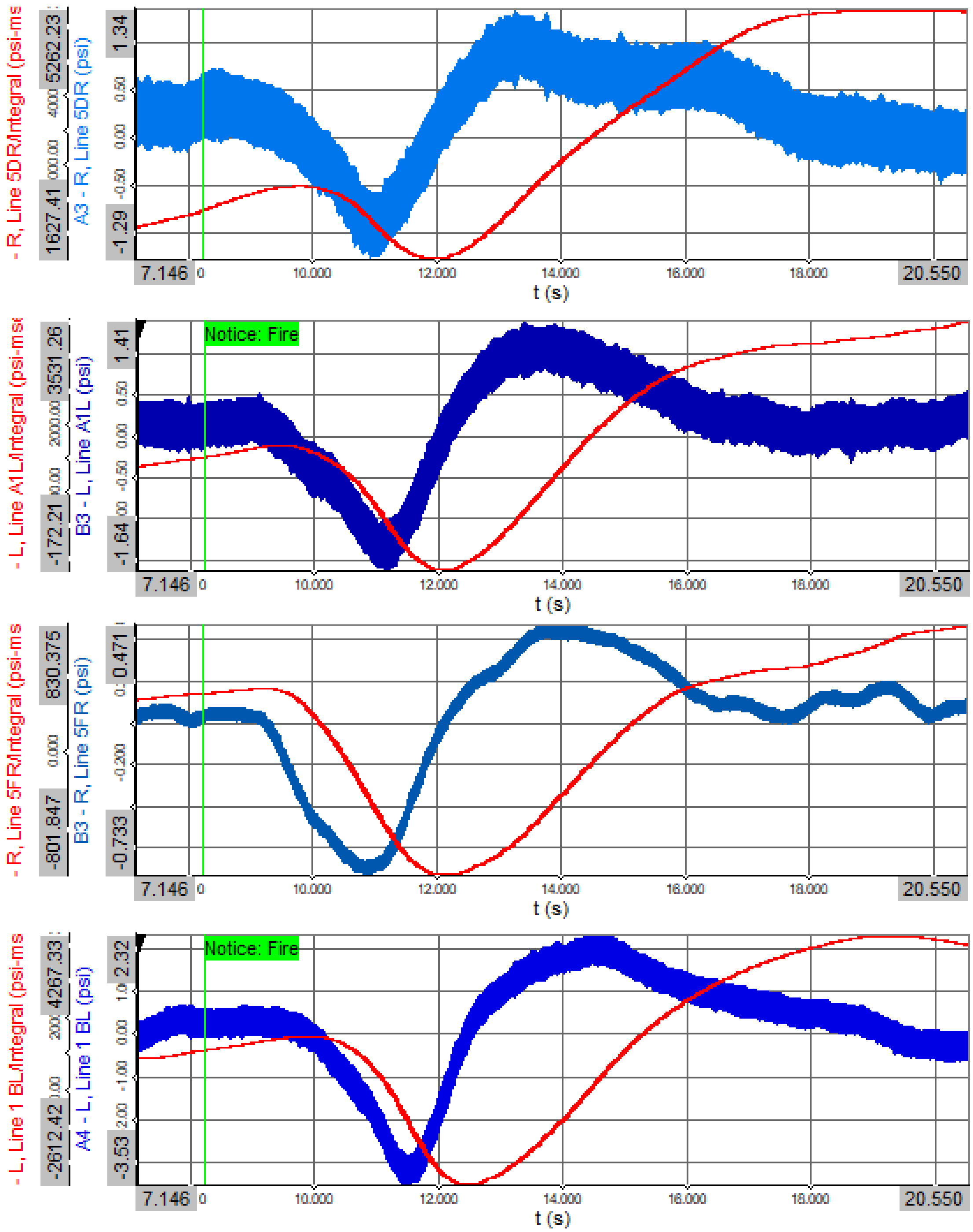


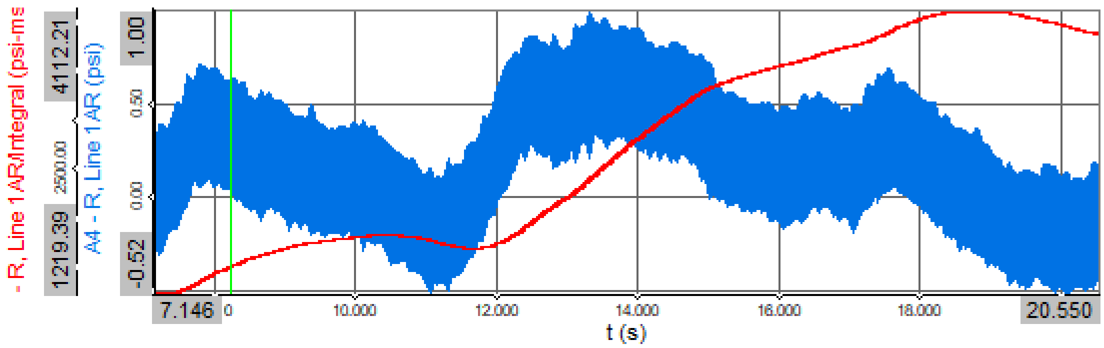

A2 - R, Line 2BR (psi)
- R, Line 2BR/Integral (psi-ms
5.95
0.00
-5.00
-9.86
2597.86
-5000
-17721.58
7.146
10.000
12.000
14.000
16.000
18.000
20.550
t (s)

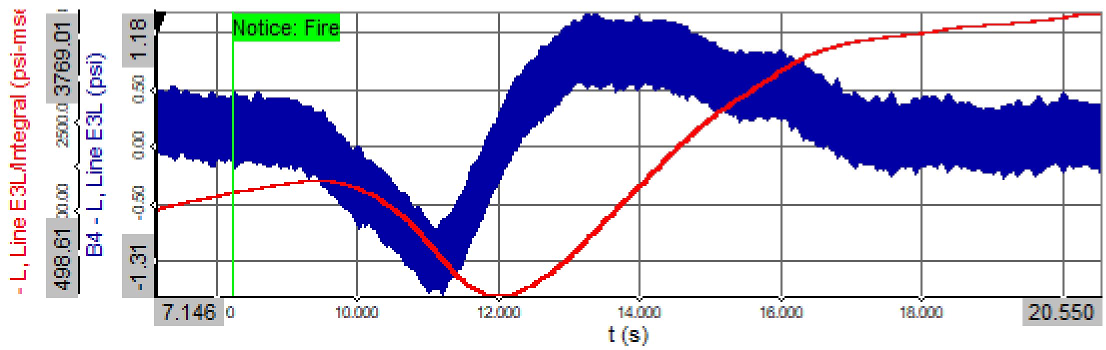

Notice: Fire
B2 - L, Line 2AL (psi)
- L, Line 2AL/Integral (psi-ms
3.15
0.00
-2.00
-4.57
4786.83
0.00
-4710.25
7.146
10.000
12.000
14.000
16.000
18.000
20.550
t (s)

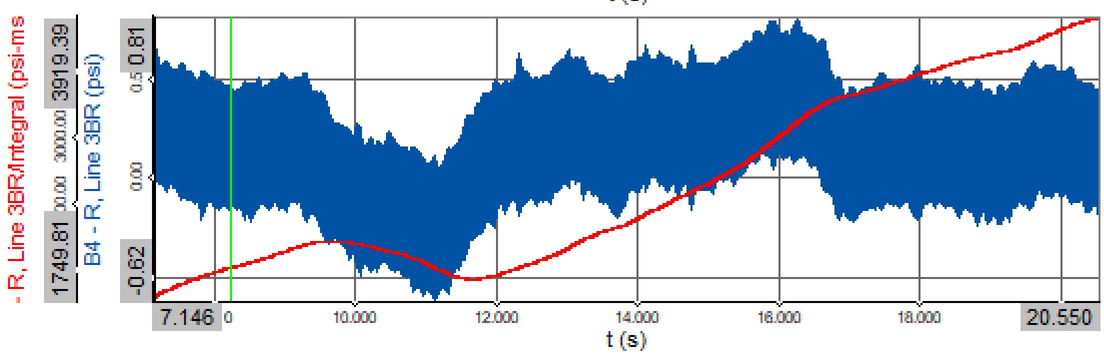

B2 - R, Line 2AR (psi)
- R, Line 2AR/Integral (psi-ms
1.58
0.50
-0.50
-1.95
3704.29
2000.0
1000.00
-698.55
7.146
10.000
12.000
14.000
16.000
18.000
20.550
t (s)

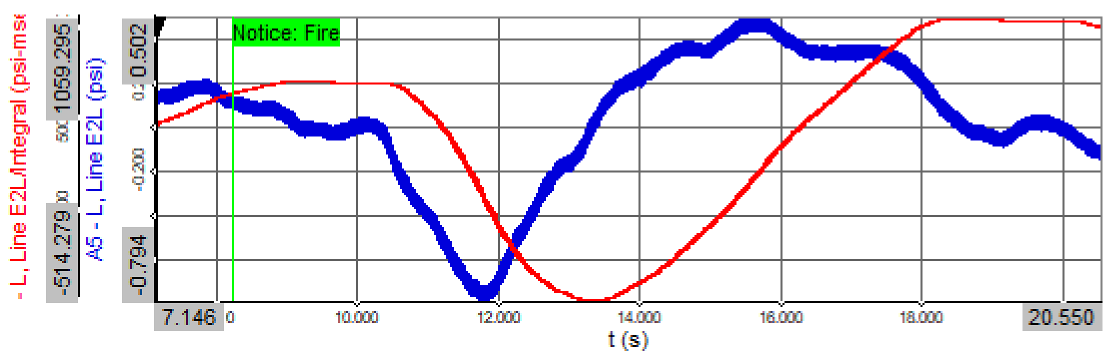

Notice: Fire
A3 - L, Line R (psi)
3 - L, Line R/Integral (psi-mse
5.571
0.000
-8.405
3902.946
-13286.567
7.146
10.000
12.000
14.000
16.000
18.000
20.550
t (s)

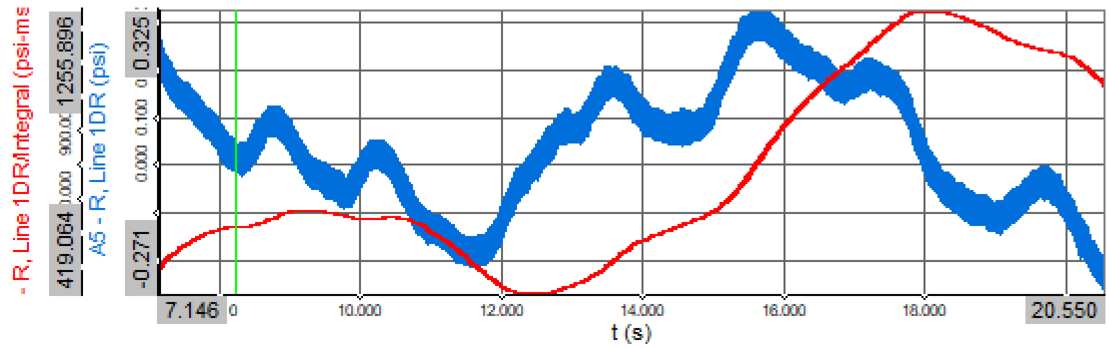

A3 - R, Line 5DR (psi)
- R, Line 5DR/Integral (psi-ms
Notice: Fire
B3 - L, Line A1L (psi)
- L, Line A1L/Integral (psi-ms
B3 - R, Line 5FR (psi)
- R, Line 5FR/Integral (psi-ms
A4 - L, Line 1 BL (psi)
- L, Line 1 BL/Integral (psi-ms
7.146
20.550
t (s)

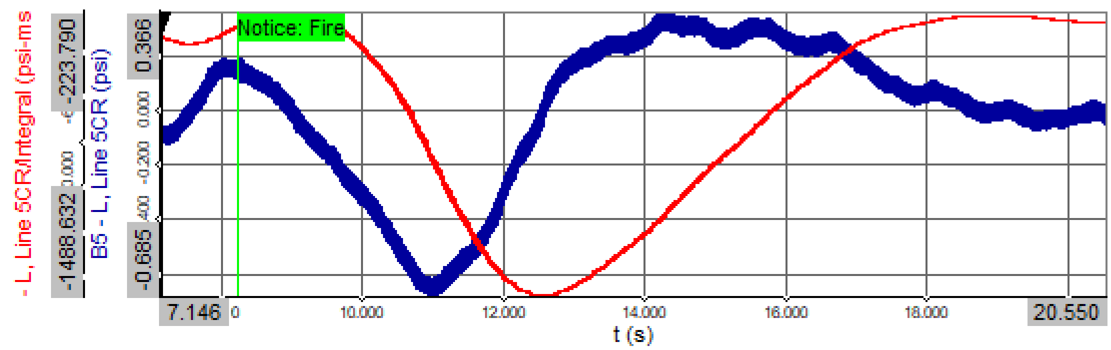

- R, Line 1AR/Integral (psi-ms
A4 - R, Line 1AR (psi)
4112.21
2500.00
1219.39
1.00
0.50
0.00
-0.52
7.146
10.000
12.000
14.000
16.000
18.000
20.550
t (s)

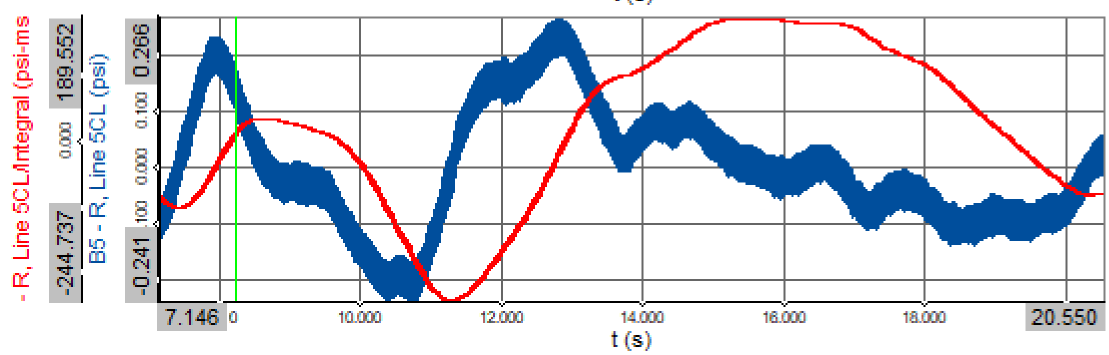

- L, Line E3L/Integral (psi-ms
B4 - L, Line E3L (psi)
3769.01
498.61
1.18
0.50
0.00
-0.50
-1.31
Notice: Fire
7.146
10.000
12.000
14.000
16.000
18.000
20.550
t (s)

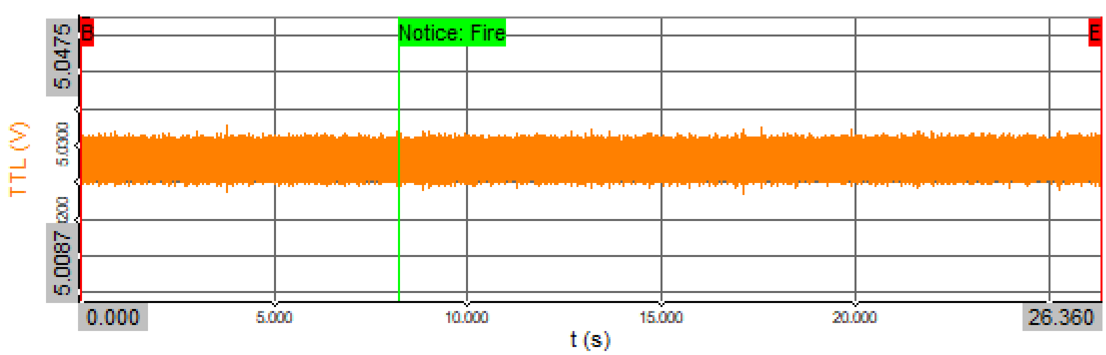

- R, Line 3BR/Integral (psi-ms
B4 - R, Line 3BR (psi)
3919.39
3000.00
1749.81
0.81
0.00
-0.62
7.146
10.000
12.000
14.000
16.000
18.000
20.550
t (s)


- L, Line E2L/Integral (psi-ms
A5 - L, Line E2L (psi)
1059.295
-514.279
0.502
-0.200
-0.794
Notice: Fire
7.146
10.000
12.000
14.000
16.000
18.000
20.550
t (s)

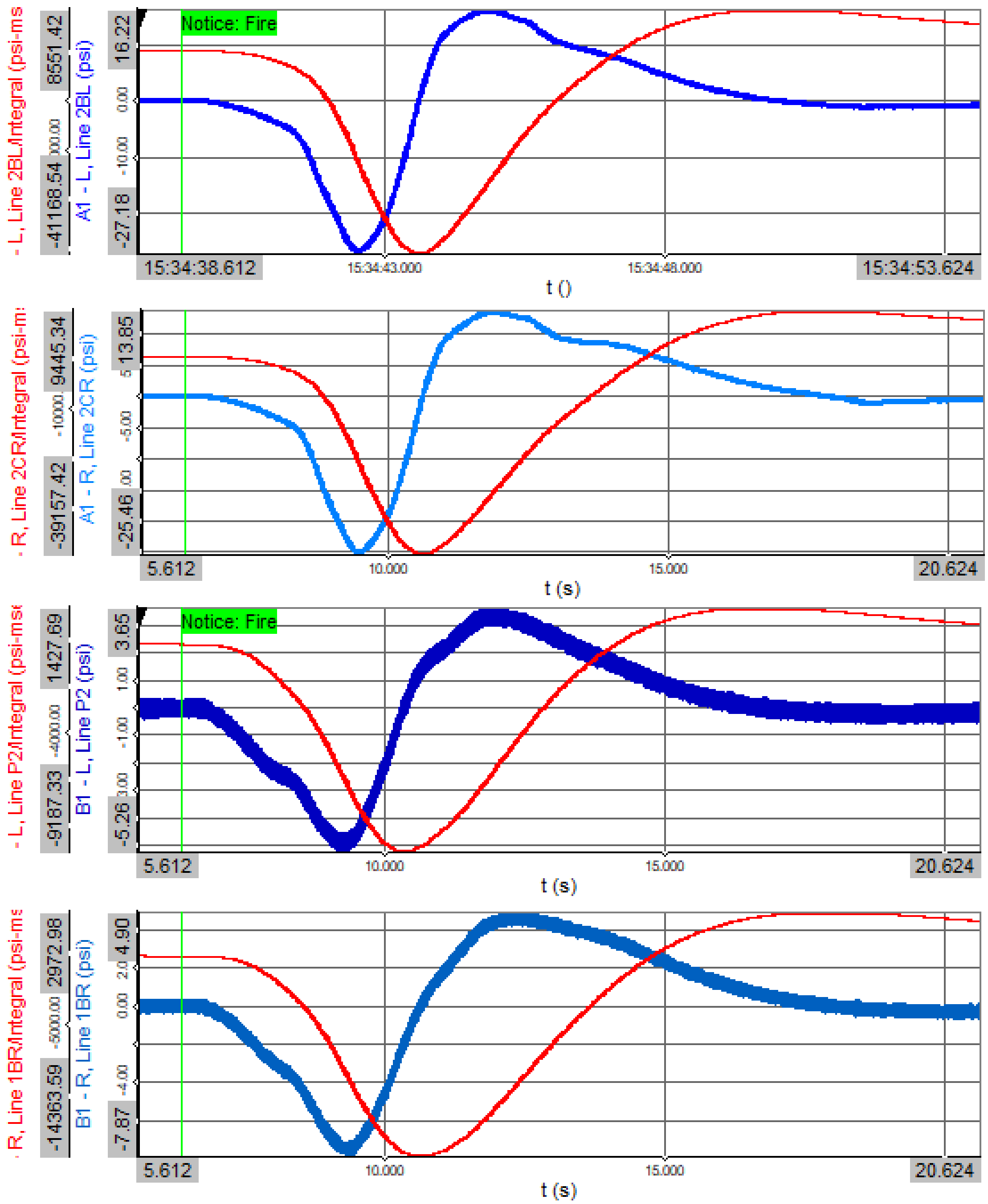

- R, Line 1DR/Integral (psi-ms
A5 - R, Line 1DR (psi)
1255.896
419.064
0.325
-0.271
7.146
10.000
12.000
14.000
16.000
18.000
20.550
t (s)

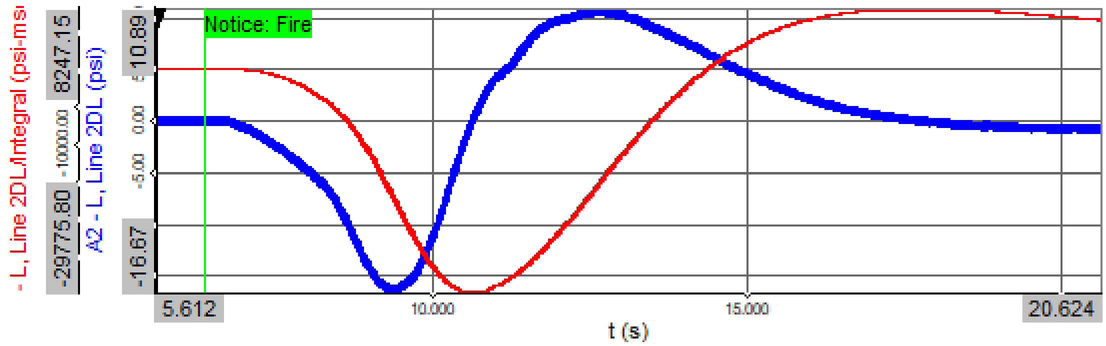

- L, Line 5CR/Integral (psi-ms
B5 - L, Line 5CR (psi)
-223.790
-1488.632
0.366
-0.685
Notice: Fire
7.146
10.000
12.000
14.000
16.000
18.000
20.550
t (s)

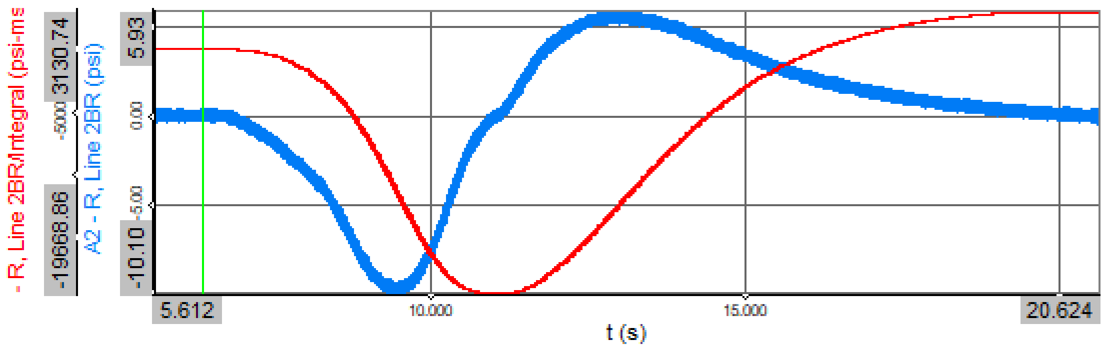

- R, Line 5CL/Integral (psi-ms
B5 - R, Line 5CL (psi)
189.552
-244.737
0.266
-0.241
7.146
10.000
12.000
14.000
16.000
18.000
20.550
t (s)

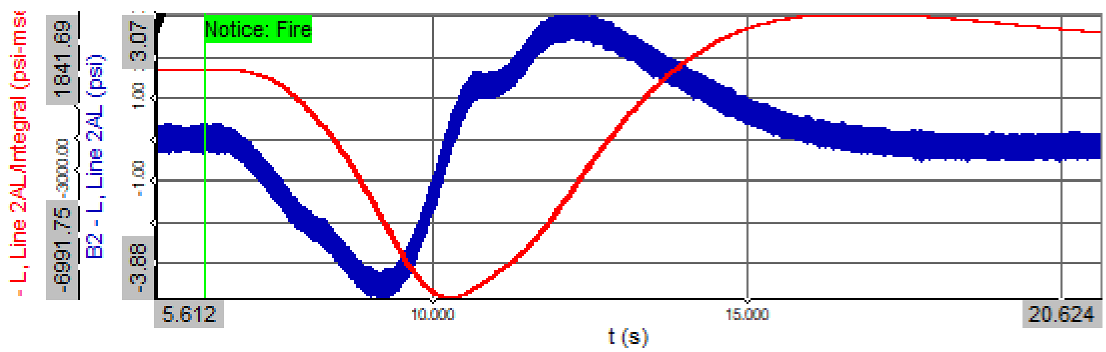

TTL (V)
5.0475
5.0087
Notice: Fire
B
E
0.000
5.000
10.000
15.000
20.000
26.360
t (s)

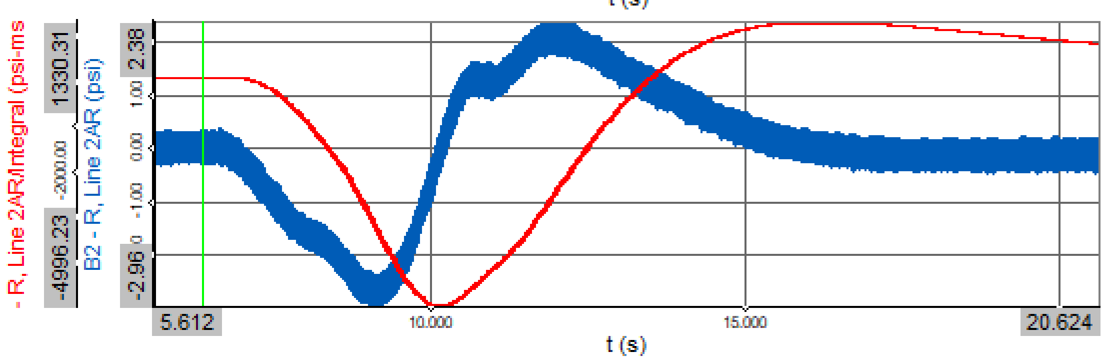
8.4.3 Trial 3 for Small-Scale Mix ID #19

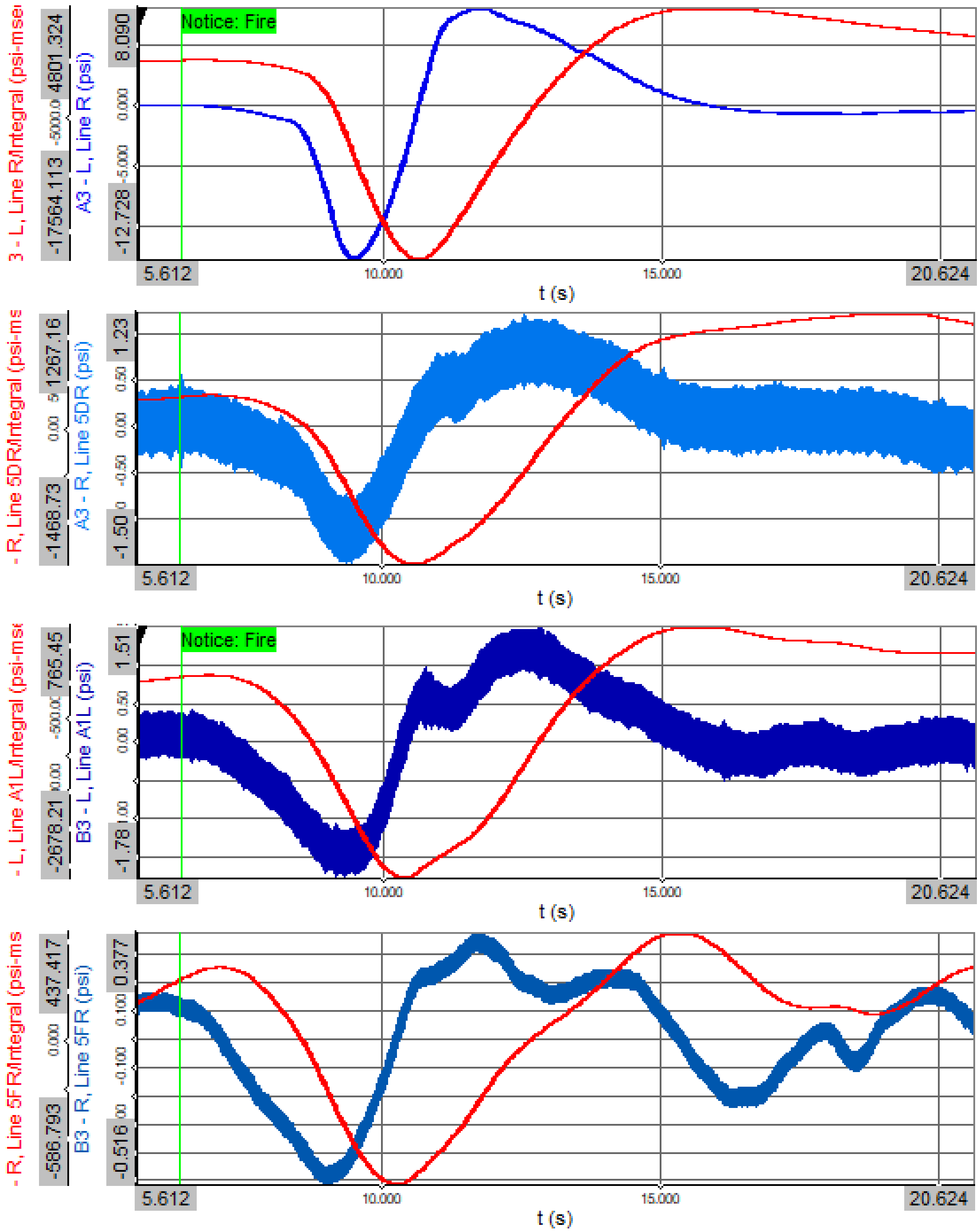


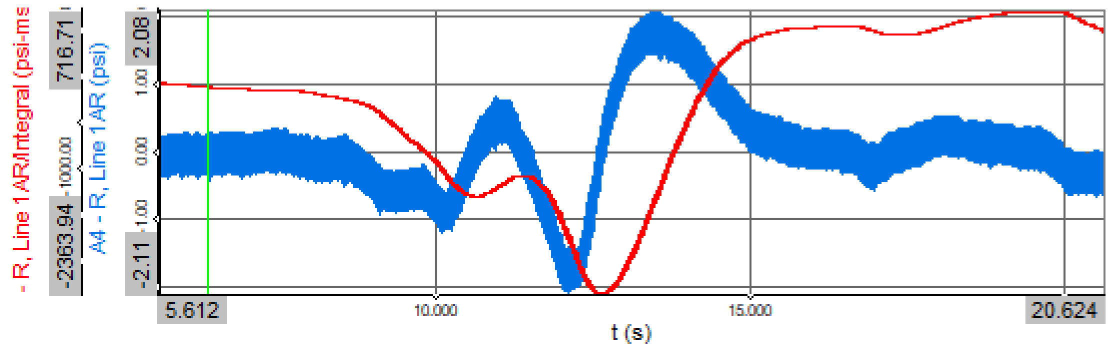

Notice: Fire
- L, Line 2DL/Integral (psi-ms
A2 - L, Line 2DL (psi)
8247.15
-29775.80
10.89
-16.67
5.612
10.000
15.000
20.624
t (s)

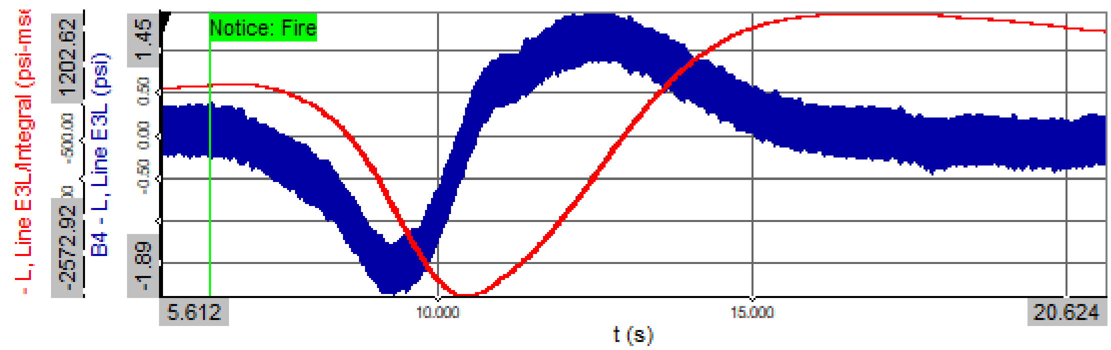

- R, Line 2BR/Integral (psi-ms
A2 - R, Line 2BR (psi)
3130.74
-19668.86
5.93
-10.10
5.612
10.000
15.000
20.624
t (s)

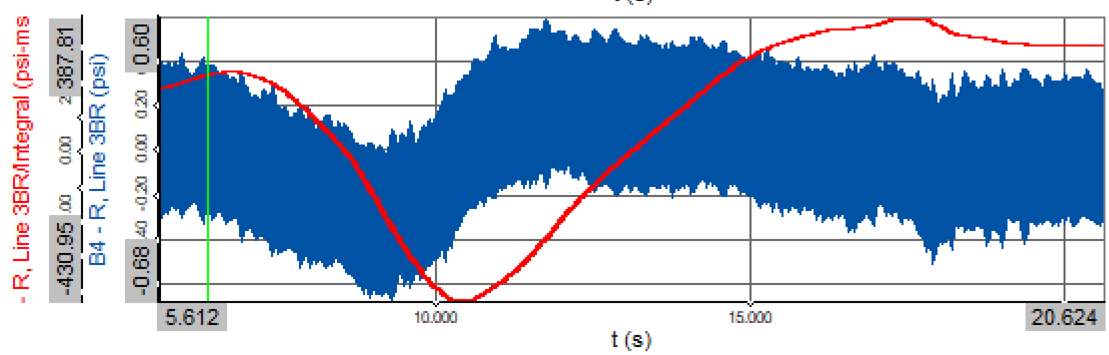

Notice: Fire
- L, Line 2AL/Integral (psi-ms
B2 - L, Line 2AL (psi)
1841.69
-6991.75
3.07
-3.88
5.612
10.000
15.000
20.624
t (s)

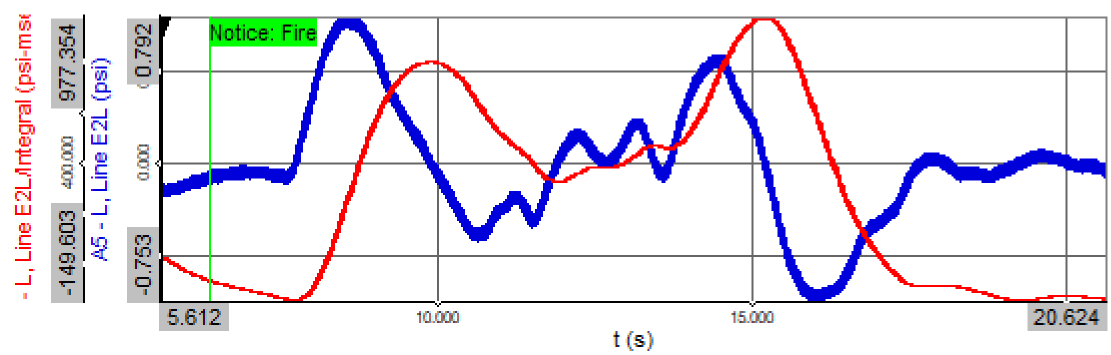

- R, Line 2AR/Integral (psi-ms
B2 - R, Line 2AR (psi)
1330.31
-4996.23
2.38
-2.96
5.612
10.000
15.000
20.624
t (s)

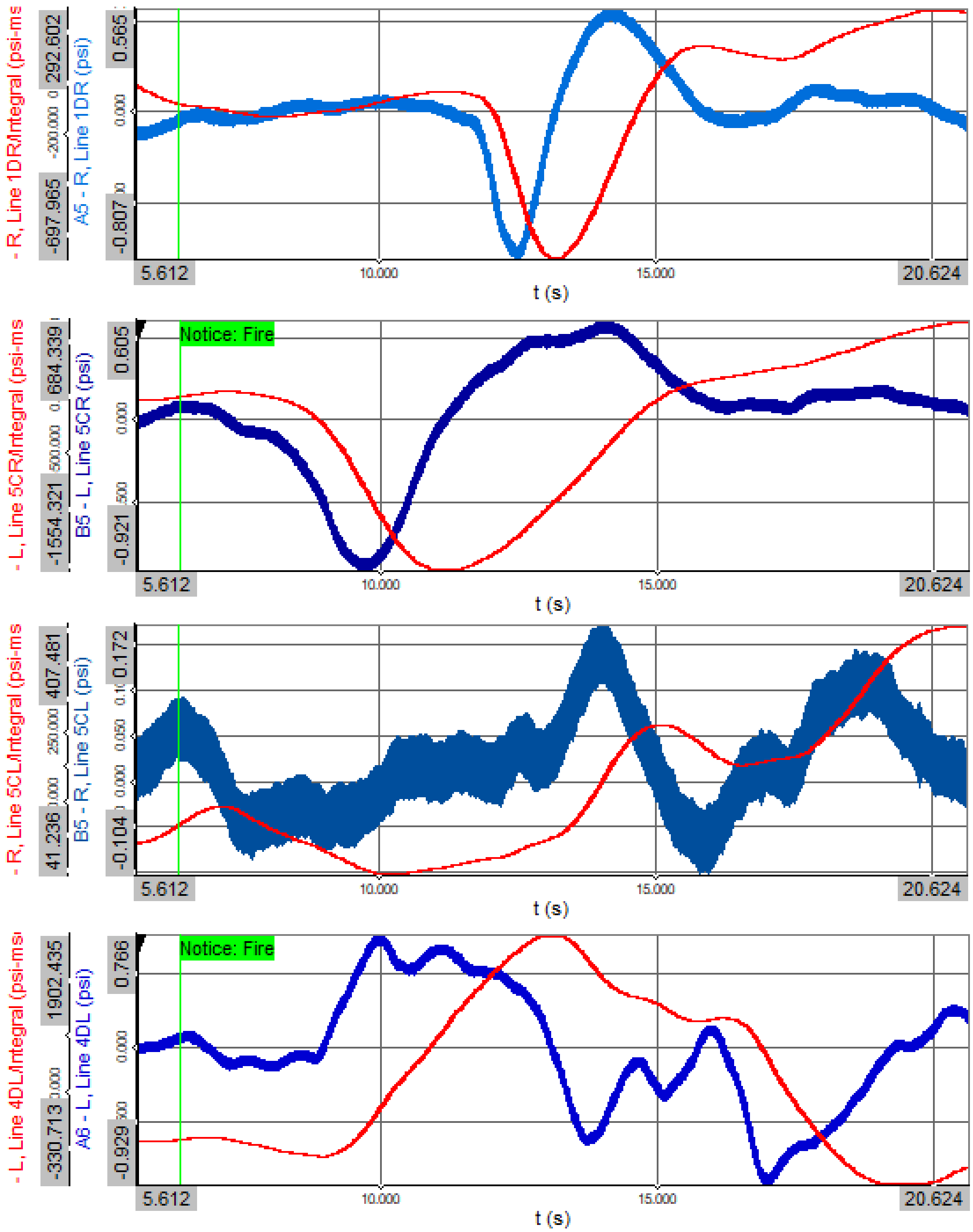

Notice: Fire
A3 - L, Line R (psi)
5.612
10.000
15.000
20.624
t (s)
A3 - R, Line 5DR (psi)
Notice: Fire
B3 - L, Line A1L (psi)
B3 - R, Line 5FR (psi)

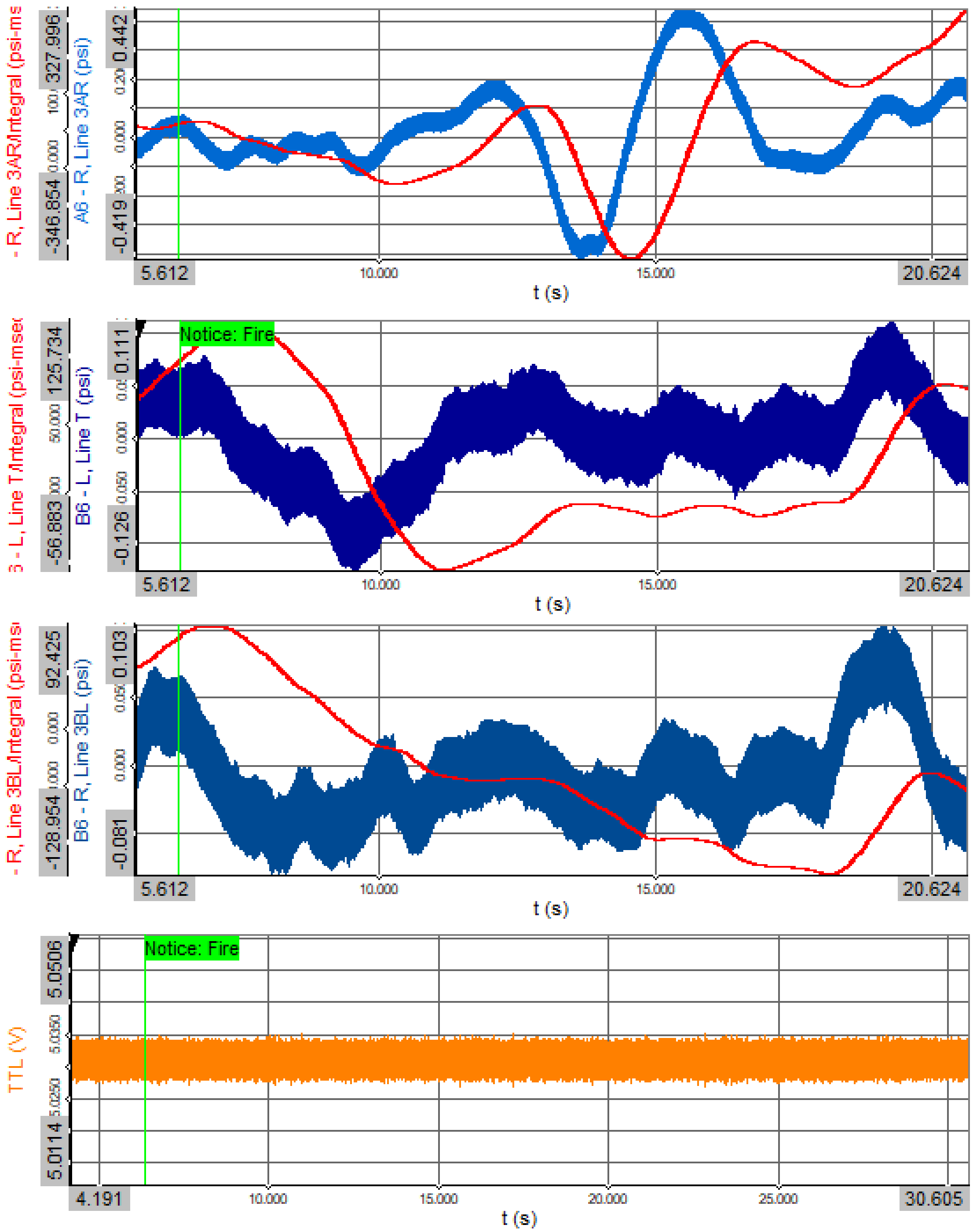

- R, Line 1AR/Integral (psi-ms
716.71
-2363.94
A4 - R, Line 1AR (psi)
2.08
1.00
0.00
-1.00
-2.11
5.612
10.000
15.000
20.624
t (s)


- L, Line E3L/Integral (psi-ms
1202.62
-2572.92
B4 - L, Line E3L (psi)
1.45
0.50
0.00
-0.50
-1.89
Notice: Fire
5.612
10.000
15.000
20.624
t (s)


- R, Line 3BR/Integral (psi-ms
387.81
-430.95
B4 - R, Line 3BR (psi)
0.60
0.20
0.00
-0.20
-0.68
5.612
10.000
15.000
20.624
t (s)

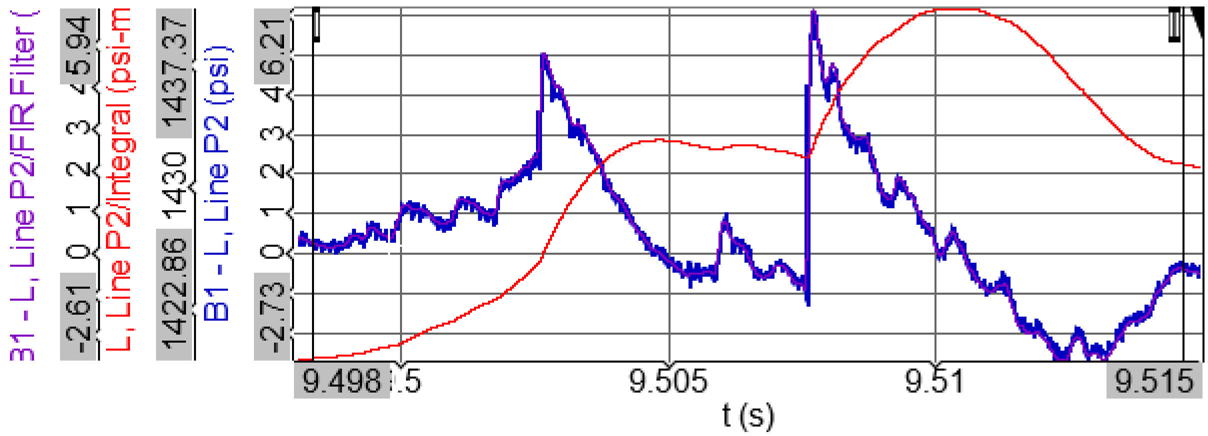

- L, Line E2L/Integral (psi-ms
977.354
-149.603
A5 - L, Line E2L (psi)
0.792
0.000
-0.753
Notice: Fire
5.612
10.000
15.000
20.624
t (s)

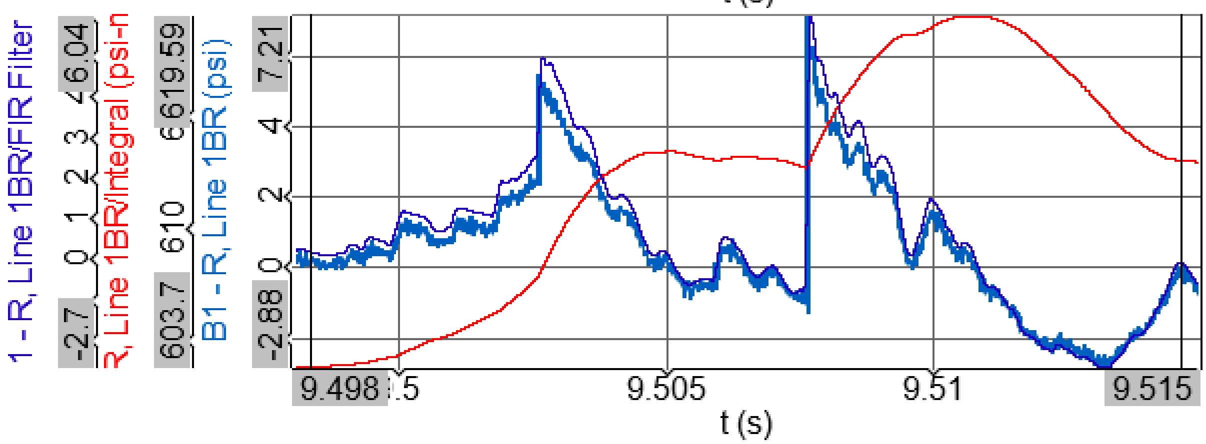

- R, Line 1DR/Integral (psi-ms
A5 - R, Line 1DR (psi)
292.602
-697.965
0.565
-0.807
5.612
10.000
15.000
20.624
t (s)
- L, Line 5CR/Integral (psi-ms
B5 - L, Line 5CR (psi)
684.339
-1554.321
0.605
-0.921
Notice: Fire
5.612
10.000
15.000
20.624
t (s)
- R, Line 5CL/Integral (psi-ms
B5 - R, Line 5CL (psi)
407.481
41.236
0.172
-0.104
5.612
10.000
15.000
20.624
t (s)
- L, Line 4DL/Integral (psi-ms
A6 - L, Line 4DL (psi)
1902.435
-330.713
0.766
-0.929
Notice: Fire
5.612
10.000
15.000
20.624
t (s)

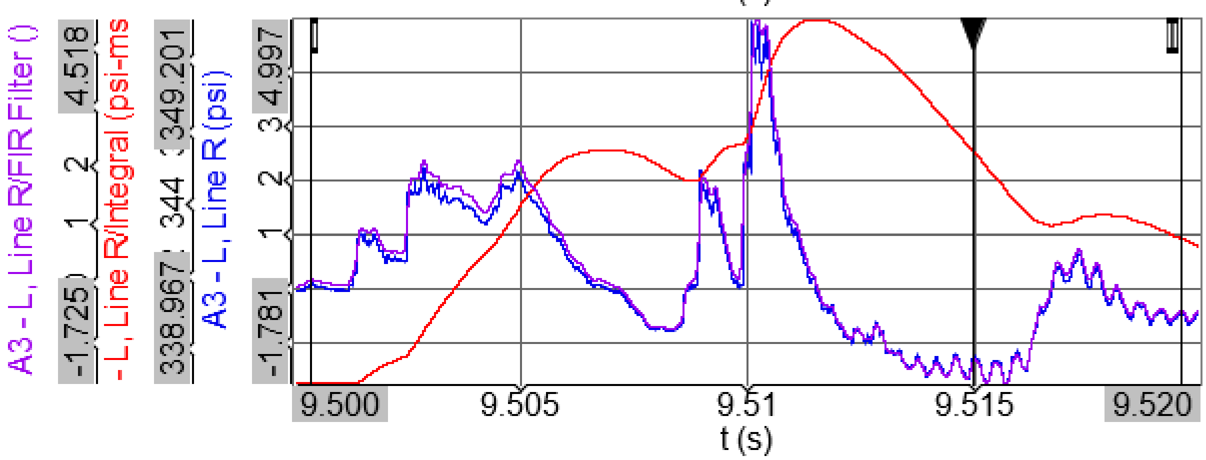

A6 - R, Line 3AR (psi)
0.442
-0.419
327.996
-346.854
5.612
10.000
15.000
20.624
t (s)
B6 - L, Line T (psi)
Notice: Fire
0.111
-0.126
125.734
-56.883
5.612
10.000
15.000
20.624
t (s)
B6 - R, Line 3BL (psi)
0.103
-0.081
92.425
-128.954
5.612
10.000
15.000
20.624
t (s)
TTL (V)
Notice: Fire
5.0506
5.0114
4.191
10.000
15.000
20.000
25.000
30.605
t (s)

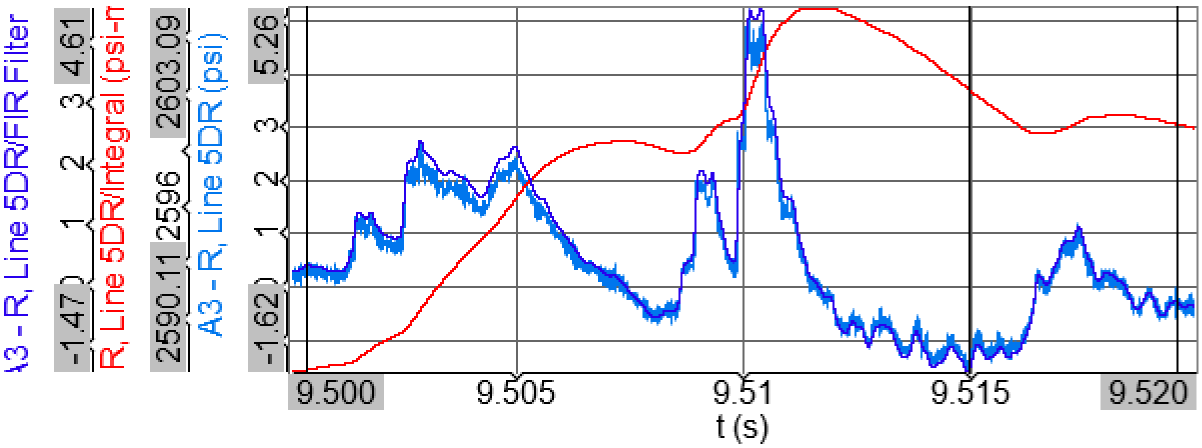
8.5 Fine Al-Bi_2O_3 Thermite – Small-Scale Mix ID #24 (SMS mixed)

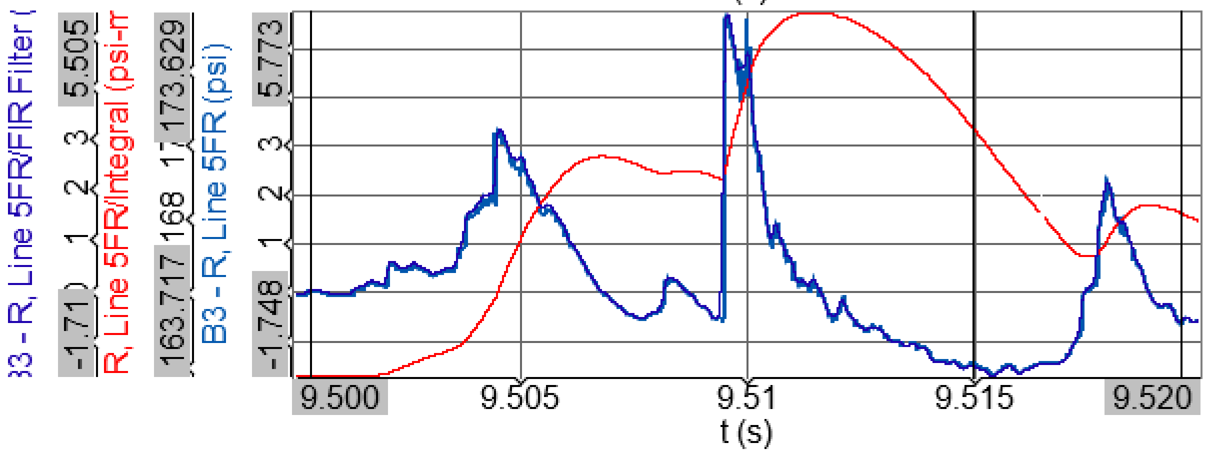
8.5.1 Trial 1 for Small-Scale Mix ID #24

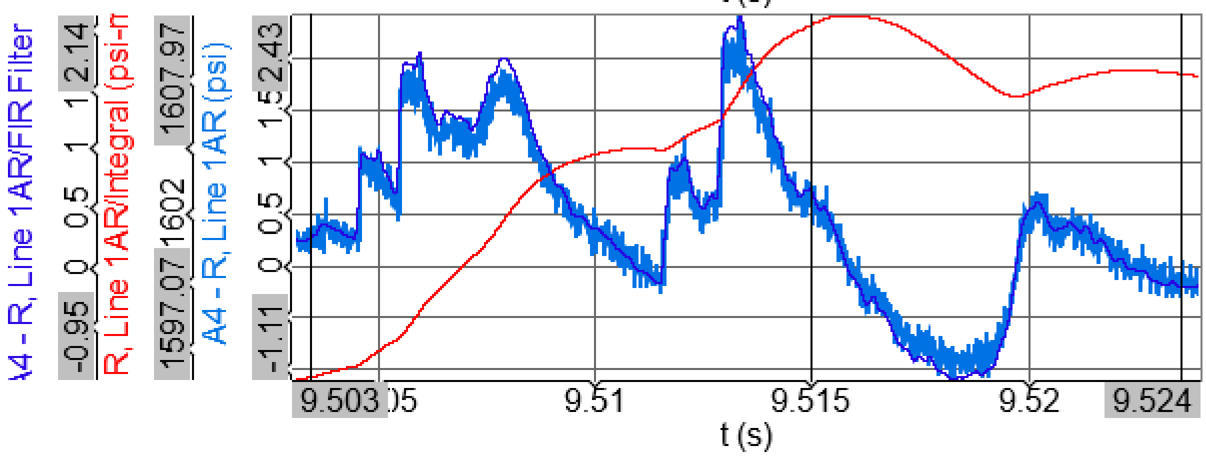


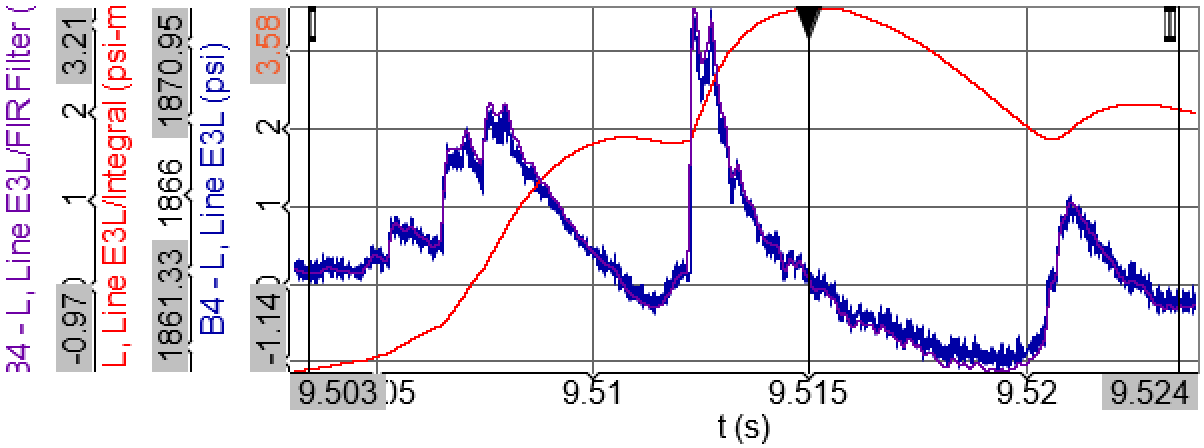


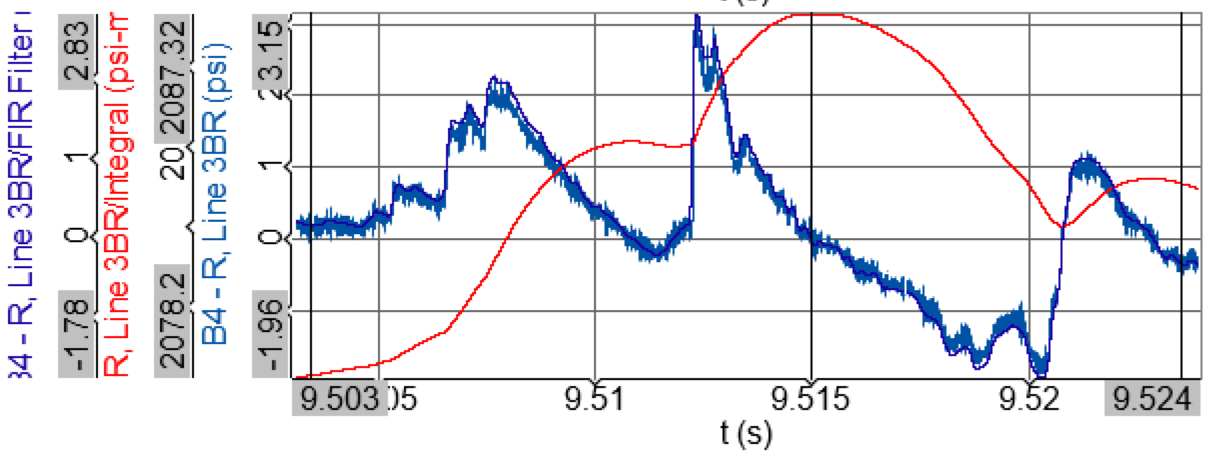


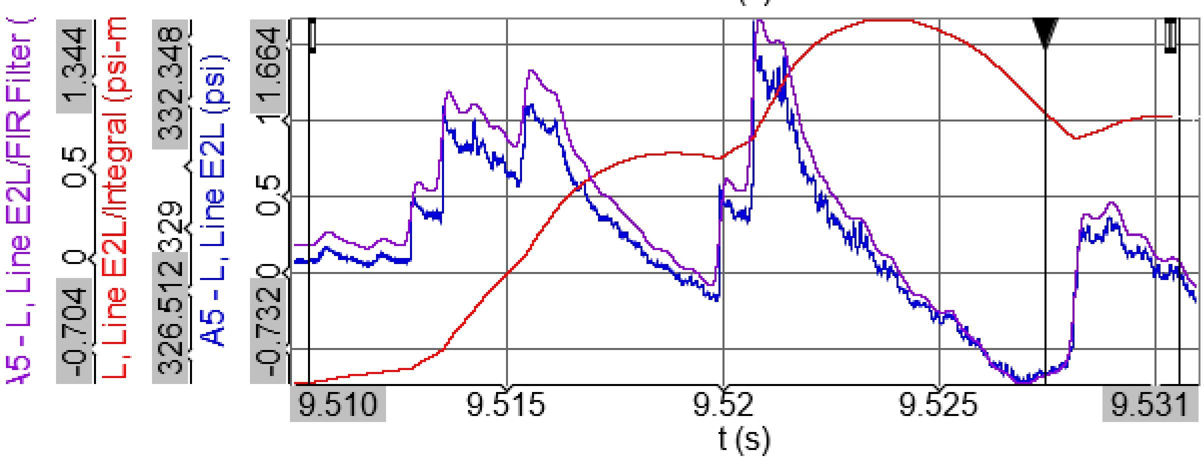

A3 - R, Line 5DR/FIR Filter
R, Line 5DR/Integral (psi-m
A3 - R, Line 5DR (psi)
-1.47
4.61
2590.11
2596
2603.09
-1.62
5.26
9.500
9.505
9.51
9.515
9.520
t (s)

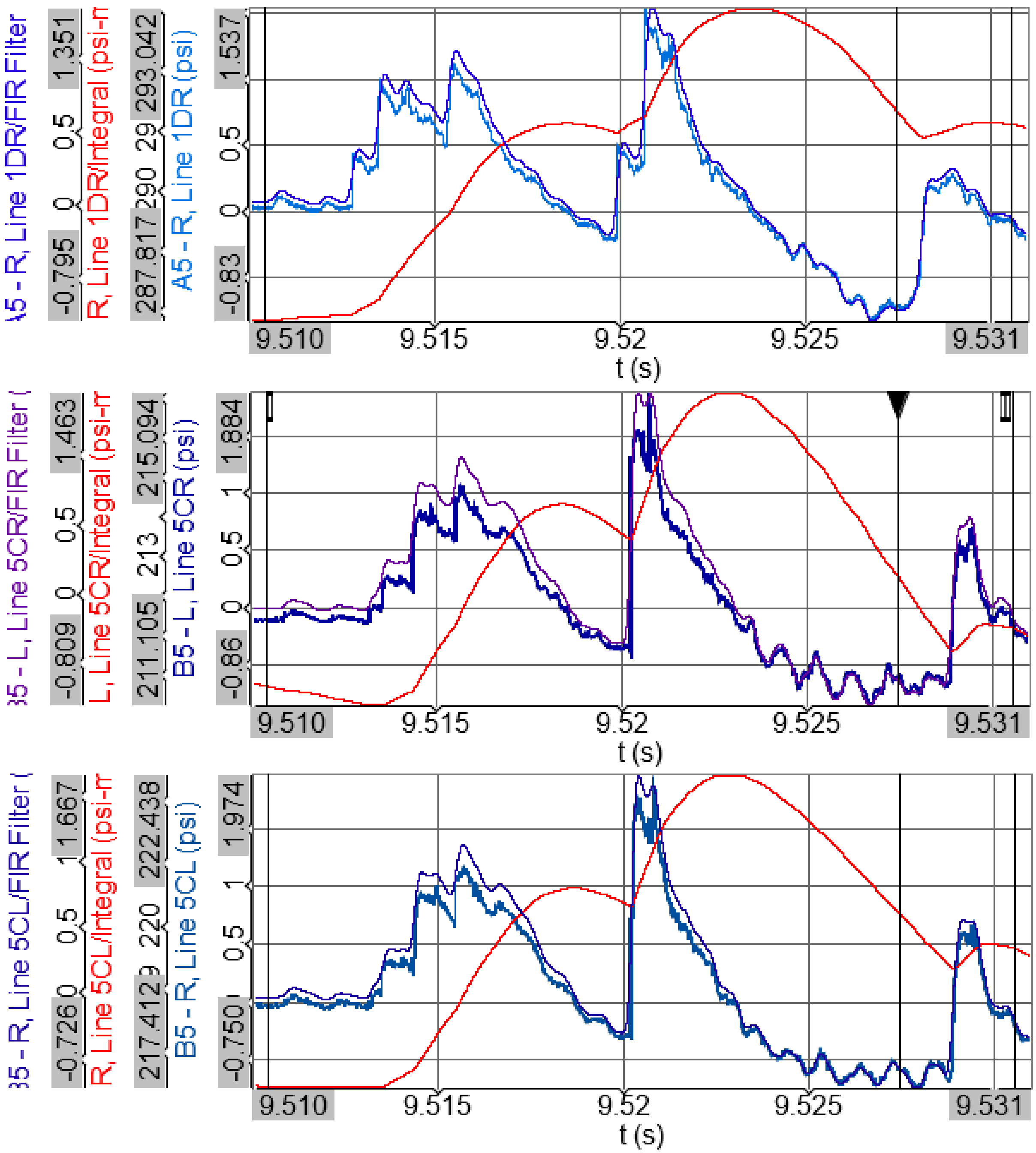

B3 - R, Line 5FR/FIR Filter
R, Line 5FR/Integral (psi-m
B3 - R, Line 5FR (psi)
-1.71
5.505
163.717
168
173.629
-1.748
5.773
9.500
9.505
9.51
9.515
9.520
t (s)

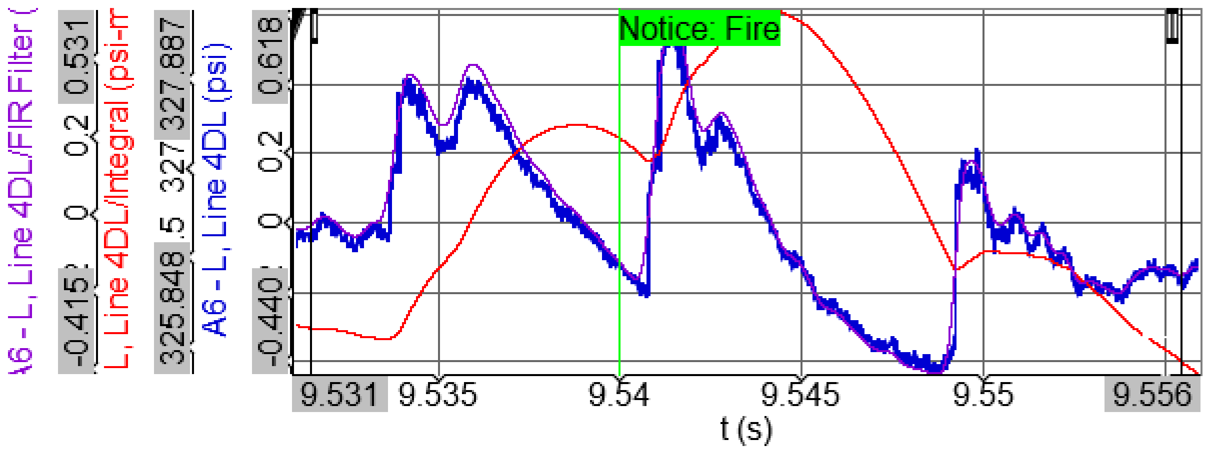

A4 - R, Line 1AR/FIR Filter
R, Line 1AR/Integral (psi-m
A4 - R, Line 1AR (psi)
-0.95
2.14
1597.07
1602
1607.97
-1.11
2.43
9.503
9.51
9.515
9.52
9.524
t (s)

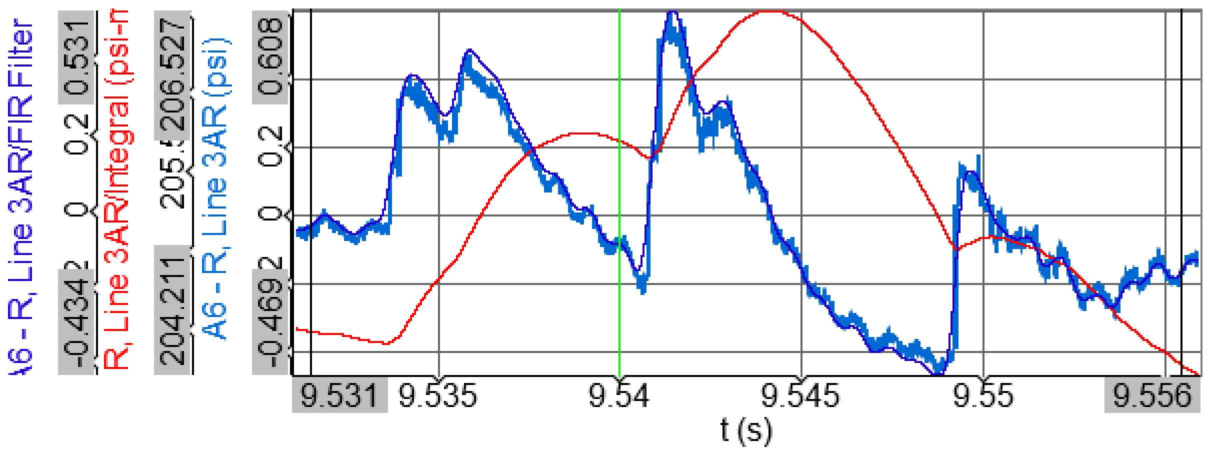

L, Line E3L/Integral (psi-m
B4 - L, Line E3L (psi)
-0.97
3.21
1861.33
1870.95
-1.14
3.58
9.503
9.51
9.515
9.52
9.524
t (s)

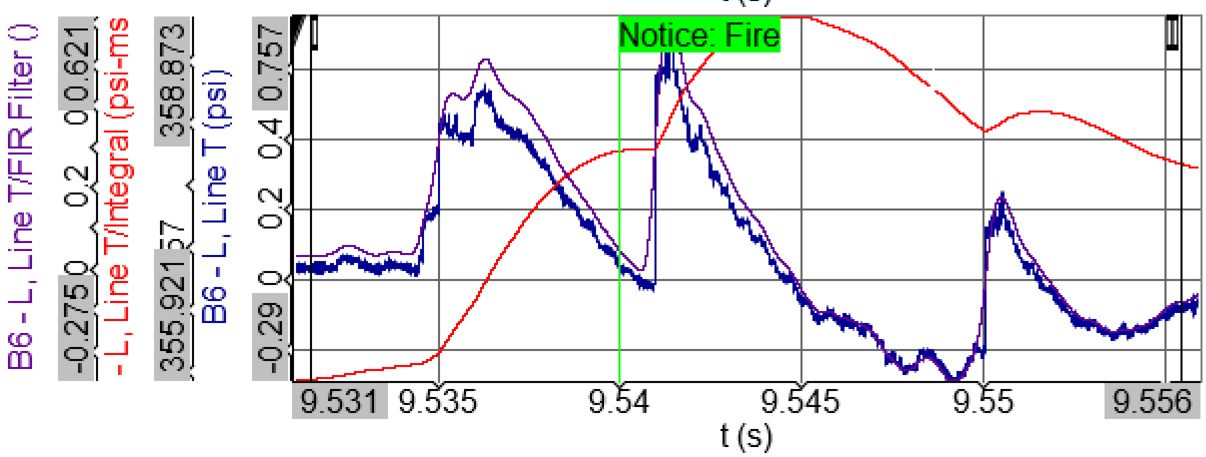

R, Line 3BR/Integral (psi-m
B4 - R, Line 3BR (psi)
-1.78
2.83
2078.2
2087.32
-1.96
3.15
9.503
9.51
9.515
9.52
9.524
t (s)

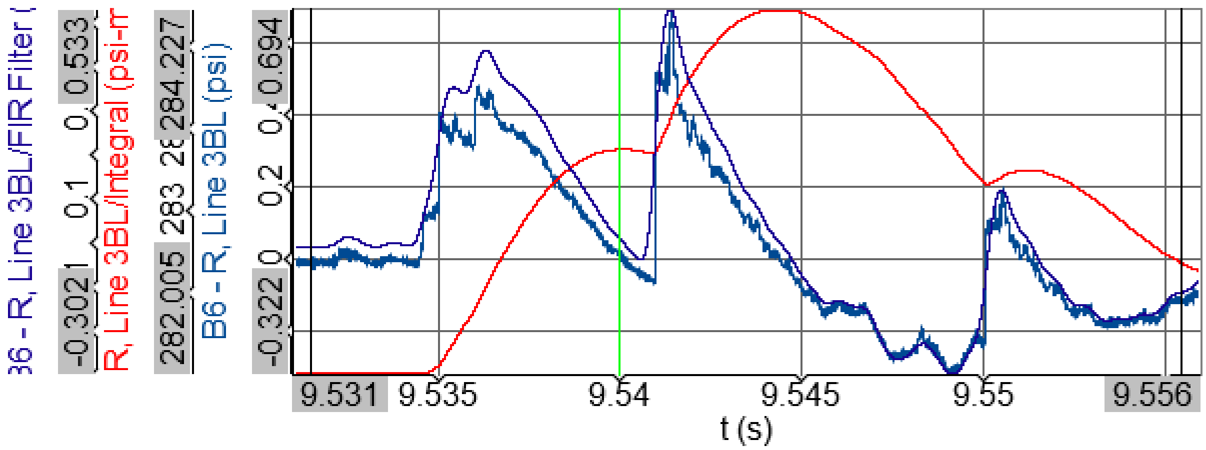

L, Line E2L/Integral (psi-m
A5 - L, Line E2L (psi)
-0.704
1.344
326.512
332.348
-0.732
1.664
9.510
9.515
9.52
9.525
9.531
t (s)

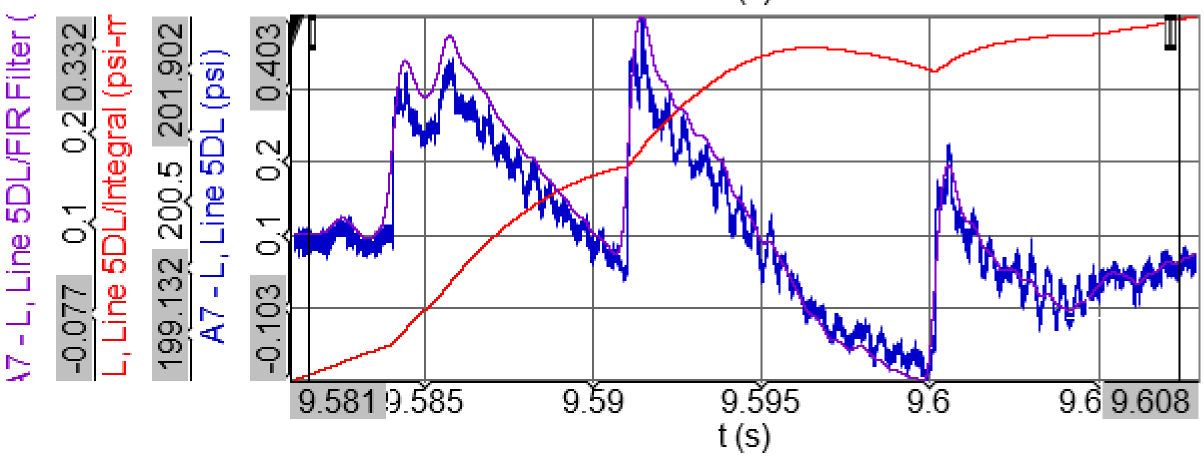

A5 - R, Line 1DR/FIR Filter
R, Line 1DR/Integral (psi-m
A5 - R, Line 1DR (psi)
-0.795 0 0.5 1.351
287.817 290 29 293.042
-0.83 0 0.5 1.537
9.510 9.515 9.52 9.525 9.531
t (s)
B5 - L, Line 5CR/FIR Filter (
L, Line 5CR/Integral (psi-m
B5 - L, Line 5CR (psi)
-0.809 0 0.5 1.463
211.105 213 215.094
-0.86 0 0.5 1 1.884
9.510 9.515 9.52 9.525 9.531
t (s)
B5 - R, Line 5CL/FIR Filter (
R, Line 5CL/Integral (psi-m
B5 - R, Line 5CL (psi)
-0.726 0 0.5 1 1.667
217.412 220 222.438
-0.750 0.5 1 1.974
9.510 9.515 9.52 9.525 9.531
t (s)

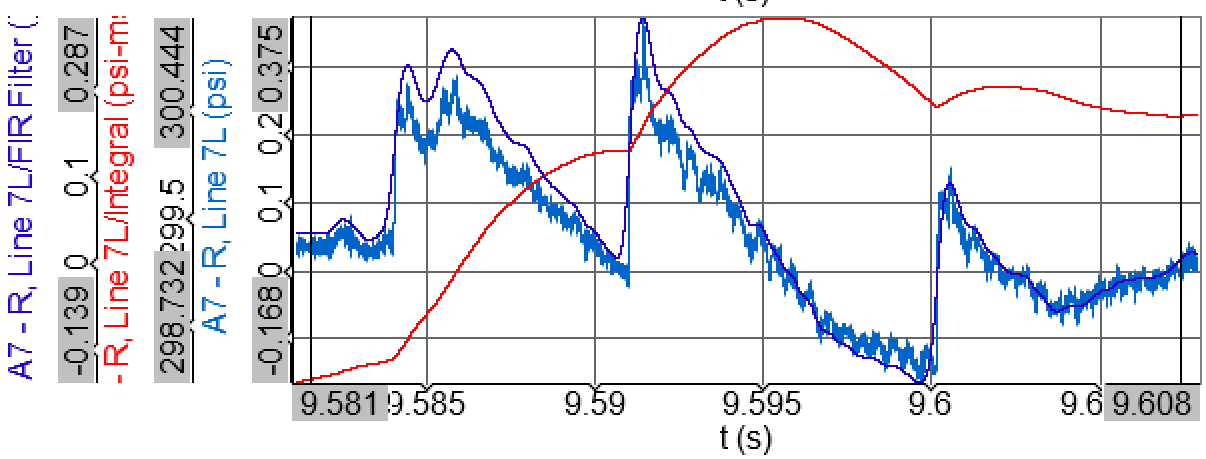

Notice: Fire
9.531
9.535
9.54
9.545
9.55
9.556
t (s)
A6 - L, Line 4DL (psi)
0.618
0.2
0
-0.440
325.848
327.887
L, Line 4DL/Integral (psi-m
-0.415
0.531

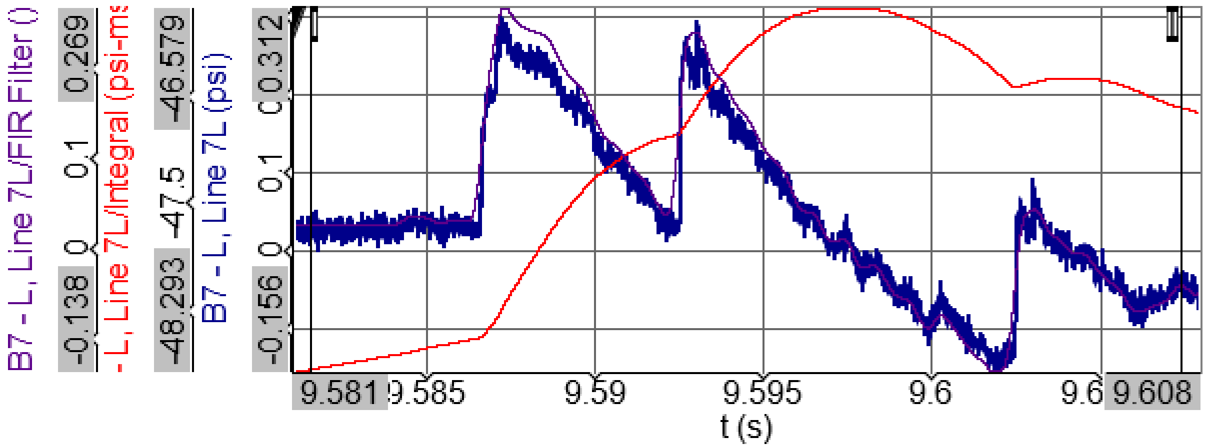

9.531
9.535
9.54
9.545
9.55
9.556
t (s)
A6 - R, Line 3AR (psi)
0.608
0.2
0
-0.469
204.211
206.527
R, Line 3AR/Integral (psi-m
-0.434
0.531
A6 - R, Line 3AR/FIR Filter

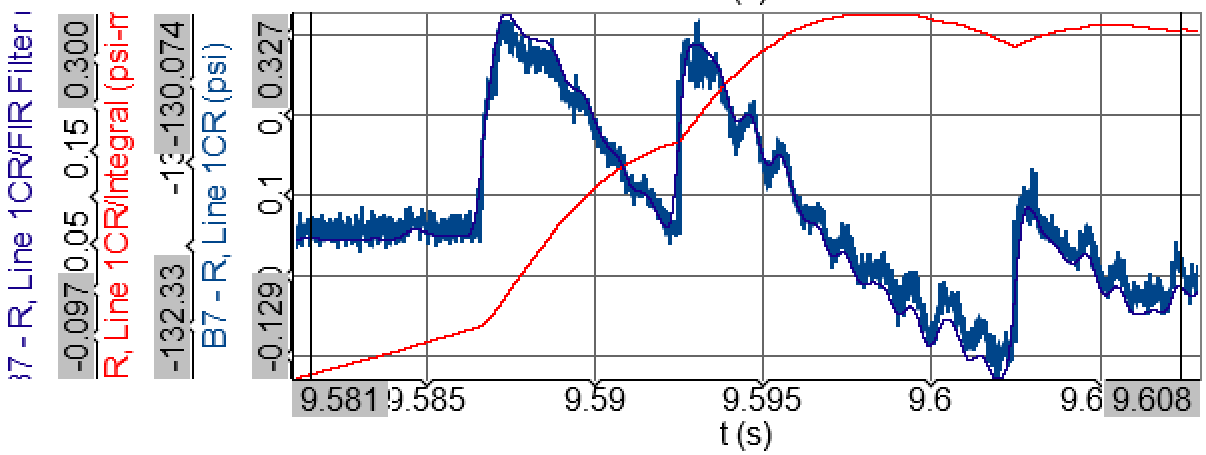

Notice: Fire
9.531
9.535
9.54
9.545
9.55
9.556
t (s)
B6 - L, Line T (psi)
0.757
0.4
0.2
0
-0.29
355.921
358.873
- L, Line T/Integral (psi-ms
-0.275
0.621
B6 - L, Line T/FIR Filter ()

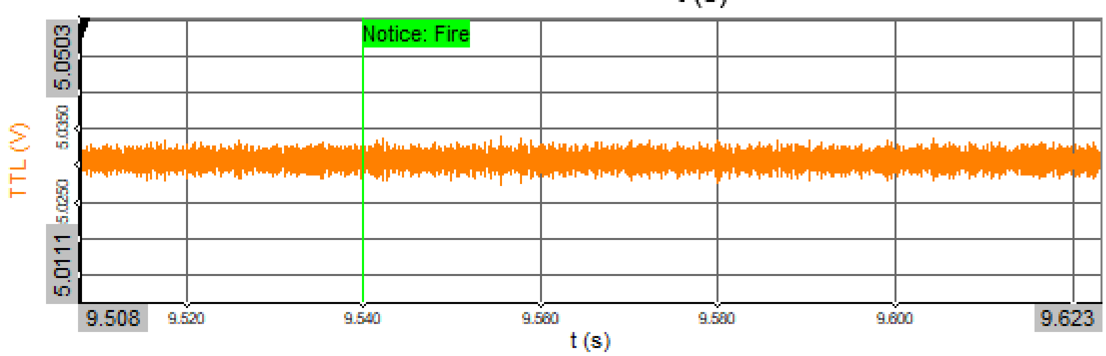

36 - R, Line 3BL/FIR Filter (
R, Line 3BL/Integral (psi-m
B6 - R, Line 3BL (psi)
-0.302 0.533
282.005 284.227
-0.322 0.694
9.531 9.535 9.54 9.545 9.55 9.556
t (s)


A7 - L, Line 5DL/FIR Filter (
L, Line 5DL/Integral (psi-m
A7 - L, Line 5DL (psi)
-0.077 0.332
199.132 201.902
-0.103 0.403
9.581 9.585 9.59 9.595 9.6 9.608
t (s)

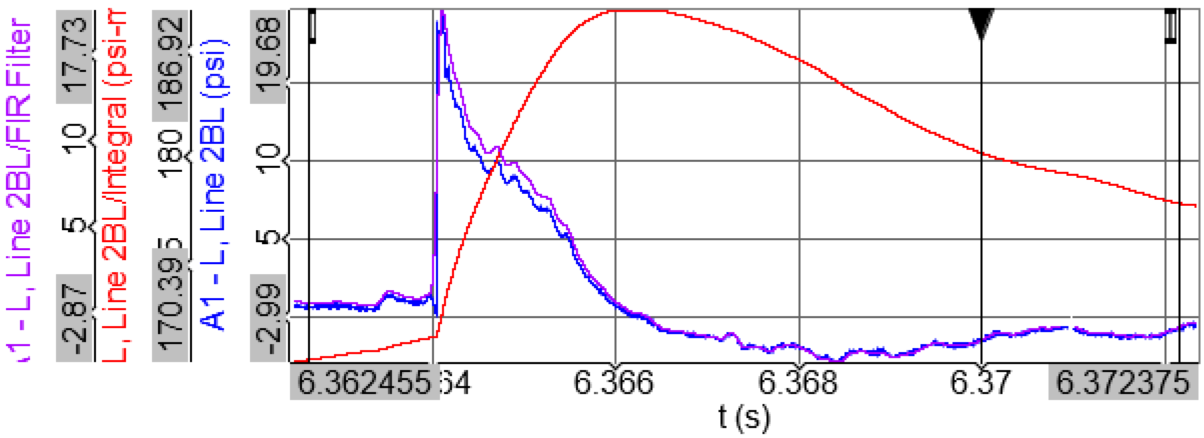

A7 - R, Line 7L/FIR Filter (
R, Line 7L/Integral (psi-m
A7 - R, Line 7L (psi)
-0.139 0.287
298.732 300.444
-0.168 0.375
9.581 9.585 9.59 9.595 9.6 9.608
t (s)

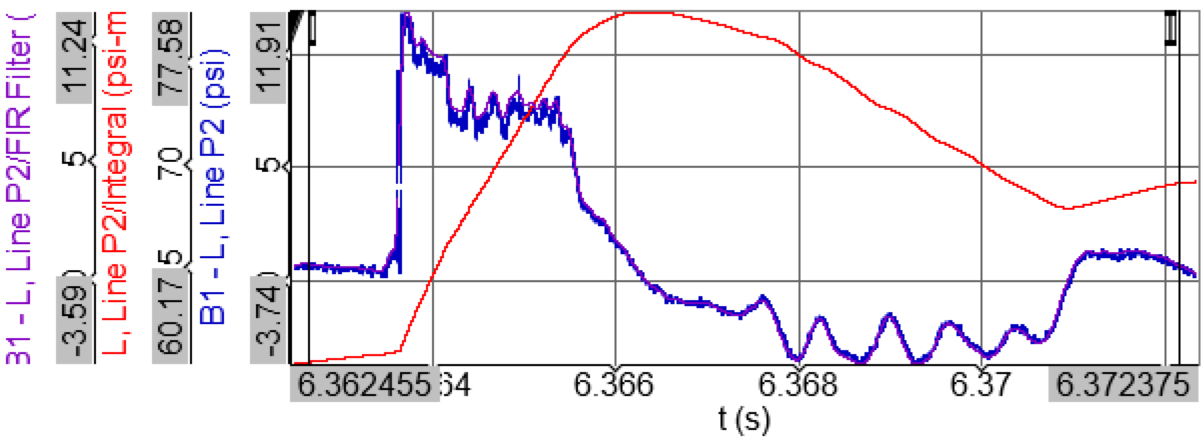

B7 - L, Line 7L/FIR Filter ()
-L, Line 7L/Integral (psi-ms
B7 - L, Line 7L (psi)
-0.138
0
0.1
0.269
-48.293
-47.5
-46.579
-0.156
0
0.1
0.312
9.581
9.585
9.59
9.595
9.6
9.608
t (s)

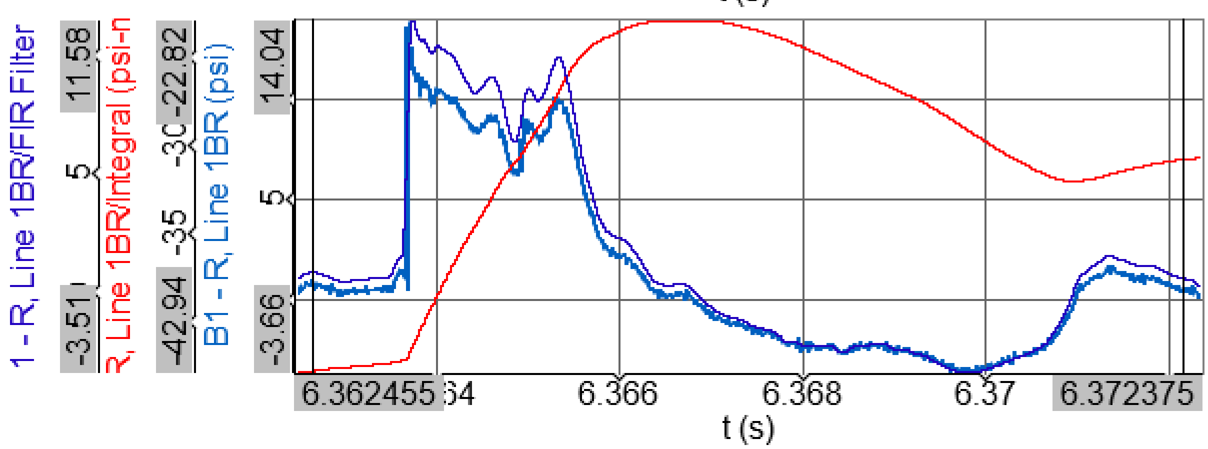

B7 - R, Line 1CR/FIR Filter
R, Line 1CR/Integral (psi-m
B7 - R, Line 1CR (psi)
-0.097
0.05
0.15
0.300
-132.33
-130.074
-0.129
0.1
0.327
9.581
9.585
9.59
9.595
9.6
9.608
t (s)

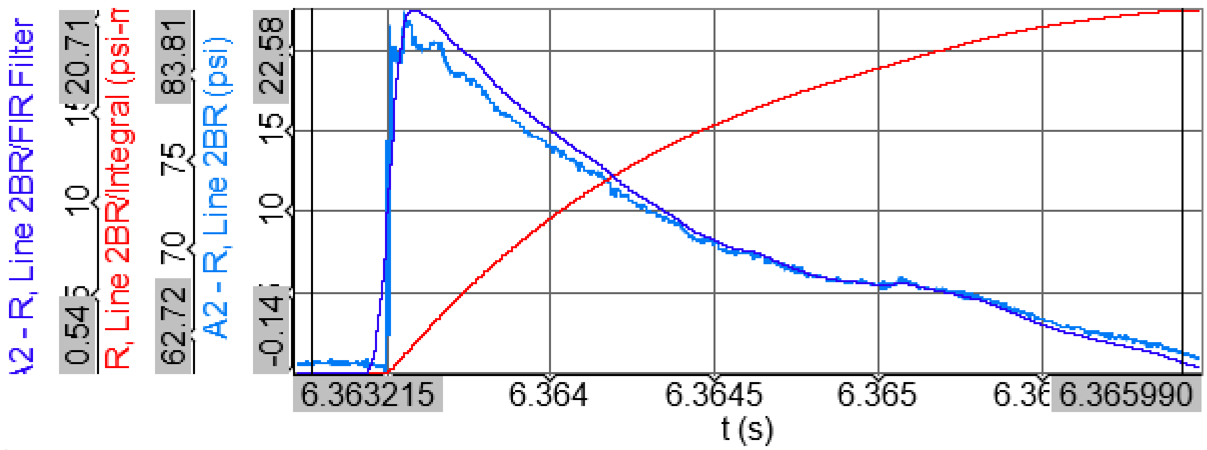

Notice: Fire
TTL (V)
5.0503
5.0350
5.0250
5.0111
9.508
9.520
9.540
9.560
9.580
9.600
9.623
t (s)

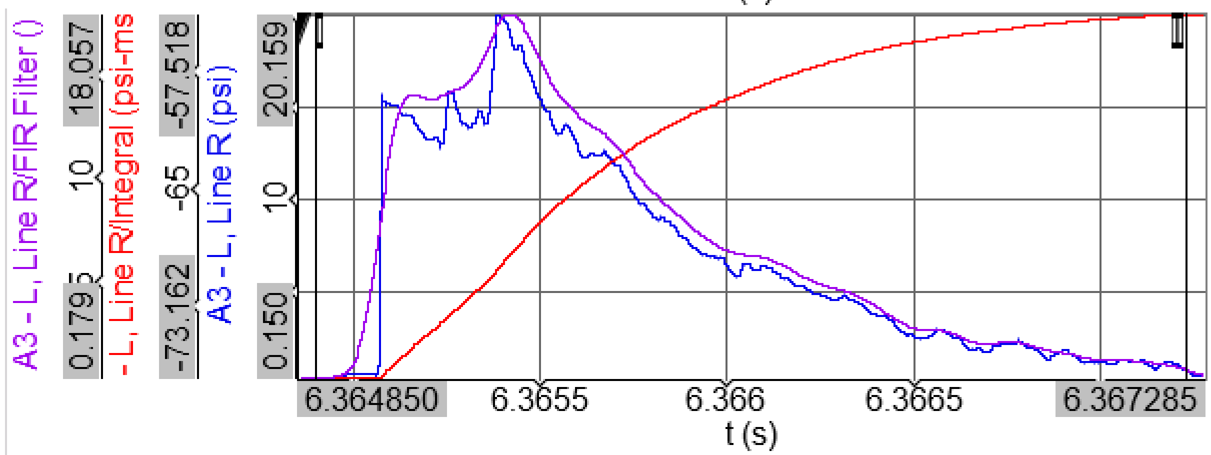
8.5.2 Trial 2 for Small-Scale Mix ID #24

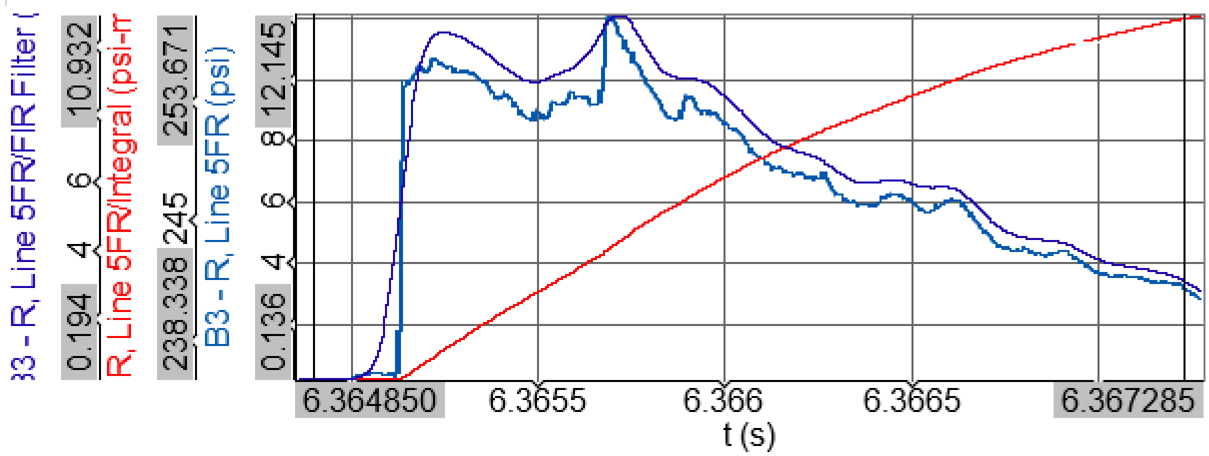


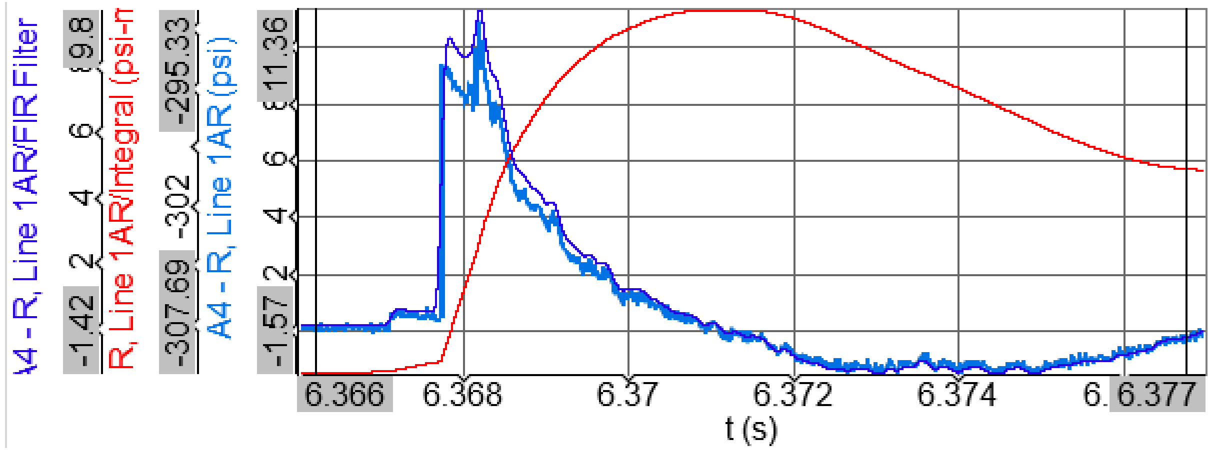


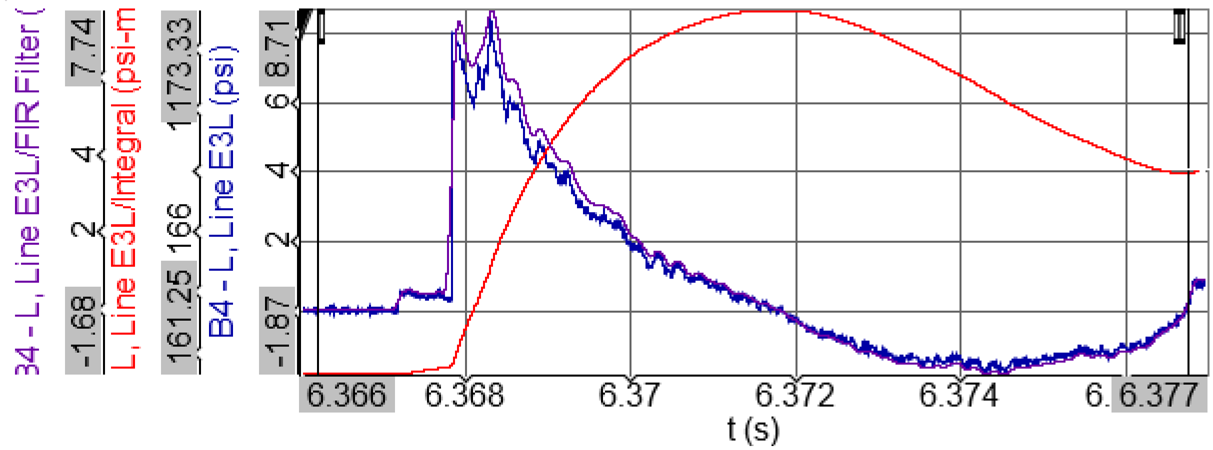


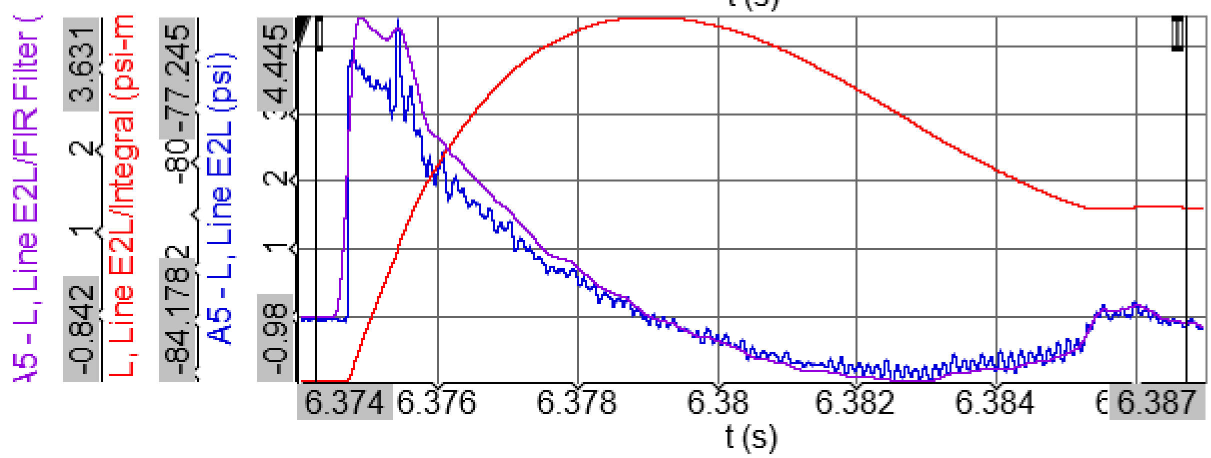

A2 - R, Line 2BR/FIR Filter
R, Line 2BR/Integral (psi-m
A2 - R, Line 2BR (psi)
6.363215
6.364
6.3645
6.365
6.365990
t (s)

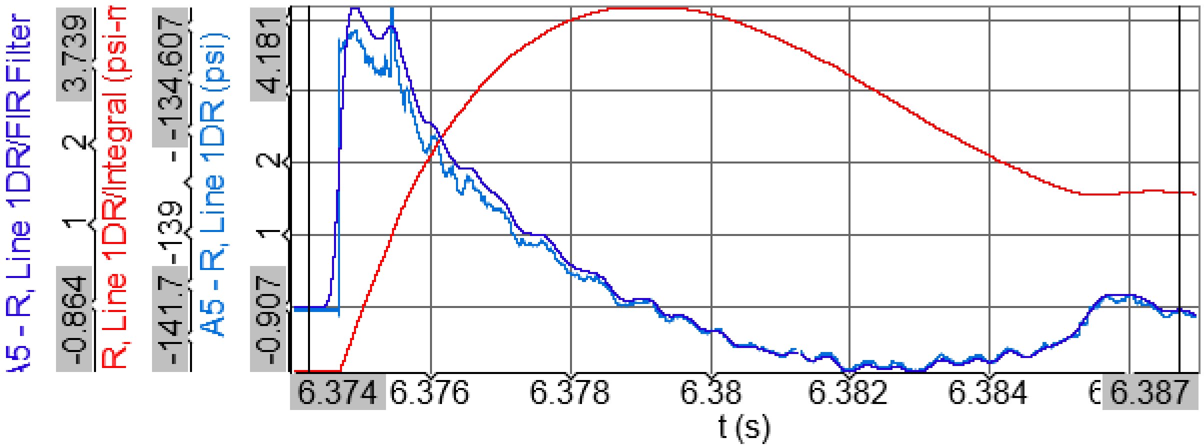

A3 - L, Line R/FIR Filter ()
- L, Line R/Integral (psi-ms
A3 - L, Line R (psi)
6.364850
6.3655
6.366
6.3665
6.367285
t (s)

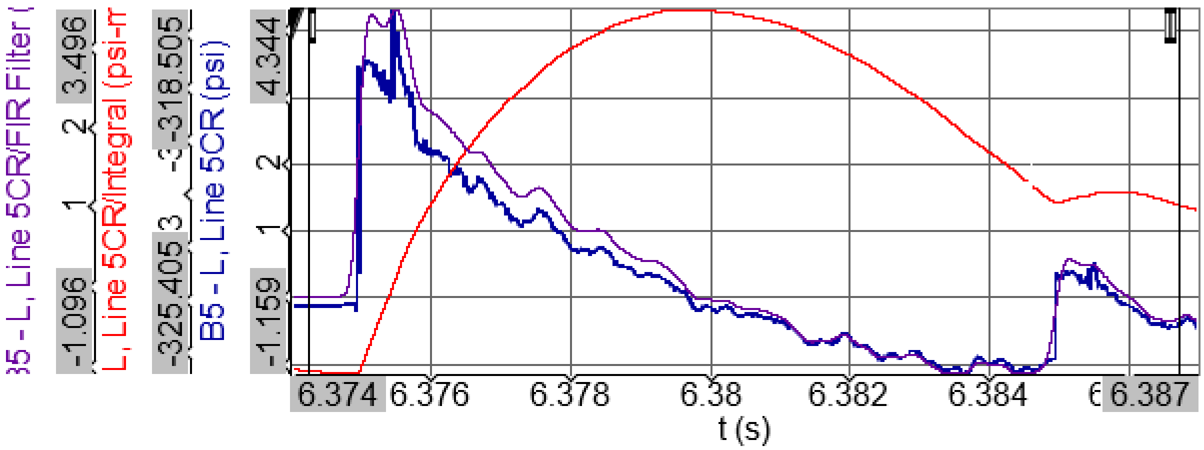

B3 - R, Line 5FR/FIR Filter (
R, Line 5FR/Integral (psi-m
B3 - R, Line 5FR (psi)
6.364850
6.3655
6.366
6.3665
6.367285
t (s)

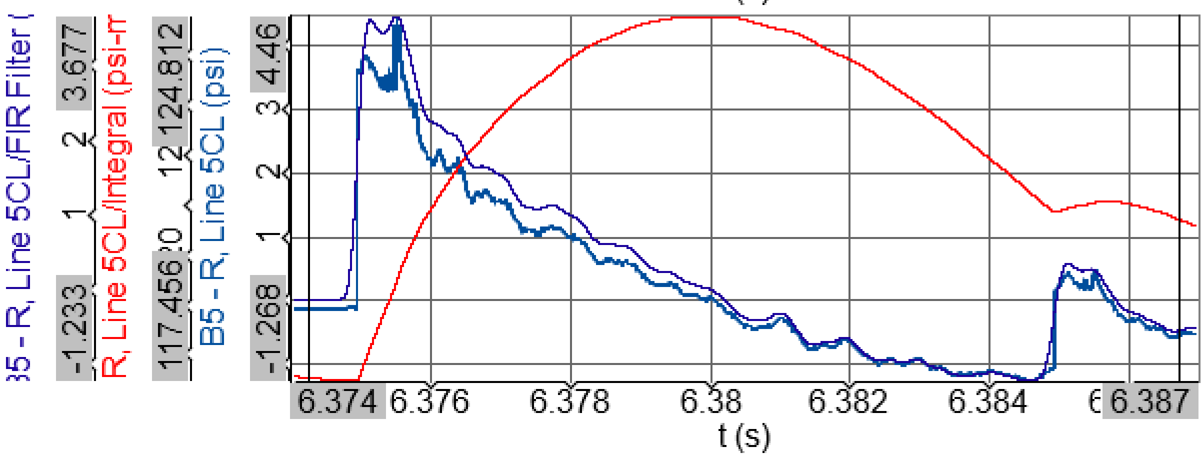

A4 - R, Line 1AR/FIR Filter
R, Line 1AR/Integral (psi-m
A4 - R, Line 1AR (psi)
-1.42
9.8
-307.69
-295.33
-1.57
11.36
6.366
6.368
6.37
6.372
6.374
6.377
t (s)

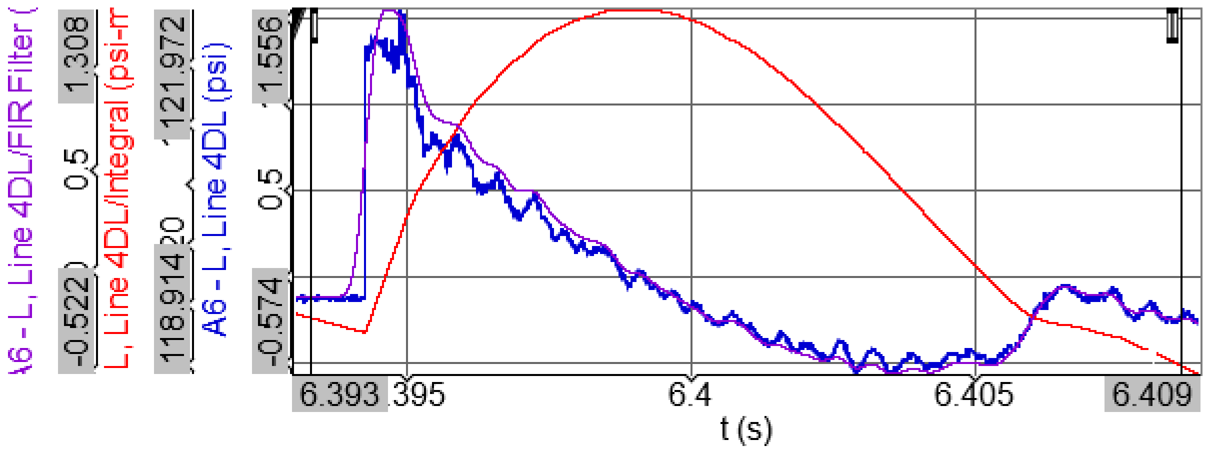

B4 - L, Line E3L/FIR Filter (
L, Line E3L/Integral (psi-m
B4 - L, Line E3L (psi)
-1.68
7.74
161.25
173.33
-1.87
8.71
6.366
6.368
6.37
6.372
6.374
6.377
t (s)

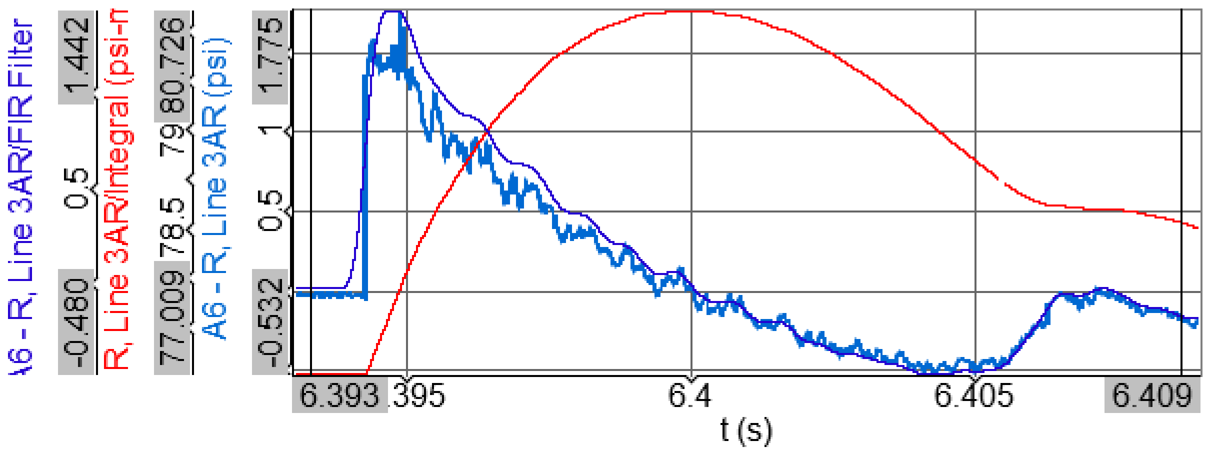

A5 - L, Line E2L/FIR Filter (
L, Line E2L/Integral (psi-m
A5 - L, Line E2L (psi)
-0.842
3.631
-84.1782
-77.245
-0.98
4.445
6.374
6.376
6.378
6.38
6.382
6.384
6.387
t (s)

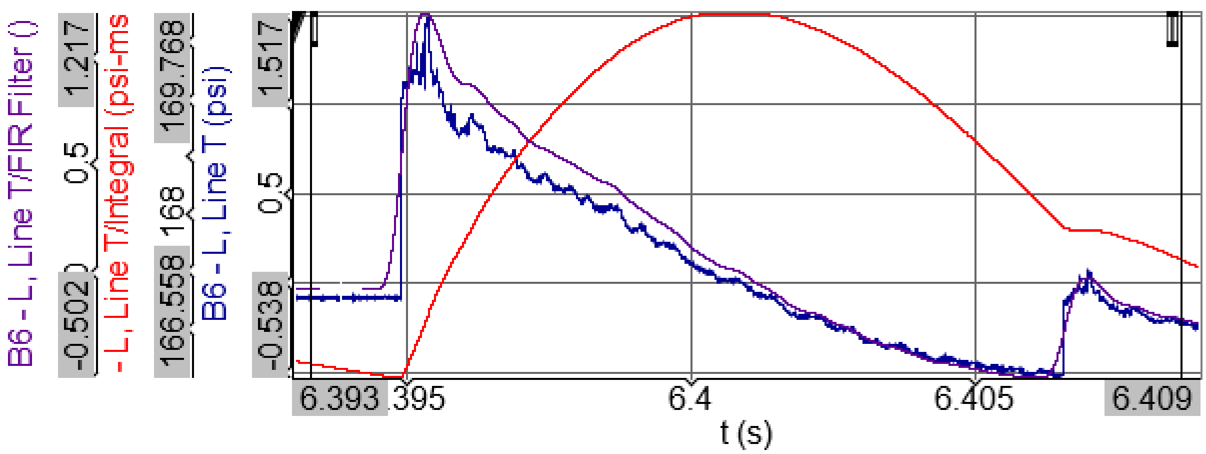

A5 - R, Line 1DR (psi)
R, Line 1DR/Integral (psi-
t (s)
6.374
6.376
6.378
6.38
6.382
6.384
6.387

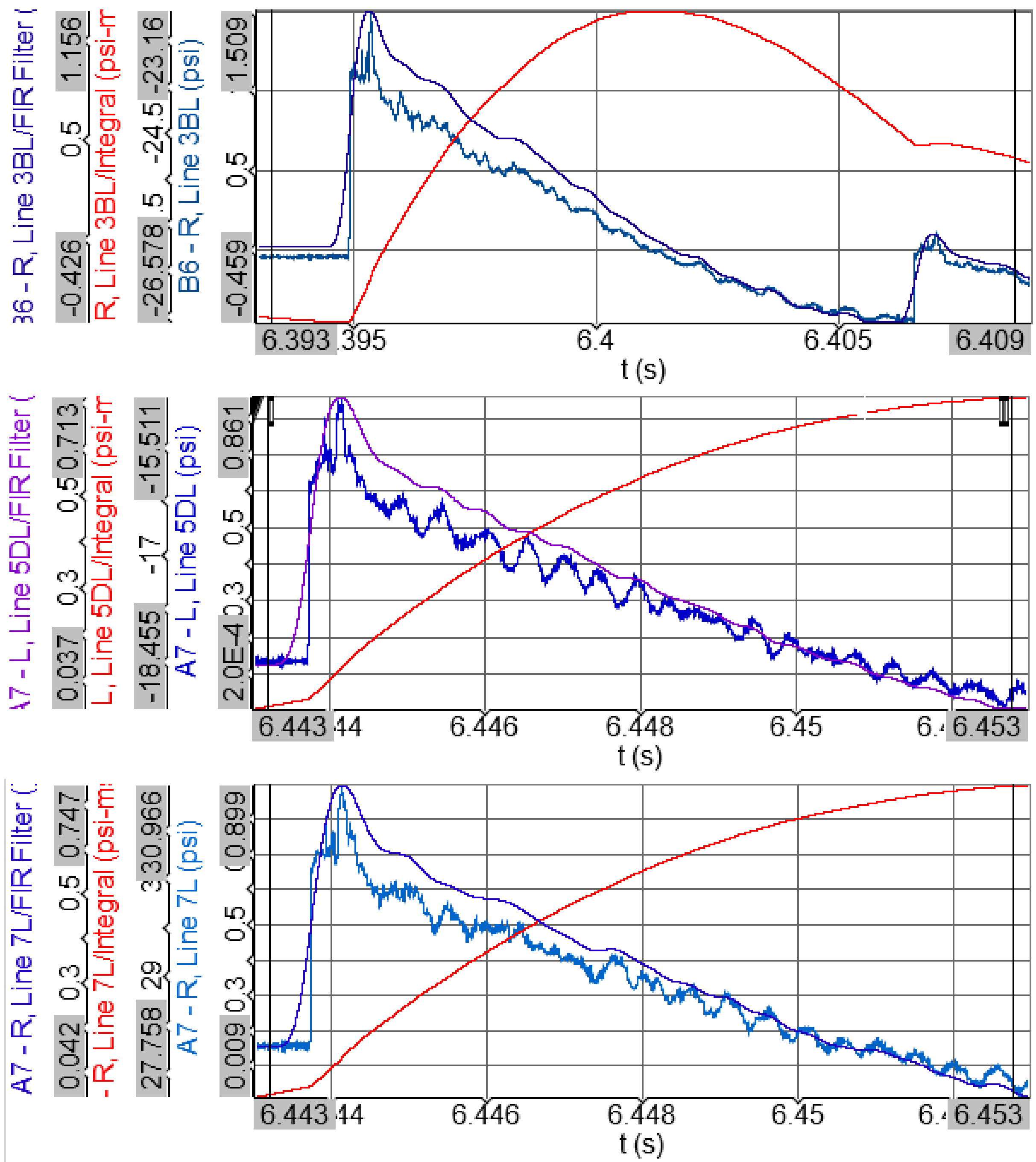

B5 - L, Line 5CR (psi)
L, Line 5CR/Integral (psi-
t (s)
6.374
6.376
6.378
6.38
6.382
6.384
6.387

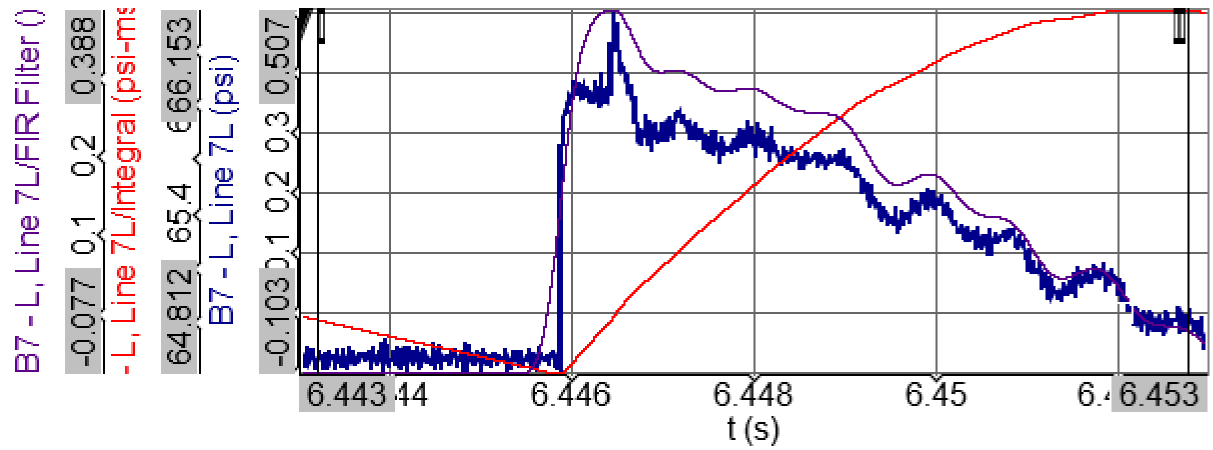

B5 - R, Line 5CL (psi)
R, Line 5CL/Integral (psi-
t (s)
6.374
6.376
6.378
6.38
6.382
6.384
6.387

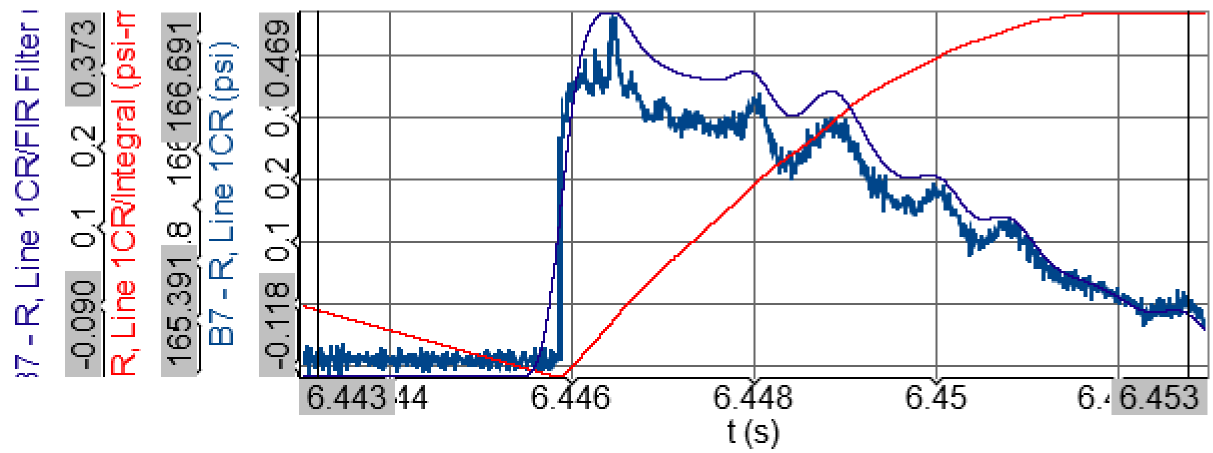

L, Line 4DL/FIR Filter (
-0.522
0.5
1.308
L, Line 4DL/Integral (psi-m
118.914
120
121.972
A6 - L, Line 4DL (psi)
-0.574
0.5
1.556
6.393
6.395
6.4
6.405
6.409
t (s)

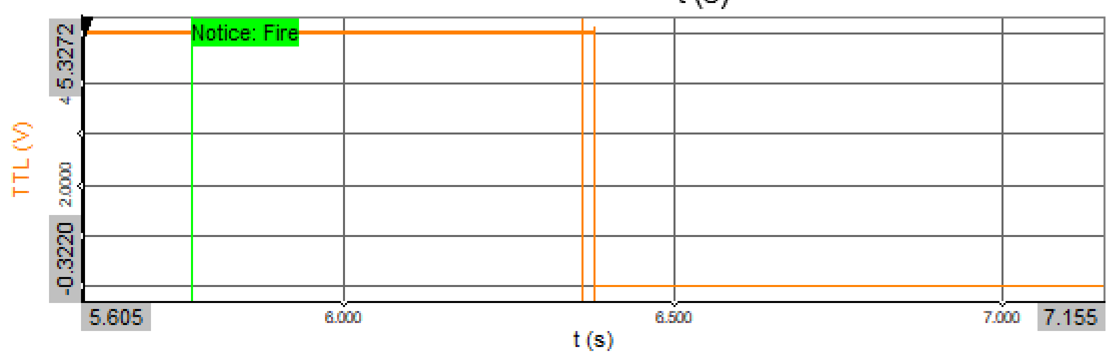

A6 - R, Line 3AR/FIR Filter
-0.480
0.5
1.442
R, Line 3AR/Integral (psi-m
77.009
78.5
79
80.726
A6 - R, Line 3AR (psi)
-0.532
0.5
1
1.775
6.393
6.395
6.4
6.405
6.409
t (s)


B6 - L, Line T/FIR Filter ()
-0.502
0.5
1.217
- L, Line T/Integral (psi-ms
166.558
168
169.768
B6 - L, Line T (psi)
-0.538
0.5
1.517
6.393
6.395
6.4
6.405
6.409
t (s)

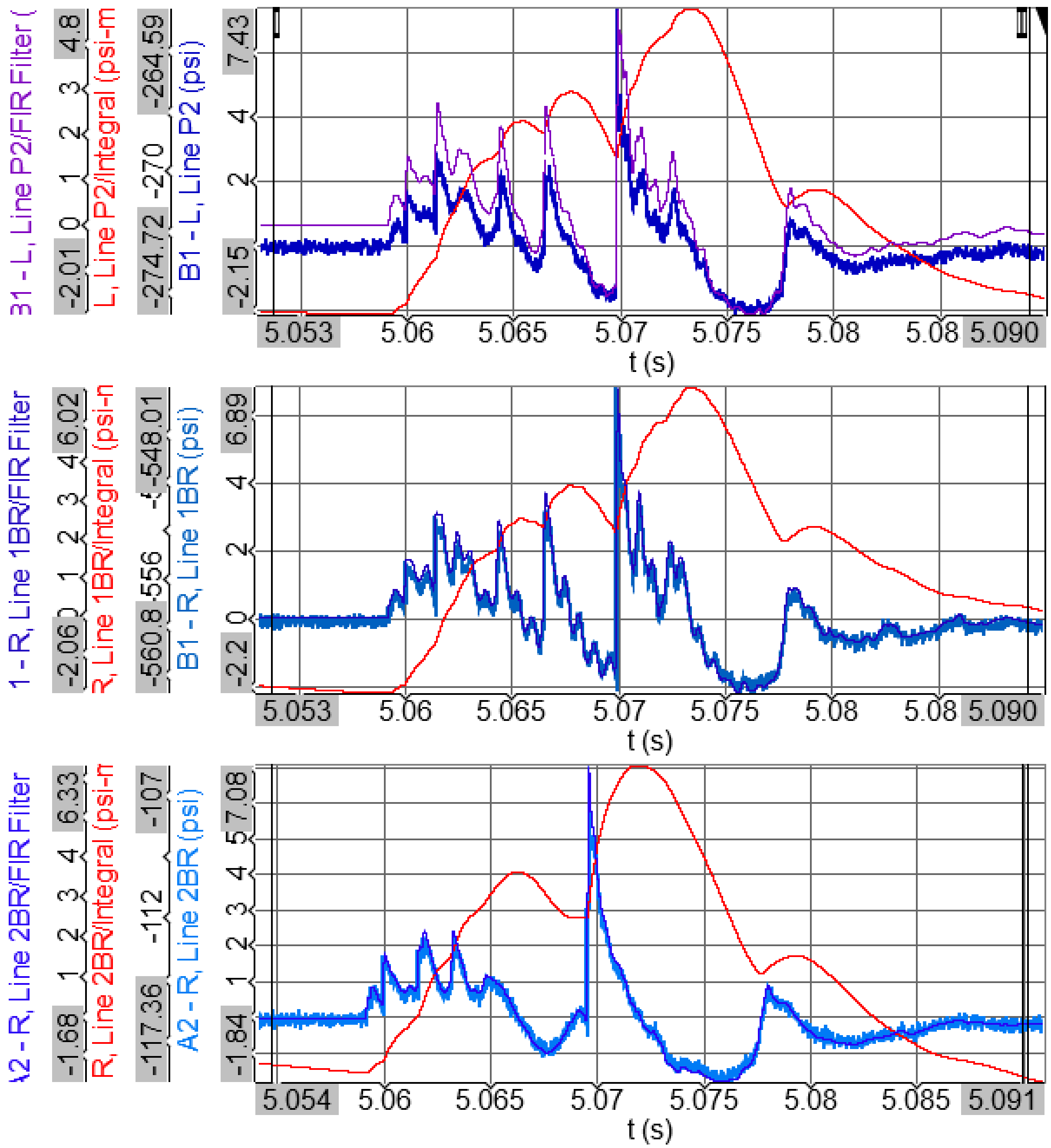

B6 - R, Line 3BL (psi)
t (s)
6.393
6.395
6.4
6.405
6.409
A7 - L, Line 5DL (psi)
t (s)
6.443
6.446
6.448
6.45
6.453
A7 - R, Line 7L (psi)
t (s)
6.443
6.446
6.448
6.45
6.453

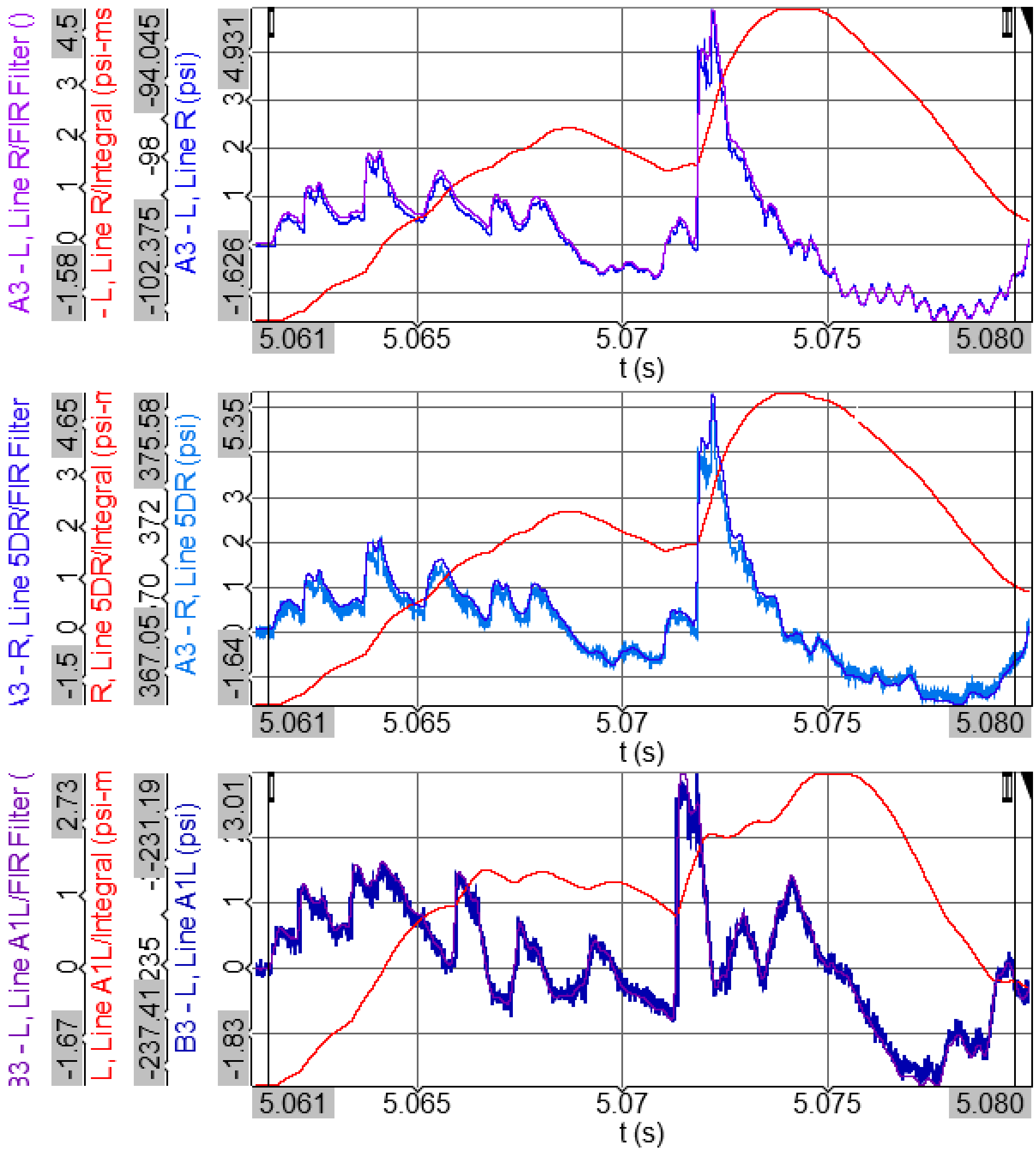

B7 - L, Line 7L/FIR Filter ()
-L, Line 7L/Integral (psi-ms
B7 - L, Line 7L (psi)
6.443
6.446
6.448
6.45
6.453
t (s)

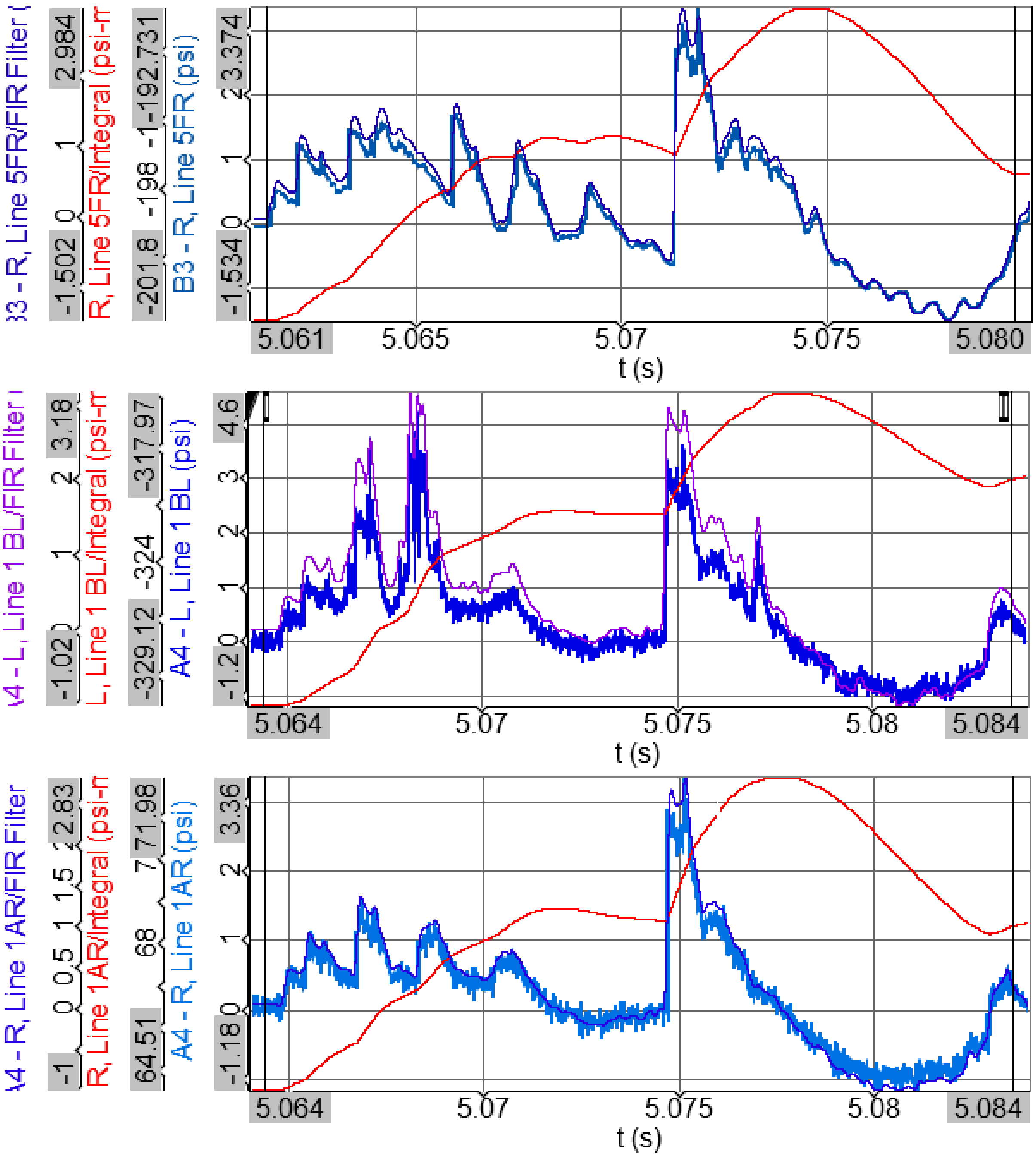

B7 - R, Line 1CR/FIR Filter
R, Line 1CR/Integral (psi-m
B7 - R, Line 1CR (psi)
6.443
6.446
6.448
6.45
6.453
t (s)

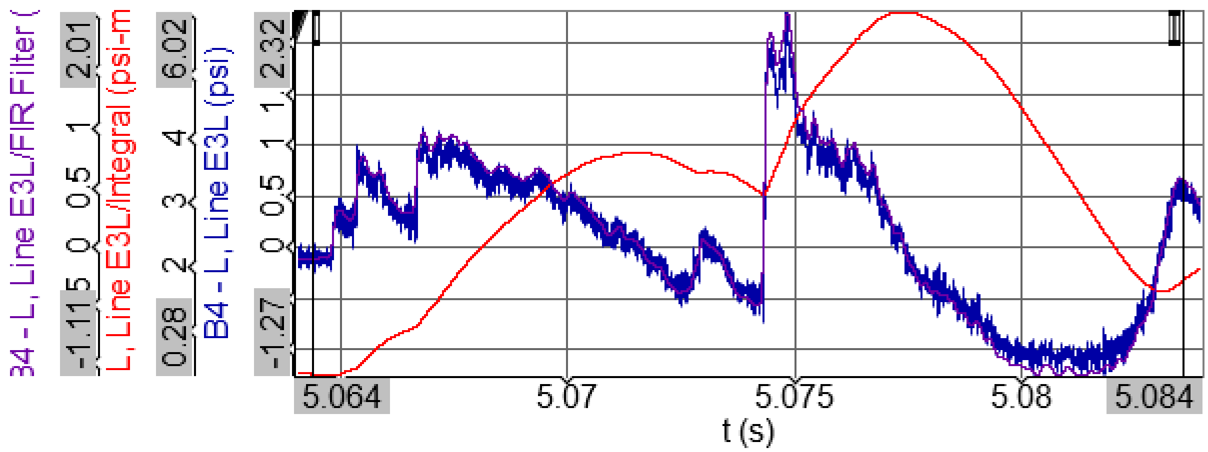

TTL (V)
Notice: Fire
5.605
6.000
6.500
7.000
7.155
t (s)

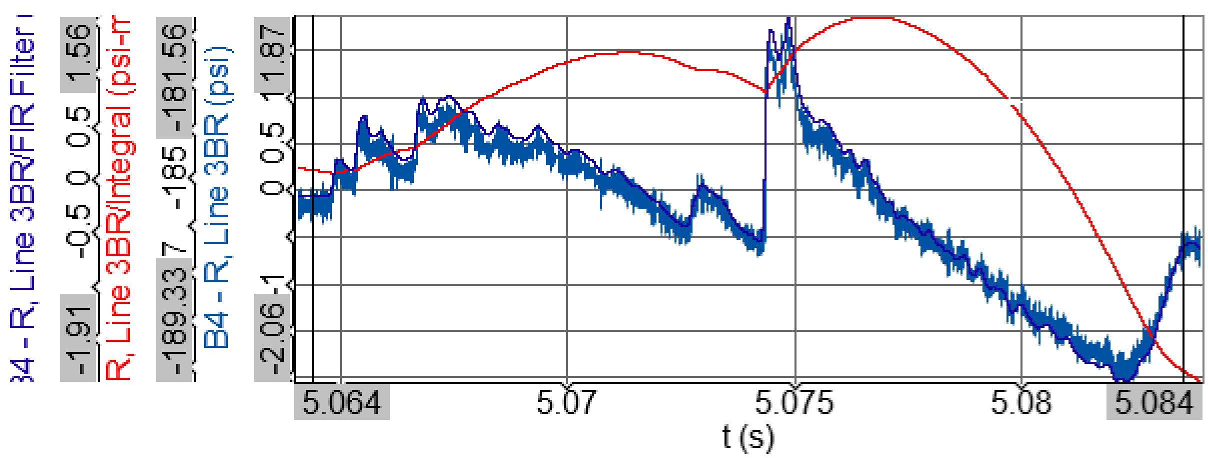
8.5.3 Trial 3 for Small-Scale Mix ID #24

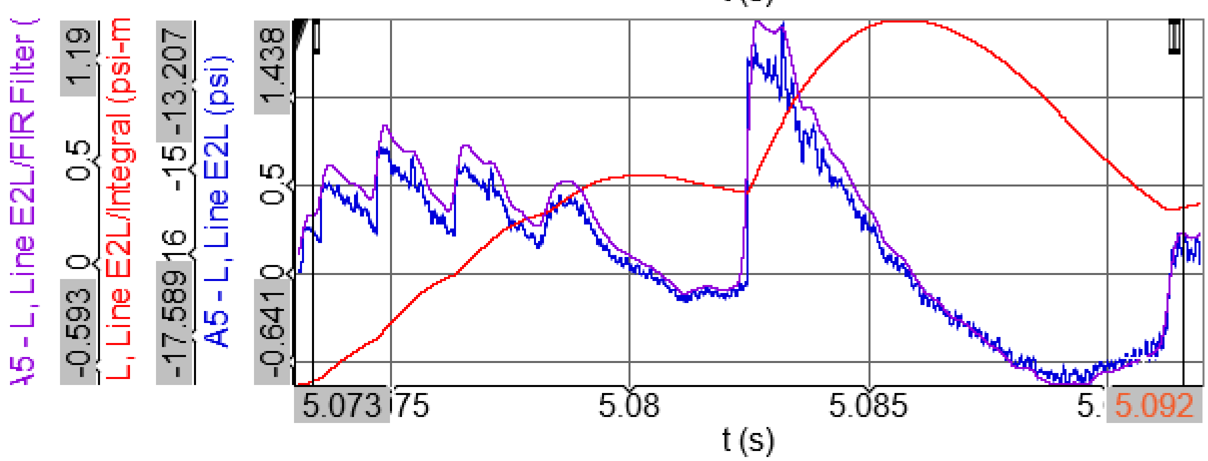


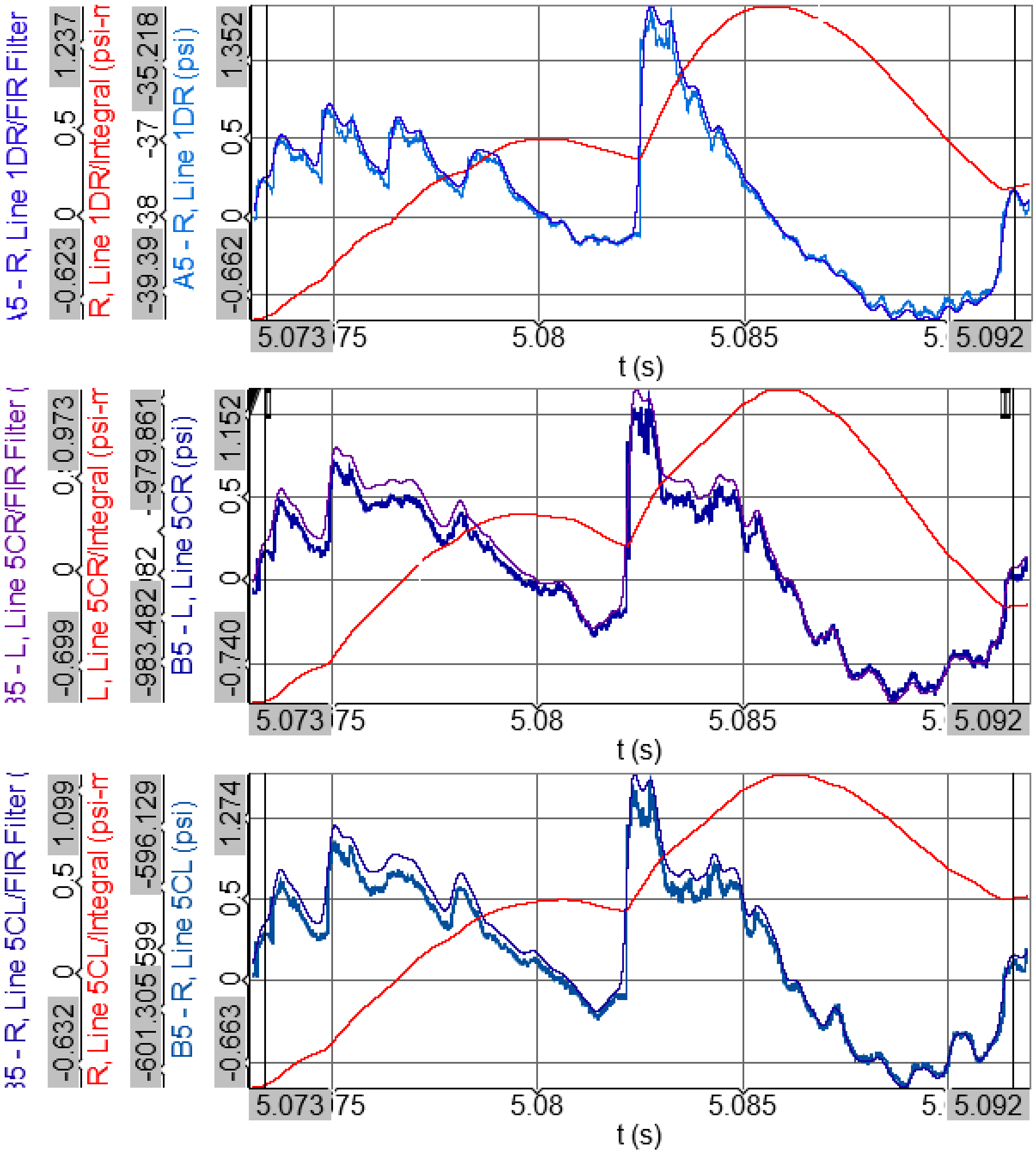

A3 - L, Line R/FIR Filter ()
-L, Line R/Integral (psi-ms
A3 - L, Line R (psi)
5.061
5.065
5.07
5.075
5.080
t (s)
A3 - R, Line 5DR/FIR Filter
R, Line 5DR/Integral (psi-m
A3 - R, Line 5DR (psi)
B3 - L, Line A1L/FIR Filter (
L, Line A1L/Integral (psi-m
B3 - L, Line A1L (psi)

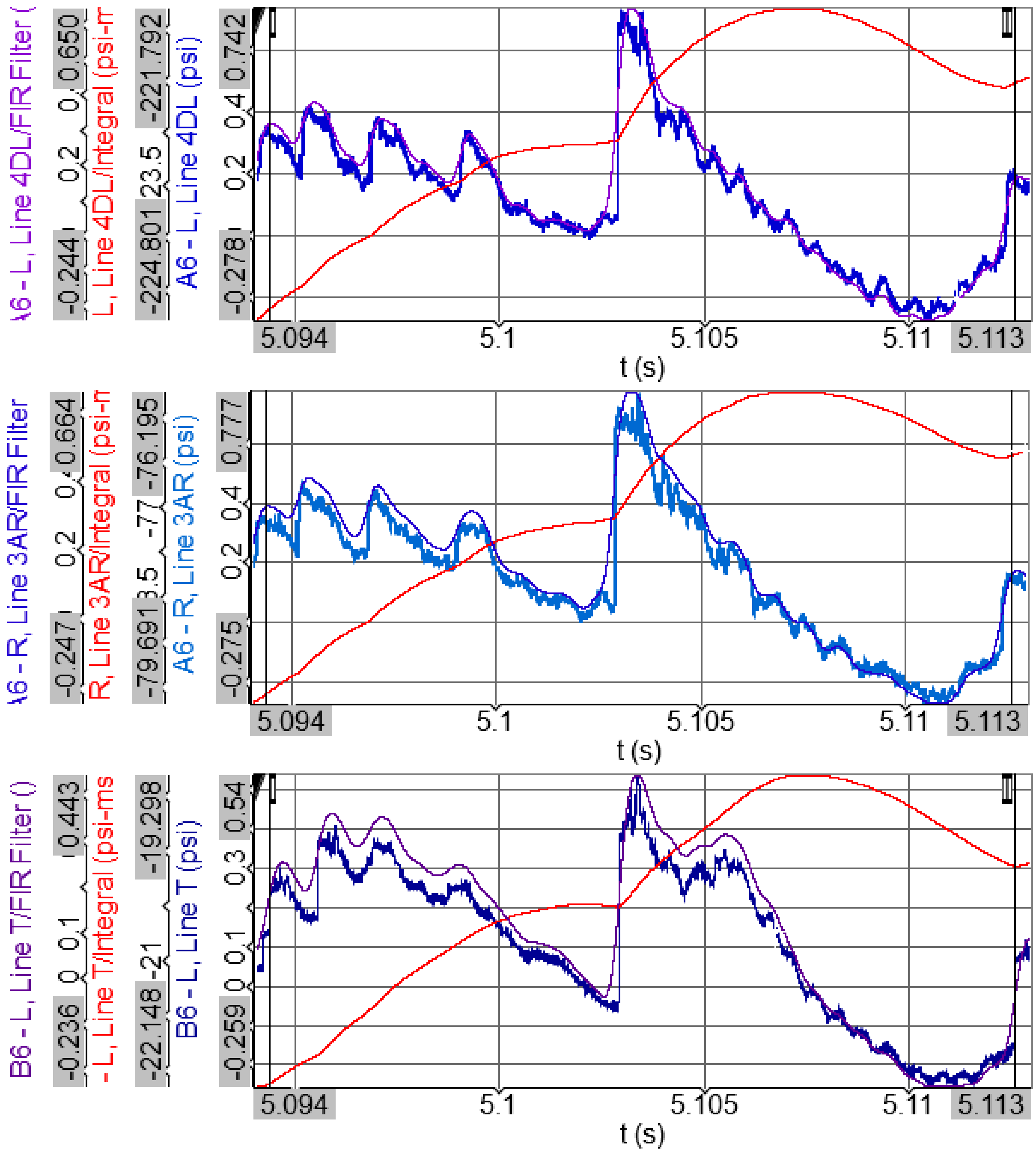

B3 - R, Line 5FR (psi)
5.061
5.065
5.07
5.075
5.080
t (s)
A4 - L, Line 1 BL (psi)
5.064
5.07
5.075
5.08
5.084
t (s)
A4 - R, Line 1AR (psi)
5.064
5.07
5.075
5.08
5.084
t (s)

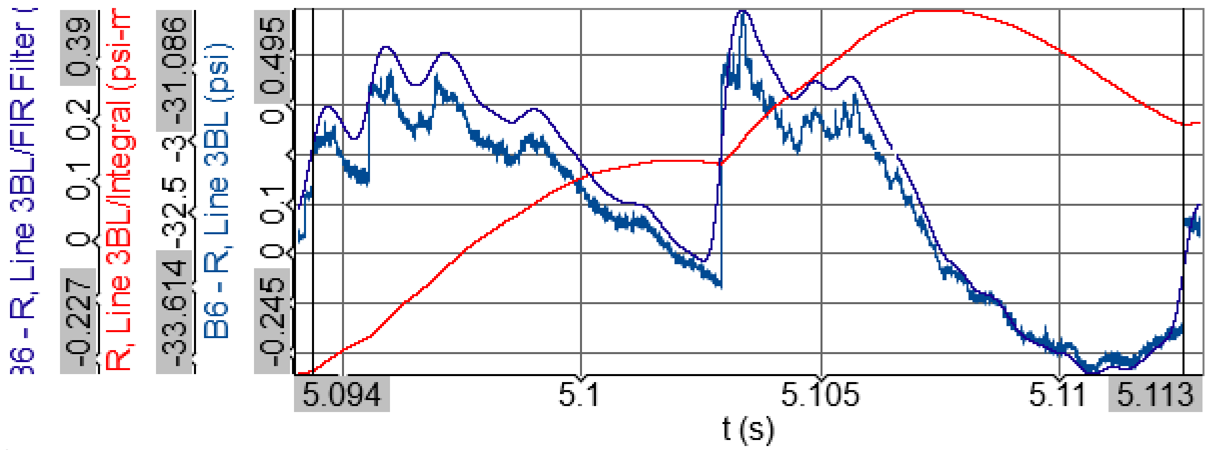

B4 - L, Line E3L/FIR Filter (
L, Line E3L/Integral (psi-m
B4 - L, Line E3L (psi)
5.064
5.07
5.075
5.08
5.084
t (s)

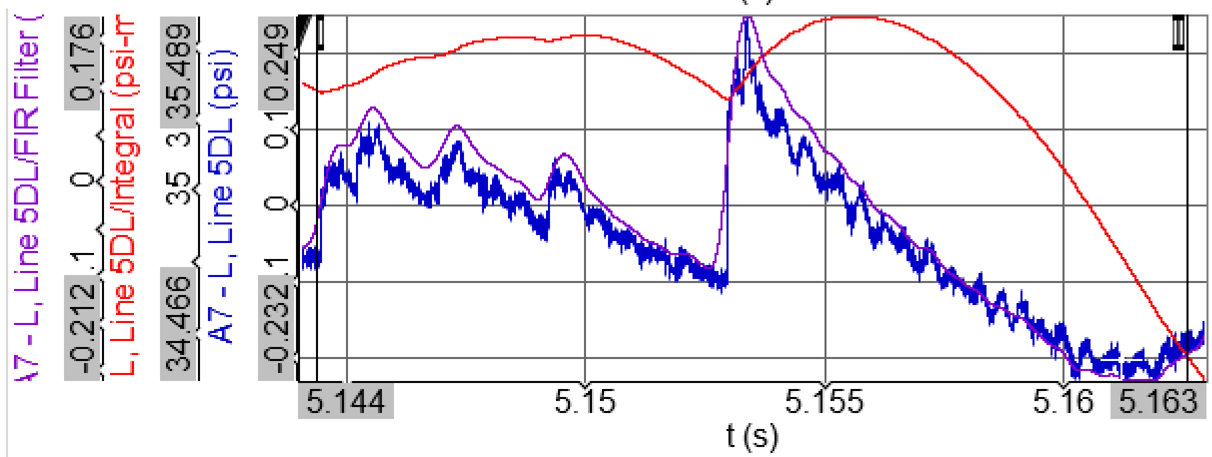

B4 - R, Line 3BR/FIR Filter
R, Line 3BR/Integral (psi-m
B4 - R, Line 3BR (psi)
5.064
5.07
5.075
5.08
5.084
t (s)

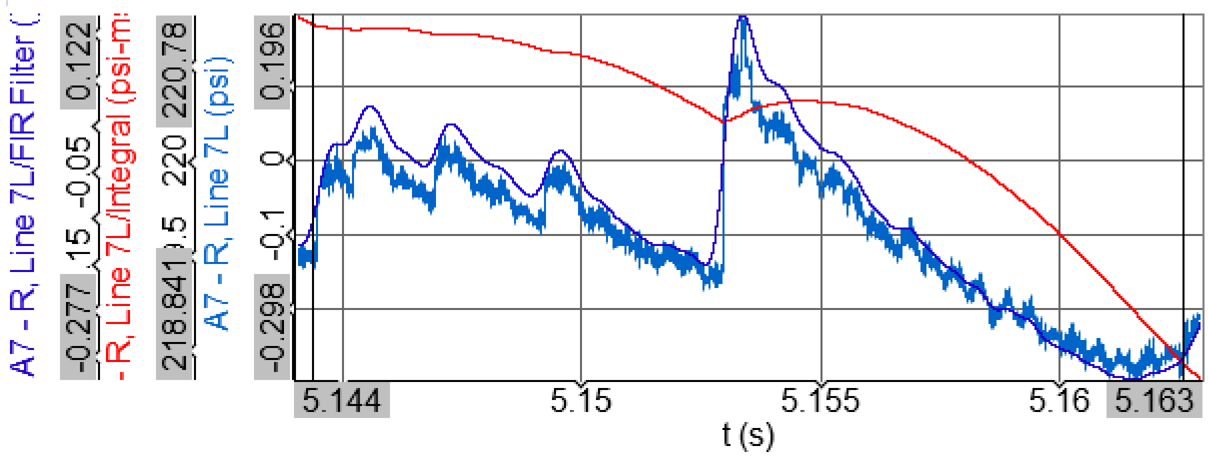

A5 - L, Line E2L/FIR Filter (
L, Line E2L/Integral (psi-m
A5 - L, Line E2L (psi)
5.073
5.08
5.085
5.092
t (s)

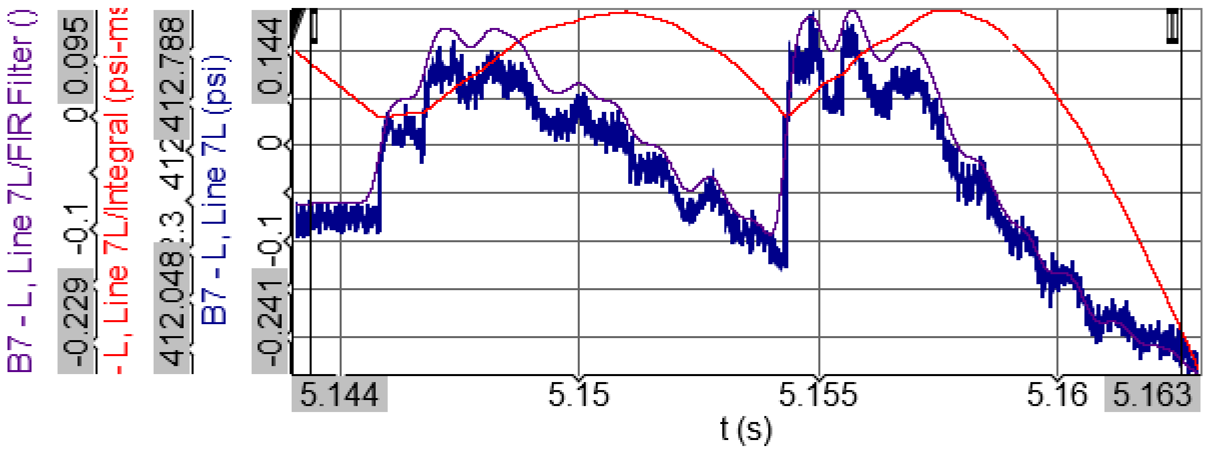

A5 - R, Line 1DR/FIR Filter
R, Line 1DR/Integral (psi-m
A5 - R, Line 1DR (psi)
t (s)
B5 - L, Line 5CR/FIR Filter
L, Line 5CR/Integral (psi-m
B5 - L, Line 5CR (psi)
t (s)
B5 - R, Line 5CL/FIR Filter
R, Line 5CL/Integral (psi-m
B5 - R, Line 5CL (psi)
t (s)

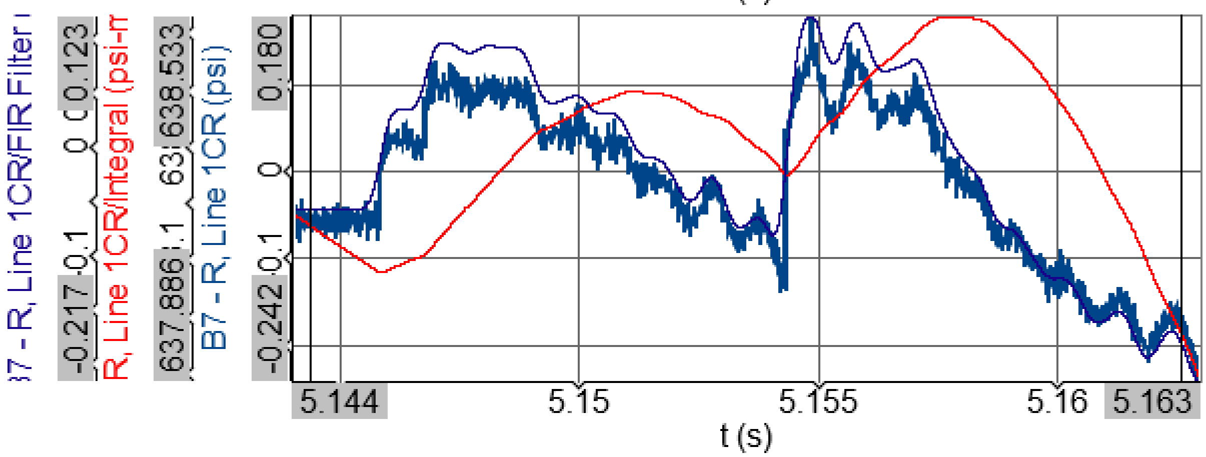

A6 - L, Line 4DL/FIR Filter (
L, Line 4DL/Integral (psi-m
A6 - L, Line 4DL (psi)
t (s)
5.094
5.1
5.105
5.11
5.113
A6 - R, Line 3AR/FIR Filter
R, Line 3AR/Integral (psi-m
A6 - R, Line 3AR (psi)
B6 - L, Line T/FIR Filter ()
- L, Line T/Integral (psi-ms
B6 - L, Line T (psi)

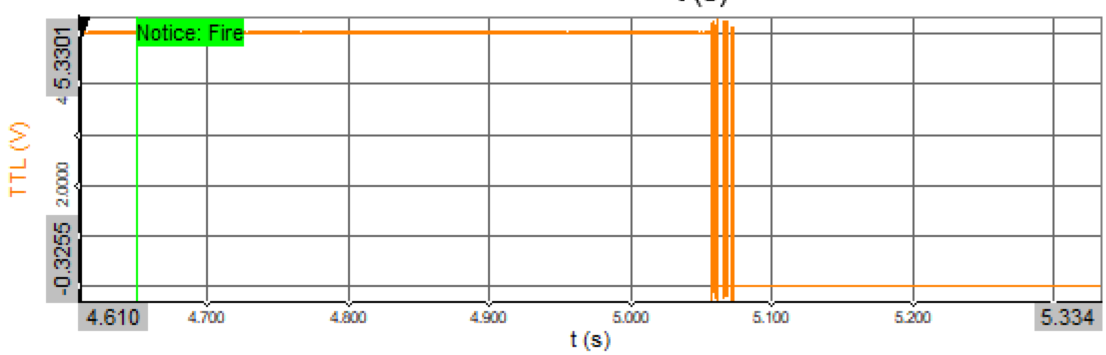

B6 - R, Line 3BL (psi)
5.094
5.1
5.105
5.11
5.113
t (s)


A7 - L, Line 5DL (psi)
5.144
5.15
5.155
5.16
5.163
t (s)


A7 - R, Line 7L/FIR Filter (
A7 - R, Line 7L (psi)
5.144
5.15
5.155
5.16
5.163
t (s)

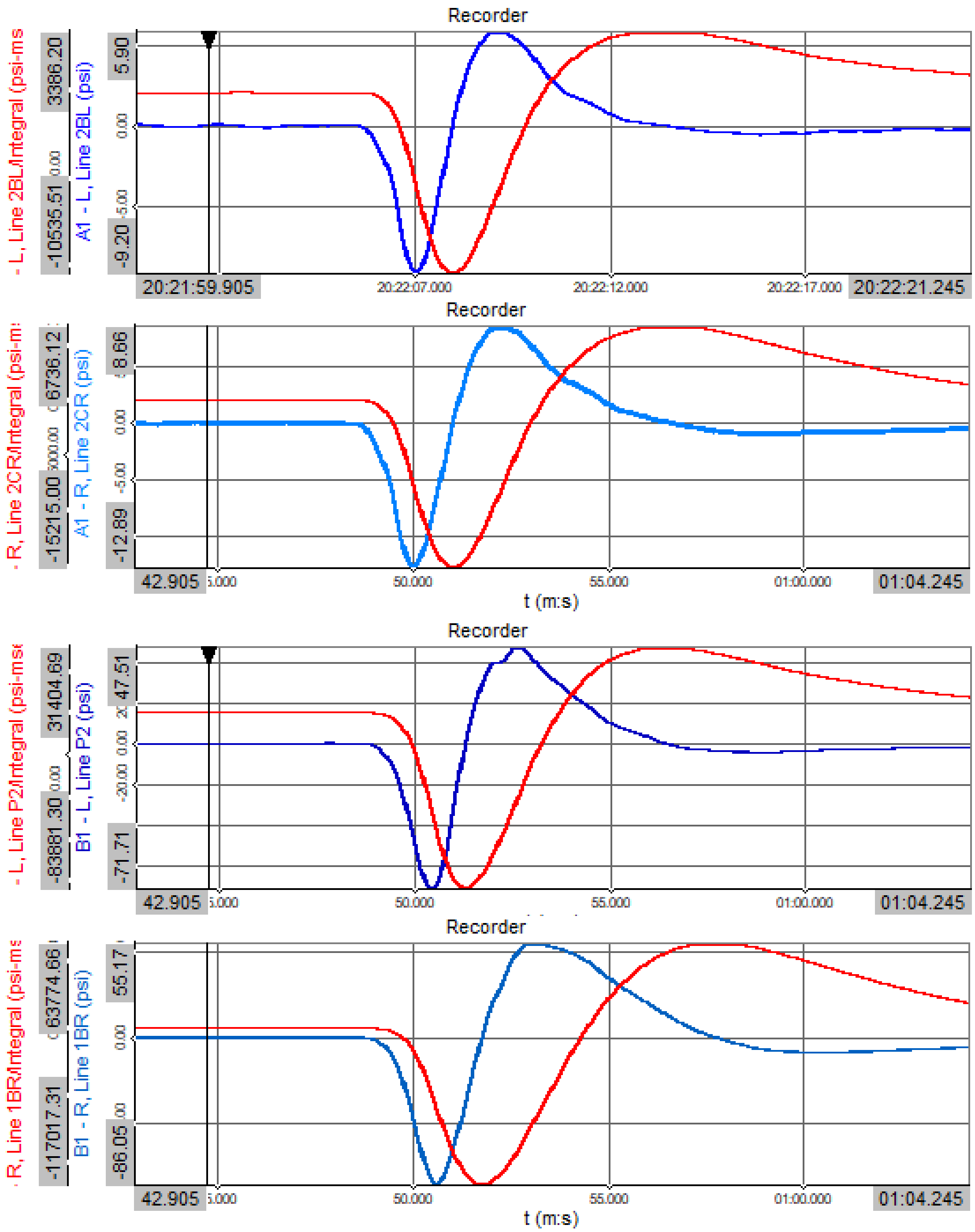

B7 - L, Line 7L/FIR Filter ()
-L, Line 7L/Integral (psi-ms
B7 - L, Line 7L (psi)
t (s)

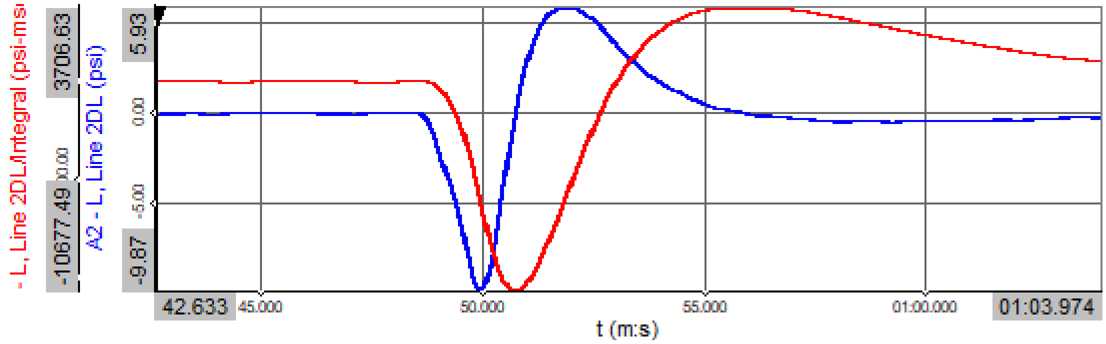

B7 - R, Line 1CR/FIR Filter
R, Line 1CR/Integral (psi-m
B7 - R, Line 1CR (psi)
t (s)

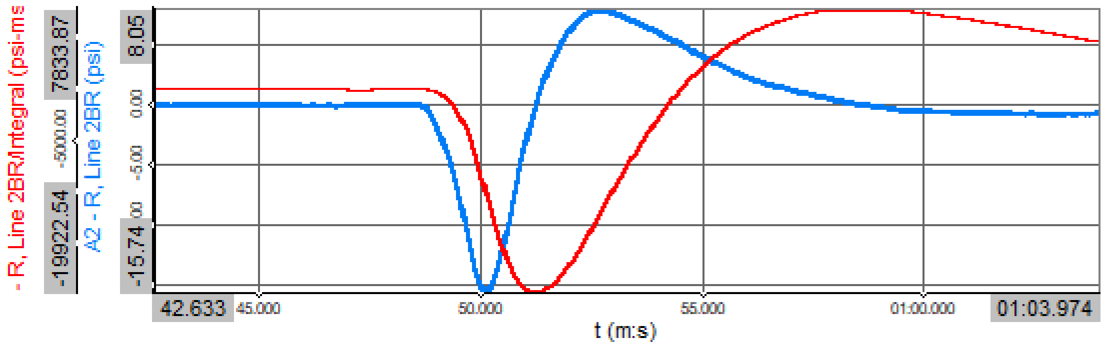

Notice: Fire
TTL (V)
t (s)

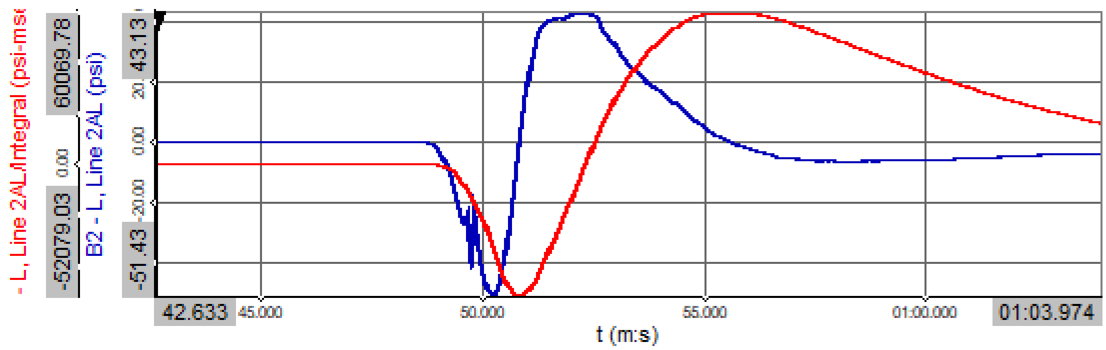
8.6 Fine Al-Fe_3O_4 – Small-Scale Mix ID #27 (SMS Mixed)

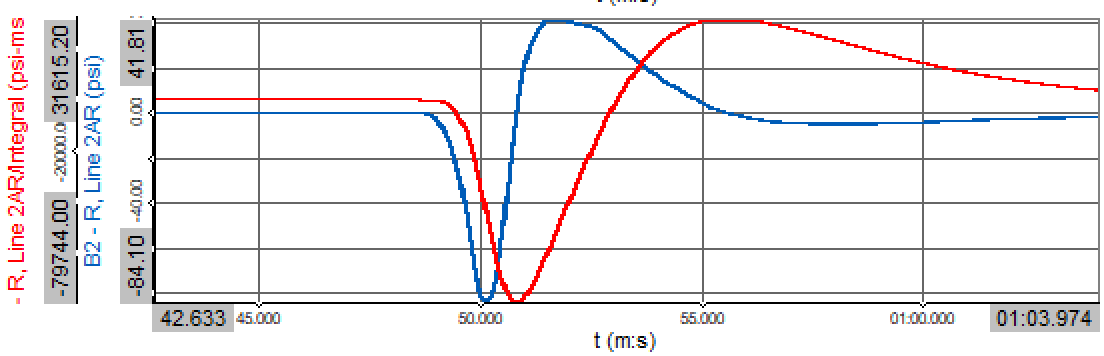
8.6.1 Trial 1 for Small-Scale Mix ID #27

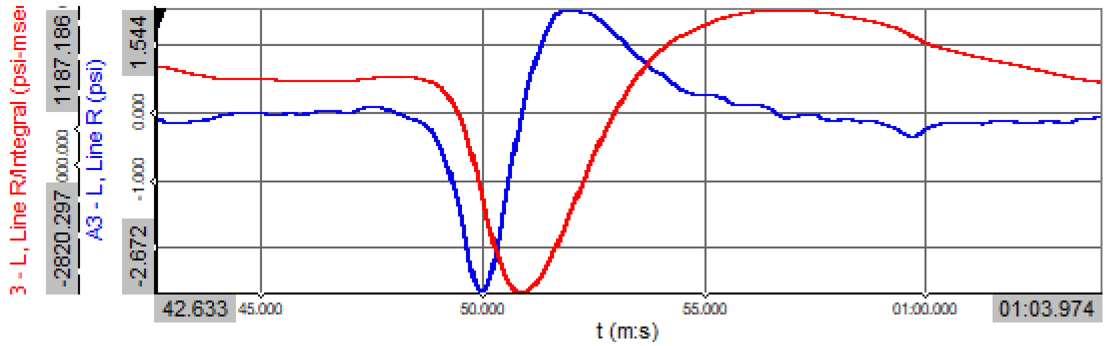


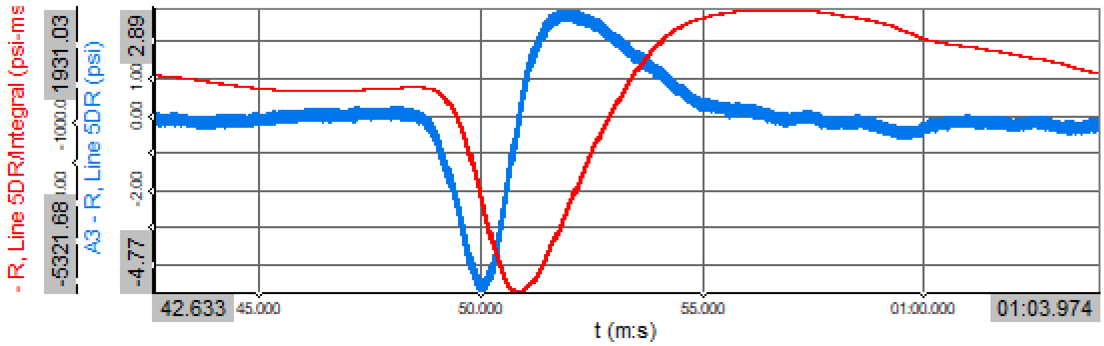

- L, Line 2DL/Integral (psi-ms)
A2 - L, Line 2DL (psi)
3706.63
-10677.49
5.93
0.00
-5.00
-9.87
42.633
45.000
50.000
55.000
01:00.000
01:03.974
t (m:s)

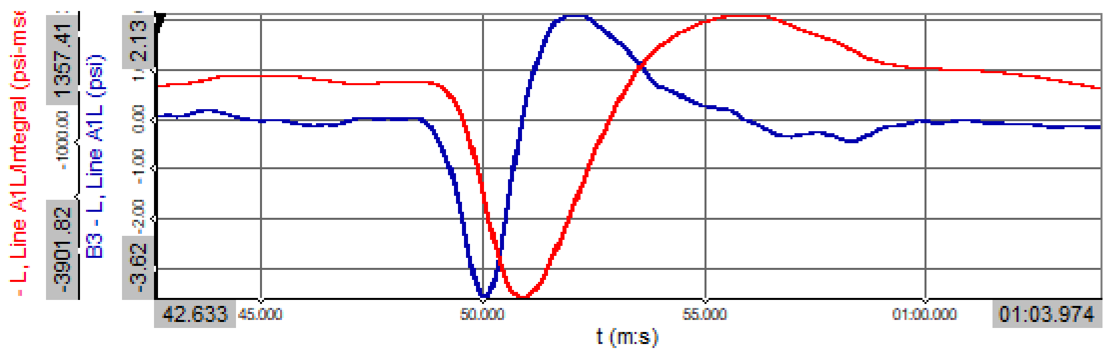

- R, Line 2BR/Integral (psi-ms)
A2 - R, Line 2BR (psi)
7833.87
-19922.54
8.05
0.00
-5.00
-15.74
42.633
45.000
50.000
55.000
01:00.000
01:03.974
t (m:s)

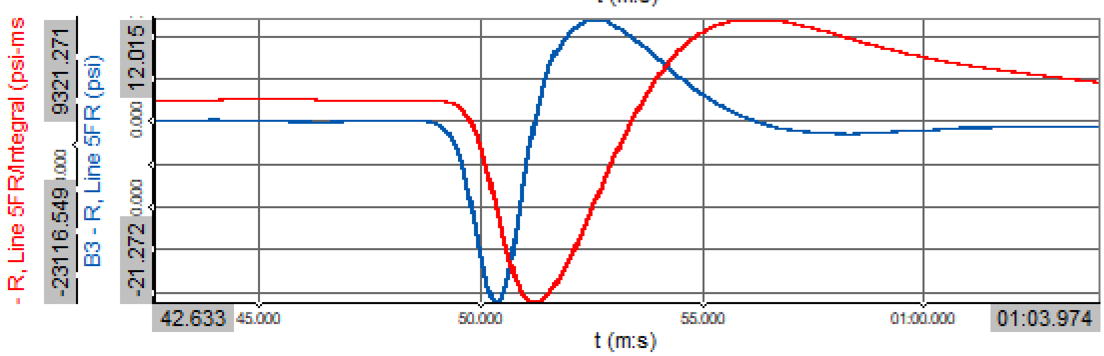

- L, Line 2AL/Integral (psi-ms)
B2 - L, Line 2AL (psi)
60069.78
0.00
-52079.03
43.13
20
0.00
-20.00
-51.43
42.633
45.000
50.000
55.000
01:00.000
01:03.974
t (m:s)

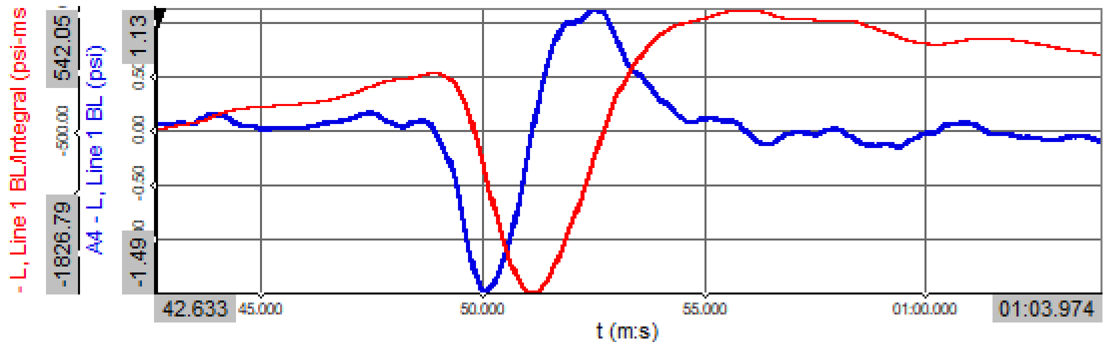

- R, Line 2AR/Integral (psi-ms)
B2 - R, Line 2AR (psi)
31615.20
-79744.00
41.81
0.00
-40.00
-84.10
42.633
45.000
50.000
55.000
01:00.000
01:03.974
t (m:s)

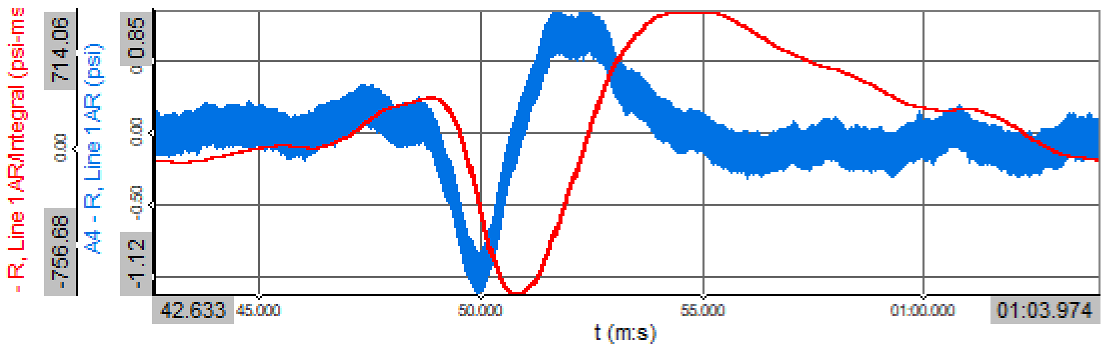

3 - L, Line R/Integral (psi-mse
A3 - L, Line R (psi)
1187.186
-2820.297
1.544
-2.672
42.633
01:03.974
t (m:s)

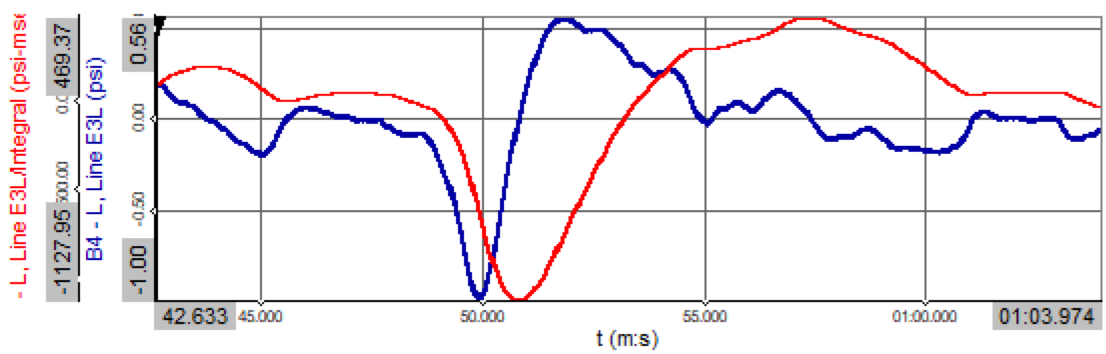

- R, Line 5DR/Integral (psi-ms
A3 - R, Line 5DR (psi)
1931.03
-5321.68
2.89
-4.77
42.633
01:03.974
t (m:s)

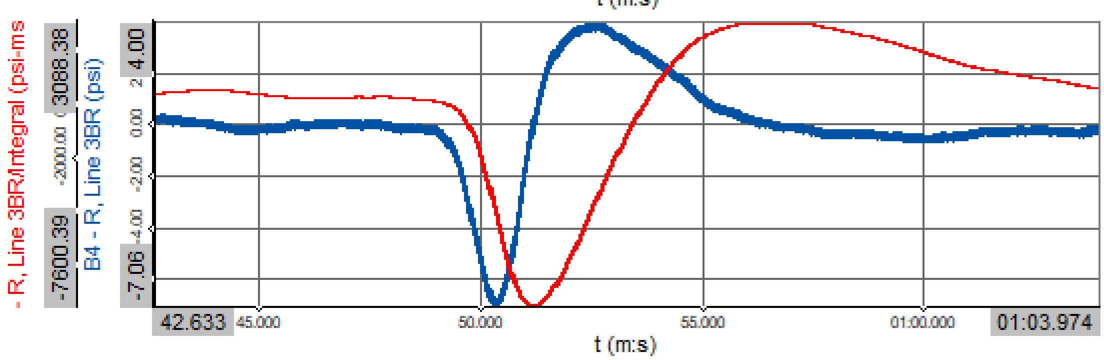

- L, Line A1L/Integral (psi-ms
B3 - L, Line A1L (psi)
1357.41
-3901.82
2.13
-3.62
42.633
01:03.974
t (m:s)

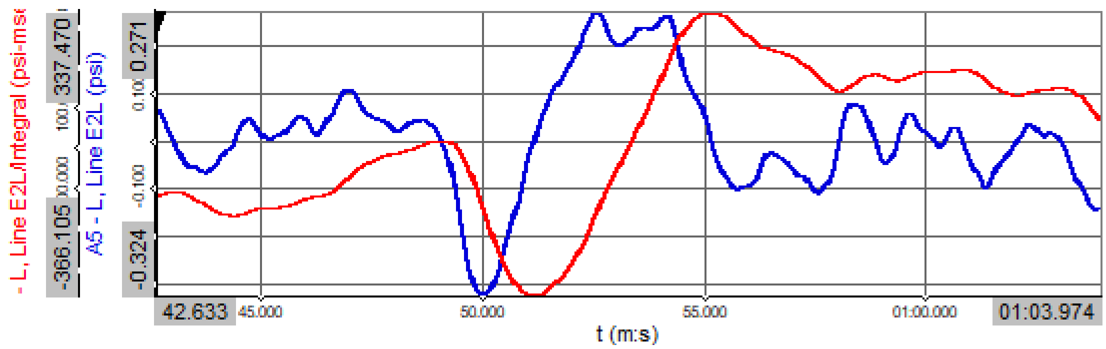

- R, Line 5FR/Integral (psi-ms
B3 - R, Line 5FR (psi)
9321.271
-23116.549
12.015
-21.272
42.633
01:03.974
t (m:s)

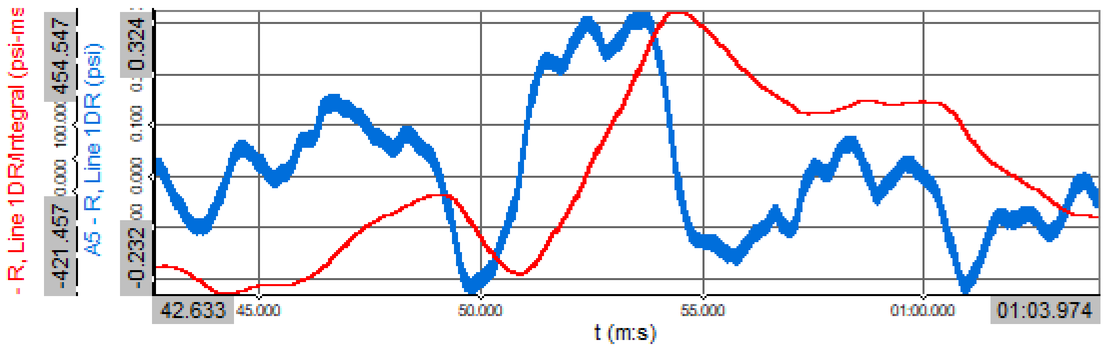

- L, Line 1 BL/Integral (psi-ms
A4 - L, Line 1 BL (psi)
542.05
-1826.79
1.13
-1.49
42.633
45.000
50.000
55.000
01:00.000
01:03.974
t (m:s)

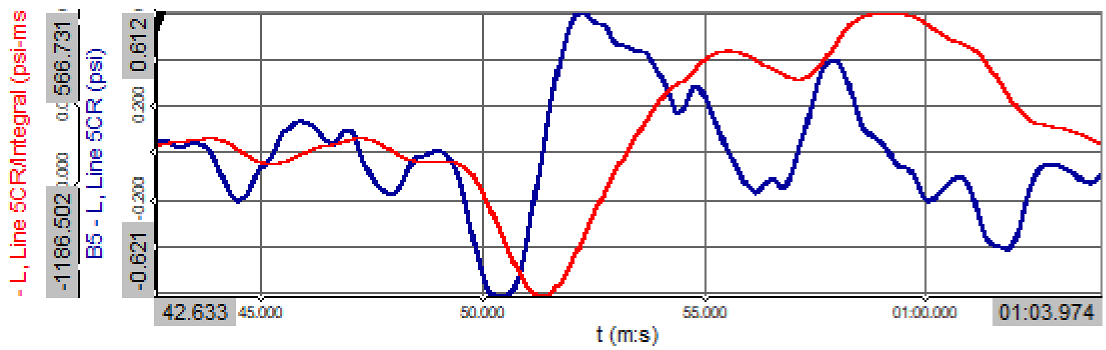

- R, Line 1 AR/Integral (psi-ms
A4 - R, Line 1 AR (psi)
714.06
-756.68
0.85
-1.12
42.633
45.000
50.000
55.000
01:00.000
01:03.974
t (m:s)

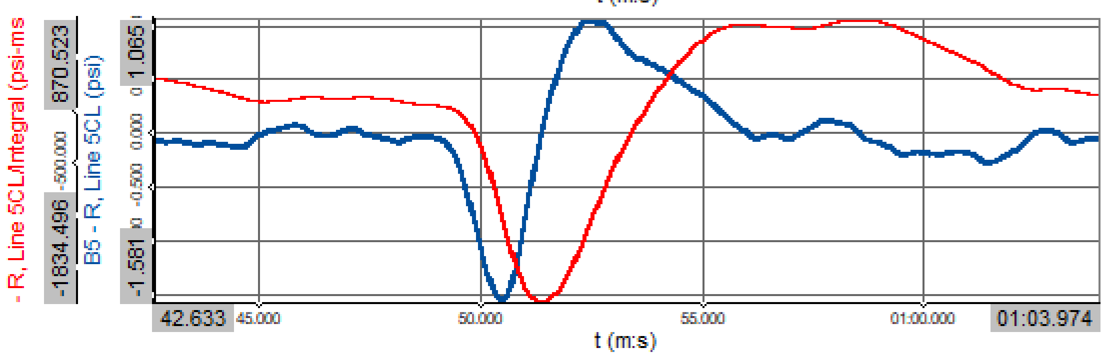

- L, Line E3L/Integral (psi-ms
B4 - L, Line E3L (psi)
469.37
-1127.95
0.56
-1.00
42.633
45.000
50.000
55.000
01:00.000
01:03.974
t (m:s)

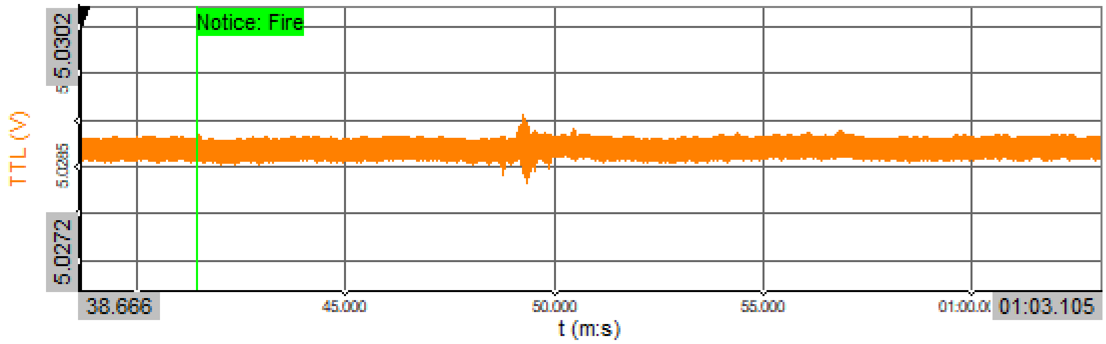

- R, Line 3BR/Integral (psi-ms
B4 - R, Line 3BR (psi)
3088.38
-7600.39
4.00
-7.06
42.633
45.000
50.000
55.000
01:00.000
01:03.974
t (m:s)


- L, Line E2L/Integral (psi-ms
337.470
-366.105
A5 - L, Line E2L (psi)
0.271
-0.324
42.633
45.000
50.000
55.000
01:00.000
01:03.974
t (m:s)

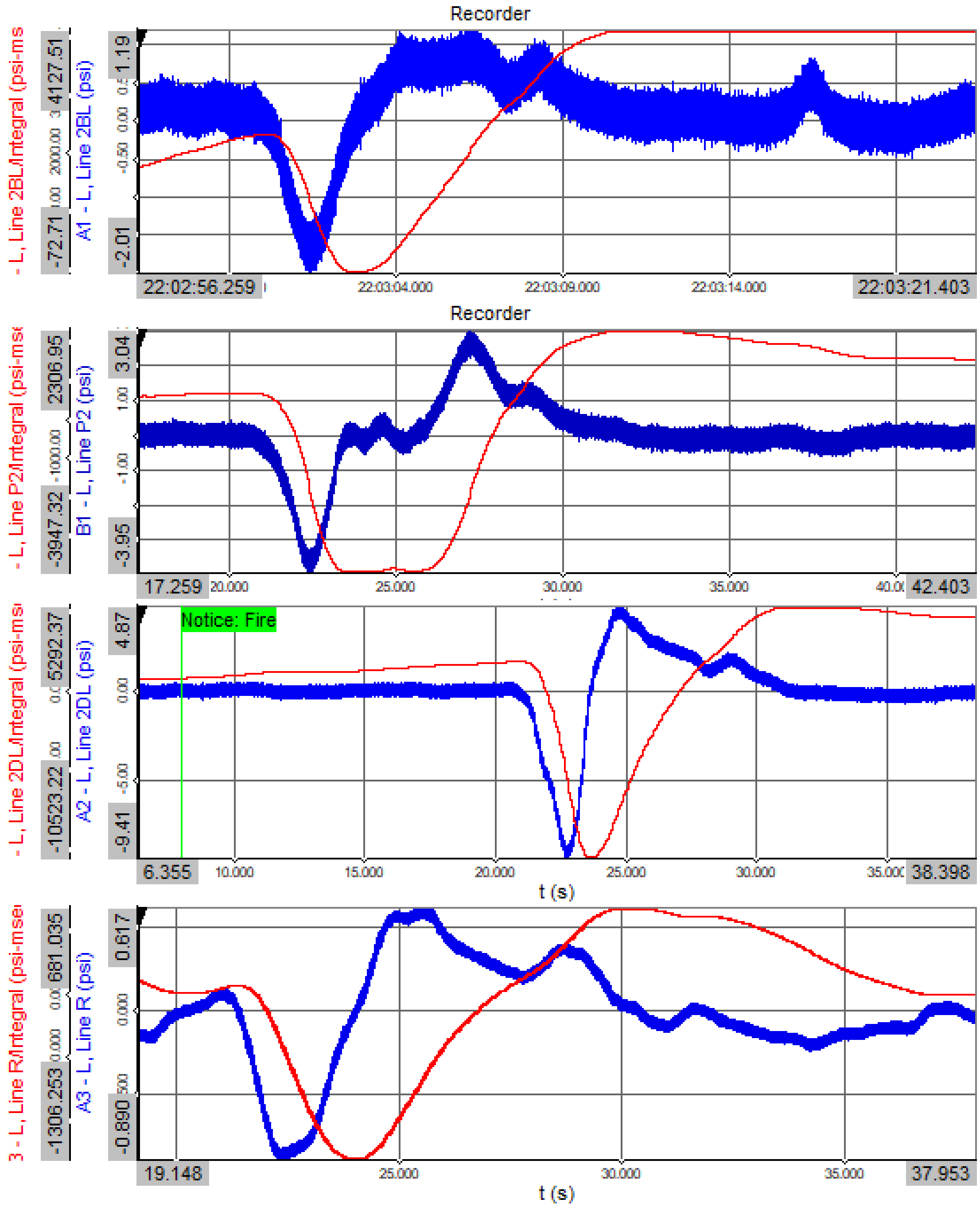

- R, Line 1DR/Integral (psi-ms
454.547
-421.457
A5 - R, Line 1DR (psi)
0.324
-0.232
42.633
45.000
50.000
55.000
01:00.000
01:03.974
t (m:s)

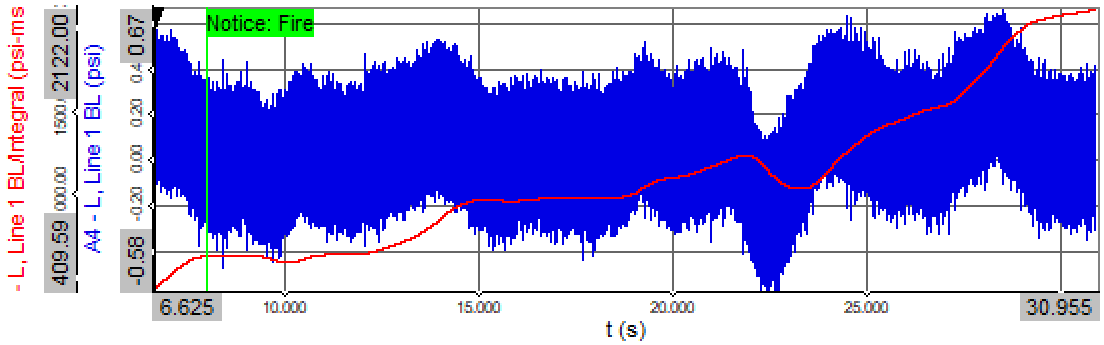

- L, Line 5CR/Integral (psi-ms
566.731
-1186.502
B5 - L, Line 5CR (psi)
0.612
-0.621
42.633
45.000
50.000
55.000
01:00.000
01:03.974
t (m:s)

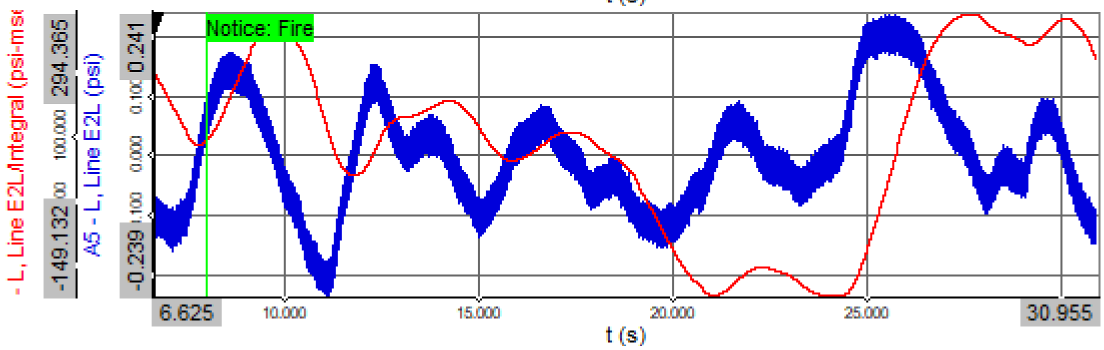

- R, Line 5CL/Integral (psi-ms
870.523
-1834.496
B5 - R, Line 5CL (psi)
1.065
-1.581
42.633
45.000
50.000
55.000
01:00.000
01:03.974
t (m:s)

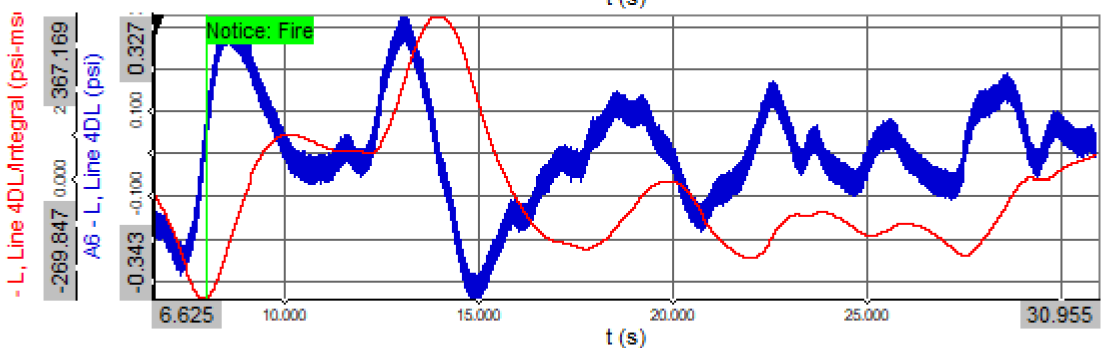

Notice: Fire
5.0302
5.0285
5.0272
TTL (V)
38.666
45.000
50.000
55.000
01:03.105
t (m:s)

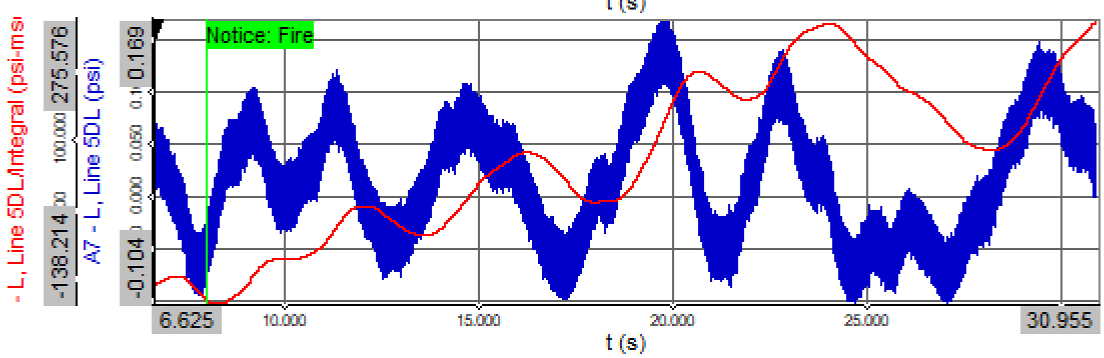
8.6.2 Trial 2 for Small-Scale Mix ID #27

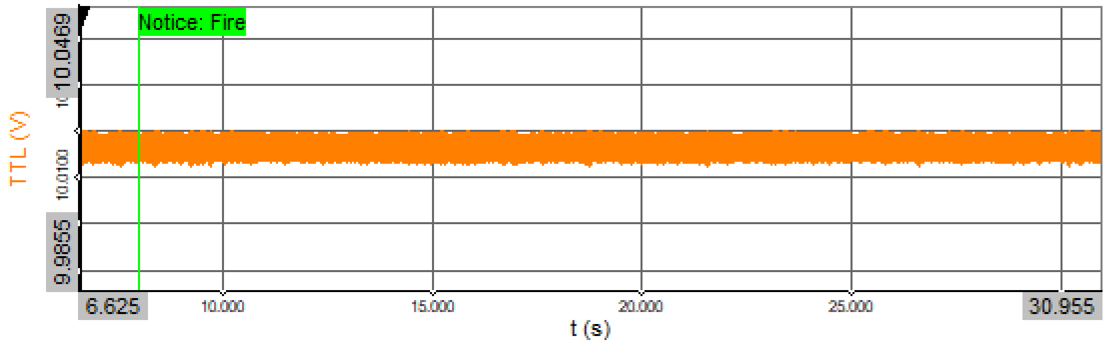



Notice: Fire
- L, Line 1 BL/Integral (psi-ms
A4 - L, Line 1 BL (psi)
2122.00
409.59
0.67
-0.58
6.625
10.000
15.000
20.000
25.000
30.955
t (s)

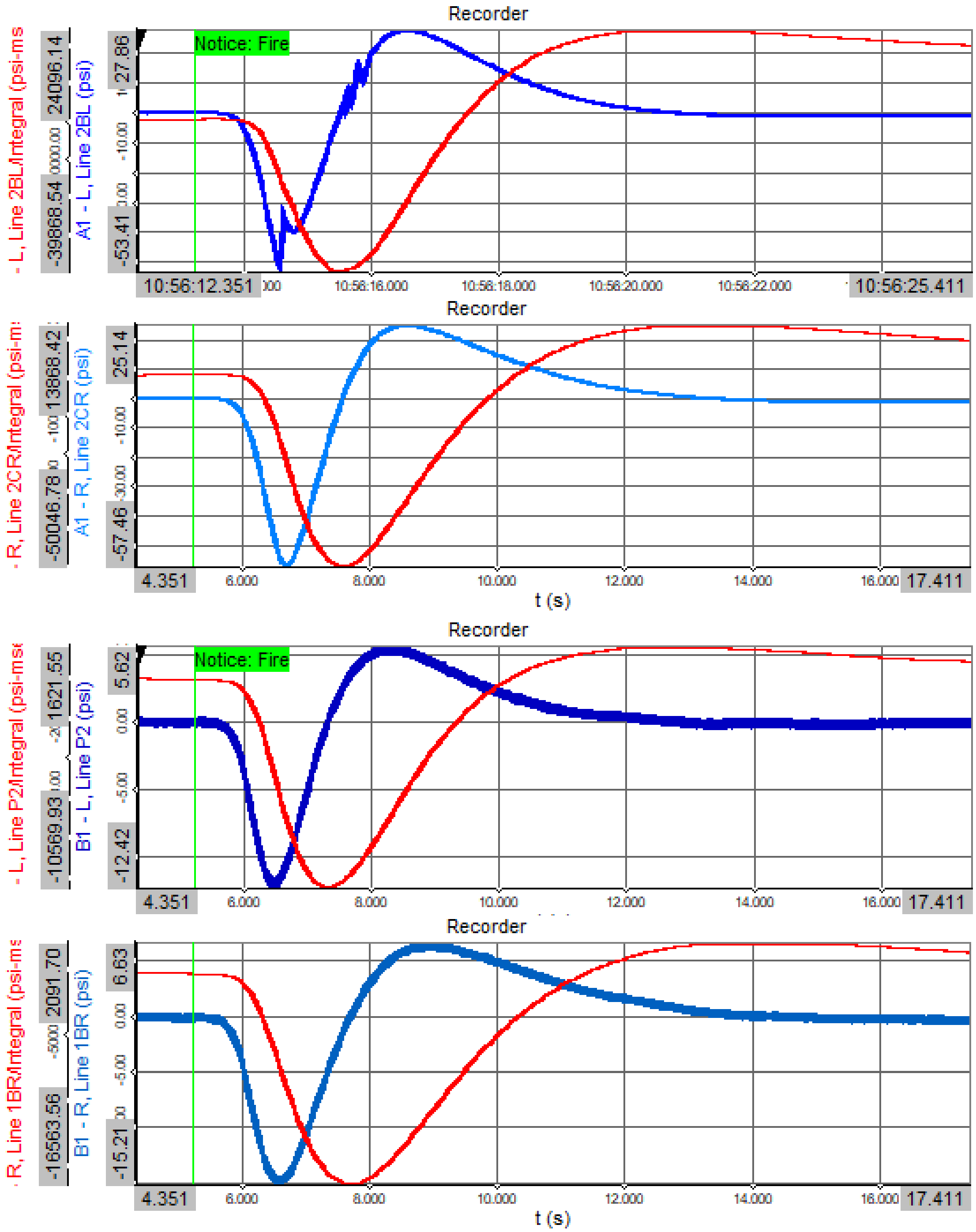

Notice: Fire
- L, Line E2L/Integral (psi-ms
A5 - L, Line E2L (psi)
294.365
-149.132
0.241
-0.239
6.625
10.000
15.000
20.000
25.000
30.955
t (s)

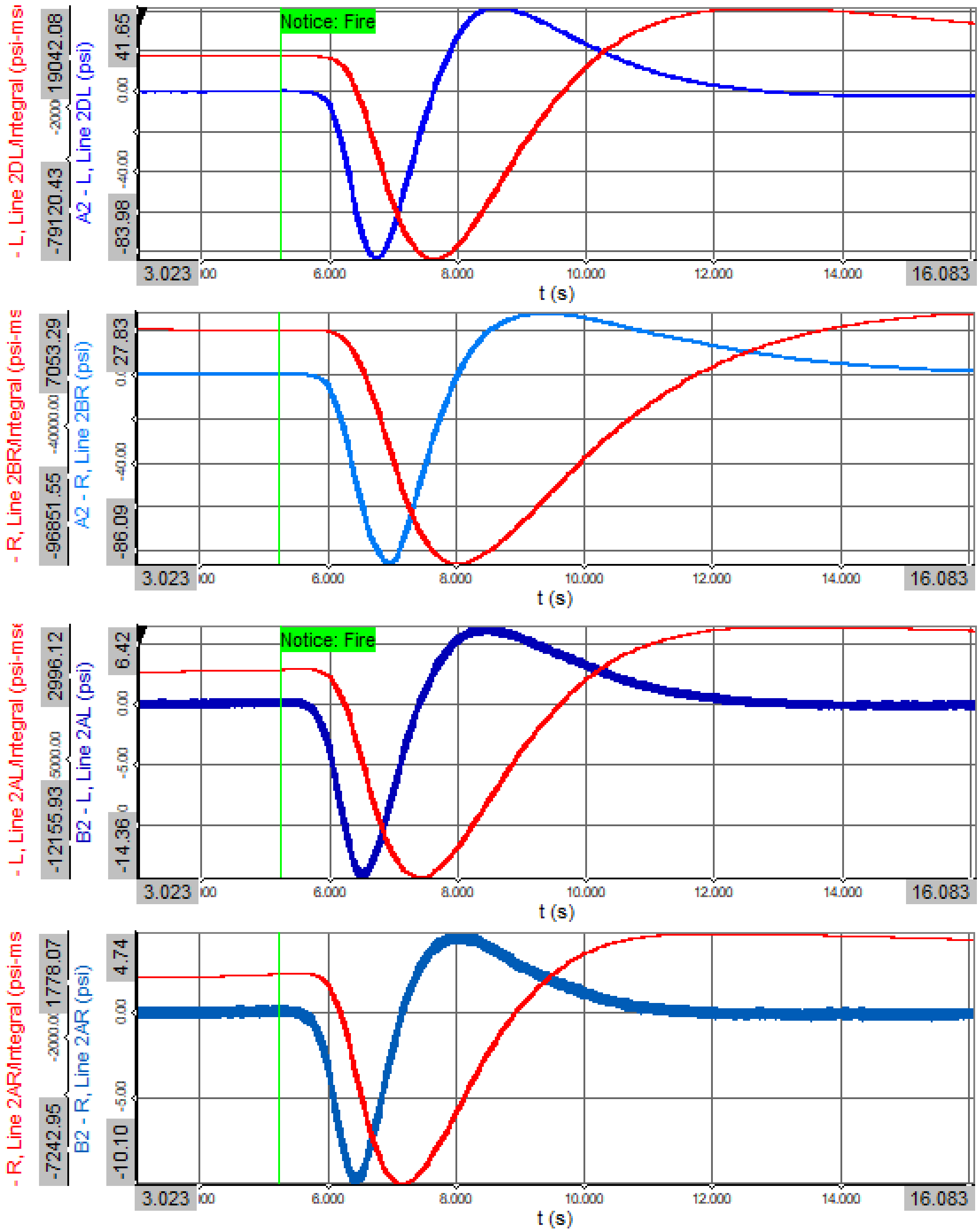

Notice: Fire
- L, Line 4DL/Integral (psi-ms
A6 - L, Line 4DL (psi)
367.169
-269.847
0.327
-0.343
6.625
10.000
15.000
20.000
25.000
30.955
t (s)

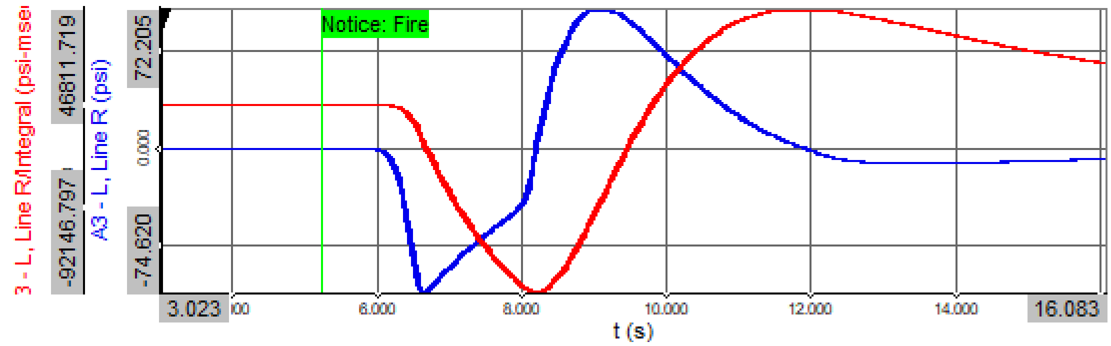

Notice: Fire
- L, Line 5DL/Integral (psi-ms
A7 - L, Line 5DL (psi)
275.576
-138.214
0.169
-0.104
6.625
10.000
15.000
20.000
25.000
30.955
t (s)

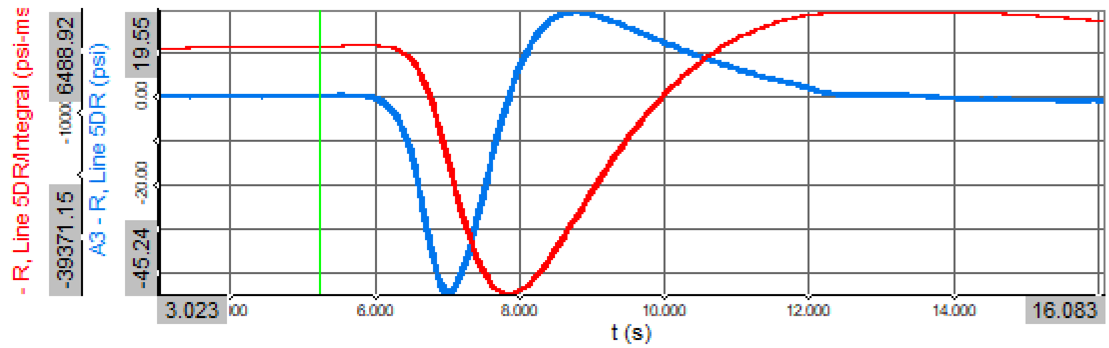

Notice: Fire
TTL (V)
10.0469
10.0100
9.9855
6.625
10.000
15.000
20.000
25.000
30.955
t (s)

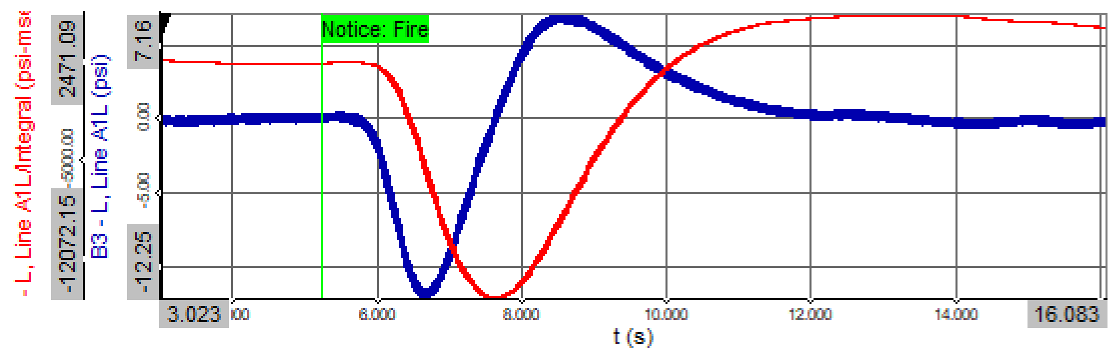
8.6.3 Trial 3 for Small-Scale Mix ID #27

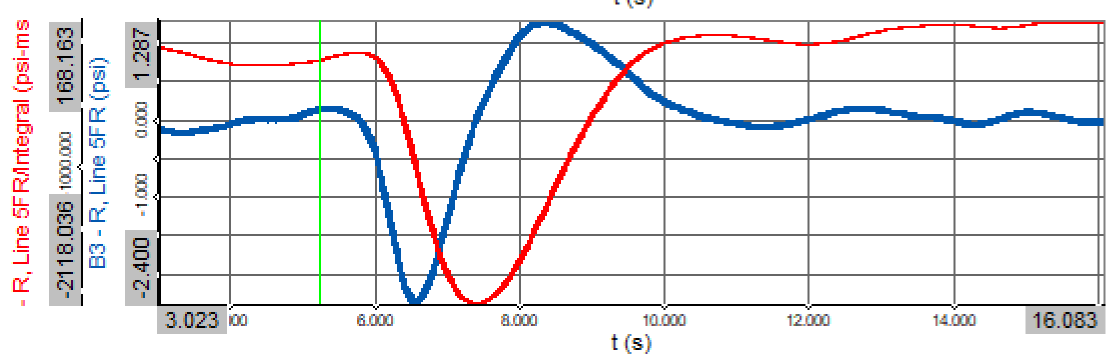


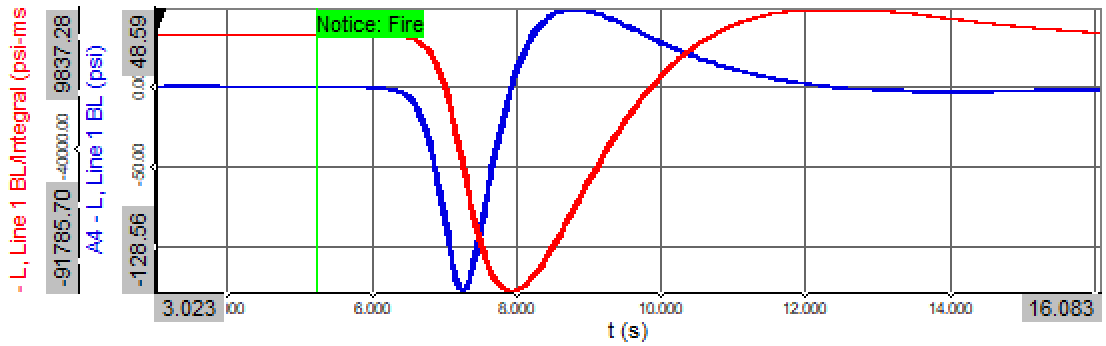

Notice: Fire
- L, Line 2DL/Integral (psi-ms
A2 - L, Line 2DL (psi)
19042.08
-79120.43
41.65
-83.98
- R, Line 2BR/Integral (psi-ms
A2 - R, Line 2BR (psi)
7053.29
-96851.55
27.83
-86.09
- L, Line 2AL/Integral (psi-ms
B2 - L, Line 2AL (psi)
2996.12
-12155.93
6.42
-14.36
- R, Line 2AR/Integral (psi-ms
B2 - R, Line 2AR (psi)
1778.07
-7242.95
4.74
-10.10
3.023
16.083
6.000
8.000
10.000
12.000
14.000
t (s)

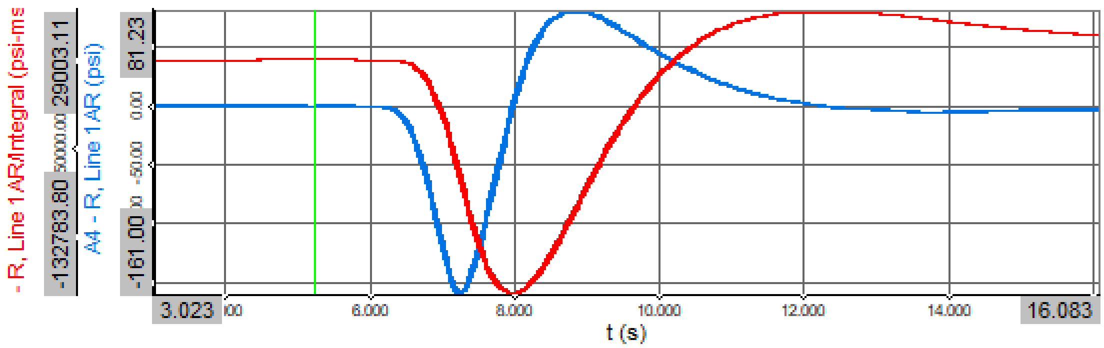

3 - L, Line R/Integral (psi-mse
46811.719
-92146.797
A3 - L, Line R (psi)
72.205
0.000
-74.620
Notice: Fire
3.023
6.000
8.000
10.000
12.000
14.000
16.083
t (s)

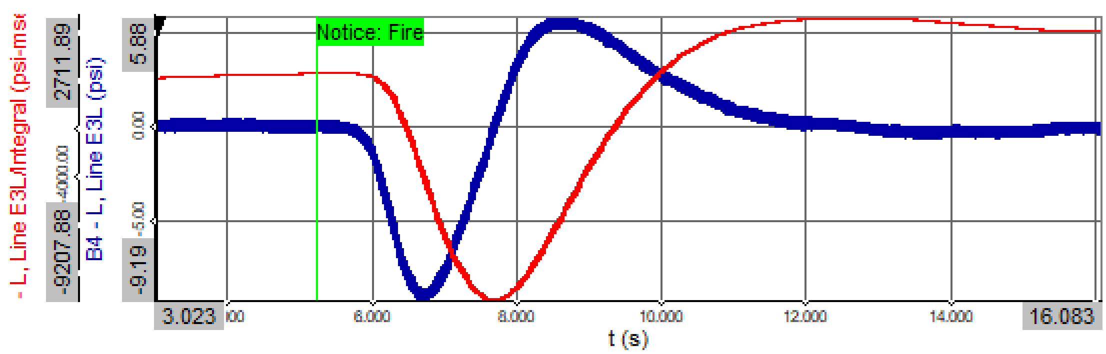

- R, Line 5DR/Integral (psi-ms
6488.92
-39371.15
A3 - R, Line 5DR (psi)
19.55
0.00
-20.00
-45.24
3.023
6.000
8.000
10.000
12.000
14.000
16.083
t (s)

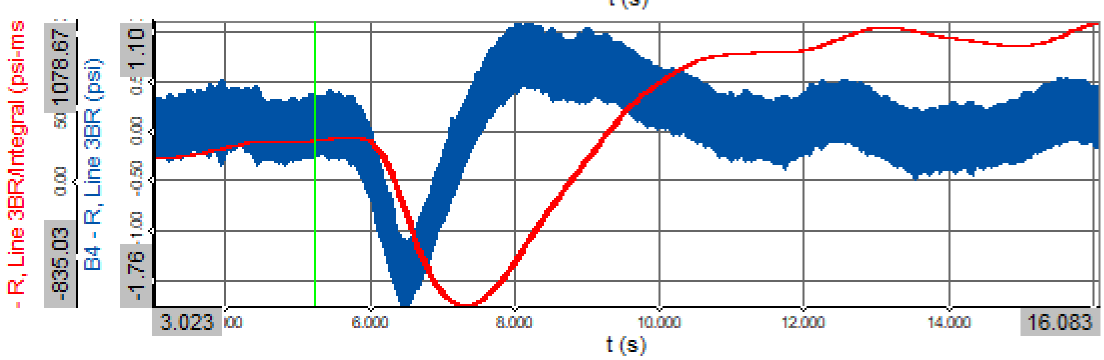

- L, Line A1L/Integral (psi-ms
2471.09
-5000.00
-12072.15
B3 - L, Line A1L (psi)
7.16
0.00
-5.00
-12.25
Notice: Fire
3.023
6.000
8.000
10.000
12.000
14.000
16.083
t (s)

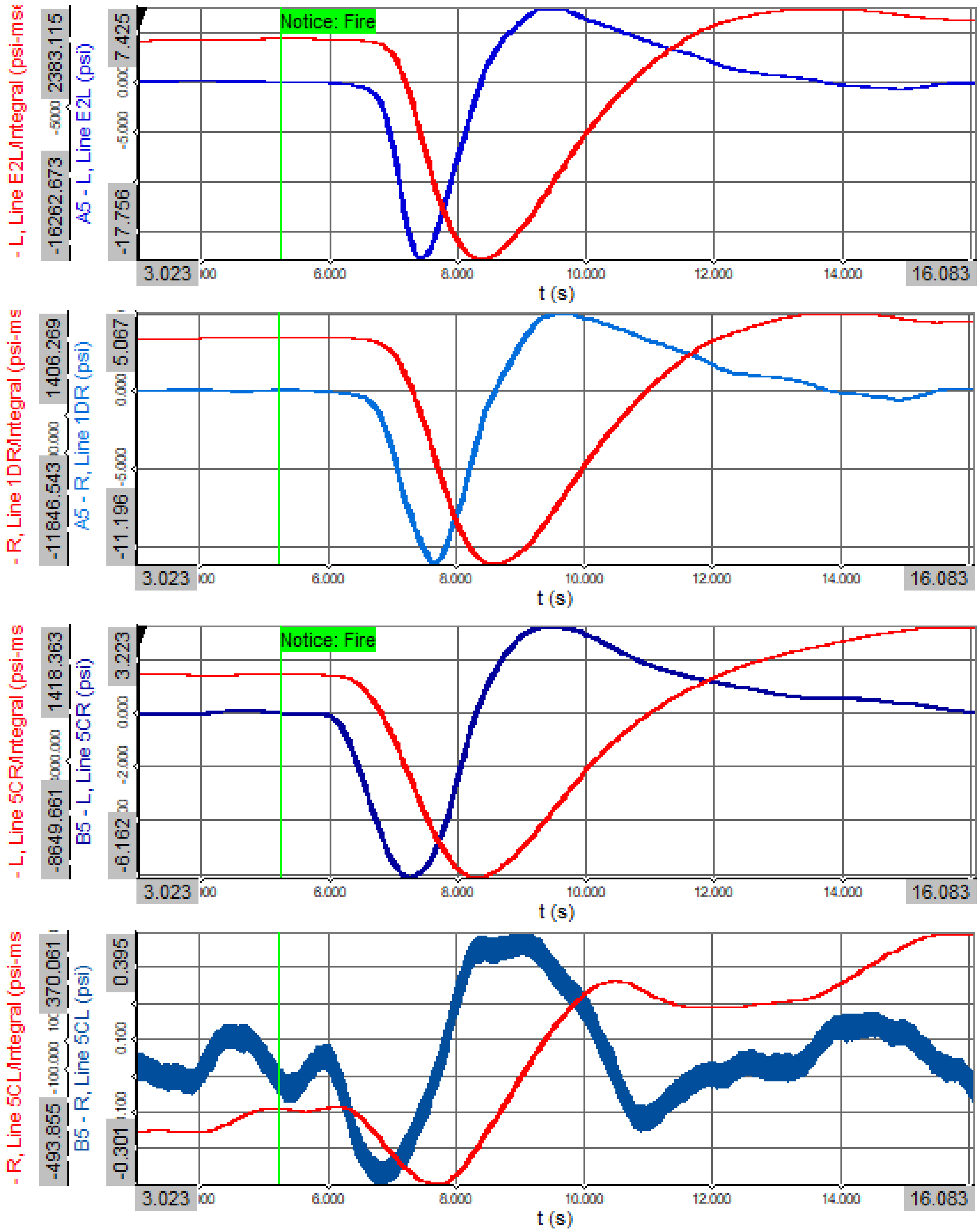

- R, Line 5FR/Integral (psi-ms
168.163
-1000.000
-2118.036
B3 - R, Line 5FR (psi)
1.287
0.000
-1.000
-2.400
3.023
6.000
8.000
10.000
12.000
14.000
16.083
t (s)

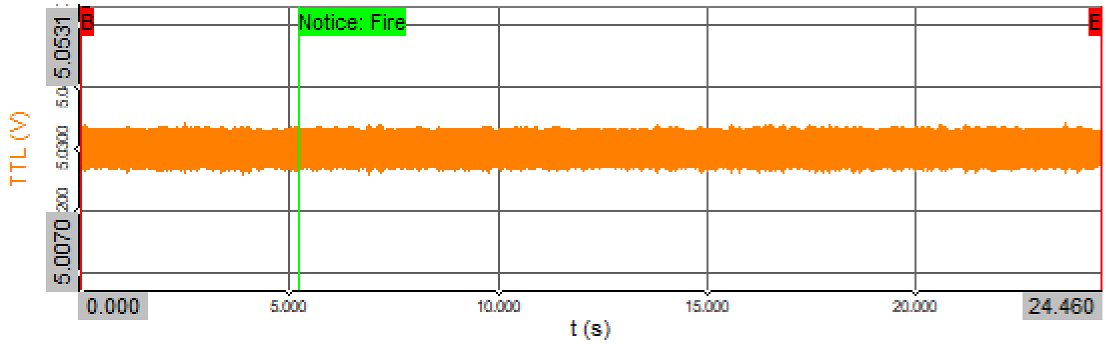

- L, Line 1 BL/Integral (psi-ms
A4 - L, Line 1 BL (psi)
9837.28
-91785.70
48.59
-128.56
Notice: Fire
3.023
16.083
t (s)


- R, Line 1 AR/Integral (psi-ms
A4 - R, Line 1 AR (psi)
29003.11
-132783.80
81.23
-161.00
3.023
16.083
t (s)


- L, Line E3L/Integral (psi-ms
B4 - L, Line E3L (psi)
2711.89
-9207.88
5.88
-9.19
Notice: Fire
3.023
16.083
t (s)

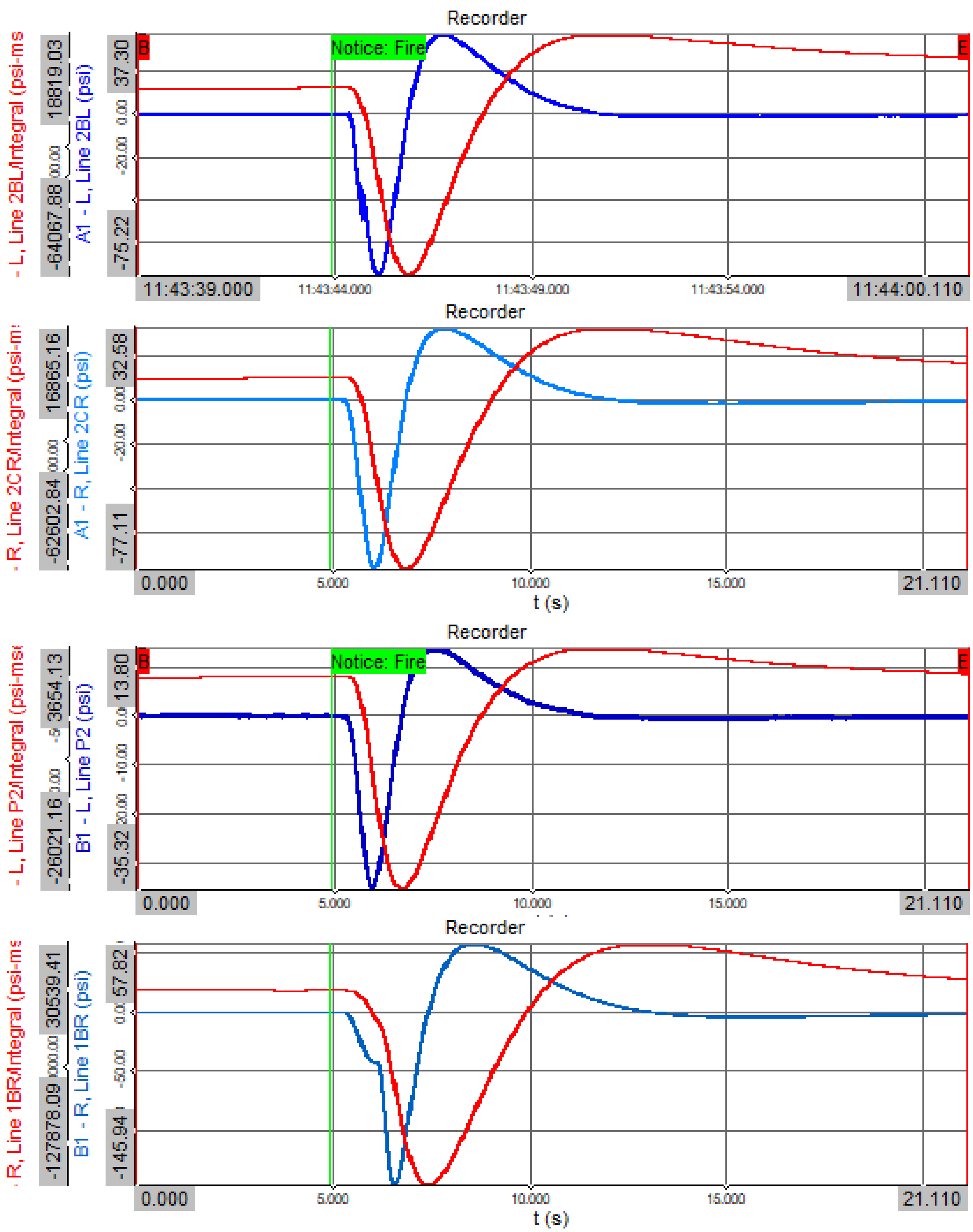

- R, Line 3BR/Integral (psi-ms
B4 - R, Line 3BR (psi)
1078.67
-835.03
1.10
-1.76
3.023
16.083
t (s)

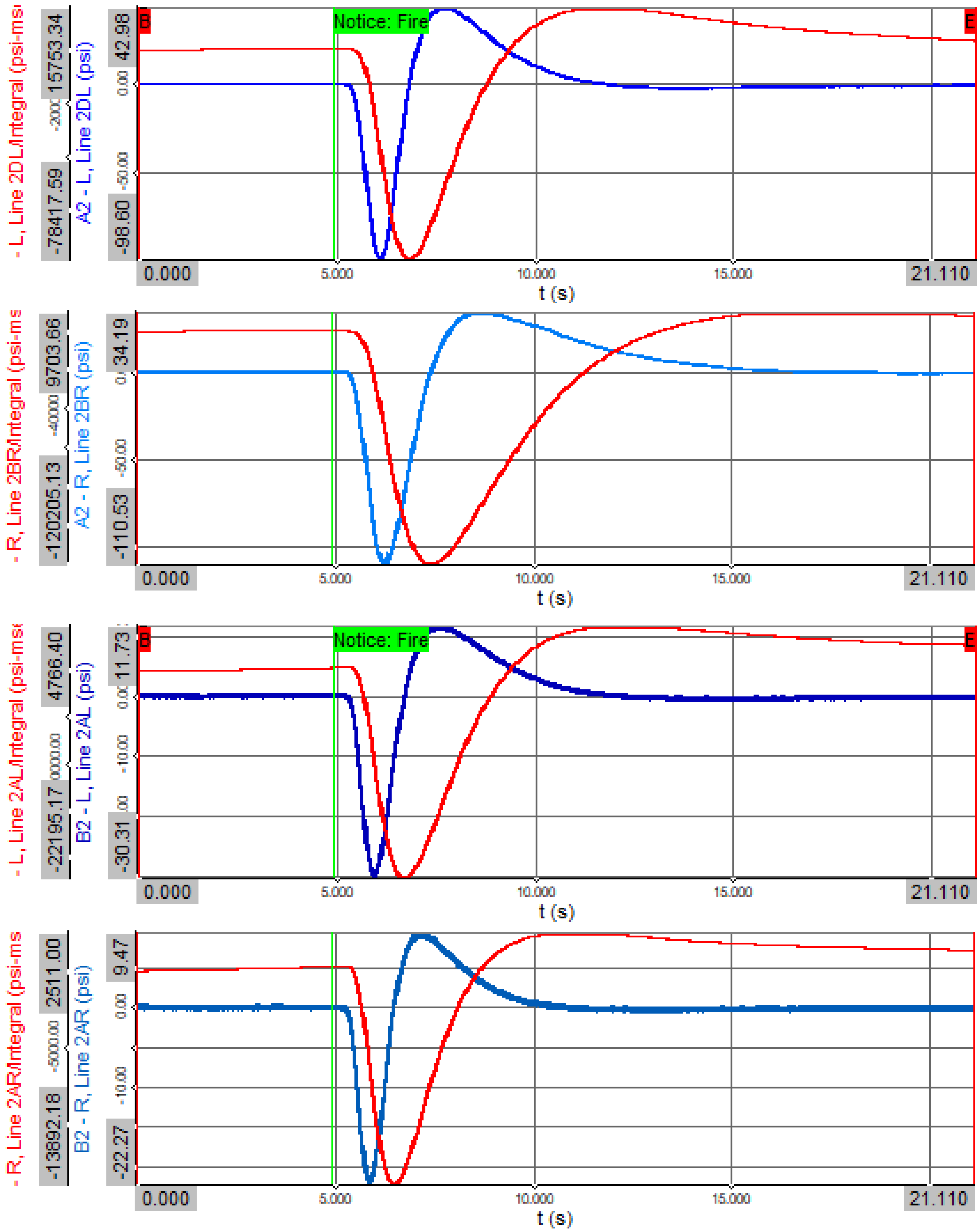

Notice: Fire
- L, Line E2L/Integral (psi-ms
A5 - L, Line E2L (psi)
2383.115
-16262.673
7.425
-17.756
- R, Line 1DR/Integral (psi-ms
A5 - R, Line 1DR (psi)
1406.269
-11846.543
5.067
-11.196
- L, Line 5CR/Integral (psi-ms
B5 - L, Line 5CR (psi)
1418.363
-8649.661
3.223
-6.162
- R, Line 5CL/Integral (psi-ms
B5 - R, Line 5CL (psi)
370.061
-493.855
0.395
-0.301
3.023
6.000
8.000
10.000
12.000
14.000
16.083
t (s)

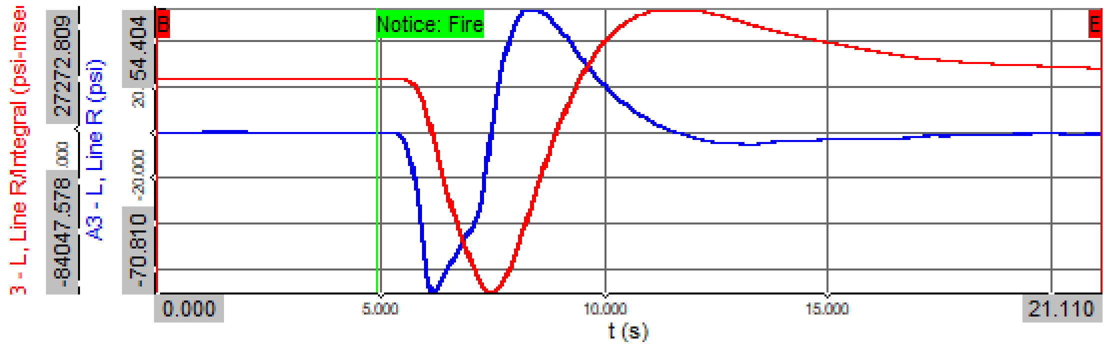

Notice: Fire
B
E
TTL (V)
5.0531
5.0070
0.000
5.000
10.000
15.000
20.000
24.460
t (s)

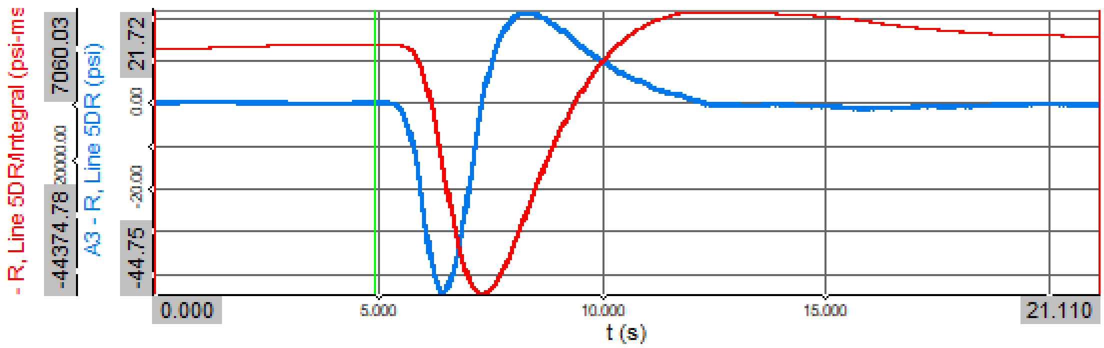
8.7 Fine Al-NiO – Small-Scale Mix ID #30 (SMS Mixed)

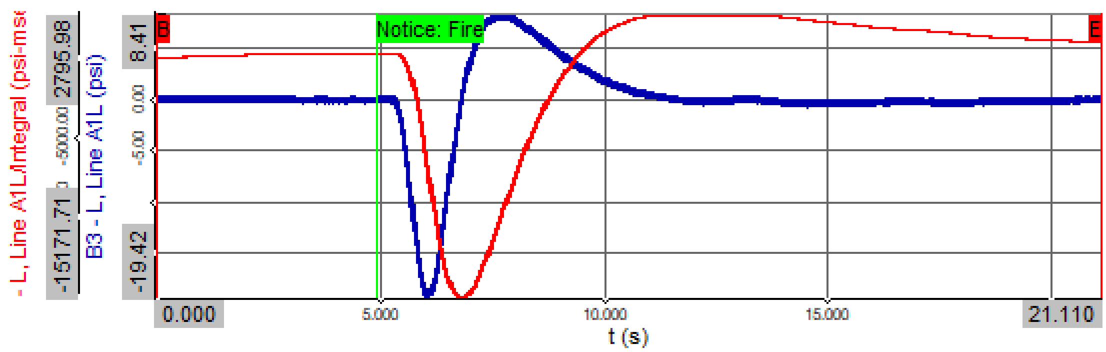
8.7.1 Trial 1 for Small-Scale Mix ID #30

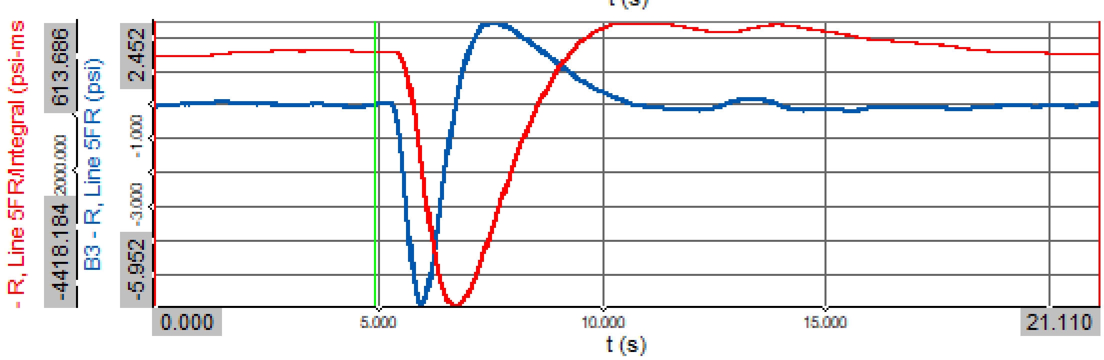


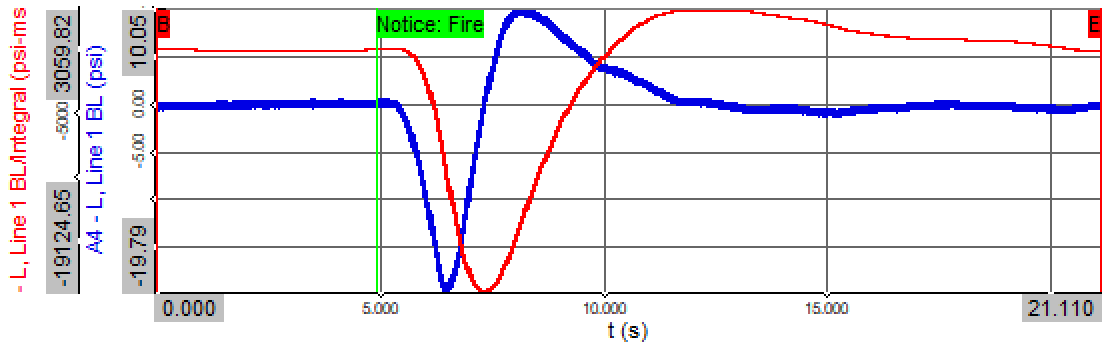

- L, Line 2DL/Integral (psi-ms
15753.34
-78417.59
A2 - L, Line 2DL (psi)
42.98
-98.60
Notice: Fire
0.000
5.000
10.000
15.000
21.110
t (s)
- R, Line 2BR/Integral (psi-ms
9703.66
-120205.13
A2 - R, Line 2BR (psi)
34.19
-110.53
t (s)
- L, Line 2AL/Integral (psi-ms
4766.40
-22195.17
B2 - L, Line 2AL (psi)
11.73
-30.31
Notice: Fire
t (s)
- R, Line 2AR/Integral (psi-ms
2511.00
-13892.18
B2 - R, Line 2AR (psi)
9.47
-22.27
t (s)

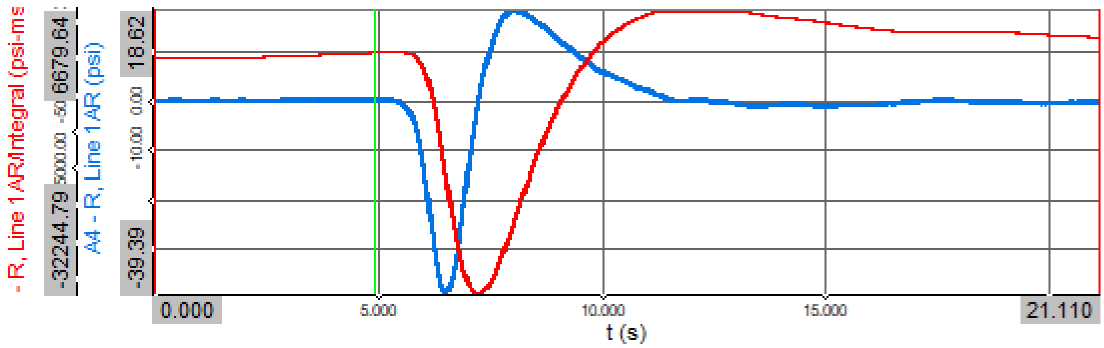

3 - L, Line R/Integral (psi-mse
A3 - L, Line R (psi)
27272.809
-84047.578
54.404
-70.810
Notice: Fire
0.000
5.000
10.000
15.000
21.110
t (s)

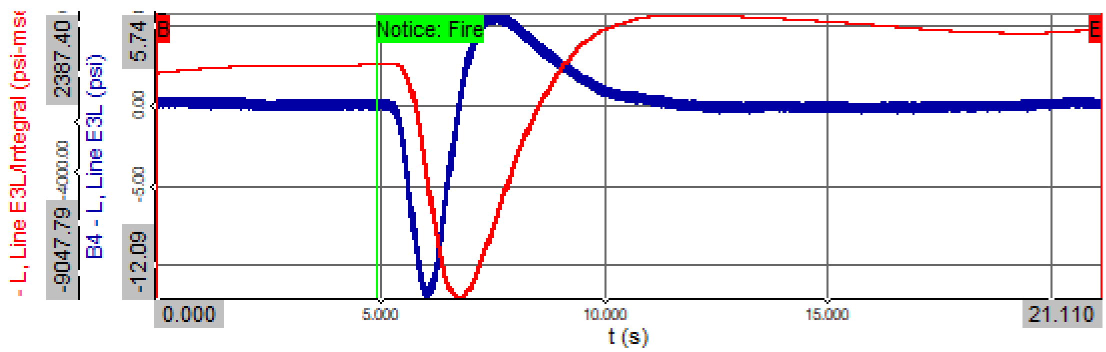

- R, Line 5DR/Integral (psi-ms
A3 - R, Line 5DR (psi)
7060.03
-44374.78
21.72
-44.75
0.000
5.000
10.000
15.000
21.110
t (s)

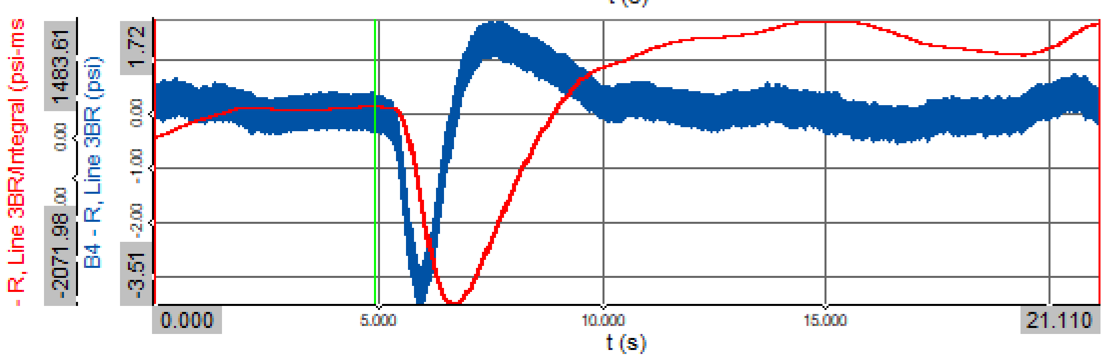

- L, Line A1L/Integral (psi-ms
B3 - L, Line A1L (psi)
2795.98
-15171.71
8.41
-19.42
Notice: Fire
0.000
5.000
10.000
15.000
21.110
t (s)

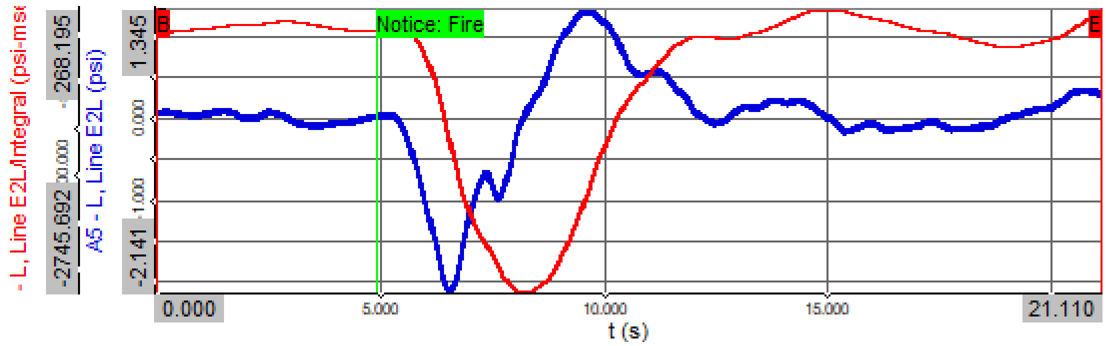

- R, Line 5FR/Integral (psi-ms
B3 - R, Line 5FR (psi)
613.686
-4418.184
2.452
-5.952
0.000
5.000
10.000
15.000
21.110
t (s)

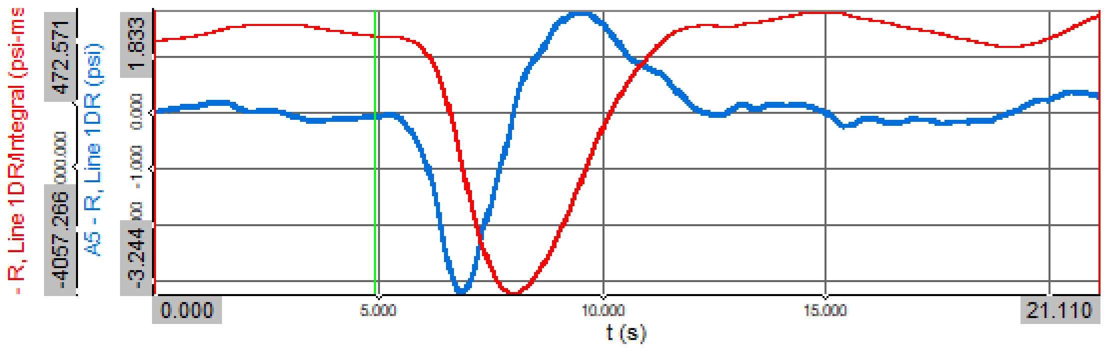

- L, Line 1 BL/Integral (psi-ms
3059.82
-19124.65
A4 - L, Line 1 BL (psi)
10.05
0.00
-5.00
-19.79
Notice: Fire
0.000
5.000
10.000
15.000
21.110
t (s)

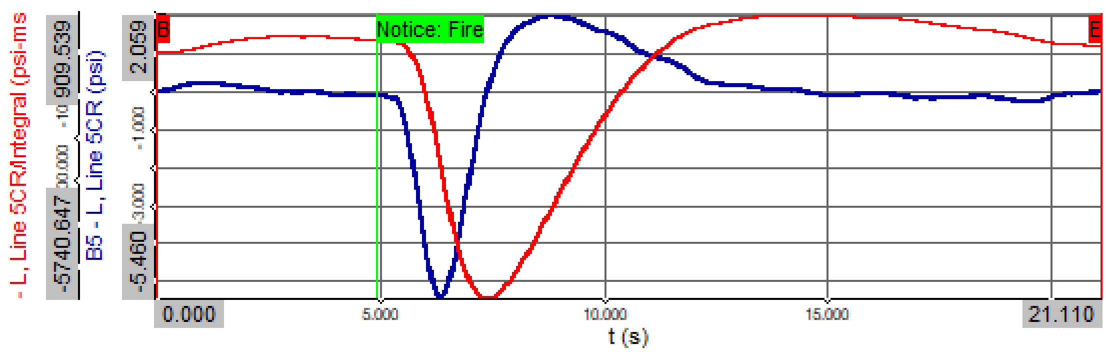

- R, Line 1 AR/Integral (psi-ms
6679.64
-32244.79
A4 - R, Line 1 AR (psi)
18.62
0.00
-10.00
-39.39
0.000
5.000
10.000
15.000
21.110
t (s)

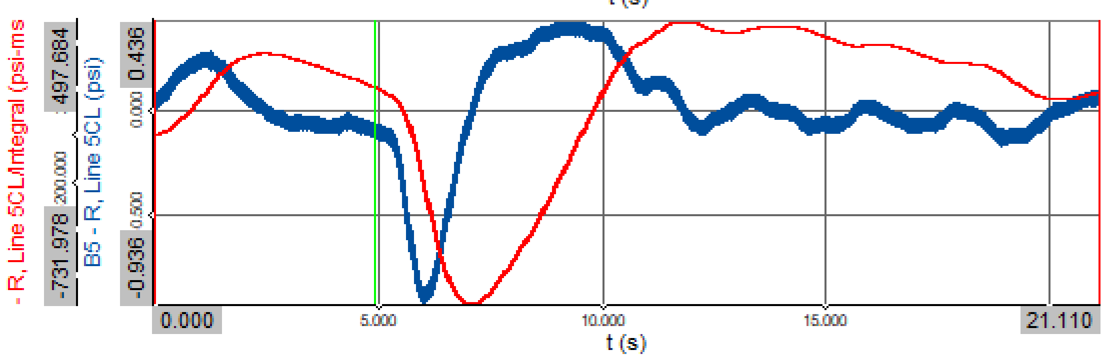

- L, Line E3L/Integral (psi-ms
2387.40
-4000.00
-9047.79
B4 - L, Line E3L (psi)
5.74
0.00
-5.00
-12.09
Notice: Fire
0.000
5.000
10.000
15.000
21.110
t (s)

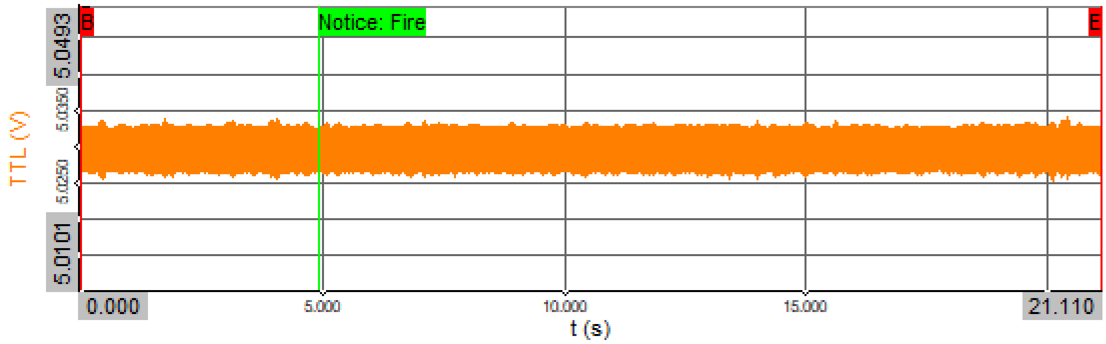

- R, Line 3BR/Integral (psi-ms
1483.61
0.00
-2071.98
B4 - R, Line 3BR (psi)
1.72
0.00
-1.00
-2.00
-3.51
0.000
5.000
10.000
15.000
21.110
t (s)


- L, Line E2L/Integral (psi-ms
268.195
-2745.692
A5 - L, Line E2L (psi)
1.345
-2.141
B
Notice: Fire
E
0.000
5.000
10.000
15.000
21.110
t (s)

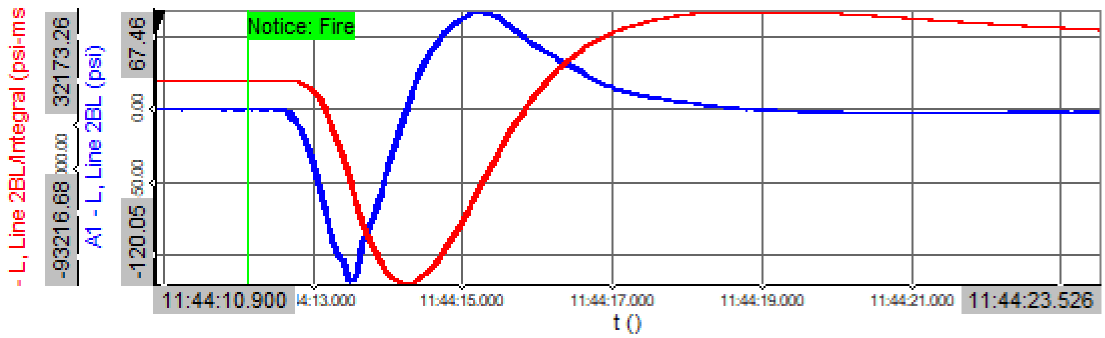

- R, Line 1DR/Integral (psi-ms
472.571
-4057.266
A5 - R, Line 1DR (psi)
1.833
-3.244
0.000
5.000
10.000
15.000
21.110
t (s)

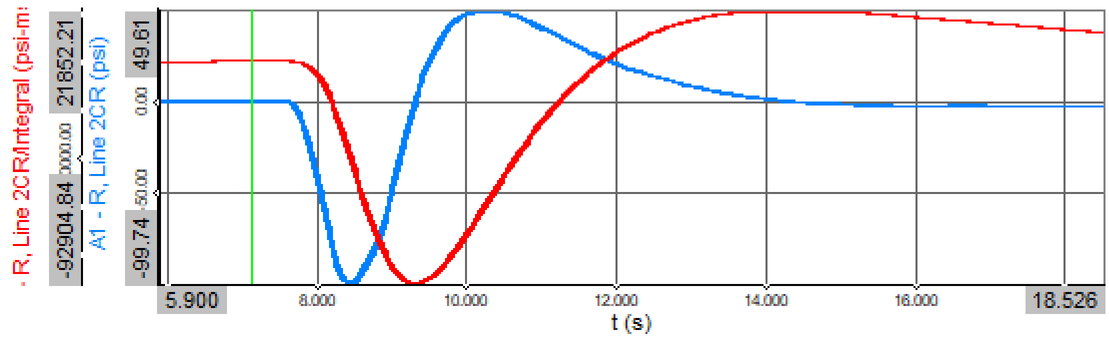

- L, Line 5CR/Integral (psi-ms
909.539
-5740.647
B5 - L, Line 5CR (psi)
2.059
-5.460
B
Notice: Fire
E
0.000
5.000
10.000
15.000
21.110
t (s)

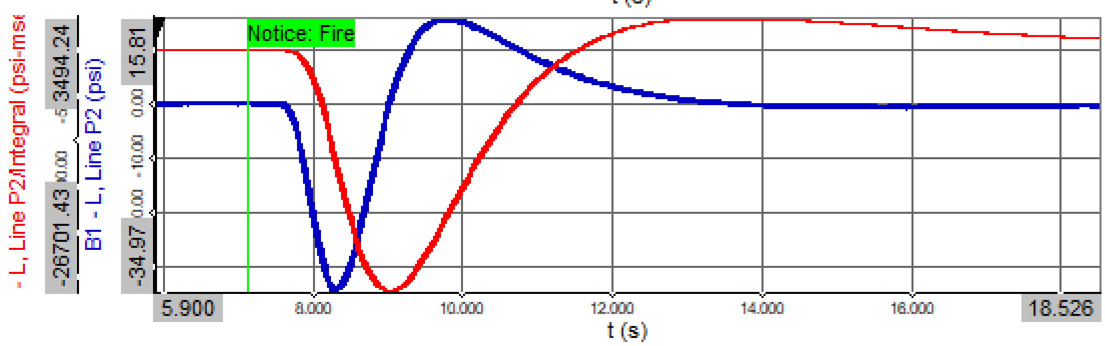

- R, Line 5CL/Integral (psi-ms
497.684
-731.978
B5 - R, Line 5CL (psi)
0.436
-0.936
0.000
5.000
10.000
15.000
21.110
t (s)

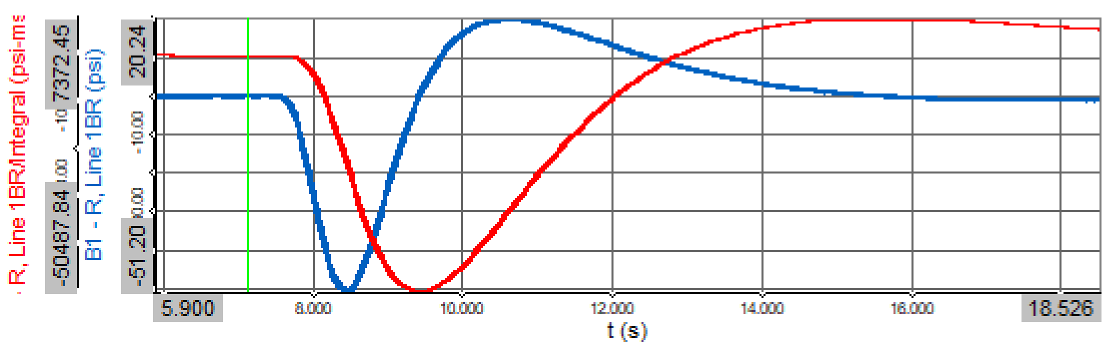

B
Notice: Fire
E
TTL (V)
5.0493
5.0350
5.0250
5.0101
0.000
5.000
10.000
15.000
21.110
t (s)

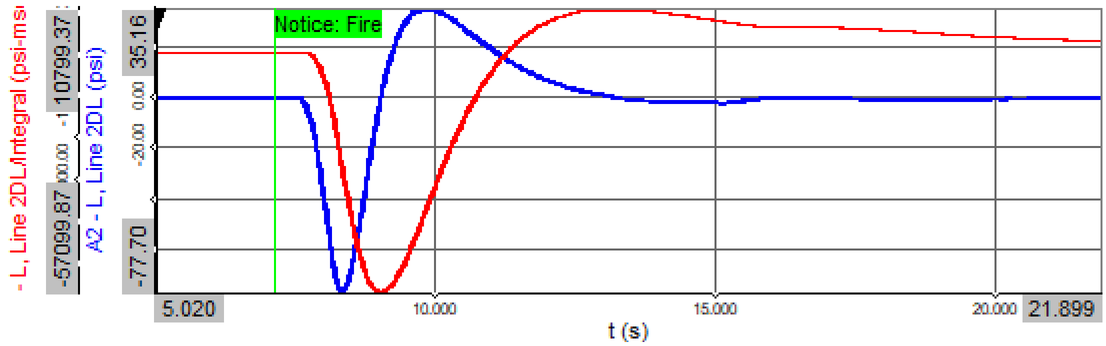
8.7.2 Trial 2 for Small-Scale Mix ID #30

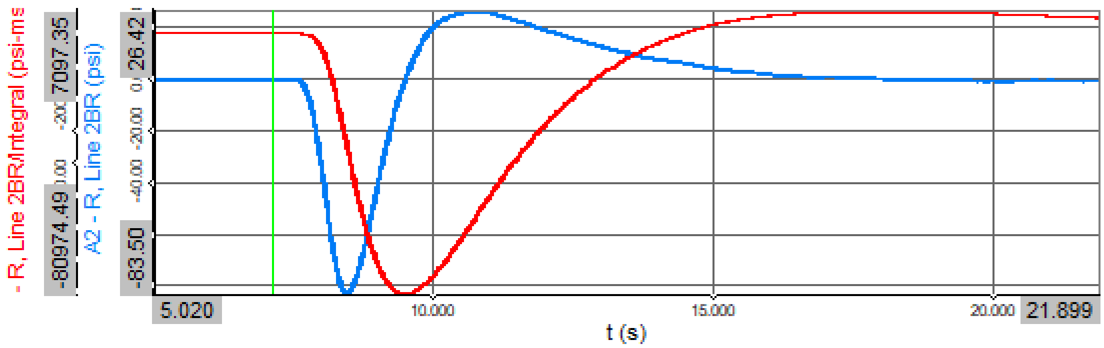


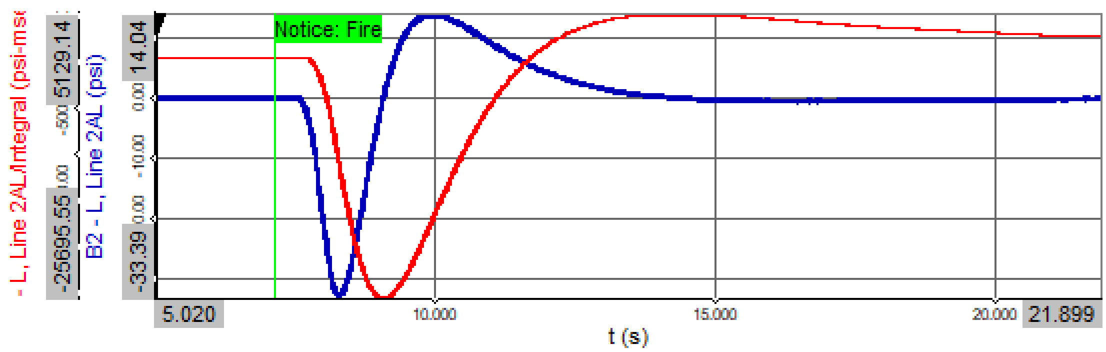


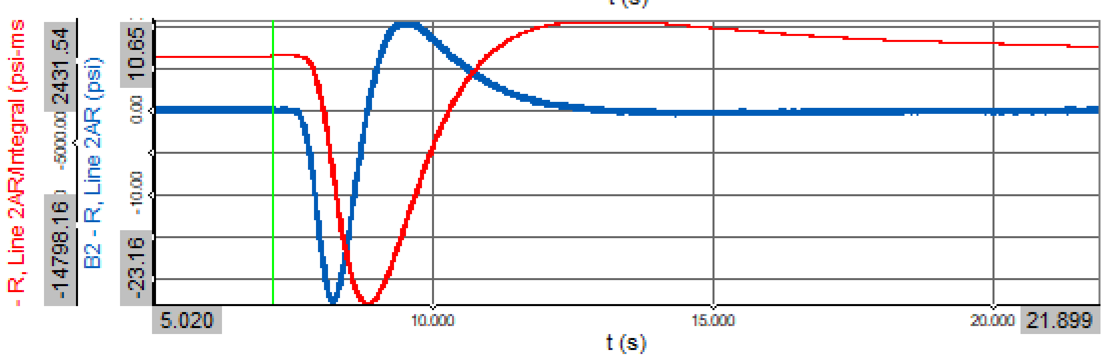


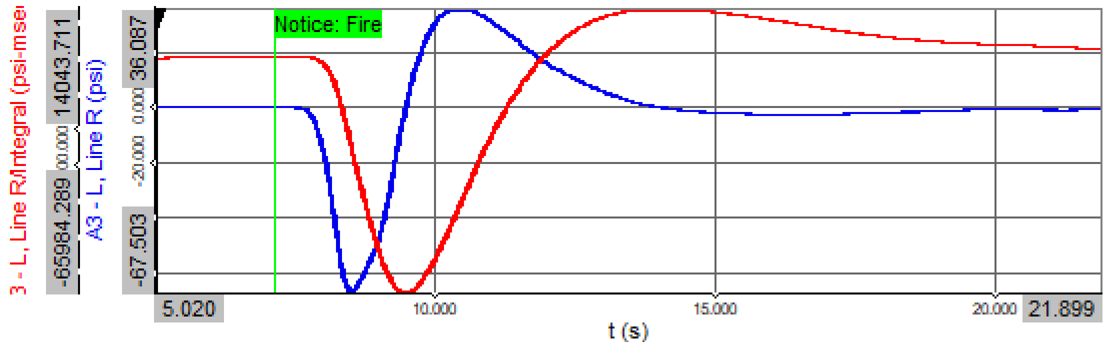


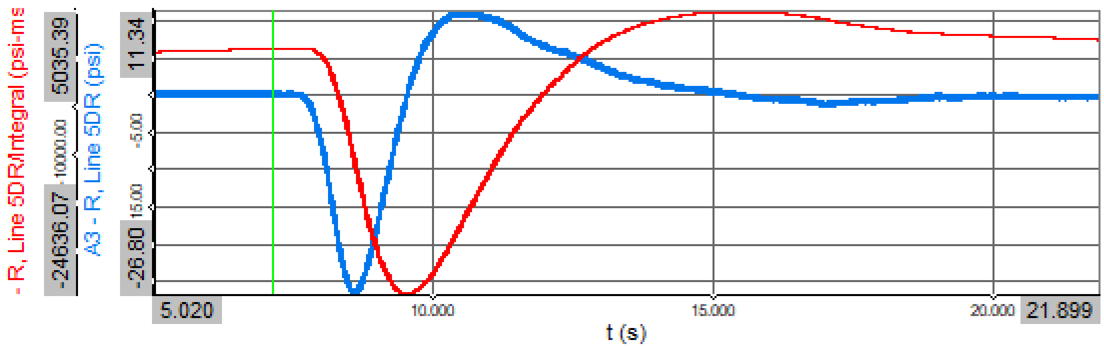

- L, Line 2DL/Integral (psi-ms
A2 - L, Line 2DL (psi)
Notice: Fire
35.16
-77.70
10799.37
-57099.87
5.020
10.000
15.000
20.000
21.899
t (s)

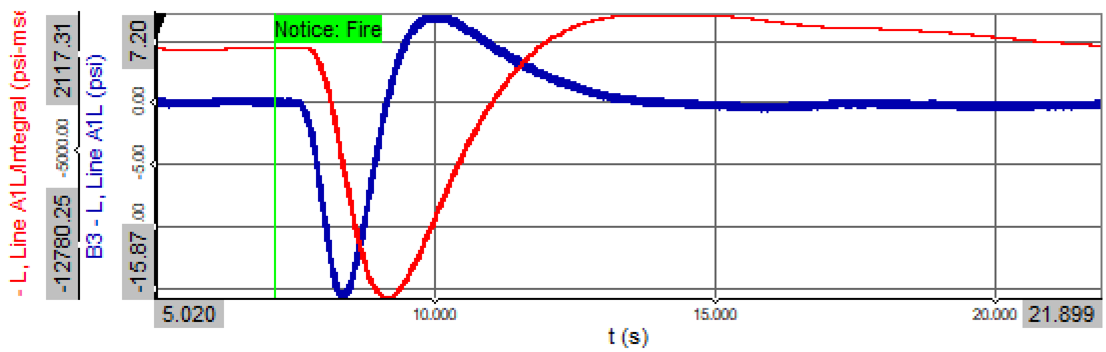

- R, Line 2BR/Integral (psi-ms
A2 - R, Line 2BR (psi)
26.42
-83.50
7097.35
-80974.49
5.020
10.000
15.000
20.000
21.899
t (s)

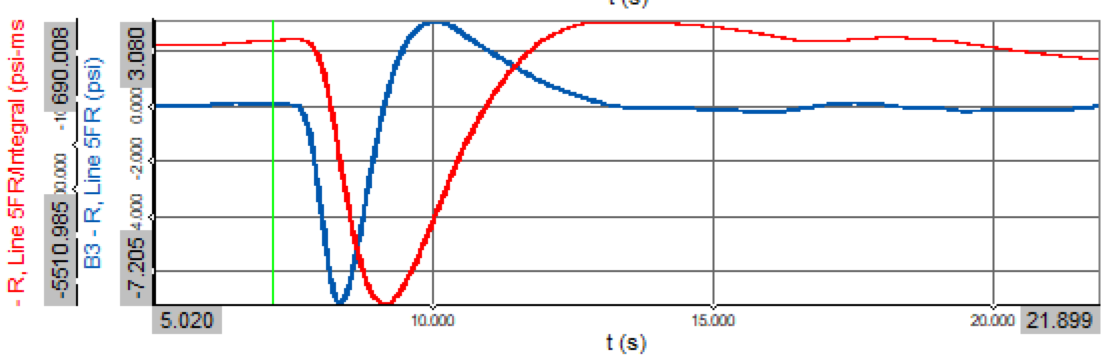

- L, Line 2AL/Integral (psi-ms
B2 - L, Line 2AL (psi)
Notice: Fire
14.04
-33.39
5129.14
-25695.55
5.020
10.000
15.000
20.000
21.899
t (s)

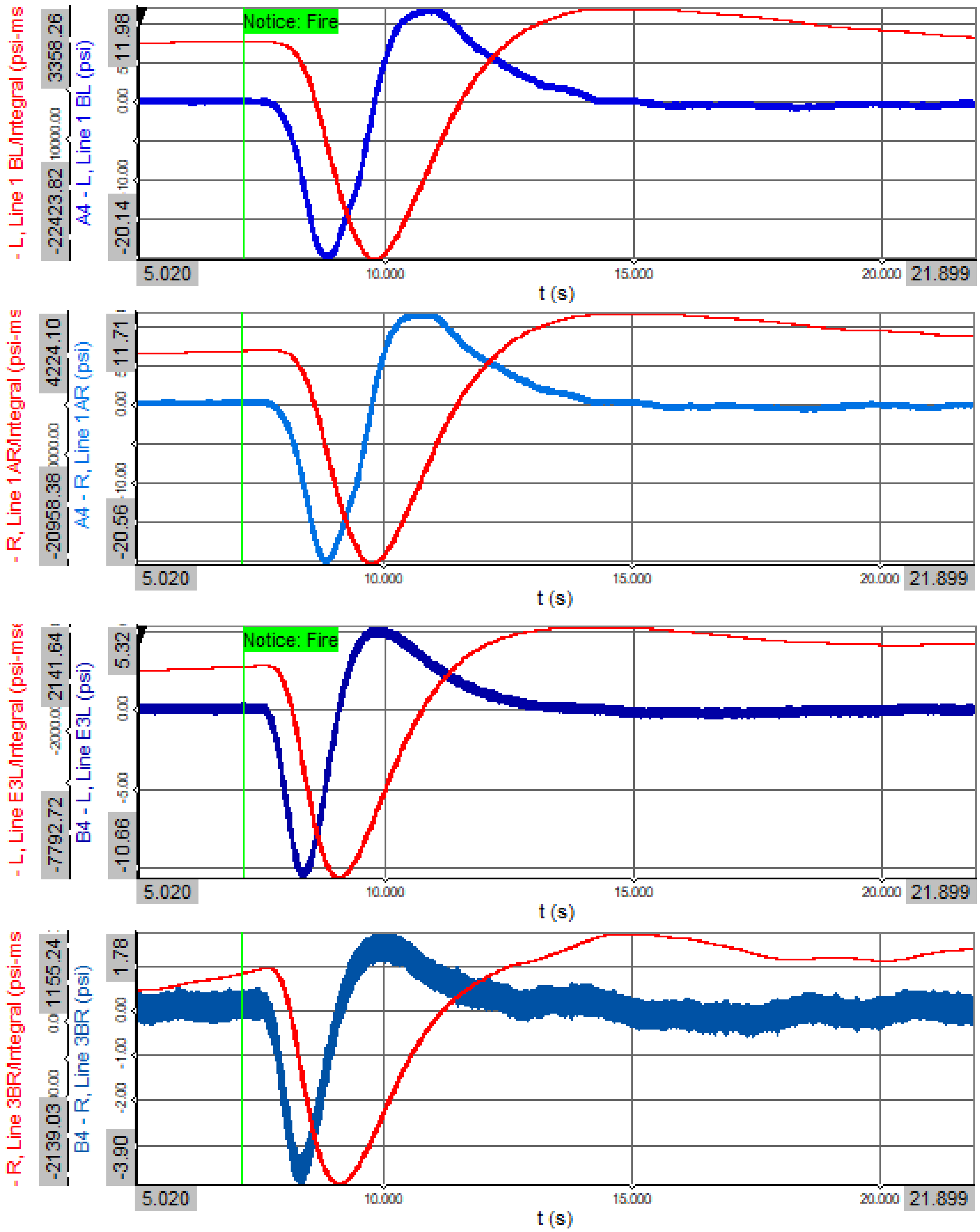

- R, Line 2AR/Integral (psi-ms
B2 - R, Line 2AR (psi)
10.65
-23.16
2431.54
-14798.16
5.020
10.000
15.000
20.000
21.899
t (s)

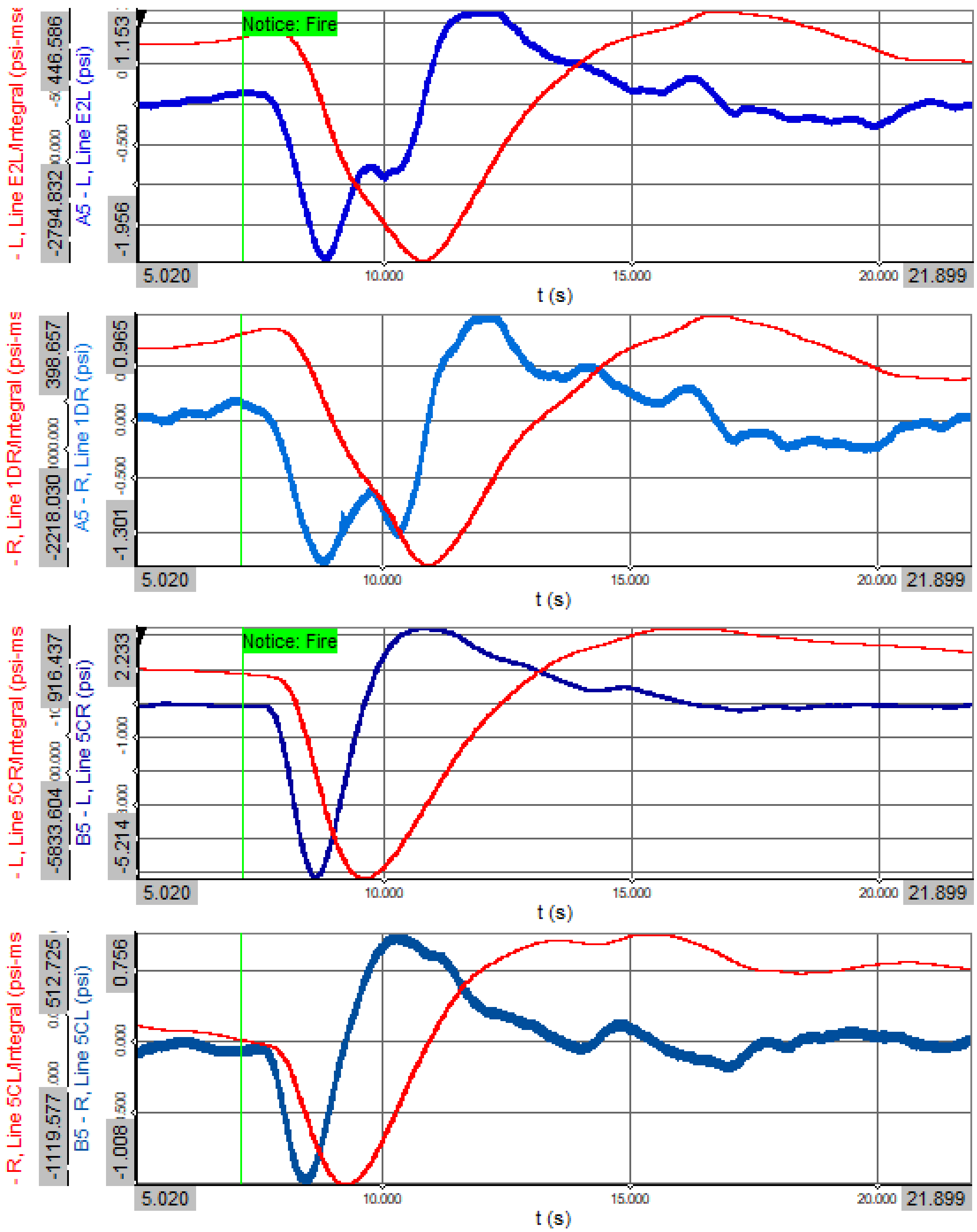

3 - L, Line R/Integral (psi-mse
14043.711
-65984.289
A3 - L, Line R (psi)
36.087
-67.503
Notice: Fire
5.020
10.000
15.000
20.000
21.899
t (s)

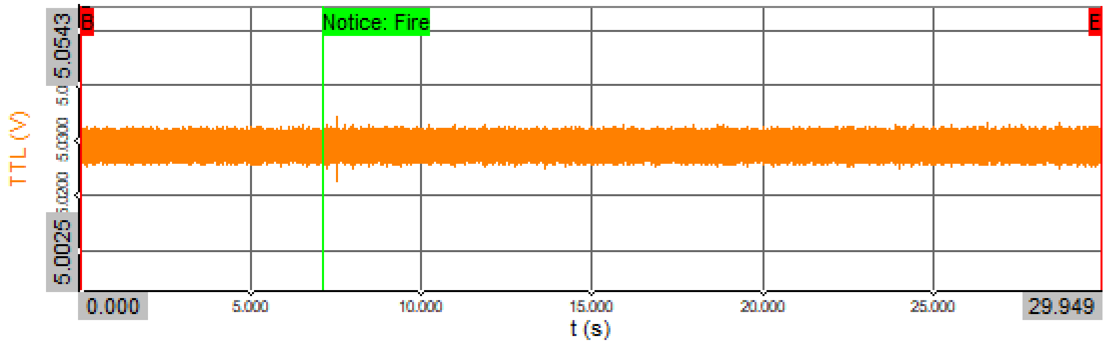

- R, Line 5DR/Integral (psi-ms
5035.39
-24636.07
A3 - R, Line 5DR (psi)
11.34
-26.80
5.020
10.000
15.000
20.000
21.899
t (s)


- L, Line A1L/Integral (psi-ms
2117.31
-12780.25
B3 - L, Line A1L (psi)
7.20
-15.87
Notice: Fire
5.020
10.000
15.000
20.000
21.899
t (s)

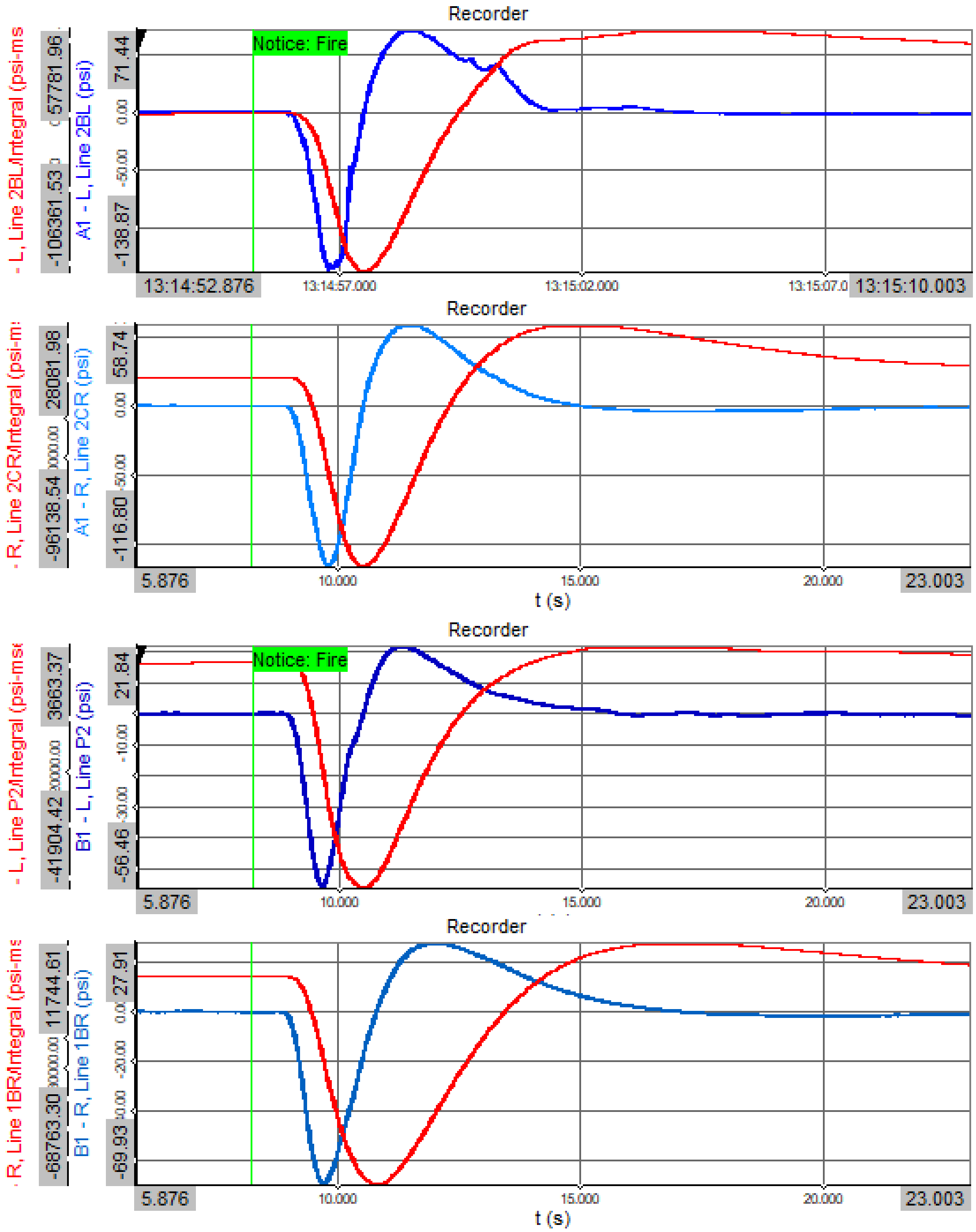

- R, Line 5FR/Integral (psi-ms
690.008
-5510.985
B3 - R, Line 5FR (psi)
3.080
-7.205
5.020
10.000
15.000
20.000
21.899
t (s)

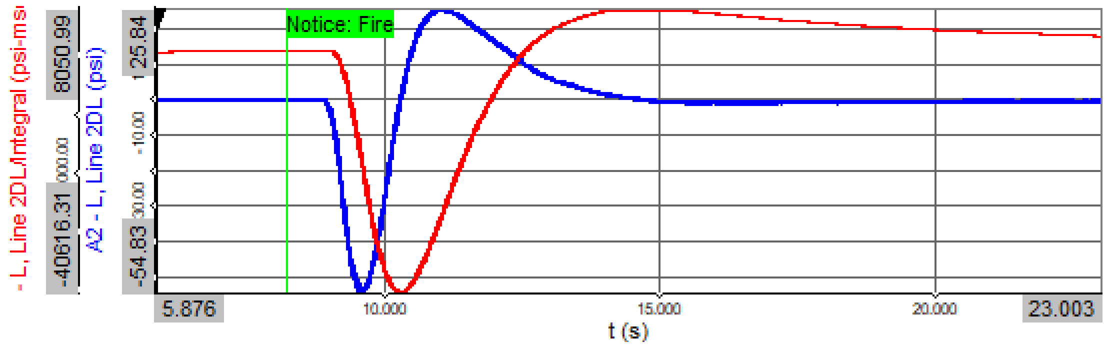

Notice: Fire
- L, Line 1 BL/Integral (psi-ms
A4 - L, Line 1 BL (psi)
3358.26
-22423.82
11.98
-20.14
5.020
10.000
15.000
20.000
21.899
t (s)
- R, Line 1AR/Integral (psi-ms
A4 - R, Line 1AR (psi)
4224.10
-20958.38
11.71
-20.56
Notice: Fire
- L, Line E3L/Integral (psi-ms
B4 - L, Line E3L (psi)
2141.64
-7792.72
5.32
-10.66
- R, Line 3BR/Integral (psi-ms
B4 - R, Line 3BR (psi)
1155.24
-2139.03
1.78
-3.90

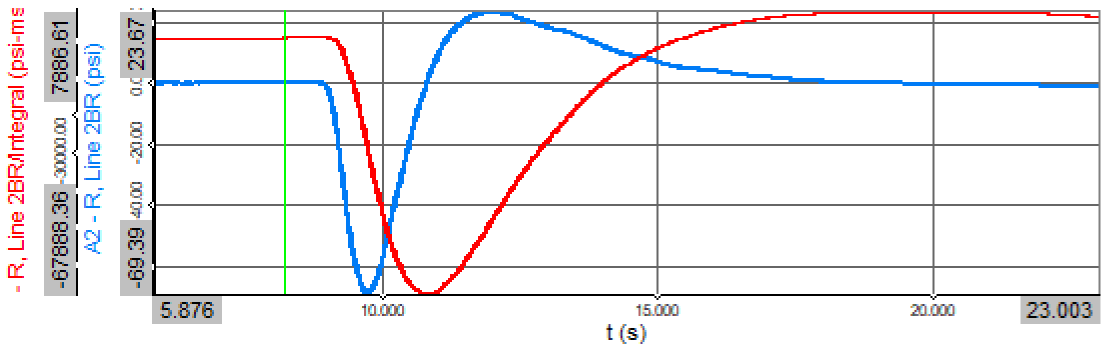

Notice: Fire
A5 - L, Line E2L (psi)
- L, Line E2L/Integral (psi-ms
446.586
-2794.832
1.153
-1.956
A5 - R, Line 1DR (psi)
- R, Line 1DR/Integral (psi-ms
398.657
-2218.030
0.965
-1.301
B5 - L, Line 5CR (psi)
- L, Line 5CR/Integral (psi-ms
916.437
-5833.604
2.233
-5.214
B5 - R, Line 5CL (psi)
- R, Line 5CL/Integral (psi-ms
512.725
-1119.577
0.756
-1.008
5.020
10.000
15.000
20.000
21.899
t (s)

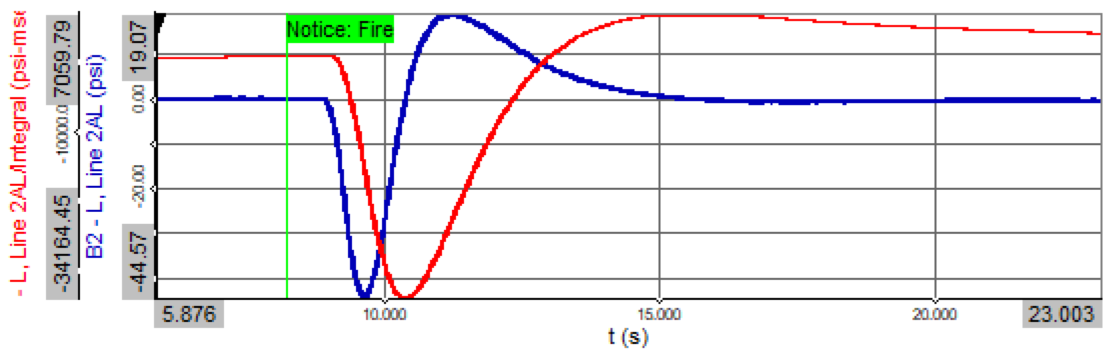

Notice: Fire
B
E
TTL (V)
5.0543
5.0025
0.000
5.000
10.000
15.000
20.000
25.000
29.949
t (s)

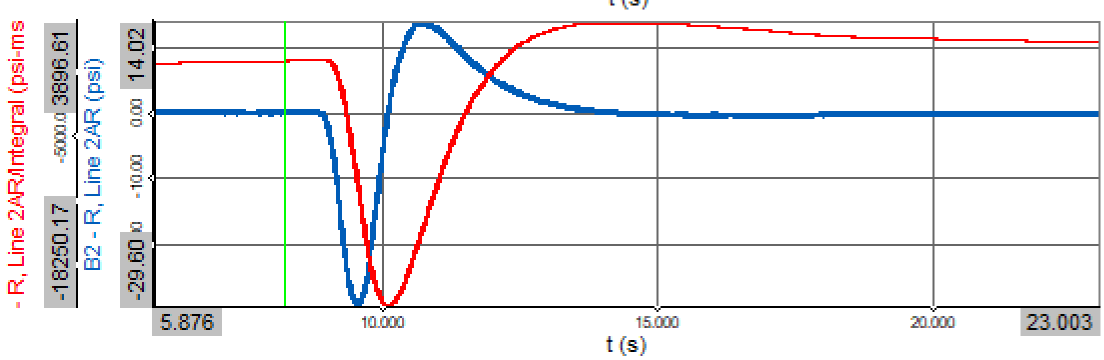
8.7.3 Trial 3 for Small-Scale Mix ID #30

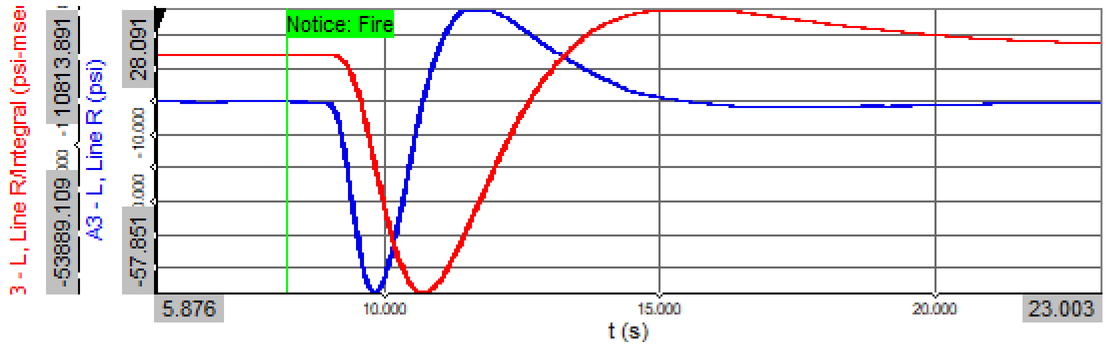


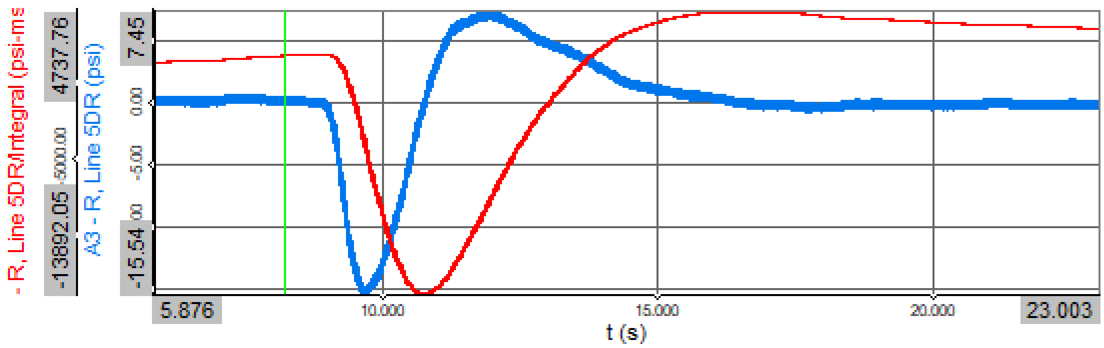

- L, Line 2DL/Integral (psi-ms
8050.99
-40616.31
A2 - L, Line 2DL (psi)
25.84
-54.83
Notice: Fire
5.876
10.000
15.000
20.000
23.003
t (s)

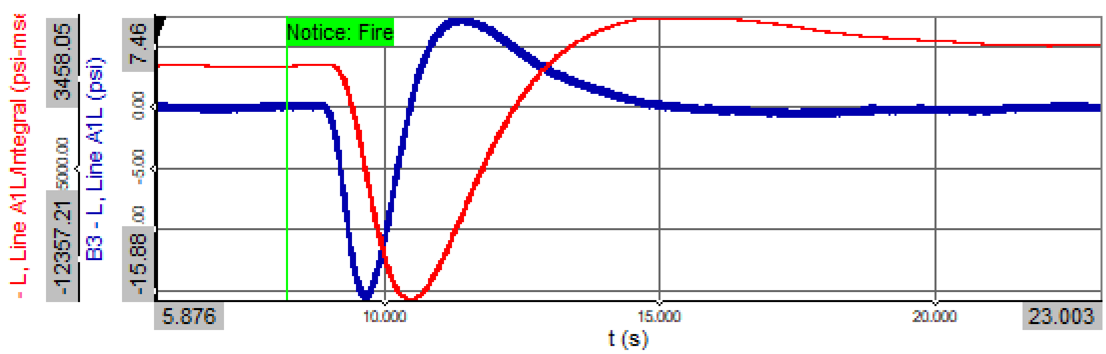

- R, Line 2BR/Integral (psi-ms
7886.61
-67888.36
A2 - R, Line 2BR (psi)
23.67
-69.39
5.876
10.000
15.000
20.000
23.003
t (s)

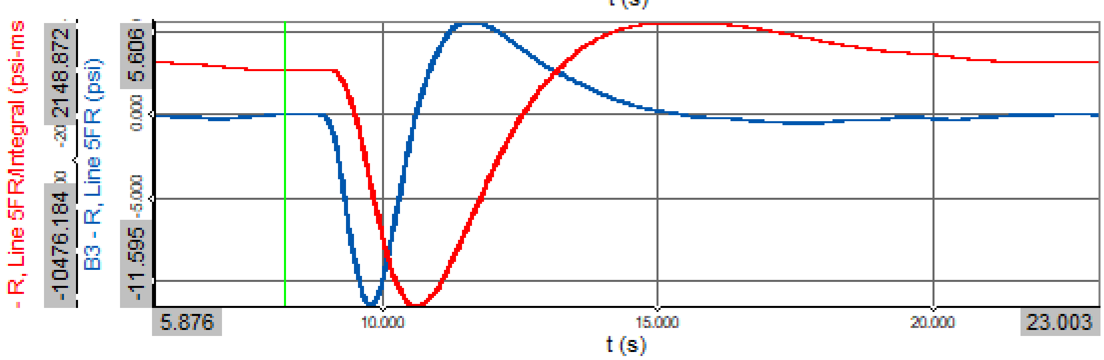

- L, Line 2AL/Integral (psi-ms
7059.79
-34164.45
B2 - L, Line 2AL (psi)
19.07
-44.57
Notice: Fire
5.876
10.000
15.000
20.000
23.003
t (s)

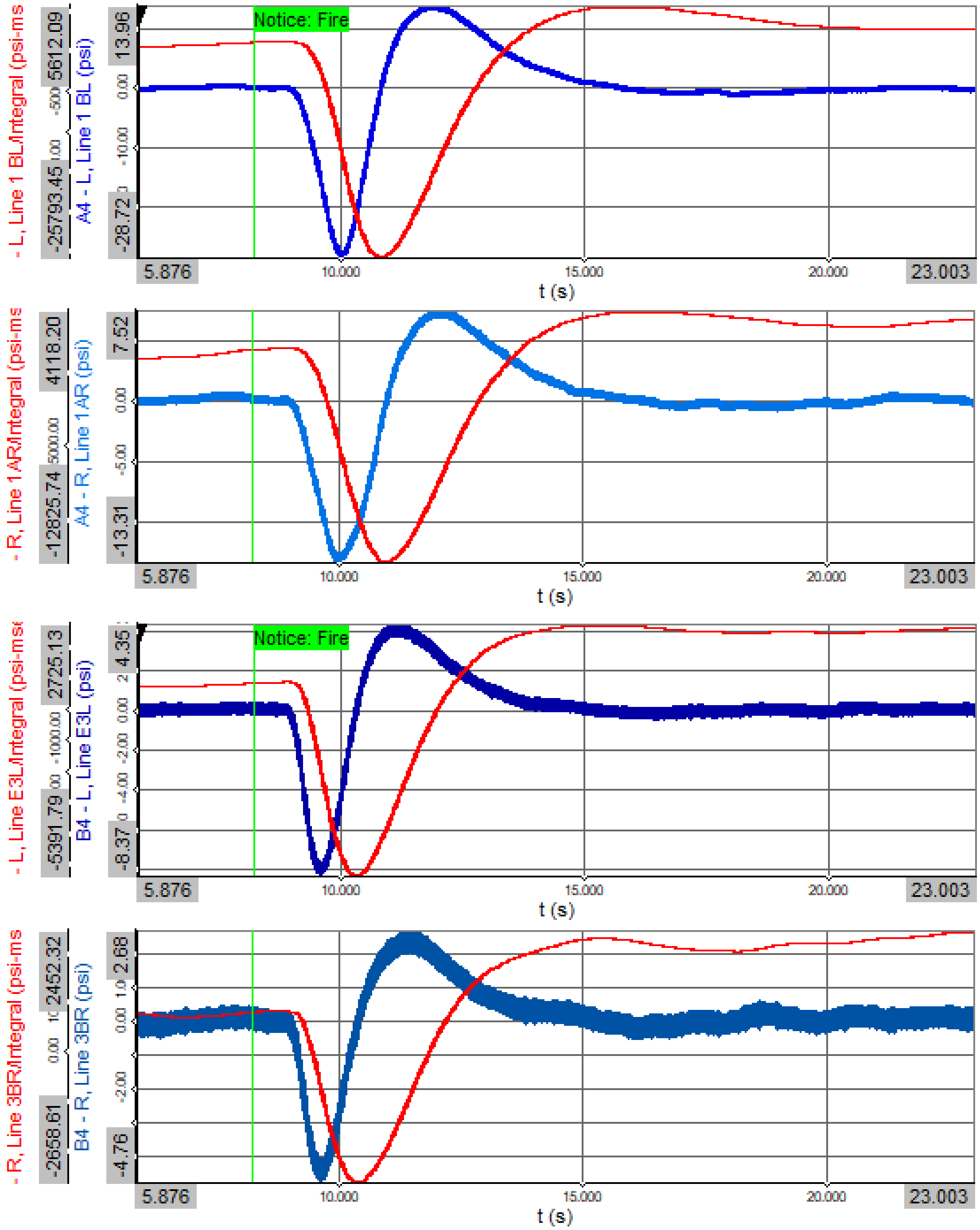

- R, Line 2AR/Integral (psi-ms
3896.61
-18250.17
B2 - R, Line 2AR (psi)
14.02
-29.60
5.876
10.000
15.000
20.000
23.003
t (s)

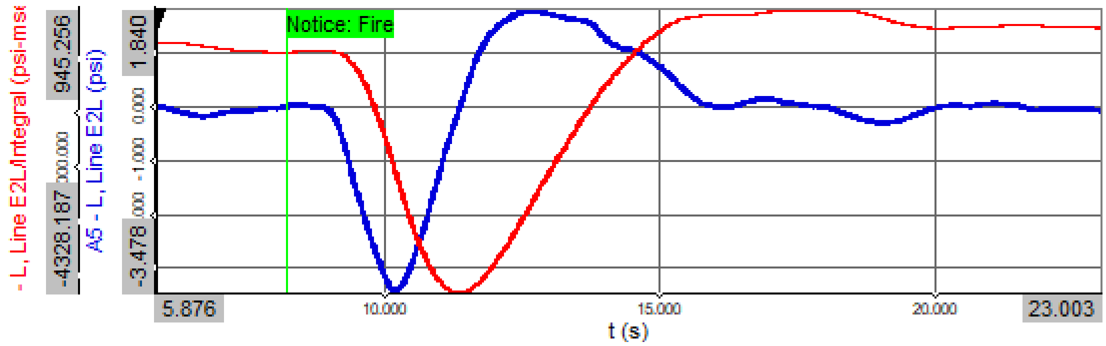

Notice: Fire
A3 - L, Line R (psi)
28.091
-57.851
-10813.891
-53889.109
5.876
10.000
15.000
20.000
23.003
t (s)

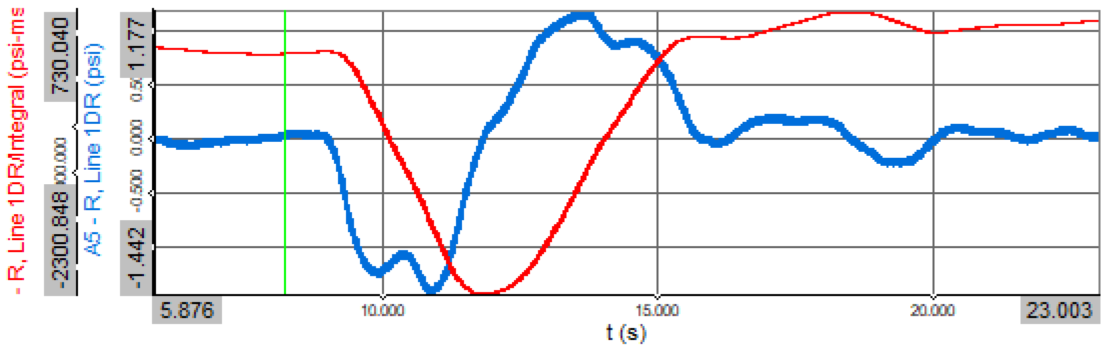

- R, Line 5DR/Integral (psi-ms
A3 - R, Line 5DR (psi)
7.45
-15.54
4737.76
-13892.05
5.876
10.000
15.000
20.000
23.003
t (s)

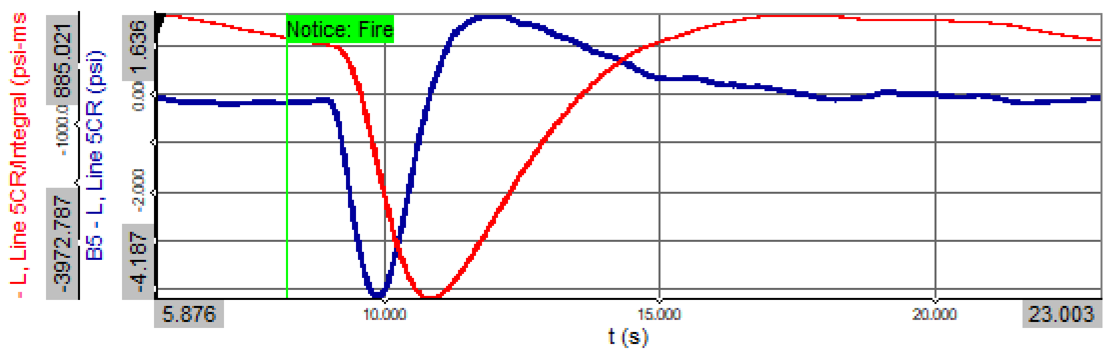

Notice: Fire
- L, Line A1L/Integral (psi-ms
B3 - L, Line A1L (psi)
7.46
-15.88
3458.05
-12357.21
5.876
10.000
15.000
20.000
23.003
t (s)

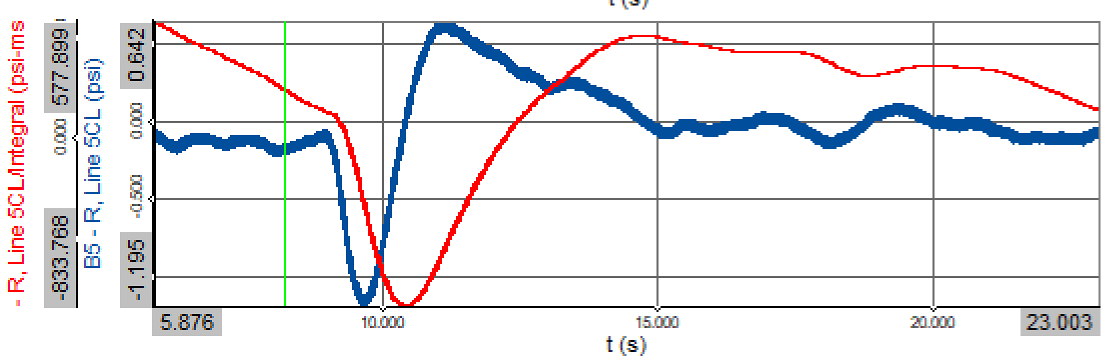

- R, Line 5FR/Integral (psi-ms
B3 - R, Line 5FR (psi)
5.606
-11.595
2148.872
-10476.184
5.876
10.000
15.000
20.000
23.003
t (s)

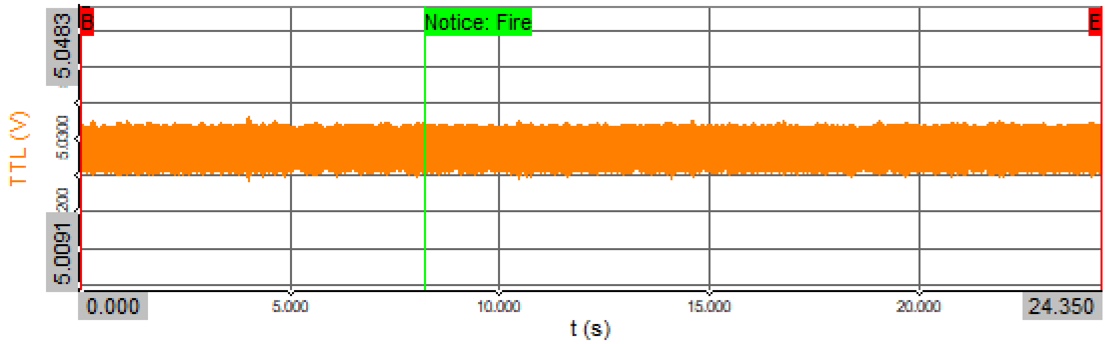

Notice: Fire
- L, Line 1 BL/Integral (psi-ms
A4 - L, Line 1 BL (psi)
5612.09
-25793.45
13.96
-28.72
5.876
10.000
15.000
20.000
23.003
t (s)
- R, Line 1AR/Integral (psi-ms
A4 - R, Line 1AR (psi)
4118.20
-12825.74
7.52
-13.31
- L, Line E3L/Integral (psi-ms
B4 - L, Line E3L (psi)
2725.13
-5391.79
4.35
-8.37
- R, Line 3BR/Integral (psi-ms
B4 - R, Line 3BR (psi)
2452.32
-2658.61
2.68
-4.76


Notice: Fire
- L, Line E2L/Integral (psi-ms
945.256
-4328.187
A5 - L, Line E2L (psi)
1.840
-3.478
5.876
10.000
15.000
20.000
23.003
t (s)


- R, Line 1DR/Integral (psi-ms
730.040
-2300.848
A5 - R, Line 1DR (psi)
1.177
-1.442
5.876
10.000
15.000
20.000
23.003
t (s)

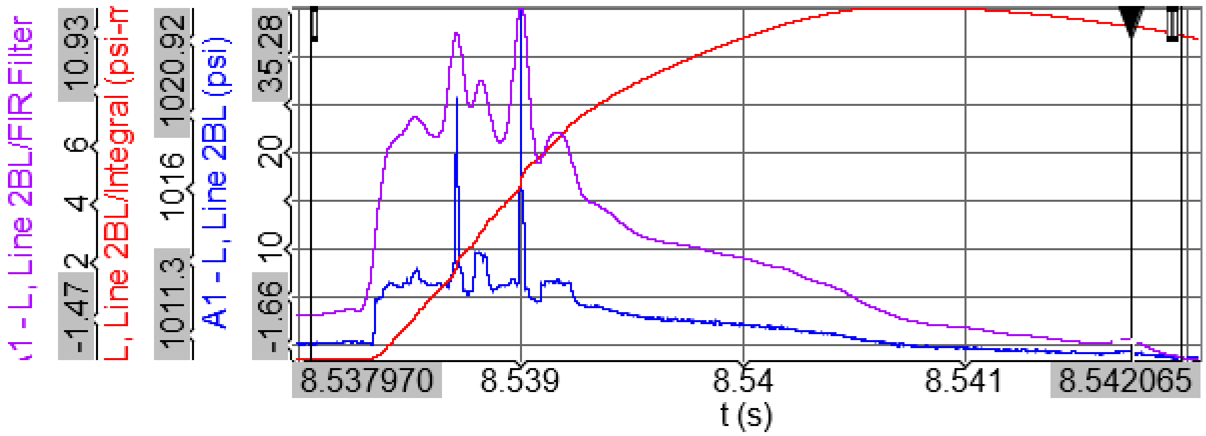

Notice: Fire
- L, Line 5CR/Integral (psi-ms
885.021
-3972.787
B5 - L, Line 5CR (psi)
1.636
-4.187
5.876
10.000
15.000
20.000
23.003
t (s)

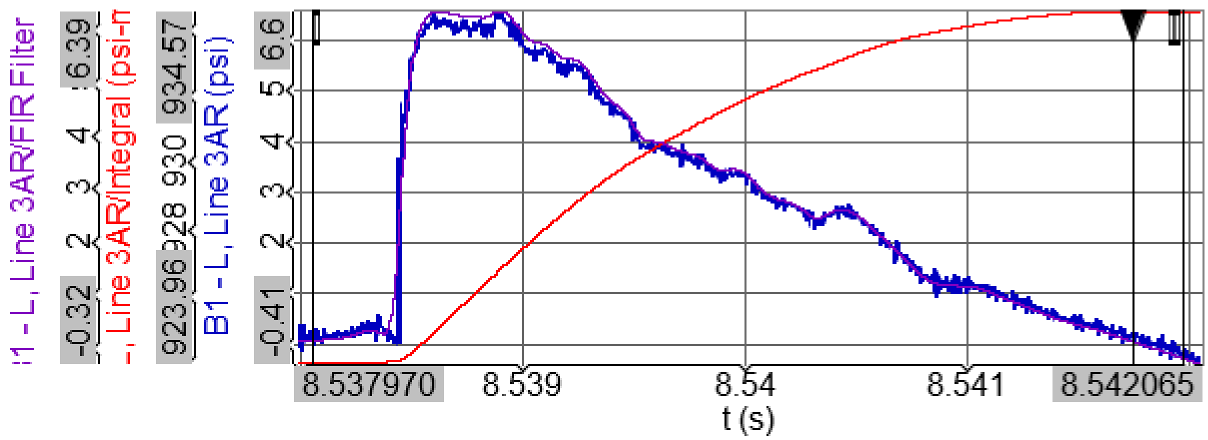

- R, Line 5CL/Integral (psi-ms
577.899
-833.768
B5 - R, Line 5CL (psi)
0.642
-1.195
5.876
10.000
15.000
20.000
23.003
t (s)

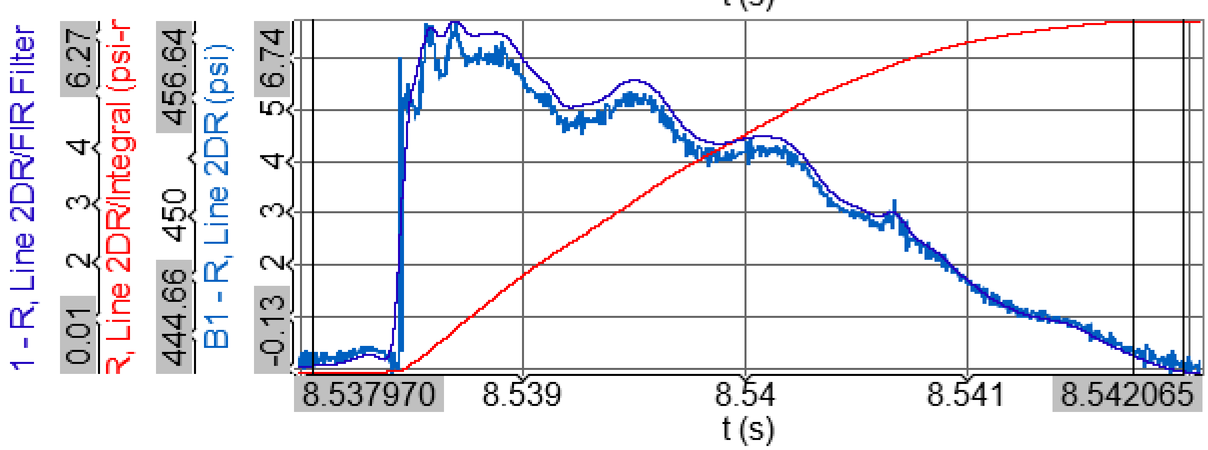

5.0483
5.0091
TTL (V)
Notice: Fire
B
E
0.000
5.000
10.000
15.000
20.000
24.350
t (s)

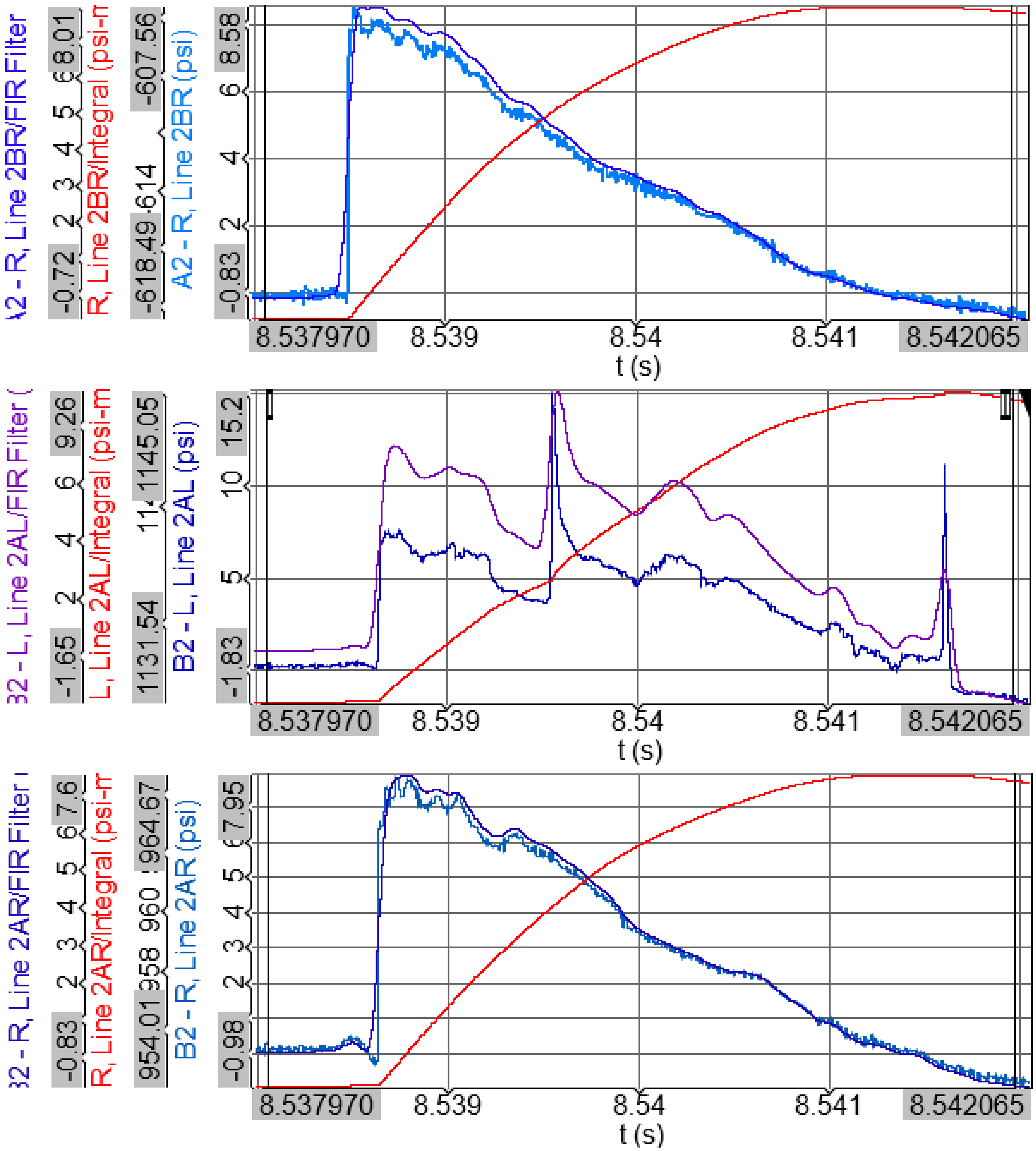
8.8 Fine Ti-Bi_2O_3 – Small-Scale Mix ID #48 (SMS Mixed)

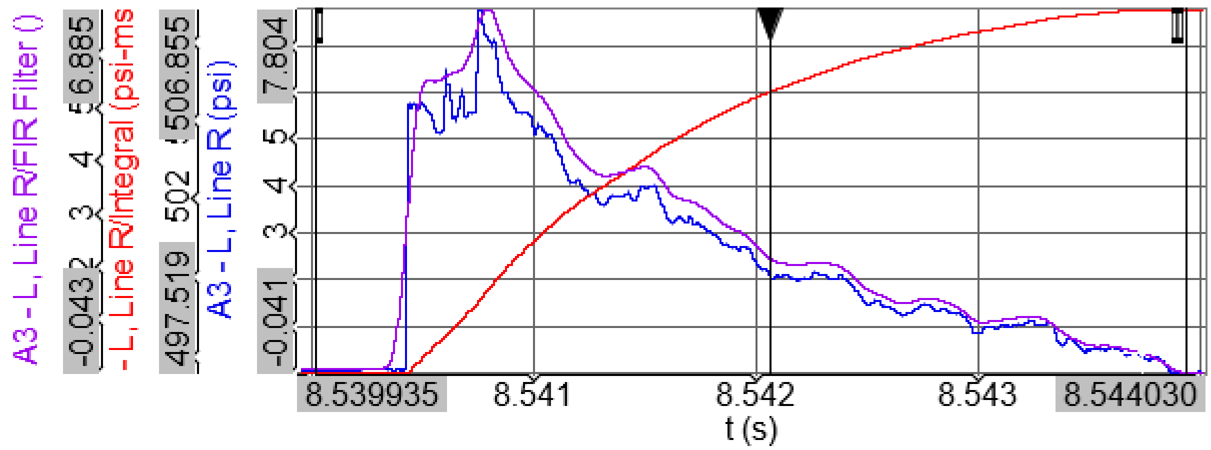
8.8.1 Trial 1 for Small-Scale Mix ID #48

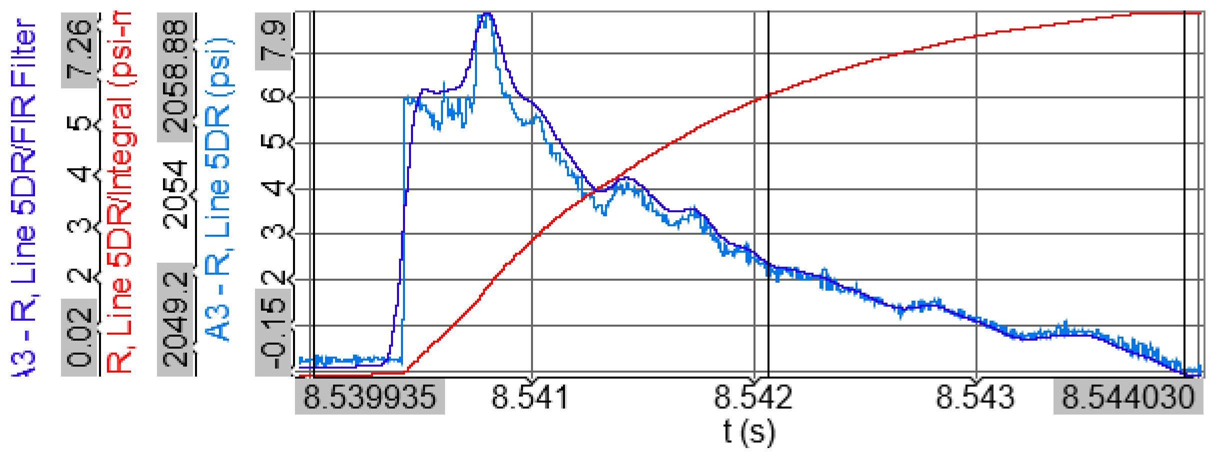


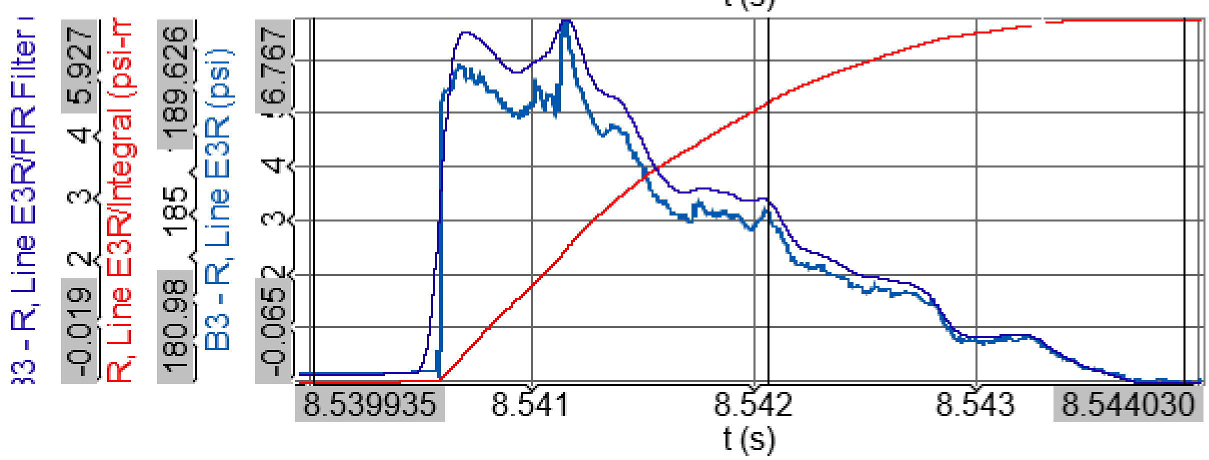


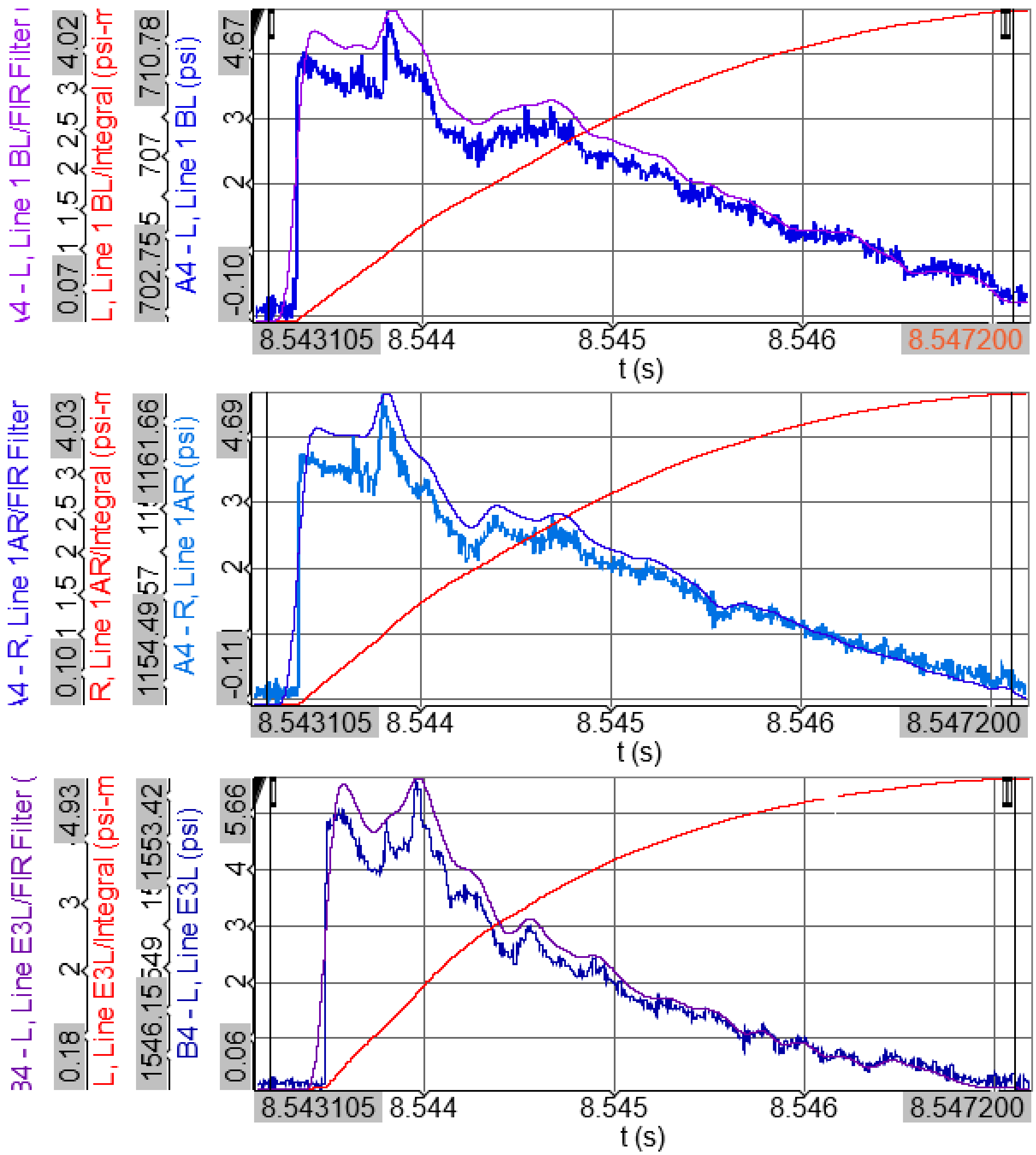


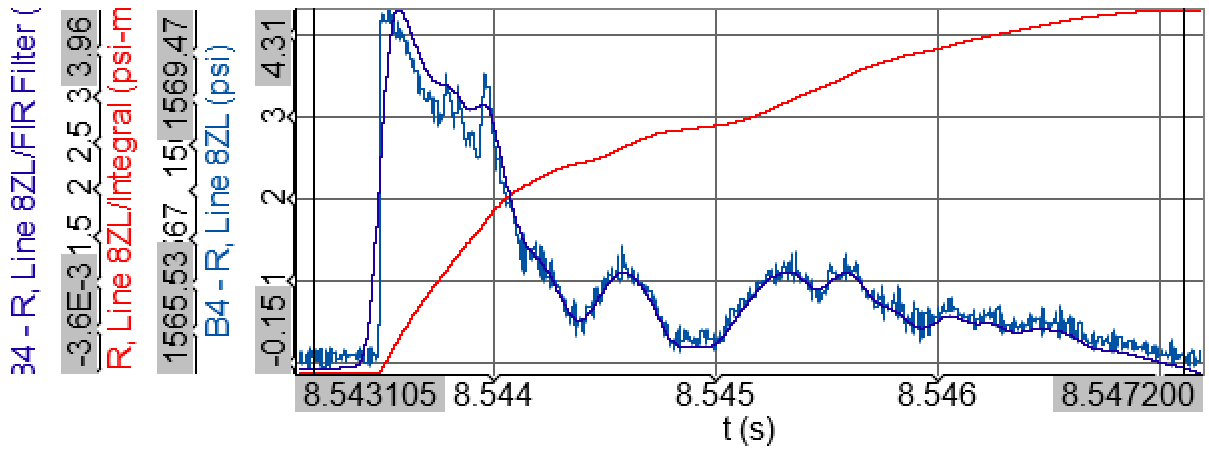

A2 - R, Line 2BR/FIR Filter
R, Line 2BR/Integral (psi-m
A2 - R, Line 2BR (psi)
8.537970
8.539
8.54
8.541
8.542065
t (s)
B2 - L, Line 2AL/FIR Filter (
L, Line 2AL/Integral (psi-m
B2 - L, Line 2AL (psi)
B2 - R, Line 2AR/FIR Filter
R, Line 2AR/Integral (psi-m
B2 - R, Line 2AR (psi)

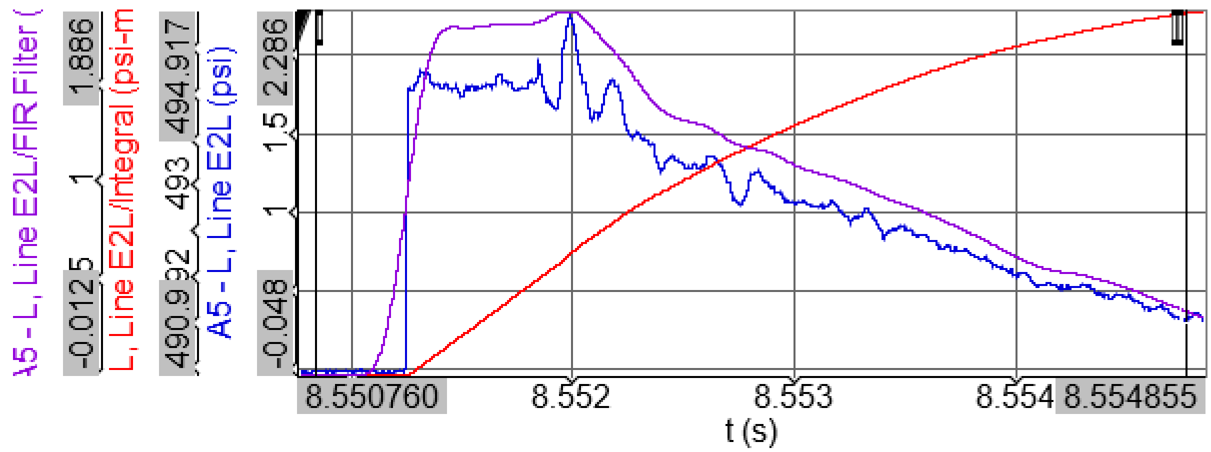

A3 - L, Line R/FIR Filter ()
-L, Line R/Integral (psi-ms
A3 - L, Line R (psi)
t (s)
8.539935
8.541
8.542
8.543
8.544030

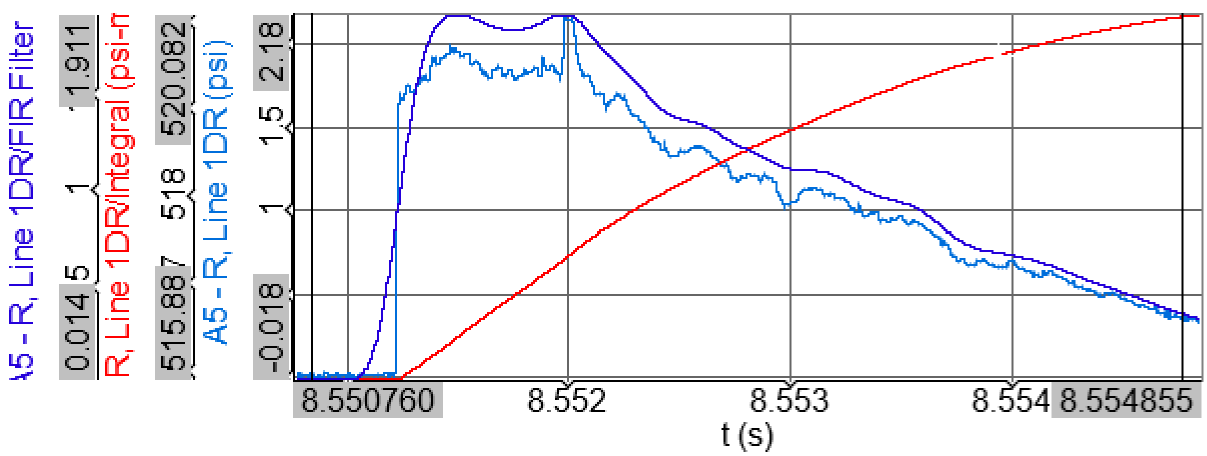

A3 - R, Line 5DR/FIR Filter
R, Line 5DR/Integral (psi-m
A3 - R, Line 5DR (psi)
t (s)
8.539935
8.541
8.542
8.543
8.544030

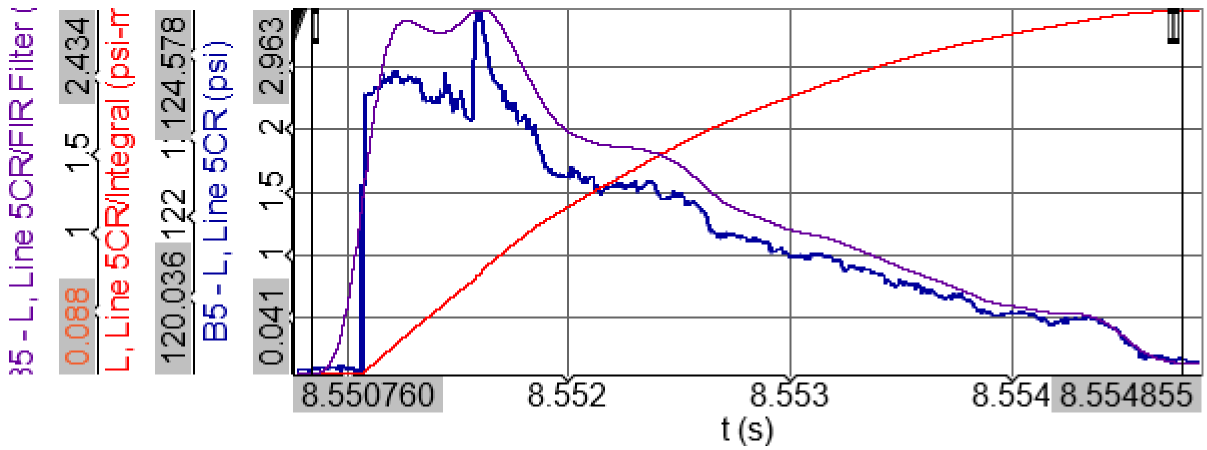

B3 - R, Line E3R/FIR Filter
R, Line E3R/Integral (psi-m
B3 - R, Line E3R (psi)
t (s)
8.539935
8.541
8.542
8.543
8.544030

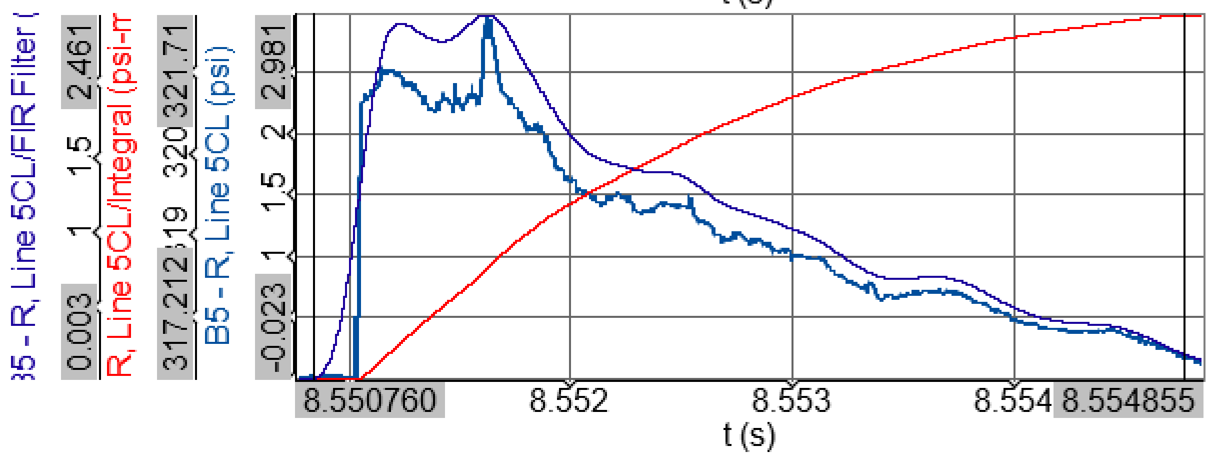

A4 - L, Line 1 BL (psi)
L, Line 1 BL/Integral (psi-m
A4 - L, Line 1 BL/FIR Filter
8.543105
8.544
8.545
8.546
8.547200
t (s)
A4 - R, Line 1AR (psi)
R, Line 1AR/Integral (psi-m
A4 - R, Line 1AR/FIR Filter
B4 - L, Line E3L (psi)
L, Line E3L/Integral (psi-m
B4 - L, Line E3L/FIR Filter (

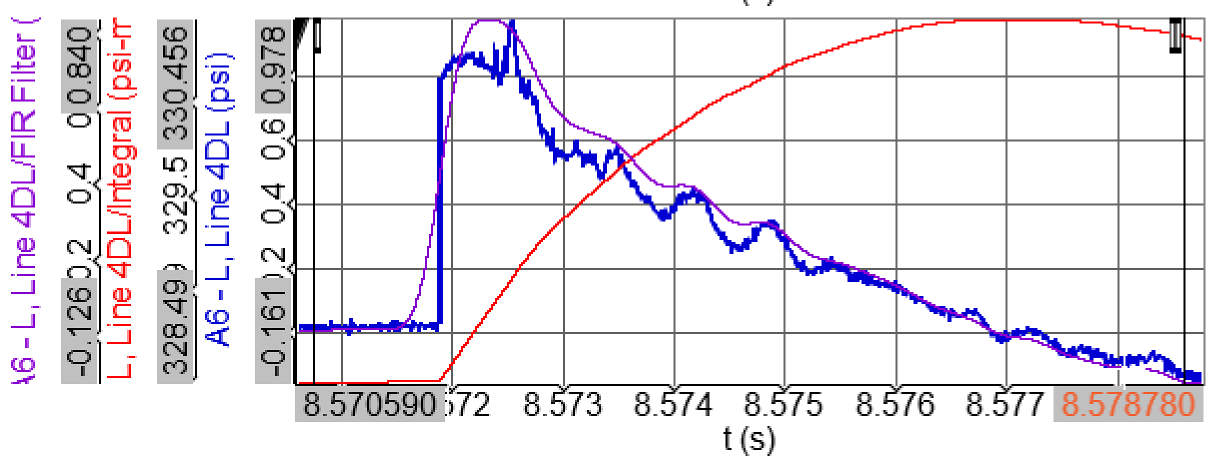

B4 - R, Line 8ZL (psi)
R, Line 8ZL/Integral (psi-m
8.543105
8.544
8.545
8.546
8.547200
t (s)

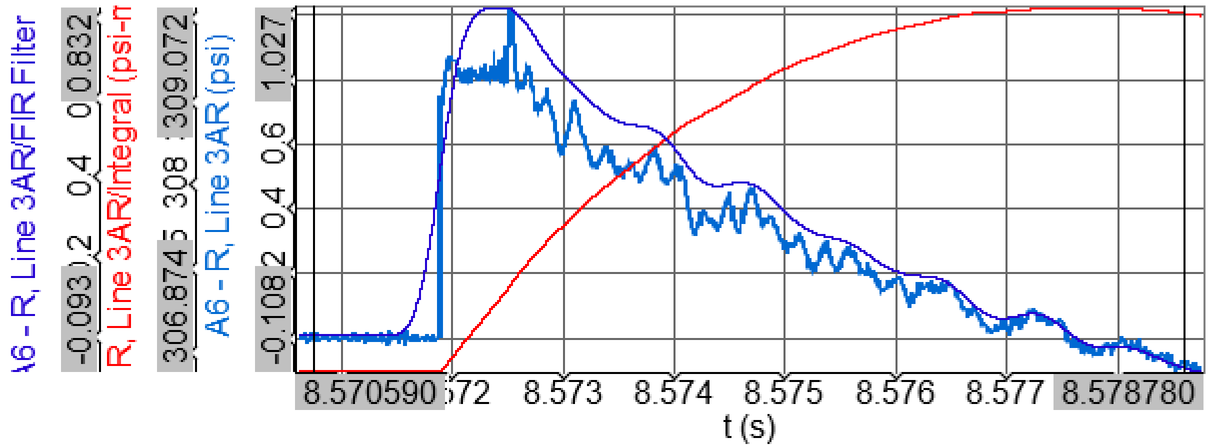

A5 - L, Line E2L (psi)
L, Line E2L/Integral (psi-m
8.550760
8.552
8.553
8.554
8.554855
t (s)

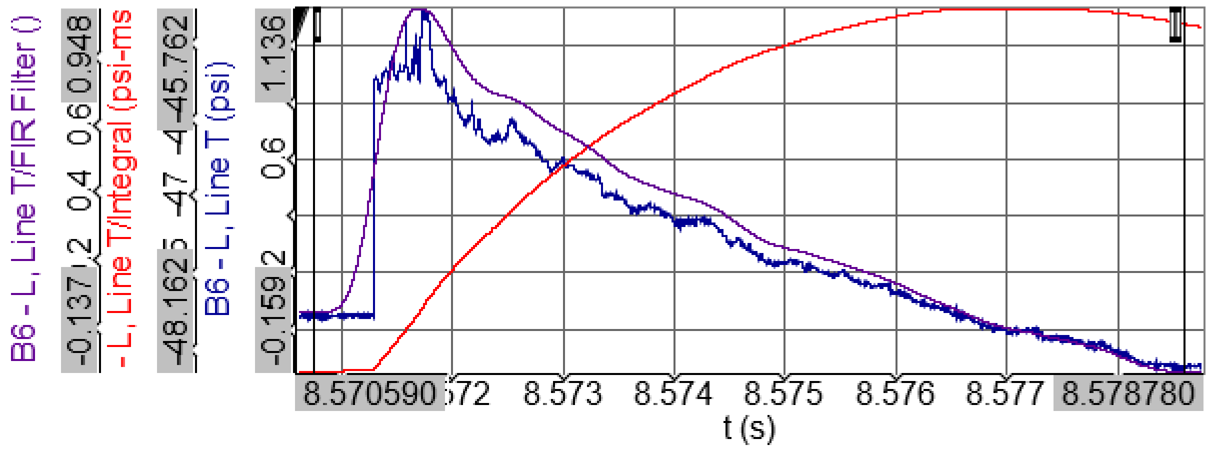

A5 - R, Line 1DR (psi)
R, Line 1DR/Integral (psi-m
8.550760
8.552
8.553
8.554
8.554855
t (s)

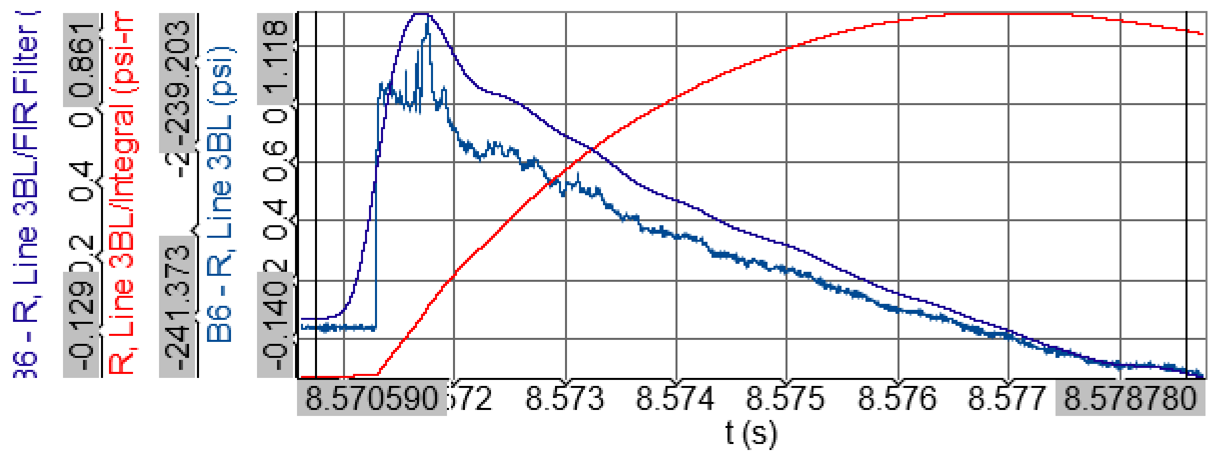

35 - L, Line 5CR/FIR Filter (
L, Line 5CR/Integral (psi-r
B5 - L, Line 5CR (psi)
0.088
1
1.5
2.434
120.036
122
124.578
0.041
1
1.5
2
2.963
8.550760
8.552
8.553
8.554
8.554855
t (s)

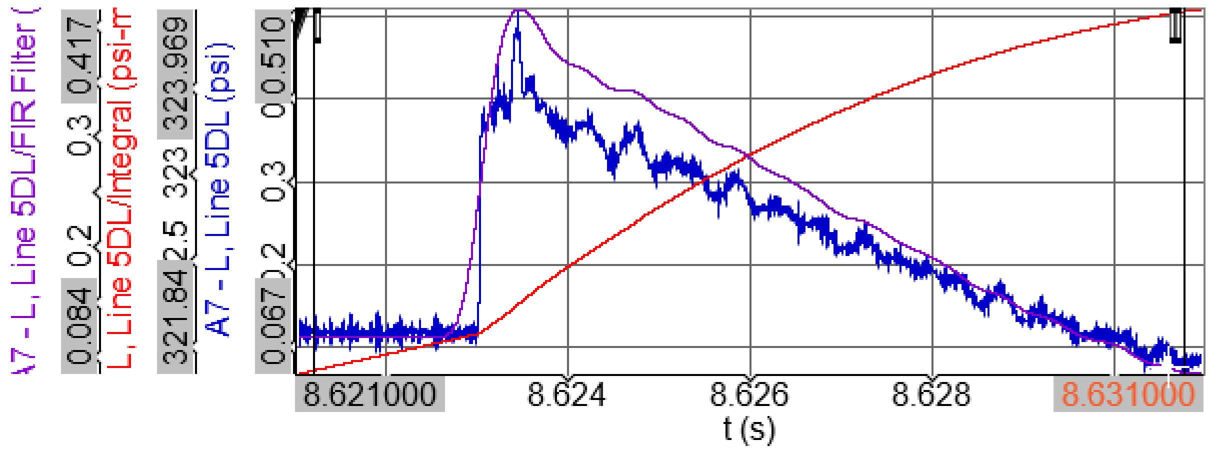

35 - R, Line 5CL/FIR Filter (
R, Line 5CL/Integral (psi-r
B5 - R, Line 5CL (psi)
0.003
1
1.5
2.461
317.212
320
321.71
-0.023
1
1.5
2
2.981
8.550760
8.552
8.553
8.554
8.554855
t (s)

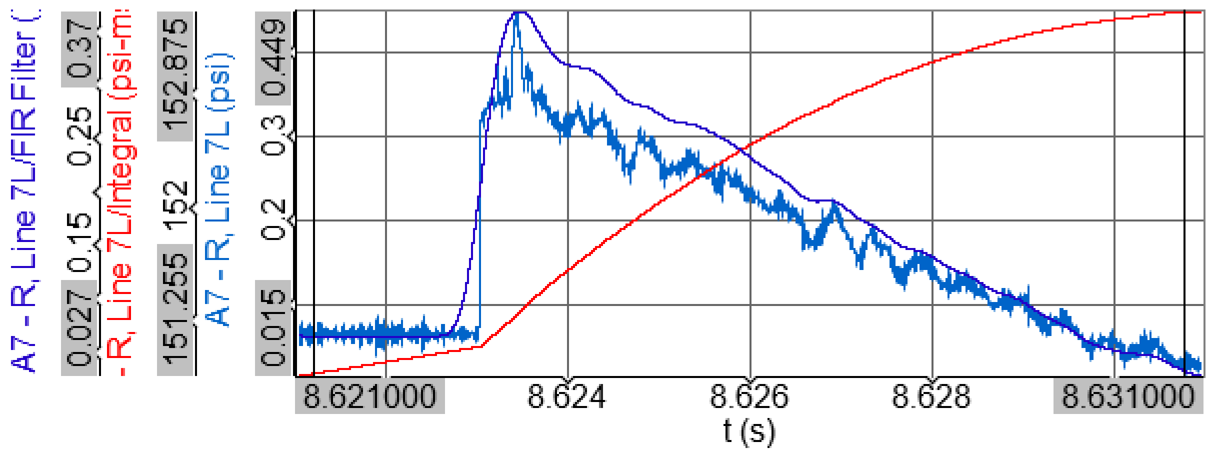

A6 - L, Line 4DL/FIR Filter (
L, Line 4DL/Integral (psi-r
A6 - L, Line 4DL (psi)
-0.126
0.4
0.840
328.49
329.5
330.456
-0.161
0.4
0.6
0.978
8.570590
8.573
8.574
8.575
8.576
8.577
8.578780
t (s)

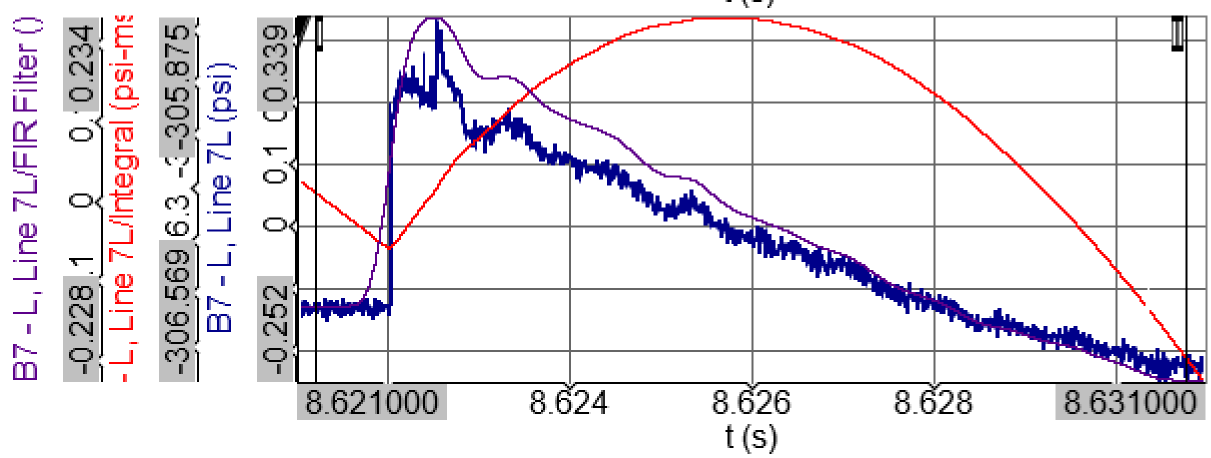

A6 - R, Line 3AR/FIR Filter
R, Line 3AR/Integral (psi-ms)
A6 - R, Line 3AR (psi)
t (s)

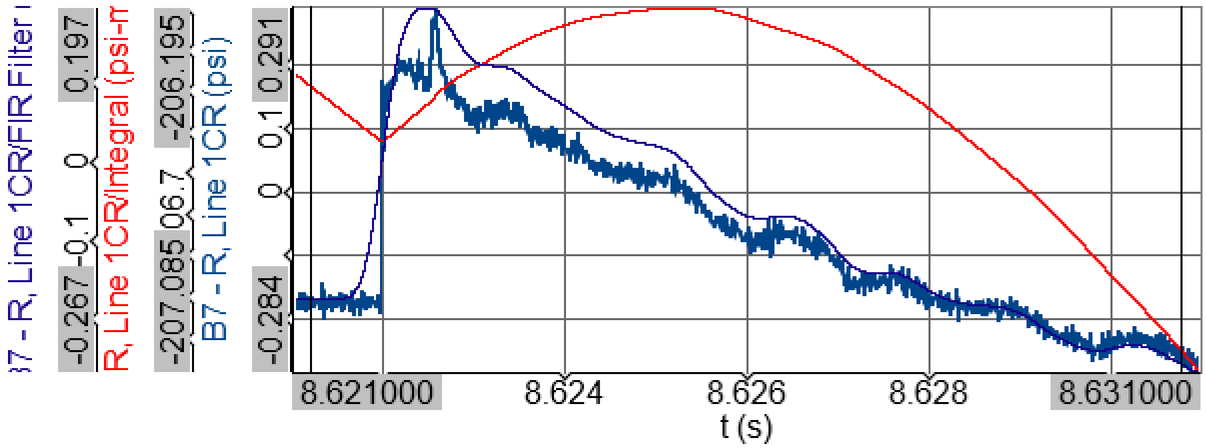

B6 - L, Line T/FIR Filter ()
- L, Line T/Integral (psi-ms
B6 - L, Line T (psi)
t (s)

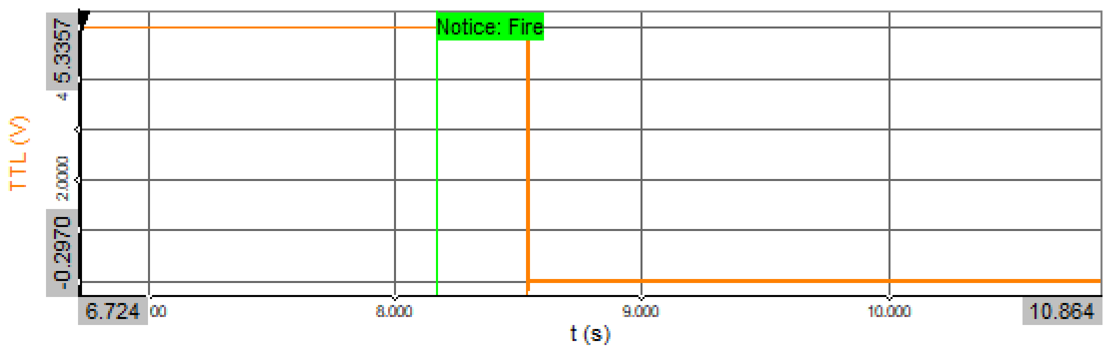

B6 - R, Line 3BL/FIR Filter (
R, Line 3BL/Integral (psi-m
B6 - R, Line 3BL (psi)
t (s)


A7 - L, Line 5DL/FIR Filter (
L, Line 5DL/Integral (psi-m
A7 - L, Line 5DL (psi)
8.621000
8.624
8.626
8.628
8.631000
t (s)

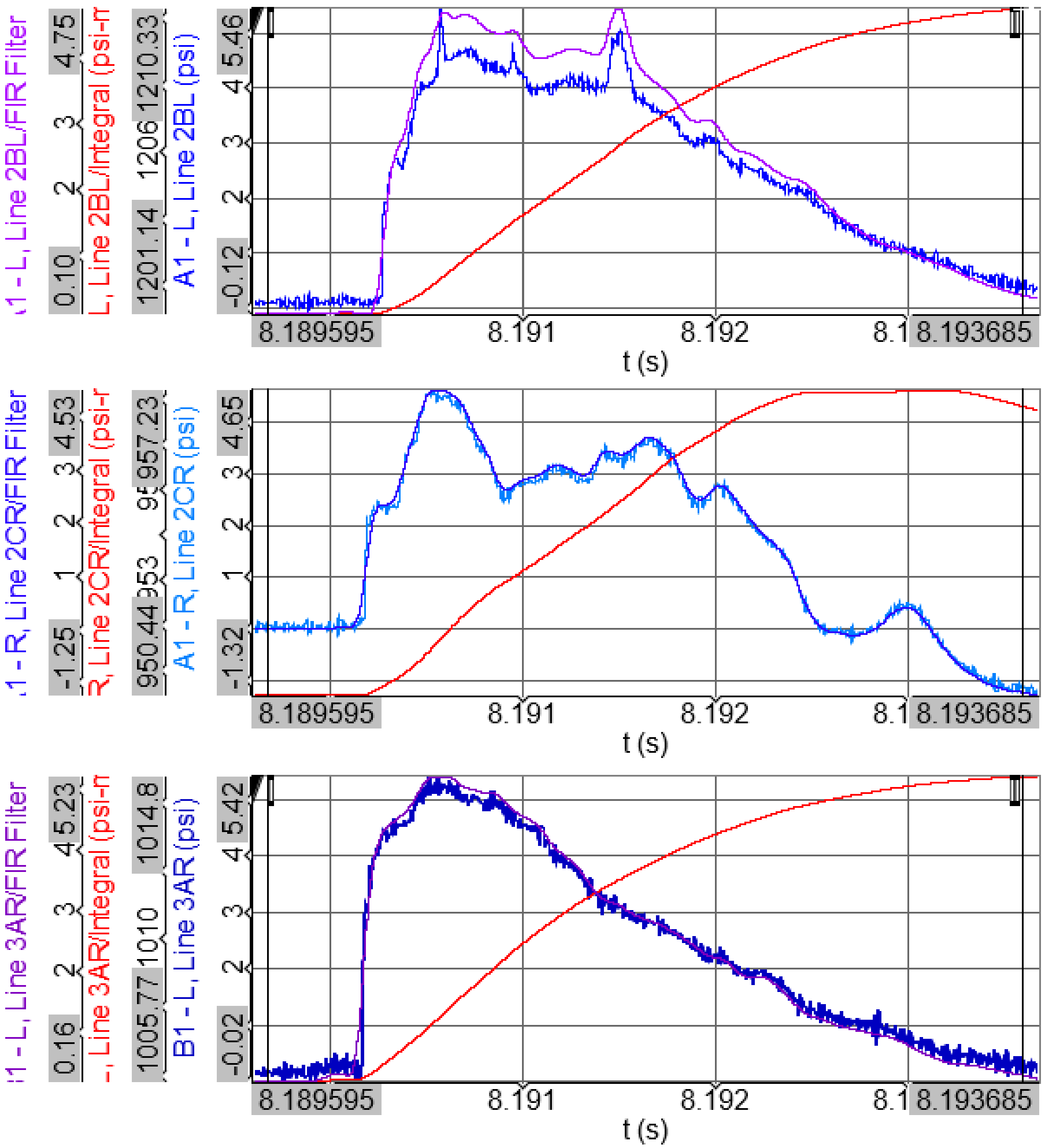

A7 - R, Line 7L/FIR Filter (
- R, Line 7L/Integral (psi-m
A7 - R, Line 7L (psi)
8.621000
8.624
8.626
8.628
8.631000
t (s)

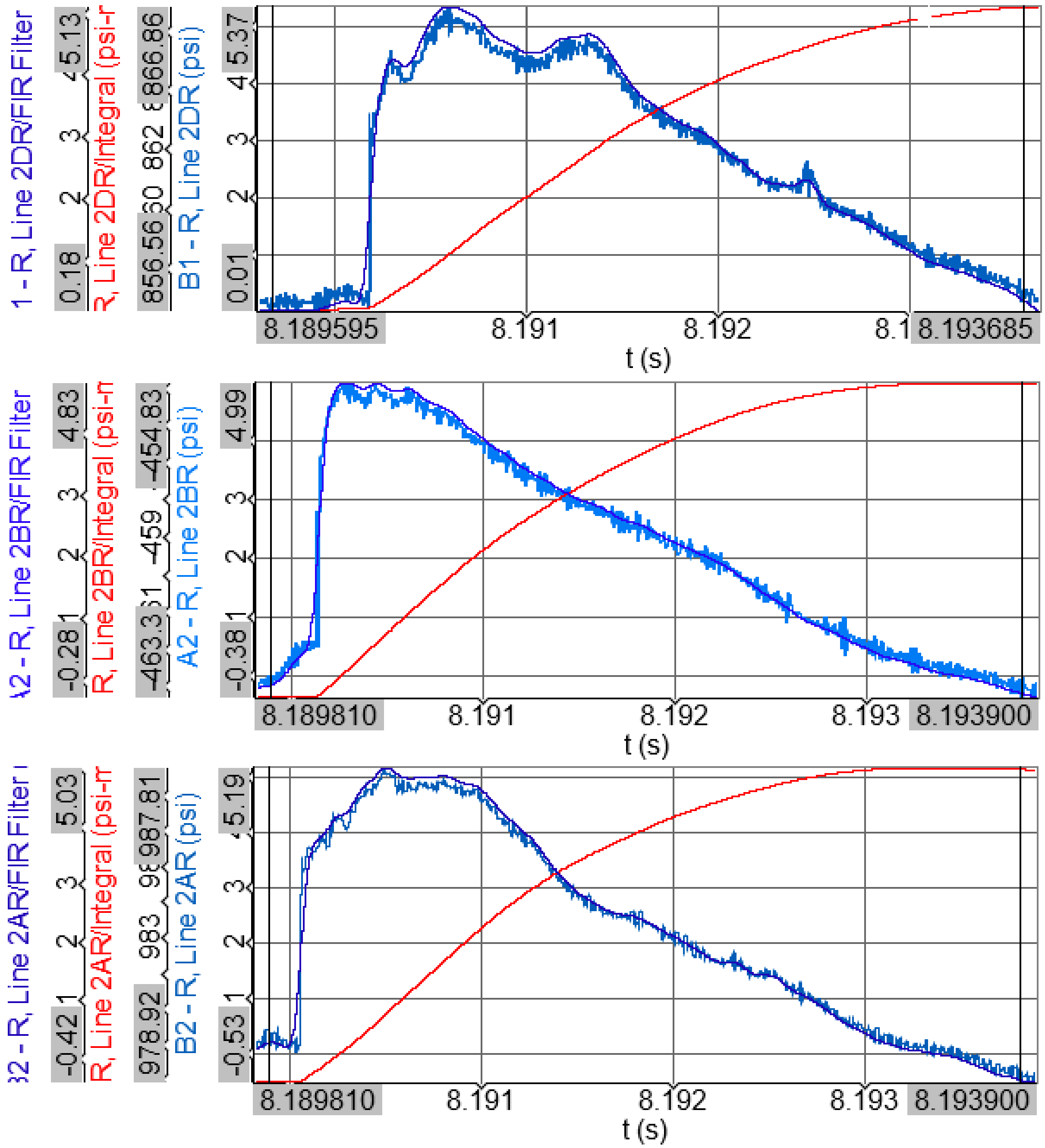

B7 - L, Line 7L/FIR Filter ()
- L, Line 7L/Integral (psi-m
B7 - L, Line 7L (psi)
8.621000
8.624
8.626
8.628
8.631000
t (s)

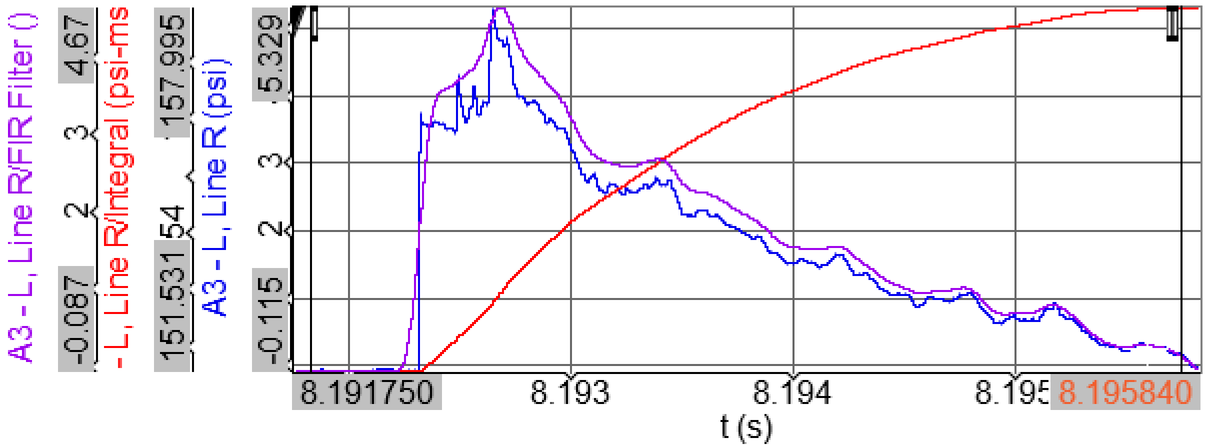

B7 - R, Line 1CR/FIR Filter
-0.267
-0.1
0
0.197
R, Line 1CR/Integral (psi-m
-207.085
06.7
-206.195
B7 - R, Line 1CR (psi)
-0.284
0
0.1
0.291
8.621000
8.624
8.626
8.628
8.631000
t (s)

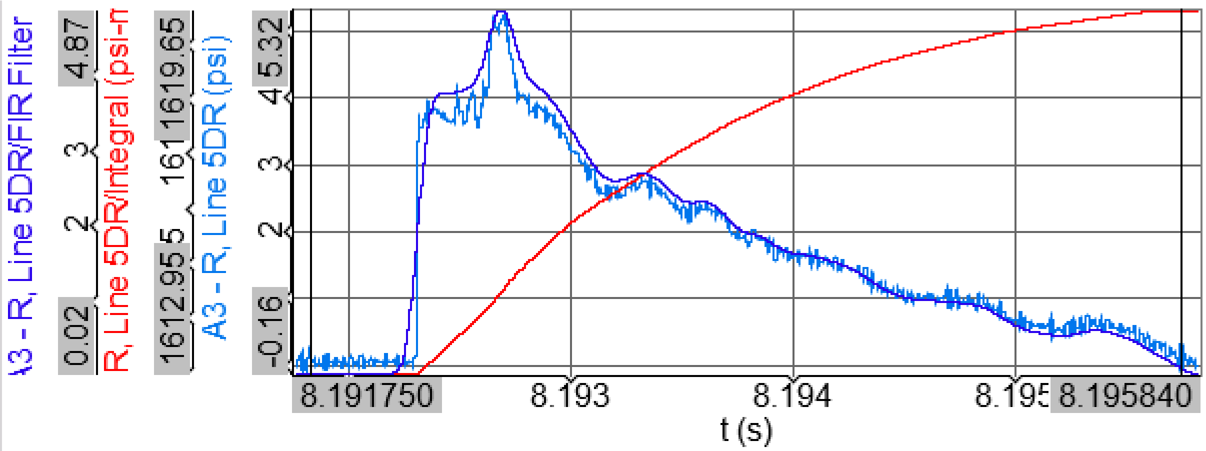

TTL (V)
5.3357
2.0000
-0.2970
Notice: Fire
6.724
8.000
9.000
10.000
10.864
t (s)

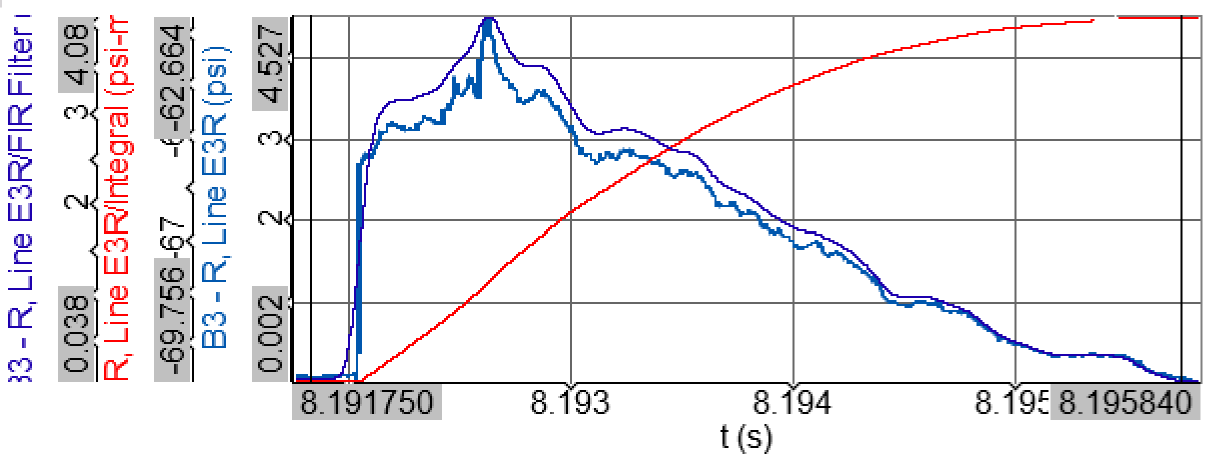
8.8.2 Trial 2 for Small-Scale Mix ID #48

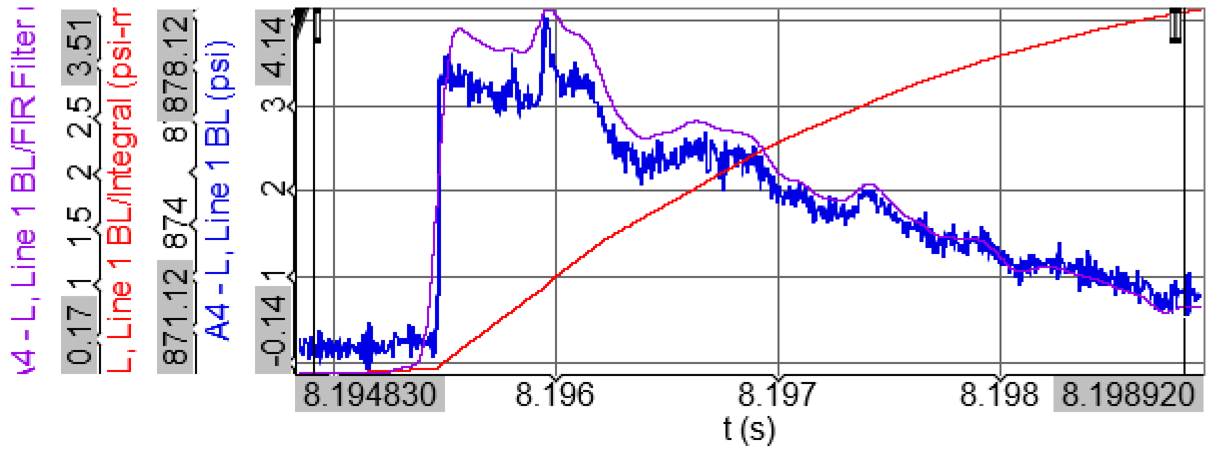


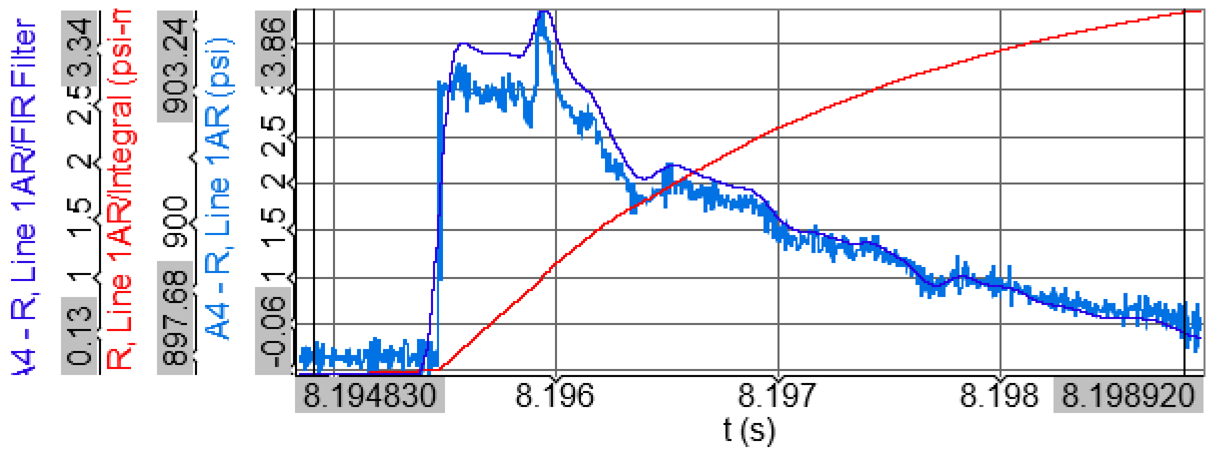

1 - R, Line 2DR/FIR Filter
R, Line 2DR/Integral (psi-r
B1 - R, Line 2DR (psi)
8.189595
8.191
8.192
8.193685
t (s)
2 - R, Line 2BR/FIR Filter
R, Line 2BR/Integral (psi-r
A2 - R, Line 2BR (psi)
8.189810
8.191
8.192
8.193
8.193900
t (s)
2 - R, Line 2AR/FIR Filter
R, Line 2AR/Integral (psi-r
B2 - R, Line 2AR (psi)
8.189810
8.191
8.192
8.193
8.193900
t (s)

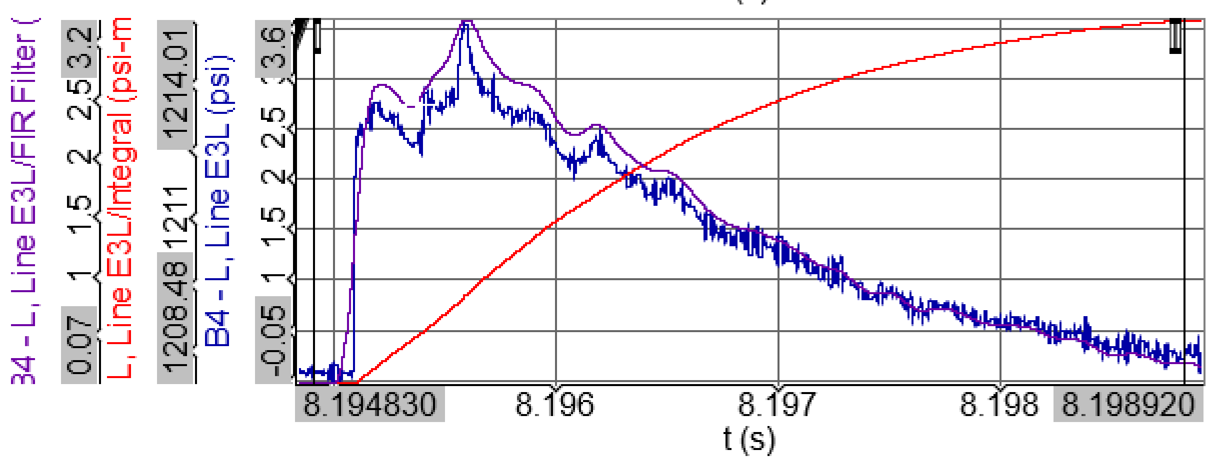

A3 - L, Line R/FIR Filter ()
-L, Line R/Integral (psi-ms
A3 - L, Line R (psi)
8.191750
8.193
8.194
8.195
8.195840
t (s)

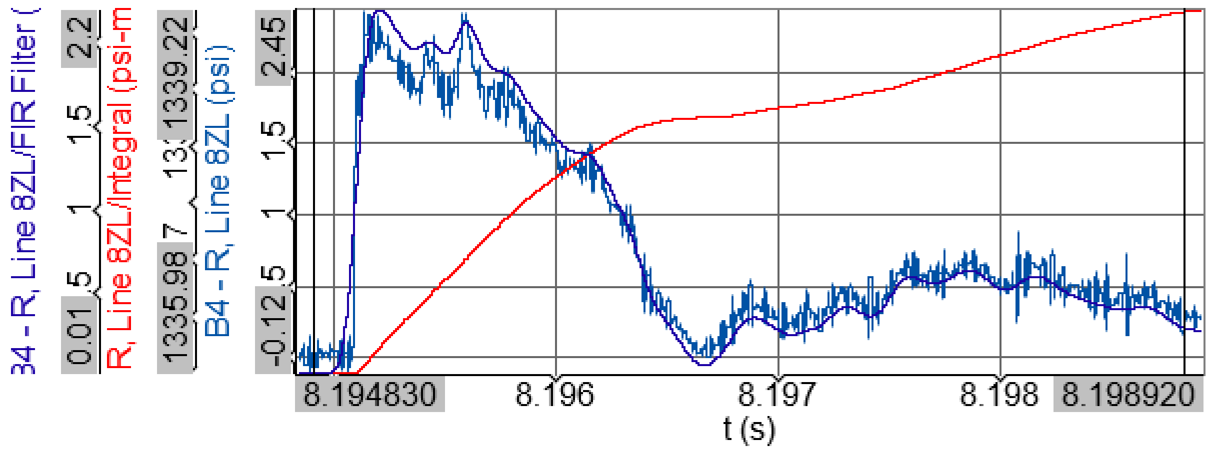

A3 - R, Line 5DR/FIR Filter
R, Line 5DR/Integral (psi-m
A3 - R, Line 5DR (psi)
8.191750
8.193
8.194
8.195
8.195840
t (s)

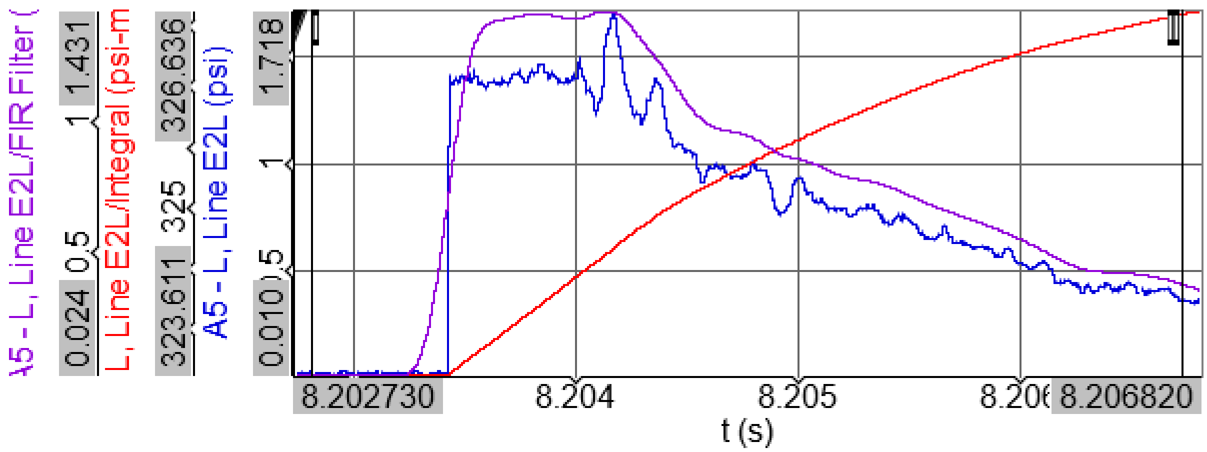

B3 - R, Line E3R/FIR Filter
R, Line E3R/Integral (psi-m
B3 - R, Line E3R (psi)
8.191750
8.193
8.194
8.195
8.195840
t (s)

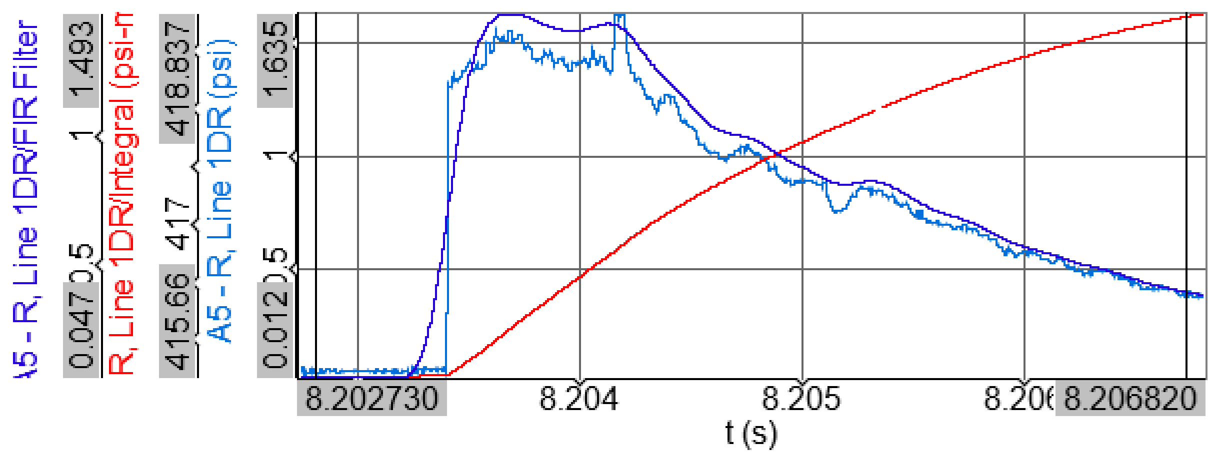

A4 - L, Line 1 BL/FIR Filter
L, Line 1 BL/Integral (psi-m
A4 - L, Line 1 BL (psi)
0.17 1 1.5 2 2.5 3.51
871.12 874 8 878.12
-0.14 1 2 3 4.14
8.194830
8.196
8.197
8.198
8.198920
t (s)

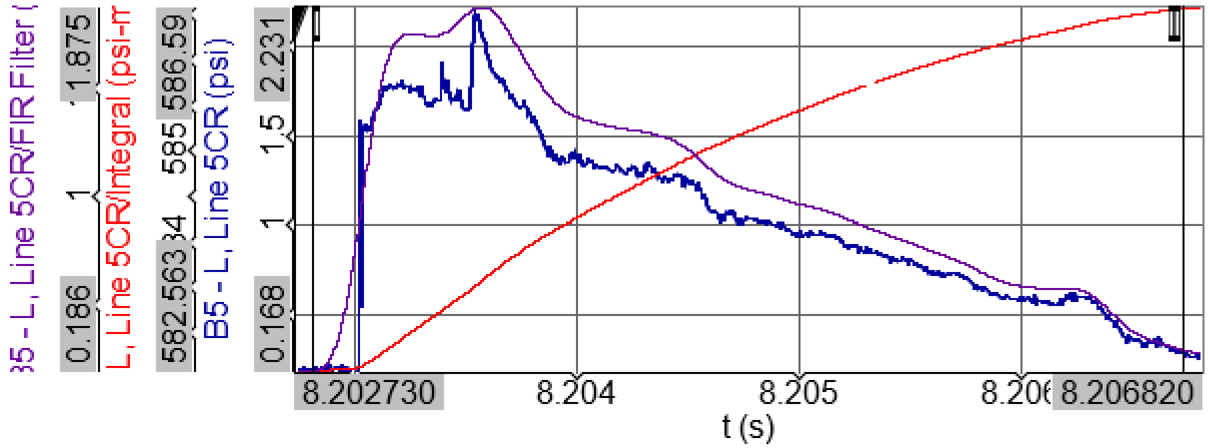

A4 - R, Line 1AR/FIR Filter
R, Line 1AR/Integral (psi-m
A4 - R, Line 1AR (psi)
0.13 1 1.5 2 2.5 3.34
897.68 900 903.24
-0.06 1 1.5 2 2.5 3.86
8.194830
8.196
8.197
8.198
8.198920
t (s)

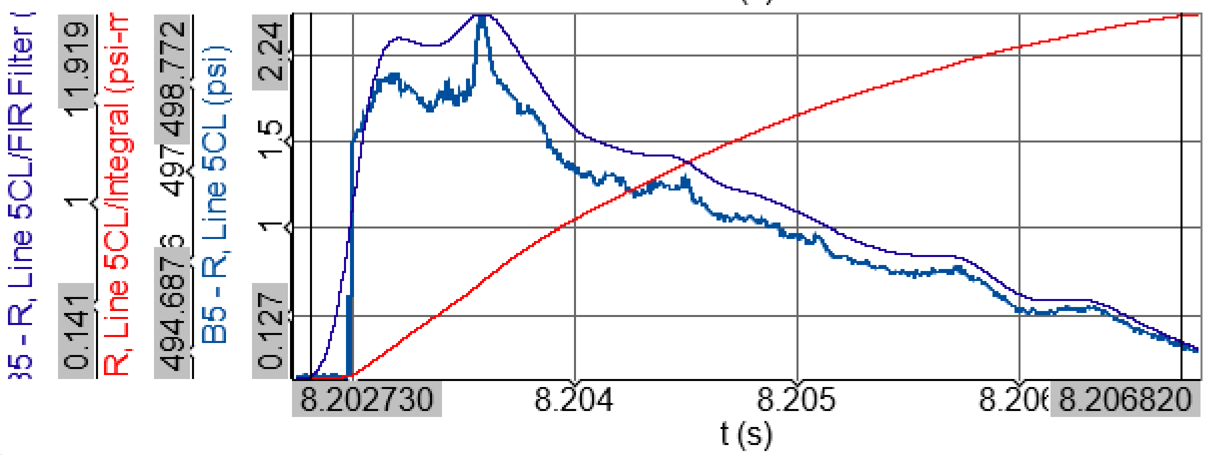

B4 - L, Line E3L/FIR Filter (
L, Line E3L/Integral (psi-m
B4 - L, Line E3L (psi)
0.07 1 1.5 2 2.5 3.2
1208.48 1211 1214.01
-0.05 1 1.5 2 2.5 3.6
8.194830
8.196
8.197
8.198
8.198920
t (s)

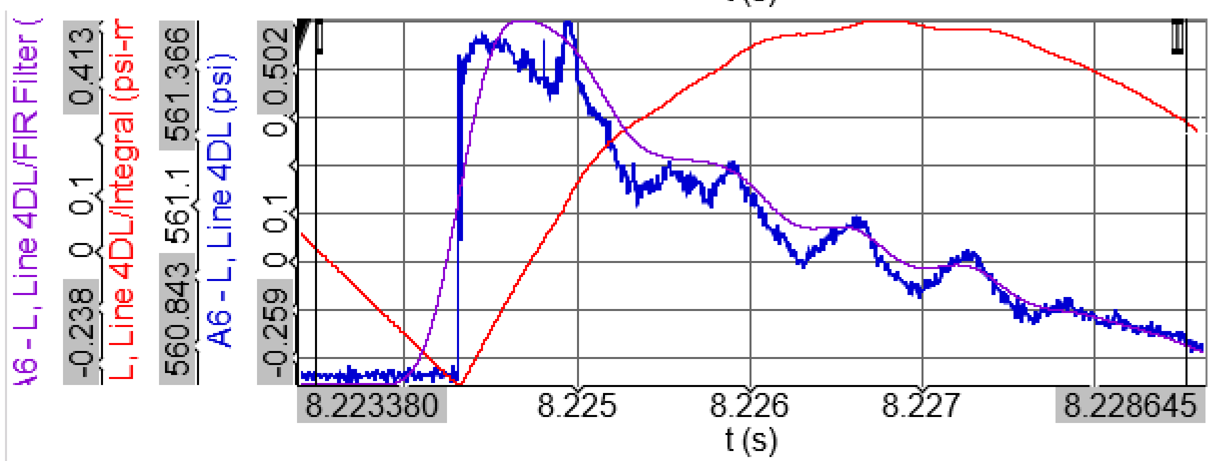

B4 - R, Line 8ZL (psi)
R, Line 8ZL/Integral (psi-m
B4 - R, Line 8ZL/FIR Filter (
8.194830
8.196
8.197
8.198
8.198920
t (s)

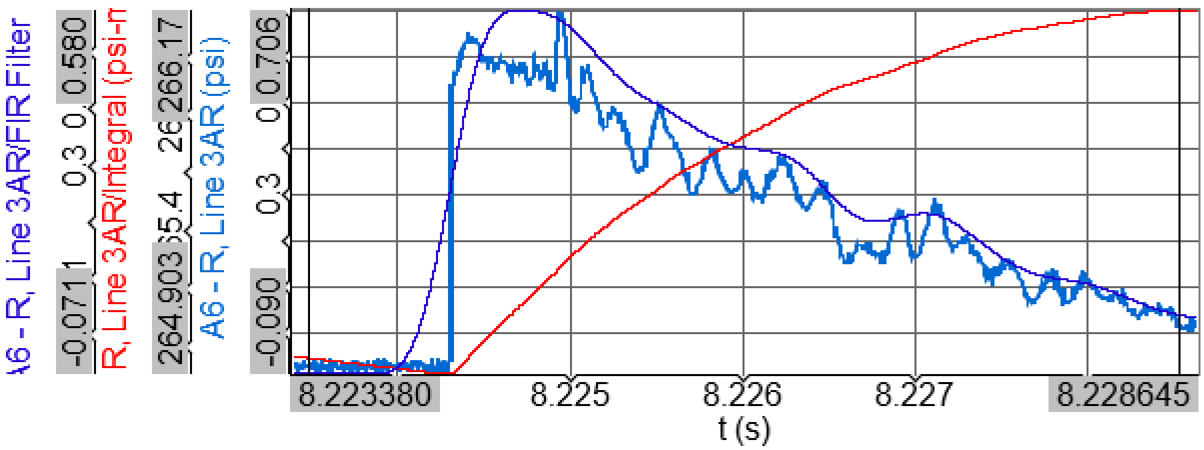

A5 - L, Line E2L (psi)
L, Line E2L/Integral (psi-m
A5 - L, Line E2L/FIR Filter (
8.202730
8.204
8.205
8.206820
t (s)

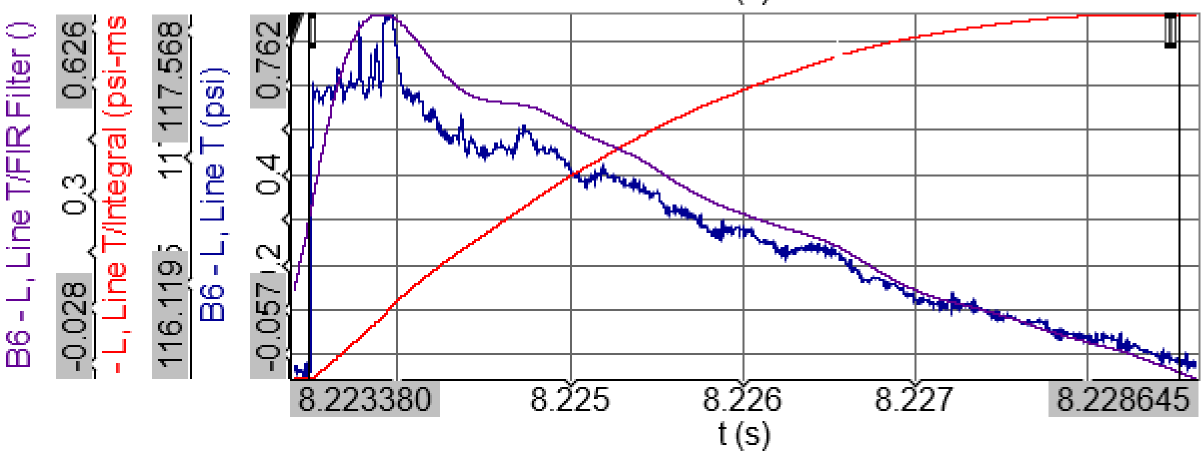

A5 - R, Line 1DR (psi)
R, Line 1DR/Integral (psi-m
A5 - R, Line 1DR/FIR Filter
8.202730
8.204
8.205
8.206820
t (s)

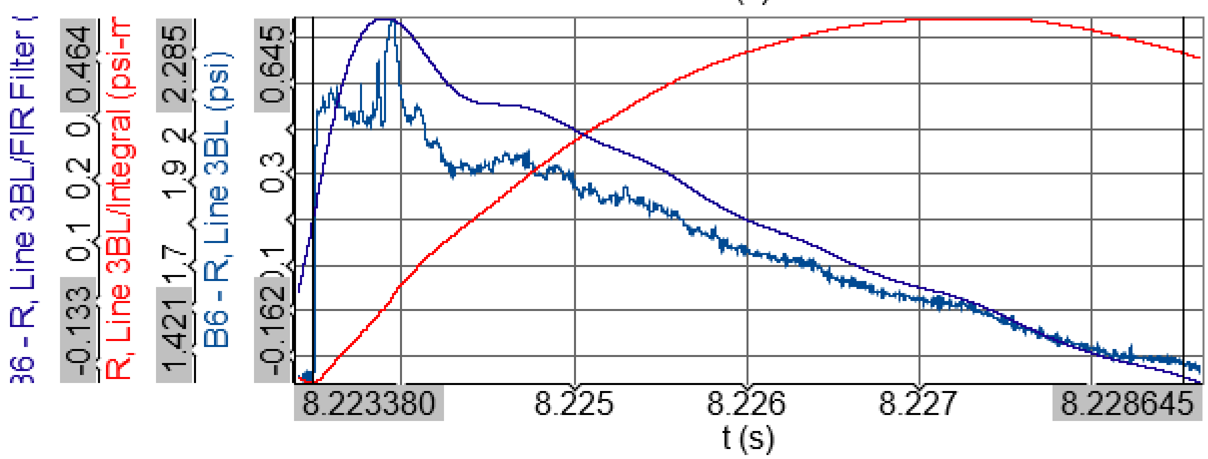

B5 - L, Line 5CR (psi)
8.202730
8.204
8.205
8.206820
t (s)

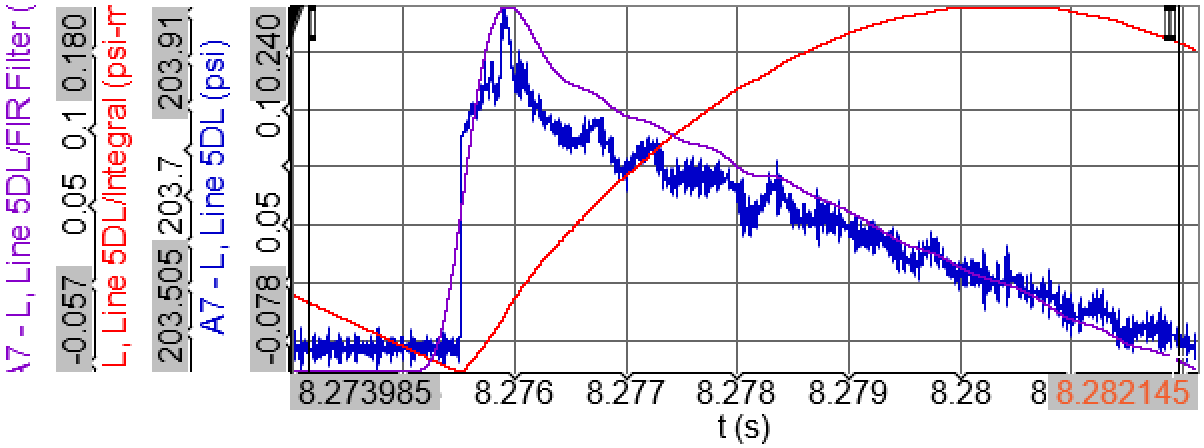

B5 - R, Line 5CL (psi)
8.202730
8.204
8.205
8.206820
t (s)

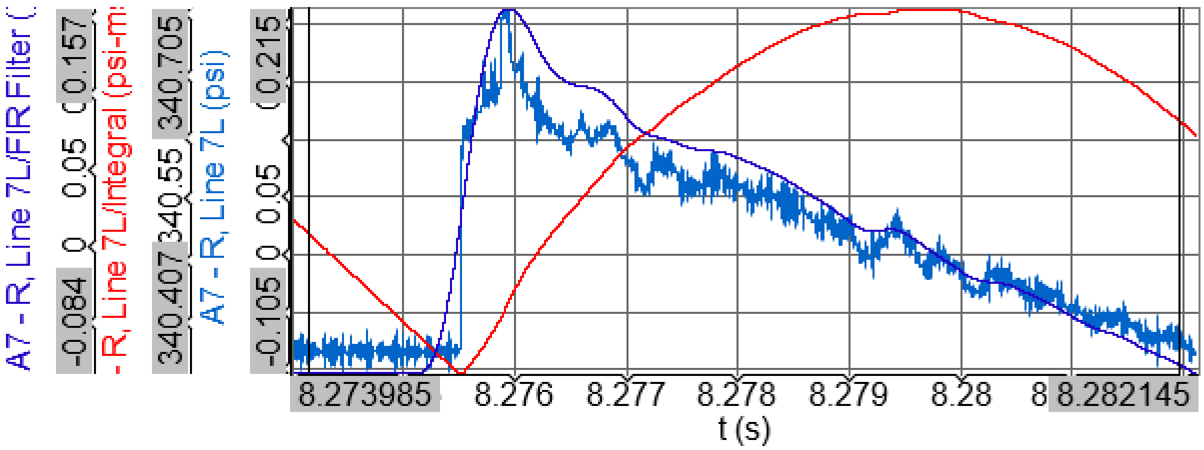

A6 - L, Line 4DL (psi)
8.223380
8.225
8.226
8.227
8.228645
t (s)

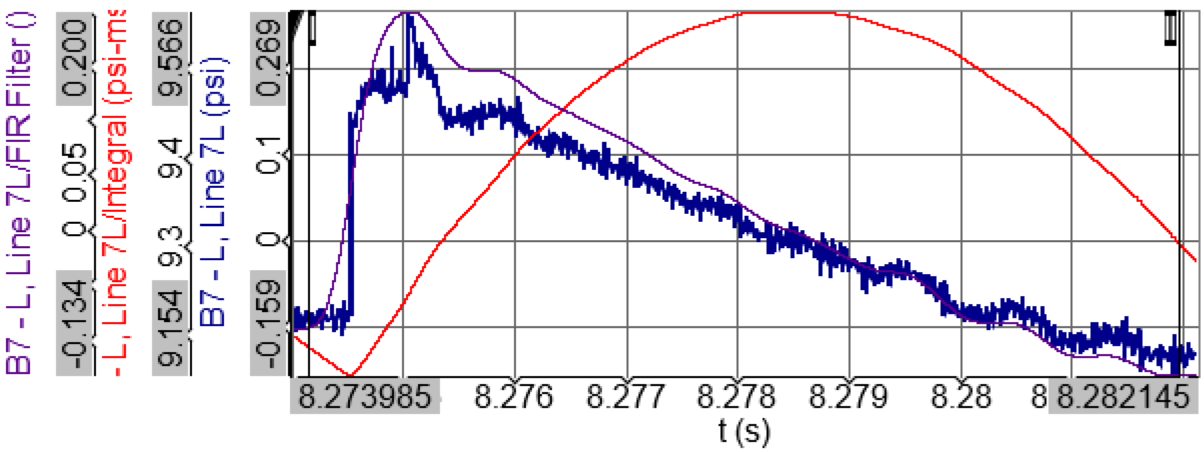

A6 - R, Line 3AR/FIR Filter
R, Line 3AR/Integral (psi-m
A6 - R, Line 3AR (psi)
-0.071
0.580
264.903
266.17
-0.090
0.706
8.223380
8.225
8.226
8.227
8.228645
t (s)

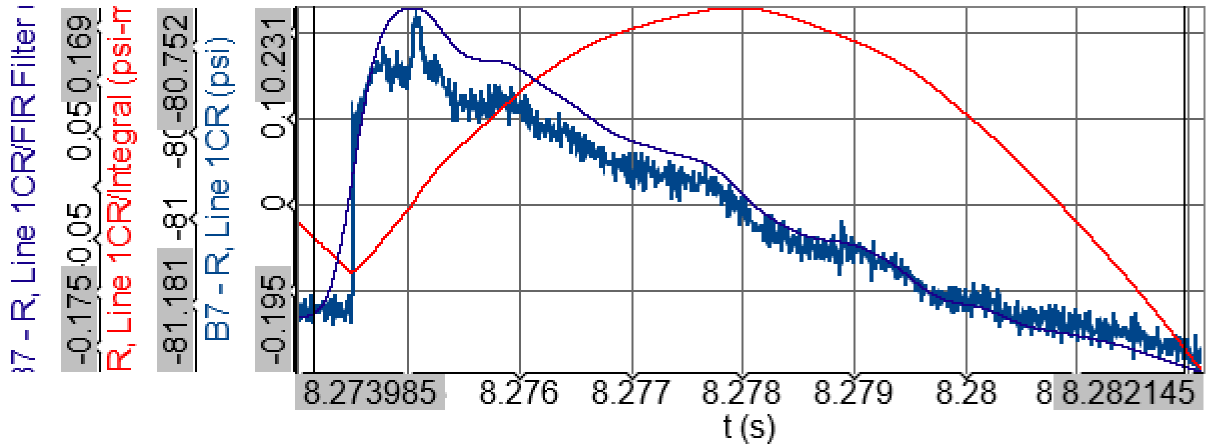

B6 - L, Line T/FIR Filter ()
- L, Line T/Integral (psi-ms
B6 - L, Line T (psi)
-0.028
0.626
116.119
117.568
-0.057
0.762
8.223380
8.225
8.226
8.227
8.228645
t (s)

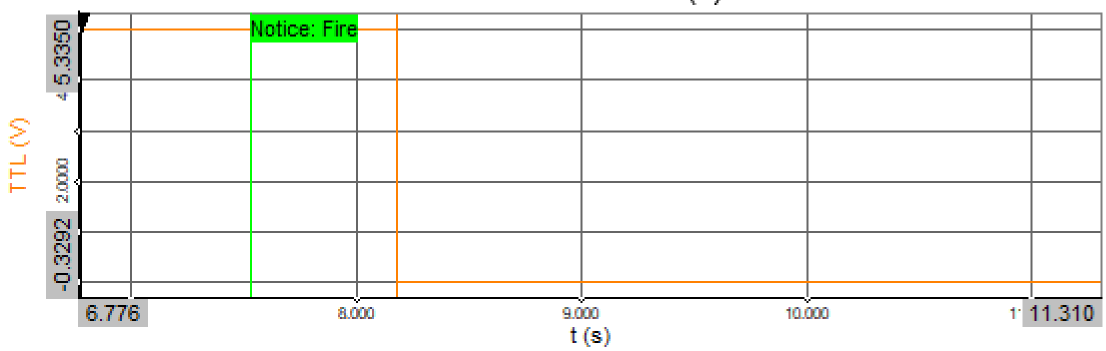

B6 - R, Line 3BL/FIR Filter (
R, Line 3BL/Integral (psi-m
B6 - R, Line 3BL (psi)
-0.133
0.464
1.421
2.285
-0.162
0.645
8.223380
8.225
8.226
8.227
8.228645
t (s)


A7 - L, Line 5DL (psi)
t (s)
8.273985
8.276
8.277
8.278
8.279
8.28
8.282145

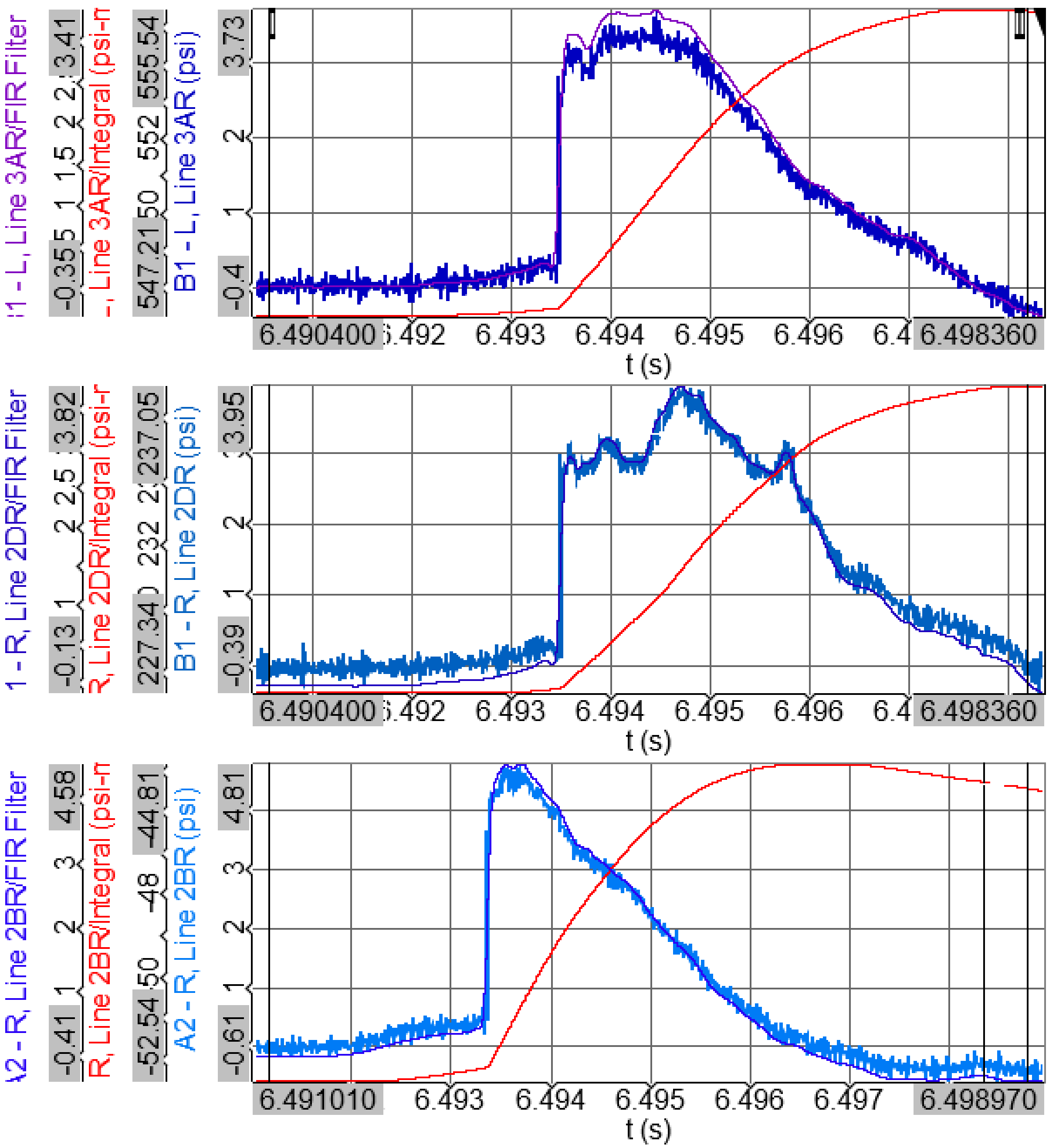

A7 - R, Line 7L/FIR Filter (
A7 - R, Line 7L (psi)
t (s)
8.273985
8.276
8.277
8.278
8.279
8.28
8.282145

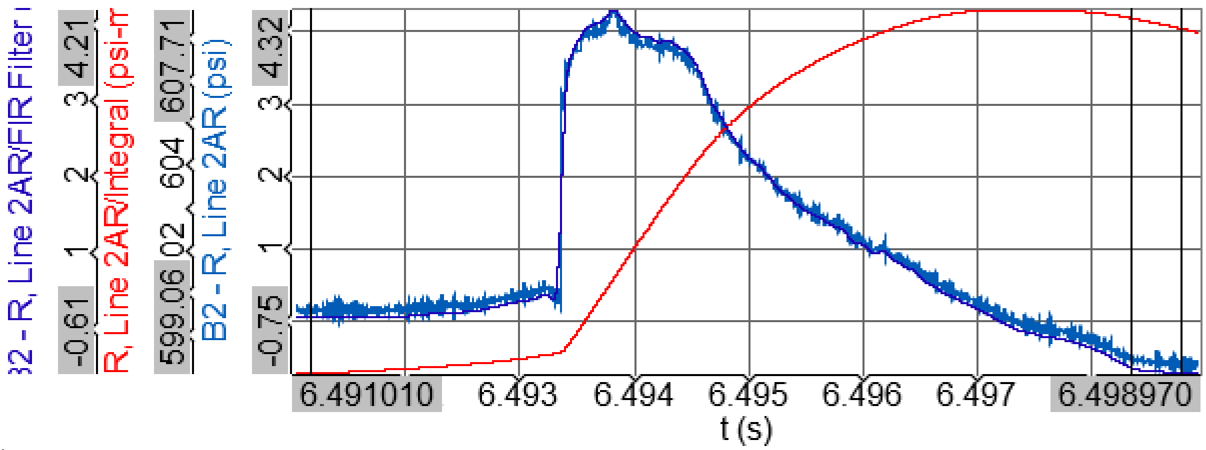

B7 - L, Line 7L/FIR Filter ()
B7 - L, Line 7L (psi)
t (s)
8.273985
8.276
8.277
8.278
8.279
8.28
8.282145

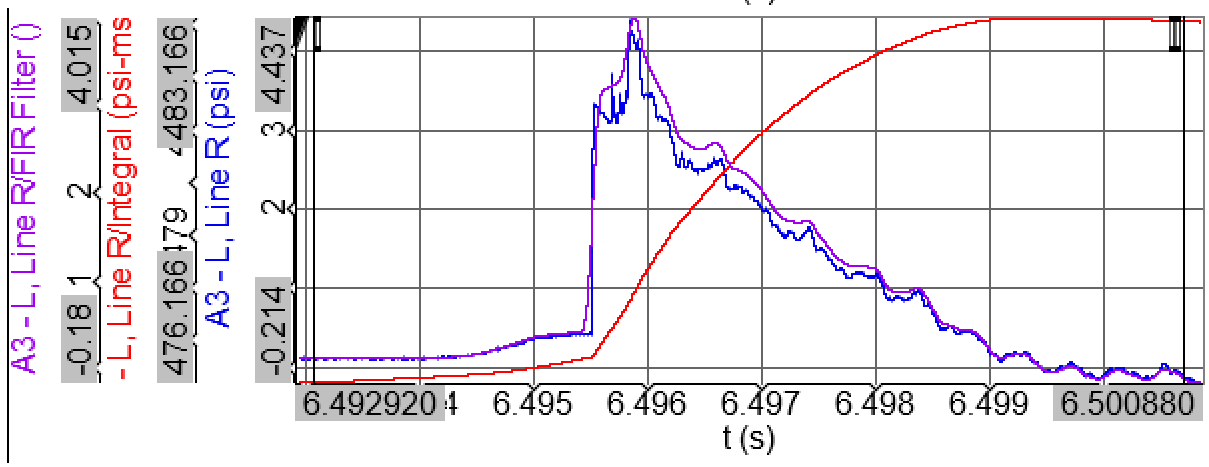

B7 - R, Line 1CR/FIR Filter
R, Line 1CR/Integral (psi-m
B7 - R, Line 1CR (psi)
t (s)
8.273985
8.276
8.277
8.278
8.279
8.28
8.282145

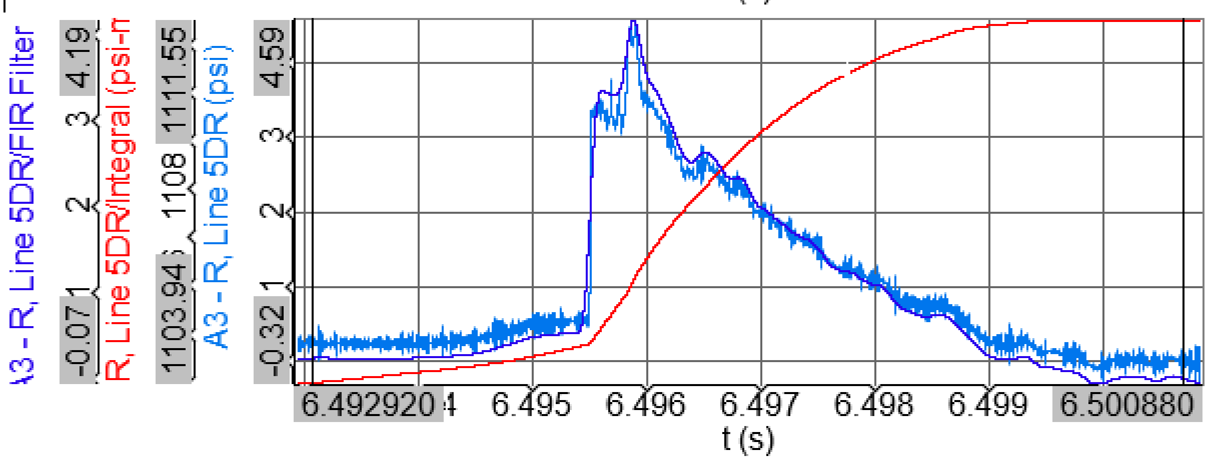

Notice: Fire
TTL (V)
5.3350
-0.3292
6.776
8.000
9.000
10.000
11.310
t (s)

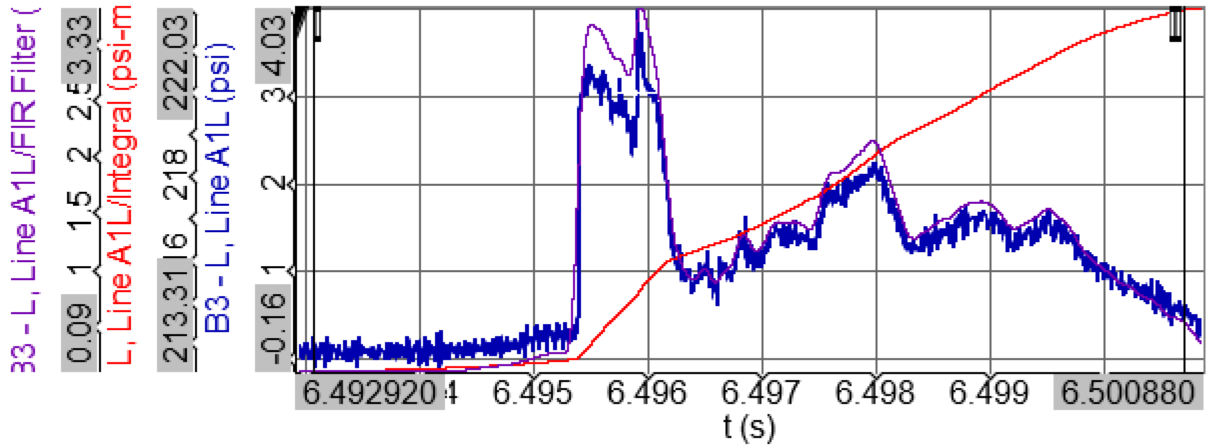
8.8.3 Trial 3 for Small-Scale Mix ID #48

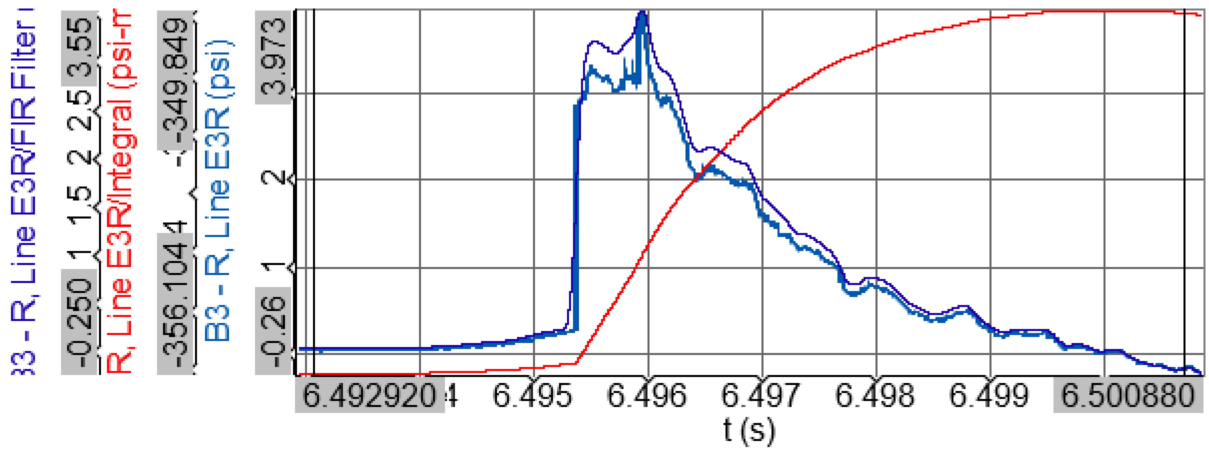


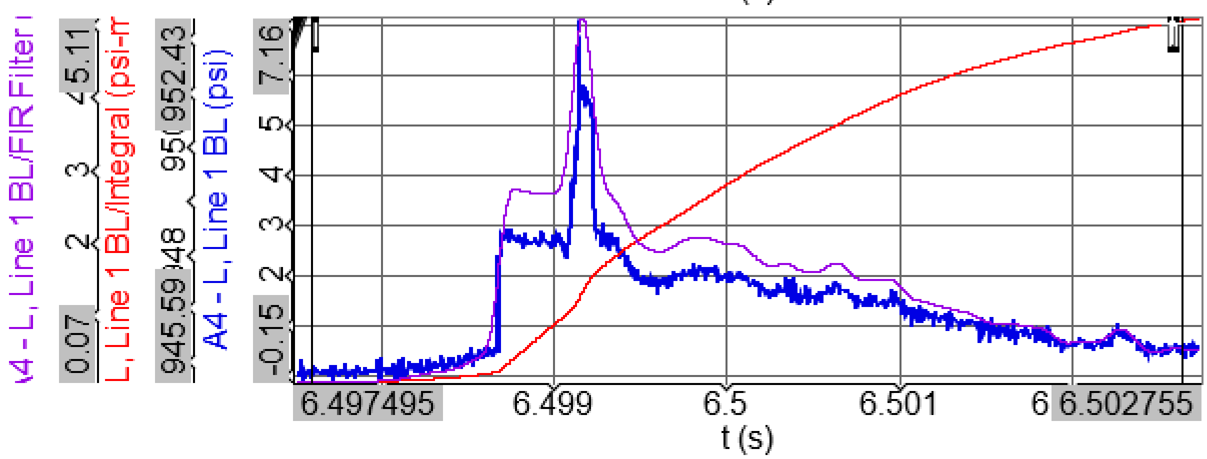

B2 - R, Line 2AR (psi)
R, Line 2AR/Integral (psi-m
t (s)
6.491010
6.493
6.494
6.495
6.496
6.497
6.498970

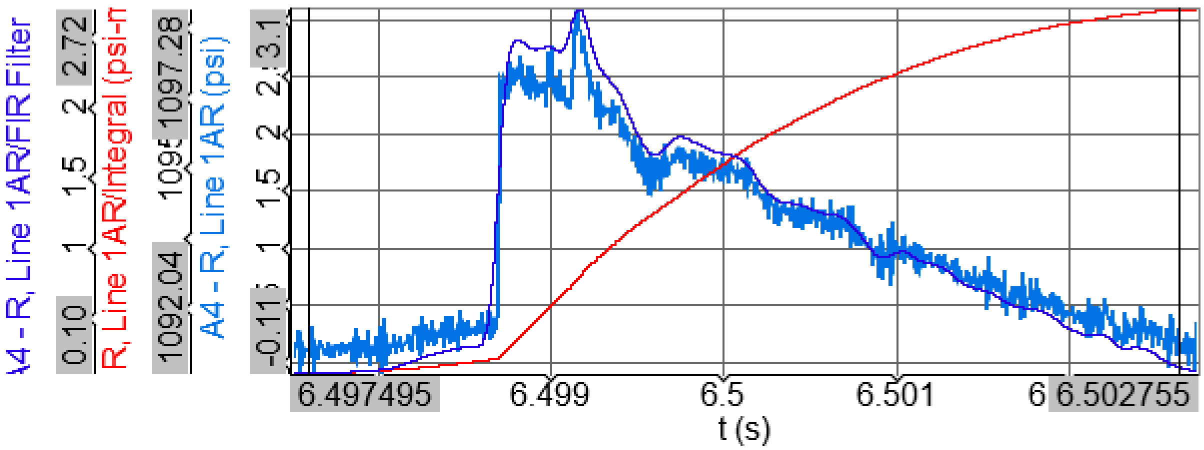

A3 - L, Line R/FIR Filter ()
- L, Line R/Integral (psi-ms
A3 - L, Line R (psi)
t (s)
6.492920
6.495
6.496
6.497
6.498
6.499
6.500880

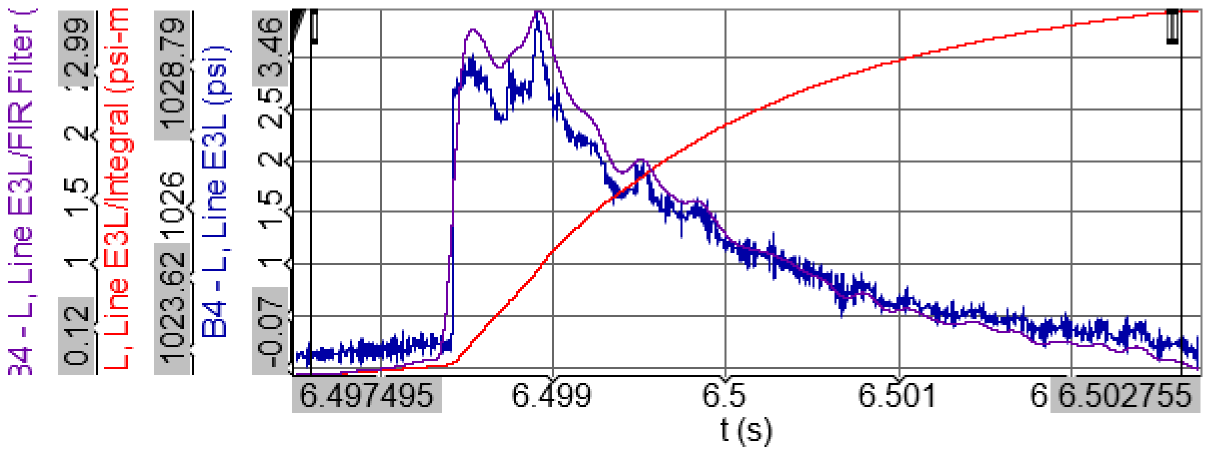

A3 - R, Line 5DR/FIR Filter
R, Line 5DR/Integral (psi-m
A3 - R, Line 5DR (psi)
t (s)
6.492920
6.495
6.496
6.497
6.498
6.499
6.500880

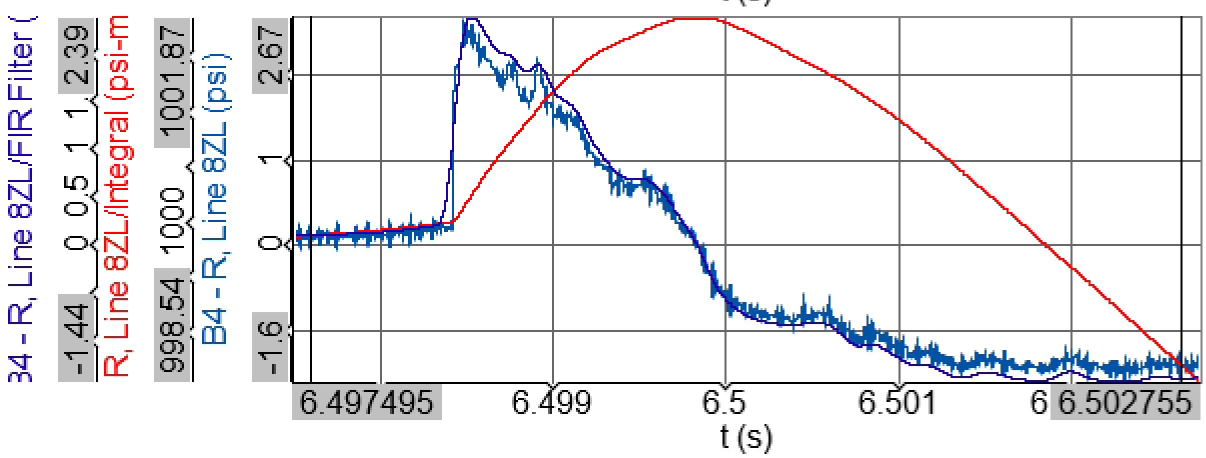

B3 - L, Line A1L (psi)
6.492920
6.495
6.496
6.497
6.498
6.499
6.500880
t (s)

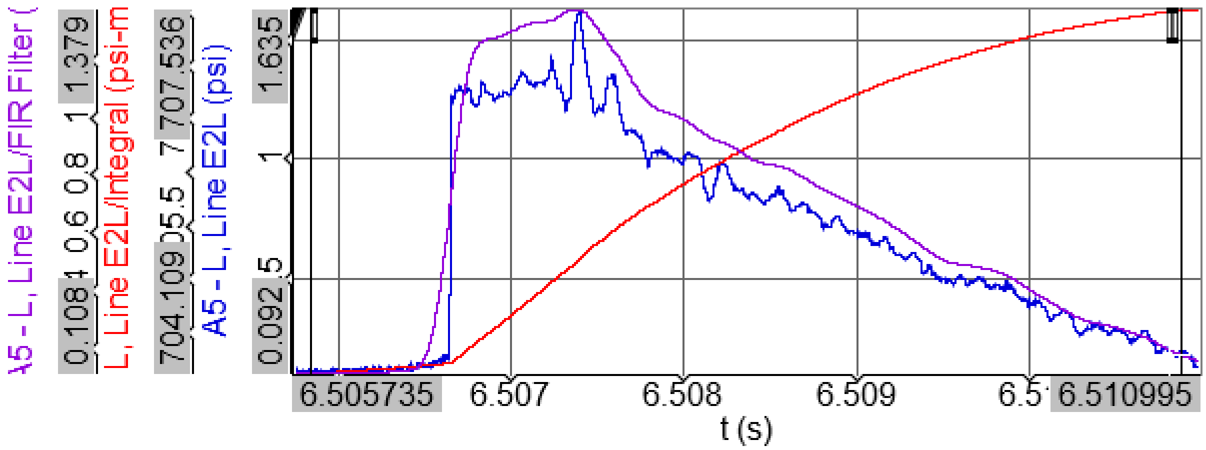

B3 - R, Line E3R (psi)
6.492920
6.495
6.496
6.497
6.498
6.499
6.500880
t (s)

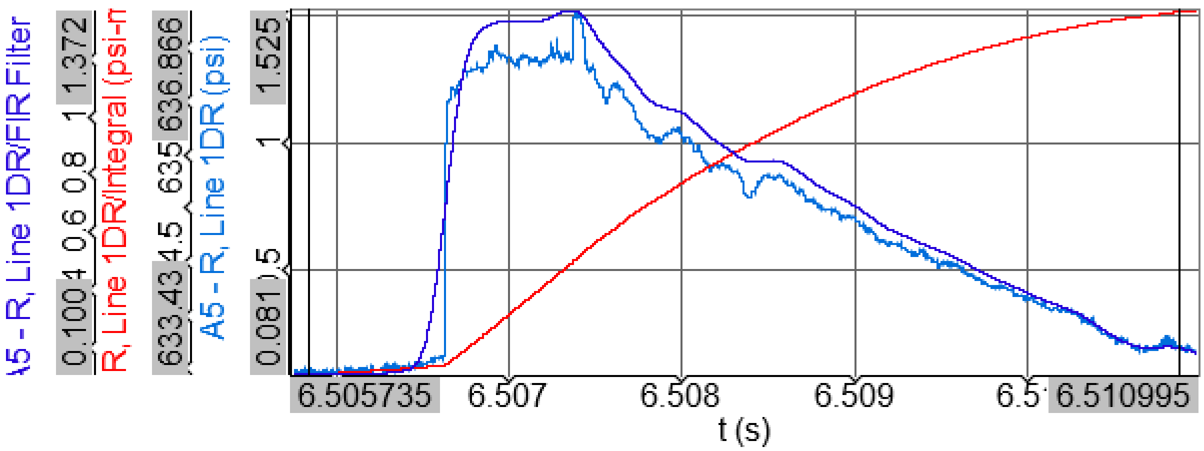

A4 - L, Line 1 BL (psi)
6.497495
6.499
6.5
6.501
6.502755
t (s)

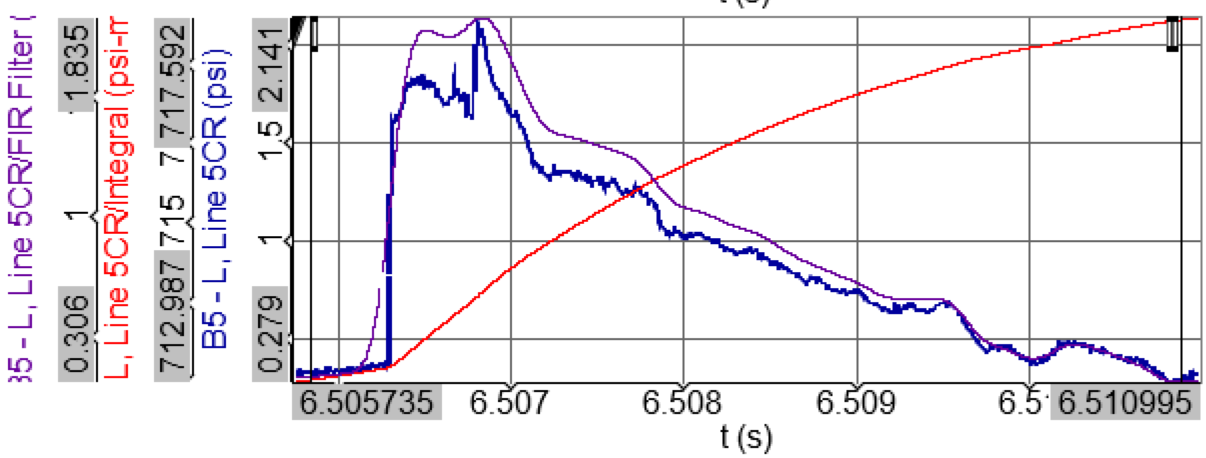

A4 - R, Line 1AR/FIR Filter
R, Line 1AR/Integral (psi-m
A4 - R, Line 1AR (psi)
6.497495
6.499
6.5
6.501
6.502755
t (s)

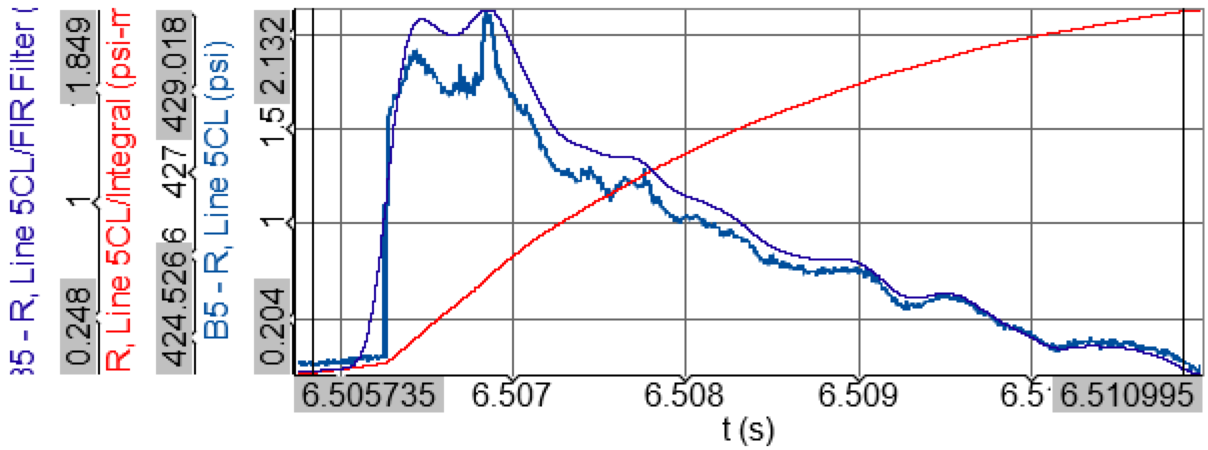

B4 - L, Line E3L/FIR Filter (
L, Line E3L/Integral (psi-m
B4 - L, Line E3L (psi)
6.497495
6.499
6.5
6.501
6.502755
t (s)

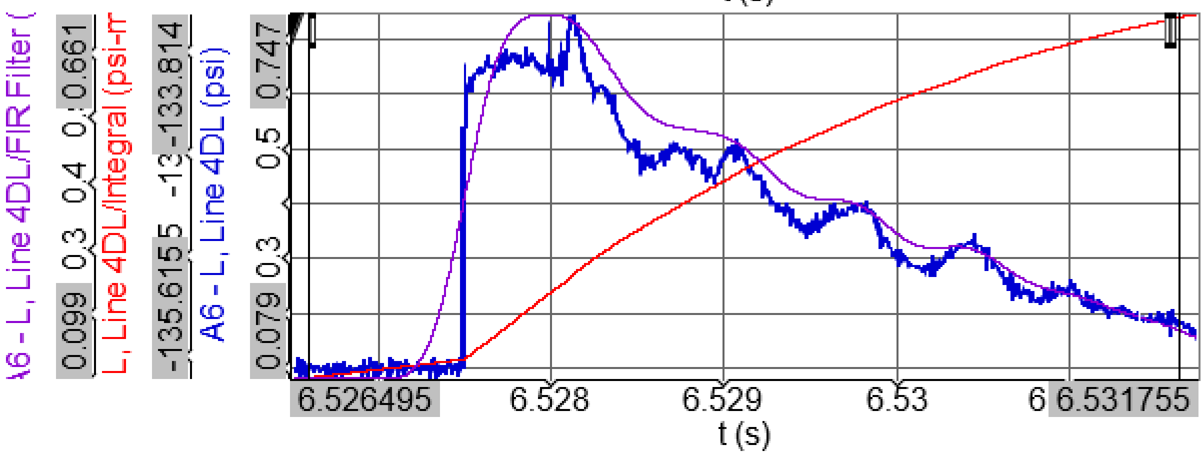

B4 - R, Line 8ZL/FIR Filter (
R, Line 8ZL/Integral (psi-m
B4 - R, Line 8ZL (psi)
6.497495
6.499
6.5
6.501
6.502755
t (s)

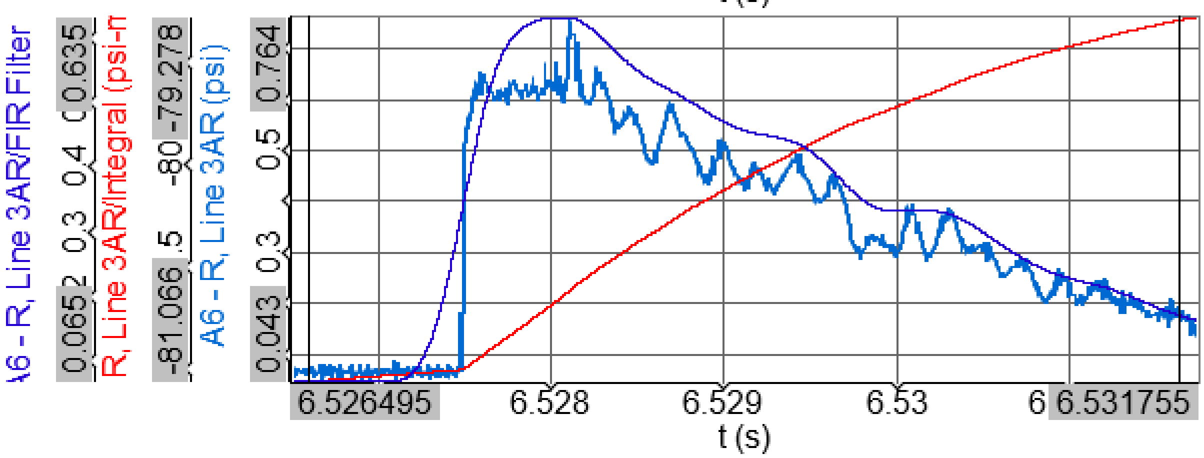

A5 - L, Line E2L (psi)
L, Line E2L/Integral (psi-m
A5 - L, Line E2L/FIR Filter (
6.505735
6.507
6.508
6.509
6.510995
t (s)

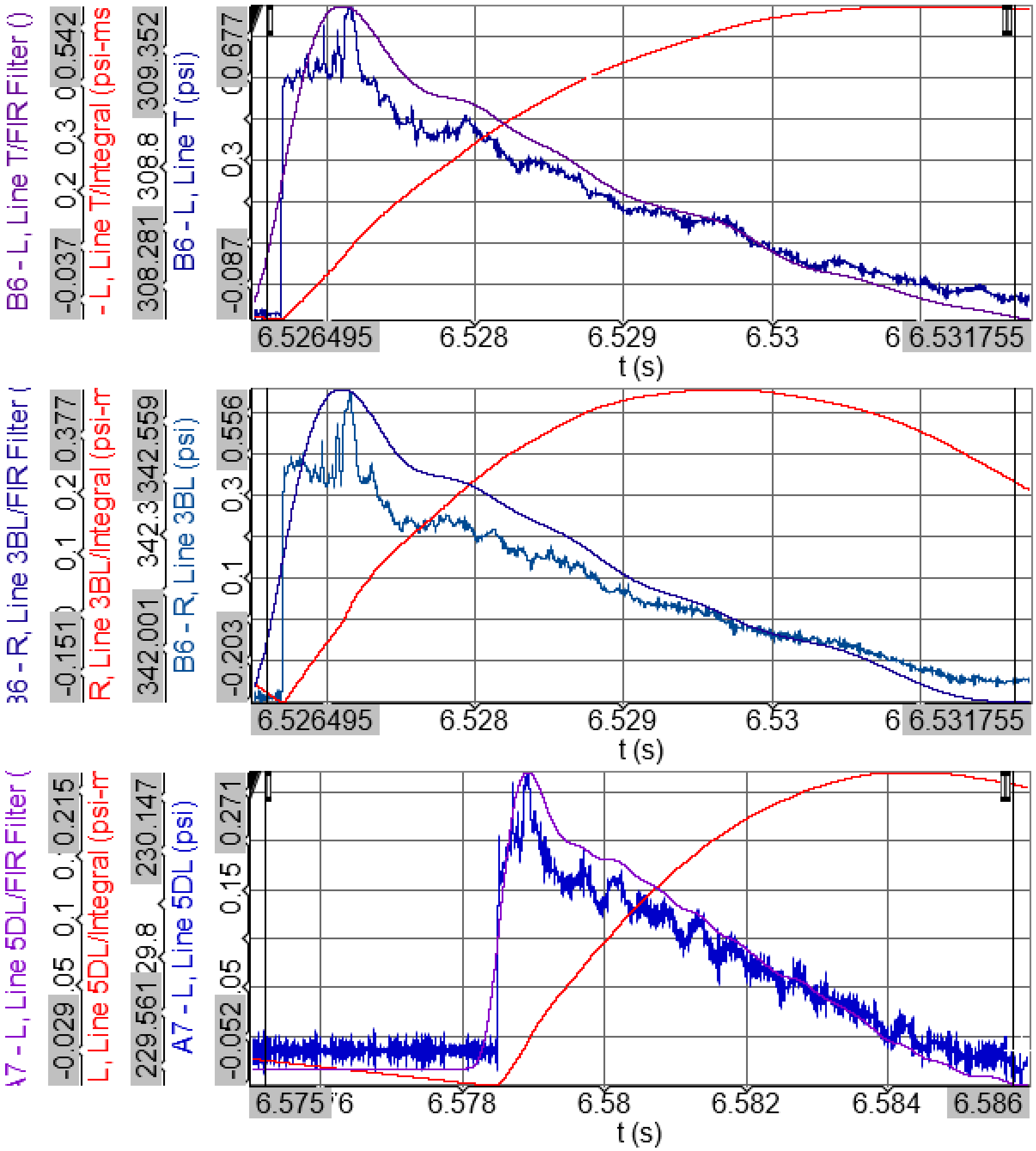

A5 - R, Line 1DR (psi)
R, Line 1DR/Integral (psi-m
A5 - R, Line 1DR/FIR Filter
6.505735
6.507
6.508
6.509
6.510995
t (s)

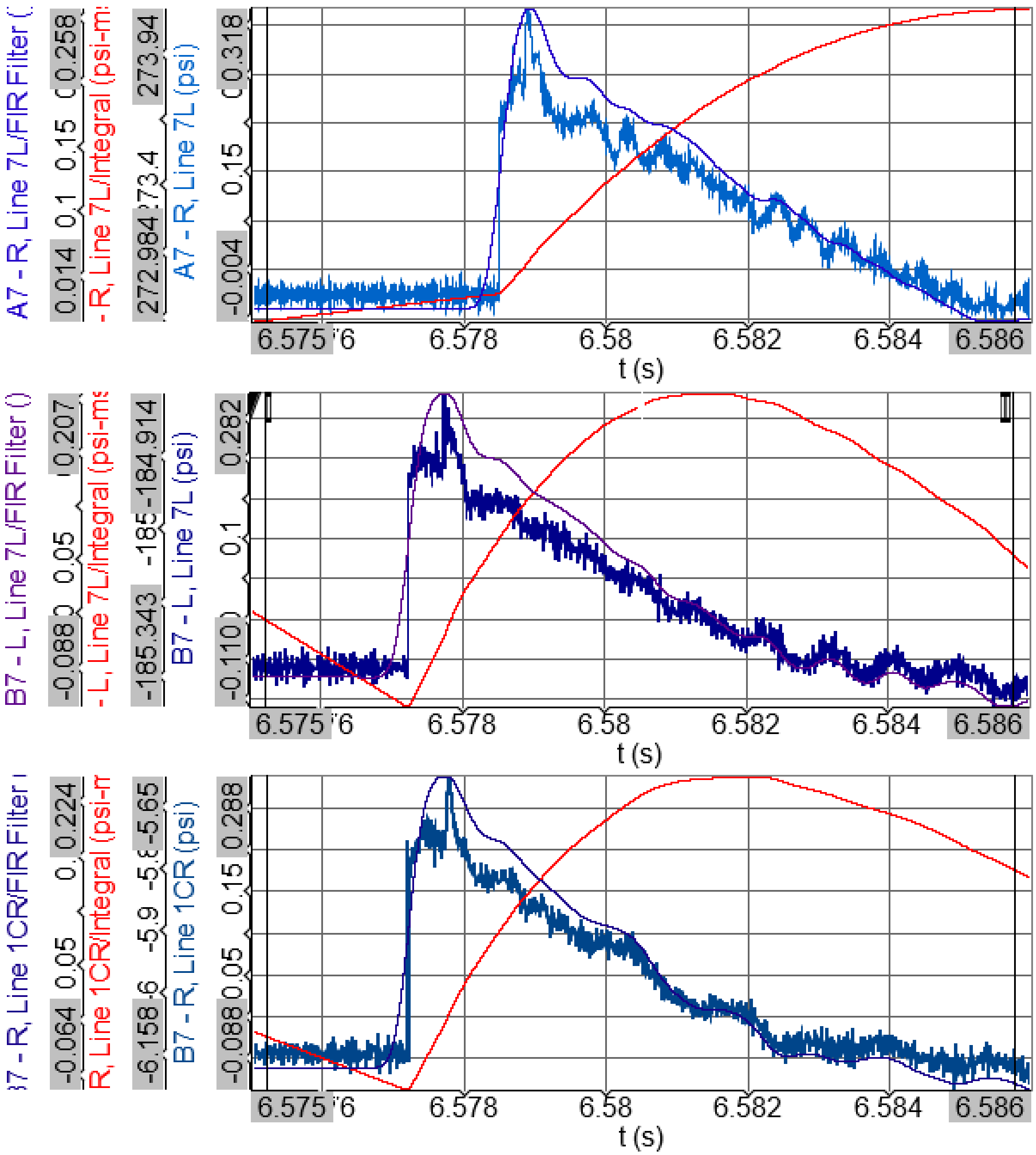

B5 - L, Line 5CR (psi)
L, Line 5CR/Integral (psi-m
B5 - L, Line 5CR/FIR Filter (
6.505735
6.507
6.508
6.509
6.510995
t (s)

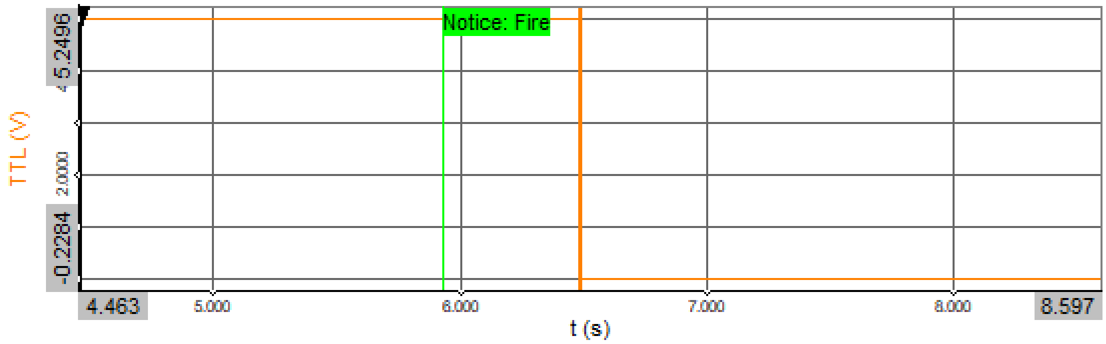

B5 - R, Line 5CL (psi)
t (s)
6.505735
6.507
6.508
6.509
6.510995


A6 - L, Line 4DL (psi)
t (s)
6.526495
6.528
6.529
6.53
6.531755


A6 - R, Line 3AR (psi)
t (s)
6.526495
6.528
6.529
6.53
6.531755

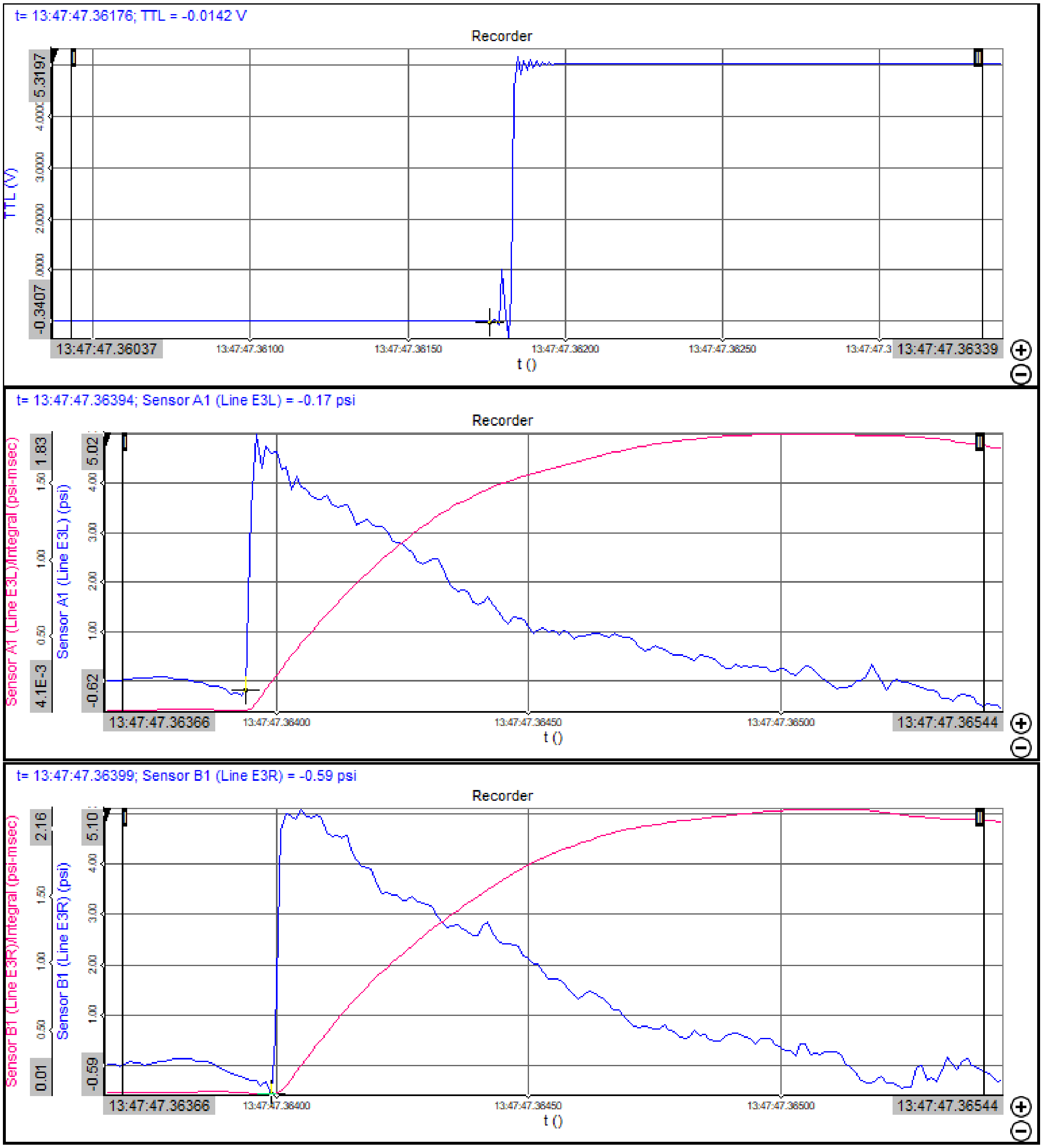

B6 - L, Line T/FIR Filter ()
- L, Line T/Integral (psi-ms
B6 - L, Line T (psi)
6.526495
6.528
6.529
6.53
6.531755
t (s)
36 - R, Line 3BL/FIR Filter (
R, Line 3BL/Integral (psi-m
B6 - R, Line 3BL (psi)
6.526495
6.528
6.529
6.53
6.531755
t (s)
A7 - L, Line 5DL/FIR Filter (
L, Line 5DL/Integral (psi-m
A7 - L, Line 5DL (psi)
6.575
6.578
6.58
6.582
6.584
6.586
t (s)

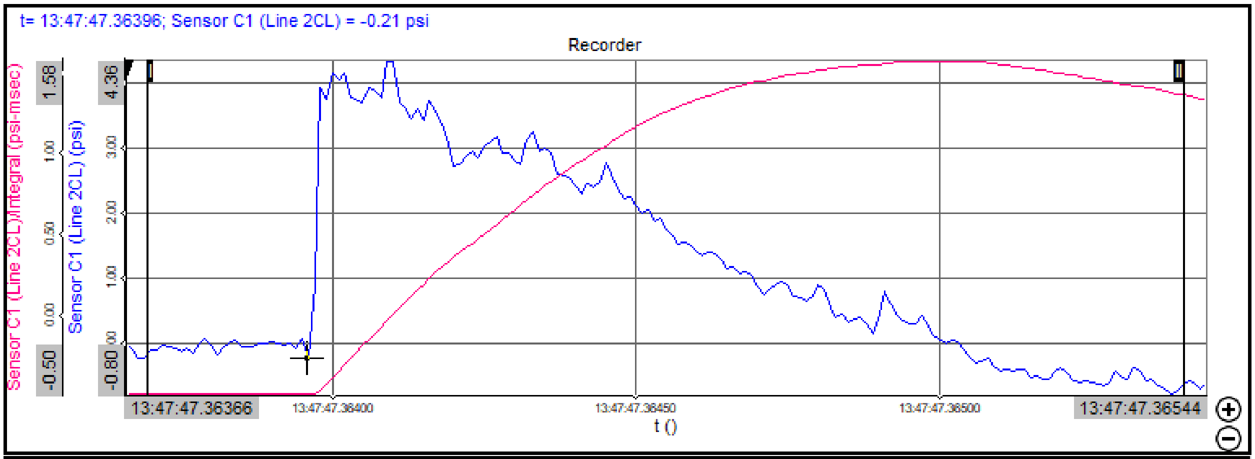

A7 - R, Line 7L/FIR Filter (
-R, Line 7L/Integral (psi-m
A7 - R, Line 7L (psi)
t (s)
B7 - L, Line 7L/FIR Filter ()
-L, Line 7L/Integral (psi-ms
B7 - L, Line 7L (psi)
t (s)
B7 - R, Line 1CR/FIR Filter
R, Line 1CR/Integral (psi-m
B7 - R, Line 1CR (psi)
t (s)

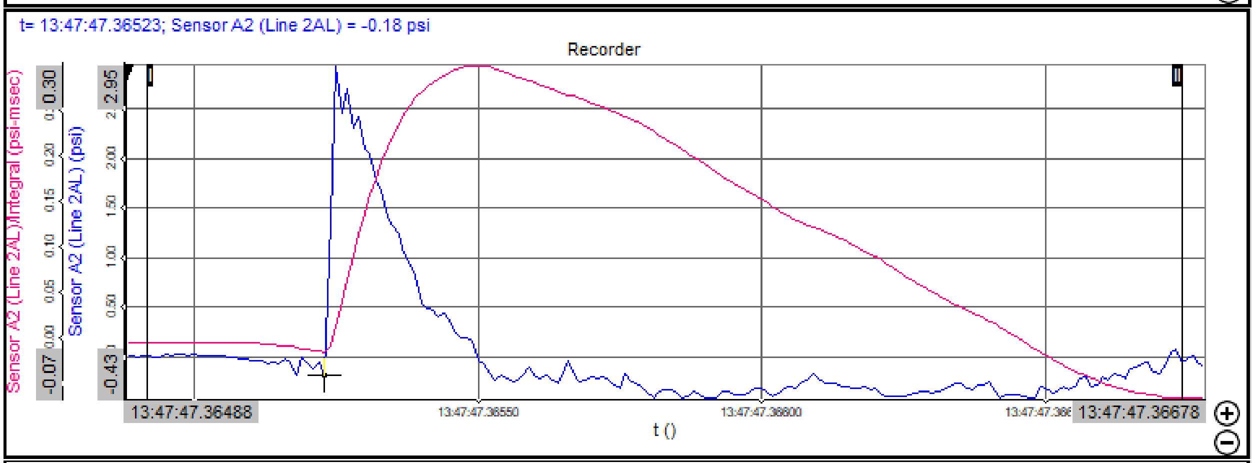

Notice: Fire
5.2496
2.0000
-0.2284
TTL (V)
4.463
5.000
6.000
7.000
8.000
8.597
t (s)

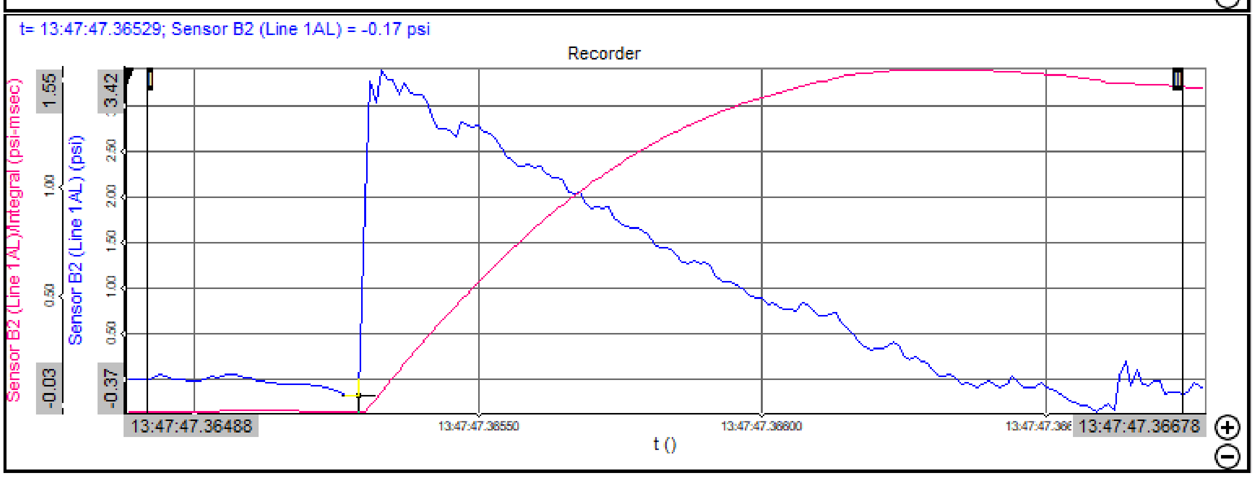
8.9 Composition A-5 Booster Pellet

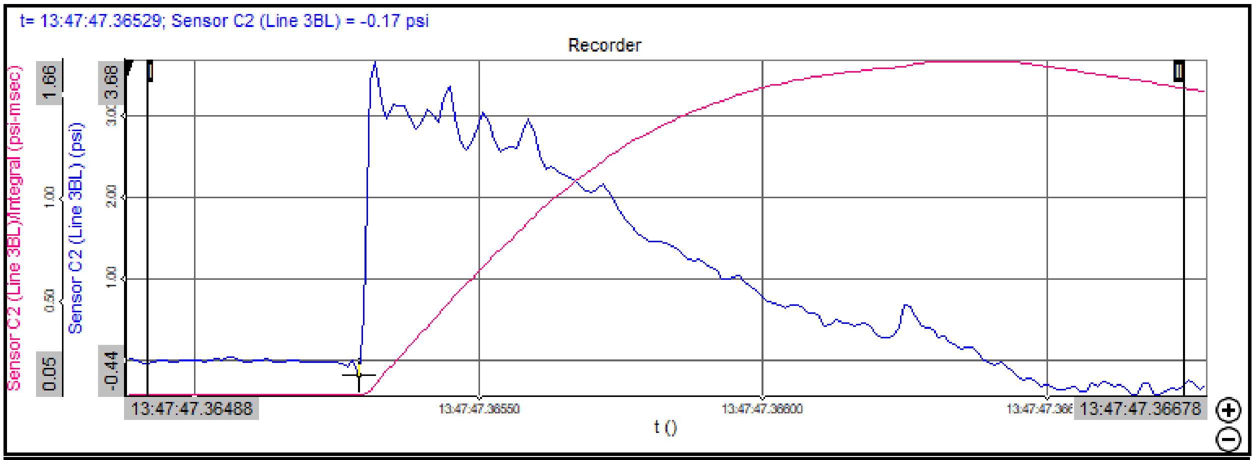
8.9.1 Trial 1 for Composition A-5 Booster Pellet

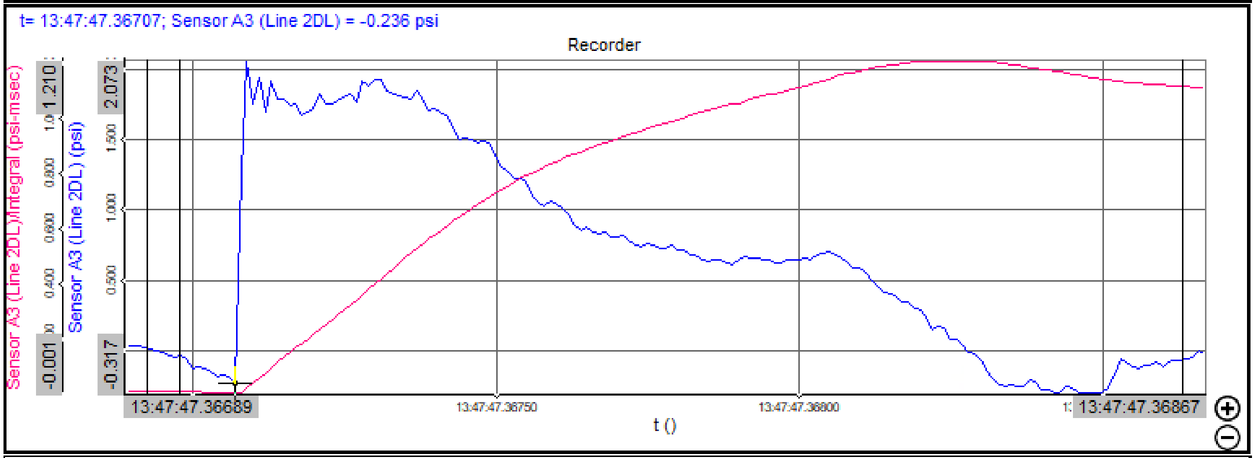


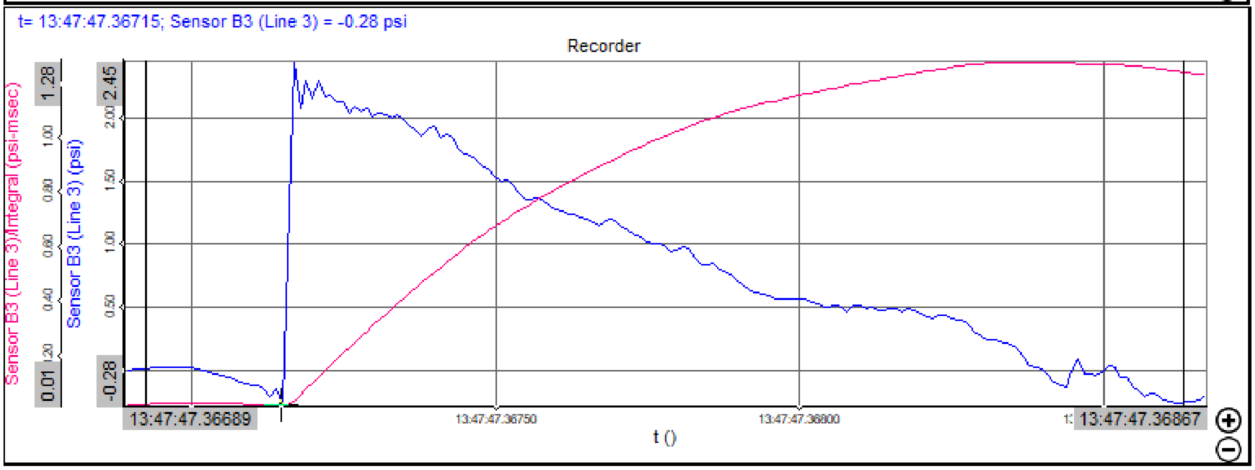

t= 13:47:47.36396; Sensor C1 (Line 2CL) = -0.21 psi
Recorder
Sensor C1 (Line 2CL) Integral (psi-msec)
Sensor C1 (Line 2CL) (psi)
13:47:47.36366
13:47:47.36400
13:47:47.36450
13:47:47.36500
13:47:47.36544
t ()

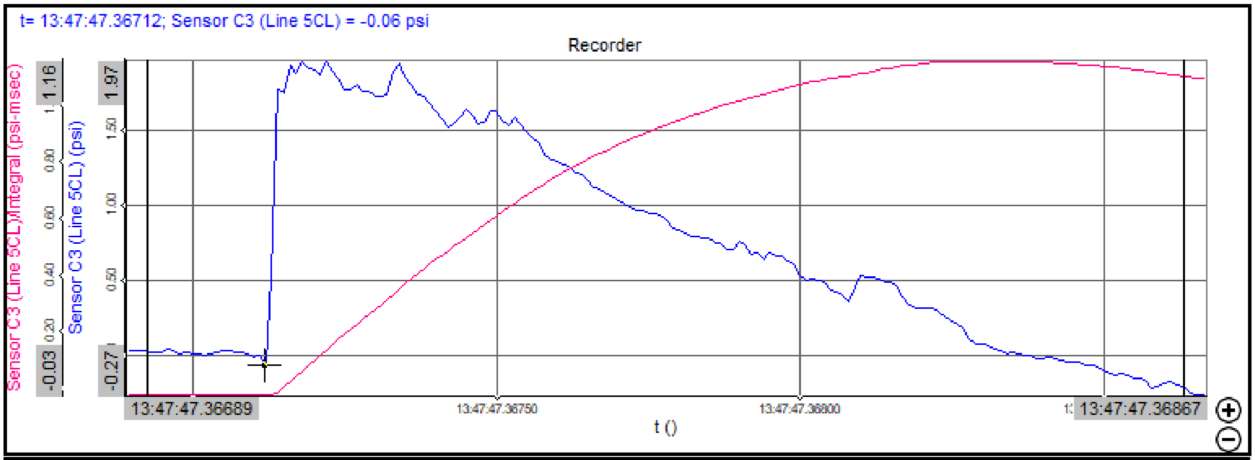

t= 13:47:47.36523; Sensor A2 (Line 2AL) = -0.18 psi
Recorder
Sensor A2 (Line 2AL) Integral (psi-msec)
Sensor A2 (Line 2AL) (psi)
13:47:47.36488
13:47:47.36550
13:47:47.36600
13:47:47.36678
t ()

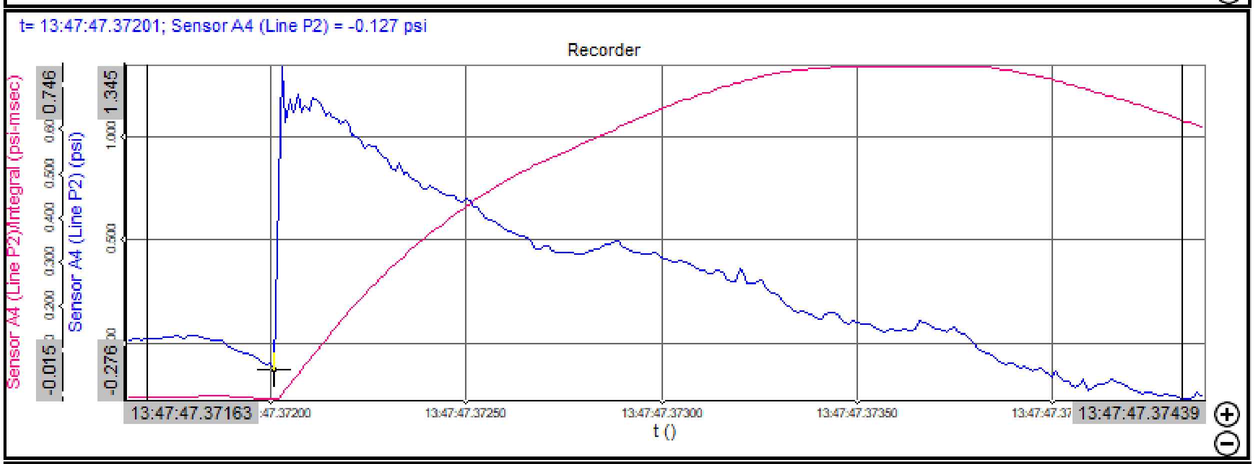

t= 13:47:47.36529; Sensor B2 (Line 1AL) = -0.17 psi
Recorder
Sensor B2 (Line 1AL) Integral (psi-msec)
Sensor B2 (Line 1AL) (psi)
13:47:47.36488
13:47:47.36550
13:47:47.36600
13:47:47.36678
t ()

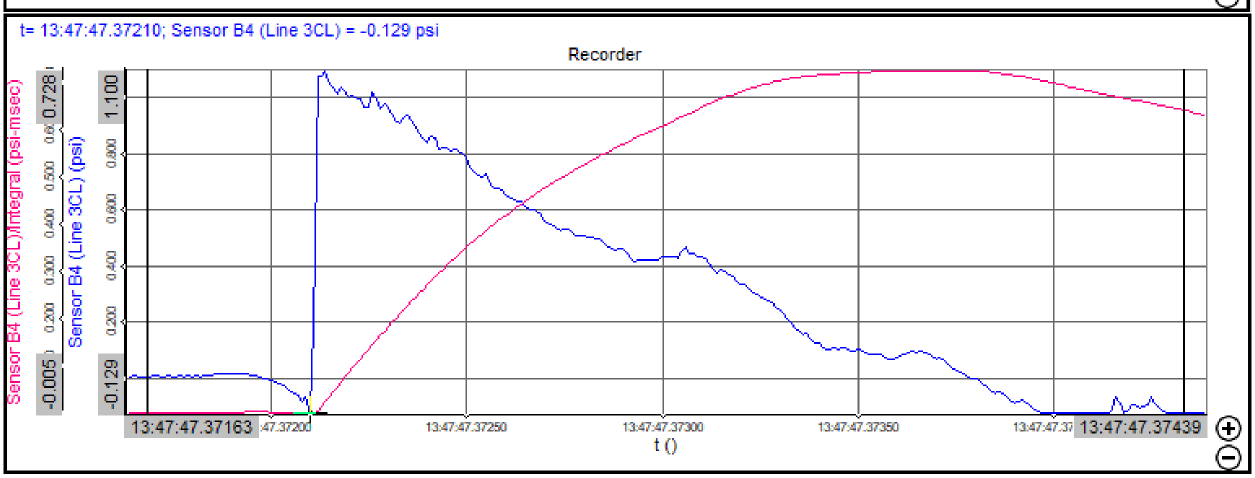

t= 13:47:47.36529; Sensor C2 (Line 3BL) = -0.17 psi
Recorder
Sensor C2 (Line 3BL) Integral (psi-msec)
Sensor C2 (Line 3BL) (psi)
1.66
0.05
3.68
-0.44
13:47:47.36488
13:47:47.36550
13:47:47.36600
13:47:47.36678
t ()

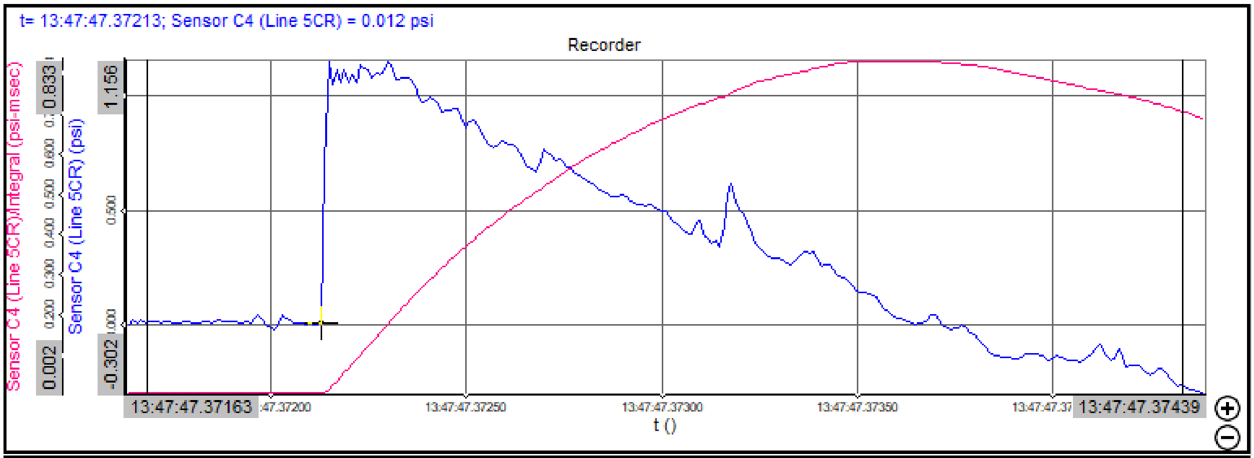

t= 13:47:47.36707; Sensor A3 (Line 2DL) = -0.236 psi
Recorder
Sensor A3 (Line 2DL) Integral (psi-msec)
Sensor A3 (Line 2DL) (psi)
1.210
-0.001
2.073
-0.317
13:47:47.36689
13:47:47.36750
13:47:47.36800
13:47:47.36867
t ()

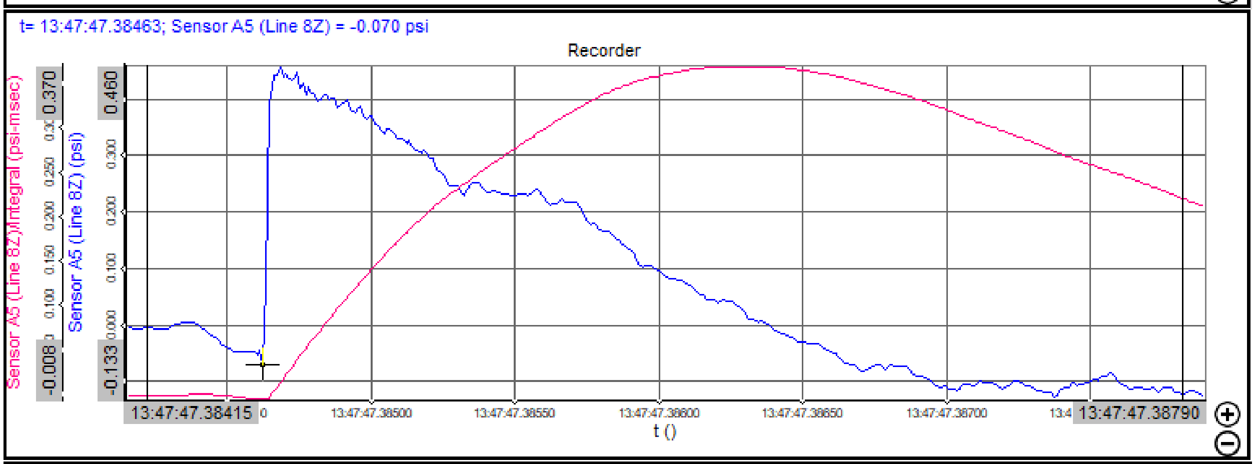

t= 13:47:47.36715; Sensor B3 (Line 3) = -0.28 psi
Recorder
Sensor B3 (Line 3) Integral (psi-msec)
Sensor B3 (Line 3) (psi)
1.28
0.01
2.45
-0.28
13:47:47.36689
13:47:47.36750
13:47:47.36800
13:47:47.36867
t ()

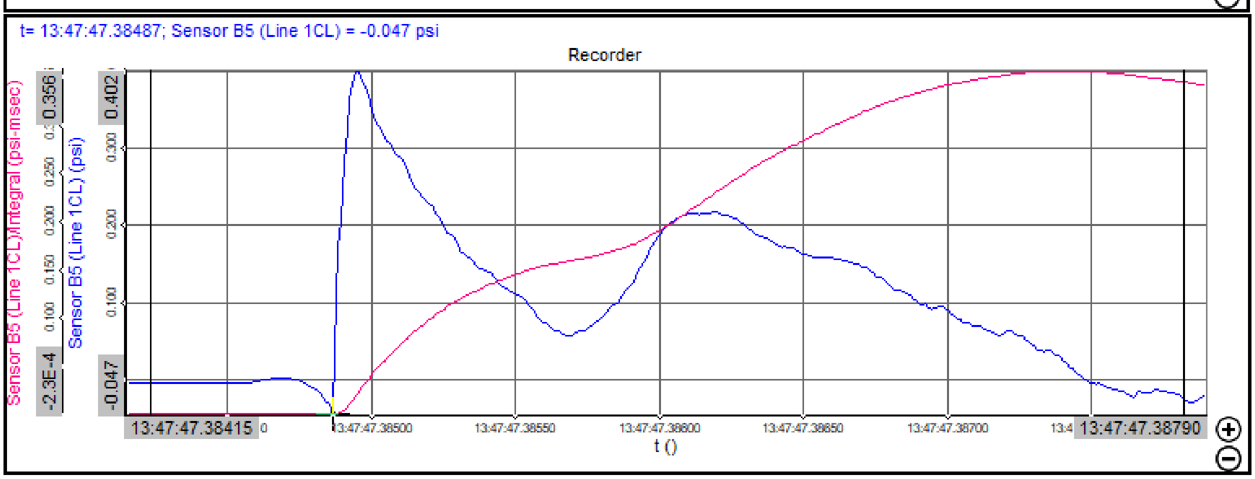

t= 13:47:47.36712; Sensor C3 (Line 5CL) = -0.06 psi
Recorder
Sensor C3 (Line 5CL)Integral (psi-msec)
Sensor C3 (Line 5CL) (psi)
1.16
-0.03
1.97
-0.27
13:47:47.36689
13:47:47.36750
13:47:47.36800
13:47:47.36867
t ()

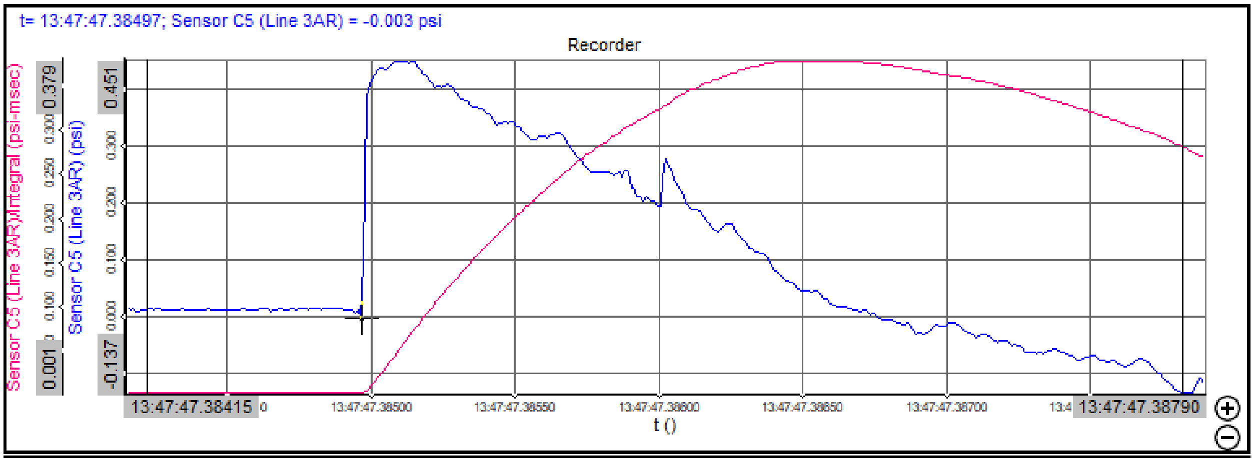

t= 13:47:47.37201; Sensor A4 (Line P2) = -0.127 psi
Recorder
Sensor A4 (Line P2)Integral (psi-msec)
Sensor A4 (Line P2) (psi)
0.746
-0.015
1.345
-0.276
13:47:47.37163
13:47:47.37250
13:47:47.37300
13:47:47.37350
13:47:47.37439
t ()

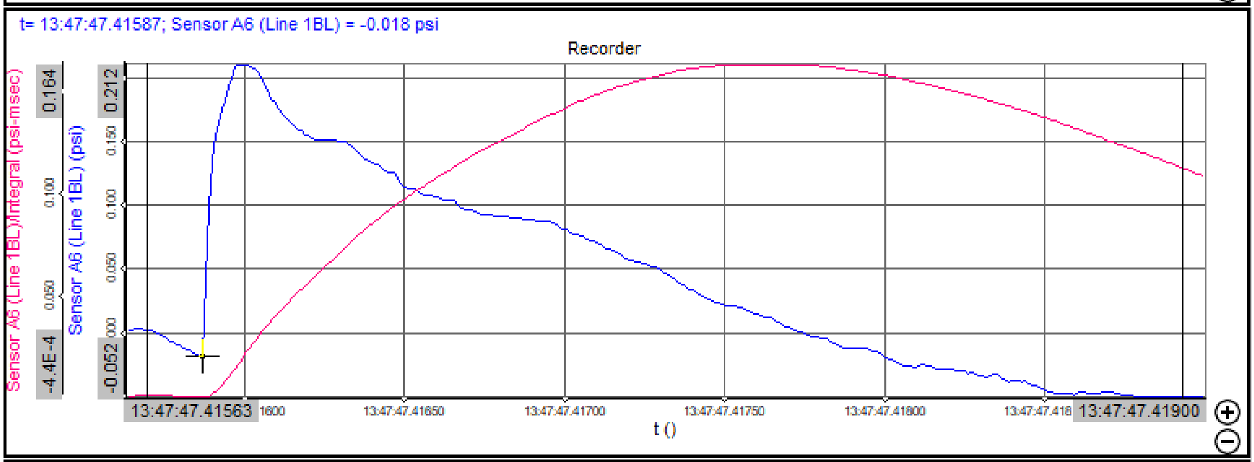

t= 13:47:47.37210; Sensor B4 (Line 3CL) = -0.129 psi
Recorder
Sensor B4 (Line 3CL)Integral (psi-msec)
Sensor B4 (Line 3CL) (psi)
0.728
-0.005
1.100
-0.129
13:47:47.37163
13:47:47.37250
13:47:47.37300
13:47:47.37350
13:47:47.37439
t ()

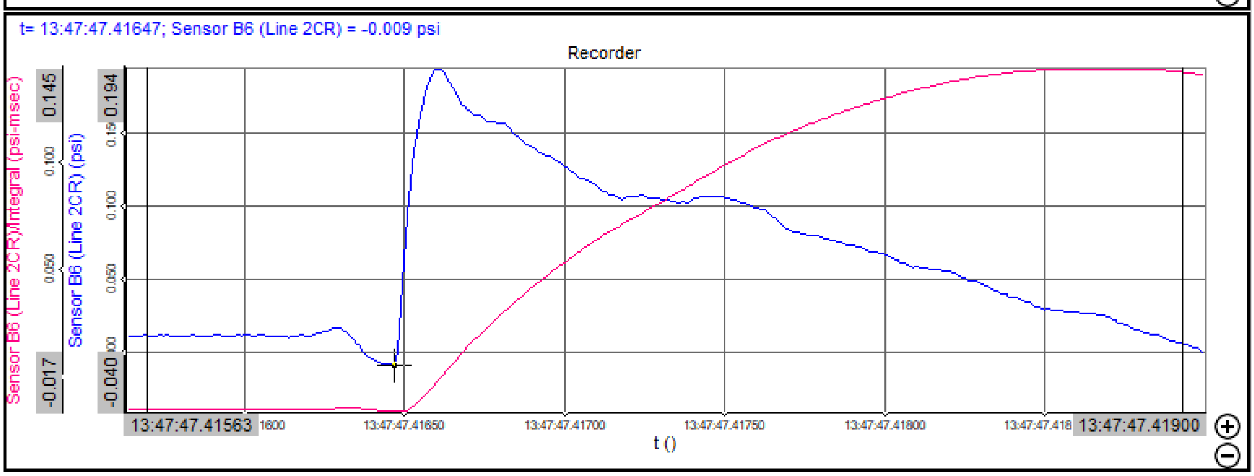

t= 13:47:47.37213; Sensor C4 (Line 5CR) = 0.012 psi
Recorder
Sensor C4 (Line 5CR)/Integral (psi-msec)
Sensor C4 (Line 5CR) (psi)
0.833
0.002
1.156
-0.302
13:47:47.37163
13:47:47.37250
13:47:47.37300
13:47:47.37350
13:47:47.37439
t ()

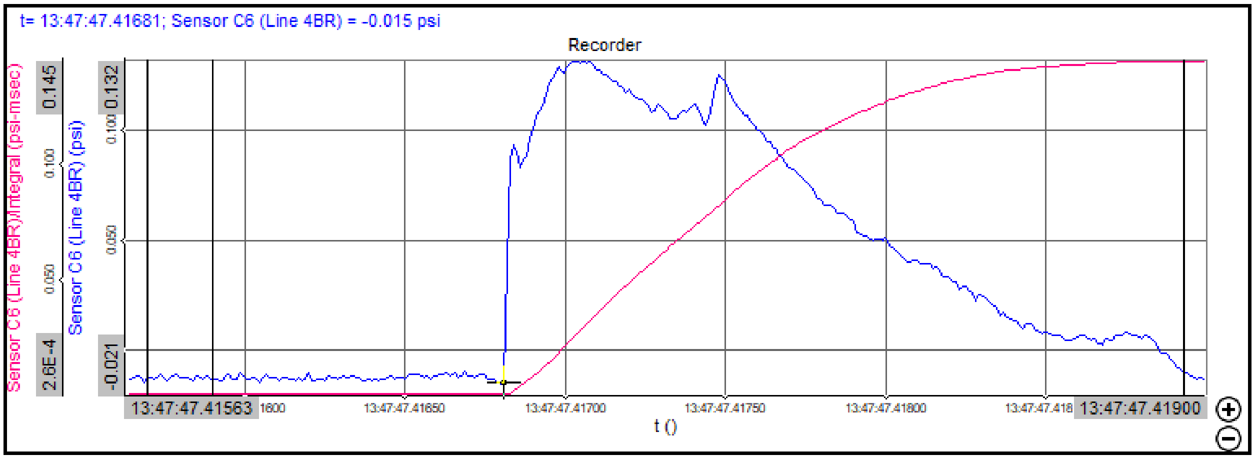

t= 13:47:47.38463; Sensor A5 (Line 8Z) = -0.070 psi
Recorder
Sensor A5 (Line 8Z)/Integral (psi-msec)
Sensor A5 (Line 8Z) (psi)
0.370
-0.008
0.460
-0.133
13:47:47.38415
13:47:47.38500
13:47:47.38550
13:47:47.38600
13:47:47.38650
13:47:47.38700
13:47:47.38790
t ()


t= 13:47:47.38487; Sensor B5 (Line 1CL) = -0.047 psi
Recorder
Sensor B5 (Line 1CL)/Integral (psi-msec)
Sensor B5 (Line 1CL) (psi)
0.356
-2.3E-4
0.402
-0.047
13:47:47.38415
13:47:47.38500
13:47:47.38550
13:47:47.38600
13:47:47.38650
13:47:47.38700
13:47:47.38790
t ()

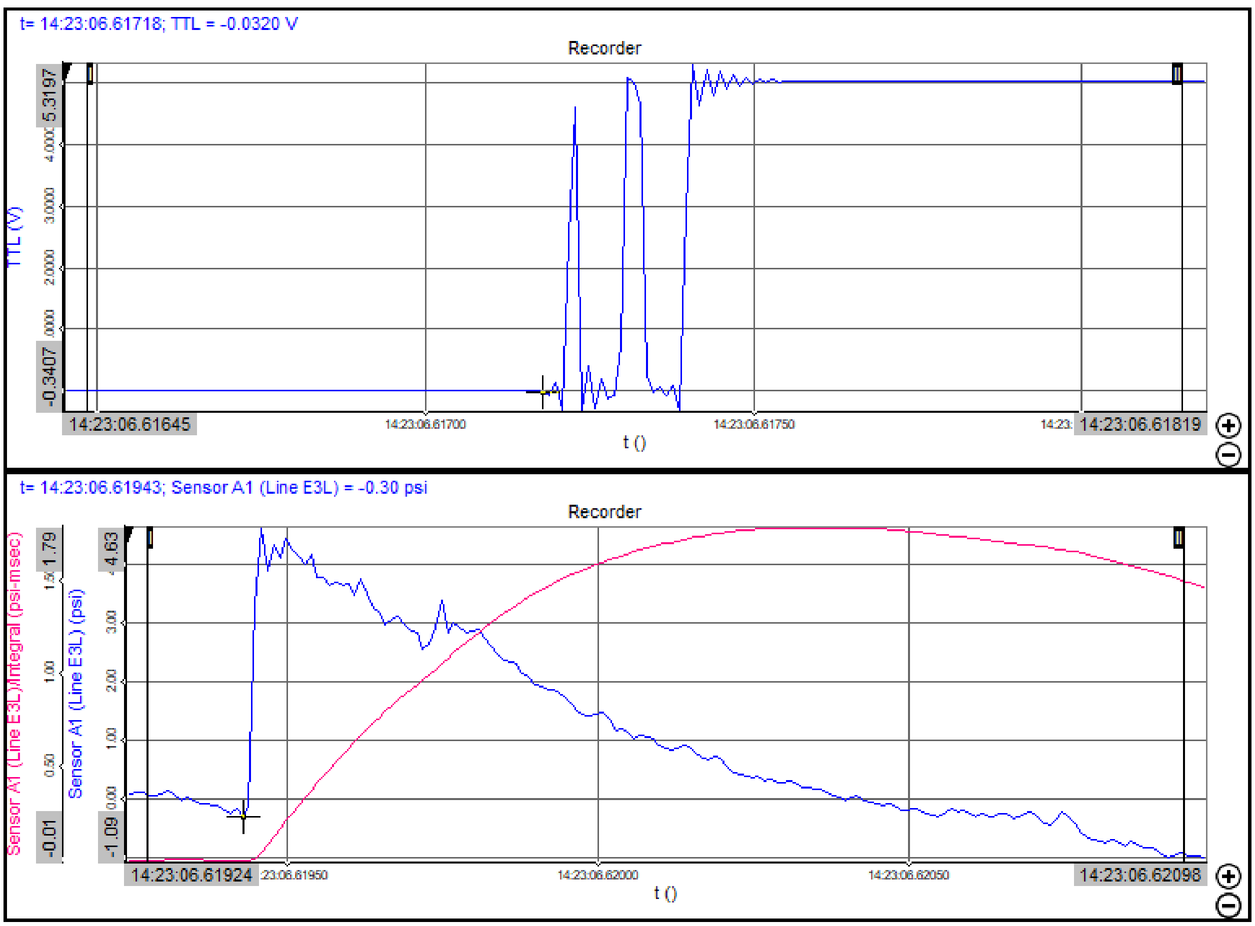

t= 13:47:47.38497; Sensor C5 (Line 3AR) = -0.003 psi
Recorder
Sensor C5 (Line 3AR)/Integral (psi-msec)
Sensor C5 (Line 3AR) (psi)
0.379
0.001
0.451
-0.137
13:47:47.38415
13:47:47.38500
13:47:47.38550
13:47:47.38600
13:47:47.38650
13:47:47.38700
13:47:47.38790
t ()

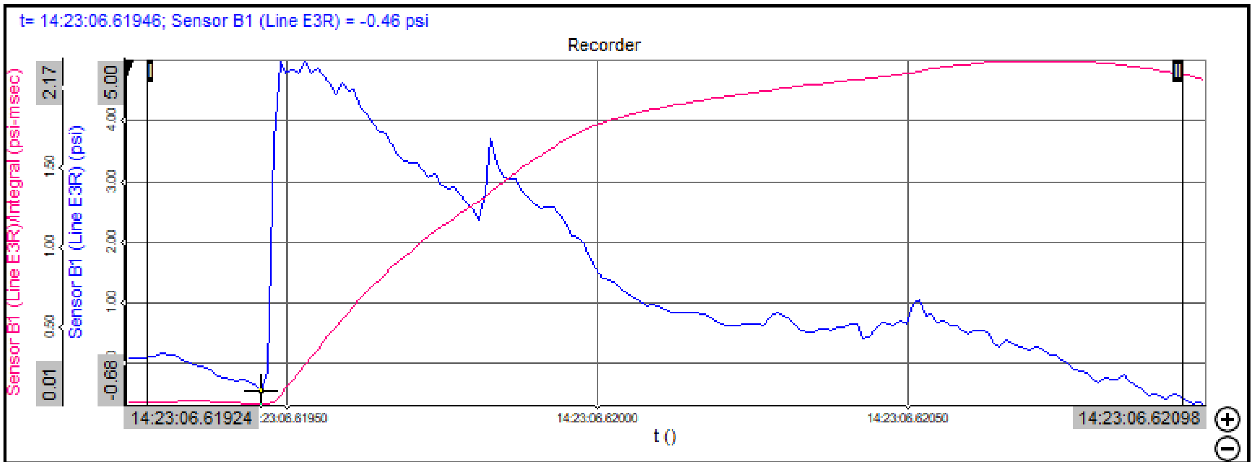

t= 13:47:47.41587; Sensor A6 (Line 1BL) = -0.018 psi
Recorder
Sensor A6 (Line 1BL)/Integral (psi-msec)
Sensor A6 (Line 1BL) (psi)
0.164
-4.4E-4
0.212
-0.052
13:47:47.41563
13:47:47.41650
13:47:47.41700
13:47:47.41750
13:47:47.41800
13:47:47.41900
t ()

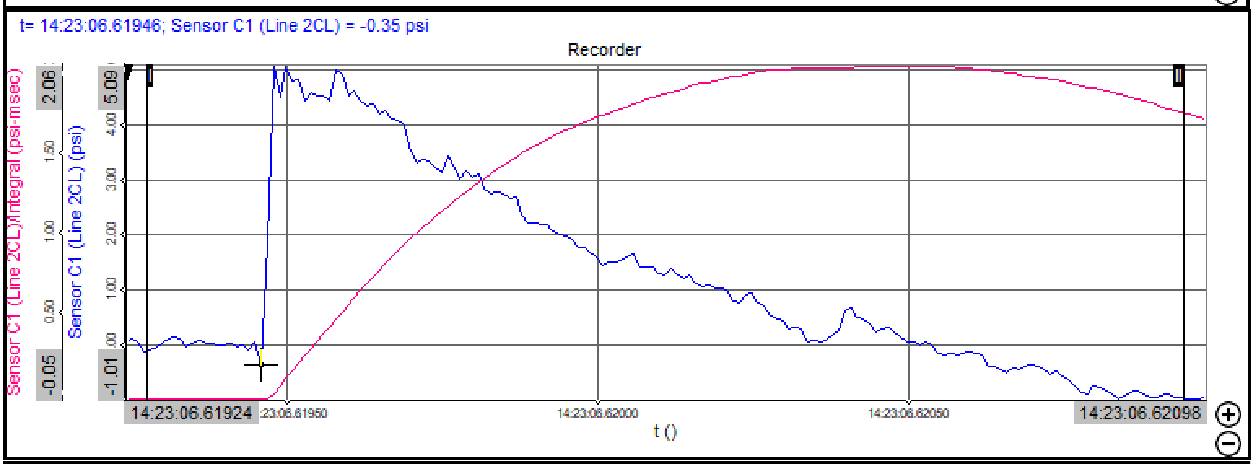

t= 13:47:47.41647; Sensor B6 (Line 2CR) = -0.009 psi
Recorder
Sensor B6 (Line 2CR)/Integral (psi-msec)
Sensor B6 (Line 2CR) (psi)
0.145
-0.017
0.194
-0.040
13:47:47.41563
13:47:47.41650
13:47:47.41700
13:47:47.41750
13:47:47.41800
13:47:47.41900
t ()

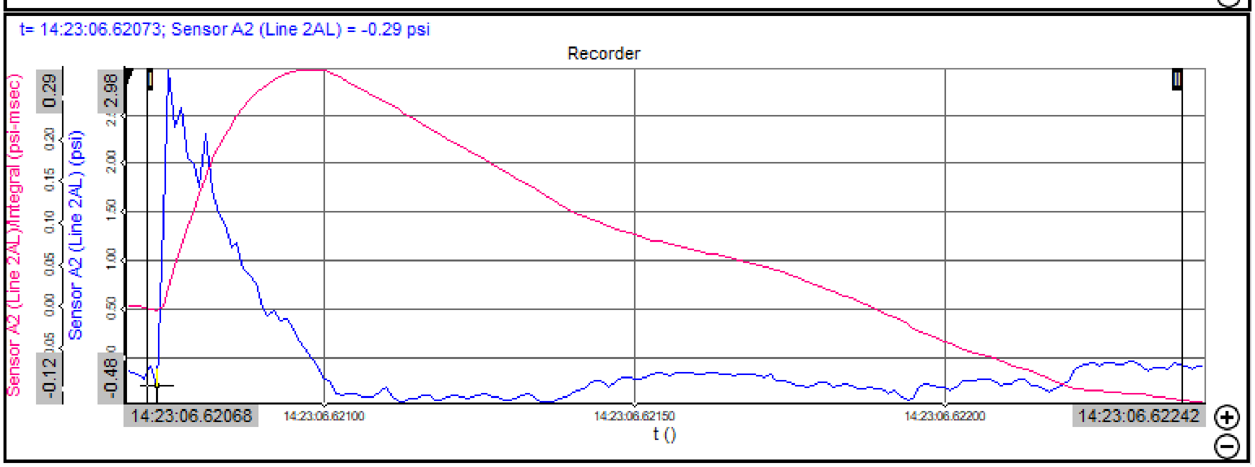


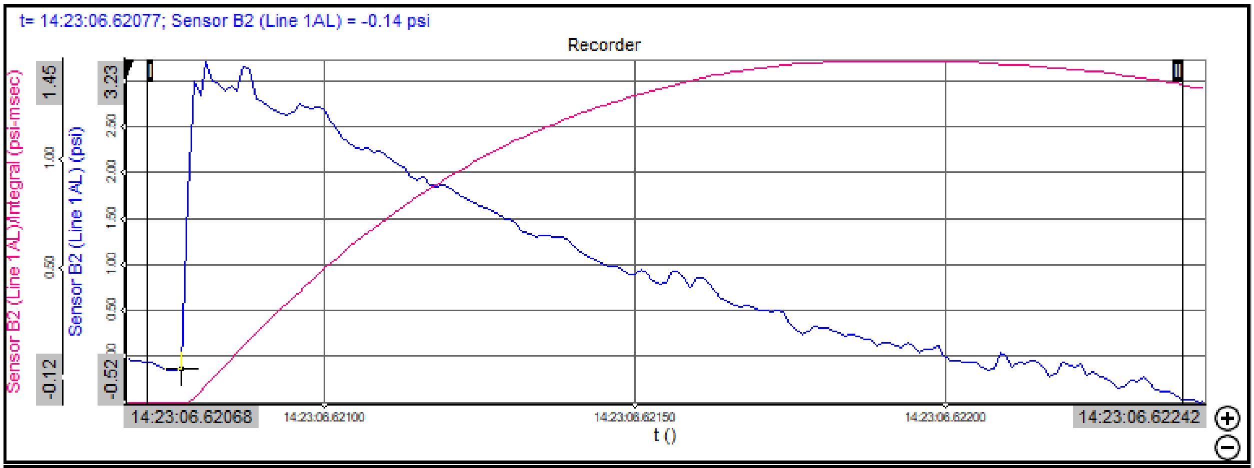
8.9.2 Trial 2 for Composition A-5 Booster Pellet

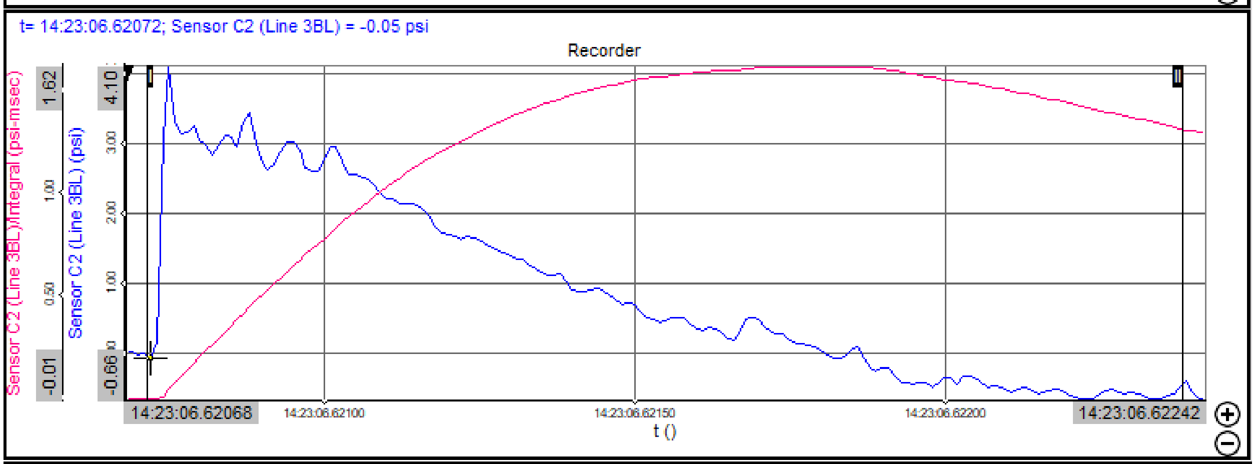


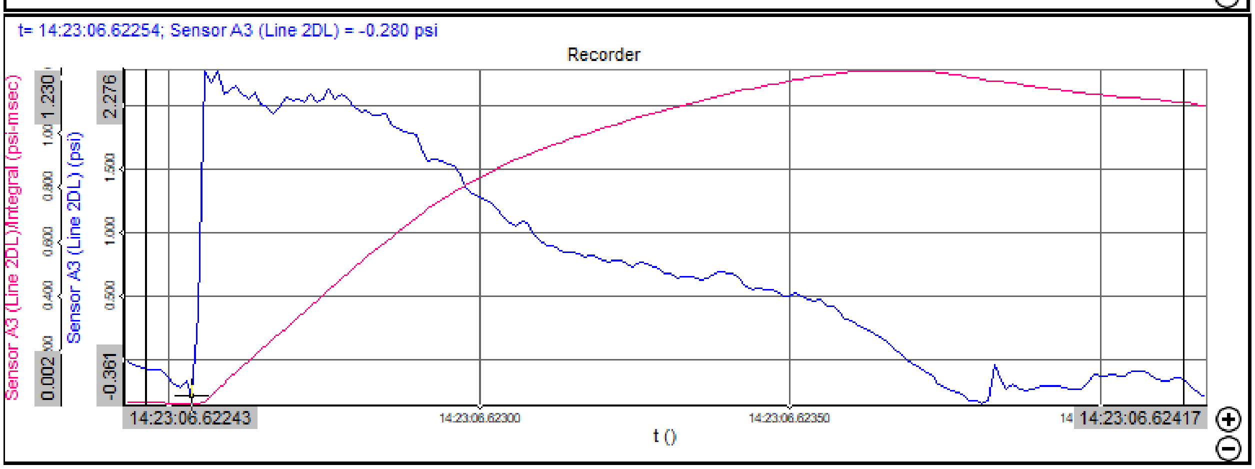

t= 14:23:06.61946; Sensor B1 (Line E3R) = -0.46 psi
Recorder
Sensor B1 (Line E3R)Integral (psi-msec)
Sensor B1 (Line E3R) (psi)
14:23:06.61924
14:23:06.62098
t ()

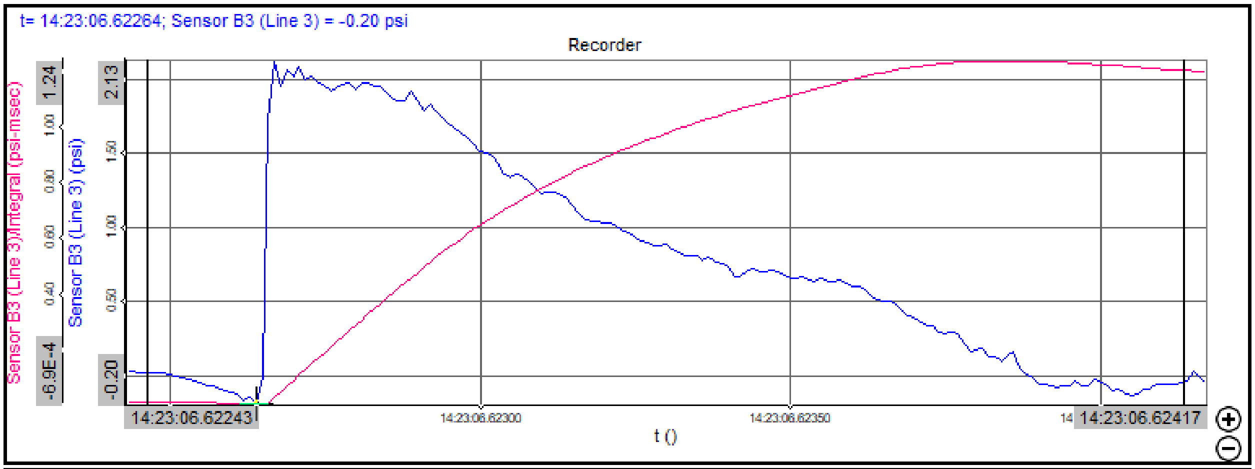

t= 14:23:06.61946; Sensor C1 (Line 2CL) = -0.35 psi
Recorder
Sensor C1 (Line 2CL)Integral (psi-msec)
Sensor C1 (Line 2CL) (psi)
14:23:06.61924
14:23:06.62098
t ()

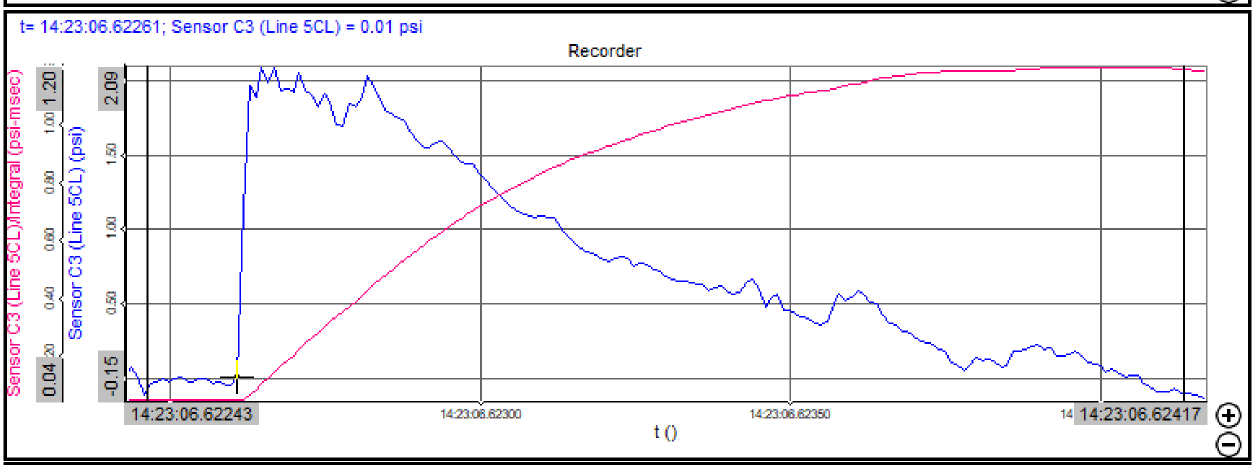

t= 14:23:06.62073; Sensor A2 (Line 2AL) = -0.29 psi
Recorder
Sensor A2 (Line 2AL)Integral (psi-msec)
Sensor A2 (Line 2AL) (psi)
14:23:06.62068
14:23:06.62242
t ()

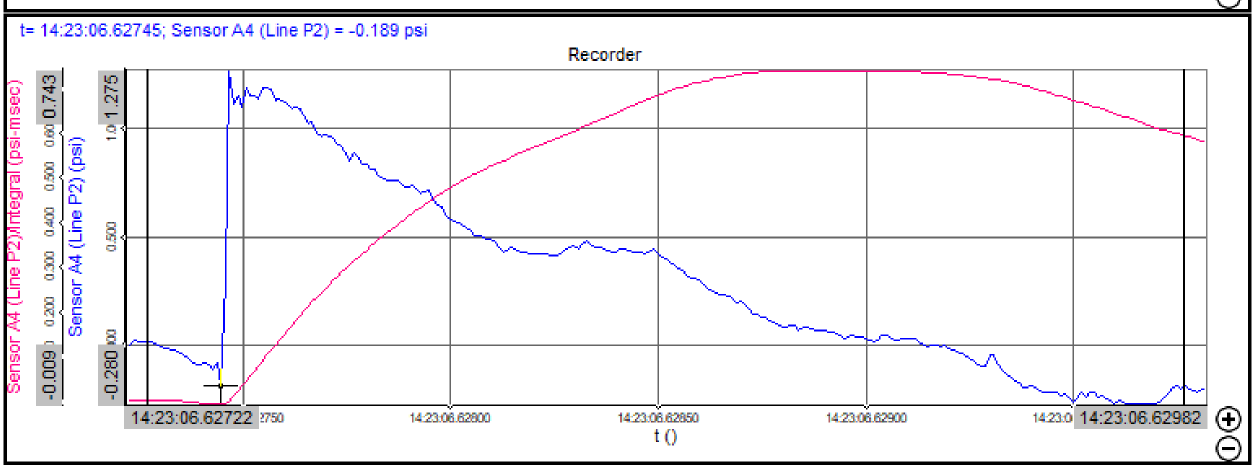

t= 14:23:06.62077; Sensor B2 (Line 1AL) = -0.14 psi
Recorder
Sensor B2 (Line 1AL)/Integral (psi-msec)
Sensor B2 (Line 1AL) (psi)
1.45
-0.12
3.23
-0.52
14:23:06.62068
14:23:06.62100
14:23:06.62150
14:23:06.62200
14:23:06.62242
t ()

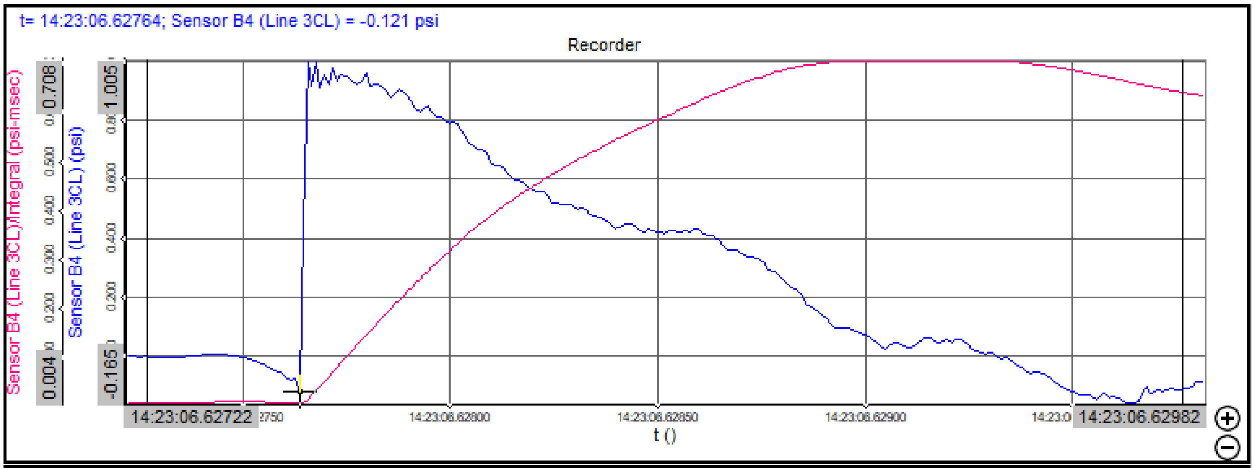

t= 14:23:06.62072; Sensor C2 (Line 3BL) = -0.05 psi
Recorder
Sensor C2 (Line 3BL)/Integral (psi-msec)
Sensor C2 (Line 3BL) (psi)
1.62
-0.01
4.10
-0.66
14:23:06.62068
14:23:06.62100
14:23:06.62150
14:23:06.62200
14:23:06.62242
t ()

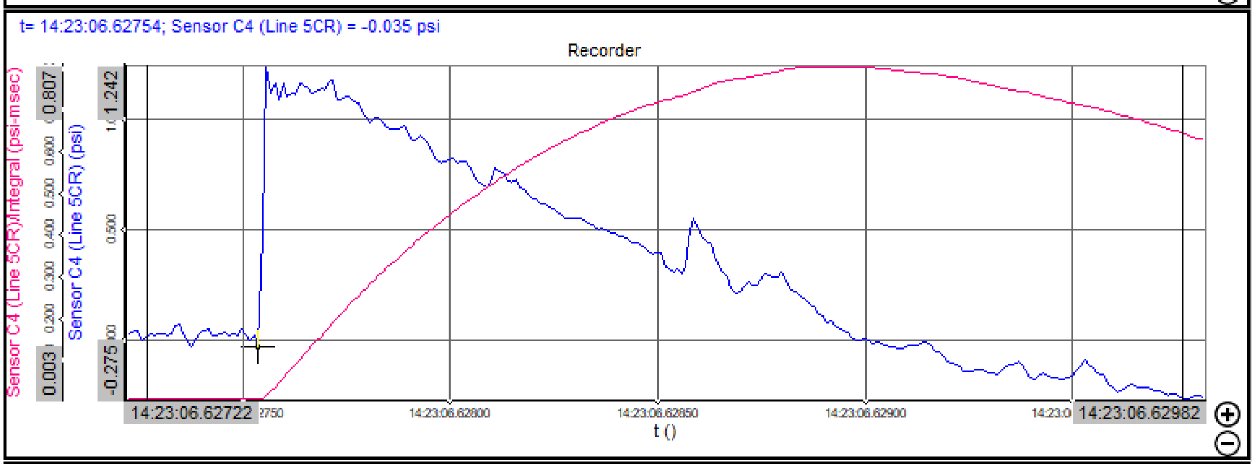

t= 14:23:06.62254; Sensor A3 (Line 2DL) = -0.280 psi
Recorder
Sensor A3 (Line 2DL)/Integral (psi-msec)
Sensor A3 (Line 2DL) (psi)
1.230
0.002
2.276
-0.361
14:23:06.62243
14:23:06.62300
14:23:06.62350
14:23:06.62417
t ()

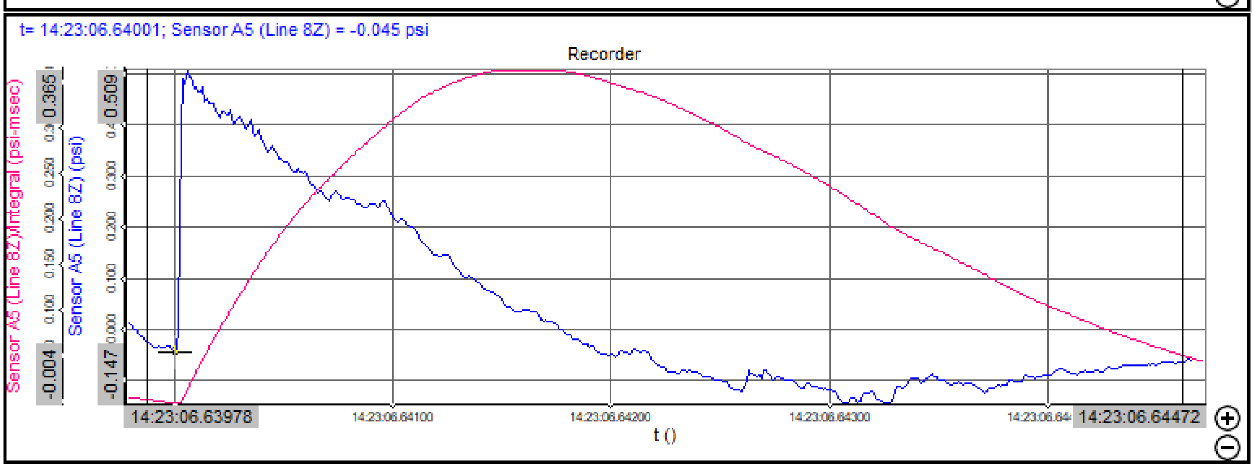

t= 14:23:06.62264; Sensor B3 (Line 3) = -0.20 psi
Recorder
Sensor B3 (Line 3)Integral (psi-msec)
Sensor B3 (Line 3) (psi)
1.24
-6.9E-4
2.13
-0.20
14:23:06.62243
14:23:06.62300
14:23:06.62350
14:23:06.62417
t ()

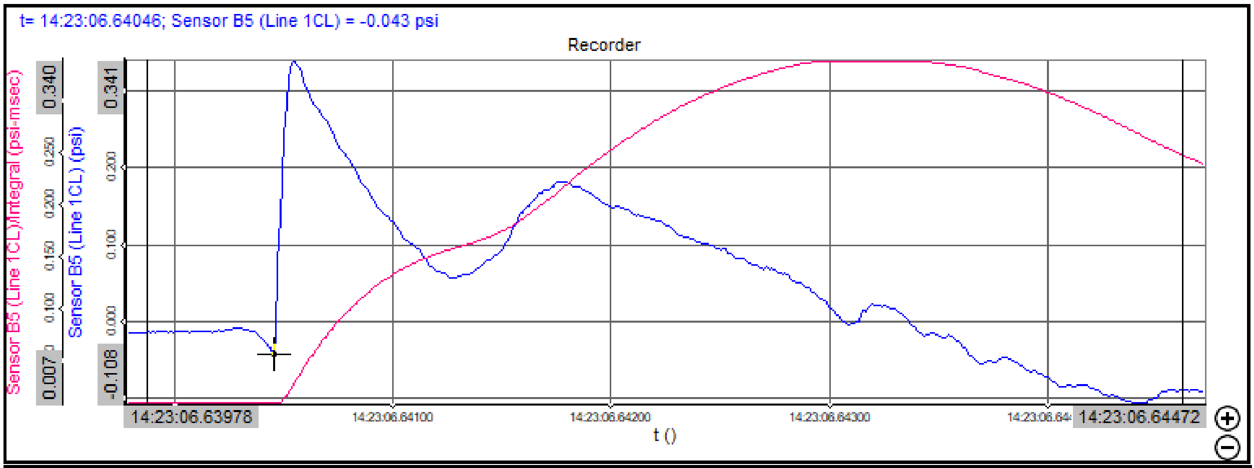

t= 14:23:06.62261; Sensor C3 (Line 5CL) = 0.01 psi
Recorder
Sensor C3 (Line 5CL)Integral (psi-msec)
Sensor C3 (Line 5CL) (psi)
1.20
0.04
2.09
-0.15
14:23:06.62243
14:23:06.62300
14:23:06.62350
14:23:06.62417
t ()

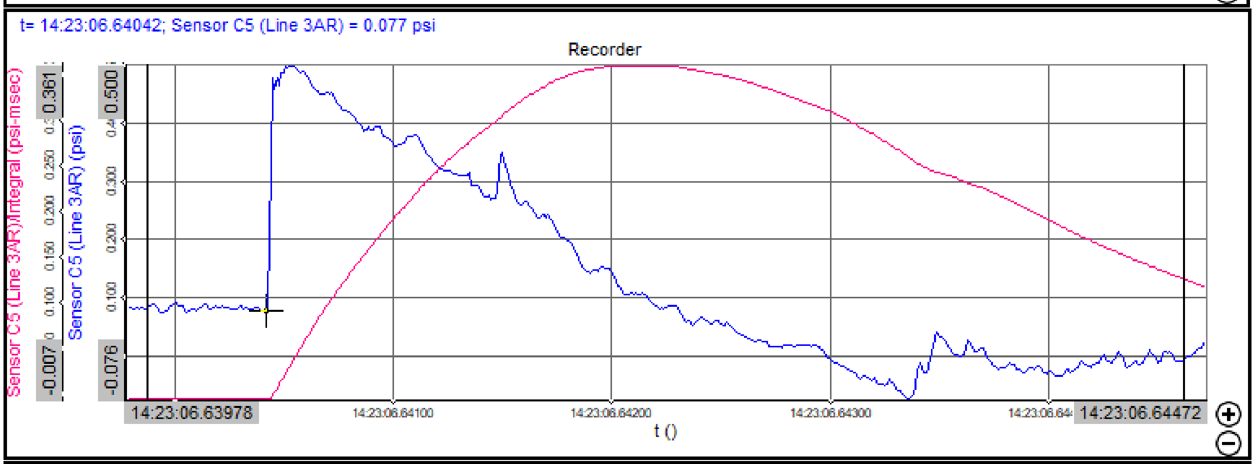

t= 14:23:06.62745; Sensor A4 (Line P2) = -0.189 psi
Recorder
Sensor A4 (Line P2)Integral (psi-msec)
Sensor A4 (Line P2) (psi)
0.743
-0.009
1.275
-0.280
14:23:06.62722
14:23:06.62800
14:23:06.62850
14:23:06.62900
14:23:06.62982
t ()

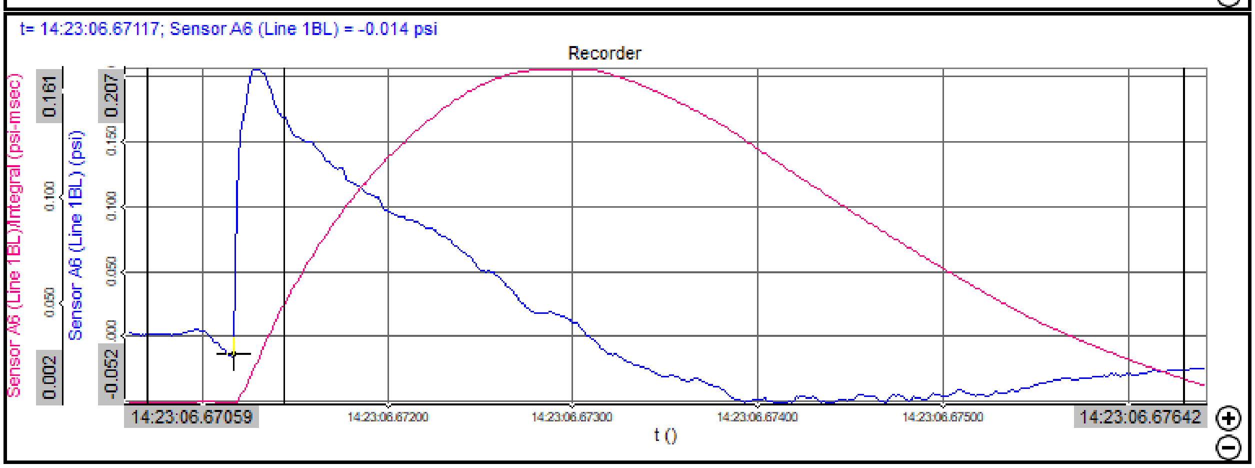

t= 14:23:06.62764; Sensor B4 (Line 3CL) = -0.121 psi
Recorder
Sensor B4 (Line 3CL) Integral (psi-msec)
Sensor B4 (Line 3CL) (psi)
0.708
0.004
1.005
-0.165
14:23:06.62722
14:23:06.62982
t ()

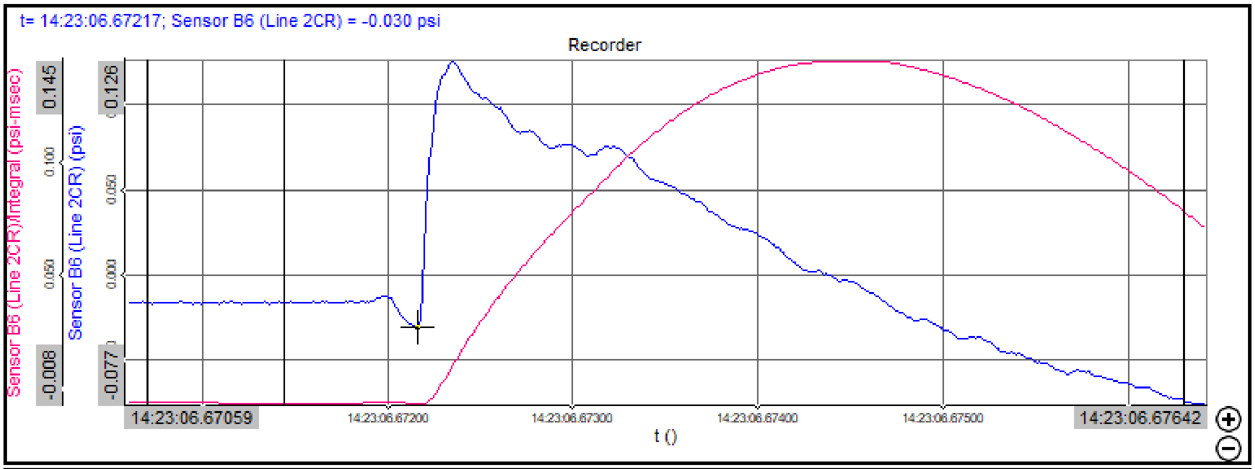

t= 14:23:06.62754; Sensor C4 (Line 5CR) = -0.035 psi
Recorder
Sensor C4 (Line 5CR) Integral (psi-msec)
Sensor C4 (Line 5CR) (psi)
0.807
0.003
1.242
-0.275
14:23:06.62722
14:23:06.62982
t ()

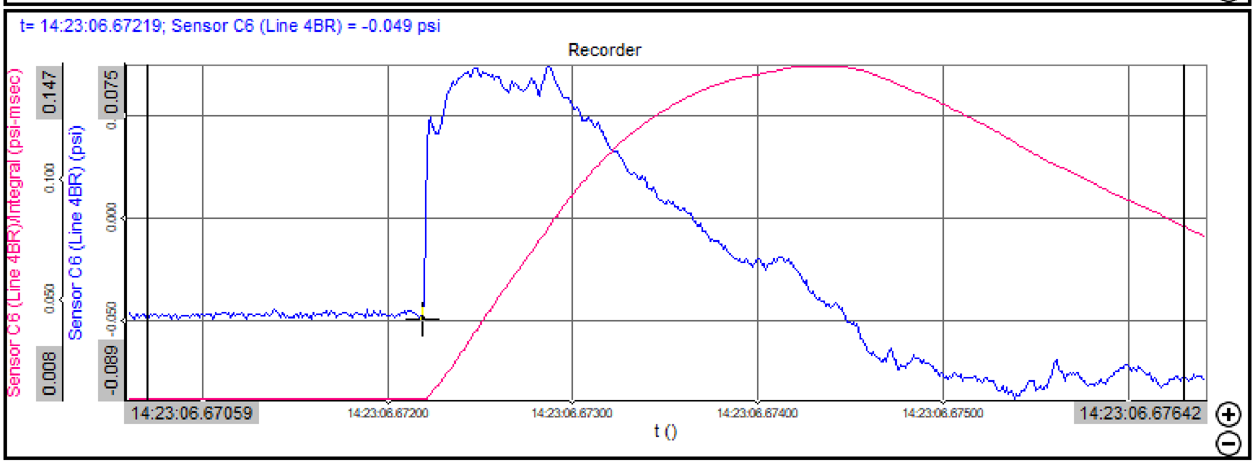

t= 14:23:06.64001; Sensor A5 (Line 8Z) = -0.045 psi
Recorder
Sensor A5 (Line 8Z) Integral (psi-msec)
Sensor A5 (Line 8Z) (psi)
0.365
-0.004
0.509
-0.147
14:23:06.63978
14:23:06.64472
t ()


t= 14:23:06.64046; Sensor B5 (Line 1CL) = -0.043 psi
Recorder
Sensor B5 (Line 1CL) (psi)
Sensor B5 (Line 1CL)/Integral (psi-msec)
14:23:06.63978
14:23:06.64472
t ()


t= 14:23:06.64042; Sensor C5 (Line 3AR) = 0.077 psi
Recorder
Sensor C5 (Line 3AR) (psi)
Sensor C5 (Line 3AR)/Integral (psi-msec)
14:23:06.63978
14:23:06.64472
t ()

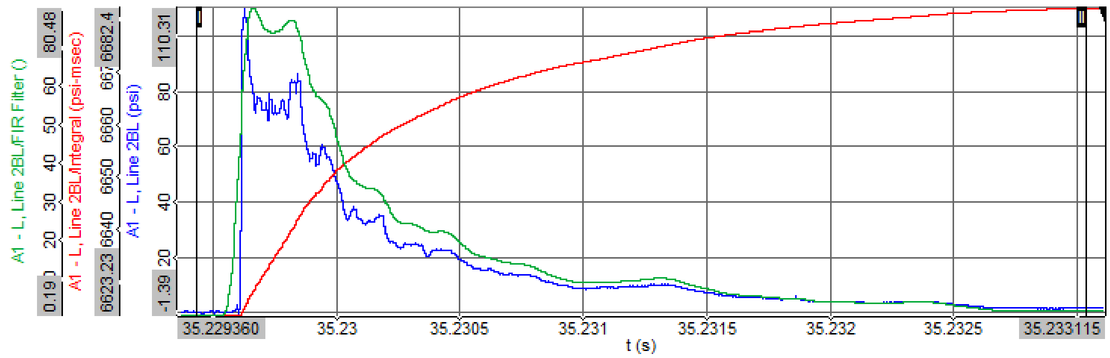

t= 14:23:06.67117; Sensor A6 (Line 1BL) = -0.014 psi
Recorder
Sensor A6 (Line 1BL) (psi)
Sensor A6 (Line 1BL)/Integral (psi-msec)
14:23:06.67059
14:23:06.67642
t ()

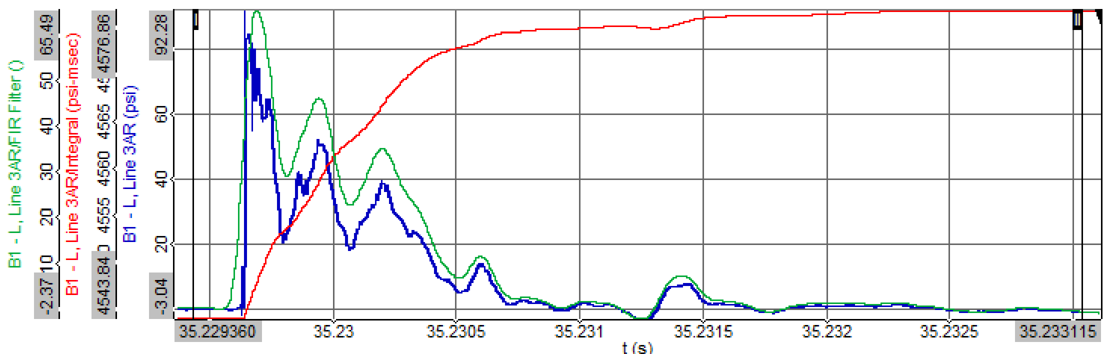

t= 14:23:06.67217; Sensor B6 (Line 2CR) = -0.030 psi
Recorder
Sensor B6 (Line 2CR)/Integral (psi-msec)
Sensor B6 (Line 2CR) (psi)
0.145
-0.008
0.126
-0.077
14:23:06.67059
14:23:06.67200
14:23:06.67300
14:23:06.67400
14:23:06.67500
14:23:06.67642
t ()

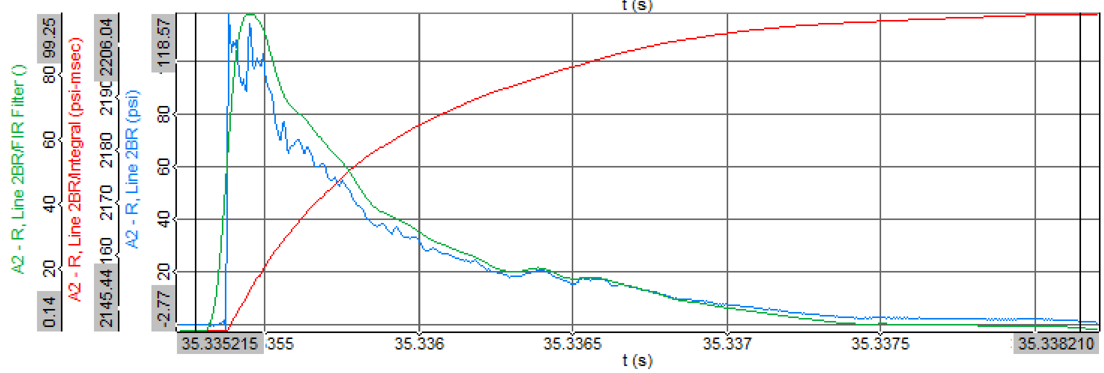

t= 14:23:06.67219; Sensor C6 (Line 4BR) = -0.049 psi
Recorder
Sensor C6 (Line 4BR)/Integral (psi-msec)
Sensor C6 (Line 4BR) (psi)
0.147
0.008
0.075
-0.089
14:23:06.67059
14:23:06.67200
14:23:06.67300
14:23:06.67400
14:23:06.67500
14:23:06.67642
t ()

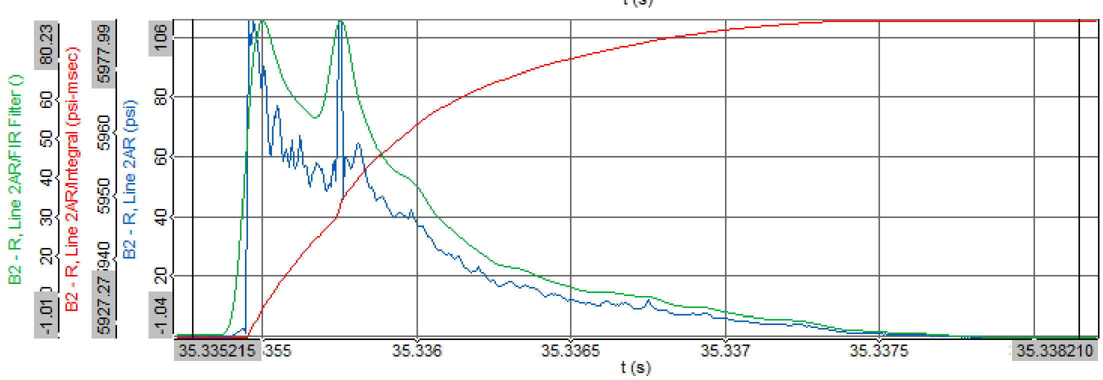
8.10 Hemispherical Cast TNT (raw and filtered data)

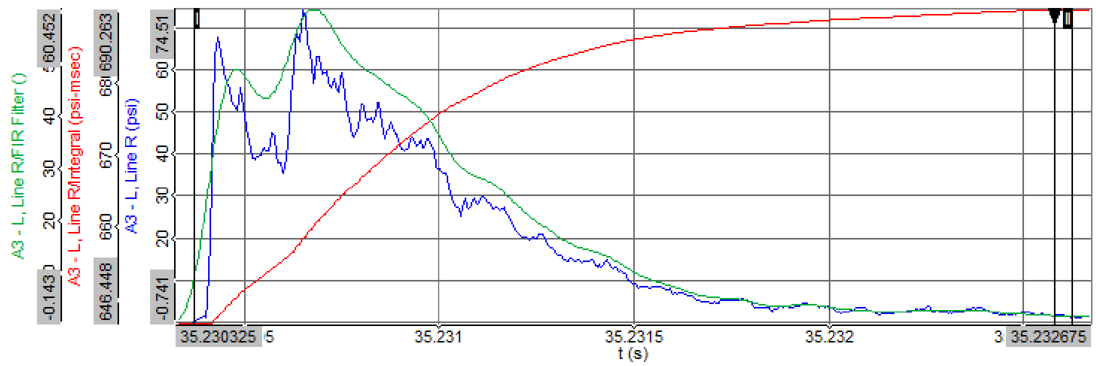
8.10.1 Trial 1 for Hemispherical Cast TNT

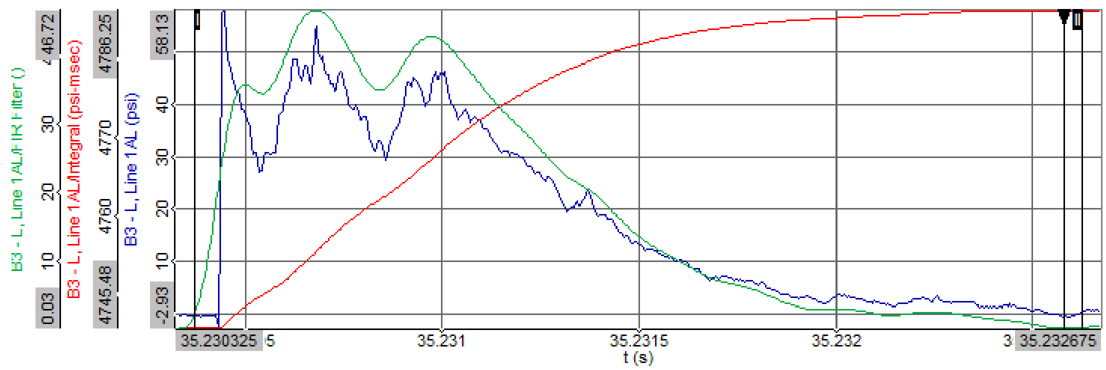


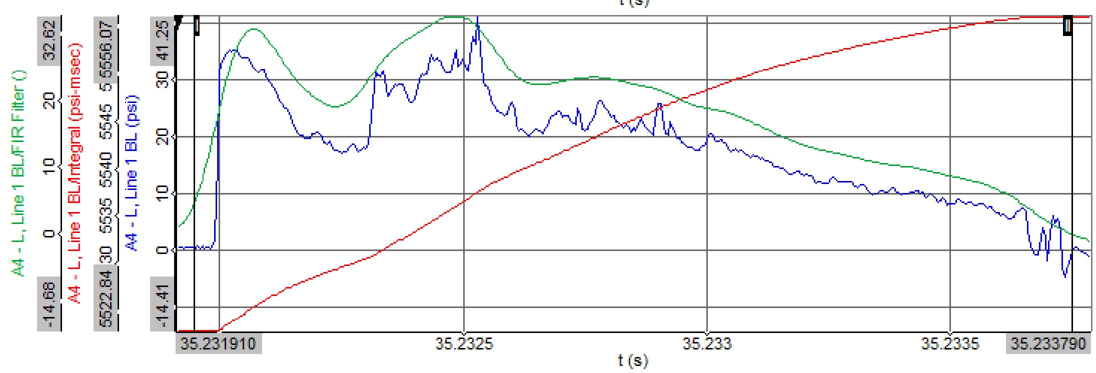


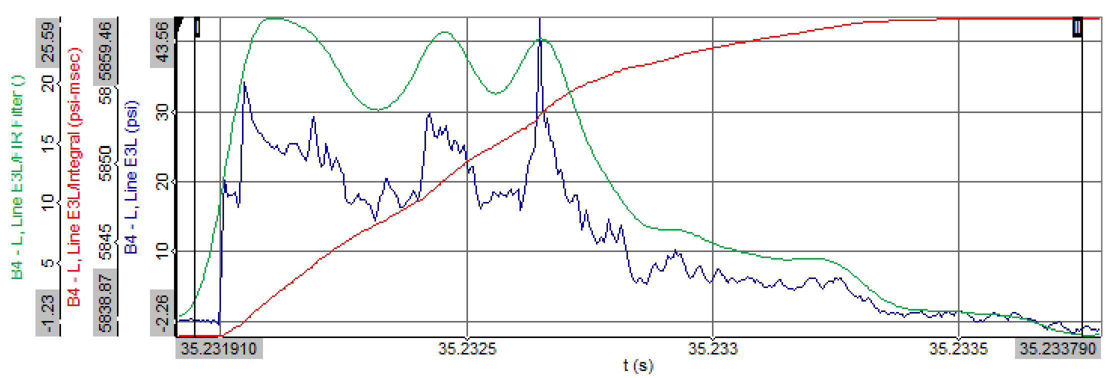


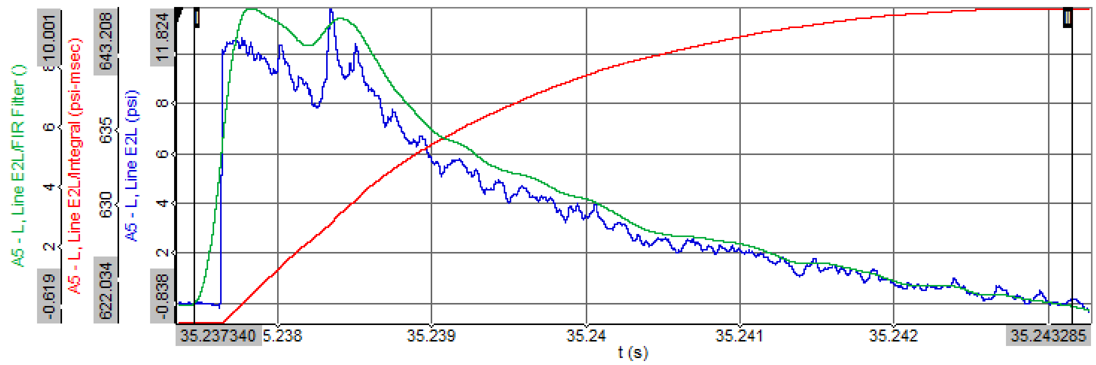


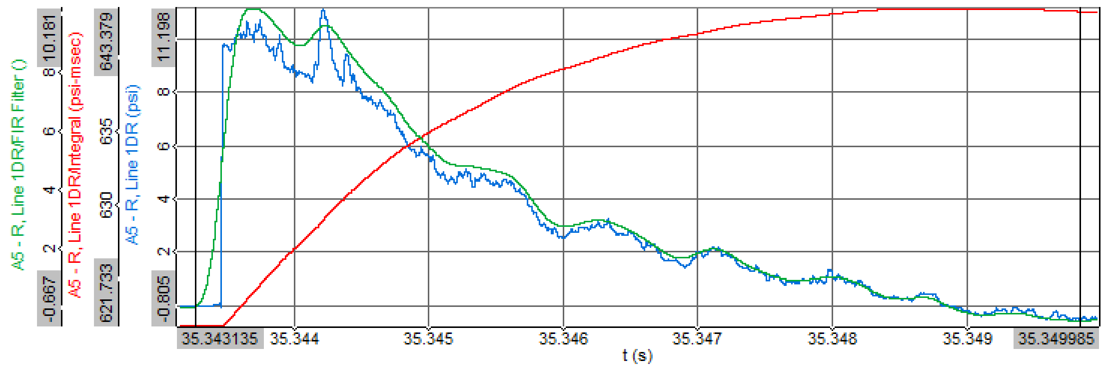

A3 - L, Line R/FIR Filter ()
A3 - L, Line R/Integral (psi-msec)
A3 - L, Line R (psi)
35.230325
35.231
35.2315
35.232
35.232675
t (s)

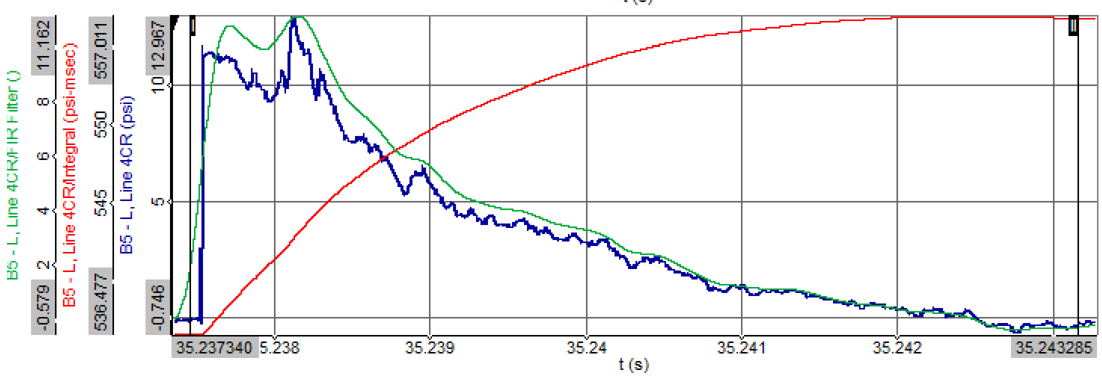

B3 - L, Line 1AL/FIR Filter ()
B3 - L, Line 1AL/Integral (psi-msec)
B3 - L, Line 1AL (psi)
35.230325
35.231
35.2315
35.232
35.232675
t (s)

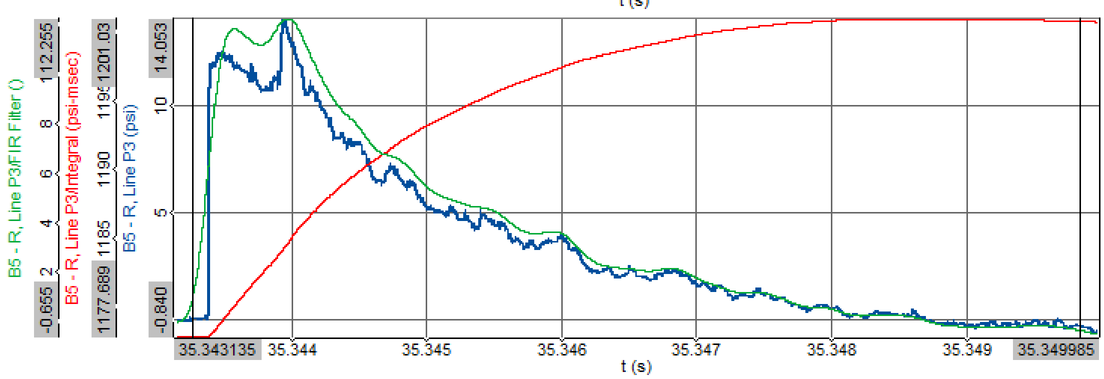

A4 - L, Line 1 BL/FIR Filter ()
A4 - L, Line 1 BL/Integral (psi-msec)
A4 - L, Line 1 BL (psi)
35.231910
35.2325
35.233
35.2335
35.233790
t (s)

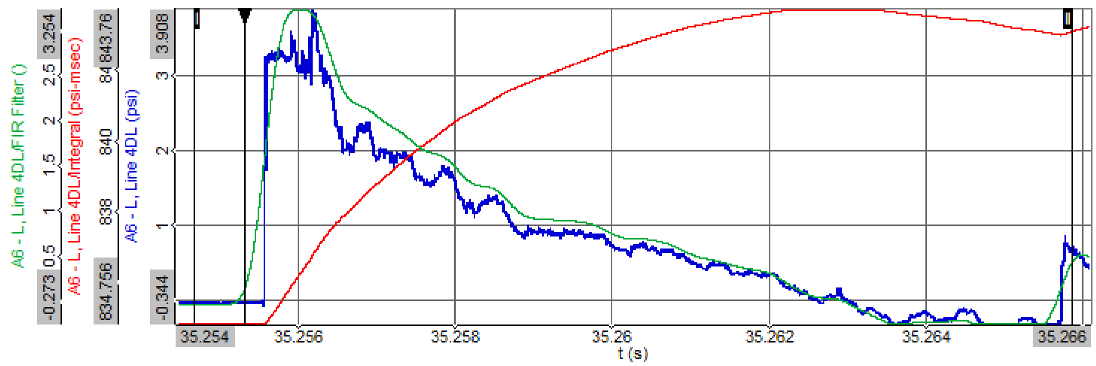

B4 - L, Line E3L/FIR Filter ()
B4 - L, Line E3L/Integral (psi-msec)
B4 - L, Line E3L (psi)
35.231910
35.2325
35.233
35.2335
35.233790
t (s)

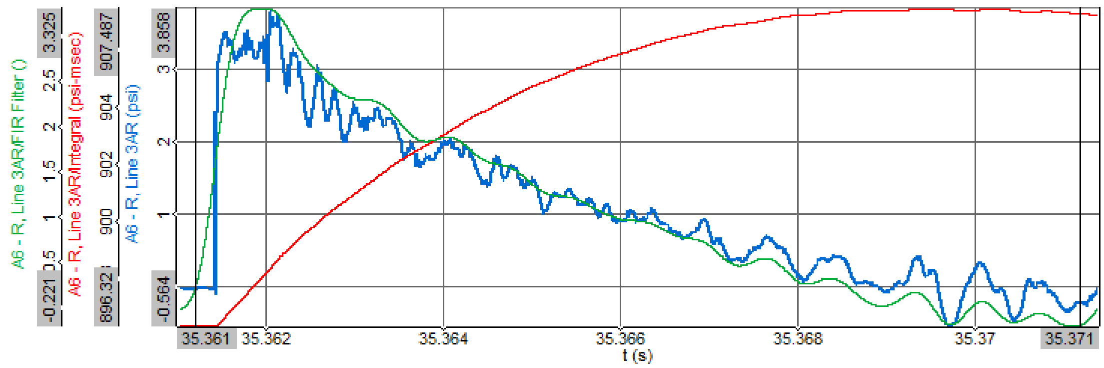

A5 - L, Line E2L/FIR Filter ()
A5 - L, Line E2L/Integral (psi-msec)
A5 - L, Line E2L (psi)
t (s)
35.237340
35.239
35.24
35.241
35.242
35.243285

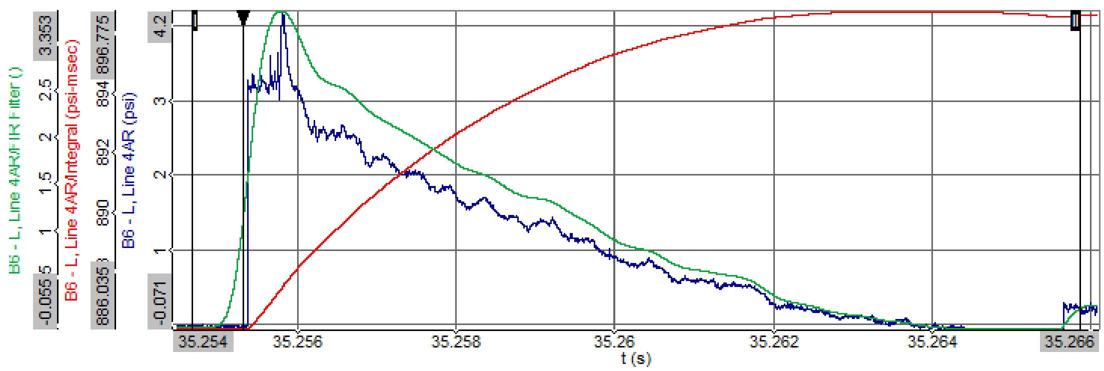

A5 - R, Line 1DR/FIR Filter ()
A5 - R, Line 1DR/Integral (psi-msec)
A5 - R, Line 1DR (psi)
t (s)
35.343135
35.344
35.345
35.346
35.347
35.348
35.349
35.349985

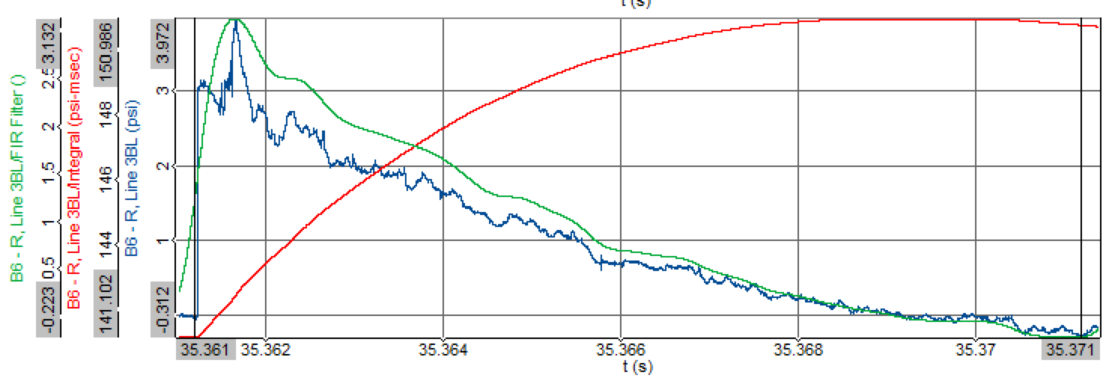

B5 - L, Line 4CR/FIR Filter ()
B5 - L, Line 4CR/Integral (psi-msec)
B5 - L, Line 4CR (psi)
t (s)
35.237340
35.239
35.24
35.241
35.242
35.243285

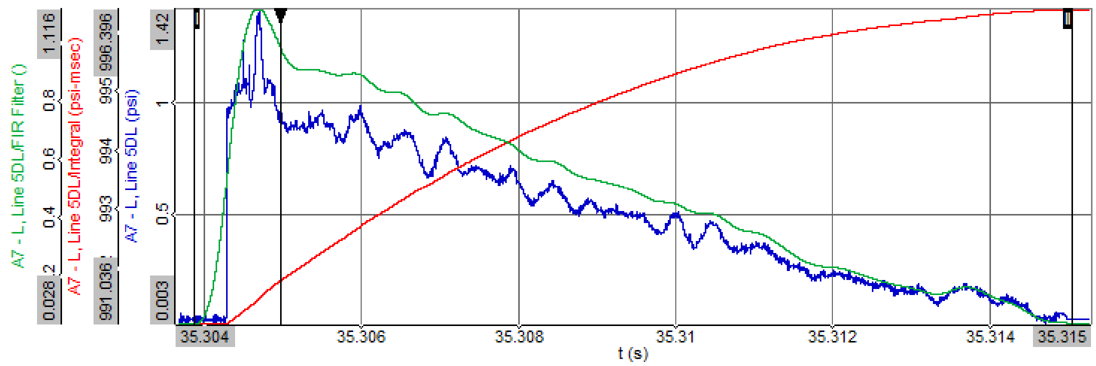

B5 - R, Line P3/FIR Filter ()
B5 - R, Line P3/Integral (psi-msec)
B5 - R, Line P3 (psi)
t (s)
35.343135
35.344
35.345
35.346
35.347
35.348
35.349
35.349985

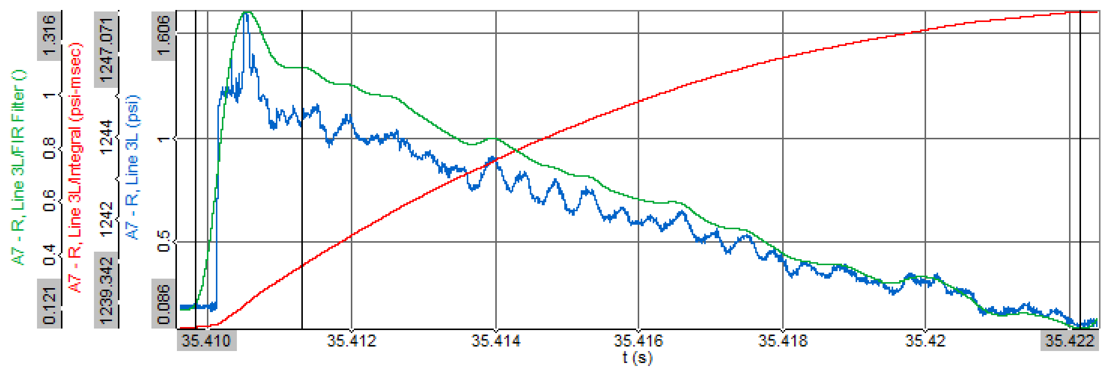

A6 - L, Line 4DL/FIR Filter ()
A6 - L, Line 4DL/Integral (psi-msec)
A6 - L, Line 4DL (psi)
35.254
35.256
35.258
35.26
35.262
35.264
35.266
t (s)

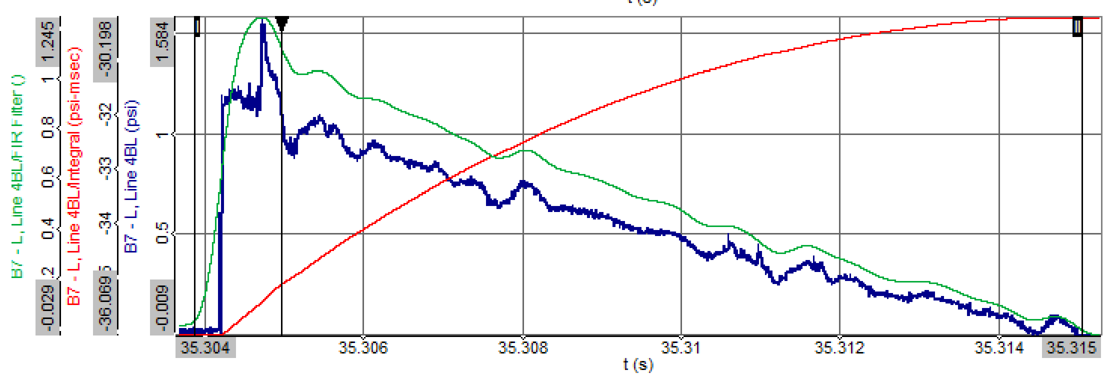

A6 - R, Line 3AR/FIR Filter ()
A6 - R, Line 3AR/Integral (psi-msec)
A6 - R, Line 3AR (psi)
35.361
35.362
35.364
35.366
35.368
35.37
35.371
t (s)

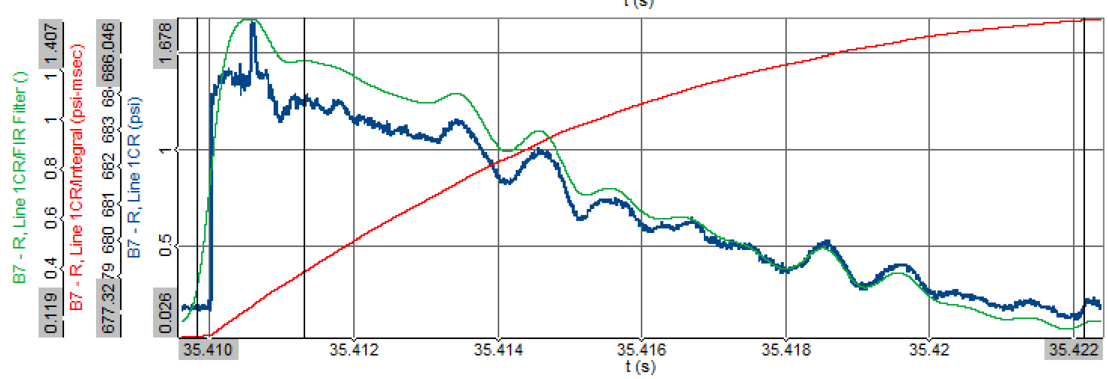

B6 - L, Line 4AR/FIR Filter ()
B6 - L, Line 4AR/Integral (psi-msec)
B6 - L, Line 4AR (psi)
35.254
35.256
35.258
35.26
35.262
35.264
35.266
t (s)

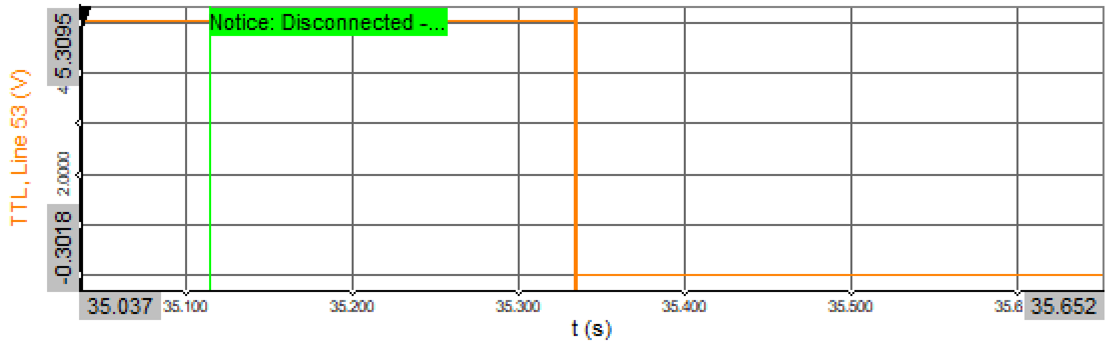

B6 - R, Line 3BL/FIR Filter ()
B6 - R, Line 3BL/Integral (psi-msec)
B6 - R, Line 3BL (psi)
35.361
35.362
35.364
35.366
35.368
35.37
35.371
t (s)


A7 - L, Line 5DL/FIR Filter ()
A7 - L, Line 5DL/Integral (psi-msec)
A7 - L, Line 5DL (psi)
t (s)

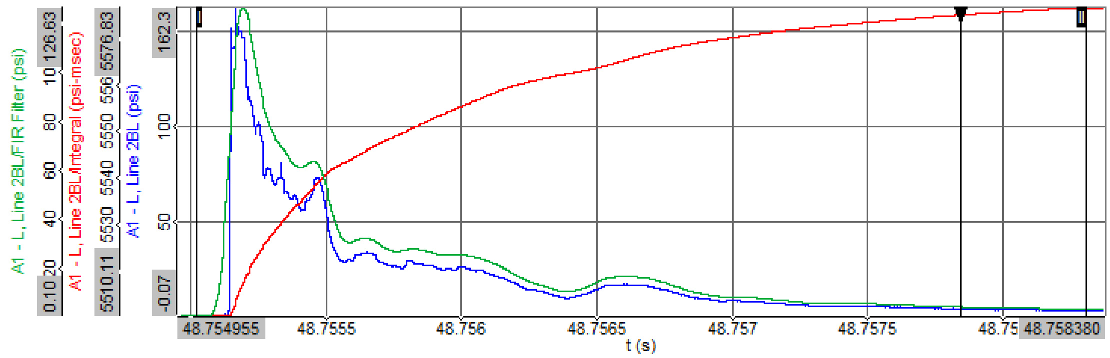

A7 - R, Line 3L/FIR Filter ()
A7 - R, Line 3L/Integral (psi-msec)
A7 - R, Line 3L (psi)
t (s)

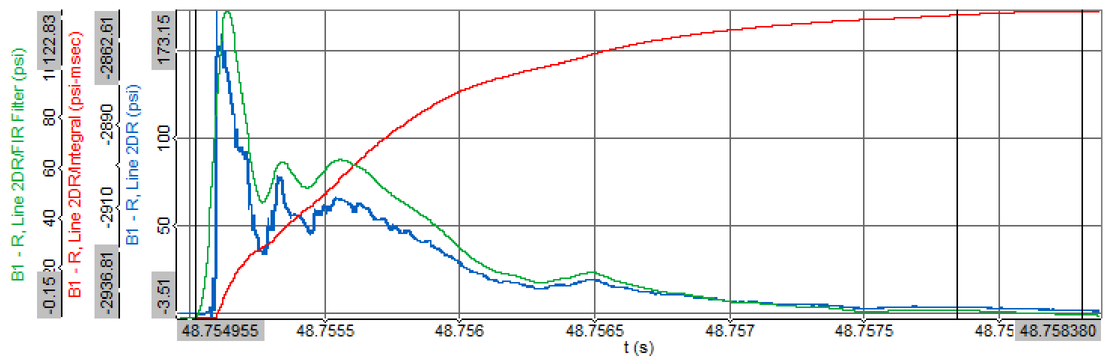

B7 - L, Line 4BL/FIR Filter ()
B7 - L, Line 4BL/Integral (psi-msec)
B7 - L, Line 4BL (psi)
t (s)

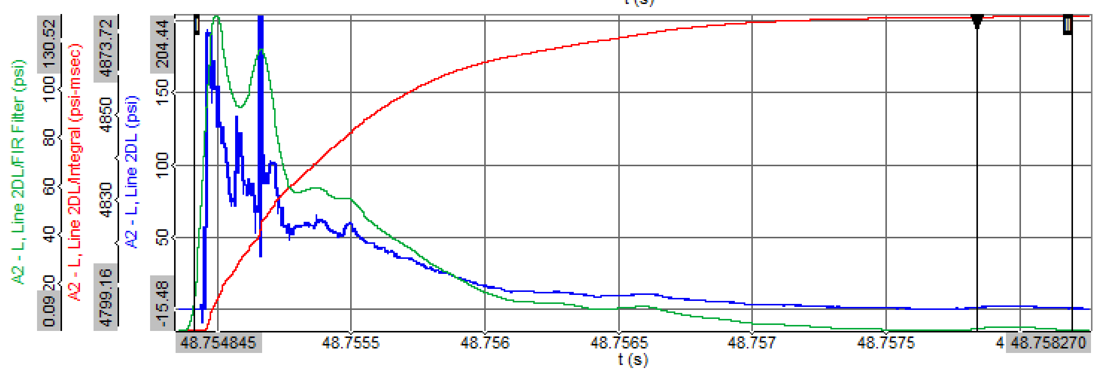

B7 - R, Line 1CR/FIR Filter ()
B7 - R, Line 1CR/Integral (psi-msec)
B7 - R, Line 1CR (psi)
t (s)

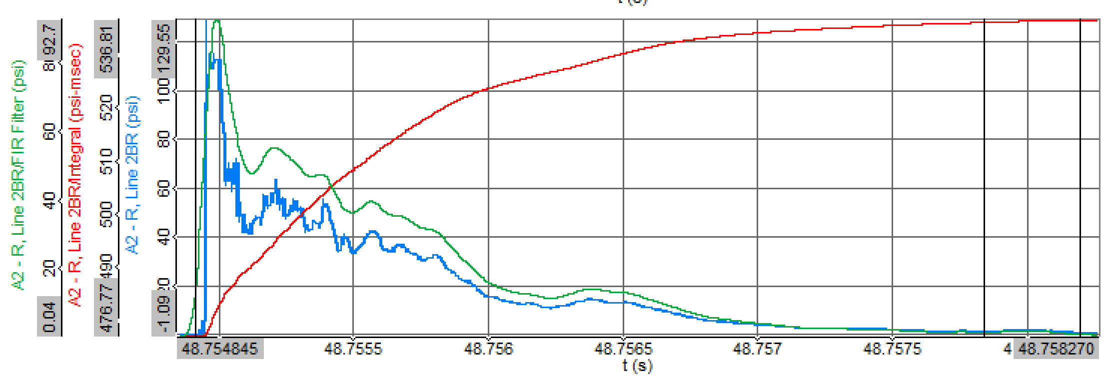

Notice: Disconnected -...
TTL, Line 53 (V)
5.3095
2.0000
-0.3018
35.037
35.100
35.200
35.300
35.400
35.500
35.652
t (s)

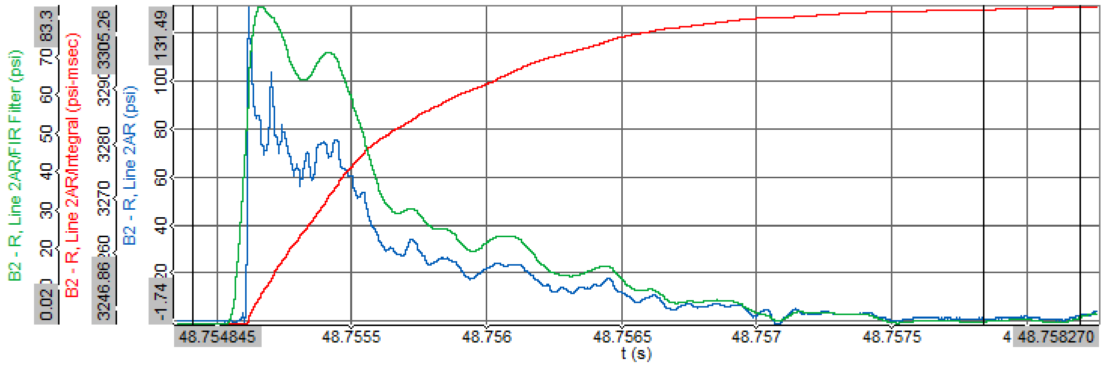
8.10.2 Trial 2 for Hemispherical Cast TNT

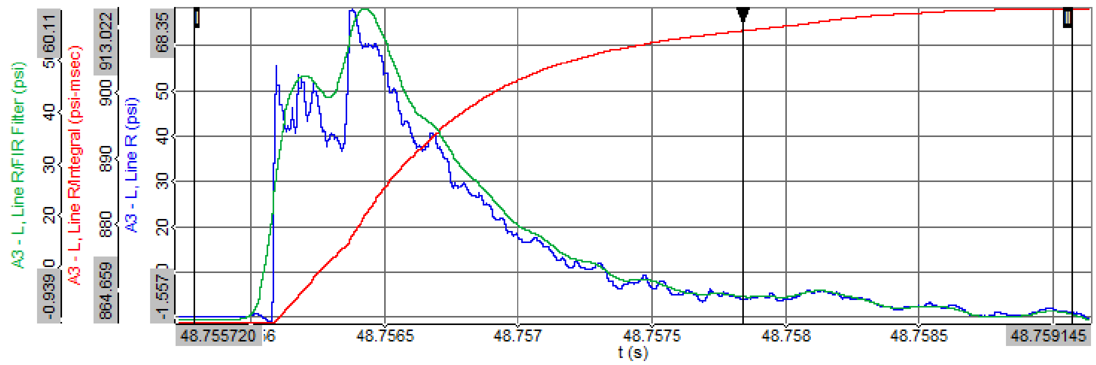


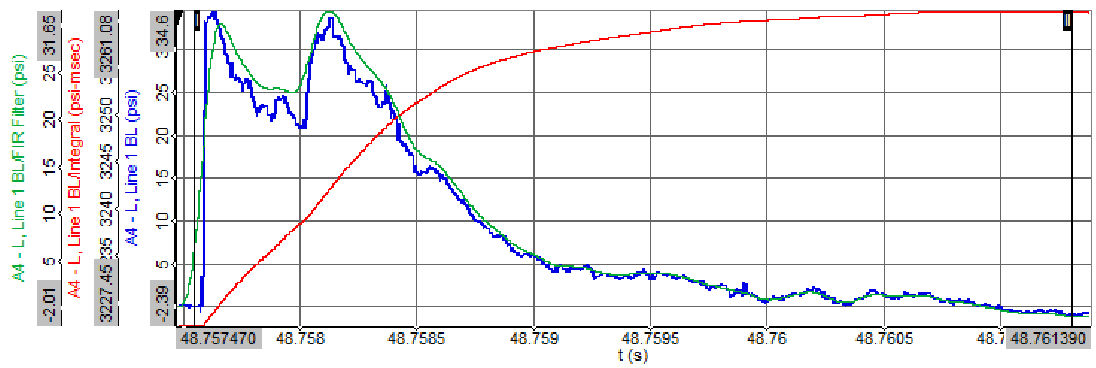


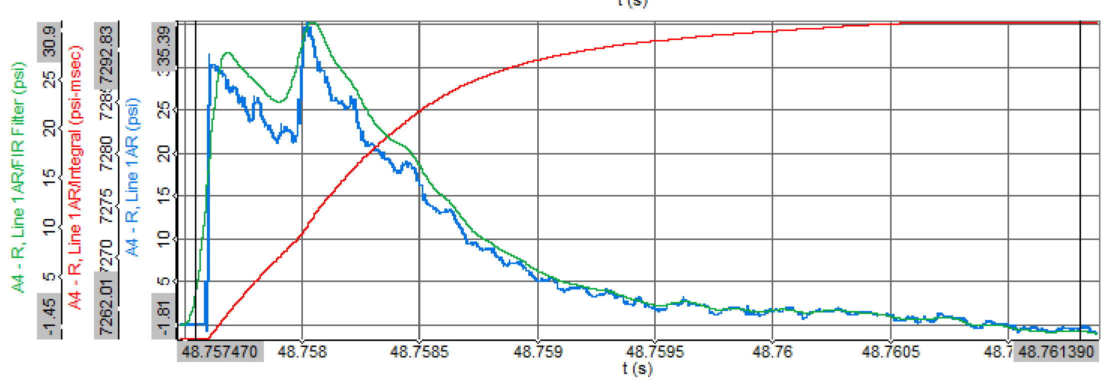


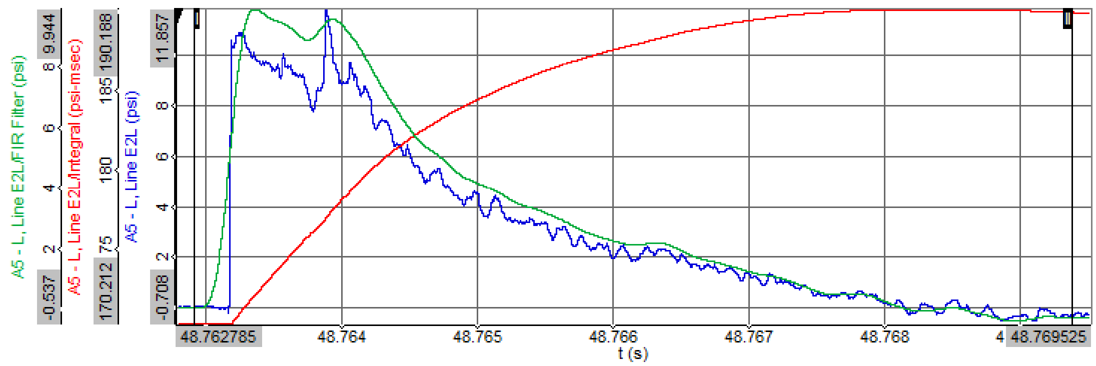


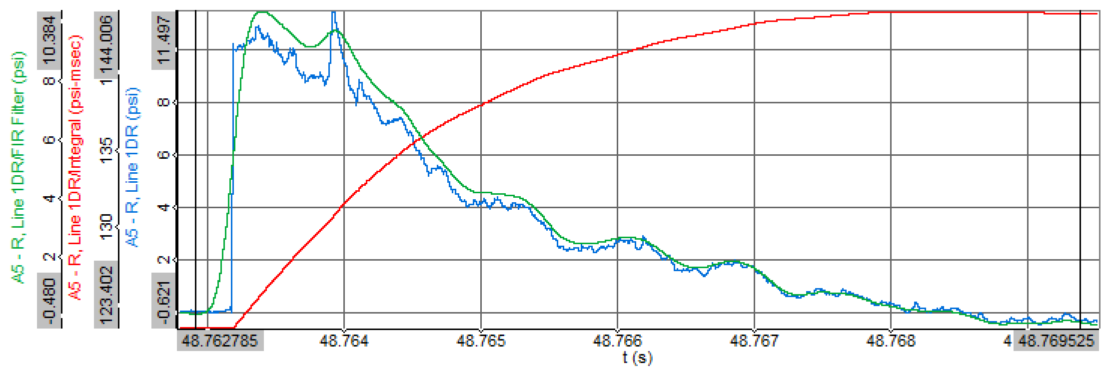

B2 - R, Line 2AR/FIR Filter (psi)
B2 - R, Line 2AR/Integral (psi-msec)
B2 - R, Line 2AR (psi)
48.754845
48.7555
48.756
48.7565
48.757
48.7575
48.758270
t (s)

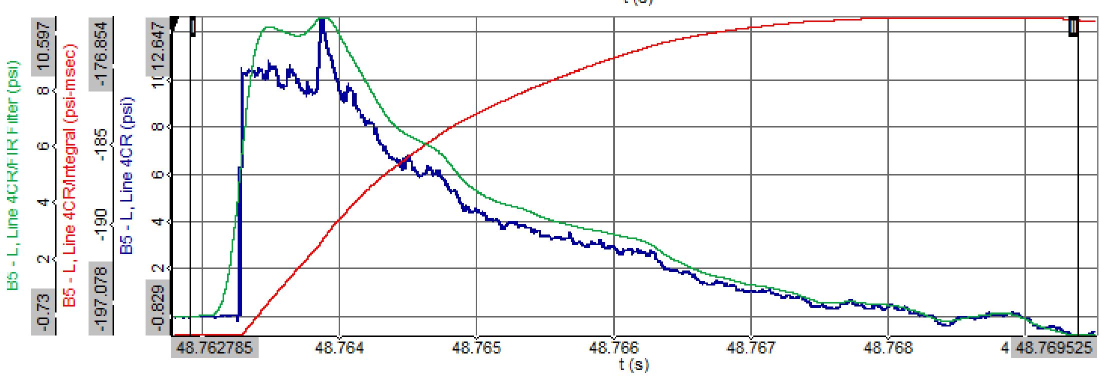

A3 - L, Line R/FIR Filter (psi)
A3 - L, Line R/Integral (psi-msec)
A3 - L, Line R (psi)
48.755720
48.7565
48.757
48.7575
48.758
48.7585
48.759145
t (s)

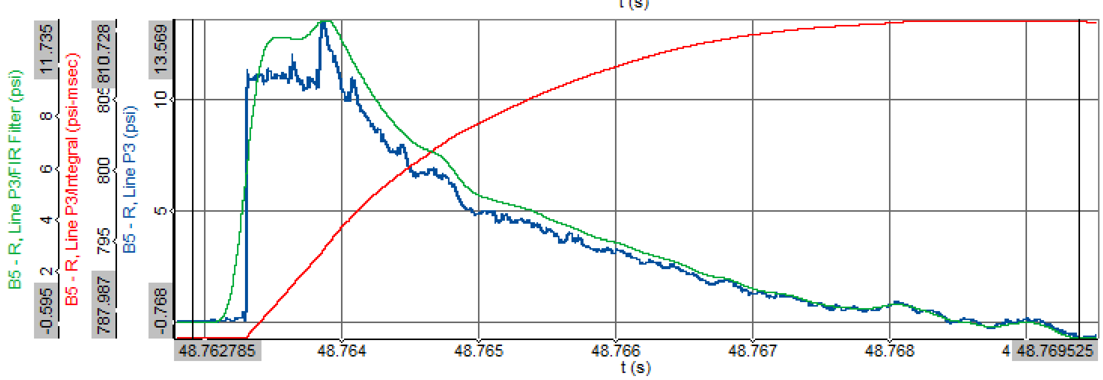

A4 - L, Line 1 BL/FIR Filter (psi)
A4 - L, Line 1 BL/Integral (psi-msec)
A4 - L, Line 1 BL (psi)
48.757470
48.758
48.7585
48.759
48.7595
48.76
48.7605
48.761390
t (s)

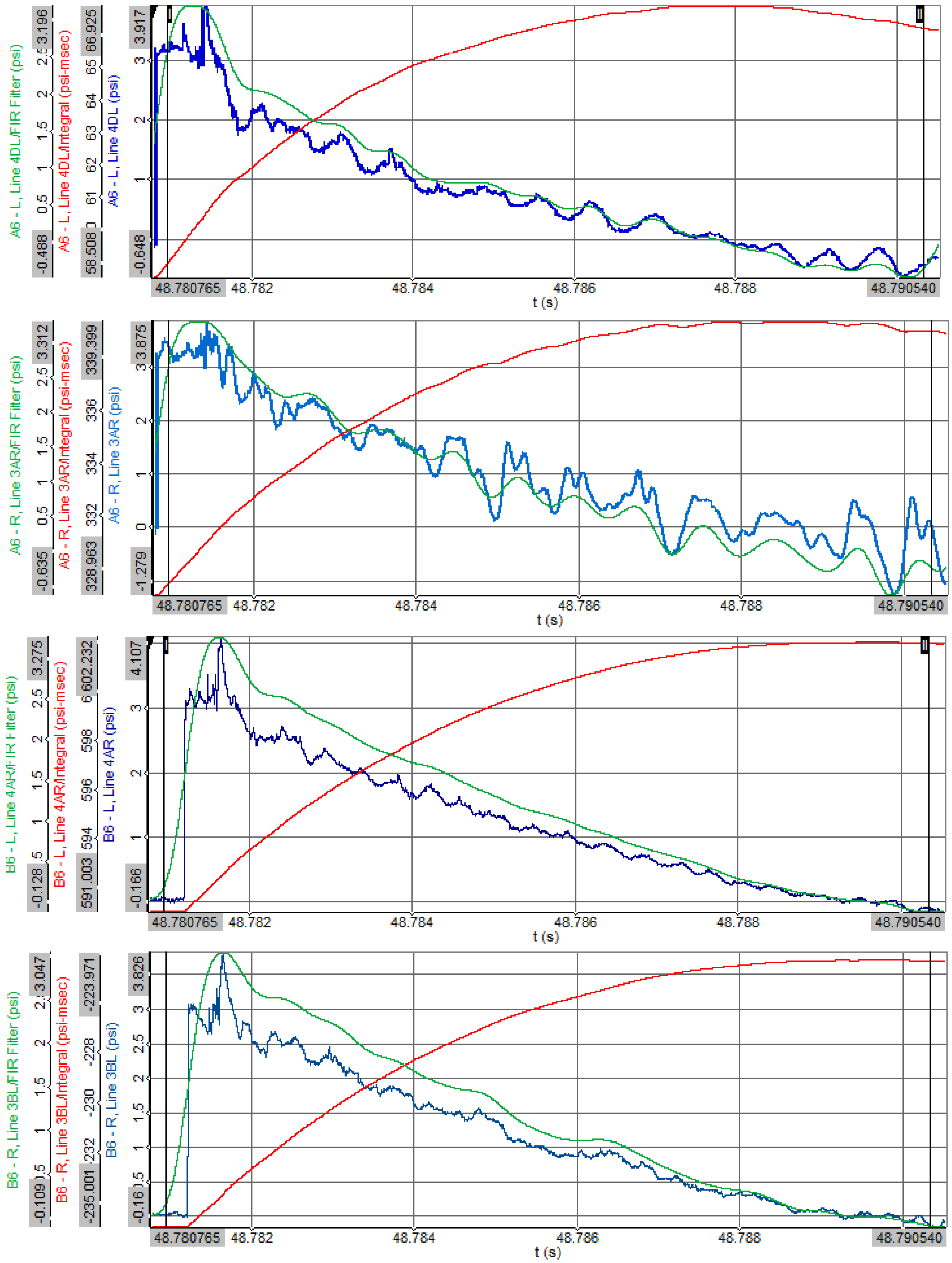

A4 - R, Line 1AR/FIR Filter (psi)
A4 - R, Line 1AR/Integral (psi-msec)
A4 - R, Line 1AR (psi)
48.757470
48.758
48.7585
48.759
48.7595
48.76
48.7605
48.761390
t (s)

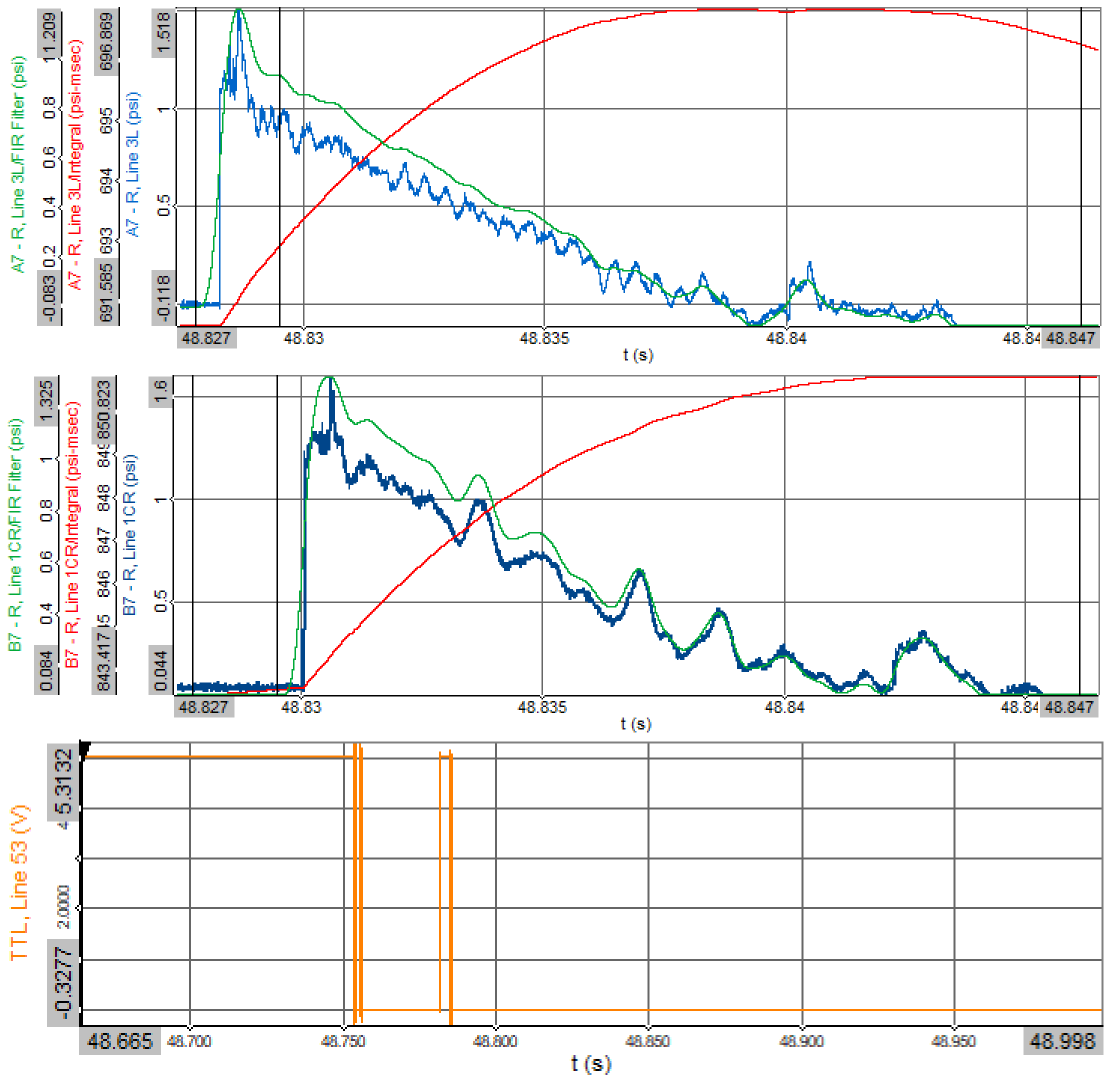

A5 - L, Line E2L/FIR Filter (psi)
A5 - L, Line E2L/Integral (psi-msec)
A5 - L, Line E2L (psi)
48.762785
48.764
48.765
48.766
48.767
48.768
48.769525
t (s)


A5 - R, Line 1DR/FIR Filter (psi)
A5 - R, Line 1DR/Integral (psi-msec)
A5 - R, Line 1DR (psi)
48.762785
48.764
48.765
48.766
48.767
48.768
48.769525
t (s)

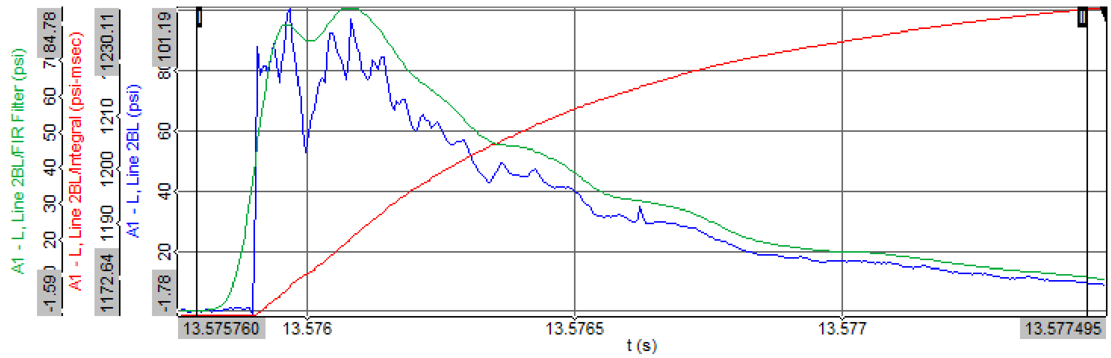

B5 - L, Line 4CR/FIR Filter (psi)
B5 - L, Line 4CR/Integral (psi-msec)
B5 - L, Line 4CR (psi)
48.762785
48.764
48.765
48.766
48.767
48.768
48.769525
t (s)

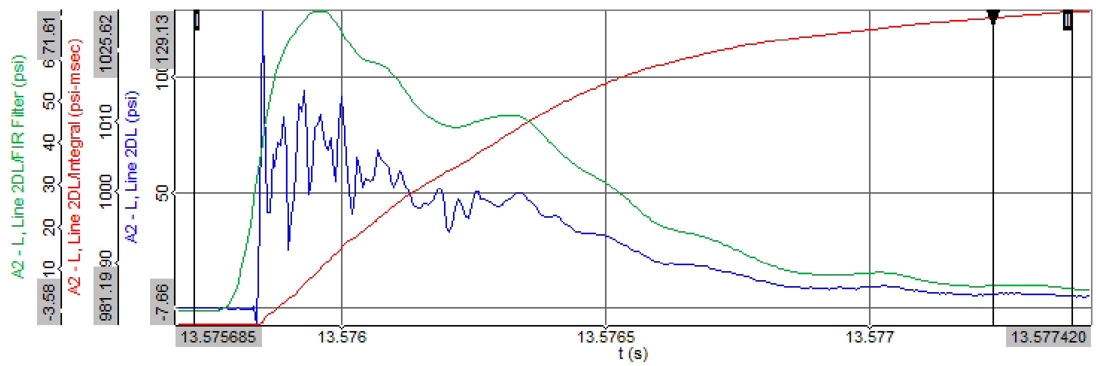

B5 - R, Line P3/FIR Filter (psi)
B5 - R, Line P3/Integral (psi-msec)
B5 - R, Line P3 (psi)
48.762785
48.764
48.765
48.766
48.767
48.768
48.769525
t (s)

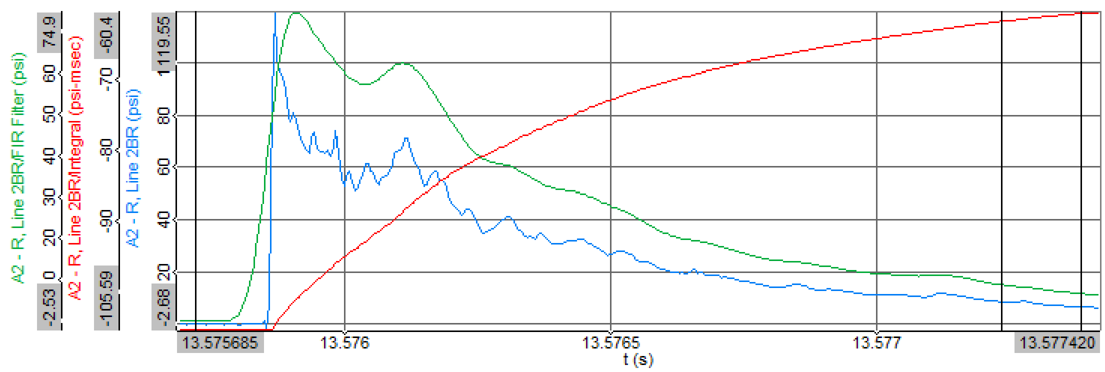

A6 - L, Line 4DL/FIR Filter (psi)
A6 - L, Line 4DL/Integral (psi-msec)
A6 - L, Line 4DL (psi)
A6 - R, Line 3AR/FIR Filter (psi)
A6 - R, Line 3AR/Integral (psi-msec)
A6 - R, Line 3AR (psi)
B6 - L, Line 4AR/FIR Filter (psi)
B6 - L, Line 4AR/Integral (psi-msec)
B6 - L, Line 4AR (psi)
B6 - R, Line 3BL/FIR Filter (psi)
B6 - R, Line 3BL/Integral (psi-msec)
B6 - R, Line 3BL (psi)
48.780765
48.782
48.784
48.786
48.788
48.790540
t (s)

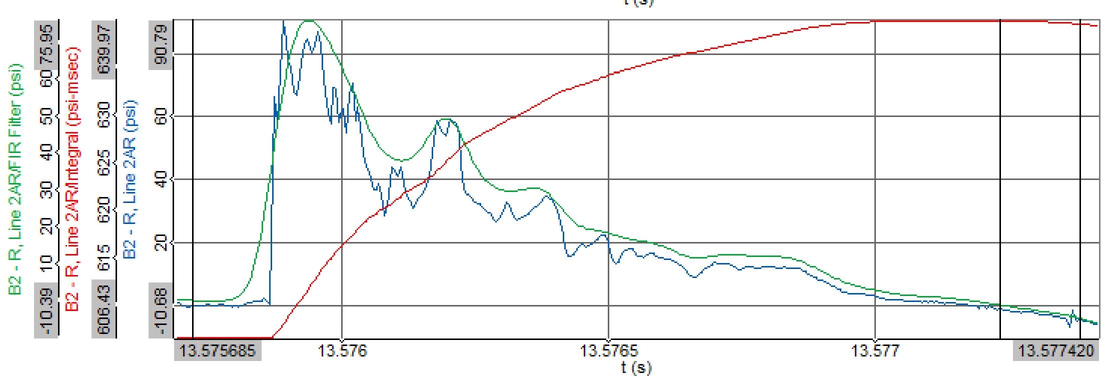

A7 - R, Line 3L/FIR Filter (psi)
A7 - R, Line 3L/Integral (psi-msec)
A7 - R, Line 3L (psi)
t (s)
B7 - R, Line 1CR/FIR Filter (psi)
B7 - R, Line 1CR/Integral (psi-msec)
B7 - R, Line 1CR (psi)
t (s)
TTL, Line 53 (V)
t (s)

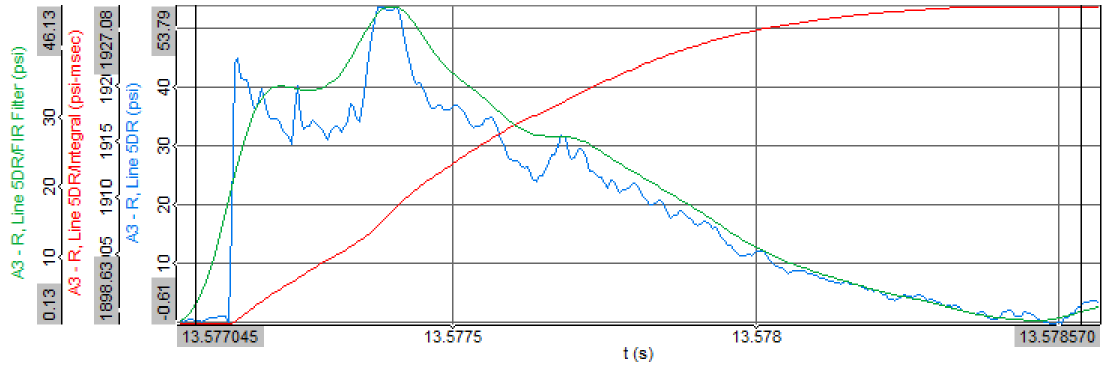
8.10.3 Trial 3 for Hemispherical Cast TNT

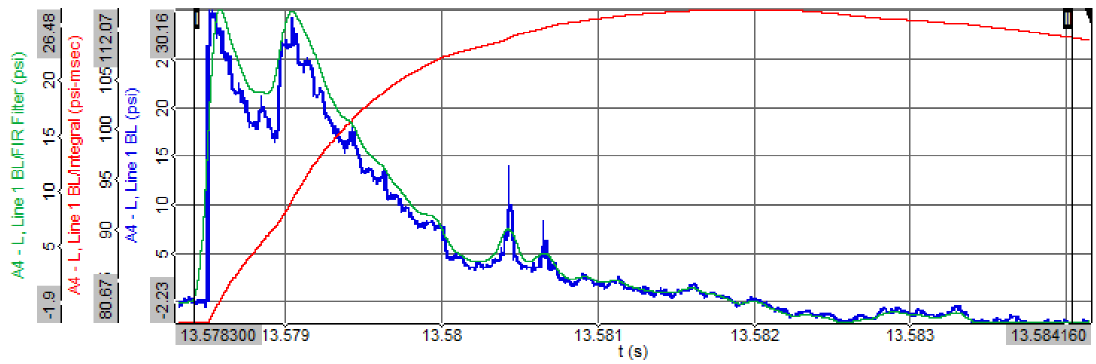


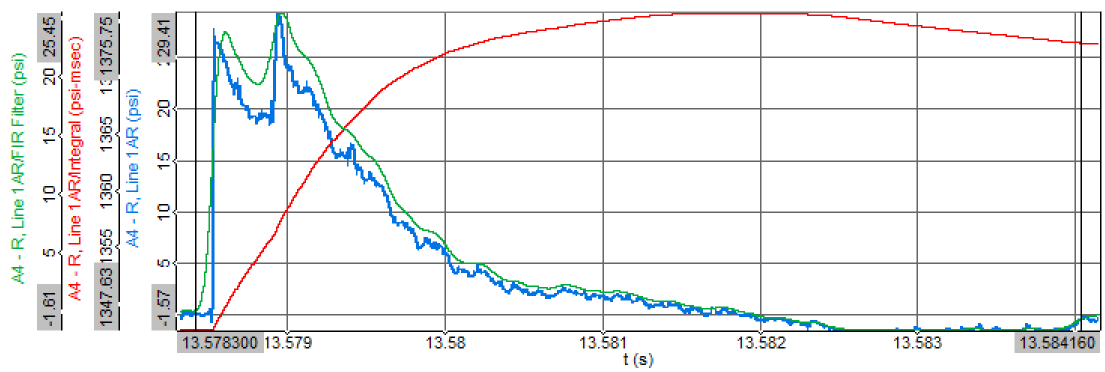


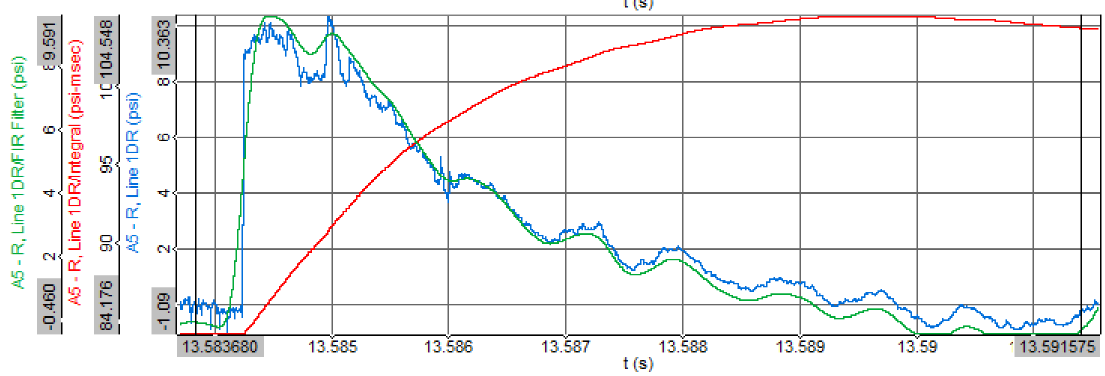


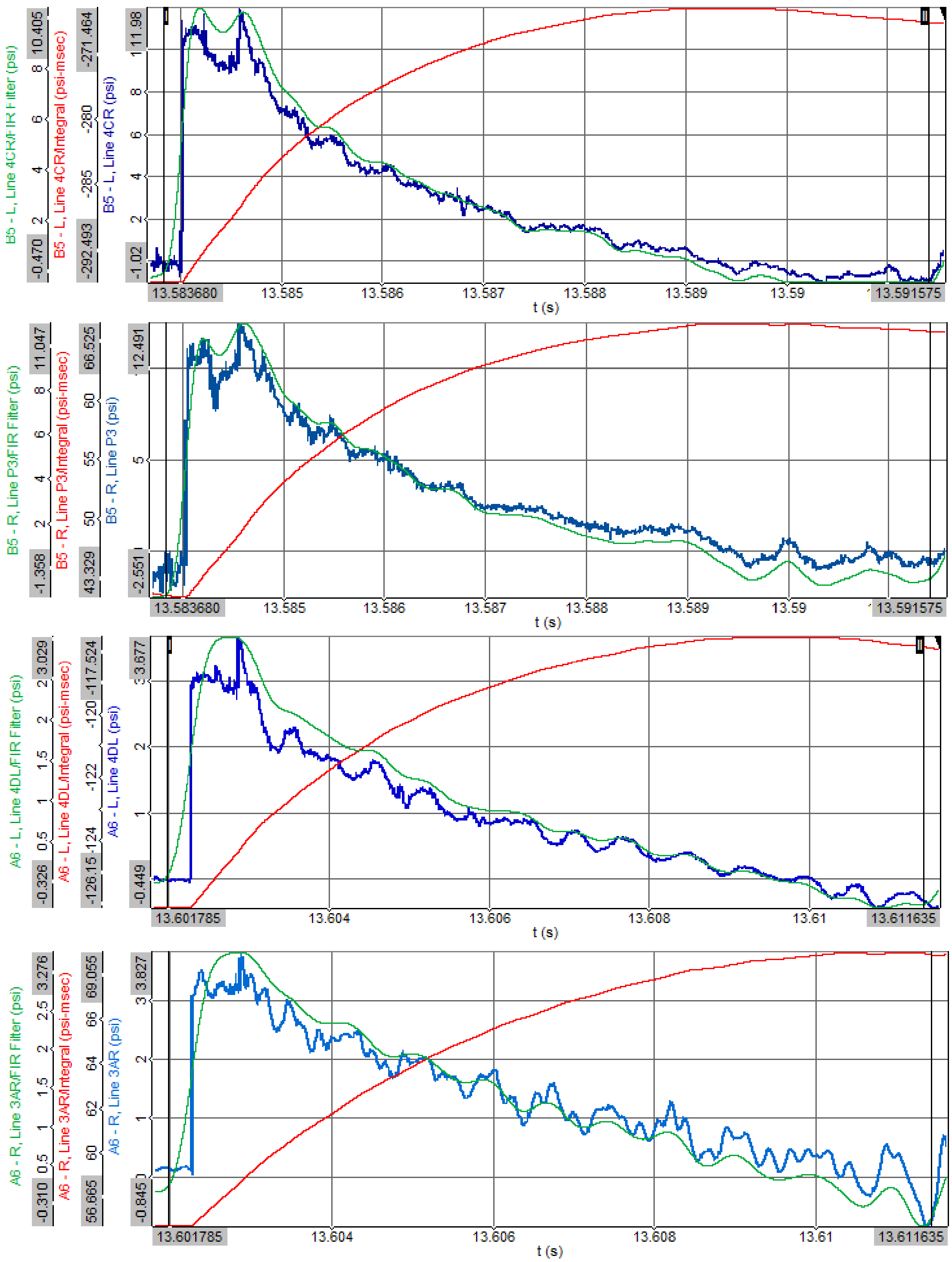


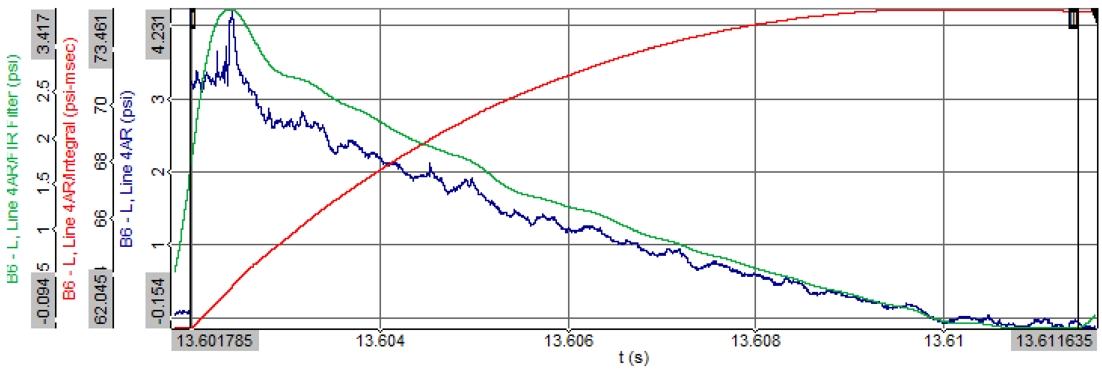

A3 - R, Line 5DR/FIR Filter (psi)
A3 - R, Line 5DR/Integral (psi-msec)
A3 - R, Line 5DR (psi)
13.577045
13.5775
13.578
13.578570
t (s)

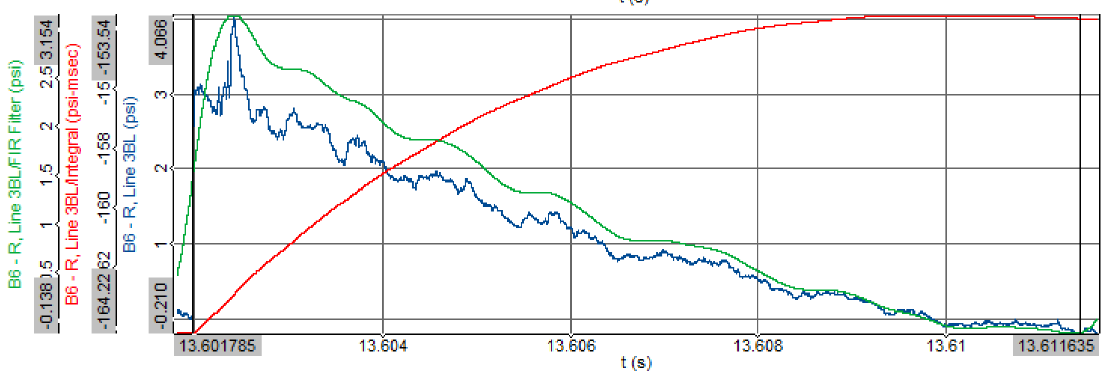

A4 - L, Line 1 BL/FIR Filter (psi)
A4 - L, Line 1 BL/Integral (psi-msec)
A4 - L, Line 1 BL (psi)
13.578300
13.579
13.58
13.581
13.582
13.583
13.584160
t (s)

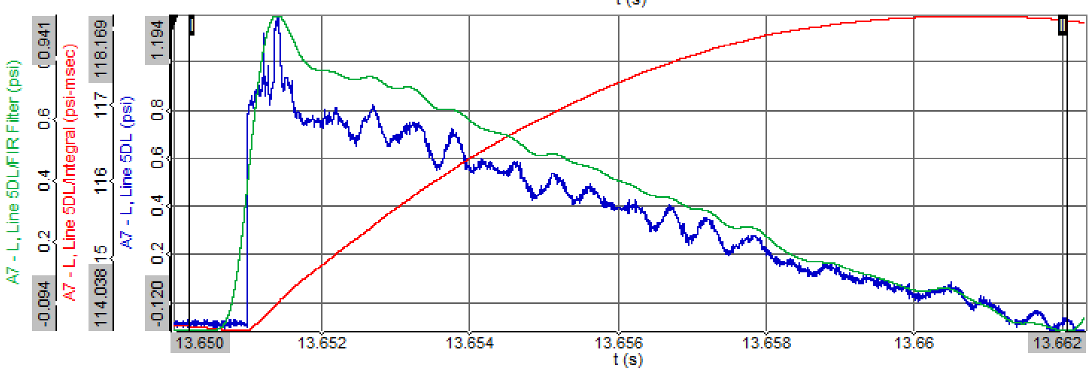

A4 - R, Line 1AR/FIR Filter (psi)
A4 - R, Line 1AR/Integral (psi-msec)
A4 - R, Line 1AR (psi)
13.578300
13.579
13.58
13.581
13.582
13.583
13.584160
t (s)

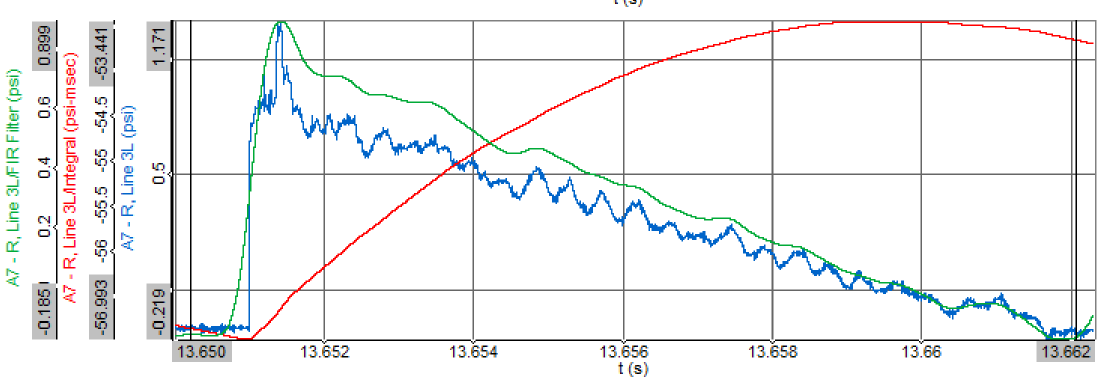

A5 - R, Line 1DR/FIR Filter (psi)
A5 - R, Line 1DR/Integral (psi-msec)
A5 - R, Line 1DR (psi)
13.583680
13.585
13.586
13.587
13.588
13.589
13.59
13.591575
t (s)

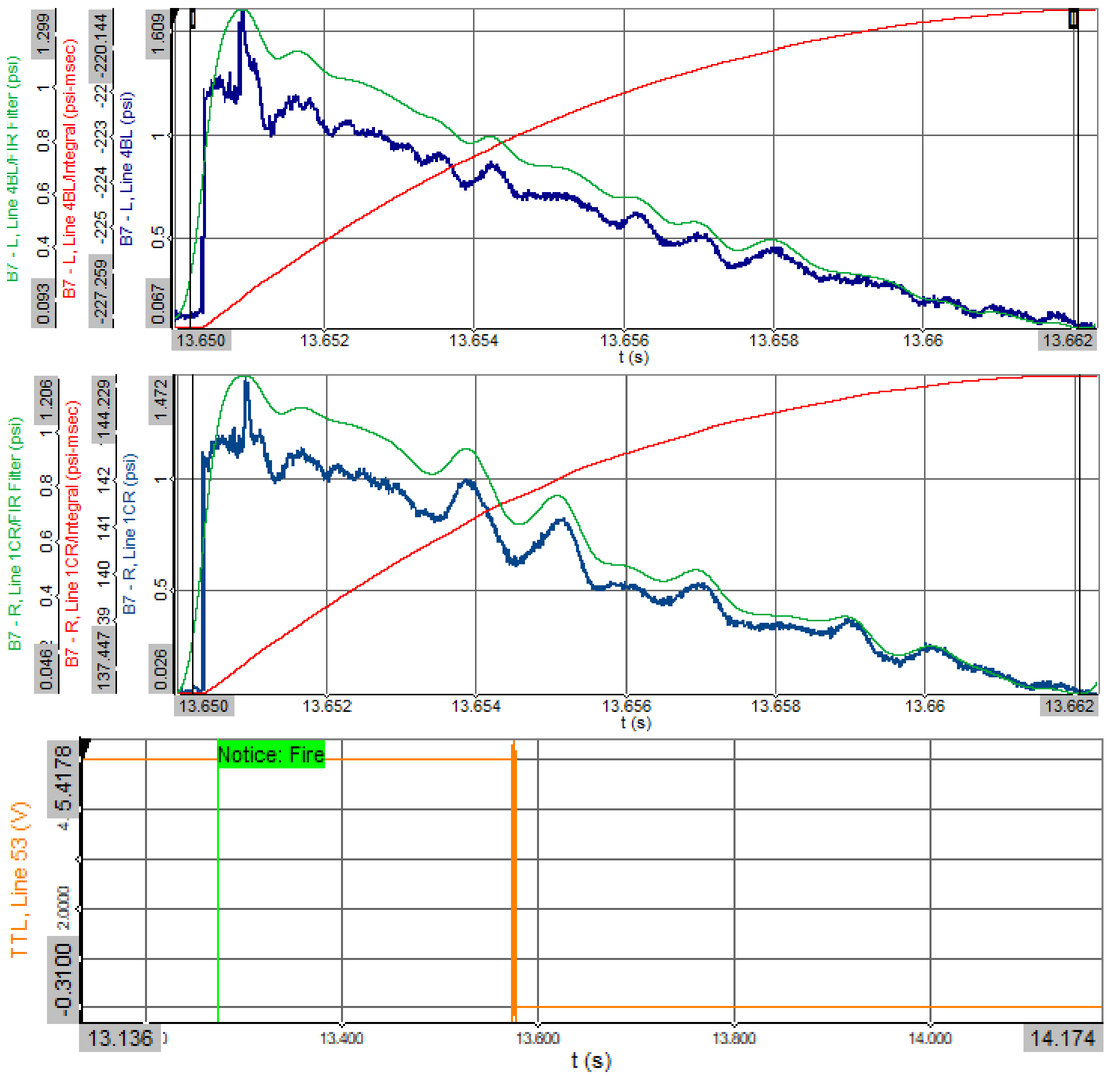



B6 - L, Line 4AR/FIR Filter (psi)
B6 - L, Line 4AR/Integral (psi-msec)
B6 - L, Line 4AR (psi)
13.601785
13.604
13.606
13.608
13.61
13.611635
t (s)


B6 - R, Line 3BL/FIR Filter (psi)
B6 - R, Line 3BL/Integral (psi-msec)
B6 - R, Line 3BL (psi)
13.601785
13.604
13.606
13.608
13.61
13.611635
t (s)


A7 - L, Line 5DL/FIR Filter (psi)
A7 - L, Line 5DL/Integral (psi-msec)
A7 - L, Line 5DL (psi)
13.650
13.652
13.654
13.656
13.658
13.66
13.662
t (s)


A7 - R, Line 3L/FIR Filter (psi)
A7 - R, Line 3L/Integral (psi-msec)
A7 - R, Line 3L (psi)
13.650
13.652
13.654
13.656
13.658
13.66
13.662
t (s)


B7 - L, Line 4BL/FIR Filter (psi)
B7 - L, Line 4BL/Integral (psi-msec)
B7 - L, Line 4BL (psi)
t (s)
B7 - R, Line 1CR/FIR Filter (psi)
B7 - R, Line 1CR/Integral (psi-msec)
B7 - R, Line 1CR (psi)
t (s)
Notice: Fire
TTL, Line 53 (V)
t (s)

9.0 EQUIVALENCY CALCULATIONS

9.1 Fine Al-MnO_2 Thermite – Large-Scale Mix ID #7 (SMS mixed)

PRESSURE AND IMPULSE TEST DATA SMOOTHING

$kPa := 1000 \cdot Pa \quad msec := 0.001 \cdot sec$

Test Sample: Large-Scale Mix #7, hemispherical on surface at the SMS Test Site in Tooele, Utah

Read in the test data summary file: $data := READPRN(\text{"DOT1-6265f-LS7-Data.prn"})$ $\quad Item := data^{\langle 0 \rangle}$

NOTE: Col 1 - Item, Col 2 - Trial, Col 3 - Line, Col 4 - Station, Col 5 - Distance in feet, Col 6 - Peak Pressure in psig, Col 7 - TTL initiation time, Col 8 - time of arrival in seconds, Col 9 - time that pressure returned to ambient in seconds (impulse maxima), Col 10 - impulse in psi-msec.

Read in the test conditions file: $cond := READPRN(\text{"DOT1-6265f-LS7-TestCond.prn"})$

NOTE: Col 1 - Trial, Col 2 - net explosives weight, Col 3 - temperature in Kelvin, Col 4 - pressure in inHg.

$trial := cond^{\langle 0 \rangle} \quad W_{trial} := cond^{\langle 1 \rangle} \cdot \frac{gm}{lb} \quad T_{trial} := cond^{\langle 2 \rangle} \cdot K \quad P_{trial} := cond^{\langle 3 \rangle} \cdot in\_Hg$

Initiation train: $W_{init} := (0) \cdot \frac{gm}{lb} \quad \varepsilon_{TNT.init.p} := 100\ \% \quad \varepsilon_{TNT.init.i} := 100\ \%$

Initial guess value for the product's average TNT equivalency: $\varepsilon_{TNT.p} := 1\ \% \quad \varepsilon_{TNT.i} := 1\ \%$

Net explosive weight of product:

$$W_p := W_{trial} + \frac{W_{init} \cdot \varepsilon_{TNT.init.p}}{\varepsilon_{TNT.p}} \qquad W_p = \begin{bmatrix} 20.00 \\ 20.00 \\ 20.00 \end{bmatrix} \qquad W_i := W_{trial} + \frac{W_{init} \cdot \varepsilon_{TNT.init.i}}{\varepsilon_{TNT.i}} \qquad W_i = \begin{bmatrix} 20.00 \\ 20.00 \\ 20.00 \end{bmatrix}$$

Split data sets by trial:

```
Split(data, item) := | i ← 0
                     | for j ∈ 0 .. rows(data) − 1
                     |   if data[j,0] = item
                     |     | T<i> ← (data^T)<j>
                     |     | i ← i + 1
                     | Split ← T^T
```

$i := 0 .. rows(trial) - 1 \qquad Set_i := Split(data, i)$

$Trial_i := (Set_i)^{\langle 1 \rangle} \quad Line_i := (Set_i)^{\langle 2 \rangle} \quad Station_i := (Set_i)^{\langle 3 \rangle}$

$R_i := (Set_i)^{\langle 4 \rangle} \quad P_{so_i} := (Set_i)^{\langle 5 \rangle} \quad t_{TTL.abs_i} := (Set_i)^{\langle 6 \rangle}$

$t_{A.abs_i} := (Set_i)^{\langle 7 \rangle} \quad t_{amb.abs_i} := (Set_i)^{\langle 8 \rangle} \quad i_{s_i} := (Set_i)^{\langle 9 \rangle}$

Calculate time of shock arrival and duration: $t_{A_i} := t_{A.abs_i} - t_{TTL.abs_i} \qquad t_{o_i} := t_{amb.abs_i} - t_{A.abs_i}$

Calculate Sachs Scaling factors to convert measurements from test site to Sea Level (SL):

$P_{SL} := 101.4 \cdot kPa$ $\quad T_{SL} := 288.2 \cdot K$

Pressure: $S_{P_i} := \frac{P_{trial_i}}{P_{SL}}$ $\quad F_{P_i} := \left(S_{P_i}\right)^{-1}$

Distance: $S_{d.p_i} := \left(W_{p_i}\right)^{\frac{1}{3}} \cdot \left(\frac{P_{SL}}{P_{trial_i}}\right)^{\frac{1}{3}}$ $\quad F_{R.p_i} := \left(S_{d.p_i}\right)^{-1}$ $\quad S_{d.i_i} := \left(W_{i_i}\right)^{\frac{1}{3}} \cdot \left(\frac{P_{SL}}{P_{trial_i}}\right)^{\frac{1}{3}}$ $\quad F_{R.i_i} := \left(S_{d.i_i}\right)^{-1}$

Time: $S_{t_i} := \left(W_{p_i}\right)^{\frac{1}{3}} \cdot \left(\frac{P_{SL}}{P_{trial_i}}\right)^{\frac{1}{3}} \cdot \left(\frac{T_{SL}}{T_{trial_i}}\right)^{\frac{1}{2}}$ $\quad F_{T_i} := \left(S_{t_i}\right)^{-1}$

Impulse: $S_{i_i} := \left(W_{i_i}\right)^{\frac{1}{3}} \cdot \left(\frac{P_{trial_i}}{P_{SL}}\right)^{\frac{2}{3}} \cdot \left(\frac{T_{SL}}{T_{trial_i}}\right)^{\frac{1}{2}}$ $\quad F_{i_i} := \left(S_{i_i}\right)^{-1}$

$F_P^T = [\ 1.006 \quad 1.006 \quad 1.006\ ]$

$F_{R.p}^T = [\ 0.368 \quad 0.368 \quad 0.368\ ]$

$F_{R.i}^T = [\ 0.368 \quad 0.368 \quad 0.368\ ]$

$F_T^T = [\ 0.376 \quad 0.377 \quad 0.377\ ]$

$F_i^T = [\ 0.378 \quad 0.379 \quad 0.379\ ]$

Apply Sachs Scaling Factors to convert measurements from test site to Sea Level:

$P_{so_i} := P_{so_i} \cdot F_{P_i}$ $\quad z_{p_i} := R_i \cdot F_{R.p_i}$ $\quad z_{i.s_i} := R_i \cdot F_{R.i_i}$ $\quad t_{A_i} := t_{A_i} \cdot F_{T_i}$ $\quad t_{o_i} := t_{o_i} \cdot F_{T_i}$ $\quad i_{s.scaled_i} := i_{s_i} \cdot F_{i_i}$

Common log of the x axes: $logz_{p_i} := \overrightarrow{\log\left(z_{p_i}\right)}$ $\quad logz_{i.s_i} := \overrightarrow{\log\left(z_{i.s_i}\right)}$

Common log of the y axes: $logP_{so_i} := \overrightarrow{\log\left(P_{so_i}\right)}$ $\quad logi_{s.scaled_i} := \overrightarrow{\log\left(i_{s.scaled_i}\right)}$

Reassemble data sets: $logz_{all.p} := 1$ $logP_{so.all} := 1$ $logz_{all.i} := 1$ $logi_{s.scaled.all} := 1$

$$Reassemble(A,B) := \left| \begin{array}{l} A \leftarrow B_0 \\ \text{for } j \in 1..rows(trial) - 1 \\ \quad A \leftarrow stack(A, B_j) \\ A \end{array} \right.$$

$logz_{all.p} := Reassemble(logz_{all.p}, logz_p)$ $logP_{so.all} := Reassemble(logP_{so.all}, logP_{so})$

$logz_{all.i} := Reassemble(logz_{all.i}, logz_{i.s})$ $logi_{s.scaled.all} := Reassemble(logi_{s.scaled.all}, logi_{s.scaled})$

Bind X-Y pairs together: $log_{data.p} := augment(logz_{all.p}, logP_{so.all})$ $log_{data.i} := augment(logz_{all.i}, logi_{s.scaled.all})$

Loess Smoothing of X-Y Data: $span_p := 0.55$ $span_i := 0.55$

$L_p := loess\left(log_{data.p}^{\langle 0 \rangle}, log_{data.p}^{\langle 1 \rangle}, span_p\right)$ $logPso(x) := interp\left(L_p, log_{data.p}^{\langle 0 \rangle}, log_{data.p}^{\langle 1 \rangle}, x\right)$

$L_i := loess\left(log_{data.i}^{\langle 0 \rangle}, log_{data.i}^{\langle 1 \rangle}, span_i\right)$ $logIscaled(x) := interp\left(L_i, log_{data.i}^{\langle 0 \rangle}, log_{data.i}^{\langle 1 \rangle}, x\right)$

$x_{p.min} := min\left(log_{data.p}^{\langle 0 \rangle}\right)$ $x_{p.max} := max\left(log_{data.p}^{\langle 0 \rangle}\right)$ $x_{i.min} := min\left(log_{data.i}^{\langle 0 \rangle}\right)$ $x_{i.max} := max\left(log_{data.i}^{\langle 0 \rangle}\right)$

$$Range2Vec(s,e,i) := \left| \begin{array}{l} count \leftarrow 0 \\ \text{for } i \in s, s+i..e \\ \quad \left| \begin{array}{l} v_{count} \leftarrow i \\ count \leftarrow count + 1 \end{array} \right. \\ v \end{array} \right.$$

$x_p := Range2Vec(x_{p.min}, x_{p.max}, 0.01)$ $z_p := \overrightarrow{10^{x_p}}$

$x_i := Range2Vec(x_{i.min}, x_{i.max}, 0.01)$ $z_i := \overrightarrow{10^{x_i}}$

$x_{min} := if(x_{p.min} > x_{i.min}, x_{p.min}, x_{i.min})$ $x_{max} := if(x_{p.max} < x_{i.max}, x_{p.max}, x_{i.max})$

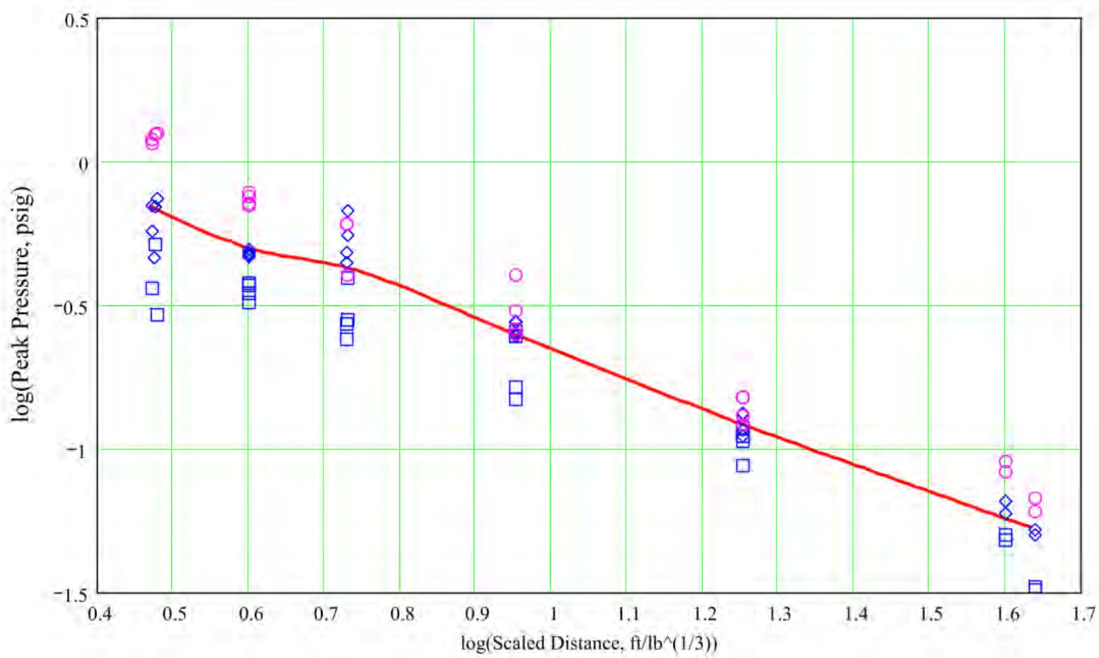
$x_{smu} := Range2Vec(x_{min}, x_{max}, 0.01)$ $P_{so.smu} := \overrightarrow{\left(10^{logPso(x_{smu})}\right)}$ $i_{s.scaled.smu} := \overrightarrow{\left(10^{logIscaled(x_{smu})}\right)}$

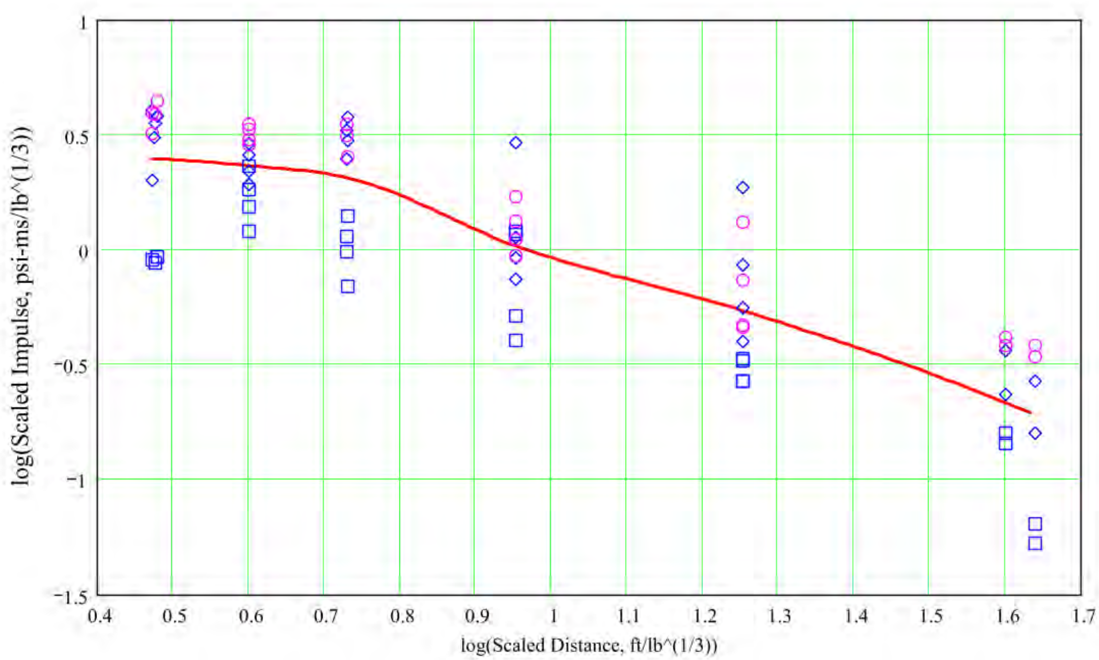
$z_{smu} := \overrightarrow{10^{x_{smu}}}$ $data_{smu} := augment(z_{smu}, P_{so.smu})$ $data_{smu} := augment(data_{smu}, i_{s.scaled.smu})$

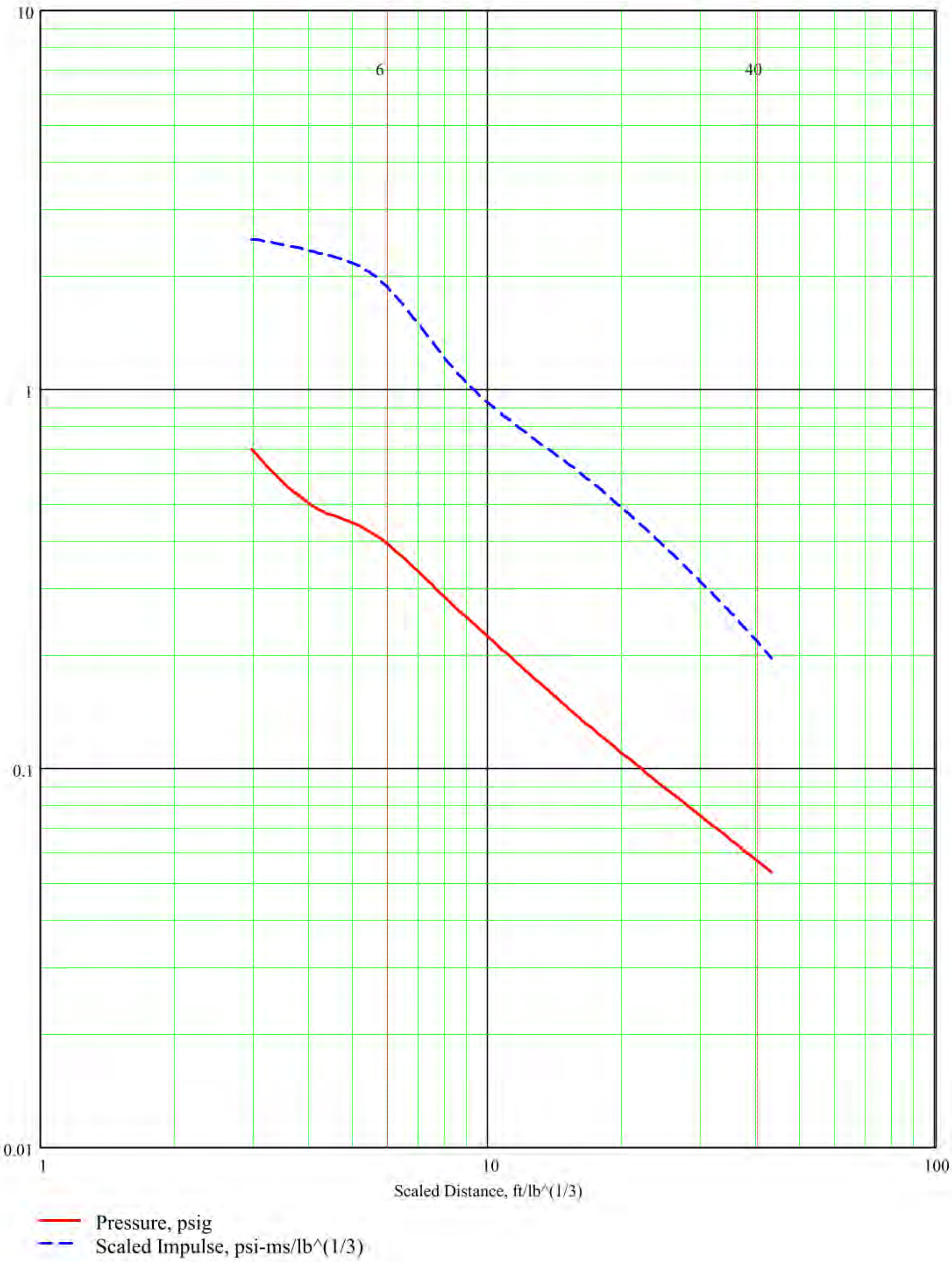
$P_{so.smu}(z) := 10^{logPso(log(z))}$ $i_{scaled.smu}(z) := 10^{logIscaled(log(z))}$

WRITEPRN("ZPIscaledData(smooth).prn") := $data_{smu}$

Plot data and smoothed fit:






10
1
0.1
0.01
1
10
100
6
40
Scaled Distance, ft/lb^(1/3)
Pressure, psig
Scaled Impulse, psi-ms/lb^(1/3)

EQUIVALENCY CALCULATIONS

Test Sample: Large-Scale Mix #7, hemispherical on surface at Sea Level
Reference: TNT, hemisphere on surface at Sea Level (UFC 3-340-02 (2008), Figure 2-15)

Blast curves for test sample:

$data_{smp} := READPRN(\text{"LS7 ZPIscaledData(smooth).prn"})$

$z_{smp} := data_{smp}^{\langle 0 \rangle}$ $P_{so.smp} := data_{smp}^{\langle 1 \rangle}$ $i_{s.scaled.smp} := data_{smp}^{\langle 2 \rangle}$

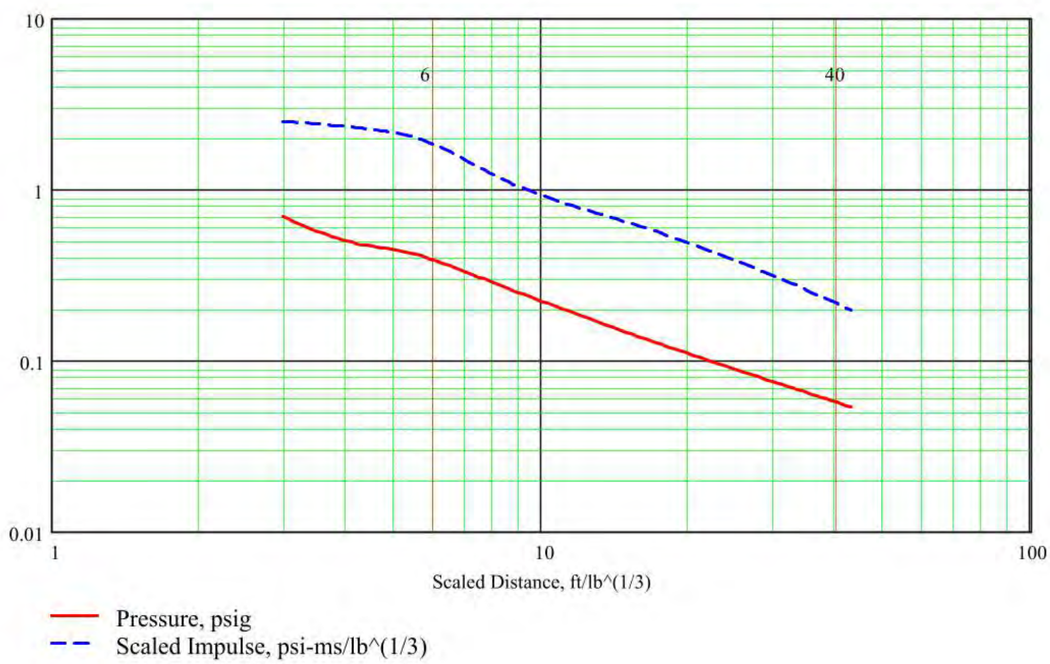
$j := 0 .. rows(z_{smp}) - 1$ $logz_{smp_j} := \log(z_{smp_j})$ $logi_{s.scaled.smp_j} := \log(i_{s.scaled.smp_j})$

$logP_{so.smp_j} := \log(P_{so.smp_j})$ $x_{smp} := \min(logz_{smp}), \min(logz_{smp}) + 0.01 .. \max(logz_{smp})$

$S1_s := lspline(logz_{smp}, logP_{so.smp})$ $S2_s := lspline(logz_{smp}, logi_{s.scaled.smp})$

$logP_{smp}(x) := interp(S1_s, logz_{smp}, logP_{so.smp}, x)$ $logI_{s.scaled.smp}(x) := interp(S2_s, logz_{smp}, logi_{s.scaled.smp}, x)$

$P_{so.smp}(z) := 10^{logP_{smp}(\log(z))}$ $i_{scaled.smp}(z) := 10^{logI_{s.scaled.smp}(\log(z))}$



Blast curves for Reference:

$data_{ref} := READPRN("UFC3-340-02Fig2-15.prn")$

$z_{ref} := data_{ref}^{\langle 0 \rangle}$ $P_{so.ref} := data_{ref}^{\langle 1 \rangle}$ $i_{s.scaled.ref} := data_{ref}^{\langle 2 \rangle}$

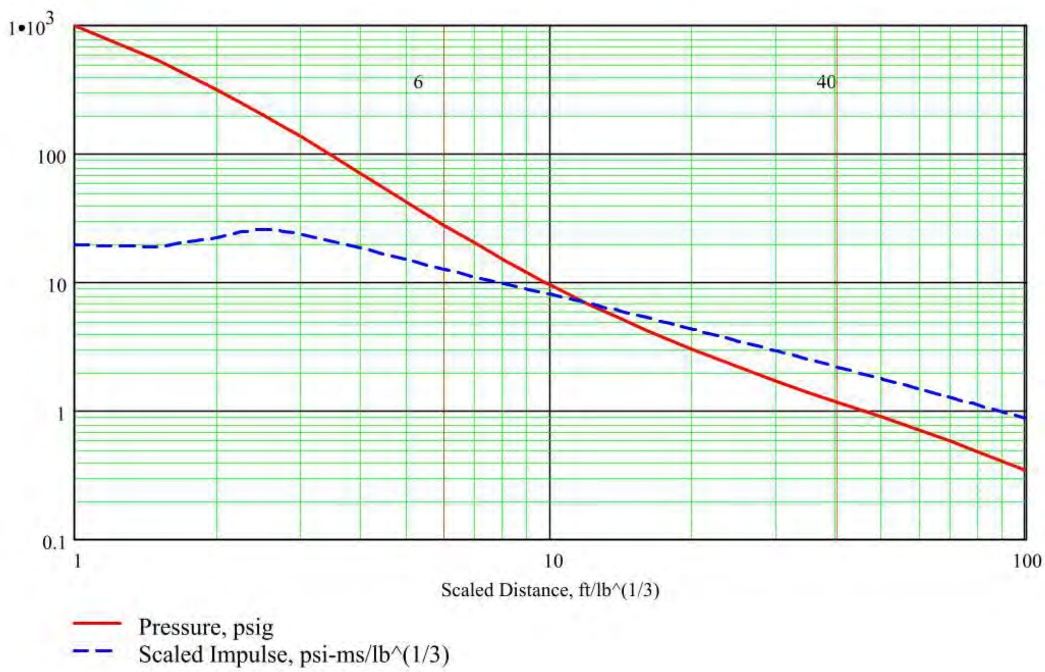
$j := 0 .. rows(z_{ref}) - 1$ $logz_{ref_j} := \log(z_{ref_j})$ $logi_{s.scaled.ref_j} := \log(i_{s.scaled.ref_j})$

$logP_{so.ref_j} := \log(P_{so.ref_j})$ $x_{ref} := \min(logz_{ref}), \min(logz_{ref}) + 0.01 .. \max(logz_{ref})$

$S1_r := lspline(logz_{ref}, logP_{so.ref})$ $S2_r := lspline(logz_{ref}, logi_{s.scaled.ref})$

$logP_{ref}(x) := interp(S1_r, logz_{ref}, logP_{so.ref}, x)$ $logI_{s.scaled.ref}(x) := interp(S2_r, logz_{ref}, logi_{s.scaled.ref}, x)$

$P_{so.ref}(z) := 10^{logP_{ref}(\log(z))}$ $i_{scaled.ref}(z) := 10^{logI_{s.scaled.ref}(\log(z))}$



$z_{min.s} := \min(z_{smp})$ $z_{min.s} = 3.0$ $z_{min.r} := \min(z_{ref})$ $z_{min.r} = 0.5$

$z_{max.s} := \max(z_{smp})$ $z_{max.s} = 43.0$ $z_{max.r} := \max(z_{ref})$ $z_{max.r} = 100.0$

$z_{min} := ceil(if(z_{min.s}>z_{min.r}, z_{min.s}, z_{min.r}))$ $z_{max} := floor(if(z_{max.s}<z_{max.r}, z_{max.s}, z_{max.r}))$

$z_{min} = 3.0$ $z_{max} = 43.0$ $l_{loop} := floor\left[\frac{(z_{max} - z_{min})}{2}\right] - 1$ $l_{loop} = 19.0$

Equivalence to Reference: $\varepsilon_{ref}(W_{ref}, W) := \frac{W_{ref}}{W}$ $R_a := \begin{bmatrix} z_{min} \\ z_{min}+1 \end{bmatrix}$

$$R_{z1} := \left| \begin{array}{l} R_b \leftarrow R_a \\ \text{for } j \in 1..l_{loop} \\ \quad \left| \begin{array}{l} R_a \leftarrow R_a + 2 \cdot j \\ R_b \leftarrow stack(R_b, R_a) \end{array} \right. \\ R_b \end{array} \right.$$

Equivalence for Peak Pressure as a function of Scaled Distance:

$W := 1$ $W_{ref} := 0.0001$ $k := 0..4$ $R_{zp_k} := R_{z1_k}$

Given $P_{so.smp}(Z(R_{zp_k}, W)) = P_{so.ref}(Z(R_{zp_k}, W_{ref}))$

$W_{p.ref_k} := find(W_{ref})$ $\varepsilon_{ref.p} := \varepsilon_{ref}(W_{p.ref}, W)$ $S3 := lspline(\overrightarrow{log(R_{zp})}, \varepsilon_{ref.p})$

$F\varepsilon_{ref.p}(x) := interp(S3, \overrightarrow{log(R_{zp})}, \varepsilon_{ref.p}, x)$ $x_{\varepsilon_k} := log(R_{zp_k})$ $mean(\varepsilon_{ref.p}) = 0.021 \cdot \%$ $np := 4$

Spot check pressure equality: $Z(R_{zp_{np}}, W) = 7.0$ $\varepsilon_{ref.p_{np}} = 0.031 \cdot \%$ $Z(R_{zp_{np}}, W_{p.ref_{np}}) = 103.3$

$$\frac{\int_{z_{min}}^{zp_{max}} F\varepsilon_{ref.p}(log(x))\,dx}{(zp_{max} - z_{min})} = 0.021 \cdot \%$$

$P_{so.smp}(Z(R_{zp_{np}}, W)) = 0.33$ $P_{so.ref}(Z(R_{zp_{np}}, W_{p.ref_{np}})) = 0.33$

RGB (226,226,226)

Equivalence for Positive Impulse as a function of Scaled Distance: $k := 0..30$ $ni := 30$

$R_{zi_k} := R_{z1_k}$ $i_{s.smp}(R, W) := i_{scaled.smp}(Z(R, W)) \cdot W^{\frac{1}{3}}$ $i_{s.ref}(R, W) := i_{scaled.ref}(Z(R, W)) \cdot W^{\frac{1}{3}}$

Given $i_{s.smp}(R_{zi_k}, W) = i_{s.ref}(R_{zi_k}, W_{ref})$ $W_{i.ref_k} := find(W_{ref})$ $\varepsilon_{ref.i} := \varepsilon_{ref}(W_{i.ref}, W)$

$S4 := lspline(\overrightarrow{log(R_{zi})}, \varepsilon_{ref.i})$ $F\varepsilon_{ref.i}(x) := interp(S4, \overrightarrow{log(R_{zi})}, \varepsilon_{ref.i}, x)$ $mean(\varepsilon_{ref.i}) = 3.6 \cdot \%$

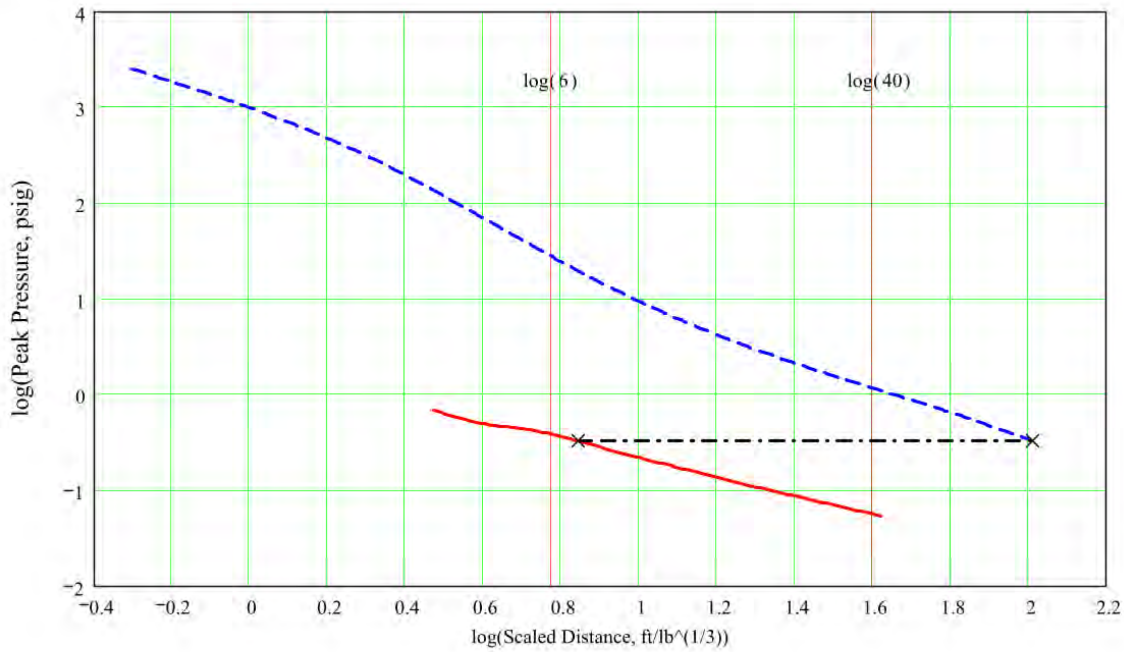
Spot check impulse equality: $Z(R_{zi_{ni}}, W) = 33.0$ $\varepsilon_{ref.i_{ni}} = 3.4 \cdot \%$ $Z(R_{zi_{ni}}, W_{i.ref_{ni}}) = 102.2$

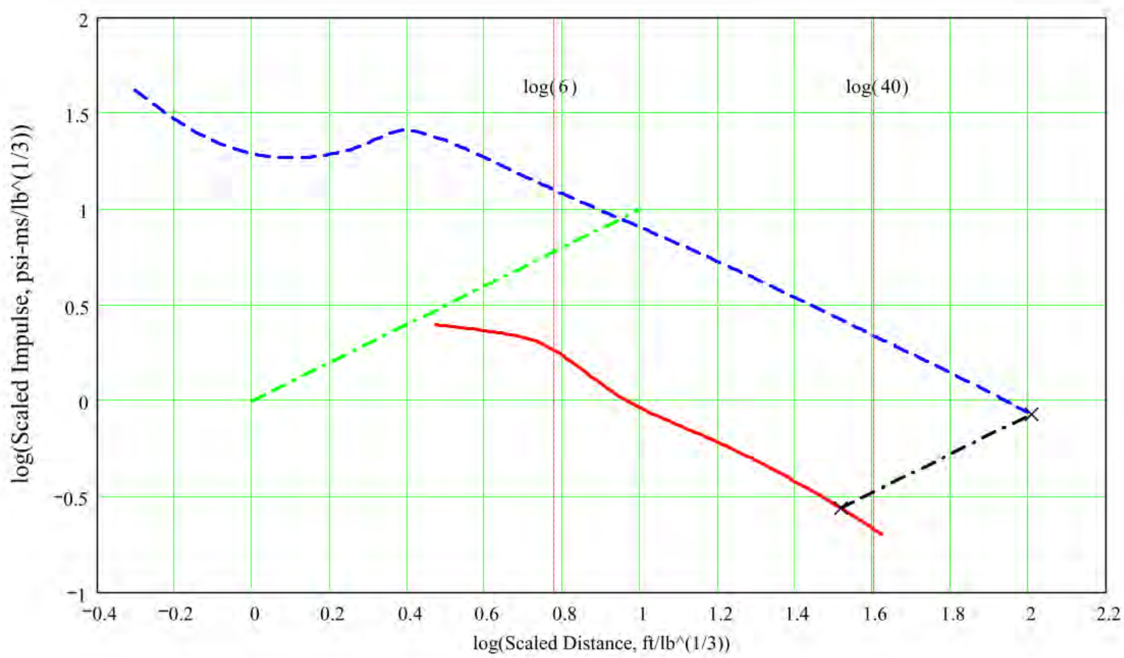
$$\frac{\int_{z_{min}}^{zi_{max}} F\varepsilon_{ref.i}(log(x))\,dx}{(zi_{max} - z_{min})} = 3.6 \cdot \%$$

$i_{s.smp}(R_{zi_{ni}}, W) = 0.28$ $i_{s.ref}(R_{zi_{ni}}, W_{i.ref_{ni}}) = 0.28$

$i_{scaled.smp}(Z(R_{zi_{ni}}, W)) = 0.28$ $i_{scaled.ref}(Z(R_{zi_{ni}}, W_{i.ref_{ni}})) = 0.86$

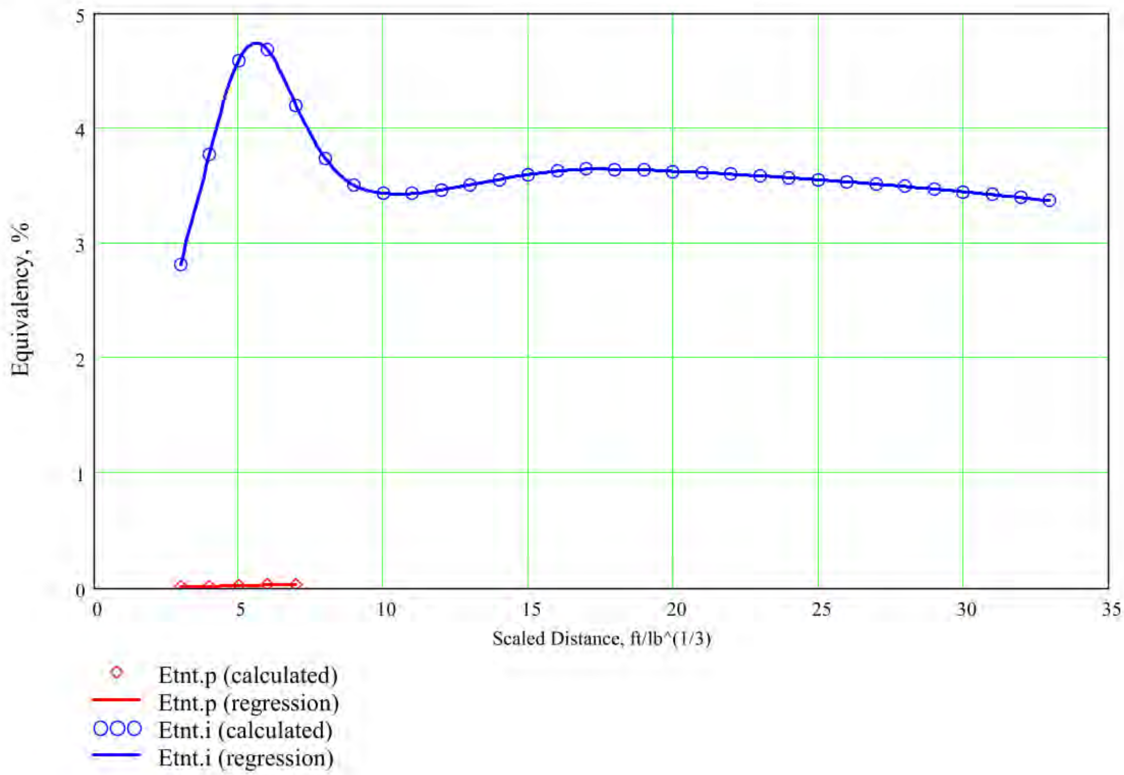
Test sample compared to Reference:





Equivalency as a Function of Scaled Distance

$z_p := z_{min}, z_{min} + 0.1 .. (np + z_{min})$ $z_i := z_{min}, z_{min} + 0.1 .. (ni + z_{min})$



9.2 Fine Mg&Al-MoO_3-CuO Thermite – Large-Scale Mix ID #8 (SMS mixed)

PRESSURE AND IMPULSE TEST DATA SMOOTHING $kPa := 1000 \cdot Pa \quad msec := 0.001 \cdot sec$

Test Sample: Large-Scale Mix #8, hemispherical on surface at the SMS Test Site in Tooele, Utah

Read in the test data summary file: $data := READPRN("DOT1\text{-}6265f\text{-}LS8\text{-}Data.prn")$ $\quad Item := data^{\langle 0 \rangle}$

NOTE: Col 1 - Item, Col 2 - Trial, Col 3 - Line, Col 4 - Station, Col 5 - Distance in feet, Col 6 - Peak Pressure in psig, Col 7 - TTL initiation time, Col 8 - time of arrival in seconds, Col 9 - time that pressure returned to ambient in seconds (impulse maxima), Col 10 - impulse in psi-msec.

Read in the test conditions file: $cond := READPRN("DOT1\text{-}6265f\text{-}LS8\text{-}TestCond.prn")$

NOTE: Col 1 - Trial, Col 2 - net explosives weight, Col 3 - temperature in Kelvin, Col 4 - pressure in inHg.

$trial := cond^{\langle 0 \rangle} \quad W_{trial} := cond^{\langle 1 \rangle} \cdot \frac{gm}{lb} \quad T_{trial} := cond^{\langle 2 \rangle} \cdot K \quad P_{trial} := cond^{\langle 3 \rangle} \cdot in\_Hg$

Initiation train: $W_{init} := (0) \cdot \frac{gm}{lb} \quad \varepsilon_{TNT.init.p} := 100\ \% \quad \varepsilon_{TNT.init.i} := 100\ \%$

Initial guess value for the product's average TNT equivalency: $\varepsilon_{TNT.p} := 2\ \% \quad \varepsilon_{TNT.i} := 11\ \%$

Net explosive weight of product:

$$W_p := W_{trial} + \frac{W_{init} \cdot \varepsilon_{TNT.init.p}}{\varepsilon_{TNT.p}} \qquad W_p = \begin{bmatrix} 19.60 \\ 19.60 \\ 19.60 \end{bmatrix} \qquad W_i := W_{trial} + \frac{W_{init} \cdot \varepsilon_{TNT.init.i}}{\varepsilon_{TNT.i}} \qquad W_i = \begin{bmatrix} 19.60 \\ 19.60 \\ 19.60 \end{bmatrix}$$

Split data sets by trial:

```
Split(data,item) := | i←0
                    | for j ∈ 0..rows(data) − 1
                    |   if data[j,0] = item
                    |     | T<i> ← (data^T)<j>
                    |     | i←i + 1
                    | Split←T^T
```

$i := 0 .. rows(trial) - 1 \qquad Set_i := Split(data, i)$

$Trial_i := (Set_i)^{\langle 1 \rangle} \quad Line_i := (Set_i)^{\langle 2 \rangle} \quad Station_i := (Set_i)^{\langle 3 \rangle}$

$R_i := (Set_i)^{\langle 4 \rangle} \quad P_{so_i} := (Set_i)^{\langle 5 \rangle} \quad t_{TTL.abs_i} := (Set_i)^{\langle 6 \rangle}$

$t_{A.abs_i} := (Set_i)^{\langle 7 \rangle} \quad t_{amb.abs_i} := (Set_i)^{\langle 8 \rangle} \quad i_{s_i} := (Set_i)^{\langle 9 \rangle}$

Calculate time of shock arrival and duration: $t_{A_i} := t_{A.abs_i} - t_{TTL.abs_i} \qquad t_{o_i} := t_{amb.abs_i} - t_{A.abs_i}$

Calculate Sachs Scaling factors to convert measurements from test site to Sea Level (SL):

$P_{SL} := 101.4 \cdot kPa$ $T_{SL} := 288.2 \cdot K$ **Pressure:** $S_{P_i} := \frac{P_{trial_i}}{P_{SL}}$ $F_{P_i} := \left(S_{P_i}\right)^{-1}$

Distance: $S_{d.p_i} := \left(W_{p_i}\right)^{\frac{1}{3}} \cdot \left(\frac{P_{SL}}{P_{trial_i}}\right)^{\frac{1}{3}}$ $F_{R.p_i} := \left(S_{d.p_i}\right)^{-1}$ $S_{d.i_i} := \left(W_{i_i}\right)^{\frac{1}{3}} \cdot \left(\frac{P_{SL}}{P_{trial_i}}\right)^{\frac{1}{3}}$ $F_{R.i_i} := \left(S_{d.i_i}\right)^{-1}$

Time: $S_{t_i} := \left(W_{p_i}\right)^{\frac{1}{3}} \cdot \left(\frac{P_{SL}}{P_{trial_i}}\right)^{\frac{1}{3}} \cdot \left(\frac{T_{SL}}{T_{trial_i}}\right)^{\frac{1}{2}}$ $F_{T_i} := \left(S_{t_i}\right)^{-1}$

Impulse: $S_{i_i} := \left(W_{i_i}\right)^{\frac{1}{3}} \cdot \left(\frac{P_{trial_i}}{P_{SL}}\right)^{\frac{2}{3}} \cdot \left(\frac{T_{SL}}{T_{trial_i}}\right)^{\frac{1}{2}}$ $F_{i_i} := \left(S_{i_i}\right)^{-1}$

$F_P^{\,T} = [\,1.007 \quad 1.007 \quad 1.008\,]$

$F_{R.p}^{\,T} = [\,0.370 \quad 0.370 \quad 0.370\,]$

$F_{R.i}^{\,T} = [\,0.370 \quad 0.370 \quad 0.370\,]$

$F_T^{\,T} = [\,0.381 \quad 0.381 \quad 0.381\,]$

$F_i^{\,T} = [\,0.383 \quad 0.383 \quad 0.383\,]$

Apply Sachs Scaling Factors to convert measurements from test site to Sea Level:

$P_{so_i} := P_{so_i} \cdot F_{P_i}$ $z_{p_i} := R_i \cdot F_{R.p_i}$ $z_{i.s_i} := R_i \cdot F_{R.i_i}$ $t_{A_i} := t_{A_i} \cdot F_{T_i}$ $t_{o_i} := t_{o_i} \cdot F_{T_i}$ $i_{s.scaled_i} := i_{s_i} \cdot F_{i_i}$

Common log of the x axes: $logz_{p_i} := \overrightarrow{\log\left(z_{p_i}\right)}$ $logz_{i.s_i} := \overrightarrow{\log\left(z_{i.s_i}\right)}$

Common log of the y axes: $logP_{so_i} := \overrightarrow{\log\left(P_{so_i}\right)}$ $logi_{s.scaled_i} := \overrightarrow{\log\left(i_{s.scaled_i}\right)}$

Reassemble data sets: $logz_{all.p} := 1$ $logP_{so.all} := 1$ $logz_{all.i} := 1$ $logi_{s.scaled.all} := 1$

$$\text{Reassemble}(A,B) := \begin{array}{|l} A \leftarrow B_0 \\ \text{for } j \in 1..\text{rows}(trial)-1 \\ \quad A \leftarrow \text{stack}(A, B_j) \\ A \end{array}$$

$logz_{all.p} := \text{Reassemble}(logz_{all.p}, logz_p)$ $logP_{so.all} := \text{Reassemble}(logP_{so.all}, logP_{so})$

$logz_{all.i} := \text{Reassemble}(logz_{all.i}, logz_{i.s})$ $logi_{s.scaled.all} := \text{Reassemble}(logi_{s.scaled.all}, logi_{s.scaled})$

Bind X-Y pairs together: $log_{data.p} := \text{augment}(logz_{all.p}, logP_{so.all})$ $log_{data.i} := \text{augment}(logz_{all.i}, logi_{s.scaled.all})$

Loess Smoothing of X-Y Data: $span_p := 0.6$ $span_i := 1.0$

$L_p := \text{loess}\left(log_{data.p}^{\langle 0\rangle}, log_{data.p}^{\langle 1\rangle}, span_p\right)$ $logPso(x) := \text{interp}\left(L_p, log_{data.p}^{\langle 0\rangle}, log_{data.p}^{\langle 1\rangle}, x\right)$

$L_i := \text{loess}\left(log_{data.i}^{\langle 0\rangle}, log_{data.i}^{\langle 1\rangle}, span_i\right)$ $logIscaled(x) := \text{interp}\left(L_i, log_{data.i}^{\langle 0\rangle}, log_{data.i}^{\langle 1\rangle}, x\right)$

$x_{p.min} := \min\left(log_{data.p}^{\langle 0\rangle}\right)$ $x_{p.max} := \max\left(log_{data.p}^{\langle 0\rangle}\right)$ $x_{i.min} := \min\left(log_{data.i}^{\langle 0\rangle}\right)$ $x_{i.max} := \max\left(log_{data.i}^{\langle 0\rangle}\right)$

$$\text{Range2Vec}(s,e,i) := \begin{array}{|l} count \leftarrow 0 \\ \text{for } i \in s, s+i..e \\ \quad \begin{array}{|l} v_{count} \leftarrow i \\ count \leftarrow count + 1 \end{array} \\ v \end{array}$$

$x_p := \text{Range2Vec}(x_{p.min}, x_{p.max}, 0.01)$ $z_p := \overrightarrow{10^{x_p}}$

$x_i := \text{Range2Vec}(x_{i.min}, x_{i.max}, 0.01)$ $z_i := \overrightarrow{10^{x_i}}$

$x_{min} := \text{if}(x_{p.min} > x_{i.min}, x_{p.min}, x_{i.min})$ $x_{max} := \text{if}(x_{p.max} < x_{i.max}, x_{p.max}, x_{i.max})$

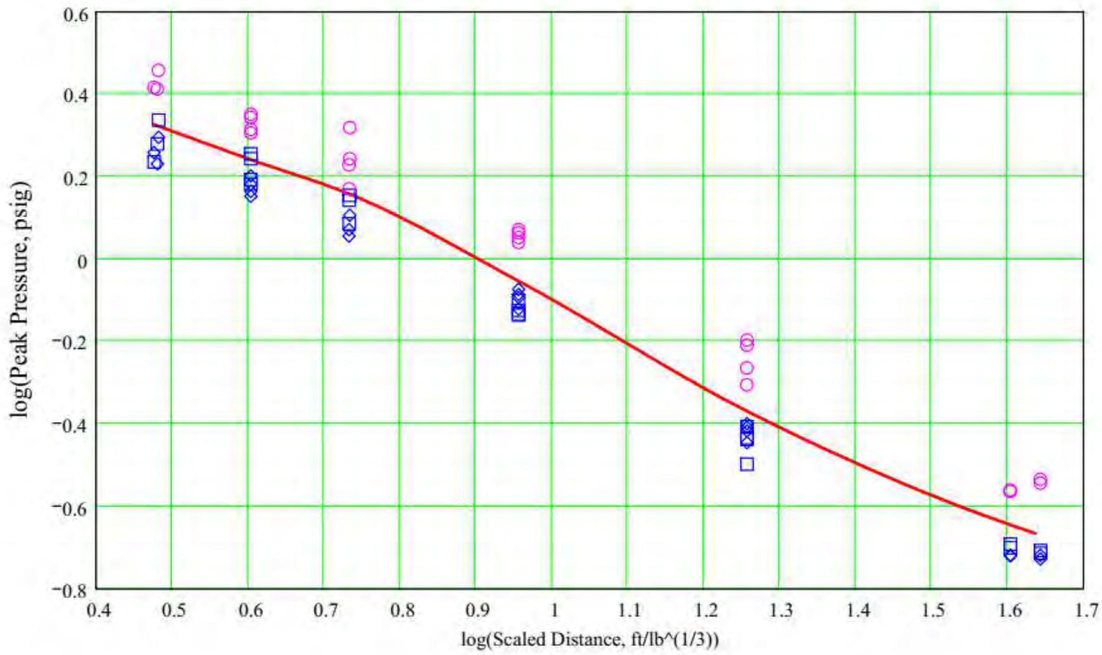
$x_{smu} := \text{Range2Vec}(x_{min}, x_{max}, 0.01)$ $P_{so.smu} := \overrightarrow{\left(10^{logPso(x_{smu})}\right)}$ $i_{s.scaled.smu} := \overrightarrow{\left(10^{logIscaled(x_{smu})}\right)}$

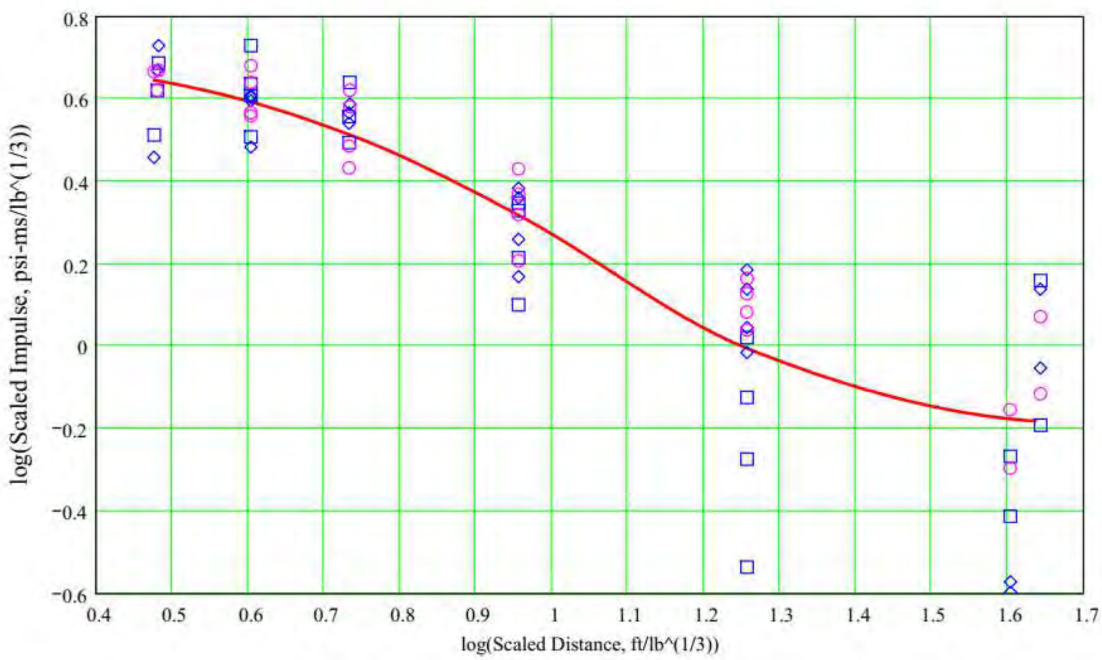
$z_{smu} := \overrightarrow{10^{x_{smu}}}$ $data_{smu} := \text{augment}(z_{smu}, P_{so.smu})$ $data_{smu} := \text{augment}(data_{smu}, i_{s.scaled.smu})$

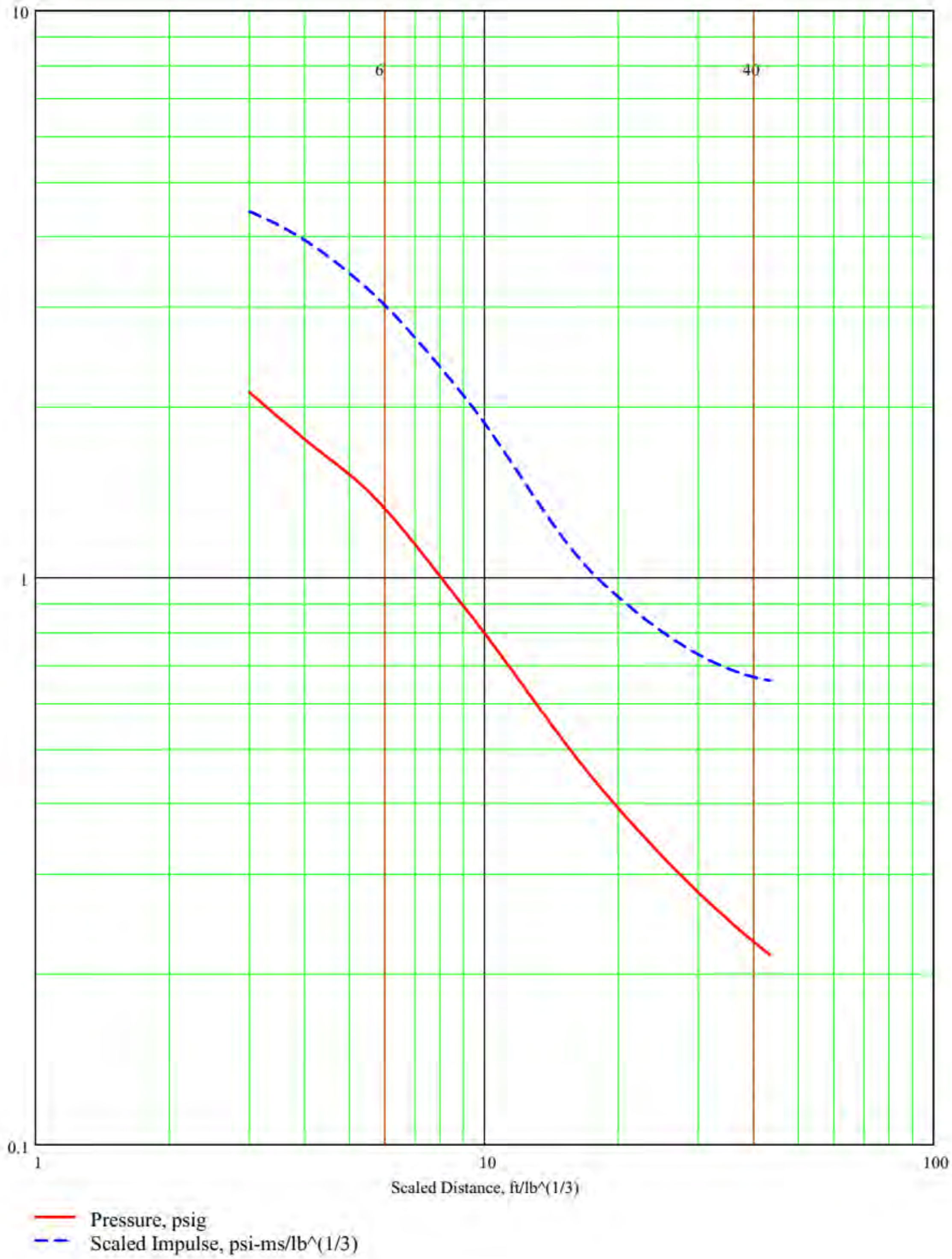
$P_{so.smu}(z) := 10^{logPso(\log(z))}$ $i_{scaled.smu}(z) := 10^{logIscaled(\log(z))}$

WRITEPRN("ZPIscaledData(smooth).prn") := $data_{smu}$

Plot data and smoothed fit:






10
1
0.1
1
10
100
6
40
Scaled Distance, ft/lb^(1/3)
Pressure, psig
Scaled Impulse, psi-ms/lb^(1/3)

EQUIVALENCY CALCULATIONS

Test Sample: Large-Scale Mix #8, hemispherical on surface at Sea Level
Reference: TNT, hemisphere on surface at Sea Level (UFC 3-340-02 (2008), Figure 2-15)

Blast curves for test sample:

$data_{smp} := READPRN(\text{"LS8-ZPIscaledData(smooth).prn"})$

$z_{smp} := data_{smp}^{\langle 0 \rangle}$ $\quad P_{so.smp} := data_{smp}^{\langle 1 \rangle}$ $\quad i_{s.scaled.smp} := data_{smp}^{\langle 2 \rangle}$

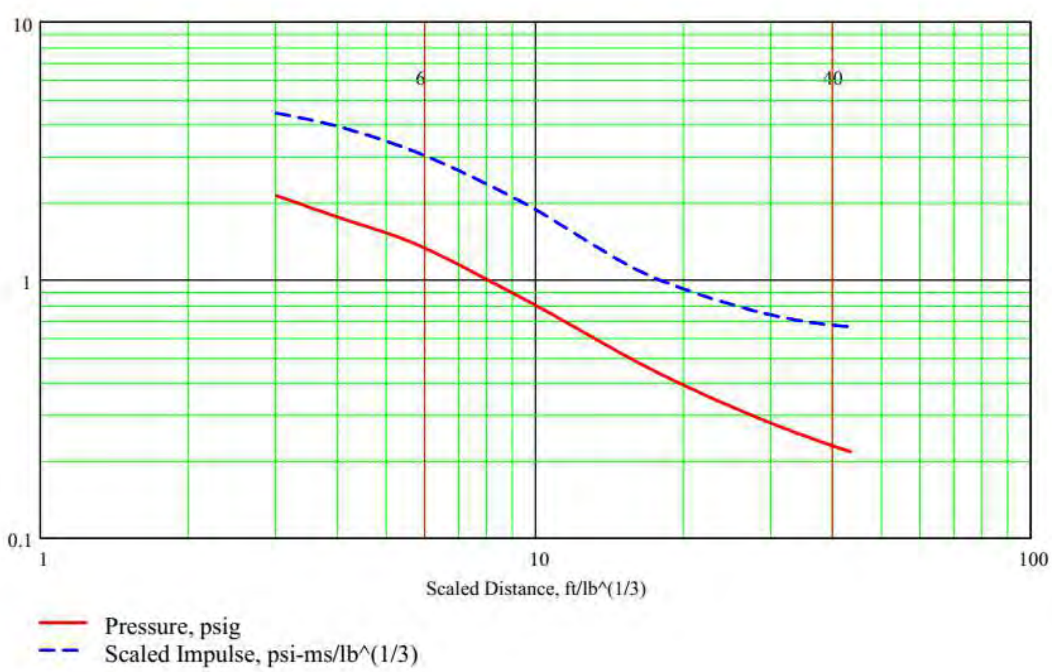
$j := 0 .. rows(z_{smp}) - 1$ $\quad logz_{smp_j} := \log(z_{smp_j})$ $\quad logi_{s.scaled.smp_j} := \log(i_{s.scaled.smp_j})$

$logP_{so.smp_j} := \log(P_{so.smp_j})$ $\quad x_{smp} := \min(logz_{smp}), \min(logz_{smp}) + 0.01 .. \max(logz_{smp})$

$S1_s := lspline(logz_{smp}, logP_{so.smp})$ $\quad S2_s := lspline(logz_{smp}, logi_{s.scaled.smp})$

$logP_{smp}(x) := interp(S1_s, logz_{smp}, logP_{so.smp}, x)$ $\quad logI_{s.scaled.smp}(x) := interp(S2_s, logz_{smp}, logi_{s.scaled.smp}, x)$

$P_{so.smp}(z) := 10^{logP_{smp}(\log(z))}$ $\quad i_{scaled.smp}(z) := 10^{logI_{s.scaled.smp}(\log(z))}$



Blast curves for Reference:

$data_{ref} := READPRN("UFC3-340-02Fig2-15.prn")$

$z_{ref} := data_{ref}^{\langle 0 \rangle}$ $P_{so.ref} := data_{ref}^{\langle 1 \rangle}$ $i_{s.scaled.ref} := data_{ref}^{\langle 2 \rangle}$

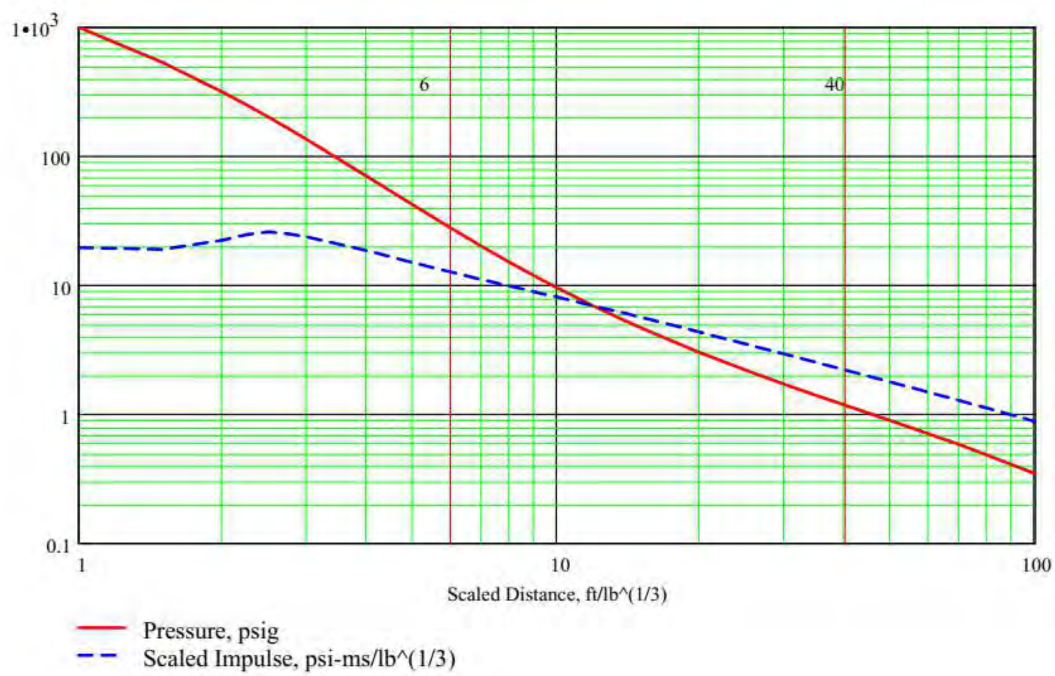
$j := 0 .. rows(z_{ref}) - 1$ $logz_{ref_j} := \log(z_{ref_j})$ $logi_{s.scaled.ref_j} := \log(i_{s.scaled.ref_j})$

$logP_{so.ref_j} := \log(P_{so.ref_j})$ $x_{ref} := \min(logz_{ref}), \min(logz_{ref}) + 0.01 .. \max(logz_{ref})$

$S1_r := lspline(logz_{ref}, logP_{so.ref})$ $S2_r := lspline(logz_{ref}, logi_{s.scaled.ref})$

$logP_{ref}(x) := interp(S1_r, logz_{ref}, logP_{so.ref}, x)$ $logI_{s.scaled.ref}(x) := interp(S2_r, logz_{ref}, logi_{s.scaled.ref}, x)$

$P_{so.ref}(z) := 10^{logP_{ref}(\log(z))}$ $i_{scaled.ref}(z) := 10^{logI_{s.scaled.ref}(\log(z))}$



$z_{min.s} := \min(z_{smp})$ $z_{min.s} = 3.0$ $z_{min.r} := \min(z_{ref})$ $z_{min.r} = 0.5$

$z_{max.s} := \max(z_{smp})$ $z_{max.s} = 43.3$ $z_{max.r} := \max(z_{ref})$ $z_{max.r} = 100.0$

$z_{min} := ceil(if(z_{min.s} > z_{min.r}, z_{min.s}, z_{min.r}))$ $z_{max} := floor(if(z_{max.s} < z_{max.r}, z_{max.s}, z_{max.r}))$

$z_{min} = 3.0$ $z_{max} = 43.0$ $l_{loop} := floor\left[\frac{(z_{max} - z_{min})}{2}\right] - 1$ $l_{loop} = 19.0$

Equivalence to Reference: $\varepsilon_{ref}(W_{ref}, W) := \frac{W_{ref}}{W}$ $R_a := \begin{bmatrix} z_{min} \\ z_{min} + 1 \end{bmatrix}$

$$R_{z1} := \begin{array}{|l} R_b \leftarrow R_a \\ \text{for } j \in 1..l_{loop} \\ \quad \begin{array}{|l} R_a \leftarrow R_a + 2 \cdot j \\ R_b \leftarrow stack(R_b, R_a) \end{array} \\ R_b \end{array}$$

Equivalence for Peak Pressure as a function of Scaled Distance:

$W := 1$ $W_{ref} := 0.002$ $np := 24$ $k := 0..np$ $R_{zp_k} := R_{z1_k}$

Given $P_{so.smp}(Z(R_{zp_k}, W)) = P_{so.ref}(Z(R_{zp_k}, W_{ref}))$

$W_{p.ref_k} := find(W_{ref})$ $\varepsilon_{ref.p} := \varepsilon_{ref}(W_{p.ref}, W)$ $S3 := lspline(\overrightarrow{log(R_{zp})}, \varepsilon_{ref.p})$

$F\varepsilon_{ref.p}(x) := interp(S3, \overrightarrow{log(R_{zp})}, \varepsilon_{ref.p}, x)$ $x_{\varepsilon_k} := log(R_{zp_k})$ $mean(\varepsilon_{ref.p}) = 0.82 \cdot \%$

Spot check pressure equality:

$Z(R_{zp_{np}}, W) = 27.0$ $\varepsilon_{ref.p_{np}} = 1.477 \cdot \%$ $Z(R_{zp_{np}}, W_{p.ref_{np}}) = 110.1$

$$\frac{\int_{z_{min}}^{zp_{max}} F\varepsilon_{ref.p}(log(x))\,dx}{(zp_{max} - z_{min})} = 0.82 \cdot \%$$

$P_{so.smp}(Z(R_{zp_{np}}, W)) = 0.30$ $P_{so.ref}(Z(R_{zp_{np}}, W_{p.ref_{np}})) = 0.30$

RGB (226,226,226)

Equivalence for Positive Impulse as a function of Scaled Distance: $ni := 39$ $k := 0..ni$

$R_{zi_k} := R_{z1_k}$ $i_{s.smp}(R, W) := i_{scaled.smp}(Z(R, W)) \cdot W^{\frac{1}{3}}$ $i_{s.ref}(R, W) := i_{scaled.ref}(Z(R, W)) \cdot W^{\frac{1}{3}}$

Given $i_{s.smp}(R_{zi_k}, W) = i_{s.ref}(R_{zi_k}, W_{ref})$ $W_{i.ref_k} := find(W_{ref})$ $\varepsilon_{ref.i} := \varepsilon_{ref}(W_{i.ref}, W)$

$S4 := lspline(\overrightarrow{log(R_{zi})}, \varepsilon_{ref.i})$ $F\varepsilon_{ref.i}(x) := interp(S4, \overrightarrow{log(R_{zi})}, \varepsilon_{ref.i}, x)$ $mean(\varepsilon_{ref.i}) = 11.5 \cdot \%$

Spot check impulse equality:

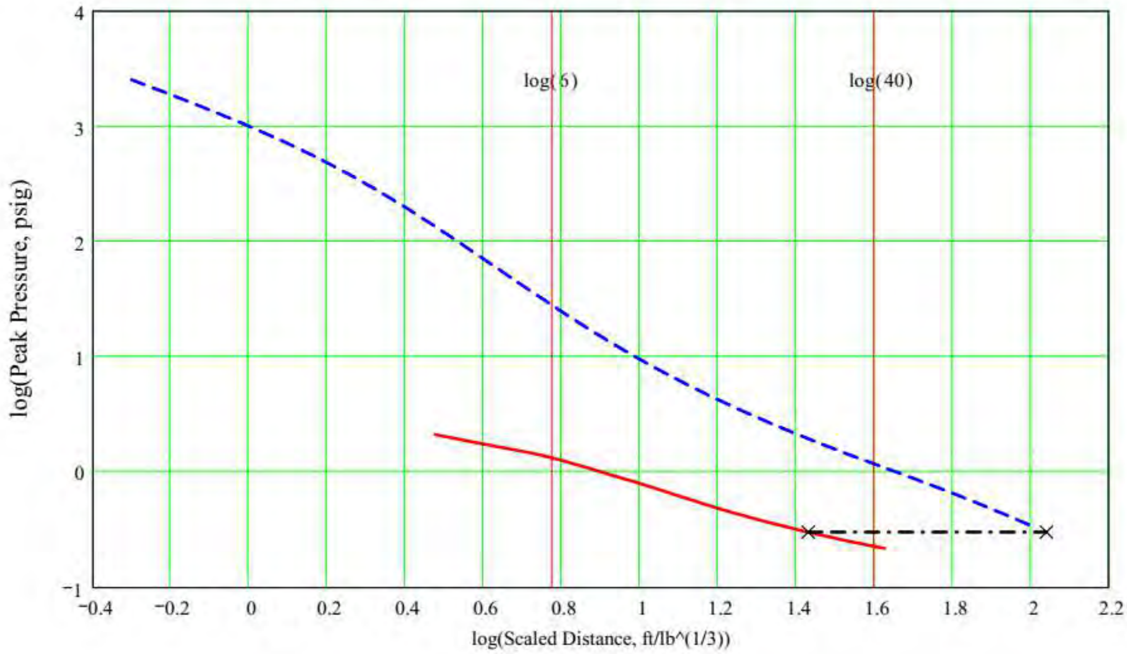
$Z(R_{zi_{ni}}, W) = 42.0$ $\varepsilon_{ref.i_{ni}} = 17.6 \cdot \%$ $Z(R_{zi_{ni}}, W_{i.ref_{ni}}) = 75.0$

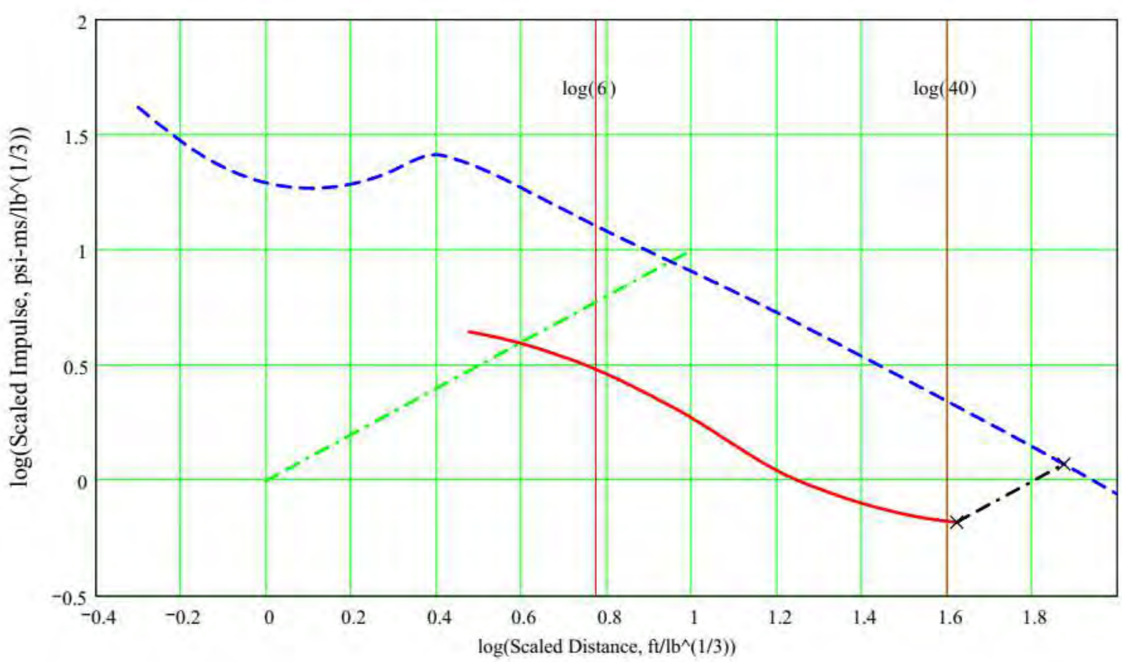
$$\frac{\int_{z_{min}}^{zi_{max}} F\varepsilon_{ref.i}(log(x))\,dx}{(zi_{max} - z_{min})} = 11.4 \cdot \%$$

$i_{s.smp}(R_{zi_{ni}}, W) = 0.66$ $i_{s.ref}(R_{zi_{ni}}, W_{i.ref_{ni}}) = 0.66$

$i_{scaled.smp}(Z(R_{zi_{ni}}, W)) = 0.66$ $i_{scaled.ref}(Z(R_{zi_{ni}}, W_{i.ref_{ni}})) = 1.18$

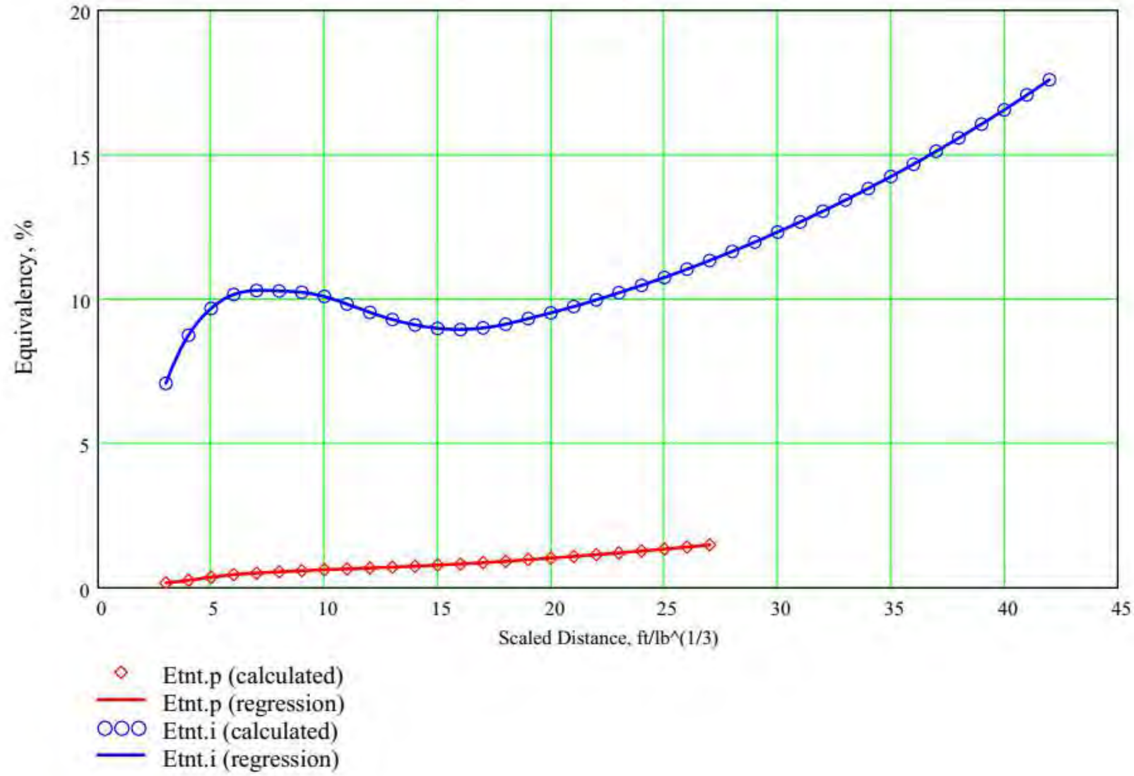
Test sample compared to Reference:





Equivalency as a Function of Scaled Distance

$z_p := z_{min}, z_{min} + 0.1 .. (np + z_{min})$ $z_i := z_{min}, z_{min} + 0.1 .. (ni + z_{min})$



9.3 Fine Mg-MnO_2 Thermite – Small-Scale Mix ID #4 (SMS mixed)

PRESSURE AND IMPULSE TEST DATA SMOOTHING $kPa := 1000 \cdot Pa \quad msec := 0.001 \cdot sec$

Test Sample: Small-Scale Mix #4, hemispherical on surface at the SMS Test Site in Tooele, Utah

Read in the test data summary file: $data := READPRN("DOT1\text{-}6265f\text{-}SS4\text{-}Data.prn")$ $\quad Item := data^{\langle 0 \rangle}$

NOTE: Col 1 - Item, Col 2 - Trial, Col 3 - Line, Col 4 - Station, Col 5 - Distance in feet, Col 6 - Peak Pressure in psig, Col 7 - TTL initiation time, Col 8 - time of arrival in seconds, Col 9 - time that pressure returned to ambient in seconds (impulse maxima), Col 10 - impulse in psi-msec.

Read in the test conditions file: $cond := READPRN("DOT1\text{-}6265f\text{-}SS4\text{-}TestCond.prn")$

NOTE: Col 1 - Trial, Col 2 - net explosives weight, Col 3 - temperature in Kelvin, Col 4 - pressure in inHg.

$trial := cond^{\langle 0 \rangle} \quad W_{trial} := cond^{\langle 1 \rangle} \cdot \frac{gm}{lb} \quad T_{trial} := cond^{\langle 2 \rangle} \cdot K \quad P_{trial} := cond^{\langle 3 \rangle} \cdot in\_Hg$

Initiation train: $W_{init} := (0) \cdot \frac{gm}{lb} \quad \varepsilon_{TNT.init.p} := 100\ \% \quad \varepsilon_{TNT.init.i} := 100\ \%$

Initial guess value for the product's average TNT equivalency: $\varepsilon_{TNT.p} := 0\ \% \quad \varepsilon_{TNT.i} := 3\ \%$

Net explosive weight of product:

$$W_p := W_{trial} + \frac{W_{init} \cdot \varepsilon_{TNT.init.p}}{\varepsilon_{TNT.p}} \quad W_p = \begin{bmatrix} 20.00 \\ 20.00 \\ 20.00 \end{bmatrix} \quad W_i := W_{trial} + \frac{W_{init} \cdot \varepsilon_{TNT.init.i}}{\varepsilon_{TNT.i}} \quad W_i = \begin{bmatrix} 20.00 \\ 20.00 \\ 20.00 \end{bmatrix}$$

Split data sets by trial:

```
Split(data,item) := | i←0
                    | for j ∈ 0..rows(data) − 1
                    |   if data[j,0] = item
                    |     | T<i> ← (data^T)<j>
                    |     | i ← i + 1
                    | Split ← T^T
```

$i := 0 .. rows(trial) - 1 \quad Set_i := Split(data, i)$

$Trial_i := (Set_i)^{\langle 1 \rangle} \quad Line_i := (Set_i)^{\langle 2 \rangle} \quad Station_i := (Set_i)^{\langle 3 \rangle}$

$R_i := (Set_i)^{\langle 4 \rangle} \quad P_{so_i} := (Set_i)^{\langle 5 \rangle} \quad t_{TTL.abs_i} := (Set_i)^{\langle 6 \rangle}$

$t_{A.abs_i} := (Set_i)^{\langle 7 \rangle} \quad t_{amb.abs_i} := (Set_i)^{\langle 8 \rangle} \quad i_{s_i} := (Set_i)^{\langle 9 \rangle}$

Calculate time of shock arrival and duration: $t_{A_i} := t_{A.abs_i} - t_{TTL.abs_i} \quad t_{o_i} := t_{amb.abs_i} - t_{A.abs_i}$

Calculate Sachs Scaling factors to convert measurements from test site to Sea Level (SL):

$P_{SL} := 101.4 \cdot kPa$ $\quad T_{SL} := 288.2 \cdot K$ $\quad$ **Pressure:** $S_{P_i} := \frac{P_{trial_i}}{P_{SL}}$ $\quad F_{P_i} := \left(S_{P_i}\right)^{-1}$

Distance: $S_{d.p_i} := \left(W_{p_i}\right)^{\frac{1}{3}} \cdot \left(\frac{P_{SL}}{P_{trial_i}}\right)^{\frac{1}{3}}$ $\quad F_{R.p_i} := \left(S_{d.p_i}\right)^{-1}$ $\quad S_{d.i_i} := \left(W_{i_i}\right)^{\frac{1}{3}} \cdot \left(\frac{P_{SL}}{P_{trial_i}}\right)^{\frac{1}{3}}$ $\quad F_{R.i_i} := \left(S_{d.i_i}\right)^{-1}$

Time: $S_{t_i} := \left(W_{p_i}\right)^{\frac{1}{3}} \cdot \left(\frac{P_{SL}}{P_{trial_i}}\right)^{\frac{1}{3}} \cdot \left(\frac{T_{SL}}{T_{trial_i}}\right)^{\frac{1}{2}}$ $\quad F_{T_i} := \left(S_{t_i}\right)^{-1}$

Impulse: $S_{i_i} := \left(W_{i_i}\right)^{\frac{1}{3}} \cdot \left(\frac{P_{trial_i}}{P_{SL}}\right)^{\frac{2}{3}} \cdot \left(\frac{T_{SL}}{T_{trial_i}}\right)^{\frac{1}{2}}$ $\quad F_{i_i} := \left(S_{i_i}\right)^{-1}$

$F_P^T = [\ 1.006 \quad 1.006 \quad 1.001\ ]$

$F_{R.p}^T = [\ 0.368 \quad 0.368 \quad 0.368\ ]$

$F_{R.i}^T = [\ 0.368 \quad 0.368 \quad 0.368\ ]$

$F_T^T = [\ 0.376 \quad 0.376 \quad 0.380\ ]$

$F_i^T = [\ 0.379 \quad 0.379 \quad 0.380\ ]$

Apply Sachs Scaling Factors to convert measurements from test site to Sea Level:

$P_{so_i} := P_{so_i} \cdot F_{P_i}$ $\quad z_{p_i} := R_i \cdot F_{R.p_i}$ $\quad z_{i.s_i} := R_i \cdot F_{R.i_i}$ $\quad t_{A_i} := t_{A_i} \cdot F_{T_i}$ $\quad t_{o_i} := t_{o_i} \cdot F_{T_i}$ $\quad i_{s.scaled_i} := i_{s_i} \cdot F_{i_i}$

Common log of the x axes: $\quad logz_{p_i} := \overrightarrow{\log\left(z_{p_i}\right)}$ $\quad logz_{i.s_i} := \overrightarrow{\log\left(z_{i.s_i}\right)}$

Common log of the y axes: $\quad logP_{so_i} := \overrightarrow{\log\left(P_{so_i}\right)}$ $\quad logi_{s.scaled_i} := \overrightarrow{\log\left(i_{s.scaled_i}\right)}$

Reassemble data sets: $logz_{all.p} := 1$ $logP_{so.all} := 1$ $logz_{all.i} := 1$ $logi_{s.scaled.all} := 1$

```
Reassemble(A,B) := | A←B_0
                   | for j ∈ 1 .. rows(trial) − 1
                   |   A←stack(A,B_j)
                   | A
```

$logz_{all.p} := Reassemble(logz_{all.p}, logz_p)$ $logP_{so.all} := Reassemble(logP_{so.all}, logP_{so})$

$logz_{all.i} := Reassemble(logz_{all.i}, logz_{i.s})$ $logi_{s.scaled.all} := Reassemble(logi_{s.scaled.all}, logi_{s.scaled})$

Bind X-Y pairs together: $log_{data.p} := augment(logz_{all.p}, logP_{so.all})$ $log_{data.i} := augment(logz_{all.i}, logi_{s.scaled.all})$

Loess Smoothing of X-Y Data: $span_p := 0.85$ $span_i := 0.85$

$L_p := loess(log_{data.p}^{\langle 0 \rangle}, log_{data.p}^{\langle 1 \rangle}, span_p)$ $logPso(x) := interp(L_p, log_{data.p}^{\langle 0 \rangle}, log_{data.p}^{\langle 1 \rangle}, x)$

$L_i := loess(log_{data.i}^{\langle 0 \rangle}, log_{data.i}^{\langle 1 \rangle}, span_i)$ $logIscaled(x) := interp(L_i, log_{data.i}^{\langle 0 \rangle}, log_{data.i}^{\langle 1 \rangle}, x)$

$x_{p.min} := min(log_{data.p}^{\langle 0 \rangle})$ $x_{p.max} := max(log_{data.p}^{\langle 0 \rangle})$ $x_{i.min} := min(log_{data.i}^{\langle 0 \rangle})$ $x_{i.max} := max(log_{data.i}^{\langle 0 \rangle})$

```
Range2Vec(s,e,i) := | count←0
                    | for i ∈ s, s + i .. e
                    |   | v_count←i
                    |   | count←count + 1
                    | v
```

$x_p := Range2Vec(x_{p.min}, x_{p.max}, 0.01)$ $z_p := \overrightarrow{10^{x_p}}$

$x_i := Range2Vec(x_{i.min}, x_{i.max}, 0.01)$ $z_i := \overrightarrow{10^{x_i}}$

$x_{min} := if(x_{p.min} > x_{i.min}, x_{p.min}, x_{i.min})$ $x_{max} := if(x_{p.max} < x_{i.max}, x_{p.max}, x_{i.max})$

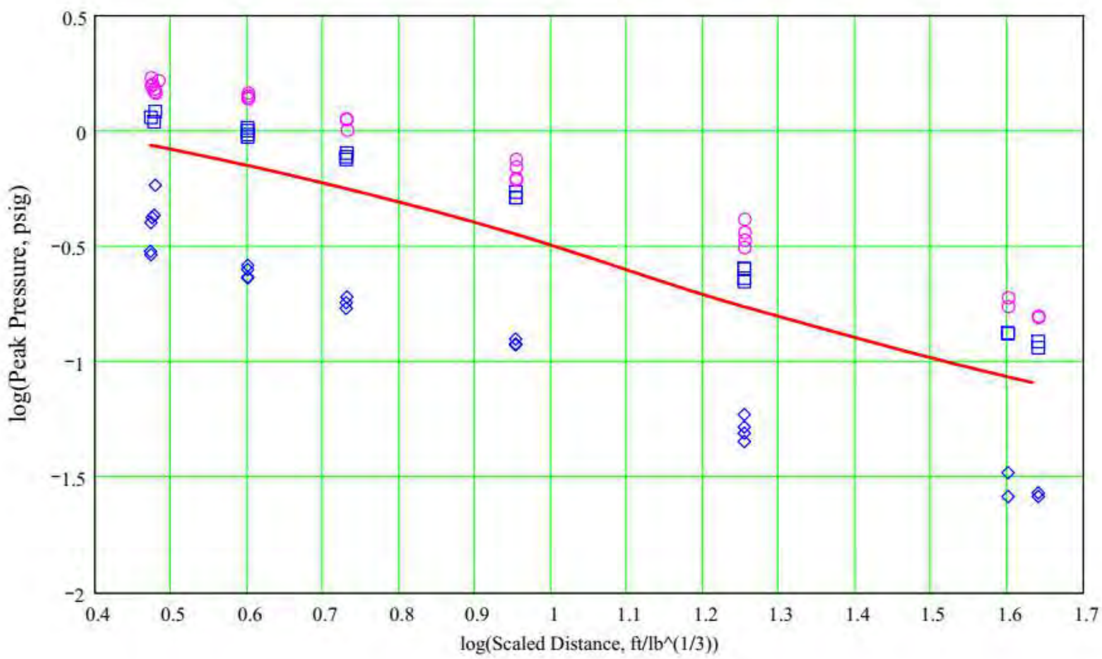
$x_{smu} := Range2Vec(x_{min}, x_{max}, 0.01)$ $P_{so.smu} := \overrightarrow{\left(10^{logPso(x_{smu})}\right)}$ $i_{s.scaled.smu} := \overrightarrow{\left(10^{logIscaled(x_{smu})}\right)}$

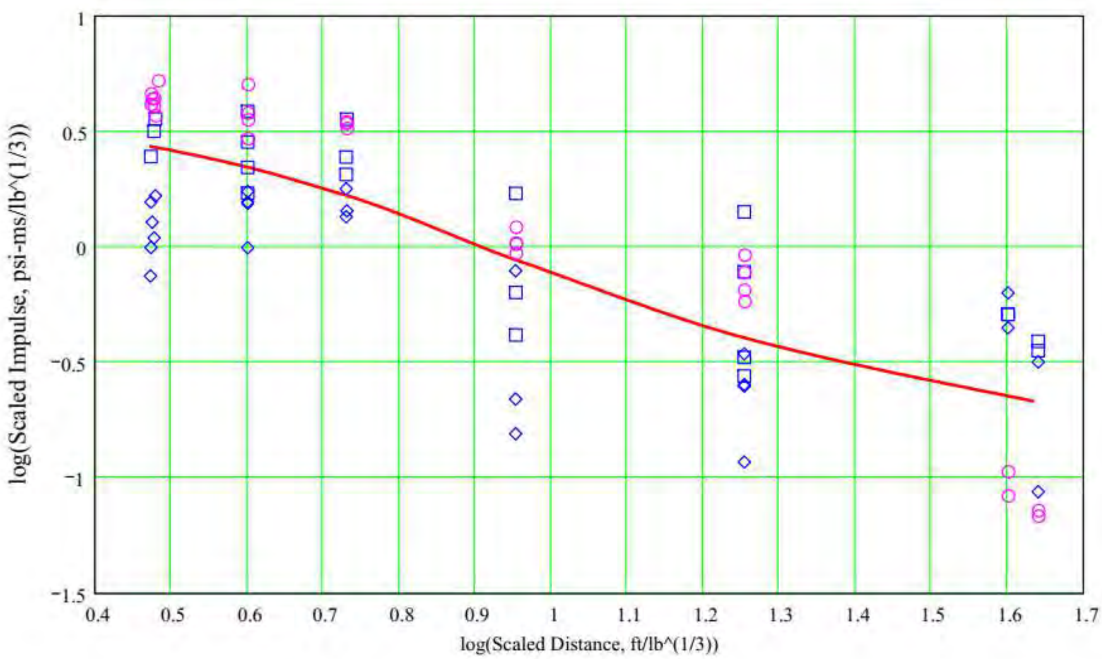
$z_{smu} := \overrightarrow{10^{x_{smu}}}$ $data_{smu} := augment(z_{smu}, P_{so.smu})$ $data_{smu} := augment(data_{smu}, i_{s.scaled.smu})$

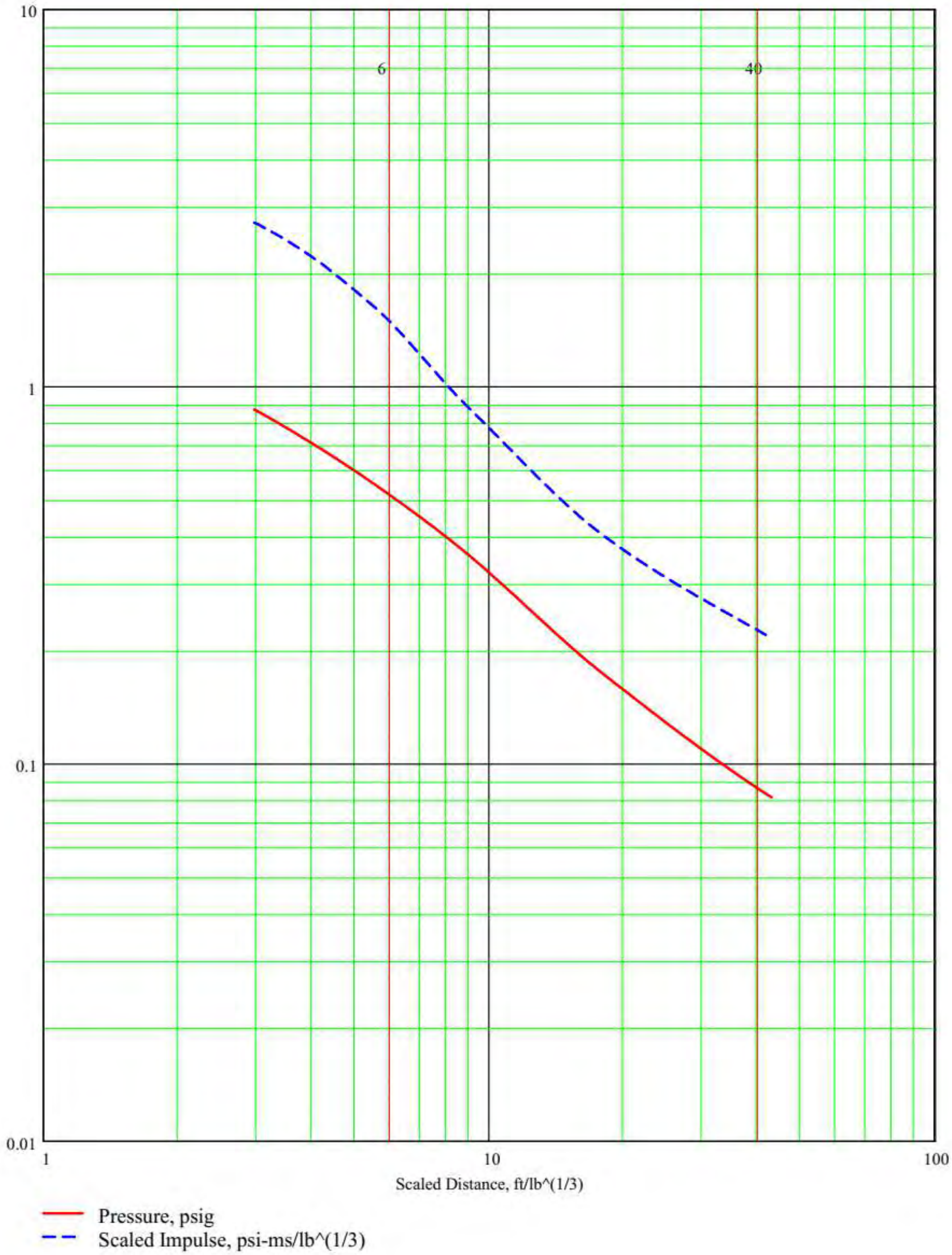
$P_{so.smu}(z) := 10^{logPso(log(z))}$ $i_{scaled.smu}(z) := 10^{logIscaled(log(z))}$

WRITEPRN("ZPIscaledData(smooth).prn") := $data_{smu}$

Plot data and smoothed fit:






10
1
0.1
0.01
1
10
100
6
40
Scaled Distance, ft/lb^(1/3)
Pressure, psig
Scaled Impulse, psi-ms/lb^(1/3)

EQUIVALENCY CALCULATIONS

Test Sample: Small-Scale Mix #4, hemispherical on surface at Sea Level
Reference: TNT, hemisphere on surface at Sea Level (UFC 3-340-02 (2008), Figure 2-15)

Blast curves for test sample:

$data_{smp} := READPRN(\text{"SS4 ZPIscaledData(smooth).prn"})$

$z_{smp} := data_{smp}^{\langle 0 \rangle}$ $\quad P_{so.smp} := data_{smp}^{\langle 1 \rangle}$ $\quad i_{s.scaled.smp} := data_{smp}^{\langle 2 \rangle}$

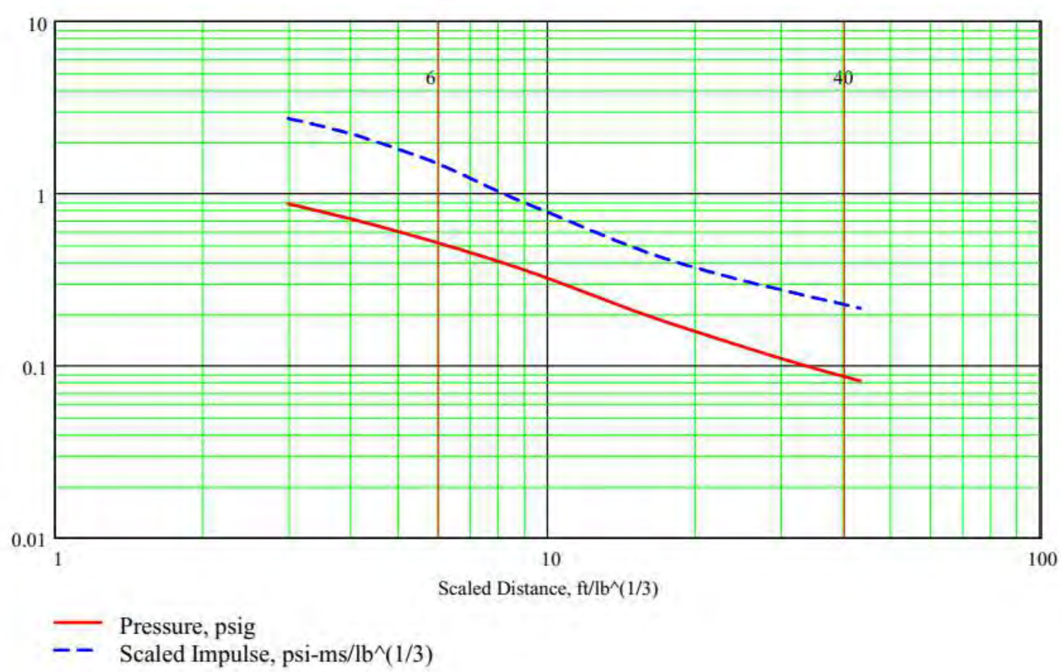
$j := 0 .. rows(z_{smp}) - 1$ $\quad logz_{smp_j} := \log(z_{smp_j})$ $\quad logi_{s.scaled.smp_j} := \log(i_{s.scaled.smp_j})$

$logP_{so.smp_j} := \log(P_{so.smp_j})$ $\quad x_{smp} := \min(logz_{smp}), \min(logz_{smp}) + 0.01 .. \max(logz_{smp})$

$S1_s := lspline(logz_{smp}, logP_{so.smp})$ $\quad S2_s := lspline(logz_{smp}, logi_{s.scaled.smp})$

$logP_{smp}(x) := interp(S1_s, logz_{smp}, logP_{so.smp}, x)$ $\quad logI_{s.scaled.smp}(x) := interp(S2_s, logz_{smp}, logi_{s.scaled.smp}, x)$

$P_{so.smp}(z) := 10^{logP_{smp}(\log(z))}$ $\quad i_{scaled.smp}(z) := 10^{logI_{s.scaled.smp}(\log(z))}$



Blast curves for Reference:

$data_{ref} := READPRN("UFC3-340-02Fig2-15.prn")$

$z_{ref} := data_{ref}^{\langle 0 \rangle}$ $P_{so.ref} := data_{ref}^{\langle 1 \rangle}$ $i_{s.scaled.ref} := data_{ref}^{\langle 2 \rangle}$

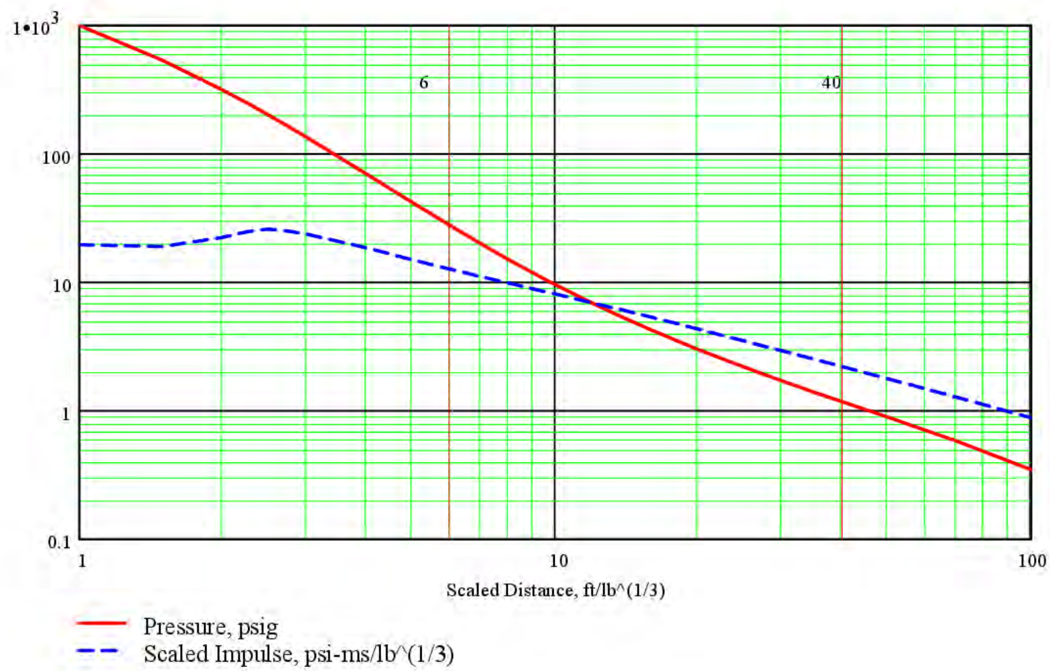
$j := 0 .. rows(z_{ref}) - 1$ $logz_{ref_j} := \log(z_{ref_j})$ $logi_{s.scaled.ref_j} := \log(i_{s.scaled.ref_j})$

$logP_{so.ref_j} := \log(P_{so.ref_j})$ $x_{ref} := \min(logz_{ref}), \min(logz_{ref}) + 0.01 .. \max(logz_{ref})$

$S1_r := lspline(logz_{ref}, logP_{so.ref})$ $S2_r := lspline(logz_{ref}, logi_{s.scaled.ref})$

$logP_{ref}(x) := interp(S1_r, logz_{ref}, logP_{so.ref}, x)$ $logI_{s.scaled.ref}(x) := interp(S2_r, logz_{ref}, logi_{s.scaled.ref}, x)$

$P_{so.ref}(z) := 10^{logP_{ref}(\log(z))}$ $i_{scaled.ref}(z) := 10^{logI_{s.scaled.ref}(\log(z))}$



$z_{min.s} := \min(z_{smp})$ $z_{min.s} = 3.0$ $z_{min.r} := \min(z_{ref})$ $z_{min.r} = 0.5$

$z_{max.s} := \max(z_{smp})$ $z_{max.s} = 43.0$ $z_{max.r} := \max(z_{ref})$ $z_{max.r} = 100.0$

$z_{min} := ceil(if(z_{min.s} > z_{min.r}, z_{min.s}, z_{min.r}))$ $z_{max} := floor(if(z_{max.s} < z_{max.r}, z_{max.s}, z_{max.r}))$

$z_{min} = 3.0$ $z_{max} = 42.0$ $l_{loop} := floor\left[\frac{(z_{max} - z_{min})}{2}\right] - 1$ $l_{loop} = 18.0$

Equivalence to Reference: $\varepsilon_{ref}(W_{ref}, W) := \frac{W_{ref}}{W}$ $R_a := \begin{bmatrix} z_{min} \\ z_{min} + 1 \end{bmatrix}$ $R_{z1} := \begin{vmatrix} R_b \leftarrow R_a \\ \text{for } j \in 1..l_{loop} \\ \quad R_a \leftarrow R_a + 2 \cdot j \\ \quad R_b \leftarrow stack(R_b, R_a) \\ R_b \end{vmatrix}$

Equivalence for Peak Pressure as a function of Scaled Distance:

$W := 1$ $W_{ref} := 0.0001$ $k := 0..8$ $R_{zp_k} := R_{z1_k}$

Given $P_{so.smp}(Z(R_{zp_k}, W)) = P_{so.ref}(Z(R_{zp_k}, W_{ref}))$

$W_{p.ref_k} := find(W_{ref})$ $\varepsilon_{ref.p} := \varepsilon_{ref}(W_{p.ref}, W)$ $S3 := lspline(\overrightarrow{log(R_{zp})}, \varepsilon_{ref.p})$

$F\varepsilon_{ref.p}(x) := interp(S3, \overrightarrow{log(R_{zp})}, \varepsilon_{ref.p}, x)$ $x_{\varepsilon_k} := log(R_{zp_k})$ $mean(\varepsilon_{ref.p}) = 0.058 \cdot \%$ $np := 8$

Spot check pressure equality: $Z(R_{zp_{np}}, W) = 11.0$ $\varepsilon_{ref.p_{np}} = 0.092 \cdot \%$ $Z(R_{zp_{np}}, W_{p.ref_{np}}) = 113.1$

$$\frac{\int_{z_{min}}^{zp_{max}} F\varepsilon_{ref.p}(log(x))\,dx}{(zp_{max} - z_{min})} = 0.058 \cdot \%$$

$P_{so.smp}(Z(R_{zp_{np}}, W)) = 0.29$ $P_{so.ref}(Z(R_{zp_{np}}, W_{p.ref_{np}})) = 0.29$

RGB (226,226,226)

Equivalence for Positive Impulse as a function of Scaled Distance: $k := 0..28$ $ni := 28$

$R_{zi_k} := R_{z1_k}$ $i_{s.smp}(R, W) := i_{scaled.smp}(Z(R, W)) \cdot W^{\frac{1}{3}}$ $i_{s.ref}(R, W) := i_{scaled.ref}(Z(R, W)) \cdot W^{\frac{1}{3}}$

Given $i_{s.smp}(R_{zi_k}, W) = i_{s.ref}(R_{zi_k}, W_{ref})$ $W_{i.ref_k} := find(W_{ref})$ $\varepsilon_{ref.i} := \varepsilon_{ref}(W_{i.ref}, W)$

$S4 := lspline(\overrightarrow{log(R_{zi})}, \varepsilon_{ref.i})$ $F\varepsilon_{ref.i}(x) := interp(S4, \overrightarrow{log(R_{zi})}, \varepsilon_{ref.i}, x)$ $mean(\varepsilon_{ref.i}) = 2.7 \cdot \%$

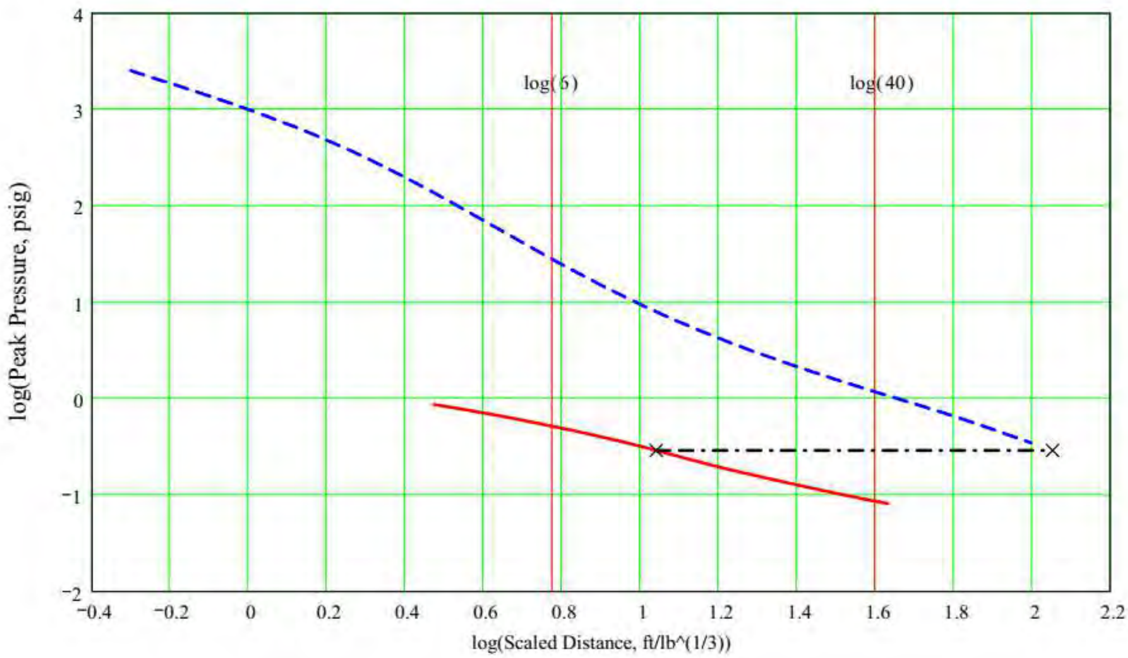
Spot check impulse equality: $Z(R_{zi_{ni}}, W) = 31.0$ $\varepsilon_{ref.i_{ni}} = 2.9 \cdot \%$ $Z(R_{zi_{ni}}, W_{i.ref_{ni}}) = 100.6$

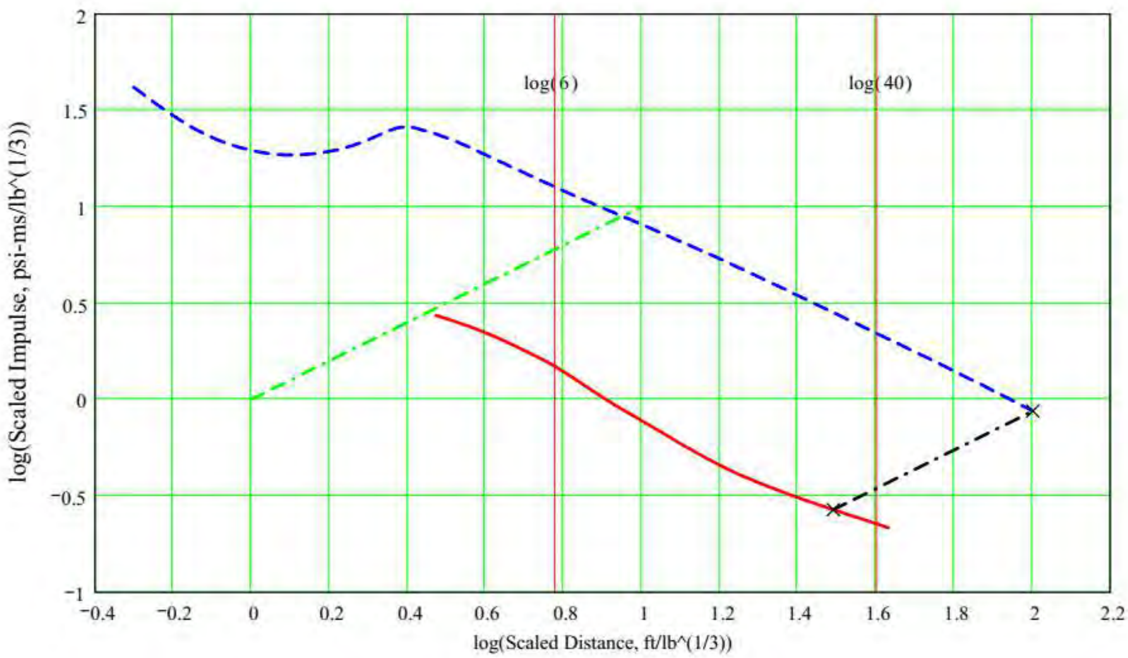
$$\frac{\int_{z_{min}}^{zi_{max}} F\varepsilon_{ref.i}(log(x))\,dx}{(zi_{max} - z_{min})} = 2.7 \cdot \%$$

$i_{s.smp}(R_{zi_{ni}}, W) = 0.27$ $i_{s.ref}(R_{zi_{ni}}, W_{i.ref_{ni}}) = 0.27$

$i_{scaled.smp}(Z(R_{zi_{ni}}, W)) = 0.27$ $i_{scaled.ref}(Z(R_{zi_{ni}}, W_{i.ref_{ni}})) = 0.87$

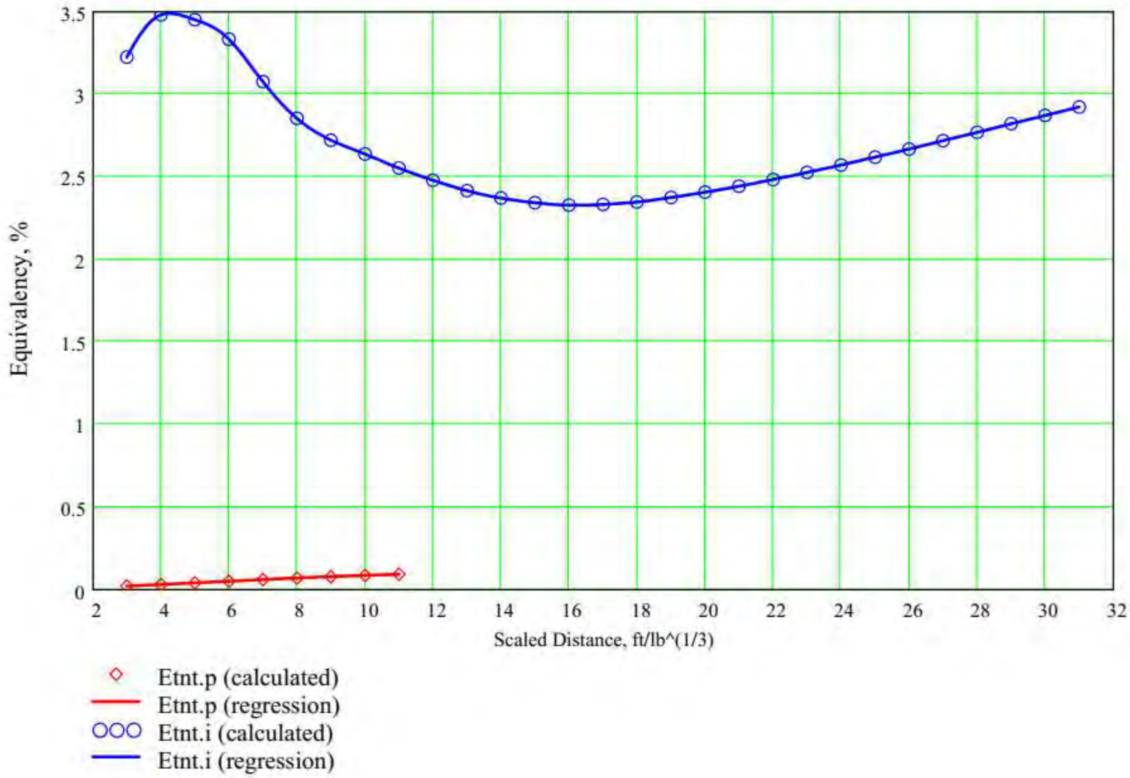
Test sample compared to Reference:





Equivalency as a Function of Scaled Distance

$z_p := z_{min}, z_{min} + 0.1 .. (np + z_{min})$ $\quad z_i := z_{min}, z_{min} + 0.1 .. (ni + z_{min})$



9.4 Fine Al-Bi_2O_3 Thermite – Small-Scale Mix ID #24 (SMS mixed)

PRESSURE AND IMPULSE TEST DATA SMOOTHING

$kPa := 1000 \cdot Pa \quad msec := 0.001 \cdot sec$

Test Sample: Small-Scale Mix #24, hemispherical on surface at the SMS Test Site in Tooele, Utah

Read in the test data summary file: data := READPRN("DOT1-6265f-SS24-Data.prn") $\quad Item := data^{\langle 0 \rangle}$

NOTE: Col 1 - Item, Col 2 - Trial, Col 3 - Line, Col 4 - Station, Col 5 - Distance in feet, Col 6 - Peak Pressure in psig, Col 7 - TTL initiation time, Col 8 - time of arrival in seconds, Col 9 - time that pressure returned to ambient in seconds (impulse maxima), Col 10 - impulse in psi-msec.

Read in the test conditions file: cond := READPRN("DOT1-6265f-SS24-TestCond.prn")

NOTE: Col 1 - Trial, Col 2 - net explosives weight, Col 3 - temperature in Kelvin, Col 4 - pressure in inHg.

$trial := cond^{\langle 0 \rangle} \quad W_{trial} := cond^{\langle 1 \rangle} \cdot \frac{gm}{lb} \quad T_{trial} := cond^{\langle 2 \rangle} \cdot K \quad P_{trial} := cond^{\langle 3 \rangle} \cdot in\_Hg$

Initiation train: $W_{init} := (0) \cdot \frac{gm}{lb} \quad \varepsilon_{TNT.init.p} := 100\ \% \quad \varepsilon_{TNT.init.i} := 100\ \%$

Initial guess value for the product's average TNT equivalency: $\varepsilon_{TNT.p} := 6\ \% \quad \varepsilon_{TNT.i} := 13\ \%$

Net explosive weight of product:

$$W_p := W_{trial} + \frac{W_{init} \cdot \varepsilon_{TNT.init.p}}{\varepsilon_{TNT.p}} \quad W_p = \begin{bmatrix} 20.00 \\ 20.00 \\ 20.00 \end{bmatrix} \quad W_i := W_{trial} + \frac{W_{init} \cdot \varepsilon_{TNT.init.i}}{\varepsilon_{TNT.i}} \quad W_i = \begin{bmatrix} 20.00 \\ 20.00 \\ 20.00 \end{bmatrix}$$

Split data sets by trial:

```
Split(data,item) := | i←0
                    | for j ∈ 0..rows(data) − 1
                    |   if data[j,0] = item
                    |     | T<i> ← (data^T)<j>
                    |     | i←i + 1
                    | Split←T^T
```

$i := 0 .. rows(trial) - 1 \quad Set_i := Split(data, i)$

$Trial_i := (Set_i)^{\langle 1 \rangle} \quad Line_i := (Set_i)^{\langle 2 \rangle} \quad Station_i := (Set_i)^{\langle 3 \rangle}$

$R_i := (Set_i)^{\langle 4 \rangle} \quad P_{so_i} := (Set_i)^{\langle 5 \rangle} \quad t_{TTL.abs_i} := (Set_i)^{\langle 6 \rangle}$

$t_{A.abs_i} := (Set_i)^{\langle 7 \rangle} \quad t_{amb.abs_i} := (Set_i)^{\langle 8 \rangle} \quad i_{s_i} := (Set_i)^{\langle 9 \rangle}$

Calculate time of shock arrival and duration: $t_{A_i} := t_{A.abs_i} - t_{TTL.abs_i} \quad t_{o_i} := t_{amb.abs_i} - t_{A.abs_i}$

Calculate Sachs Scaling factors to convert measurements from test site to Sea Level (SL):

$P_{SL} := 101.4 \cdot kPa$ $T_{SL} := 288.2 \cdot K$ **Pressure:** $S_{P_i} := \frac{P_{trial_i}}{P_{SL}}$ $F_{P_i} := \left(S_{P_i}\right)^{-1}$

Distance: $S_{d.p_i} := \left(W_{p_i}\right)^{\frac{1}{3}} \cdot \left(\frac{P_{SL}}{P_{trial_i}}\right)^{\frac{1}{3}}$ $F_{R.p_i} := \left(S_{d.p_i}\right)^{-1}$ $S_{d.i_i} := \left(W_{i_i}\right)^{\frac{1}{3}} \cdot \left(\frac{P_{SL}}{P_{trial_i}}\right)^{\frac{1}{3}}$ $F_{R.i_i} := \left(S_{d.i_i}\right)^{-1}$

Time: $S_{t_i} := \left(W_{p_i}\right)^{\frac{1}{3}} \cdot \left(\frac{P_{SL}}{P_{trial_i}}\right)^{\frac{1}{3}} \cdot \left(\frac{T_{SL}}{T_{trial_i}}\right)^{\frac{1}{2}}$ $F_{T_i} := \left(S_{t_i}\right)^{-1}$

Impulse: $S_{i_i} := \left(W_{i_i}\right)^{\frac{1}{3}} \cdot \left(\frac{P_{trial_i}}{P_{SL}}\right)^{\frac{2}{3}} \cdot \left(\frac{T_{SL}}{T_{trial_i}}\right)^{\frac{1}{2}}$ $F_{i_i} := \left(S_{i_i}\right)^{-1}$

$F_P^T = [\, 1.007 \quad 1.007 \quad 1.007 \,]$

$F_{R.p}^T = [\, 0.368 \quad 0.368 \quad 0.368 \,]$

$F_{R.i}^T = [\, 0.368 \quad 0.368 \quad 0.368 \,]$

$F_T^T = [\, 0.376 \quad 0.377 \quad 0.377 \,]$

$F_i^T = [\, 0.379 \quad 0.379 \quad 0.379 \,]$

Apply Sachs Scaling Factors to convert measurements from test site to Sea Level:

$P_{so_i} := P_{so_i} \cdot F_{P_i}$ $z_{p_i} := R_i \cdot F_{R.p_i}$ $z_{i.s_i} := R_i \cdot F_{R.i_i}$ $t_{A_i} := t_{A_i} \cdot F_{T_i}$ $t_{o_i} := t_{o_i} \cdot F_{T_i}$ $i_{s.scaled_i} := i_{s_i} \cdot F_{i_i}$

Common log of the x axes: $logz_{p_i} := \overrightarrow{\log\left(z_{p_i}\right)}$ $logz_{i.s_i} := \overrightarrow{\log\left(z_{i.s_i}\right)}$

Common log of the y axes: $logP_{so_i} := \overrightarrow{\log\left(P_{so_i}\right)}$ $logi_{s.scaled_i} := \overrightarrow{\log\left(i_{s.scaled_i}\right)}$

Reassemble data sets: $logz_{all.p} := 1$ $logP_{so.all} := 1$ $logz_{all.i} := 1$ $logi_{s.scaled.all} := 1$

$$\text{Reassemble}(A,B) := \left| \begin{array}{l} A \leftarrow B_0 \\ \text{for } j \in 1..\text{rows}(\text{trial}) - 1 \\ \quad A \leftarrow \text{stack}(A, B_j) \\ A \end{array} \right.$$

$logz_{all.p} := \text{Reassemble}(logz_{all.p}, logz_p)$ $logP_{so.all} := \text{Reassemble}(logP_{so.all}, logP_{so})$

$logz_{all.i} := \text{Reassemble}(logz_{all.i}, logz_{i.s})$ $logi_{s.scaled.all} := \text{Reassemble}(logi_{s.scaled.all}, logi_{s.scaled})$

Bind X-Y pairs together: $log_{data.p} := \text{augment}(logz_{all.p}, logP_{so.all})$ $log_{data.i} := \text{augment}(logz_{all.i}, logi_{s.scaled.all})$

Loess Smoothing of X-Y Data: $span_p := 0.60$ $span_i := 0.75$

$L_p := \text{loess}(log_{data.p}^{\langle 0 \rangle}, log_{data.p}^{\langle 1 \rangle}, span_p)$ $\text{logPso}(x) := \text{interp}(L_p, log_{data.p}^{\langle 0 \rangle}, log_{data.p}^{\langle 1 \rangle}, x)$

$L_i := \text{loess}(log_{data.i}^{\langle 0 \rangle}, log_{data.i}^{\langle 1 \rangle}, span_i)$ $\text{logIscaled}(x) := \text{interp}(L_i, log_{data.i}^{\langle 0 \rangle}, log_{data.i}^{\langle 1 \rangle}, x)$

$x_{p.min} := \min(log_{data.p}^{\langle 0 \rangle})$ $x_{p.max} := \max(log_{data.p}^{\langle 0 \rangle})$ $x_{i.min} := \min(log_{data.i}^{\langle 0 \rangle})$ $x_{i.max} := \max(log_{data.i}^{\langle 0 \rangle})$

$$\text{Range2Vec}(s,e,i) := \left| \begin{array}{l} count \leftarrow 0 \\ \text{for } i \in s, s+i..e \\ \quad \left| \begin{array}{l} v_{count} \leftarrow i \\ count \leftarrow count + 1 \end{array} \right. \\ v \end{array} \right.$$

$x_p := \text{Range2Vec}(x_{p.min}, x_{p.max}, 0.01)$ $z_p := \overrightarrow{10^{x_p}}$

$x_i := \text{Range2Vec}(x_{i.min}, x_{i.max}, 0.01)$ $z_i := \overrightarrow{10^{x_i}}$

$x_{min} := \text{if}(x_{p.min} > x_{i.min}, x_{p.min}, x_{i.min})$ $x_{max} := \text{if}(x_{p.max} < x_{i.max}, x_{p.max}, x_{i.max})$

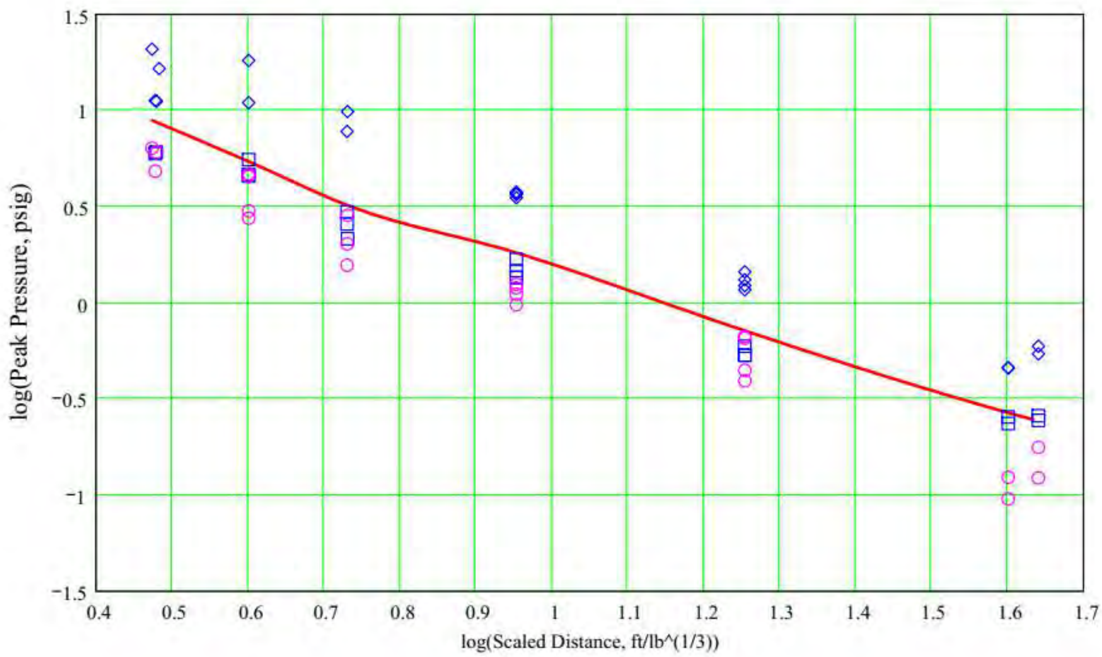
$x_{smu} := \text{Range2Vec}(x_{min}, x_{max}, 0.01)$ $P_{so.smu} := \overrightarrow{\left(10^{\text{logPso}(x_{smu})}\right)}$ $i_{s.scaled.smu} := \overrightarrow{\left(10^{\text{logIscaled}(x_{smu})}\right)}$

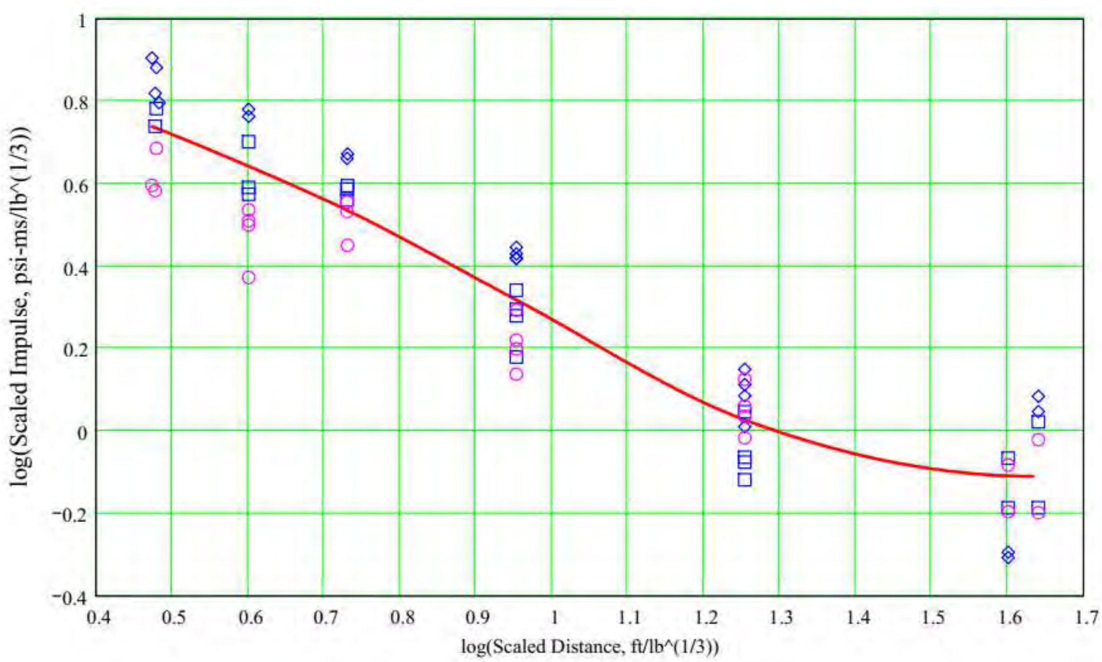
$z_{smu} := \overrightarrow{10^{x_{smu}}}$ $data_{smu} := \text{augment}(z_{smu}, P_{so.smu})$ $data_{smu} := \text{augment}(data_{smu}, i_{s.scaled.smu})$

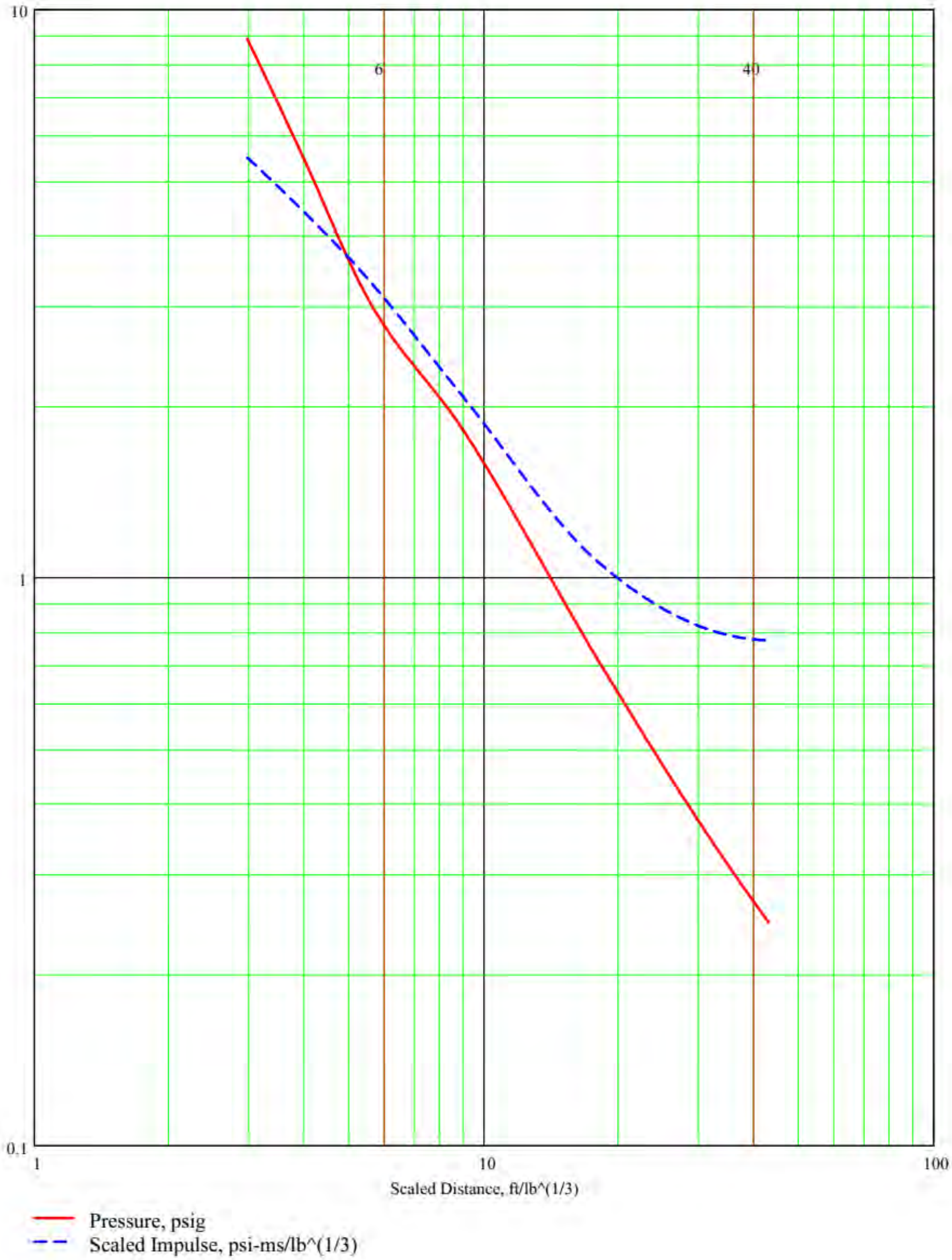
$P_{so.smu}(z) := 10^{\text{logPso}(\log(z))}$ $i_{scaled.smu}(z) := 10^{\text{logIscaled}(\log(z))}$

WRITEPRN("ZPIscaledData(smooth).prn") := $data_{smu}$

Plot data and smoothed fit:






10
1
0.1
6
40
1
10
100
Scaled Distance, ft/lb^(1/3)
Pressure, psig
Scaled Impulse, psi-ms/lb^(1/3)

EQUIVALENCY CALCULATIONS

Test Sample: Small-Scale Mix #24, hemispherical on surface at Sea Level
Reference: TNT, hemisphere on surface at Sea Level (UFC 3-340-02 (2008), Figure 2-15)

Blast curves for test sample:

$data_{smp} := READPRN(\text{"SS24 ZPIscaledData(smooth).prn"})$

$z_{smp} := data_{smp}^{\langle 0 \rangle}$ $P_{so.smp} := data_{smp}^{\langle 1 \rangle}$ $i_{s.scaled.smp} := data_{smp}^{\langle 2 \rangle}$

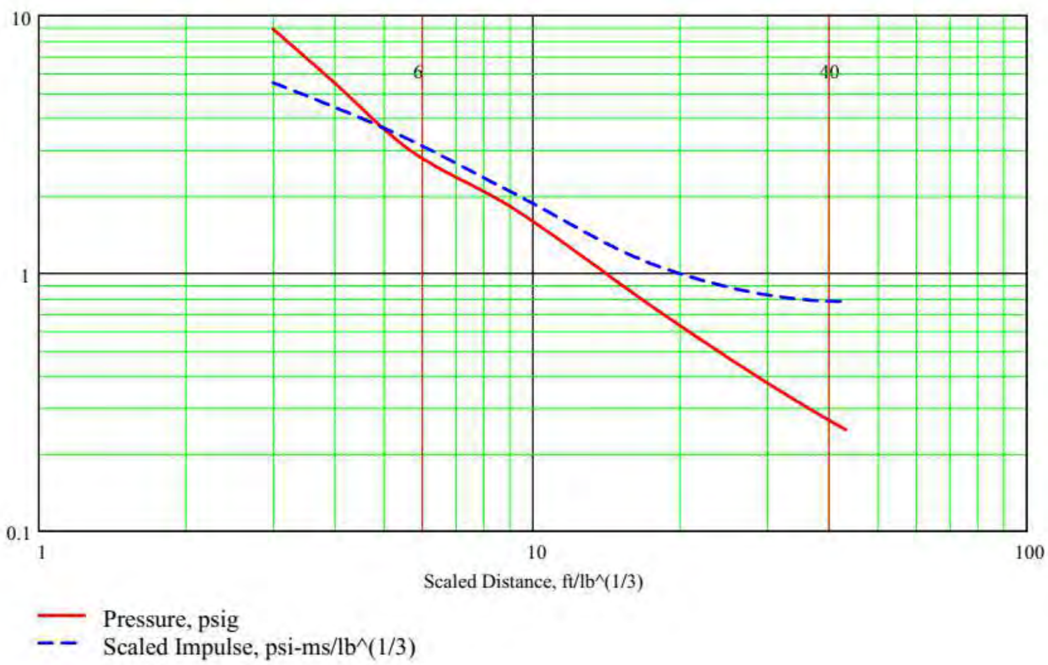
$j := 0 .. rows(z_{smp}) - 1$ $logz_{smp_j} := \log(z_{smp_j})$ $logi_{s.scaled.smp_j} := \log(i_{s.scaled.smp_j})$

$logP_{so.smp_j} := \log(P_{so.smp_j})$ $x_{smp} := \min(logz_{smp}), \min(logz_{smp}) + 0.01 .. \max(logz_{smp})$

$S1_s := lspline(logz_{smp}, logP_{so.smp})$ $S2_s := lspline(logz_{smp}, logi_{s.scaled.smp})$

$logP_{smp}(x) := interp(S1_s, logz_{smp}, logP_{so.smp}, x)$ $logI_{s.scaled.smp}(x) := interp(S2_s, logz_{smp}, logi_{s.scaled.smp}, x)$

$P_{so.smp}(z) := 10^{logP_{smp}(\log(z))}$ $i_{scaled.smp}(z) := 10^{logI_{s.scaled.smp}(\log(z))}$



$z_{min} := \text{ceil}\left(\text{if}\left(z_{min.s} > z_{min.r}, z_{min.s}, z_{min.r}\right)\right) \qquad z_{max} := \text{floor}\left(\text{if}\left(z_{max.s} < z_{max.r}, z_{max.s}, z_{max.r}\right)\right)$

$z_{min} = 3.0 \qquad z_{max} = 43.0 \qquad l_{loop} := \text{floor}\left[\frac{\left(z_{max} - z_{min}\right)}{2}\right] - 1 \qquad l_{loop} = 19.0$

Equivalence to Reference: $\varepsilon_{ref}\left(W_{ref}, W\right) := \frac{W_{ref}}{W} \qquad R_a := \begin{bmatrix} z_{min} \\ z_{min} + 1 \end{bmatrix}$

$R_{z1} := \begin{array}{|l} R_b \leftarrow R_a \\ \text{for } j \in 1..l_{loop} \\ \quad \begin{array}{|l} R_a \leftarrow R_a + 2 \cdot j \\ R_b \leftarrow \text{stack}\left(R_b, R_a\right) \end{array} \\ R_b \end{array}$

Equivalence for Peak Pressure as a function of Scaled Distance:

$W := 1 \qquad W_{ref} := 0.03 \qquad np := 39 \qquad k := 0..np \qquad R_{zp_k} := R_{z1_k}$

Given $P_{so.smp}\left(Z\left(R_{zp_k}, W\right)\right) = P_{so.ref}\left(Z\left(R_{zp_k}, W_{ref}\right)\right)$

$W_{p.ref_k} := \text{find}\left(W_{ref}\right) \qquad \varepsilon_{ref.p} := \varepsilon_{ref}\left(W_{p.ref}, W\right) \qquad S3 := \text{lspline}\left(\overrightarrow{\log\left(R_{zp}\right)}, \varepsilon_{ref.p}\right)$

$F\varepsilon_{ref.p}(x) := \text{interp}\left(S3, \overrightarrow{\log\left(R_{zp}\right)}, \varepsilon_{ref.p}, x\right) \qquad x_{\varepsilon_k} := \log\left(R_{zp_k}\right) \qquad \text{mean}\left(\varepsilon_{ref.p}\right) = 3.05 \cdot \%$

Spot check pressure equality:

$Z\left(R_{zp_{np}}, W\right) = 42.0 \qquad \varepsilon_{ref.p_{np}} = 3.850 \cdot \% \qquad Z\left(R_{zp_{np}}, W_{p.ref_{np}}\right) = 124.4$

$\frac{\int_{z_{min}}^{zp_{max}} F\varepsilon_{ref.p}(\log(x))\,dx}{\left(zp_{max} - z_{min}\right)} = 3.05 \cdot \%$

$P_{so.smp}\left(Z\left(R_{zp_{np}}, W\right)\right) = 0.25 \qquad P_{so.ref}\left(Z\left(R_{zp_{np}}, W_{p.ref_{np}}\right)\right) = 0.25$

RGB (226,226,226)

Equivalence for Positive Impulse as a function of Scaled Distance: $ni := 39 \qquad k := 0..ni$

$R_{zi_k} := R_{z1_k} \qquad i_{s.smp}(R, W) := i_{scaled.smp}(Z(R, W)) \cdot W^{\frac{1}{3}} \qquad i_{s.ref}(R, W) := i_{scaled.ref}(Z(R, W)) \cdot W^{\frac{1}{3}}$

Given $i_{s.smp}\left(R_{zi_k}, W\right) = i_{s.ref}\left(R_{zi_k}, W_{ref}\right) \qquad W_{i.ref_k} := \text{find}\left(W_{ref}\right) \qquad \varepsilon_{ref.i} := \varepsilon_{ref}\left(W_{i.ref}, W\right)$

$S4 := \text{lspline}\left(\overrightarrow{\log\left(R_{zi}\right)}, \varepsilon_{ref.i}\right) \qquad F\varepsilon_{ref.i}(x) := \text{interp}\left(S4, \overrightarrow{\log\left(R_{zi}\right)}, \varepsilon_{ref.i}, x\right) \qquad \text{mean}\left(\varepsilon_{ref.i}\right) = 13.3 \cdot \%$

Spot check impulse equality:

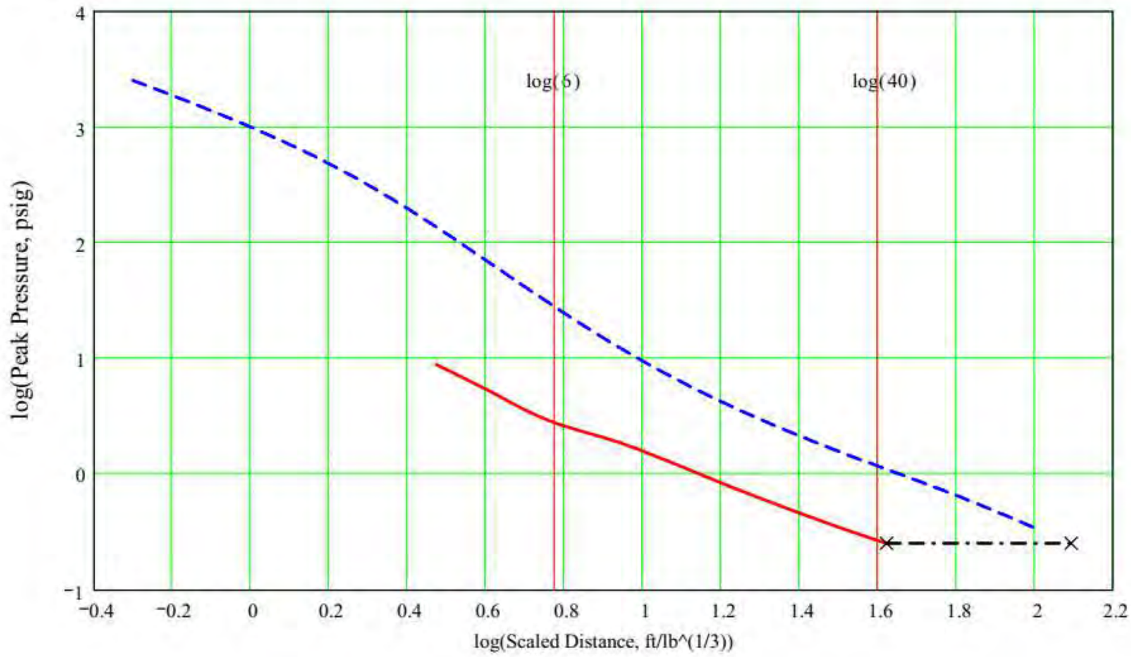
$Z\left(R_{zi_{ni}}, W\right) = 42.0 \qquad \varepsilon_{ref.i_{ni}} = 22.3 \cdot \% \qquad Z\left(R_{zi_{ni}}, W_{i.ref_{ni}}\right) = 69.2$

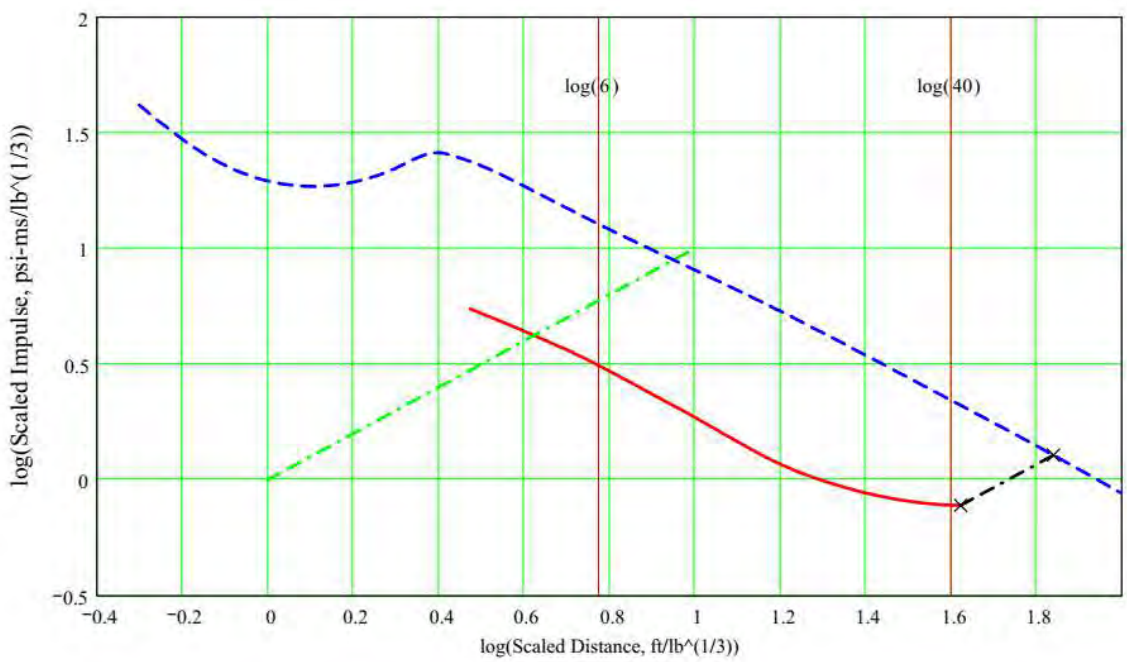
$i_{s.smp}\left(R_{zi_{ni}}, W\right) = 0.78 \qquad i_{s.ref}\left(R_{zi_{ni}}, W_{i.ref_{ni}}\right) = 0.78$

$\frac{\int_{z_{min}}^{zi_{max}} F\varepsilon_{ref.i}(\log(x))\,dx}{\left(zi_{max} - z_{min}\right)} = 13.2 \cdot \%$

$i_{scaled.smp}\left(Z\left(R_{zi_{ni}}, W\right)\right) = 0.78 \qquad i_{scaled.ref}\left(Z\left(R_{zi_{ni}}, W_{i.ref_{ni}}\right)\right) = 1.28$

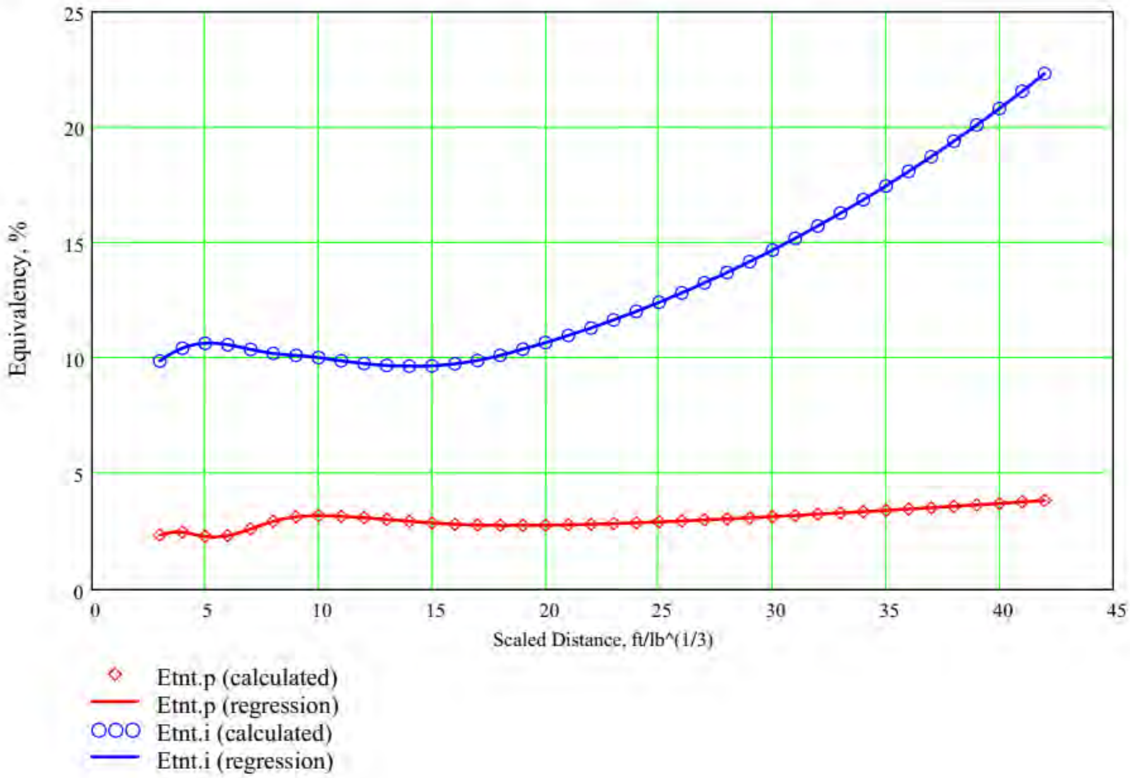
Test sample compared to Reference:





Equivalency as a Function of Scaled Distance

$z_p := z_{min}, z_{min} + 0.1 .. (np + z_{min})$ $z_i := z_{min}, z_{min} + 0.1 .. (ni + z_{min})$



9.5 Fine Ti-Bi_2O_3 – Small-Scale Mix ID #48 (SMS Mixed)

PRESSURE AND IMPULSE TEST DATA SMOOTHING

$kPa := 1000 \cdot Pa \quad msec := 0.001 \cdot sec$

Test Sample: Small-Scale Mix #48, hemispherical on surface at the SMS Test Site in Tooele, Utah

Read in the test data summary file: $data := READPRN(\text{"DOT1-6265f-SS48-Data.prn"})$ $\quad Item := data^{\langle 0 \rangle}$

NOTE: Col 1 - Item, Col 2 - Trial, Col 3 - Line, Col 4 - Station, Col 5 - Distance in feet, Col 6 - Peak Pressure in psig, Col 7 - TTL initiation time, Col 8 - time of arrival in seconds, Col 9 - time that pressure returned to ambient in seconds (impulse maxima), Col 10 - impulse in psi-msec.

Read in the test conditions file: $cond := READPRN(\text{"DOT1-6265f-SS48-TestCond.prn"})$

NOTE: Col 1 - Trial, Col 2 - net explosives weight, Col 3 - temperature in Kelvin, Col 4 - pressure in inHg.

$trial := cond^{\langle 0 \rangle} \quad W_{trial} := cond^{\langle 1 \rangle} \cdot \frac{gm}{lb} \quad T_{trial} := cond^{\langle 2 \rangle} \cdot K \quad P_{trial} := cond^{\langle 3 \rangle} \cdot in\_Hg$

Initiation train: $W_{init} := (0) \cdot \frac{gm}{lb} \quad \varepsilon_{TNT.init.p} := 100\ \% \quad \varepsilon_{TNT.init.i} := 100\ \%$

Initial guess value for the product's average TNT equivalency: $\varepsilon_{TNT.p} := 1\ \% \quad \varepsilon_{TNT.i} := 1\ \%$

Net explosive weight of product:

$$W_p := W_{trial} + \frac{W_{init} \cdot \varepsilon_{TNT.init.p}}{\varepsilon_{TNT.p}} \quad W_p = \begin{bmatrix} 20.00 \\ 20.00 \\ 20.00 \end{bmatrix} \quad W_i := W_{trial} + \frac{W_{init} \cdot \varepsilon_{TNT.init.i}}{\varepsilon_{TNT.i}} \quad W_i = \begin{bmatrix} 20.00 \\ 20.00 \\ 20.00 \end{bmatrix}$$

Split data sets by trial:

```
Split(data,item) := | i←0
                    | for j ∈ 0..rows(data) − 1
                    |   if data[j,0] = item
                    |     | T<i> ← (data^T)<j>
                    |     | i ← i + 1
                    | Split ← T^T
```

$i := 0 .. rows(trial) - 1 \quad Set_i := Split(data, i)$

$Trial_i := (Set_i)^{\langle 1 \rangle} \quad Line_i := (Set_i)^{\langle 2 \rangle} \quad Station_i := (Set_i)^{\langle 3 \rangle}$

$R_i := (Set_i)^{\langle 4 \rangle} \quad P_{so_i} := (Set_i)^{\langle 5 \rangle} \quad t_{TTL.abs_i} := (Set_i)^{\langle 6 \rangle}$

$t_{A.abs_i} := (Set_i)^{\langle 7 \rangle} \quad t_{amb.abs_i} := (Set_i)^{\langle 8 \rangle} \quad i_{s_i} := (Set_i)^{\langle 9 \rangle}$

Calculate time of shock arrival and duration: $t_{A_i} := t_{A.abs_i} - t_{TTL.abs_i} \quad t_{o_i} := t_{amb.abs_i} - t_{A.abs_i}$

Calculate Sachs Scaling factors to convert measurements from test site to Sea Level (SL):

$P_{SL} := 101.4 \cdot kPa$ $T_{SL} := 288.2 \cdot K$ **Pressure:** $S_{P_i} := \frac{P_{trial_i}}{P_{SL}}$ $F_{P_i} := \left(S_{P_i}\right)^{-1}$

Distance: $S_{d.p_i} := \left(W_{p_i}\right)^{\frac{1}{3}} \cdot \left(\frac{P_{SL}}{P_{trial_i}}\right)^{\frac{1}{3}}$ $F_{R.p_i} := \left(S_{d.p_i}\right)^{-1}$ $S_{d.i_i} := \left(W_{i_i}\right)^{\frac{1}{3}} \cdot \left(\frac{P_{SL}}{P_{trial_i}}\right)^{\frac{1}{3}}$ $F_{R.i_i} := \left(S_{d.i_i}\right)^{-1}$

Time: $S_{t_i} := \left(W_{p_i}\right)^{\frac{1}{3}} \cdot \left(\frac{P_{SL}}{P_{trial_i}}\right)^{\frac{1}{3}} \cdot \left(\frac{T_{SL}}{T_{trial_i}}\right)^{\frac{1}{2}}$ $F_{T_i} := \left(S_{t_i}\right)^{-1}$

Impulse: $S_{i_i} := \left(W_{i_i}\right)^{\frac{1}{3}} \cdot \left(\frac{P_{trial_i}}{P_{SL}}\right)^{\frac{2}{3}} \cdot \left(\frac{T_{SL}}{T_{trial_i}}\right)^{\frac{1}{2}}$ $F_{i_i} := \left(S_{i_i}\right)^{-1}$

$F_P^T = [\ 1.005 \quad 1.005 \quad 1.005\ ]$

$F_{R.p}^T = [\ 0.368 \quad 0.368 \quad 0.368\ ]$

$F_{R.i}^T = [\ 0.368 \quad 0.368 \quad 0.368\ ]$

$F_T^T = [\ 0.376 \quad 0.376 \quad 0.376\ ]$

$F_i^T = [\ 0.378 \quad 0.378 \quad 0.378\ ]$

Apply Sachs Scaling Factors to convert measurements from test site to Sea Level:

$P_{so_i} := P_{so_i} \cdot F_{P_i}$ $z_{p_i} := R_i \cdot F_{R.p_i}$ $z_{i.s_i} := R_i \cdot F_{R.i_i}$ $t_{A_i} := t_{A_i} \cdot F_{T_i}$ $t_{o_i} := t_{o_i} \cdot F_{T_i}$ $i_{s.scaled_i} := i_{s_i} \cdot F_{i_i}$

Common log of the x axes: $logz_{p_i} := \overrightarrow{\log\left(z_{p_i}\right)}$ $logz_{i.s_i} := \overrightarrow{\log\left(z_{i.s_i}\right)}$

Common log of the y axes: $logP_{so_i} := \overrightarrow{\log\left(P_{so_i}\right)}$ $logi_{s.scaled_i} := \overrightarrow{\log\left(i_{s.scaled_i}\right)}$

Reassemble data sets: $logz_{all.p} := 1$ $logP_{so.all} := 1$ $logz_{all.i} := 1$ $logi_{s.scaled.all} := 1$

$$Reassemble(A,B) := \left| \begin{array}{l} A \leftarrow B_0 \\ \text{for } j \in 1..rows(trial) - 1 \\ \quad A \leftarrow stack(A, B_j) \\ A \end{array} \right.$$

$logz_{all.p} := Reassemble(logz_{all.p}, logz_p)$ $logP_{so.all} := Reassemble(logP_{so.all}, logP_{so})$

$logz_{all.i} := Reassemble(logz_{all.i}, logz_{i.s})$ $logi_{s.scaled.all} := Reassemble(logi_{s.scaled.all}, logi_{s.scaled})$

Bind X-Y pairs together: $log_{data.p} := augment(logz_{all.p}, logP_{so.all})$ $log_{data.i} := augment(logz_{all.i}, logi_{s.scaled.all})$

Loess Smoothing of X-Y Data: $span_p := 0.75$ $span_i := 0.75$

$L_p := loess\left(log_{data.p}^{\langle 0 \rangle}, log_{data.p}^{\langle 1 \rangle}, span_p\right)$ $logPso(x) := interp\left(L_p, log_{data.p}^{\langle 0 \rangle}, log_{data.p}^{\langle 1 \rangle}, x\right)$

$L_i := loess\left(log_{data.i}^{\langle 0 \rangle}, log_{data.i}^{\langle 1 \rangle}, span_i\right)$ $logIscaled(x) := interp\left(L_i, log_{data.i}^{\langle 0 \rangle}, log_{data.i}^{\langle 1 \rangle}, x\right)$

$x_{p.min} := min\left(log_{data.p}^{\langle 0 \rangle}\right)$ $x_{p.max} := max\left(log_{data.p}^{\langle 0 \rangle}\right)$ $x_{i.min} := min\left(log_{data.i}^{\langle 0 \rangle}\right)$ $x_{i.max} := max\left(log_{data.i}^{\langle 0 \rangle}\right)$

$$Range2Vec(s,e,i) := \left| \begin{array}{l} count \leftarrow 0 \\ \text{for } i \in s, s+i..e \\ \quad \left| \begin{array}{l} v_{count} \leftarrow i \\ count \leftarrow count + 1 \end{array} \right. \\ v \end{array} \right.$$

$x_p := Range2Vec(x_{p.min}, x_{p.max}, 0.01)$ $z_p := \overrightarrow{10^{x_p}}$

$x_i := Range2Vec(x_{i.min}, x_{i.max}, 0.01)$ $z_i := \overrightarrow{10^{x_i}}$

$x_{min} := if(x_{p.min} > x_{i.min}, x_{p.min}, x_{i.min})$ $x_{max} := if(x_{p.max} < x_{i.max}, x_{p.max}, x_{i.max})$

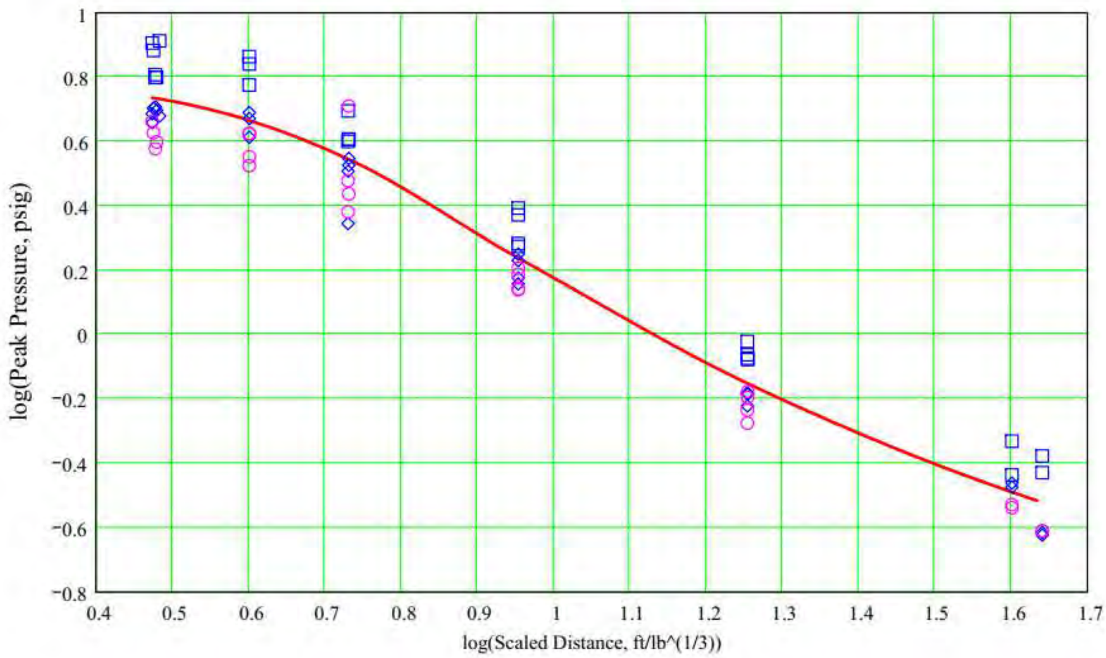
$x_{smu} := Range2Vec(x_{min}, x_{max}, 0.01)$ $P_{so.smu} := \overrightarrow{\left(10^{logPso(x_{smu})}\right)}$ $i_{s.scaled.smu} := \overrightarrow{\left(10^{logIscaled(x_{smu})}\right)}$

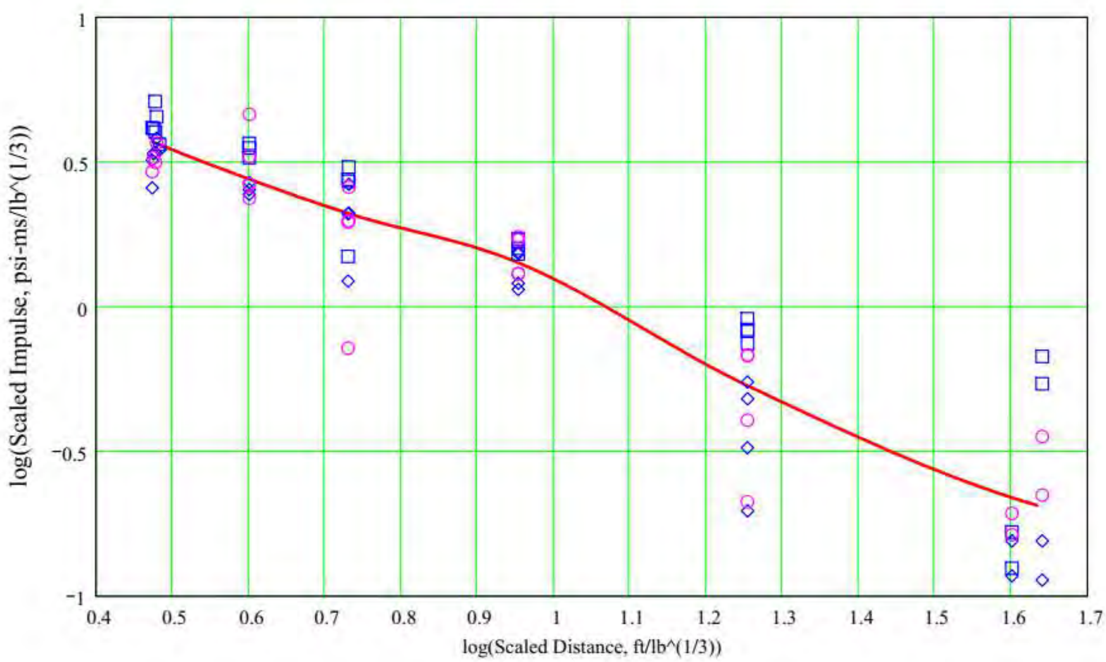
$z_{smu} := \overrightarrow{10^{x_{smu}}}$ $data_{smu} := augment(z_{smu}, P_{so.smu})$ $data_{smu} := augment(data_{smu}, i_{s.scaled.smu})$

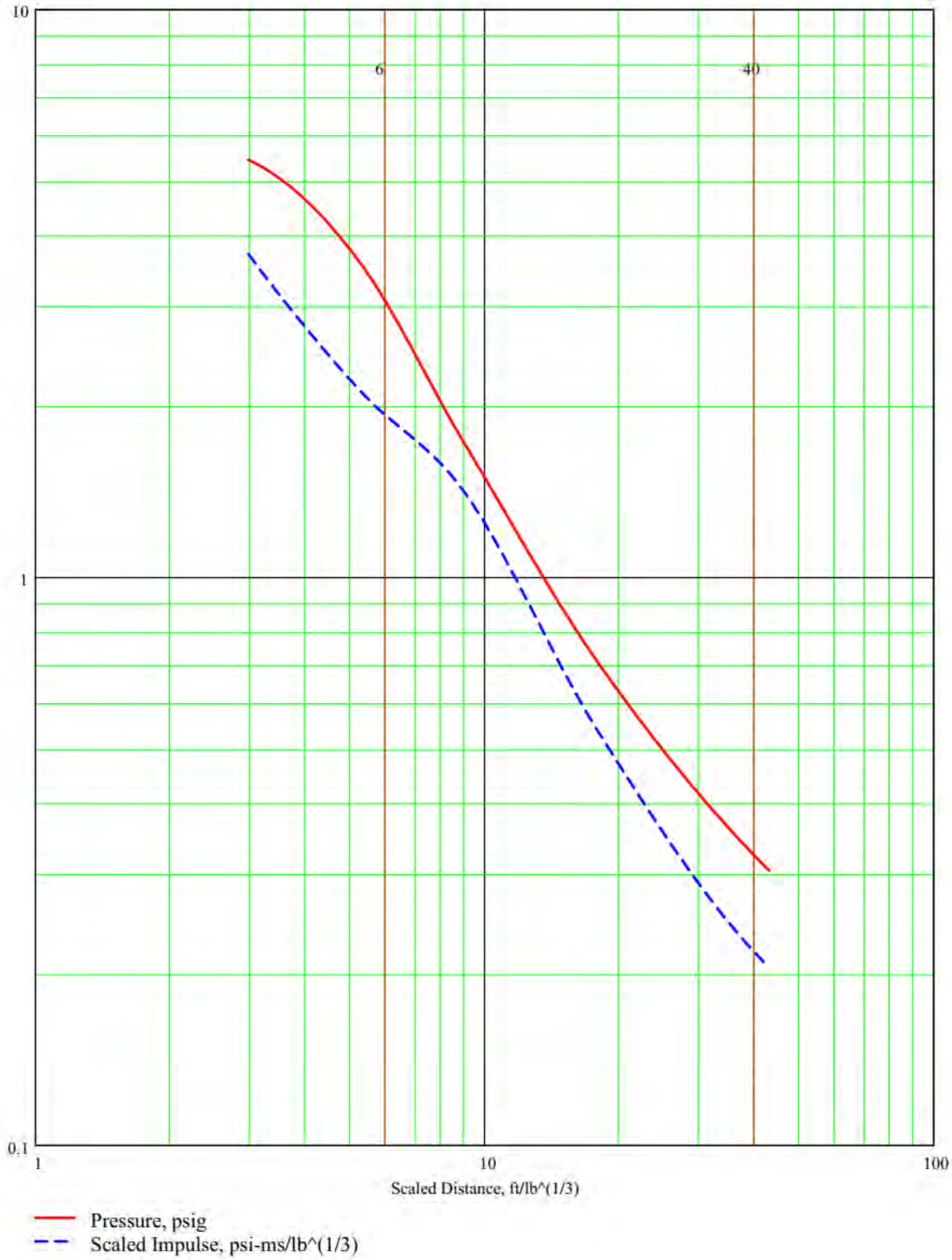
$P_{so.smu}(z) := 10^{logPso(log(z))}$ $i_{scaled.smu}(z) := 10^{logIscaled(log(z))}$

WRITEPRN("ZPIscaledData(smooth).prn") := $data_{smu}$

Plot data and smoothed fit:






10
6
40
1
0.1
1
10
100
Scaled Distance, ft/lb^(1/3)
Pressure, psig
Scaled Impulse, psi-ms/lb^(1/3)

EQUIVALENCY CALCULATIONS

Test Sample: Small-Scale Mix #48, hemispherical on surface at Sea Level
Reference: TNT, hemisphere on surface at Sea Level (UFC 3-340-02 (2008), Figure 2-15)

Blast curves for test sample:

$data_{smp} := READPRN("SS48-ZPIscaledData(smooth).prn")$

$z_{smp} := data_{smp}^{\langle 0 \rangle}$ $P_{so.smp} := data_{smp}^{\langle 1 \rangle}$ $i_{s.scaled.smp} := data_{smp}^{\langle 2 \rangle}$

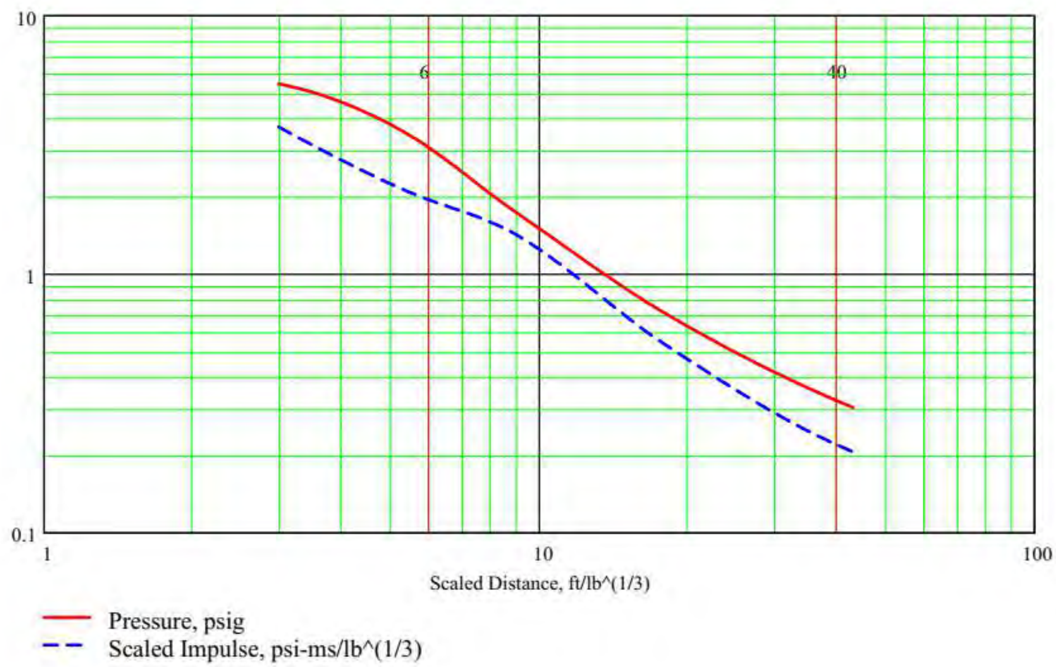
$j := 0 .. rows(z_{smp}) - 1$ $logz_{smp_j} := log(z_{smp_j})$ $logi_{s.scaled.smp_j} := log(i_{s.scaled.smp_j})$

$logP_{so.smp_j} := log(P_{so.smp_j})$ $x_{smp} := min(logz_{smp}), min(logz_{smp}) + 0.01 .. max(logz_{smp})$

$S1_s := lspline(logz_{smp}, logP_{so.smp})$ $S2_s := lspline(logz_{smp}, logi_{s.scaled.smp})$

$logP_{smp}(x) := interp(S1_s, logz_{smp}, logP_{so.smp}, x)$ $logI_{s.scaled.smp}(x) := interp(S2_s, logz_{smp}, logi_{s.scaled.smp}, x)$

$P_{so.smp}(z) := 10^{logP_{smp}(log(z))}$ $i_{scaled.smp}(z) := 10^{logI_{s.scaled.smp}(log(z))}$



Blast curves for Reference:

$data_{ref} := READPRN("UFC3-340-02Fig2-15.prn")$

$z_{ref} := data_{ref}^{<0>}$ $P_{so.ref} := data_{ref}^{<1>}$ $i_{s.scaled.ref} := data_{ref}^{<2>}$

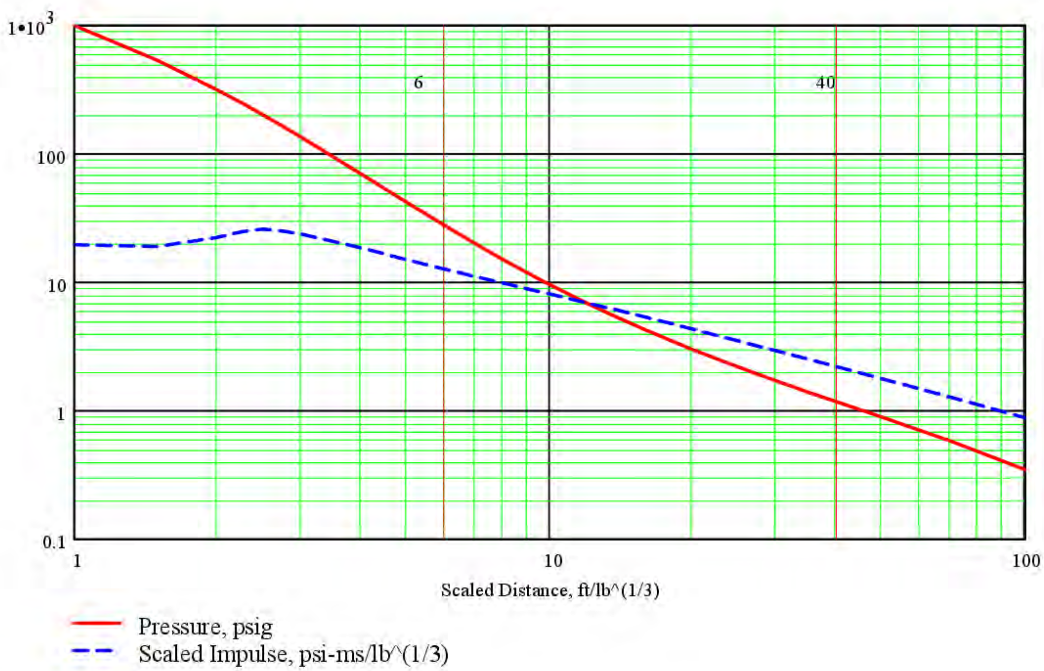
$j := 0 .. rows(z_{ref}) - 1$ $logz_{ref_j} := \log(z_{ref_j})$ $logi_{s.scaled.ref_j} := \log(i_{s.scaled.ref_j})$

$logP_{so.ref_j} := \log(P_{so.ref_j})$ $x_{ref} := \min(logz_{ref}), \min(logz_{ref}) + 0.01 .. \max(logz_{ref})$

$S1_r := lspline(logz_{ref}, logP_{so.ref})$ $S2_r := lspline(logz_{ref}, logi_{s.scaled.ref})$

$logP_{ref}(x) := interp(S1_r, logz_{ref}, logP_{so.ref}, x)$ $logI_{s.scaled.ref}(x) := interp(S2_r, logz_{ref}, logi_{s.scaled.ref}, x)$

$P_{so.ref}(z) := 10^{logP_{ref}(\log(z))}$ $i_{scaled.ref}(z) := 10^{logI_{s.scaled.ref}(\log(z))}$



$z_{min.s} := \min(z_{smp})$ $z_{min.s} = 3.0$ $z_{min.r} := \min(z_{ref})$ $z_{min.r} = 0.5$

$z_{max.s} := \max(z_{smp})$ $z_{max.s} = 43.0$ $z_{max.r} := \max(z_{ref})$ $z_{max.r} = 100.0$

$z_{min} := \text{ceil}\left(\text{if}\left(z_{min.s} > z_{min.r}, z_{min.s}, z_{min.r}\right)\right)$ $z_{max} := \text{floor}\left(\text{if}\left(z_{max.s} < z_{max.r}, z_{max.s}, z_{max.r}\right)\right)$

$z_{min} = 3.0$ $z_{max} = 43.0$ $l_{loop} := \text{floor}\left[\frac{\left(z_{max} - z_{min}\right)}{2}\right] - 1$ $l_{loop} = 19.0$

Equivalence to Reference: $\varepsilon_{ref}\left(W_{ref}, W\right) := \frac{W_{ref}}{W}$ $R_a := \begin{bmatrix} z_{min} \\ z_{min} + 1 \end{bmatrix}$ $R_{z1} := \left| \begin{array}{l} R_b \leftarrow R_a \\ \text{for } j \in 1..l_{loop} \\ \quad \left| \begin{array}{l} R_a \leftarrow R_a + 2 \cdot j \\ R_b \leftarrow \text{stack}\left(R_b, R_a\right) \end{array} \right. \\ R_b \end{array} \right.$

Equivalence for Peak Pressure as a function of Scaled Distance:

$W := 1$ $W_{ref} := 0.012$ $np := 38$ $k := 0..np$ $R_{zp_k} := R_{z1_k}$

Given $P_{so.smp}\left(Z\left(R_{zp_k}, W\right)\right) = P_{so.ref}\left(Z\left(R_{zp_k}, W_{ref}\right)\right)$

$W_{p.ref_k} := \text{find}\left(W_{ref}\right)$ $\varepsilon_{ref.p} := \varepsilon_{ref}\left(W_{p.ref}, W\right)$ $S3 := \text{lspline}\left(\overrightarrow{\log\left(R_{zp}\right)}, \varepsilon_{ref.p}\right)$

$F\varepsilon_{ref.p}(x) := \text{interp}\left(S3, \overrightarrow{\log\left(R_{zp}\right)}, \varepsilon_{ref.p}, x\right)$ $x_{\varepsilon_k} := \log\left(R_{zp_k}\right)$ $\text{mean}\left(\varepsilon_{ref.p}\right) = 3.439 \cdot \%$

Spot check pressure equality: $Z\left(R_{zp_{np}}, W\right) = 41.0$ $\varepsilon_{ref.p_{np}} = 5.719 \cdot \%$ $Z\left(R_{zp_{np}}, W_{p.ref_{np}}\right) = 106.4$

$$\frac{\int_{z_{min}}^{zp_{max}} F\varepsilon_{ref.p}(\log(x))\,dx}{\left(zp_{max} - z_{min}\right)} = 3.442 \cdot \%$$

$P_{so.smp}\left(Z\left(R_{zp_{np}}, W\right)\right) = 0.32$ $P_{so.ref}\left(Z\left(R_{zp_{np}}, W_{p.ref_{np}}\right)\right) = 0.32$

RGB (226,226,226)

Equivalence for Positive Impulse as a function of Scaled Distance: $ni := 39$ $k := 0..ni$

$R_{zi_k} := R_{z1_k}$ $i_{s.smp}(R, W) := i_{scaled.smp}(Z(R, W)) \cdot W^{\frac{1}{3}}$ $i_{s.ref}(R, W) := i_{scaled.ref}(Z(R, W)) \cdot W^{\frac{1}{3}}$

Given $i_{s.smp}\left(R_{zi_k}, W\right) = i_{s.ref}\left(R_{zi_k}, W_{ref}\right)$ $W_{i.ref_k} := \text{find}\left(W_{ref}\right)$ $\varepsilon_{ref.i} := \varepsilon_{ref}\left(W_{i.ref}, W\right)$

$S4 := \text{lspline}\left(\overrightarrow{\log\left(R_{zi}\right)}, \varepsilon_{ref.i}\right)$ $F\varepsilon_{ref.i}(x) := \text{interp}\left(S4, \overrightarrow{\log\left(R_{zi}\right)}, \varepsilon_{ref.i}, x\right)$ $\text{mean}\left(\varepsilon_{ref.i}\right) = 3.8 \cdot \%$

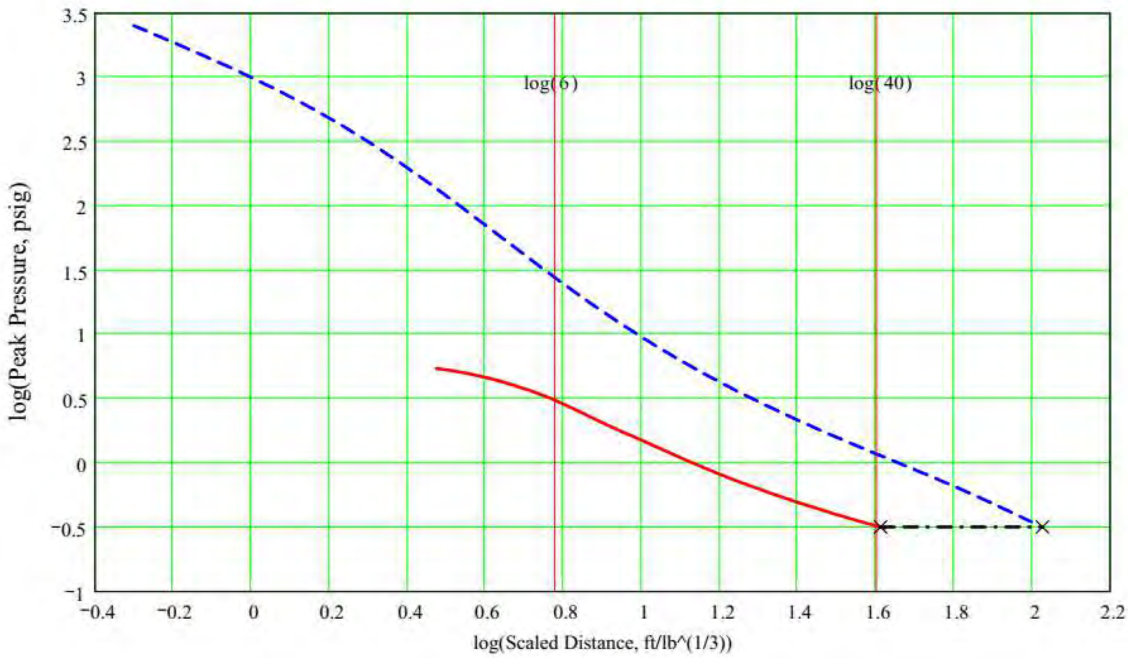
Spot check impulse equality: $Z\left(R_{zi_{ni}}, W\right) = 42.0$ $\varepsilon_{ref.i_{ni}} = 3.2 \cdot \%$ $Z\left(R_{zi_{ni}}, W_{i.ref_{ni}}\right) = 131.6$

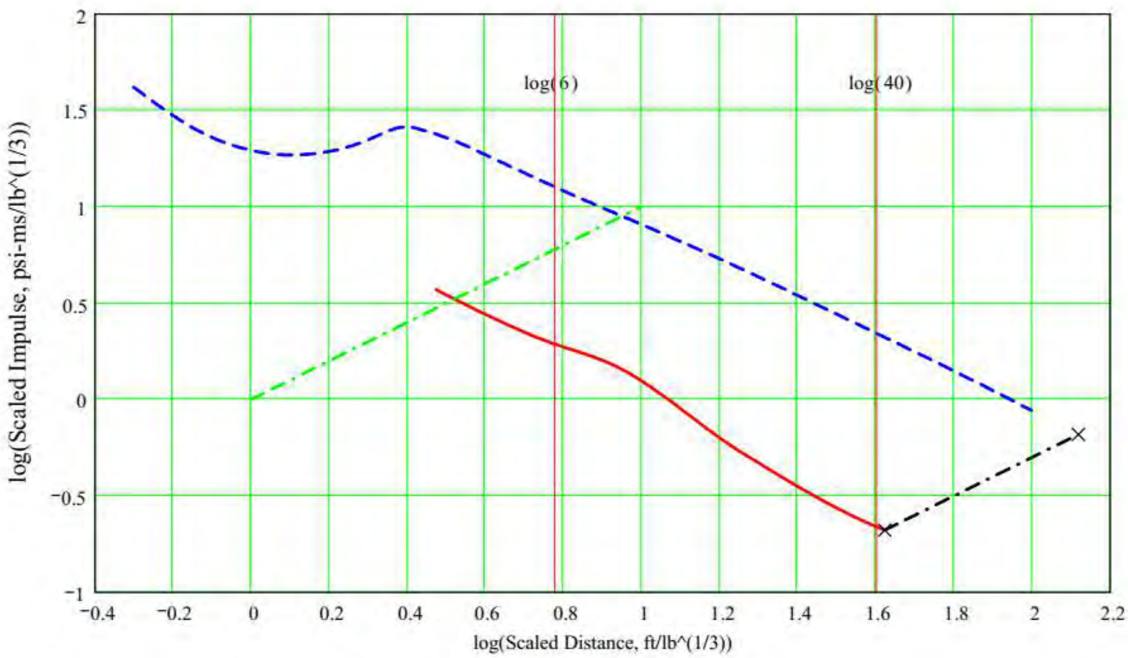
$$\frac{\int_{z_{min}}^{zi_{max}} F\varepsilon_{ref.i}(\log(x))\,dx}{\left(zi_{max} - z_{min}\right)} = 3.8 \cdot \%$$

$i_{s.smp}\left(R_{zi_{ni}}, W\right) = 0.21$ $i_{s.ref}\left(R_{zi_{ni}}, W_{i.ref_{ni}}\right) = 0.21$

$i_{scaled.smp}\left(Z\left(R_{zi_{ni}}, W\right)\right) = 0.21$ $i_{scaled.ref}\left(Z\left(R_{zi_{ni}}, W_{i.ref_{ni}}\right)\right) = 0.66$

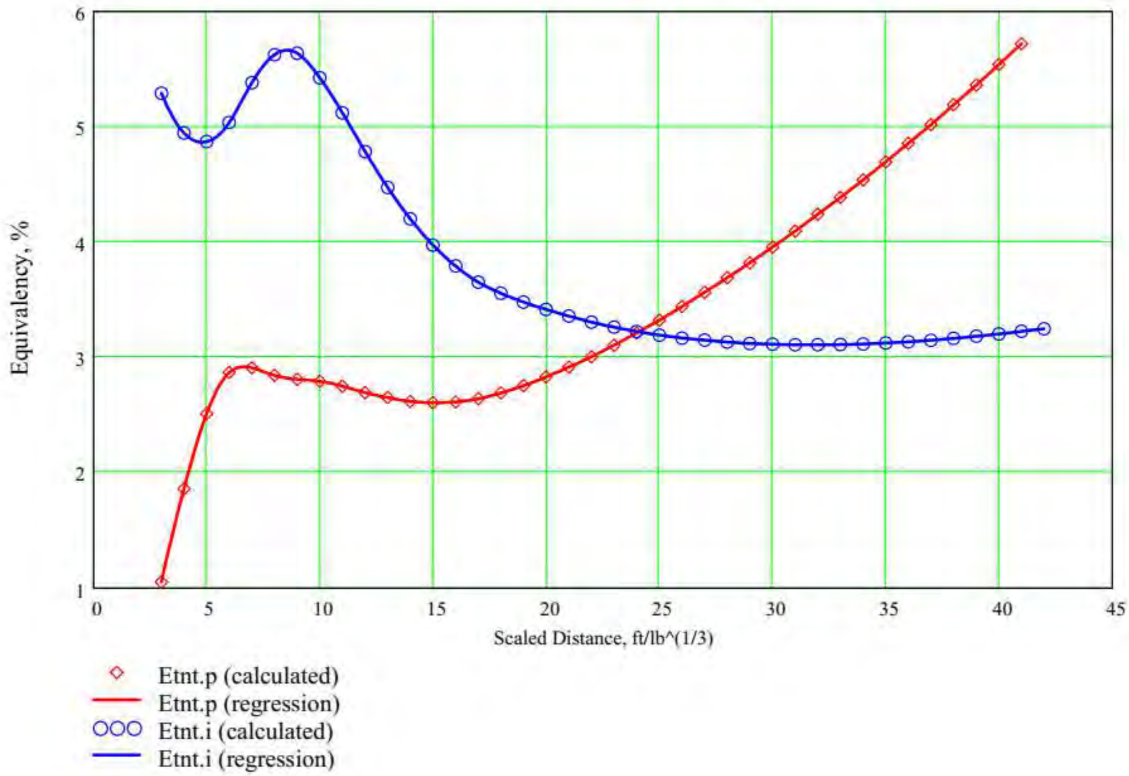
Test sample compared to Reference:





Equivalency as a Function of Scaled Distance

$z_p := z_{min}, z_{min} + 0.1 .. (np + z_{min})$ $\qquad$ $z_i := z_{min}, z_{min} + 0.1 .. (ni + z_{min})$



9.6 Composition A-5 Booster Pellet

PRESSURE AND IMPULSE TEST DATA SMOOTHING

$kPa := 1000 \cdot Pa \quad msec := 0.001 \cdot sec$

Test Sample: Composition A-5, cylinder 1:1 on surface at the SMS Test Site in Tooele, Utah

Read in the test data summary file: data := READPRN("C:\HRNA-7150-A5-Data.prn") $\quad Item := data^{\langle 0 \rangle}$

NOTE: Col 1 - Item, Col 2 - Trial, Col 3 - Line, Col 4 - Station, Col 5 - Distance in feet, Col 6 - Peak Pressure in psig, Col 7 - TTL initiation time, Col 8 - time of arrival in seconds, Col 9 - time that pressure returned to ambient in seconds (impulse maxima), Col 10 - impulse in psi-msec.

Read in the test conditions file: cond := READPRN("C:\HRNA-7150-A5-TestCond.prn")

NOTE: Col 1 - Trial, Col 2 - net explosives weight, Col 3 - temperature in Kelvin, Col 4 - pressure in inHg.

$trial := cond^{\langle 0 \rangle} \quad W_{trial} := cond^{\langle 1 \rangle} \cdot \frac{gm}{lb} \quad T_{trial} := cond^{\langle 2 \rangle} \cdot K \quad P_{trial} := cond^{\langle 3 \rangle} \cdot in\_Hg$

Initiation train: $W_{init} := (0) \cdot \frac{gm}{lb} \quad \varepsilon_{TNT.init.p} := 90\,\% \quad \varepsilon_{TNT.init.i} := 85\,\%$

Initial guess value for the product's average TNT equivalency: $\varepsilon_{TNT.p} := 90\,\% \quad \varepsilon_{TNT.i} := 85\,\%$

Net explosive weight of product:

$$W_p := W_{trial} + \frac{W_{init} \cdot \varepsilon_{TNT.init.p}}{\varepsilon_{TNT.p}} \qquad W_p = \begin{bmatrix} 0.05 \\ 0.05 \end{bmatrix} \qquad W_i := W_{trial} + \frac{W_{init} \cdot \varepsilon_{TNT.init.i}}{\varepsilon_{TNT.i}} \qquad W_i = \begin{bmatrix} 0.05 \\ 0.05 \end{bmatrix}$$

Split data sets by trial:

```
Split(data, item) := | i ← 0
                     | for j ∈ 0 .. rows(data) − 1
                     |   if data[j,0] = item
                     |     | T<i> ← (data^T)<j>
                     |     | i ← i + 1
                     | Split ← T^T
```

$i := 0 .. rows(trial) - 1 \qquad Set_i := Split(data, i)$

$Trial_i := (Set_i)^{\langle 1 \rangle} \quad Line_i := (Set_i)^{\langle 2 \rangle} \quad Station_i := (Set_i)^{\langle 3 \rangle}$

$R_i := (Set_i)^{\langle 4 \rangle} \quad P_{so_i} := (Set_i)^{\langle 5 \rangle} \quad t_{TTL.abs_i} := (Set_i)^{\langle 6 \rangle}$

$t_{A.abs_i} := (Set_i)^{\langle 7 \rangle} \quad t_{amb.abs_i} := (Set_i)^{\langle 8 \rangle} \quad i_{s_i} := (Set_i)^{\langle 9 \rangle}$

Calculate time of shock arrival and duration: $t_{A_i} := t_{A.abs_i} - t_{TTL.abs_i} \qquad t_{o_i} := t_{amb.abs_i} - t_{A.abs_i}$

Calculate Sachs Scaling factors to convert measurements from test site to Sea Level (SL):

$P_{SL} := 101.4\cdot kPa$ $T_{SL} := 288.2\cdot K$ **Pressure:** $S_{P_i} := \frac{P_{trial_i}}{P_{SL}}$ $F_{P_i} := \left(S_{P_i}\right)^{-1}$

Distance: $S_{d.p_i} := \left(W_{p_i}\right)^{\frac{1}{3}}\cdot\left(\frac{P_{SL}}{P_{trial_i}}\right)^{\frac{1}{3}}$ $F_{R.p_i} := \left(S_{d.p_i}\right)^{-1}$ $S_{d.i_i} := \left(W_{i_i}\right)^{\frac{1}{3}}\cdot\left(\frac{P_{SL}}{P_{trial_i}}\right)^{\frac{1}{3}}$ $F_{R.i_i} := \left(S_{d.i_i}\right)^{-1}$

Time: $S_{t_i} := \left(W_{p_i}\right)^{\frac{1}{3}}\cdot\left(\frac{P_{trial_i}}{P_{SL}}\right)^{\frac{1}{3}}\cdot\left(\frac{T_{SL}}{T_{trial_i}}\right)^{\frac{1}{2}}$ $F_{T_i} := \left(S_{t_i}\right)^{-1}$

Impulse: $S_{i_i} := \left(W_{i_i}\right)^{\frac{1}{3}}\cdot\left(\frac{P_{SL}}{P_{trial_i}}\right)^{\frac{2}{3}}\cdot\left(\frac{T_{SL}}{T_{trial_i}}\right)^{\frac{1}{2}}$ $F_{i_i} := \left(S_{i_i}\right)^{-1}$

$F_P^T = [\ 1.002 \quad 1.002\ ]$

$F_{R.p}^T = [\ 2.673 \quad 2.673\ ]$

$F_{R.i}^T = [\ 2.673 \quad 2.673\ ]$

$F_T^T = [\ 2.725 \quad 2.725\ ]$

$F_i^T = [\ 2.720 \quad 2.720\ ]$

Apply Sachs Scaling Factors to convert measurements from test site to Sea Level:

$P_{so_i} := P_{so_i}\cdot F_{P_i}$ $z_{p_i} := R_i\cdot F_{R.p_i}$ $z_{i.s_i} := R_i\cdot F_{R.i_i}$ $t_{A_i} := t_{A_i}\cdot F_{T_i}$ $t_{o_i} := t_{o_i}\cdot F_{T_i}$ $i_{s.scaled_i} := i_{s_i}\cdot F_{i_i}$

Common log of the x axes: $logz_{p_i} := \overrightarrow{\log\left(z_{p_i}\right)}$ $logz_{i.s_i} := \overrightarrow{\log\left(z_{i.s_i}\right)}$

Common log of the y axes: $logP_{so_i} := \overrightarrow{\log\left(P_{so_i}\right)}$ $logi_{s.scaled_i} := \overrightarrow{\log\left(i_{s.scaled_i}\right)}$

Reassemble data sets: $logz_{all.p} := 1$ $logP_{so.all} := 1$ $logz_{all.i} := 1$ $logi_{s.scaled.all} := 1$

$$Reassemble(A,B) := \left[\begin{array}{l} A \leftarrow B_0 \\ \text{for } j \in 1..rows(trial)-1 \\ \quad A \leftarrow stack(A, B_j) \\ A \end{array}\right]$$

$logz_{all.p} := Reassemble(logz_{all.p}, logz_p)$ $logP_{so.all} := Reassemble(logP_{so.all}, logP_{so})$

$logz_{all.i} := Reassemble(logz_{all.i}, logz_{i.s})$ $logi_{s.scaled.all} := Reassemble(logi_{s.scaled.all}, logi_{s.scaled})$

Bind X-Y pairs together: $log_{data.p} := augment(logz_{all.p}, logP_{so.all})$ $log_{data.i} := augment(logz_{all.i}, logi_{s.scaled.all})$

Loess Smoothing of X-Y Data: $span_p := 0.60$ $span_i := 0.60$

$L_p := loess(log_{data.p}^{\langle 0 \rangle}, log_{data.p}^{\langle 1 \rangle}, span_p)$ $logPso(x) := interp(L_p, log_{data.p}^{\langle 0 \rangle}, log_{data.p}^{\langle 1 \rangle}, x)$

$L_i := loess(log_{data.i}^{\langle 0 \rangle}, log_{data.i}^{\langle 1 \rangle}, span_i)$ $logIscaled(x) := interp(L_i, log_{data.i}^{\langle 0 \rangle}, log_{data.i}^{\langle 1 \rangle}, x)$

$x_{p.min} := min(log_{data.p}^{\langle 0 \rangle})$ $x_{p.max} := max(log_{data.p}^{\langle 0 \rangle})$ $x_{i.min} := min(log_{data.i}^{\langle 0 \rangle})$ $x_{i.max} := max(log_{data.i}^{\langle 0 \rangle})$

$$Range2Vec(s,e,i) := \left|\begin{array}{l} count \leftarrow 0 \\ \text{for } i \in s, s+i..e \\ \quad \left| \begin{array}{l} v_{count} \leftarrow i \\ count \leftarrow count + 1 \end{array}\right. \\ v \end{array}\right.$$

$x_p := Range2Vec(x_{p.min}, x_{p.max}, 0.01)$ $z_p := \overrightarrow{10^{x_p}}$

$x_i := Range2Vec(x_{i.min}, x_{i.max}, 0.01)$ $z_i := \overrightarrow{10^{x_i}}$

$x_{min} := if(x_{p.min} > x_{i.min}, x_{p.min}, x_{i.min})$ $x_{max} := if(x_{p.max} < x_{i.max}, x_{p.max}, x_{i.max})$

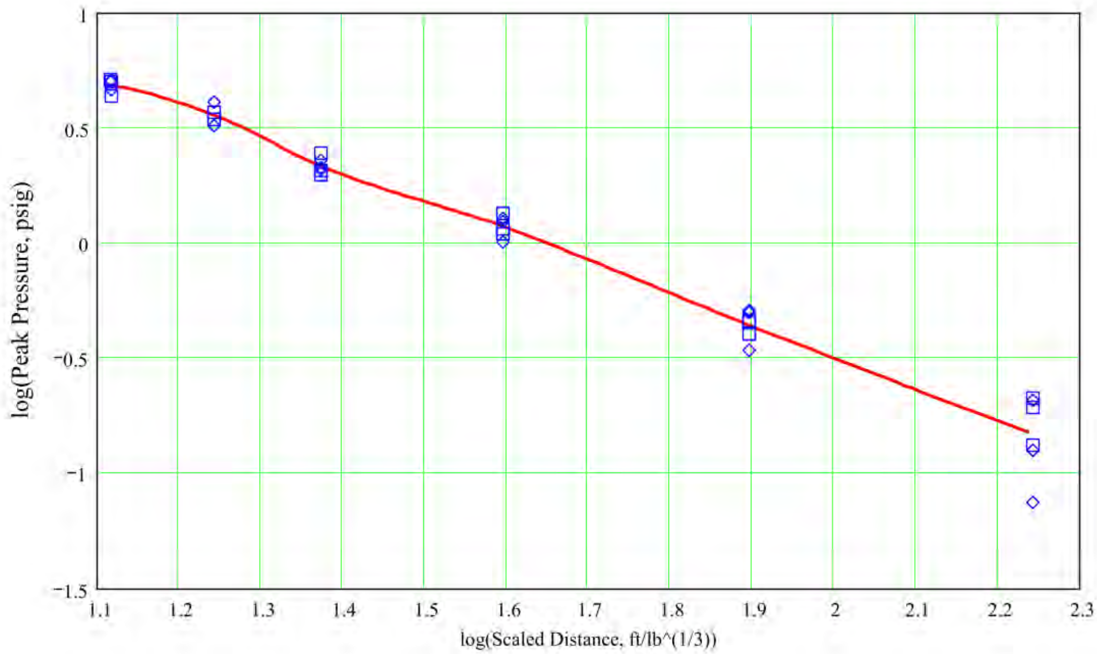
$x_{smu} := Range2Vec(x_{min}, x_{max}, 0.01)$ $P_{so.smu} := \overrightarrow{\left(10^{logPso(x_{smu})}\right)}$ $i_{s.scaled.smu} := \overrightarrow{\left(10^{logIscaled(x_{smu})}\right)}$

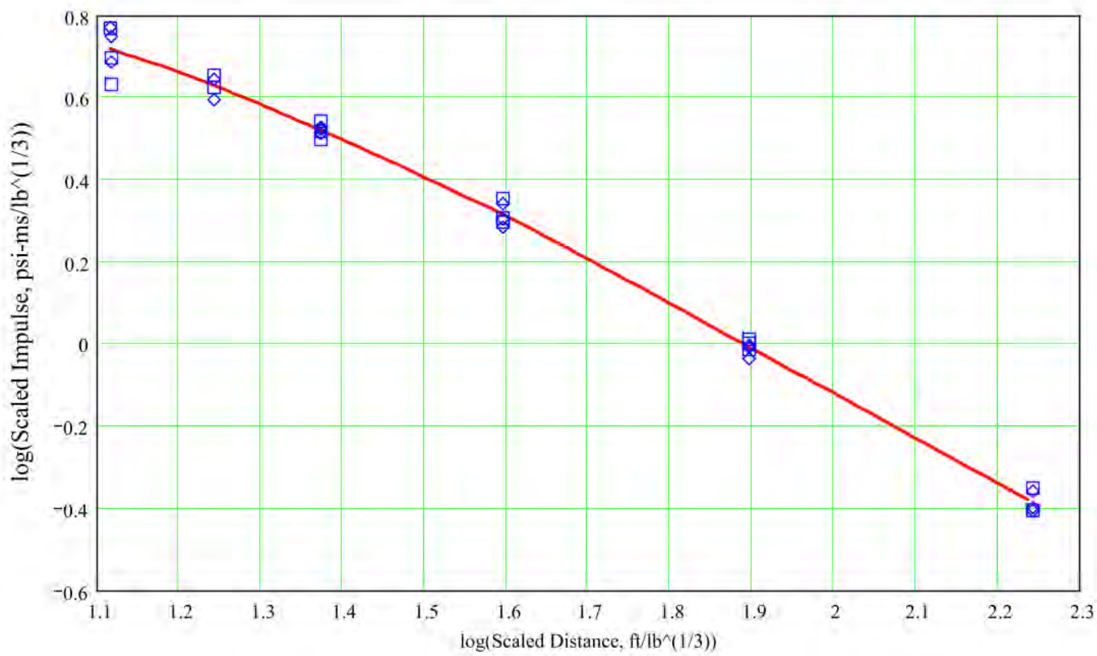
$z_{smu} := \overrightarrow{10^{x_{smu}}}$ $data_{smu} := augment(z_{smu}, P_{so.smu})$ $data_{smu} := augment(data_{smu}, i_{s.scaled.smu})$

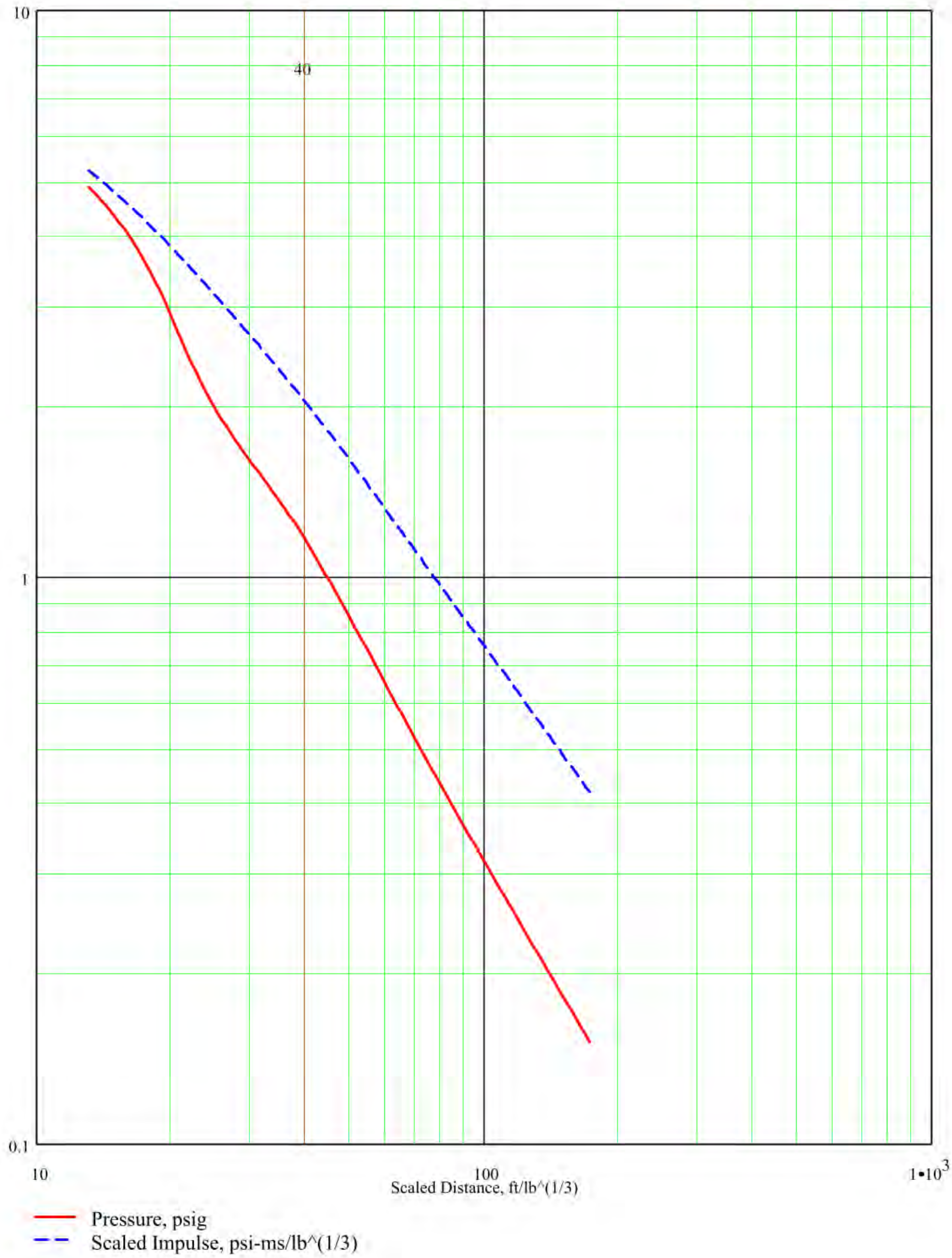
$P_{so.smu}(z) := 10^{logPso(log(z))}$ $i_{scaled.smu}(z) := 10^{logIscaled(log(z))}$

WRITEPRN("C:\ZPIscaledData(smooth).prn") := $data_{smu}$

Plot data and smoothed fit:






10
40
1
0.1
10
100
Scaled Distance, ft/lb^(1/3)
1•10^3
Pressure, psig
Scaled Impulse, psi-ms/lb^(1/3)

EQUIVALENCY CALCULATIONS

Test Sample: Composition A-5, cylinder 1:1 on surface at the SMS Test Site in Tooele, Utah
Reference: TNT, hemisphere on surface at Sea Level (UFC 3-340-02 (2008), Figure 2-15)

Blast curves for test sample:

$data_{smp} := READPRN(\text{"C:\A5 ZPIscaledData(smooth).prn"})$

$z_{smp} := data_{smp}^{\langle 0\rangle}$ $P_{so.smp} := data_{smp}^{\langle 1\rangle}$ $i_{s.scaled.smp} := data_{smp}^{\langle 2\rangle}$

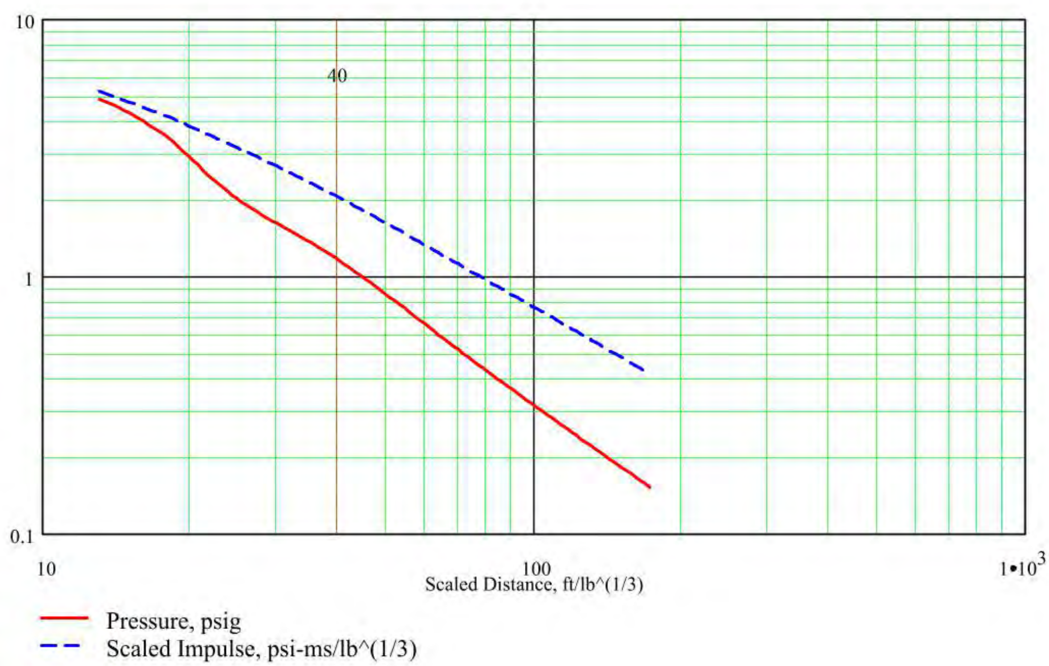
$j := 0..rows(z_{smp}) - 1$ $logz_{smp_j} := log(z_{smp_j})$ $logi_{s.scaled.smp_j} := log(i_{s.scaled.smp_j})$

$logP_{so.smp_j} := log(P_{so.smp_j})$ $x_{smp} := min(logz_{smp}), min(logz_{smp}) + 0.01 .. max(logz_{smp})$

$S1_s := lspline(logz_{smp}, logP_{so.smp})$ $S2_s := lspline(logz_{smp}, logi_{s.scaled.smp})$

$logP_{smp}(x) := interp(S1_s, logz_{smp}, logP_{so.smp}, x)$ $logI_{s.scaled.smp}(x) := interp(S2_s, logz_{smp}, logi_{s.scaled.smp}, x)$

$P_{so.smp}(z) := 10^{logP_{smp}(log(z))}$ $i_{scaled.smp}(z) := 10^{logI_{s.scaled.smp}(log(z))}$



Blast curves for Reference:

$data_{ref} := READPRN("C:\backslash UFC3\text{-}340\text{-}02Fig2\text{-}15.prn")$

$z_{ref} := data_{ref}^{\langle 0 \rangle}$ $\quad P_{so.ref} := data_{ref}^{\langle 1 \rangle}$ $\quad i_{s.scaled.ref} := data_{ref}^{\langle 2 \rangle}$

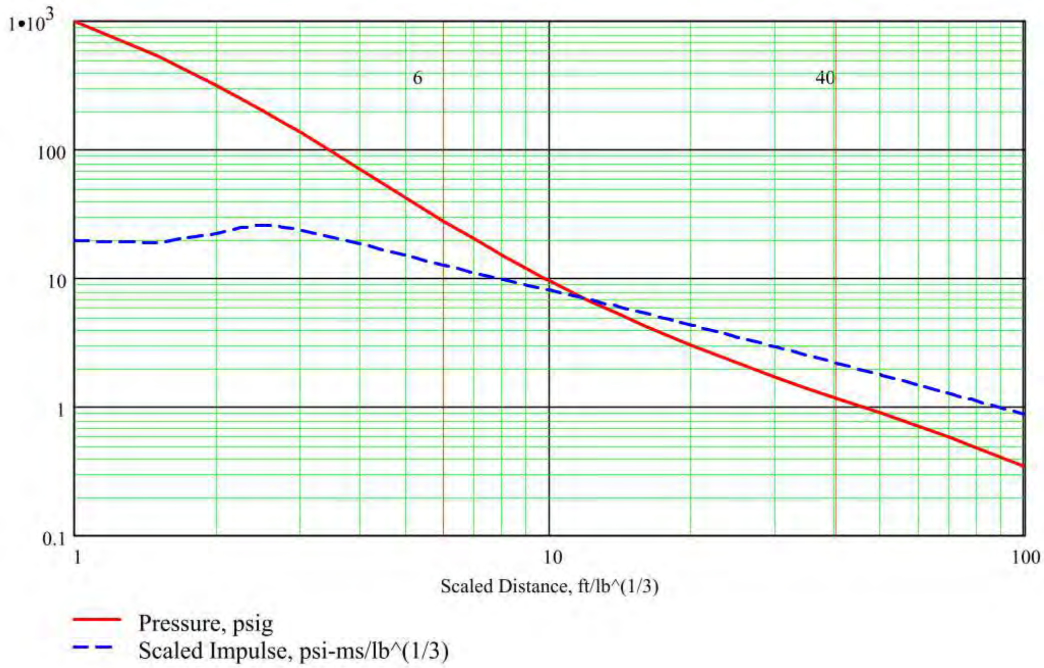
$j := 0 .. rows(z_{ref}) - 1$ $\quad logz_{ref_j} := \log(z_{ref_j})$ $\quad logi_{s.scaled.ref_j} := \log(i_{s.scaled.ref_j})$

$logP_{so.ref_j} := \log(P_{so.ref_j})$ $\quad x_{ref} := \min(logz_{ref}), \min(logz_{ref}) + 0.01 .. \max(logz_{ref})$

$S1_r := lspline(logz_{ref}, logP_{so.ref})$ $\quad S2_r := lspline(logz_{ref}, logi_{s.scaled.ref})$

$logP_{ref}(x) := interp(S1_r, logz_{ref}, logP_{so.ref}, x)$ $\quad logI_{s.scaled.ref}(x) := interp(S2_r, logz_{ref}, logi_{s.scaled.ref}, x)$

$P_{so.ref}(z) := 10^{logP_{ref}(\log(z))}$ $\quad i_{scaled.ref}(z) := 10^{logI_{s.scaled.ref}(\log(z))}$



$z_{min.s} := \min(z_{smp})$ $\quad z_{min.s} = 13.1$ $\quad z_{min.r} := \min(z_{ref})$ $\quad z_{min.r} = 0.5$

$z_{max.s} := \max(z_{smp})$ $\quad z_{max.s} = 172.7$ $\quad z_{max.r} := \max(z_{ref})$ $\quad z_{max.r} = 100.0$

$z_{min} := \text{floor}(\text{if}(z_{min.s}>6, z_{min.s}, 6))$ $z_{min} = 13.0$ $z_{max} := \text{ceil}(\text{if}(z_{max.s}<40, z_{max.s}, 40))$ $z_{max} = 40.0$

$l_{loop} := \text{floor}\left[\frac{(z_{max} - z_{min})}{2}\right]$ $l_{loop} = 13.0$

Equivalence to Reference: $\varepsilon_{ref}(W_{ref}, W) := \frac{W_{ref}}{W}$ $R_a := \begin{bmatrix} z_{min} \\ z_{min} + 1 \end{bmatrix}$

$$R_{z1} := \begin{array}{|l} R_b \leftarrow R_a \\ \text{for } j \in 1..l_{loop} \\ \quad \begin{array}{|l} R_a \leftarrow R_a + 2 \cdot j \\ R_b \leftarrow \text{stack}(R_b, R_a) \end{array} \\ R_b \end{array}$$

Equivalence for Peak Pressure as a function of Scaled Distance:

$W := 1$ $W_{ref} := 0.5$ $k := 0..\text{rows}(R_{z1}) - 1$ $R_{zp_k} := R_{z1_k}$

Given $P_{so.smp}(Z(R_{zp_k}, W)) = P_{so.ref}(Z(R_{zp_k}, W_{ref}))$

$W_{p.ref_k} := \text{find}(W_{ref})$ $\varepsilon_{ref.p} := \varepsilon_{ref}(W_{p.ref}, W)$ $S3 := \text{lspline}(\overrightarrow{\log(R_{zp})}, \varepsilon_{ref.p})$

$F\varepsilon_{ref.p}(x) := \text{interp}(S3, \overrightarrow{\log(R_{zp})}, \varepsilon_{ref.p}, x)$ $x_{\varepsilon_k} := \log(R_{zp_k})$ $\text{mean}(\varepsilon_{ref.p}) = 90\,\%$ $n := 0$

Spot check pressure equality: $Z(R_{zp_n}, W) = 13.0$ $\varepsilon_{ref.p_n} = 71\,\%$ $Z(R_{zp_n}, W_{p.ref_n}) = 14.6$

$$\frac{\int_{z_{min}}^{z_{max}} F\varepsilon_{ref.p}(\log(x))\,dx}{(z_{max} - z_{min})} = 90\,\%$$

$P_{so.smp}(Z(R_{zp_n}, W)) = 4.90$ $P_{so.ref}(Z(R_{zp_n}, W_{p.ref_n})) = 4.90$

RGB (228,226,226)

Equivalence for Positive Impulse as a function of Scaled Distance: $k := 0..\text{rows}(R_{z1}) - 1$

$R_{zi_k} := R_{z1_k}$ $i_{s.smp}(R, W) := i_{scaled.smp}(Z(R, W)) \cdot W^{\frac{1}{3}}$ $i_{s.ref}(R, W) := i_{scaled.ref}(Z(R, W)) \cdot W^{\frac{1}{3}}$

Given $i_{s.smp}(R_{zi_k}, W) = i_{s.ref}(R_{zi_k}, W_{ref})$ $W_{i.ref_k} := \text{find}(W_{ref})$ $\varepsilon_{ref.i} := \varepsilon_{ref}(W_{i.ref}, W)$

$S4 := \text{lspline}(\overrightarrow{\log(R_{zi})}, \varepsilon_{ref.i})$ $F\varepsilon_{ref.i}(x) := \text{interp}(S4, \overrightarrow{\log(R_{zi})}, \varepsilon_{ref.i}, x)$ $\text{mean}(\varepsilon_{ref.i}) = 85\,\%$

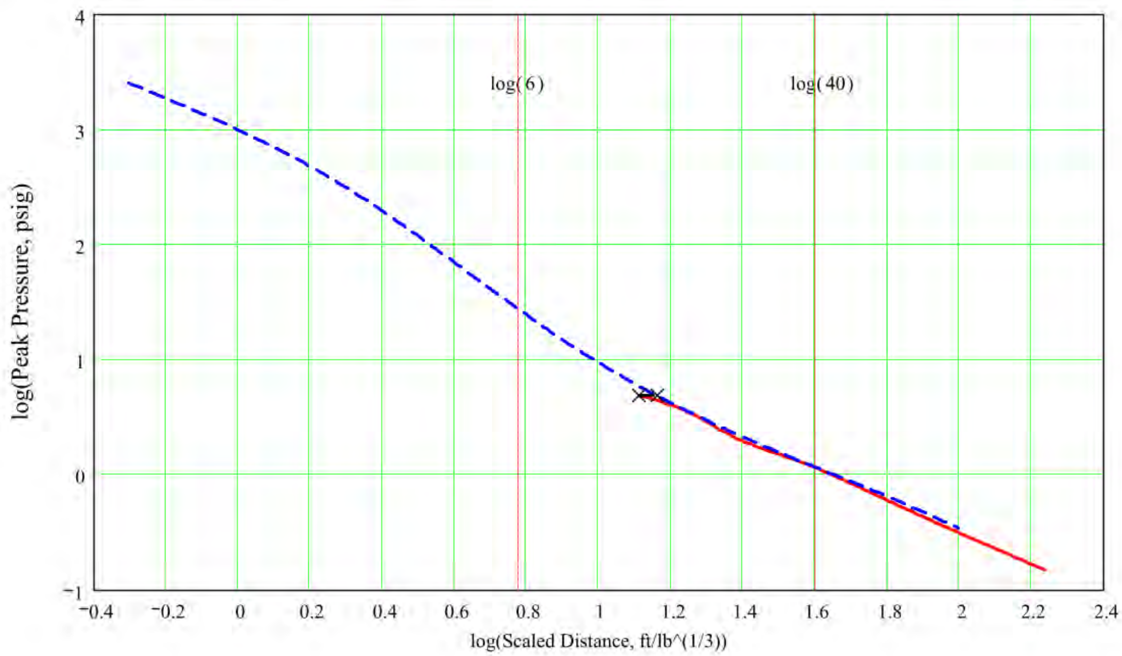
Spot check impulse equality: $Z(R_{zi_n}, W) = 13.0$ $\varepsilon_{ref.i_n} = 73\,\%$ $Z(R_{zi_n}, W_{i.ref_n}) = 14.4$

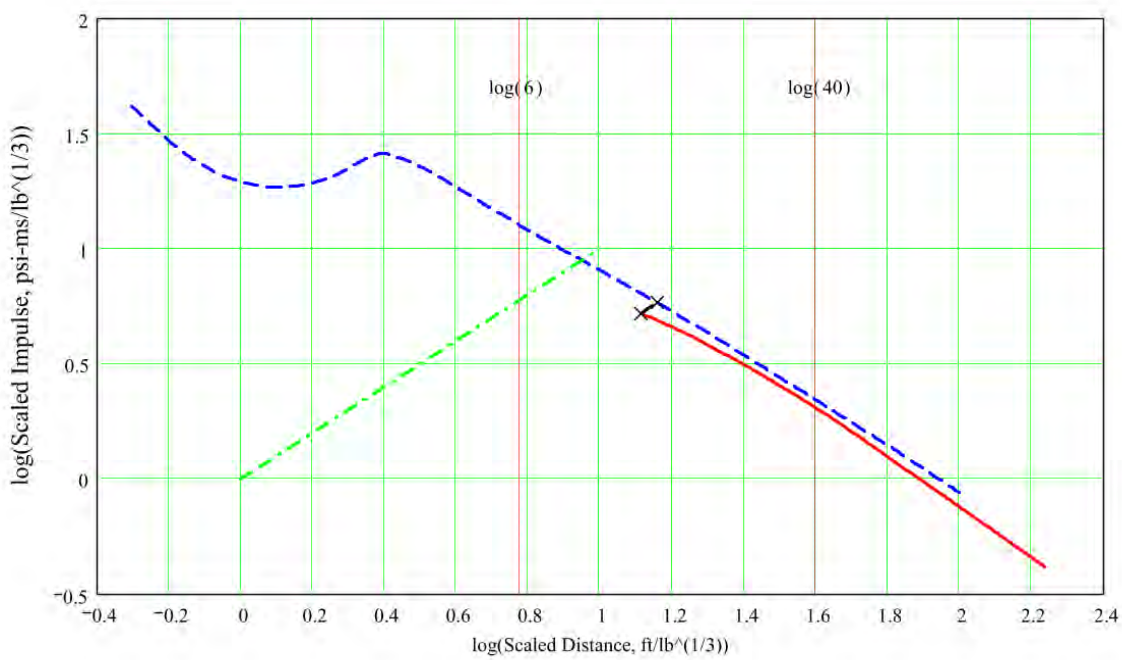
$$\frac{\int_{z_{min}}^{z_{max}} F\varepsilon_{ref.i}(\log(x))\,dx}{(z_{max} - z_{min})} = 85\,\%$$

$i_{s.smp}(R_{zi_n}, W) = 5.25$ $i_{s.ref}(R_{zi_n}, W_{i.ref_n}) = 5.25$

$i_{scaled.smp}(Z(R_{zi_n}, W)) = 5.25$ $i_{scaled.ref}(Z(R_{zi_n}, W_{i.ref_n})) = 5.84$

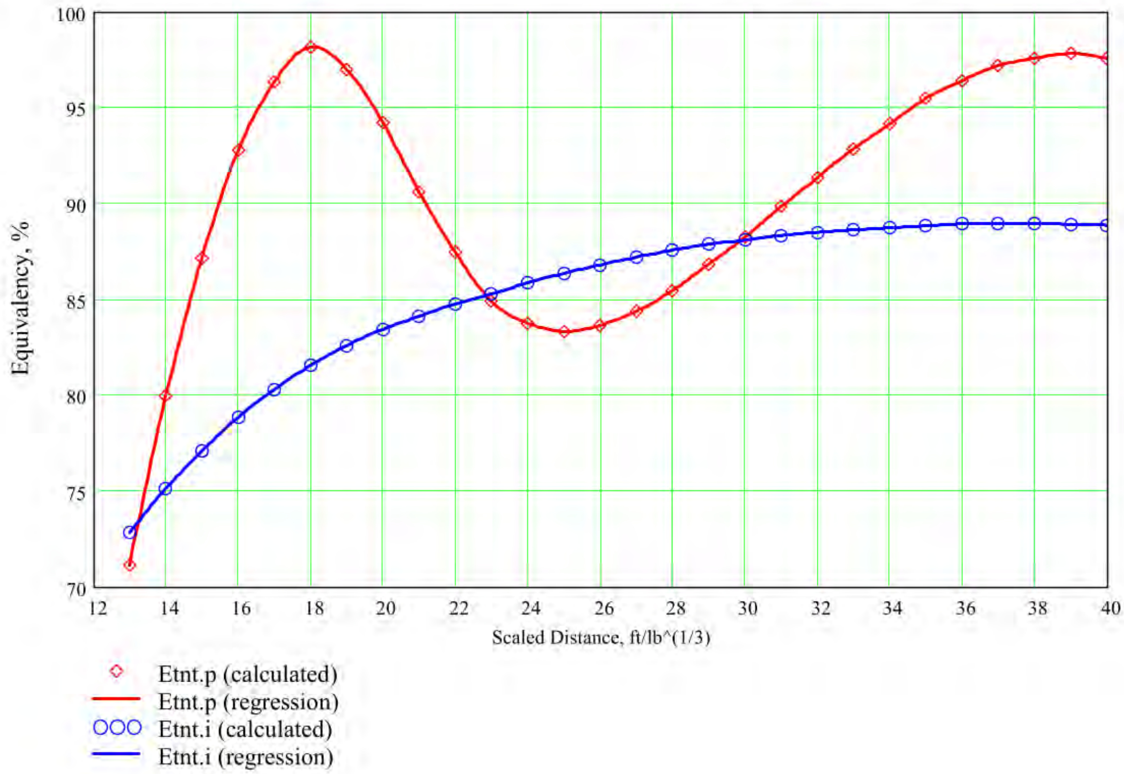
Test sample compared to Reference:





Equivalency as a Function of Scaled Distance

$z := z_{min}, z_{min} + 0.1 .. z_{max}$



9.7 Hemispherical Cast TNT

PRESSURE AND IMPULSE TEST DATA SMOOTHING

$kPa := 1000 \cdot Pa \quad msec := 0.001 \cdot sec$

Test Sample: TNT, hemispherical on surface at the SMS Test Site in Tooele, Utah

Read in the test data summary file: $data := READPRN(\text{"DOT1-6265f-TNT-Data.prn"})$ $\quad Item := data^{\langle 0 \rangle}$

NOTE: Col 1 - Item, Col 2 - Trial, Col 3 - Line, Col 4 - Station, Col 5 - Distance in feet, Col 6 - Peak Pressure in psig, Col 7 - TTL initiation time, Col 8 - time of arrival in seconds, Col 9 - time that pressure returned to ambient in seconds (impulse maxima), Col 10 - impulse in psi-msec.

Read in the test conditions file: $cond := READPRN(\text{"DOT1-6265f-TNT-TestCond.prn"})$

NOTE: Col 1 - Trial, Col 2 - net explosives weight, Col 3 - temperature in Kelvin, Col 4 - pressure in inHg.

$trial := cond^{\langle 0 \rangle} \quad W_{trial} := cond^{\langle 1 \rangle} \cdot \frac{gm}{lb} \quad T_{trial} := cond^{\langle 2 \rangle} \cdot K \quad P_{trial} := cond^{\langle 3 \rangle} \cdot in\_Hg$

Initiation train: $W_{init} := (21.25 + 0.5) \cdot \frac{gm}{lb} \quad \varepsilon_{TNT.init.p} := 90\% \quad \varepsilon_{TNT.init.i} := 85\%$

Initial guess value for the product's average TNT equivalency: $\varepsilon_{TNT.p} := 96\% \quad \varepsilon_{TNT.i} := 89\%$

Net explosive weight of product:

$$W_p := W_{trial} + \frac{W_{init} \cdot \varepsilon_{TNT.init.p}}{\varepsilon_{TNT.p}} \qquad W_p = \begin{bmatrix} 19.06 \\ 19.10 \\ 19.00 \end{bmatrix} \qquad W_i := W_{trial} + \frac{W_{init} \cdot \varepsilon_{TNT.init.i}}{\varepsilon_{TNT.i}} \qquad W_i = \begin{bmatrix} 19.07 \\ 19.10 \\ 19.00 \end{bmatrix}$$

Split data sets by trial:

```
Split(data, item) := | i ← 0
                     | for j ∈ 0 .. rows(data) − 1
                     |   if data_(j,0) = item
                     |     | T^<i> ← (data^T)^<j>
                     |     | i ← i + 1
                     | Split ← T^T
```

$i := 0..rows(trial) - 1 \qquad Set_i := Split(data, i)$

$Trial_i := (Set_i)^{\langle 1 \rangle} \quad Line_i := (Set_i)^{\langle 2 \rangle} \quad Station_i := (Set_i)^{\langle 3 \rangle}$

$R_i := (Set_i)^{\langle 4 \rangle} \quad P_{so_i} := (Set_i)^{\langle 5 \rangle} \quad t_{TTL.abs_i} := (Set_i)^{\langle 6 \rangle}$

$t_{A.abs_i} := (Set_i)^{\langle 7 \rangle} \quad t_{amb.abs_i} := (Set_i)^{\langle 8 \rangle} \quad i_{s_i} := (Set_i)^{\langle 9 \rangle}$

Calculate time of shock arrival and duration: $t_{A_i} := t_{A.abs_i} - t_{TTL.abs_i} \qquad t_{o_i} := t_{amb.abs_i} - t_{A.abs_i}$

Calculate Sachs Scaling factors to convert measurements from test site to Sea Level (SL):

$P_{SL} := 101.4 \cdot kPa$ $T_{SL} := 288.2 \cdot K$ **Pressure:** $S_{P_i} := \frac{P_{trial_i}}{P_{SL}}$ $F_{P_i} := \left(S_{P_i}\right)^{-1}$

Distance: $S_{d.p_i} := \left(W_{p_i}\right)^{\frac{1}{3}} \cdot \left(\frac{P_{SL}}{P_{trial_i}}\right)^{\frac{1}{3}}$ $F_{R.p_i} := \left(S_{d.p_i}\right)^{-1}$ $S_{d.i_i} := \left(W_{i_i}\right)^{\frac{1}{3}} \cdot \left(\frac{P_{SL}}{P_{trial_i}}\right)^{\frac{1}{3}}$ $F_{R.i_i} := \left(S_{d.i_i}\right)^{-1}$

Time: $S_{t_i} := \left(W_{p_i}\right)^{\frac{1}{3}} \cdot \left(\frac{P_{SL}}{P_{trial_i}}\right)^{\frac{1}{3}} \cdot \left(\frac{T_{SL}}{T_{trial_i}}\right)^{\frac{1}{2}}$ $F_{T_i} := \left(S_{t_i}\right)^{-1}$

Impulse: $S_{i_i} := \left(W_{i_i}\right)^{\frac{1}{3}} \cdot \left(\frac{P_{trial_i}}{P_{SL}}\right)^{\frac{2}{3}} \cdot \left(\frac{T_{SL}}{T_{trial_i}}\right)^{\frac{1}{2}}$ $F_{i_i} := \left(S_{i_i}\right)^{-1}$

$F_P^T = [\,1.002 \quad 1.005 \quad 1.006\,]$

$F_{R.p}^T = [\,0.374 \quad 0.374 \quad 0.374\,]$

$F_{R.i}^T = [\,0.374 \quad 0.373 \quad 0.374\,]$

$F_T^T = [\,0.384 \quad 0.384 \quad 0.385\,]$

$F_i^T = [\,0.384 \quad 0.386 \quad 0.387\,]$

Apply Sachs Scaling Factors to convert measurements from test site to Sea Level:

$P_{so_i} := P_{so_i} \cdot F_{P_i}$ $z_{p_i} := R_i \cdot F_{R.p_i}$ $z_{i.s_i} := R_i \cdot F_{R.i_i}$ $t_{A_i} := t_{A_i} \cdot F_{T_i}$ $t_{o_i} := t_{o_i} \cdot F_{T_i}$ $i_{s.scaled_i} := i_{s_i} \cdot F_{i_i}$

Common log of the x axes: $logz_{p_i} := \overrightarrow{\log\left(z_{p_i}\right)}$ $logz_{i.s_i} := \overrightarrow{\log\left(z_{i.s_i}\right)}$

Common log of the y axes: $logP_{so_i} := \overrightarrow{\log\left(P_{so_i}\right)}$ $logi_{s.scaled_i} := \overrightarrow{\log\left(i_{s.scaled_i}\right)}$

Reassemble data sets: $logz_{all.p} := 1$ $logP_{so.all} := 1$ $logz_{all.i} := 1$ $logi_{s.scaled.all} := 1$

$$Reassemble(A,B) := \left| \begin{array}{l} A \leftarrow B_0 \\ \text{for } j \in 1..rows(trial) - 1 \\ \quad A \leftarrow stack(A, B_j) \\ A \end{array} \right.$$

$logz_{all.p} := Reassemble(logz_{all.p}, logz_p)$ $logP_{so.all} := Reassemble(logP_{so.all}, logP_{so})$

$logz_{all.i} := Reassemble(logz_{all.i}, logz_{i.s})$ $logi_{s.scaled.all} := Reassemble(logi_{s.scaled.all}, logi_{s.scaled})$

Bind X-Y pairs together: $log_{data.p} := augment(logz_{all.p}, logP_{so.all})$ $log_{data.i} := augment(logz_{all.i}, logi_{s.scaled.all})$

Loess Smoothing of X-Y Data: $span_p := 0.65$ $span_i := 0.65$

$L_p := loess\left(log_{data.p}^{\langle 0 \rangle}, log_{data.p}^{\langle 1 \rangle}, span_p\right)$ $logPso(x) := interp\left(L_p, log_{data.p}^{\langle 0 \rangle}, log_{data.p}^{\langle 1 \rangle}, x\right)$

$L_i := loess\left(log_{data.i}^{\langle 0 \rangle}, log_{data.i}^{\langle 1 \rangle}, span_i\right)$ $logIscaled(x) := interp\left(L_i, log_{data.i}^{\langle 0 \rangle}, log_{data.i}^{\langle 1 \rangle}, x\right)$

$x_{p.min} := min\left(log_{data.p}^{\langle 0 \rangle}\right)$ $x_{p.max} := max\left(log_{data.p}^{\langle 0 \rangle}\right)$ $x_{i.min} := min\left(log_{data.i}^{\langle 0 \rangle}\right)$ $x_{i.max} := max\left(log_{data.i}^{\langle 0 \rangle}\right)$

$$Range2Vec(s,e,i) := \left| \begin{array}{l} count \leftarrow 0 \\ \text{for } i \in s, s+i..e \\ \quad \left| \begin{array}{l} v_{count} \leftarrow i \\ count \leftarrow count + 1 \end{array} \right. \\ v \end{array} \right.$$

$x_p := Range2Vec(x_{p.min}, x_{p.max}, 0.01)$ $z_p := \overrightarrow{10^{x_p}}$

$x_i := Range2Vec(x_{i.min}, x_{i.max}, 0.01)$ $z_i := \overrightarrow{10^{x_i}}$

$x_{min} := if(x_{p.min} > x_{i.min}, x_{p.min}, x_{i.min})$ $x_{max} := if(x_{p.max} < x_{i.max}, x_{p.max}, x_{i.max})$

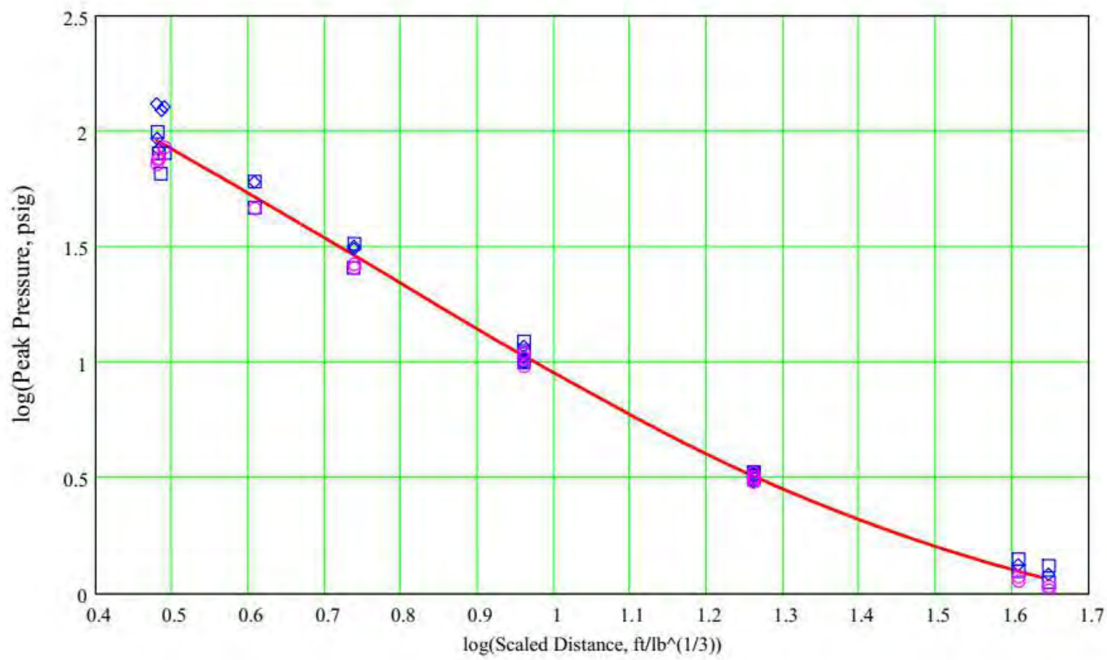
$x_{smu} := Range2Vec(x_{min}, x_{max}, 0.01)$ $P_{so.smu} := \overrightarrow{\left(10^{logPso(x_{smu})}\right)}$ $i_{s.scaled.smu} := \overrightarrow{\left(10^{logIscaled(x_{smu})}\right)}$

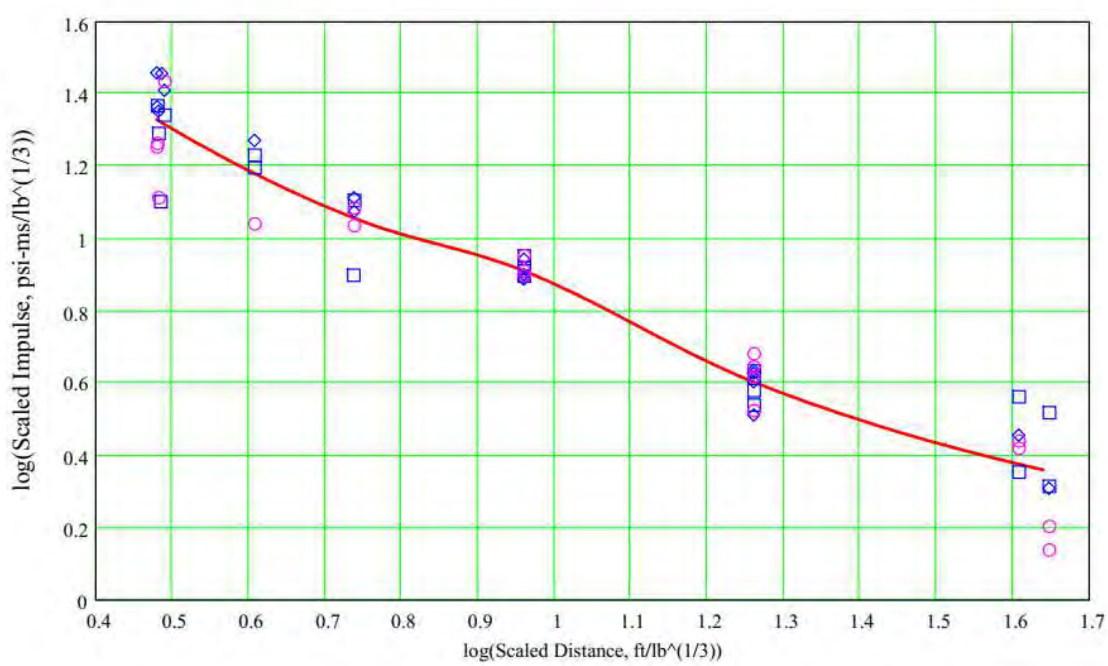
$z_{smu} := \overrightarrow{10^{x_{smu}}}$ $data_{smu} := augment(z_{smu}, P_{so.smu})$ $data_{smu} := augment(data_{smu}, i_{s.scaled.smu})$

$P_{so.smu}(z) := 10^{logPso(log(z))}$ $i_{scaled.smu}(z) := 10^{logIscaled(log(z))}$

WRITEPRN("ZPIscaledData(smooth).prn") := $data_{smu}$

Plot data and smoothed fit:






100
10
1
6
40
1
10
100
Scaled Distance, ft/lb^(1/3)
Pressure, psig
Scaled Impulse, psi-ms/lb^(1/3)

EQUIVALENCY CALCULATIONS

Test Sample: TNT, hemisphere on surface at Sea Level
Reference: TNT, hemisphere on surface at Sea Level (UFC 3-340-02 (2008), Figure 2-15)

Blast curves for test sample:

$data_{smp} := READPRN("TNT ZPIscaledData(smooth).prn")$

$z_{smp} := data_{smp}^{\langle 0 \rangle}$ $P_{so.smp} := data_{smp}^{\langle 1 \rangle}$ $i_{s.scaled.smp} := data_{smp}^{\langle 2 \rangle}$

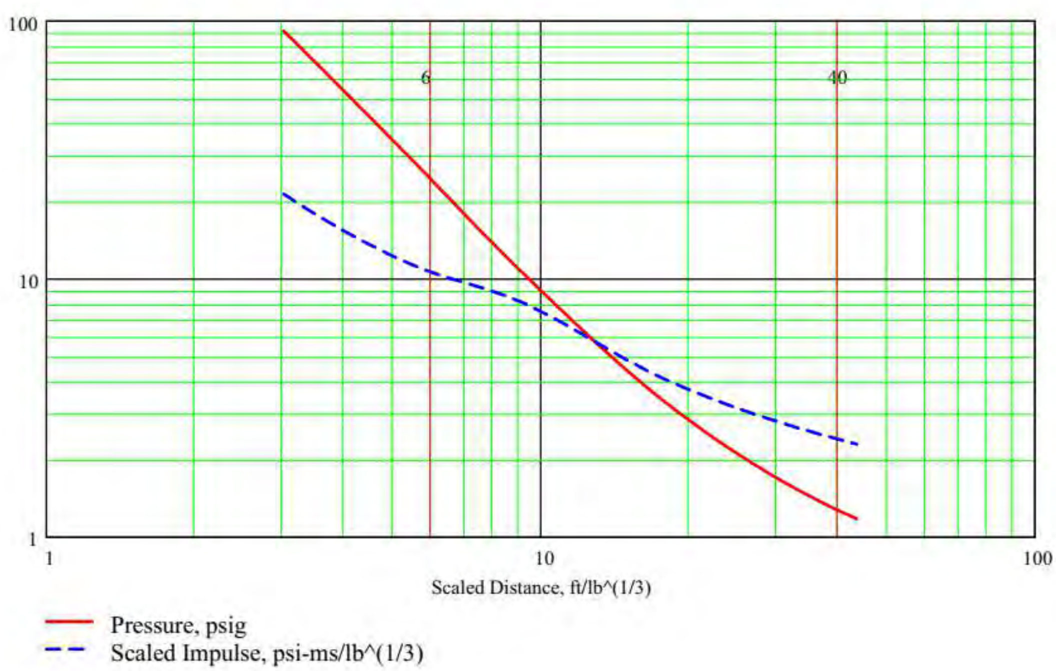
$j := 0 .. rows(z_{smp}) - 1$ $logz_{smp_j} := log(z_{smp_j})$ $logi_{s.scaled.smp_j} := log(i_{s.scaled.smp_j})$

$logP_{so.smp_j} := log(P_{so.smp_j})$ $x_{smp} := min(logz_{smp}), min(logz_{smp}) + 0.01 .. max(logz_{smp})$

$S1_s := lspline(logz_{smp}, logP_{so.smp})$ $S2_s := lspline(logz_{smp}, logi_{s.scaled.smp})$

$logP_{smp}(x) := interp(S1_s, logz_{smp}, logP_{so.smp}, x)$ $logI_{s.scaled.smp}(x) := interp(S2_s, logz_{smp}, logi_{s.scaled.smp}, x)$

$P_{so.smp}(z) := 10^{logP_{smp}(log(z))}$ $i_{scaled.smp}(z) := 10^{logI_{s.scaled.smp}(log(z))}$



Blast curves for Reference:

$data_{ref} := READPRN("UFC3-340-02Fig2-15.prn")$

$z_{ref} := data_{ref}^{\langle 0 \rangle}$ $P_{so.ref} := data_{ref}^{\langle 1 \rangle}$ $i_{s.scaled.ref} := data_{ref}^{\langle 2 \rangle}$

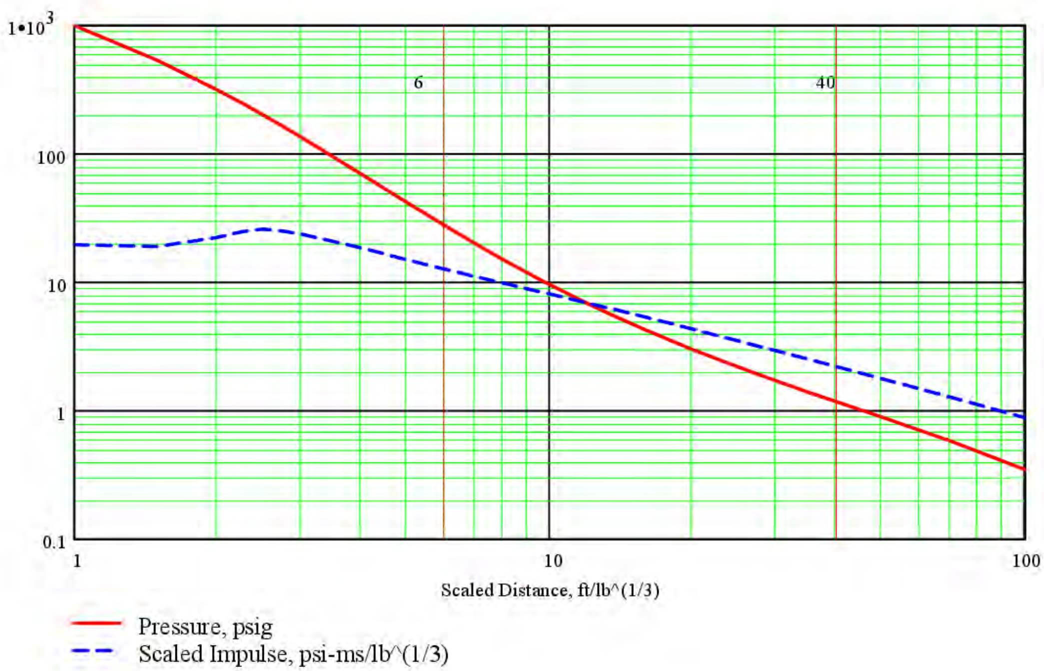
$j := 0 .. rows(z_{ref}) - 1$ $logz_{ref_j} := \log(z_{ref_j})$ $logi_{s.scaled.ref_j} := \log(i_{s.scaled.ref_j})$

$logP_{so.ref_j} := \log(P_{so.ref_j})$ $x_{ref} := \min(logz_{ref}), \min(logz_{ref}) + 0.01 .. \max(logz_{ref})$

$S1_r := lspline(logz_{ref}, logP_{so.ref})$ $S2_r := lspline(logz_{ref}, logi_{s.scaled.ref})$

$logP_{ref}(x) := interp(S1_r, logz_{ref}, logP_{so.ref}, x)$ $logI_{s.scaled.ref}(x) := interp(S2_r, logz_{ref}, logi_{s.scaled.ref}, x)$

$P_{so.ref}(z) := 10^{logP_{ref}(\log(z))}$ $i_{scaled.ref}(z) := 10^{logI_{s.scaled.ref}(\log(z))}$



$z_{min.s} := \min(z_{smp})$ $z_{min.s} = 3.0$ $z_{min.r} := \min(z_{ref})$ $z_{min.r} = 0.5$

$z_{max.s} := \max(z_{smp})$ $z_{max.s} = 43.7$ $z_{max.r} := \max(z_{ref})$ $z_{max.r} = 100.0$

$z_{min} := \text{ceil}(\text{if}(z_{min.s} > z_{min.r}, z_{min.s}, z_{min.r}))$ $z_{max} := \text{floor}(\text{if}(z_{max.s} < z_{max.r}, z_{max.s}, z_{max.r}))$

$z_{min} = 4.0$ $z_{max} = 43.0$ $l_{loop} := \text{floor}\left[\frac{(z_{max} - z_{min})}{2}\right] - 1$ $l_{loop} = 18.0$

Equivalence to Reference: $\varepsilon_{ref}(W_{ref}, W) := \frac{W_{ref}}{W}$ $R_a := \begin{bmatrix} z_{min} \\ z_{min} + 1 \end{bmatrix}$ $R_{z1} := \left| \begin{array}{l} R_b \leftarrow R_a \\ \text{for } j \in 1..l_{loop} \\ \quad \left| \begin{array}{l} R_a \leftarrow R_a + 2 \cdot j \\ R_b \leftarrow \text{stack}(R_b, R_a) \end{array} \right. \\ R_b \end{array} \right.$

Equivalence for Peak Pressure as a function of Scaled Distance:

$W := 1$ $W_{ref} := 0.9$ $np := 37$ $k := 0..np$ $R_{zp_k} := R_{z1_k}$

Given $P_{so.smp}(Z(R_{zp_k}, W)) = P_{so.ref}(Z(R_{zp_k}, W_{ref}))$

$W_{p.ref_k} := \text{find}(W_{ref})$ $\varepsilon_{ref.p} := \varepsilon_{ref}(W_{p.ref}, W)$ $S3 := \text{lspline}(\overrightarrow{\log(R_{zp})}, \varepsilon_{ref.p})$

$F\varepsilon_{ref.p}(x) := \text{interp}(S3, \overrightarrow{\log(R_{zp})}, \varepsilon_{ref.p}, x)$ $x_{\varepsilon_k} := \log(R_{zp_k})$ $\text{mean}(\varepsilon_{ref.p}) = 96 \cdot \%$

Spot check pressure equality: $Z(R_{zp_{np}}, W) = 41.0$ $\varepsilon_{ref.p_{np}} = 122.838 \cdot \%$ $Z(R_{zp_{np}}, W_{p.ref_{np}}) = 38.3$

$\frac{\int_{z_{min}}^{zp_{max}} F\varepsilon_{ref.p}(\log(x))\,dx}{(zp_{max} - z_{min})} = 96 \cdot \%$ $P_{so.smp}(Z(R_{zp_{np}}, W)) = 1.24$ $P_{so.ref}(Z(R_{zp_{np}}, W_{p.ref_{np}})) = 1.24$

RGB (226,226,226)

Equivalence for Positive Impulse as a function of Scaled Distance: $ni := 37$ $k := 0..ni$

$R_{zi_k} := R_{z1_k}$ $i_{s.smp}(R, W) := i_{scaled.smp}(Z(R, W)) \cdot W^{\frac{1}{3}}$ $i_{s.ref}(R, W) := i_{scaled.ref}(Z(R, W)) \cdot W^{\frac{1}{3}}$

Given $i_{s.smp}(R_{zi_k}, W) = i_{s.ref}(R_{zi_k}, W_{ref})$ $W_{i.ref_k} := \text{find}(W_{ref})$ $\varepsilon_{ref.i} := \varepsilon_{ref}(W_{i.ref}, W)$

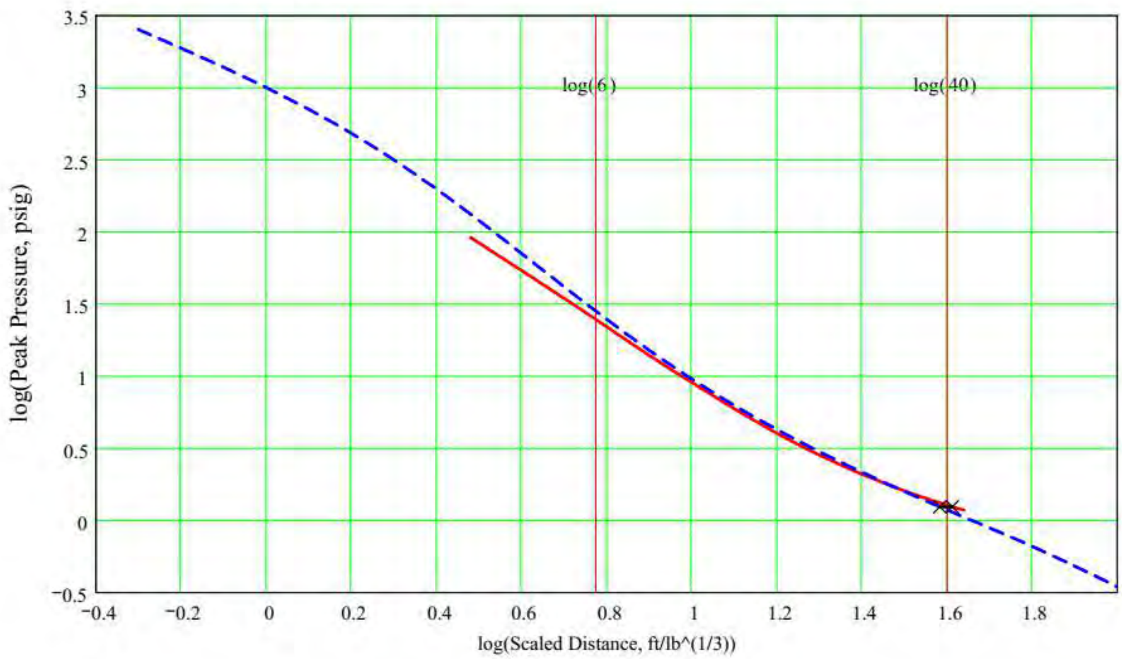
$S4 := \text{lspline}(\overrightarrow{\log(R_{zi})}, \varepsilon_{ref.i})$ $F\varepsilon_{ref.i}(x) := \text{interp}(S4, \overrightarrow{\log(R_{zi})}, \varepsilon_{ref.i}, x)$ $\text{mean}(\varepsilon_{ref.i}) = 89.8 \cdot \%$

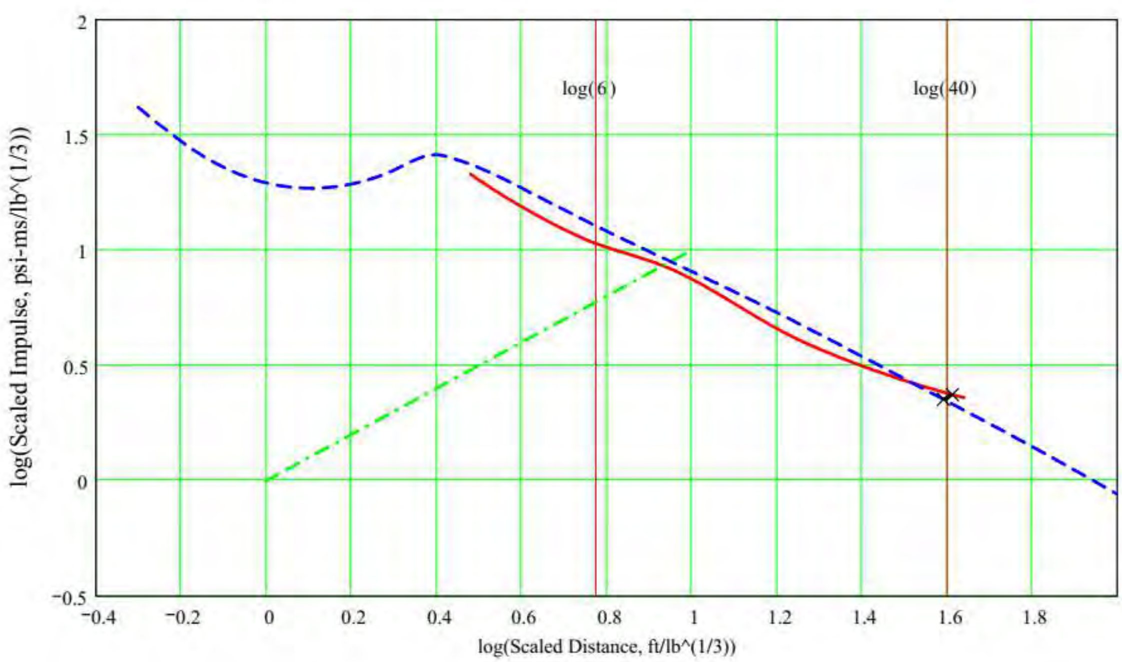
Spot check impulse equality: $Z(R_{zi_{ni}}, W) = 41.0$ $\varepsilon_{ref.i_{ni}} = 115.5 \cdot \%$ $Z(R_{zi_{ni}}, W_{i.ref_{ni}}) = 39.1$

$\frac{\int_{z_{min}}^{zi_{max}} F\varepsilon_{ref.i}(\log(x))\,dx}{(zi_{max} - z_{min})} = 89.6 \cdot \%$ $i_{s.smp}(R_{zi_{ni}}, W) = 2.36$ $i_{s.ref}(R_{zi_{ni}}, W_{i.ref_{ni}}) = 2.36$

$i_{scaled.smp}(Z(R_{zi_{ni}}, W)) = 2.36$ $i_{scaled.ref}(Z(R_{zi_{ni}}, W_{i.ref_{ni}})) = 2.25$

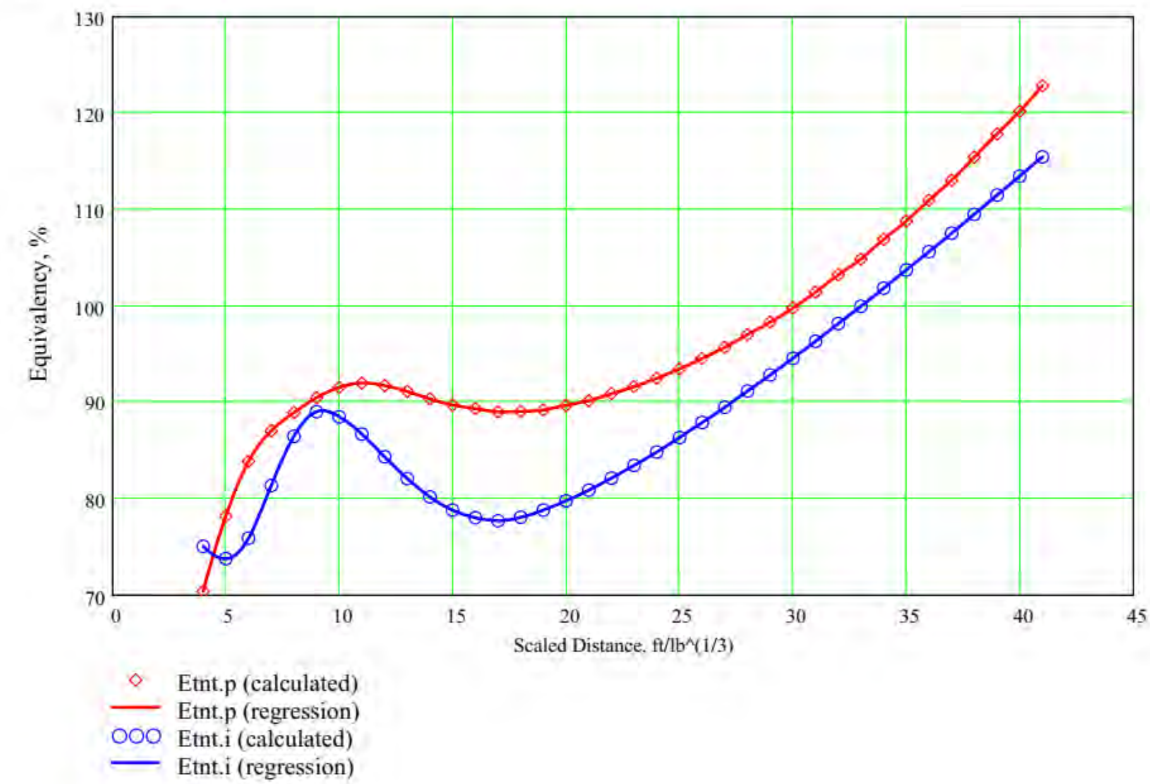
Test sample compared to Reference:





Equivalency as a Function of Scaled Distance

$z_p := z_{min}, z_{min} + 0.1 .. (np + z_{min})$ $\qquad$ $z_i := z_{min}, z_{min} + 0.1 .. (ni + z_{min})$



10.0 PRODUCT CERTIFICATIONS

10.1 Product Certification for Al Metal Powder

ATLANTIC EQUIPMENT ENGINEERS
HIGH PURITY METALS AND COMPOUNDS

Certificate of Analysis
ALUMINUM METAL POWDER
AL-100

1.1 General

SOLD TO	PURCHASE ORDER #	SHIP DATE	DOCUMENT NUMBER
SAFETY MANAGEMENT SERVICES for COMMANDER TOOELE ARMY DEPOT	1526	9 MAR 2021	2101018
CATALOG NUMBER	LOT NUMBER	QUANTITY	CAS NUMBER
AL-100	2002510-6	173 LBS	7429-90-5

2.1 Chemical Analysis (in percentage (%) unless otherwise stated)

Al	Ti	Si	Fe
99.9%	<0.06	<0.10	<0.20

3.1 Screen Analysis (percent passing) / Other

Size	D 10	D 50	D 90
1-5 microns	1.6 microns	3.6 microns	9 microns

4.1 Notes

5.1 Statement

Shelf life is indefinite when material is stored in a tightly sealed container in a cool, dry place.

The above analysis is carried out as part of our internal quality control testing and is based upon our analysis methods.

We do not assume any warranty, liability, or risk based on such findings. Our quality is warranted within the scope of our general sales conditions.

Please refer to SDS for material handling instructions.

Very Truly Yours,

M. Gerald, QA

24 Industrial Ave, Upper Saddle River, NJ 07458 Tel: 201.828.9400 Fax: 201.387.0291
On the web at: www.micronmetals.com Email: info@micronmetals.com

10.2 Product Certification for CuO

ATLANTIC EQUIPMENT ENGINEERS
HIGH PURITY METALS AND COMPOUNDS

Certificate of Analysis
CUPRIC OXIDE
CU-602

1.1 General

SOLD TO	PURCHASE ORDER #	SHIP DATE	DOCUMENT NUMBER
SAFETY MANAGEMENT SERVICES for COMMANDER TOOELE ARMY DEPOT	1526	9 MAR 2021	2101018
CATALOG NUMBER	LOT NUMBER	QUANTITY	CAS NUMBER
CU-602	2102518	548 LBS	1317-38-0

2.1 Chemical Analysis (in percentage (%) unless otherwise stated)

Cu	CuO	Cu2O	Zn	Fe	Ca	Mg
75	94	3	0.3	0.02	0.01	0.002
Mn	Pb	Cd	As	Sb	Moisture	
0.001	0.05	0.01	0.01	0.01	0.2	

3.1 Screen Analysis (percent passing) / Other

Size	Specific Gravity	-325 mesh	Loose Bulk Density
1-5 microns	8.7 g/cc	99.9	80 lbs / ft³

4.1 Notes

5.1 Statement

The above analysis is carried out as part of our internal quality control testing and is based upon our analysis methods.

We do not assume any warranty, liability, or risk based on such findings. Our quality is warranted within the scope of our general sales conditions.

Please refer to SDS for material handling instructions.

Very Truly Yours,

M. Gerald, QA

24 Industrial Ave, Upper Saddle River, NJ 07458 Tel: 201.828.9400 Fax: 201.387.0291
On the web at: www.micronmetals.com Email: info@micronmetals.com

Page 1 of 1

10.3 Product Certification for Fe_3O_4

ATLANTIC EQUIPMENT ENGINEERS
HIGH PURITY METALS AND COMPOUNDS

Certificate of Analysis

BLACK IRON OXIDE
FE-602

1.1 General

SOLD TO	PURCHASE ORDER #	SHIP DATE	DOCUMENT NUMBER
SAFETY MANAGEMENT SERVICES for COMMANDER TOOELE ARMY DEPOT	1526	9 MAR 2021	2101018
CATALOG NUMBER	LOT NUMBER	QUANTITY	CAS NUMBER
FE-602	2009517	1 LB	1317-61-6

2.1 Chemical Analysis (in percentage (%) unless otherwise stated)

Tint Strength	pH	FeO	Moisture
97.6	8.91	23.4	0.39
Water soluble Salts		Fe2O3	
0.18		99.9	

3.1 Screen Analysis (percent passing) / Other

Size	+325 mesh
1-5 microns	0.009

4.1 Notes

Very fine, black powder, manufactured in the USA.

5.1 Statement

The above analysis is carried out as part of our internal quality control testing and is based upon our analysis methods.

We do not assume any warranty, liability, or risk based on such findings. Our quality is warranted within the scope of our general sales conditions.

Please refer to SDS for material handling instructions.

Very Truly Yours,

M. Gerald, QA

24 Industrial Ave, Upper Saddle River, NJ 07458 Tel: 201.828.9400 Fax: 201.387.0291
On the web at: www.micronmetals.com Email: info@micronmetals.com

Page 1 of 1

10.4 Product Certification for Ti Metal Powder

ATLANTIC EQUIPMENT ENGINEERS
HIGH PURITY METALS AND COMPOUNDS

Certificate of Analysis

TITANIUM METAL POWDER
TI 101

1.1 General

SOLD TO	PURCHASE ORDER #	SHIP DATE	DOCUMENT NUMBER
SAFETY MANAGEMENT SERVICES for COMMANDER TOOELE ARMY DEPOT	1526	9 MAR 2021	2101018
CATALOG NUMBER	LOT NUMBER	QUANTITY	CAS NUMBER
TI 101	2012519	7 LBS	7440-32-6

2.1 Chemical Analysis (in percentage (%) unless otherwise stated)

Al	Cl	Cr	Fe	H	Mg	Mn
0.007	<0.025	0.004	0.028	0.51	<0.010	<0.005
Mo	Zr	Na	Ni	O	P	Pb & Cd
<0.005	<0.01	<0.001	0.006	0.91	<0.010	<0.002
Si	Sn	V	Ti			
0.007	<0.010	<0.005	99.8% min			

3.1 Screen Analysis (percent passing) / Other

Size	
< 20 microns	

4.1 Notes
99.8% min metals basis

5.1 Statement

The above analysis is carried out as part of our internal quality control testing and is based upon our analysis methods.

We do not assume any warranty, liability, or risk based on such findings. Our quality is warranted within the scope of our general sales conditions.

Please refer to SDS for material handling instructions.

Very Truly Yours,

M. Gerald, QA

24 Industrial Ave, Upper Saddle River, NJ 07458 Tel: 201.828.9400 Fax: 201.387.0291
On the web at: www.micronmetals.com Email: info@micronmetals.com

Page 1 of 1

10.5 Product Certification for MnO_2

AMERICAN ELEMENTS

World's Leading Manufacturer of Rare Earth and Advanced Material Products

A MERELEX CORPORATION • 10884 WEYBURN AVE. LOS ANGELES, CA 90024
TEL. 310-208-0551 • FAX 310-208-0351 • E-MAIL: customerservice@americanelements.com

CERTIFICATE OF COMPLIANCE

99+% (metals basis) Manganese Oxide Powder

MnO2

Product Code: MN-OX-021M-P.5UM

CAS #: 1313-13-9

LOT #: 1441516447-410

American Elements certifies that the materials listed below and shipped on 4/8/2021 meets the purity and dimensional requirements set forth in SMS Energetics, Inc. purchase order: DOT1-6265D.

99+% (metals basis) Manganese Oxide Powder
MnO2
APS: 5 um

AMERICAN ELEMENTS

By

AEC FORM 102:CA REV. APP. 2/3/99

10.6 Product Certification for Bi_2O_3

10.7 Product Certification for SnO_2

SIGMA-ALDRICH

sigma-aldrich.com

3050 Spruce Street, Saint Louis, MO 63103, USA
Website: www.sigmaaldrich.com
Email USA: techserv@sial.com
Outside USA: eurtechserv@sial.com

Certificate of Analysis

Product Name:
Tin(IV) oxide - -325 mesh, 99.9% trace metals basis

Product Number:	**244651**
Batch Number:	**MKBX0592V**
Brand:	ALDRICH
CAS Number:	18282-10-5
MDL Number:	MFCD00011244
Formula:	O2Sn
Formula Weight:	150.71 g/mol
Quality Release Date:	16 DEC 2015

SnO_2

Test	Specification	Result
Appearance (Color) Off-White to Grey	Conforms to Requirements	Light Grey
Appearance (Form)	Powder	Powder
X-Ray Diffraction	Conforms to Structure	Conforms
Loss on Ignition 1 Hour at 1000 Degrees Celsius	$\le$ 0.5 %	0.1 %
ICP Major Analysis Confirms Tin Component	Confirmed	Conforms
Purity 99.9% Based On Trace Metals Analysis	Conforms	Conforms
Trace Metal Analysis	$\le$ 1000.0 ppm	579.0 ppm
Silver (Ag)		9.0 ppm
Aluminum (Al)		4.4 ppm
Arsenic (As)		4.5 ppm
Bismuth (Bi)		16.0 ppm
Calcium (Ca)		35.0 ppm
Chromium (Cr)		2.2 ppm
Copper (Cu)		15.0 ppm
Iron (Fe)		120.0 ppm
Potassium (K)		2.0 ppm
Magnesium (Mg)		24.0 ppm
Manganese (Mn)		0.7 ppm
Sodium (Na)		11.0 ppm
Nickel (Ni)		1.9 ppm
Lead (Pb)		79.0 ppm
Antimony (Sb)		250.0 ppm
Titanium (Ti)		2.0 ppm
Zinc (Zn)		2.2 ppm
Zirconium (Zr)		0.1 ppm

Michael Grady, Manager
Quality Control
Milwaukee, WI US

10.8 Product Certification for Mg Metal Powder

SIGMA-ALDRICH

3050 Spruce Street, Saint Louis, MO 63103 USA
Email USA: techserv@sial.com Outside USA: eurtechserv@sial.com

Certificate of Analysis

Product Name:	MAGNESIUM powder, >= 99 %
Product Number:	13112
Batch Number:	STBH6715
Brand:	Aldrich
CAS Number:	7439-95-4
Formula:	Mg
Formula Weight:	24.31
Quality Release Date:	09 JUL 2018
Recommended Retest Date:	DEC 2021

TEST	SPECIFICATION	RESULT
APPEARANCE (COLOR)	WHITE TO GREY	LIGHT GREY
APPEARANCE (FORM)	POWDER	POWDER
ASSAY	≥ 99 %	100.7 %
INSOLUBLE MATTER	≤ 0.05 % (INSOLUBLE IN HCL)	< 0.05 %
IRON	≤ 0.05 %	< 0.05 %

Claudia Mayer
Manager Quality Control
Steinheim, Germany

10.9 Product Certification for NiO

Sigma-Aldrich.

3050 Spruce Street, Saint Louis, MO 63103, USA
Website: www.sigmaaldrich.com
Email USA: techserv@sial.com
Outside USA: eurtechserv@sial.com

Certificate of Analysis

Product Name:
Nickel(II) oxide - green, −325 mesh, 99%

NiO

Product Number:	**399523**
Batch Number:	**MKCN2758**
Brand:	ALDRICH
CAS Number:	1313-99-1
MDL Number:	MFCD00011145
Formula:	NiO
Formula Weight:	74.69 g/mol
Quality Release Date:	11 DEC 2020

Test	Specification	Result
Appearance (Color)	Green to Very Dark Green and Green-Brown and Brown-Green	Green
Appearance (Form)	Powder	Powder
X-Ray Diffraction	Conforms to Structure	Conforms
Nickel	77.4 - 79.8 %	77.9 %
Particle Size -325 Mesh	Confirmed	Confirmed

Michael Grady, Manager
Quality Control
Milwaukee, WI US

Version Number: 1 Page 1 of 1

10.10 Product Certification for MoO_3

STANFORD ADVANCED MATERIALS

Stanford Advanced Materials
23661 Birtcher Dr. Lake Forest, CA 92630, USA
Tel: (949) 407-8904 Fax: (949) 812-6690

Certificate of Analysis

Product Name:	Molybdenum Trioxide (MoO3) Powder
Purity:	≥99.5%
Particle Size:	-325mesh
Lot Number:	OC210201-12629-1
Date:	2/1/21

Purity (wt%)	99.5
C (wt%)	0.05
H (wt%)	0.02
O (wt%)	0.01
N (wt%)	0.01
Mg (wt%)	0.01
Al (wt%)	0.01
Si (wt%)	0.02
Ca (wt%)	0.01
Ti (wt%)	0.01
Fe (wt%)	0.08
Ni (wt%)	0.01
Cu (wt%)	0.02
Sn (wt%)	0.01
W (wt%)	0.03
Pb (wt%)	0.01

Stanford Advanced Materials

10.11 Product Certification for TNT

Accurate Energetic Systems, LLC

5891 Highway 230 West • McEwen, Tennessee 37101
Telephone: (931)729-4207 • Fax: (931)729-4217
www.aesys.biz

October 21, 2022

Sales Order No. 4635
Purchase Order No. 1571

Safety Management Services
1847 West 9000 South, Suite 205
West Jordan, UT 84088
USA

Subject: **Certification of Conformance**

Accurate Energetic Systems (AES) certifies that the materials as described below are in accordance with applicable drawings and specifications unless otherwise listed below as authorized deviations. Originals of supporting documentation are on file at AES and available for review by authorized representatives.

Nomenclature	:	20 LB TNT CAST HEMISPHERE
AES Part Number	:	FB-10073
Quantity	:	5 pcs
AES Lot Number	:	19OC22A1 (See material COA's attached)

Authorized Waivers and/or Deviations: None
Remarks/Comments: See attached copies of original material COA's
FB-10073: NCH19G005-548 / NCH19G005-566

Respectfully,

Mike Capps
Quality Supervisor

QF-71-08 RA 12/15/06 Page 1 of 1

NITRO CHEM | Zakłady Chemiczne "NITRO-CHEM" S.A. [illegible] | [illegible] 85-552 Bydgoszcz, POLAND [illegible] | [illegible] 52 374 76 50 fax 52 361 11 24

Bydgoszcz, 28.11.2019

CHEMICAL WORKS „NITRO-CHEM" S.A.

CERTIFICATION OF COMPLIANCE / ANALYSIS
(CMTR) No.: 1640/2019

Material name: *Trinitrotoluene (TNT) Type 1, Flake*
UN No.: 0209
Lot No.: **NCH19G005-566** **Lot size:** 14000 kg
Packing: 560 cardboard boxes a 25 kg
Customer / Consignee: **Dyno Nobel Inc. USA**

Order number: 4501204191
Analysis No.: 6293 **Date of analysis:** 07.08.2019

No	Determination	Test results	Requirements by MIL-DTL-248D	Test Method Applicable Parag: MIL-DTL-248D
1.	Form	Flake	Flake	4.4.1.1
2.	Color	No darker than No. 30257	No darker than No. 30257	4.4.1.2
3.	Solidification Point, (°C)	min.80,38	min. 80,20	4.4.2
4.	Moisture, %	max.0,1	max. 0,10	4.4.3
5.	Acidity (as sulphuric acid), %	max. 0,001	max. 0,02	4.4.4
6.	Alkalinity	None	None	4.4.5
7.	Insoluble matter, %	max. 0,005	max. 0,05	4.4.6
8.	Sodium, %	max. 0,0002	max. 0,001	4.4.7
9.	Thickness of flake average, inch	max. 0,021	max. 0,025	4.4.8
10.	Thickness of flake individual, inch	max. 0,023	max. 0,04	4.4.8
11.	Pass through screen 3/8" square opening	100%	100%	4.4.11.1

Meets requirements according to MIL-DTL-248D.
A.m. article was released for sale.

Bydgoszcz, 28.11.2019

Deputy Manager of the Quality and Audit Department

mgr inż. Małgorzata Miśkiewicz

Sąd Rejonowy w Bydgoszczy, XIII Wydział Gospodarczy [illegible] KRS [illegible],
Kapitał zakładowy [illegible] zł, NIP 554-03-10-422, REGON [illegible]

NITRO CHEM | Zakłady Chemiczne "NITRO-CHEM" S.A. www.nitrochem.com.pl | ul.Theodora Wulffa 18 85-862 Bydgoszcz, POLAND nitrochem@nitrochem.com.pl | tel. 52 374 76 60 fax 52 361 11 24

Bydgoszcz, 28.11.2019

CHEMICAL WORKS „NITRO-CHEM" S.A.

CERTIFICATION OF COMPLIANCE / ANALYSIS (CMTR) No.: 1622/2019

Material name: *Trinitrotoluene (TNT) Type I, Flake*
UN No.: 0209
Lot No.: NCH19G005-548 **Lot size:** 14000 kg
Packing: 560 cardboard boxes a 25 kg
Customer / Consignee: Dyno Nobel Inc. USA

Order number: 4501204191
Analysis No.: 5973 **Date of analysis:** 23.07.2019

No	Determination	Test results	Requirements by MIL-DTL-248D	Test Method Applicable Parag: MIL-DTL-248D
1.	Form	Flake	Flake	4.4.1.1
2.	Color	No darker than No. 30257	No darker than No: 30257	4.4.1.2
3.	Solidification Point, (°C)	min.80.34	min. 80.20	4.4.2
4.	Moisture, %	max.0.05	max. 0,10	4.4.3
5.	Acidity (as sulphuric acid), %	max: 0,0012	max. 0,02	4.4.4
6.	Alkalinity	None	None	4.4.5
7.	Insoluble matter, %	max. 0,009	max. 0,05	4.4.6
8.	Sodium, %	max. 0,0	max. 0,001	4.4.7
9.	Thickness of flake average, inch	max. 0,022	max. 0,025	4.4.8
10.	Thickness of flake individual, inch	max. 0,024	max. 0,04	4.4.8
11.	Pass through screen 3/8" square opening	100%	100%	4.4.11.1

Meets requirements according to MIL-DTL-248D.
A.m. article was released for sale.

Bydgoszcz, 28.11.2019

Deputy Manager of the Quality and Audit Department

mgr inż. Małgorzata Miśkiewicz

Sąd Rejonowy w Bydgoszczy, XIII Wydział Gospodarczy Nr KRS 0000067791,
kapitał zakładowy 15 793 890 zł, NIP 554-03-10-422, REGON 091179184

TEST REPORT

Effect of Confinement on the Reactivity of Exploding Thermites

DOT Contract # 693JK320C000005

U.S. Department of Transportation
Pipeline and Hazardous Materials Safety Administration
(PHMSA)

Attention: PHH-20
Hazardous Materials Technology
1200 New Jersey Avenue, SE
E21-317
Washington, DC 20590

Troy A. Gardner, PE, CSP
Jackson Zarbock

May 29, 2023

SMS-6265g-R1, Rev 0

1847 West 9000 South, Suite 205 • West Jordan, Utah 84088 • 801-567-0456 • www.smsenergetics.com

Test Report

Effect of Confinement on the Reactivity of Exploding Thermites

May 29, 2023
SMS-6265g-R1, Rev 0

Troy A. Gardner, PE, CSP
Testing & Classifications Manager
Safety Management Services, Inc.

Jackson D. Zarbock
Project Engineer
Safety Management Services, Inc.

TABLE OF CONTENTS

TABLES

FIGURES

PHOTOS

1.0 STATEMENT OF WORK

DOT Contract # 693JK320C000005 with Safety Management Services, Inc. (SMS) of West Jordan, Utah defines that for Task 7, "Dependence of Thermite Reaction upon Confinement", SMS shall perform the following tests on eight exploding thermites:

1) Perform three standard Internal Ignition trials, increasing the amount of head space in each trial.
2) Perform additional internal ignition trials, varying the level of confinement:
    - Thin fiberboard tube
    - Thin-walled steel tube
    - Thick-walled steel tube

2.0 SUMMARY AND CONCLUSIONS

SMS performed Internal ignition trials on the following eight exploding thermites:

- LS #7 Al-MnO_2
- LS #8 Mg&Al-MoO_3 & CuO
- SS #4 Mg-MnO_2
- SS #19 Al-SnO_2
- SS #24 Al-Bi_2O_3
- SS #27 Al-Fe_3O_4
- SS #30 Al-NiO
- SS #48 Ti-Bi_2O_3

The tests were witnessed by Kirt N. Sasser and Jason T. Ford with the test results summarized in Table 1. A test video for each of the Internal ignition tests (SMS-6265g-V1) is being sent to the attention of the Contracting Officer's Representative (COR).

Table 1: Summary of Variable Confinement Internal Ignition Trials of Exploding Thermites

Tube Type	Fiberboard (0.07 inch)	Stainless (0.07 inch)	Mild Steel (0.30 inch)	Mild Steel (0.30 inch)	Mild Steel (0.30 inch)	Mild Steel (0.30 inch)
Fill Level	**100%**	**100%**	**100%**	**25%**	**50%**	**75%**
LS #7	(+) Explosion	(+) Explosion	(-) Burning	(-) Burning	(-) No Reaction	(-) Burning
LS #8	(+) Explosion	(+) Explosion	(-) Burning	(-) Burning	(-) Burning	(-) Burning
SS #4	(+) Explosion	(+) Explosion	(-) Burning	(-) Burning	(-) Burning	(-) Burning
SS #19	(+) Explosion	(-) Burning	(-) Burning	(-) Burning	(-) No Reaction	(-) No Reaction
SS #24	(+) Explosion	(+) Explosion	(-) Burning	(-) Burning	(-) Burning	(-) Burning
SS #27	(-) Burning	(-) Burning	(-) Burning	(-) No Reaction	(-) Burning	(-) No Reaction
SS #30	(-) Burning	(-) Burning	(-) Burning	(-) No Reaction	(-) Burning	(-) Burning
SS #48	(+) Explosion	(+) Explosion	(-) Burning	(-) Burning	(-) Burning	(-) Burning

Based on the test results, the strength of the confining media has a significant influence on reaction severity during a confined ignition of an exploding thermite. Explosions were observed on most of the trials conducted in confining media less robust than the standard internal ignition pipe. All tested thermites trended towards decreased reaction violence when placed in further confinement. This is consistent with previous test results and general thermite behavior.

The UN Series 1 and 2 tests were designed on the premise of utilizing shock, heating and ignition under confinement to determine whether a material will exhibit explosive properties when confined. However, for a thermite, confinement suppresses the explosive properties. Trials conducted in the thick-walled steel tubes further indicate that current parameters of UN tests used for classification of explosives, specifically UN Series 1/2 (c) (ii) Internal Ignition Test, misrepresent the hazards of potentially explosive thermites, as thermites that appear to possess no explosive properties when ignited under confinement in an internal ignition pipe can readily exhibit explosive properties in less robust containment.

Increasing head space in the internal ignition pipe did not result in increased reaction violence.

3.0 ACKNOWLEDGEMENTS

Mixing of all thermites was performed by Greg J. Dohm, Jordan D. Dzubak, Derek M. Sutton and Jackson D. Zarbock. The insulated nichrome wire igniters were prepared by Chandler K. Davis and Joshua A. Kneeland. Internal ignition trials were prepared by Jackson D. Zarbock and Collin L. Boren.

4.0 BACKGROUND

Historically, industry has offered traditional thermite formulations (containing only metal and metal oxides) for transport in Class 4 as flammable or water-reactive solids. The reaction produces a burst of heat, high temperature, and molten metal for various uses including joining steel railroad ties or copper transmission lines, metal refining, disabling munitions, etc. Traditional thermite formulations pass the UN Manual of Tests and Criteria, Appendix 6 “Screening Procedures” for substances which may have explosive properties as they do not contain any of the chemical groups listed in Table A6.1 that are associated with explosive properties. NOTE: The Appendix 6 Screening Procedures cannot be used for substances manufactured with the view to producing a practical explosive or pyrotechnic effect.

Newer “exotic” thermite formulations include those with additives such as plastics, oxidizers, nano materials, explosives, etc. to confer special compositions or actions upon use. Thermite research was needed to identify families of new and existing thermite compositions and to determine their hazards in transport and to transport vehicles.

Safety Management Services, Inc. (SMS) was contracted to perform research on thermite formulations in cooperation with Southwest Research Institute (SwRI) and the U.S. Department of Transportation (DOT) Pipeline and Hazardous Materials Safety Administration (PHMSA). This effort is considered to be Phase I of thermite testing. During Phase I, eight thermites for large-scale testing and fifteen thermite formulations were selected for small-scale testing. It was discovered that thermite mixtures exhibited hazards ranging from rapid reactions that were consistent with 1.3G materials to exploding when ignited in unconfined 5-gram quantities, similar to 1.1G flash powders. Two of the eight large-scale thermite mixtures and six of the fifteen small-scale thermite mixtures mixed by SMS also exploded in unconfined 5-gram quantities.

These findings prompted the request for SMS to perform additional testing to further research the energetic properties of thermite and develop the technical basis to base policies and decision on thermite-based products.

Thirty additional thermite formulations were selected during Task 2 of Phase II to determine if there are other metal-metal oxide combinations that exhibit 1.1-type hazards. The following thermites from Phase I and Phase II were found to explode when ignited in unconfined 25-gram quantities (see SMS-6265b-R1 for additional information):

- LS #7 Al-MnO_2
- LS #8 Mg&Al-MoO_3 & CuO
- SS #4 Mg-MnO_2
- SS #19 Al-SnO_2
- SS #24 Al-Bi_2O_3
- SS #27 Al-Fe_3O_4
- SS #30 Al-NiO
- SS #38 Mg-CrO_3
- SS #47 Ti-CrO_3
- SS #48 Ti-Bi_2O_3
- SS #56 Mg&Al-MoO_3 & CuO

Of these exploding thermites, eight were selected to undergo further testing. Selections were made based on reaction violence observed during the unconfined ignition testing (see SMS-6265b-V1) and sensitivity test data (due to safe handling concerns for larger quantities, thermites were not selected that were very sensitive to impact, friction and/or ESD stimuli). The following eight thermites were submitted for approval to PHMSA to undergo additional testing:

- LS #7 Al-MnO_2
- LS #8 Mg&Al-MoO_3 & CuO
- SS #4 Mg-MnO_2
- SS #19 Al-SnO_2
- SS #24 Al-Bi_2O_3
- SS #27 Al-Fe_3O_4
- SS #30 Al-NiO
- SS #48 Ti-Bi_2O_3

PHMSA approved the recommended thermites. SMS then procured raw ingredients and the thermites were mixed in quantities sufficient to complete all six Internal Ignition test trials.

5.0 DESCRIPTION OF THERMITE TEST SAMPLES

5.1 Fine Al-MnO_2 Thermite – Large-Scale Mix ID #7 (SMS mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 29.27% aluminum (Al) and 70.73% manganese(IV) oxide (MnO_2). The aluminum was 3N purity (99.9% pure), 1 - 5 micrometers (microns) in size, and offered for transport as a Division 4.1 flammable solid. The manganese(IV) oxide was 2N purity (99% pure), 5 microns in size, and offered for transport as non-regulated. This thermite was a very fine, dark gray powder when fully mixed.

Photo 1: Fine Al-MnO_2 Thermite – Large-Scale Mix ID #7 (SMS mixed)

5.2 Fine Mg&Al-MoO_3 & CuO Thermite – Large-Scale Mix ID #8 (SMS mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 25% magnalium (magnesium-aluminum), 34% molybdenum trioxide (MoO_3), and 41% copper(II)/cupric oxide (CuO). The magnalium was 2N purity (99% pure), 44 micrometers (microns) in size, and offered for transport as a Division 4.3 dangerous when wet substance with a subsidiary hazard of Division 4.2 spontaneously combustible. The molybdenum trioxide was 2N purity (99% pure), 44 microns in size, and offered for transport as a Division 6.1 toxic substance. The cupric oxide was 3N purity (99.9% pure), 1 - 5 microns in size, and offered for transport as Class 9. This thermite was a very fine, gray powder when fully mixed.

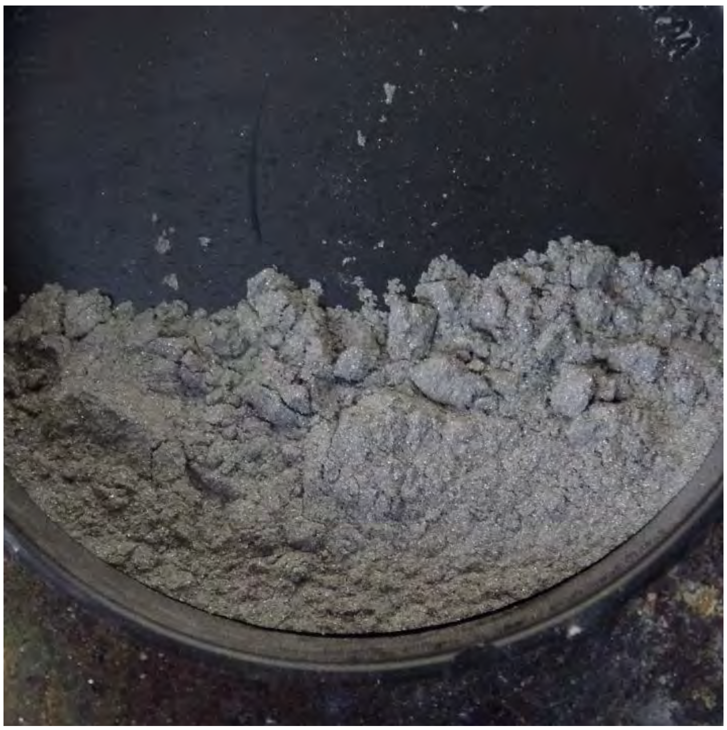


Photo 2: Fine Mg&Al-MoO_3-CuO Thermite – Large-Scale Mix ID #8 (SMS mixed)

5.3 Fine Mg-MnO_2 Thermite – Small-Scale Mix ID #4 (SMS mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 35.86% magnesium (Mg) and 64.14% manganese(IV) oxide (MnO_2). The manganese(IV) oxide was 2N purity (99% pure), 5 microns in size, and offered for transport as non-regulated. This thermite was a very fine, gray powder when fully mixed.

Photo 3: Fine Mg-MnO_2 Thermite – Small-Scale Mix ID #4 (SMS mixed)

5.4 Fine Al-SnO_2 Thermite – Small-Scale Mix ID #19 (SMS mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 19.27% aluminum (Al) and 80.73% tin(IV) oxide (SnO_2). The aluminum was 3N purity (99.9% pure), 1 - 5 micrometers (microns) in size, and offered for transport as a Division 4.1 flammable solid. This thermite was a very fine, off-white powder when fully mixed.

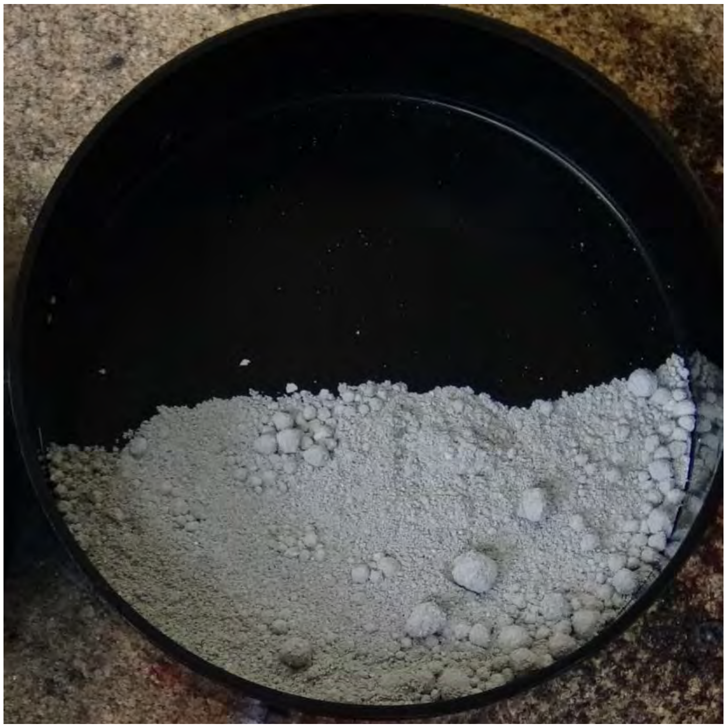


Photo 4: Fine Al-SnO_2 Thermite – Small-Scale Mix ID #19 (SMS mixed)

5.5 Fine Al-Bi_2O_3 Thermite – Small-Scale Mix ID #24 (SMS mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 10.38% aluminum (Al) and 89.62% bismuth oxide (Bi_2O_3). The aluminum was 3N purity (99.9% pure), 1 - 5 micrometers (microns) in size, and offered for transport as a Division 4.1 flammable solid. This thermite was a very fine, off-white powder when fully mixed.

Photo 5: Fine Al-Bi_2O_3 Thermite – Small-Scale Mix ID #24 (SMS mixed)

5.6 Fine Al-Fe_3O_4 – Small-Scale Mix ID #27 (SMS Mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 23.71% aluminum (Al) and 76.29% iron tetroxide (Fe_3O_4). The aluminum was 3N purity (99.9% pure), 1 - 5 micrometers (microns) in size, and offered for transport as a Division 4.1 flammable solid. The iron tetroxide was 3N purity (99.9% pure) and 1-5 micrometers (microns) in size. This thermite was a fine, dark gray powder when fully mixed.

Photo 6: Fine Al-Fe_3O_4 – Small-Scale Mix ID #27

5.7 Fine Al-NiO – Small-Scale Mix ID #30 (SMS Mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 19.41% aluminum (Al) and 80.59% nickel oxide (NiO). The aluminum was 3N purity (99.9% pure), 1 - 5 micrometers (microns) in size, and offered for transport as a Division 4.1 flammable solid. The nickel oxide was 1N purity (99% pure) and 1 - 5 micrometers (microns) in size. This thermite was a fine light green powder when fully mixed.

Photo 7: Fine Al-NiO – Small-Scale Mix ID #30

5.8 Fine Ti-Bi_2O_3 – Small-Scale Mix ID #48 (SMS Mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 13.35% titanium (Ti) and 86.65% bismuth trioxide (Bi_2O_3). The titanium was 2N purity (99.9% pure), less than 20 micrometers in size, and offered for transport as a Division 4.1 flammable solid. The bismuth trioxide was 3N purity (99.9% pure) and 1- 5 micrometers (micron) in size. This thermite was a fine, light-yellow powder when fully mixed.

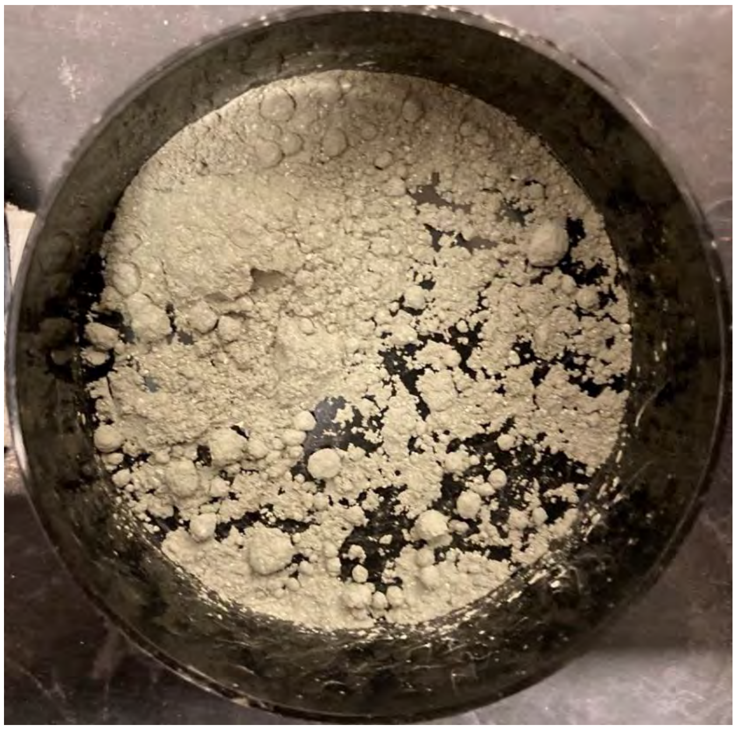


Photo 8: Fine Ti-Bi_2O_3 – Small-Scale Mix ID #48

6.0 TESTING INTRODUCTION

6.1 Ignition System

All Internal Ignition trials were ignited using an insulated Nichrome hotwire igniter. A length of 12-gauge nichrome wire was bent into a "U" shape. Each end was firmly attached to one line of a two-conductor wire. The connection points between the nichrome and the conductor wire were placed inside high-temperature borosilicate glass tubes to prevent shorting or damage to the connections during handling and when buried in thermite powder in the pipes. The ends of the borosilicate glass tubes were filled with high-temperature ceramic insulation to prevent thermite from shorting out the electrical connections. An example insulated Nichrome hotwire igniter is shown in Photo 9.

Photo 9: Insulated Nichrome Hotwire Igniter – Typical

The nichrome hotwire igniters were placed inside each pipe at the center of the material. To ignite the thermite, the leads of the nichrome wire igniters were connected to a high-amperage DC power supply. Prior to testing, the voltage and current of the power supply were set at 15 V and 23 amps, respectively. These power supply parameters resulted in the igniter reaching the highest temperature that did not result in the nichrome wire breaking. This ensured that the thermite would be exposed to the maximum temperature for the longest time.

6.2 Various Confining Media Overview

In accordance with Task 7.4 of Phase II, SMS was tasked with performing an Internal Ignition test using three confining media in order to determine the effect the strength of confinement has on the reaction violence of a confined ignition of exploding thermites. Three confining media were selected for testing: thin fiberboard tube, thin-walled steel tube, and thick-walled steel tube. SMS procured confining media that matched these descriptions. All varying confining media trials were conducted at the 100% fill level.

6.2.1 Thin Fiberboard Tube

The thin fiberboard tubes used during testing were spiral-wound, rigid tubes that were 18-inches long with a 3-inch inner diameter and a 0.07-inch-thick wall. The end caps were tight fitting plastic plugs that were glued in place. The fiber tube used during testing are shown in Figure 1.

Figure 1: Thin Fiberboard Tube Components

6.2.2 Thin-walled Steel Tube

The thin-walled steel tubes were obtained from a sanitary pipe supplier. The tubes were stainless steel, 18-inch-long spool tubes with clamp ends, a 3-inch inner diameter and a 0.07-inch-thick wall. Each end was secured with a high-pressure end cap, gasket, and clamp, The end closure was rated for 1000 psi at room temperature. All components of the thin-walled steel tube setup are shown in Figure 2.

Figure 2: Thin-walled Steel Tube Components

6.2.3 Thick-walled Steep Tube

The thick-walled steel tube used was a standard Internal Ignition pipe. The tube was Schedule 80 carbon steel, 18-inches long with a 2.9-inch inner diameter and 0.30-inch-thick wall. Both ends of the pipe were threaded and fitted with 3,000-pound forged steel end caps that were tightened using a strap wrench. Components for the standard Internal Ignition pipe are shown in Figure 3.

Threaded Pipe

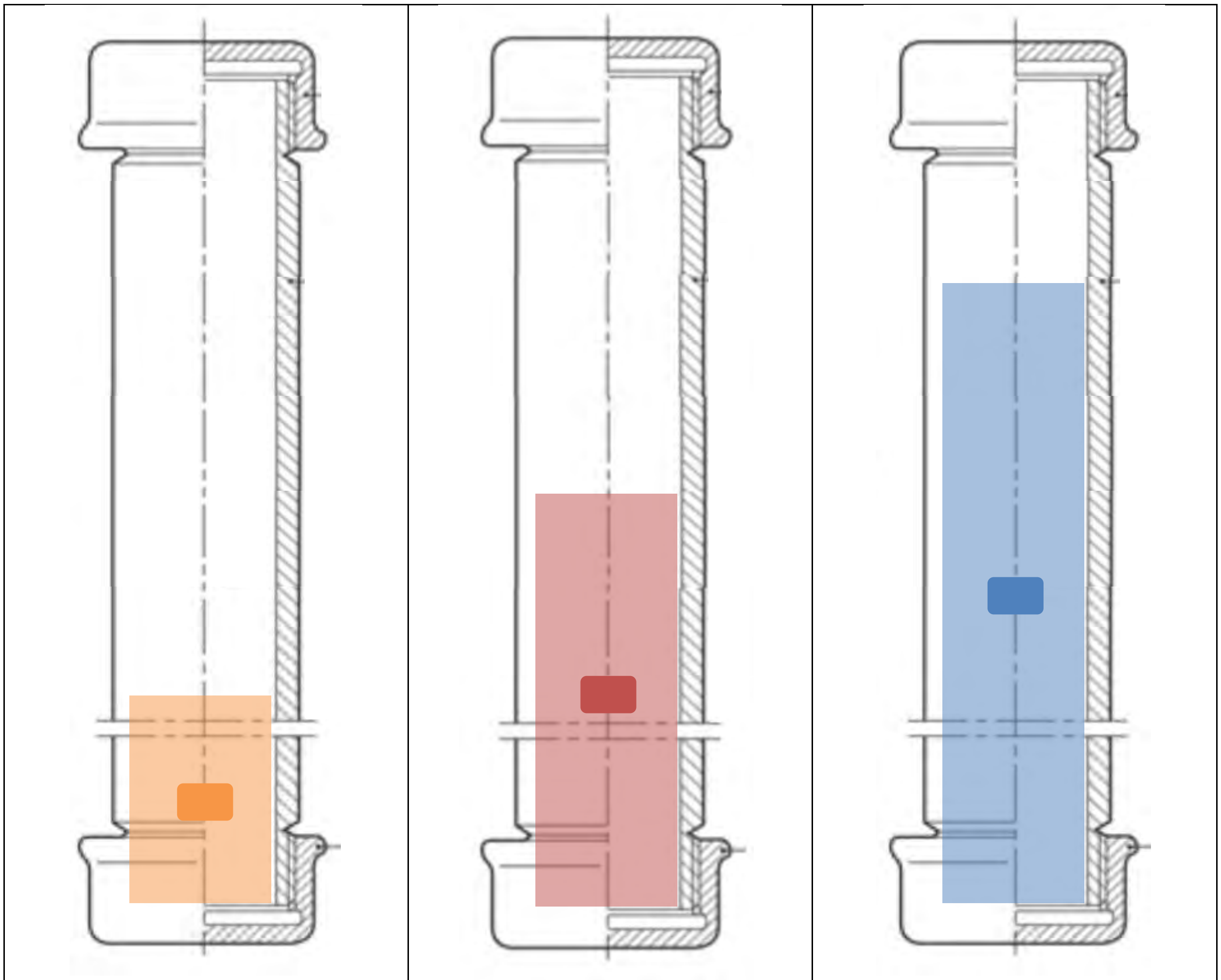
End Cap

Figure 3: Thick-walled Steel Tube Components

6.3 <u>Varying Head Space Overview</u>

Internal ignition tests were performed at various fill levels to determine the effect different levels of head space has on the reaction violence of exploding thermites ignited in a high confinement scenario. Fill levels of 25%, 50%, and 75% were selected for testing. The varying head space trials were conducted in the standard Internal Ignition pipe described in section 6.2.3.

Fill heights were determined by using the weight of the thermite required to fill the internal ignition pipe during the thick-walled steel trials. For example, if 10 pounds of LS #8 was required to fill an internal ignition pipe, then 2.5 pounds was used for the 25% fill level, 5.0 pounds for the 50% fill level, and 7.5 pounds for the 75% fill level. Each pipe was tapped at the height at which the igniter would be located at the center of the material. Figure 4 shows the relative fill height and igniter placement for each level.



25% Fill (75% Head Space)	50% Fill (50% Head Space)	75% Fill (25% Head Space)

Fill height is indicated by the translucent rectangle. Igniter location indicated by the smaller, opaque rectangle.

Figure 4: Fill Level and Igniter Location for Varying Head Space Internal Ignition Trials

7.0 TEST SETUP AND RESULTS

7.1 Thin Fiberboard Tube – 100% Fill

7.1.1 Test Setup

For each trial, a plastic end cap was secured to one end of the tube using a high strength all-purpose adhesive. The tube was tapped to allow the igniter to be placed at the center of the tube. The tube was filled halfway with material. The igniter was oriented at the center of the thermite powder. The holes where the igniter leads exited were sealed with epoxy and the rest of the tube was filled. The material was periodically tamped during the filling process to ensure no voids were present in the tube. When the tube was full, the other plastic end cap was secured in the same manner as the first. The tube was then weighed, and the weight of the tube and end caps was subtracted to determine the net explosive weight of each trial. A typical fiber board tube internal ignition test setup is shown in Photo 10. The net explosive weight of the thin fiberboard tube trial for each thermite is given in Table 2.

Photo 10: Internal Ignition Test Setup for the Thin Fiberboard Tube – Typical

Table 2: Net Explosive Weights for Thin Fiberboard Tube Trials

Thermite Formulation	Net Explosive Weight (lb)
LS #7	8.377
LS #8	8.096
SS #4	7.629
SS #19	7.046
SS #24	12.594
SS #27	6.277
SS #30	13.301
SS #48	12.643

7.1.2 Test Results

All fiberboard tube samples were successfully ignited, with six of the eight thermites transitioning to explosion. Test results are summarized in Table 3 and shown in Photo 11 - Photo 18.

Table 3: Internal Ignition Test Results for the Thin Fiberboard Tube

Tube Type	Result
LS #7	(+) Explosion
LS #8	(+) Explosion
SS #4	(+) Explosion
SS #19	(+) Explosion
SS #24	(+) Explosion
SS #27	(-) Burning
SS #30	(-) Burning
SS #48	(+) Explosion

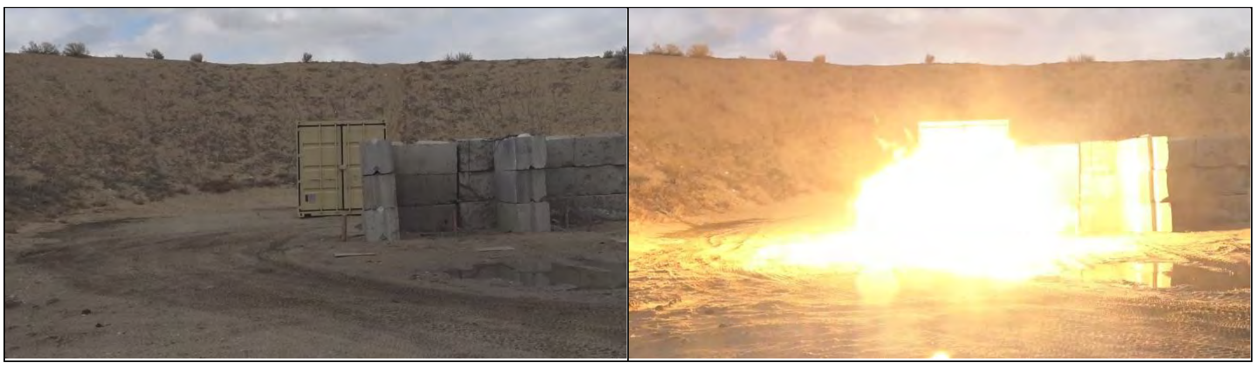


Photo 11: Internal Ignition Test Results (Explosion) for LS #7 Al-MnO_2 in the Thin Fiberboard Tube

Photo 12: Internal Ignition Test Results (Explosion) for LS #8 Mg&Al-MoO_3 & CuO in the Thin Fiberboard Tube

Photo 13: Internal Ignition Test Results (Explosion) for SS #4 Mg-MnO_2 in the Thin Fiberboard Tube

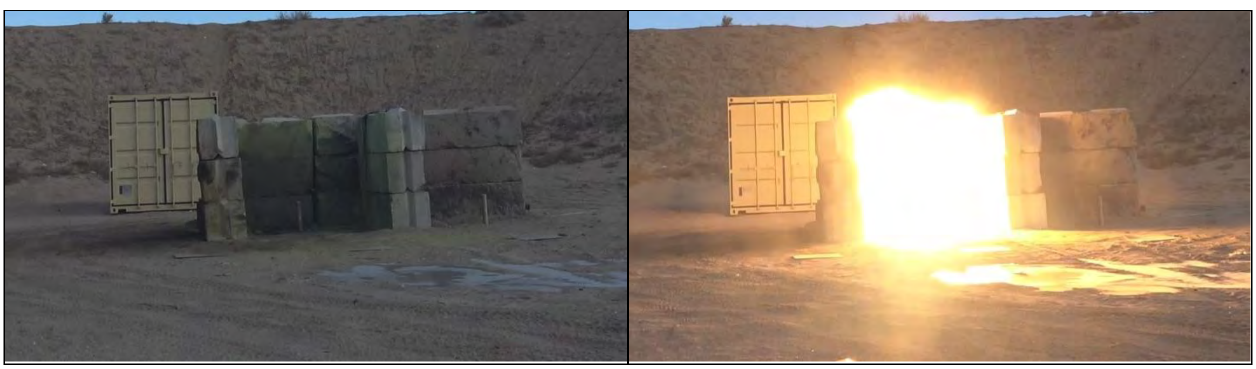


Photo 14: Internal Ignition Test Results (Explosion) for SS #19 Al-SnO_2 in the Thin Fiberboard Tube

Photo 15: Internal Ignition Test Results (Explosion) for SS #24 Al-Bi_2O_3 in the Thin Fiberboard Tube

Photo 16: Internal Ignition Test Results (Burning) for SS #27 Al-Fe_3O_4 in the Thin Fiberboard Tube

Photo 17: Internal Ignition Test Results (Burning) for SS #30 Al-NiO in the Thin Fiberboard Tube

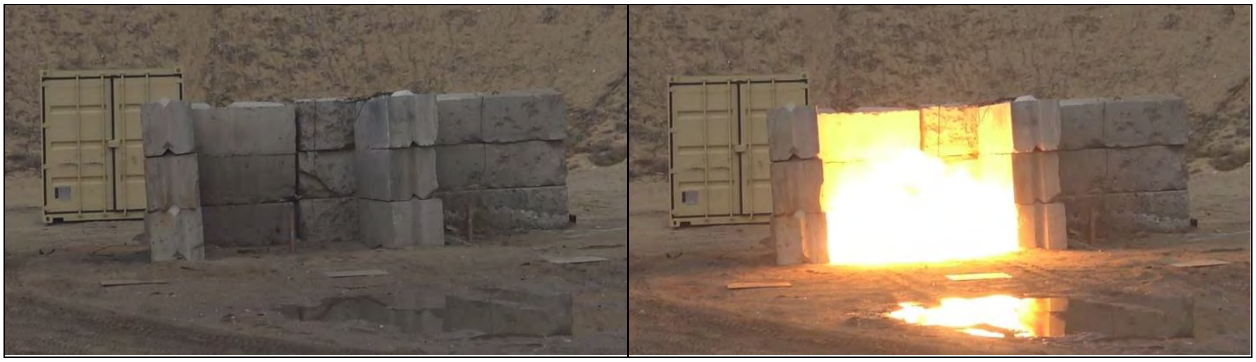


Photo 18: Internal Ignition Test Results (Explosion) for SS #48 Ti-Bi_2O_3 in the Thin Fiberboard Tube

In most trials, the entire tube was consumed. A single intact or melted end cap remained for three trials.

7.2 Thin-walled Steel Tube – 100% Fill

7.2.1 Test Setup

For each trial, a high-pressure end cap, gasket, and clamp was placed on one end of a spool and tightened into place. The tube was tapped to allow the igniter to be placed at the center of the tube. The tube was filled halfway with material. The igniter was oriented at the center of the thermite powder. The holes where the igniter leads exited were sealed with epoxy and the rest of the tube was filled. The material was periodically tamped during the filling process to ensure no voids were present in the tube. When the tube was full, the other end of the spool was secured with a high-pressure end cap, gasket, and clamp. The tube was then weighed, and the weight of the spool and end caps was subtracted to determine the net explosive weight of each trial. A typical thin-walled steel tube internal ignition test setup is shown in Photo 19. The net explosive weight of the thin-walled steel tube trial for each thermite is given in Table 4.

Photo 19: Internal Ignition Test Setup for the Thin-walled Steel Tube – Typical

Table 4: Net Explosive Weights for Thin-walled Steel Tube Trials

Thermite Formulation	Net Explosive Weight (lb)
LS #7	7.507
LS #8	6.968
SS #4	6.155
SS #19	6.141
SS #24	10.995
SS #27	5.345
SS #30	11.270
SS #48	12.473

7.2.2 Test Results

All thin-walled steel trials were successfully ignited, with five of the eight thermites transitioning to explosion. In the trials where an explosion was observed, the pipe was fragmented into two or more pieces. In trials the resulted in burning reactions, the pipe remained intact with the thermite melting through the pipe. The results of the thin-walled steel trials are summarized in Table 5. Photos of test results are given in Photo 20.

Table 5: Internal Ignition Test Results for the Thin-walled Steel Tube

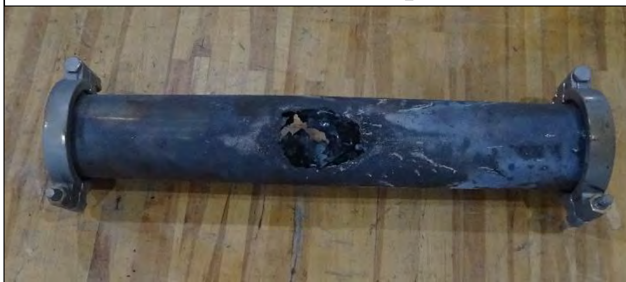
Thermite Formulation	Result
LS #7	(+) Explosion
LS #8	(+) Explosion
SS #4	(+) Explosion
SS #19	(-) Burning
SS #24	(+) Explosion
SS #27	(-) Burning
SS #30	(-) Burning
SS #48	(+) Explosion

Photo 20: Internal Ignition Test Results (Explosion) for the Thin-walled Steel Tube

LS #7 Al-MnO_2	LS #8 Mg&Al-MoO_3 & CuO
	

<table>
<tr><th>SS #4 Mg-MnO_2</th><th>SS #24 Al-Bi_2O_3</th></tr>
<tr><td></td><td></td></tr>
<tr><th>SS #48 Ti-Bi_2O_3</th><th></th></tr>
<tr><td></td><td></td></tr>
</table>

Photo 21: Internal Ignition Test Results (Burning) for the Thin-walled Steel Tube

SS #19 Al-SnO_2	SS #27 Al-Fe_3O_4
	
SS #30 Al-NiO	
	

7.3 Thick-walled Steel Tube – 100% Fill

7.3.1 Test Setup

For each trial, a 3,000-pound forged steel end cap was screwed into place on one end of the pipe. The tube was tapped to allow the igniter to be placed at the center of the tube. The tube was filled halfway with material. The igniter was oriented at the center of the thermite powder. The holes where the igniter leads exited were sealed with epoxy and the rest of the tube was filled.

The material was periodically tamped during the filling process to ensure no voids were present in the tube. Once the tube was full, another 3,000-pound end cap was screwed and tightened into place. The end cap was tightened while the pipe was in a vertical position to prevent any contamination of the threads during tightening. The tube was then weighed, and the weight of the pipe and end caps was subtracted to determine the net explosive weight of each trial. A typical thick-walled steel tube internal ignition test setup is shown in Photo 22. The net explosive weight of the thick-walled steel tube trial for each thermite is given in Table 6.

Photo 22: Internal Ignition Test Setup for the Thick-walled Steel Tube – Typical

Table 6: Net Explosive Weights for the Thick-walled Steel Tube Trials at 100% Fill

Thermite Formulation	Net Explosive Weight (lb)
LS #7	8.118
LS #8	8.336
SS #4	6.790
SS #19	6.360
SS #24	11.338
SS #27	6.479
SS #30	11.538
SS #48	10.819

7.3.2 Test Results

All trials were successfully ignited. However, no trials resulted in an explosion or fragmented pipe. The threads failed on the top end cap of SS #24. The cap was not recovered. The test results are summarized in Table 7. Pictures of test results are shown in Photo 23.

Table 7: Internal Ignition Test Results for the Thick-walled Steel Tube at 100% Fill

Thermite Formulation	Result
LS #7	(-) Burning
LS #8	(-) Burning
SS #4	(-) Burning
SS #19	(-) Burning
SS #24	(-) Burning
SS #27	(-) Burning
SS #30	(-) Burning
SS #48	(-) Burning

Photo 23: Internal Ignition Test Results for the Thick-walled Steel Tube at 100% Fill

LS #7 Al-MnO_2

LS #8 Mg&Al-MoO_3 & CuO

SS #4 Mg-MnO_2

SS #19 Al-SnO_2

SS #24 Al-Bi_2O_3

SS #27 Al-Fe_3O_4

SS #30 Al-NiO	SS #48 Ti-Bi_2O_3
	

7.4 Thick-walled Steel Tube – 25% Fill

7.4.1 Test Setup

For each trial, a 3,000-pound forged steel end cap was screwed into place on one end of the pipe. The tube was tapped to allow the igniter to be placed at the center of the material, as shown in Figure 4. The thermite quantity needed for 25% fill was determined to be 25% of the total quantity required to fill the internal ignition pipe for the 100% fill trials. Half the required material was loaded into the pipe. The igniter was then oriented at the center of the thermite powder. The holes where the igniter leads exited were sealed with epoxy and the rest of the thermite was loaded.

The material was periodically tamped during the filling process to ensure no voids were present in the tube. Once the rest of the thermite was fully loaded, another 3,000-pound end cap was screwed and tightened into place. The end cap was tightened while the pipe was in a vertical position to prevent any contamination of the threads during tightening. The tube was then weighed, and the weight of the pipe and end caps was subtracted to determine the net explosive weight of each trial. A typical thick-walled steel tube internal ignition test setup at 25% fill is shown in Photo 24. The net explosive weight of the thick-walled steel tube trial for each thermite is given in Table 8.

Photo 24: Internal Ignition Test Setup for the Thick-walled Steel Tube at 25% Fill – Typical

Table 8: Net Explosive Weights for Thick-walled Steel Tube Trials at 25% Fill

Thermite Formulation	Net Explosive Weight (lb)
LS #7	2.040
LS #8	2.080
SS #4	1.700
SS #19	1.590
SS #24	2.840
SS #27	1.620
SS #30	2.890
SS #48	2.740

7.4.2 Test Results

No ignitions at the 25% fill level for thick-walled steel resulted in an explosion. Two thermites, SS #27 and SS #30, were exposed to the powered igniter for more than ten minutes with no observable reaction. The test results are summarized in Table 9. Pictures of test results are shown in Photo 25.

Table 9: Internal Ignition Test Results for the Thick-walled Steel Tube at 25% Fill

Thermite Formulation	Result
LS #7	(-) Burning
LS #8	(-) Burning
SS #4	(-) Burning
SS #19	(-) Burning
SS #24	(-) Burning
SS #27	(-) No Reaction
SS #30	(-) No Reaction
SS #48	(-) Burning

Photo 25: Internal Ignition Test Results for the Thick-walled Steel Tube at 25% Fill

LS #7 Al-MnO_2	LS #8 Mg&Al-MoO_3 & CuO
	
SS #4 Mg-MnO_2	**SS #19 Al-SnO_2**
	
SS #24 Al-Bi_2O_3	**SS #27 Al-Fe_3O_4**
	**[No Reaction]**

SS #30 Al-NiO	SS #48 Ti-Bi_2O_3
[No Reaction]	

7.5 Thick-walled Steel Tube – 50% Fill

7.5.1 Test Setup

For each trial, a 3,000-pound forged steel end cap was screwed into place on one end of the pipe. The tube was tapped to allow the igniter to be placed at the center of the material, as shown in Figure 4. The thermite quantity needed for 50% fill was determined to be 50% of the total quantity required to fill the internal ignition pipe for the 100% fill trials. Half the required material was loaded into the pipe. The igniter was then oriented at the center of the thermite powder. The holes where the igniter leads exited were sealed with epoxy and the rest of the thermite was loaded.

The material was periodically tamped during the filling process to ensure no voids were present in the tube. Once the rest of the thermite was fully loaded, another 3,000-pound end cap was screwed and tightened into place. The end cap was tightened while the pipe was in a vertical position to prevent any contamination of the threads during tightening. The tube was then weighed, and the weight of the pipe and end caps was subtracted to determine the net explosive weight of each trial. A typical thick-walled steel tube internal ignition test setup at 50% fill is shown in Photo 26. The net explosive weight of the thick-walled steel tube trial for each thermite is given in Table 10.

Photo 26: Internal Ignition Test Setup for the Thick-walled Steel Tube at 50% Fill – Typical

Table 10: Net Explosive Weights for the Thick-walled Steel Tube Trials at 50% Fill

Thermite Formulation	Net Explosive Weight (lb)
LS #7	4.065
LS #8	4.160
SS #4	3.400
SS #19	3.180
SS #24	5.670
SS #27	3.240
SS #30	5.770
SS #48	5.410

7.5.2 Test Results

No ignitions at the 50% fill level for thick-walled steel resulted in an explosion. Two thermites, LS #7 and SS #19, were exposed to the powered igniter for more than ten minutes with no observable reaction. The test results are summarized in Table 11. Pictures of test results are shown in Photo 27.

Table 11: Internal Ignition Test Results for the Thick-walled Steel Tube at 50% Fill

Thermite Formulation	Result
LS #7	(-) No Reaction
LS #8	(-) Burning
SS #4	(-) Burning
SS #19	(-) No Reaction
SS #24	(-) Burning
SS #27	(-) Burning
SS #30	(-) Burning
SS #48	(-) Burning

Photo 27: Internal Ignition Test Results for the Thick-walled Steel Tube at 50% Fill

LS #7 Al-MnO_2	**LS #8 Mg&Al-MoO_3 & CuO**
[No Reaction]	
SS #4 Mg-MnO_2	**SS #19 Al-SnO_2**
	**[No Reaction]**
SS #24 Al-Bi_2O_3	**SS #27 Al-Fe_3O_4**
	

SS #30 Al-NiO	SS #48 Ti-Bi_2O_3
	

7.6 Thick-walled Steel Tube – 75% Fill

7.6.1 Test Setup

For each trial, a 3,000-pound forged steel end cap was screwed into place on one end of the pipe. The tube was tapped to allow the igniter to be placed at the center of the material, as shown in Figure 4. The thermite quantity needed for 75% fill was determined to be 75% of the total quantity required to fill the internal ignition pipe for the 100% fill trials. Half the required material was loaded into the pipe. The igniter was then oriented at the center of the thermite powder. The holes where the igniter leads exited were sealed with epoxy and the rest of the thermite was loaded.

The material was periodically tamped during the filling process to ensure no voids were present in the tube. Once the rest of the thermite was fully loaded, another 3,000-pound end cap was screwed and tightened into place. The end cap was tightened while the pipe was in a vertical position to prevent any contamination of the threads during tightening. The tube was then weighed, and the weight of the pipe and end caps was subtracted to determine the net explosive weight of each trial. A typical thick-walled steel tube internal ignition test setup at 75% fill is shown in Photo 28. The net explosive weight of the thick-walled steel tube trial for each thermite is given in Table 12.

Photo 28: Internal Ignition Test Setup for the Thick-walled Steel Tube at 75% Fill – Typical

Table 12: Net Explosive Weights for Thick-walled Steel Tube Trials at 75% Fill

Thermite Formulation	Net Explosive Weight (lb)
LS #7	6.140
LS #8	6.250
SS #4	5.090
SS #19	4.770
SS #24	8.500
SS #27	4.860
SS #30	8.650
SS #48	8.110

7.6.2 Test Results

No ignitions at the 75% fill level for thick-walled steel resulted in an explosion. Two thermites, SS #19 and SS #27, were exposed to the powered igniter for more than ten minutes with no observable reaction. The test results are summarized in Table 13. Pictures of test results are shown in Photo 29.

Table 13: Internal Ignition Test Results for the Thick-walled Steel Tube at 75% Fill

Thermite Formulation	Result
LS #7	(-) Burning
LS #8	(-) Burning
SS #4	(-) Burning
SS #19	(-) No Reaction
SS #24	(-) Burning
SS #27	(-) No Reaction
SS #30	(-) Burning
SS #48	(-) Burning

Photo 29: Internal Ignition Test Results for the Thick-walled Steel Tube at 75% Fill

LS #7 Al-MnO_2	**LS #8 Mg&Al-MoO_3 & CuO**
	
SS #4 Mg-MnO_2	**SS #19 Al-SnO_2**
	**[No Reaction]**
SS #24 Al-Bi_2O_3	**SS #27 Al-Fe_3O_4**
	**[No Reaction]**

SS #30 Al-NiO	SS #48 Ti-Bi_2O_3
	

8.0 CONCLUSIONS

Based on the test results, the strength of the confining media has a significant influence on reaction severity during a confined ignition of an exploding thermite. Explosions were observed on most of the trials conducted in confining media less robust than the standard internal ignition pipe. All tested thermites trended towards decreased reaction violence when placed in further confinement. This is consistent with previous test results and general thermite behavior.

The UN Series 1 and 2 tests were designed on the premise of utilizing shock, heating and ignition under confinement to determine whether a material will exhibit explosive properties when confined. However, for a thermite, confinement suppresses the explosive properties. Trials conducted in the thick-walled steel tubes further indicate that current parameters of UN tests used for classification of explosives, specifically UN Series 1/2 (c) (ii) Internal Ignition Test, misrepresent the hazards of potentially explosive thermites, as thermites that appear to possess no explosive properties when ignited under confinement in an internal ignition pipe can readily exhibit explosive properties in less robust containment.

Increasing head space in the internal ignition pipe did not result in increased reaction violence.

APPENDIX A

– PRODUCT CERTIFICATIONS

Figure D1: Product Certification for Al Metal Powder

ATLANTIC EQUIPMENT ENGINEERS
HIGH PURITY METALS AND COMPOUNDS

Certificate of Analysis

ALUMINUM METAL POWDER
AL-100

1.1 General

SOLD TO	PURCHASE ORDER #	SHIP DATE	DOCUMENT NUMBER
SAFETY MANAGEMENT SERVICES for COMMANDER TOOELE ARMY DEPOT	1526	9 MAR 2021	2101018
CATALOG NUMBER	LOT NUMBER	QUANTITY	CAS NUMBER
AL-100	2002510-6	173 LBS	7429-90-5

2.1 Chemical Analysis (in percentage (%) unless otherwise stated)

Al	Ti	Si	Fe
99.9%	<0.06	<0.10	<0.20

3.1 Screen Analysis (percent passing) / Other

Size	D 10	D 50	D 90
1-5 microns	1.6 microns	3.6 microns	9 microns

4.1 Notes

5.1 Statement

Shelf life is indefinite when material is stored in a tightly sealed container in a cool, dry place.

The above analysis is carried out as part of our internal quality control testing and is based upon our analysis methods.

We do not assume any warranty, liability, or risk based on such findings. Our quality is warranted within the scope of our general sales conditions.

Please refer to SDS for material handling instructions.

Very Truly Yours,

M. Gerald, QA

24 Industrial Ave, Upper Saddle River, NJ 07458 Tel: 201.828.9400 Fax: 201.387.0291
On the web at: www.micronmetals.com Email: info@micronmetals.com

Figure D2: Product Certification for CuO

ATLANTIC EQUIPMENT ENGINEERS
HIGH PURITY METALS AND COMPOUNDS

Certificate of Analysis
CUPRIC OXIDE
CU-602

1.1 General

SOLD TO	PURCHASE ORDER #	SHIP DATE	DOCUMENT NUMBER
SAFETY MANAGEMENT SERVICES for COMMANDER TOOELE ARMY DEPOT	1526	9 MAR 2021	2101018
CATALOG NUMBER	LOT NUMBER	QUANTITY	CAS NUMBER
CU-602	2102518	548 LBS	1317-38-0

2.1 Chemical Analysis (in percentage (%) unless otherwise stated)

Cu	CuO	Cu2O	Zn	Fe	Ca	Mg
75	94	3	0.3	0.02	0.01	0.002
Mn	Pb	Cd	As	Sb	Moisture	
0.001	0.05	0.01	0.01	0.01	0.2	

3.1 Screen Analysis (percent passing) / Other

Size	Specific Gravity	-325 mesh	Loose Bulk Density
1-5 microns	8.7 g/cc	99.9	80 lbs / ft³

4.1 Notes

5.1 Statement

The above analysis is carried out as part of our internal quality control testing and is based upon our analysis methods.

We do not assume any warranty, liability, or risk based on such findings. Our quality is warranted within the scope of our general sales conditions.

Please refer to SDS for material handling instructions.

Very Truly Yours,

M. Gerald, QA

24 Industrial Ave, Upper Saddle River, NJ 07458 Tel: 201.828.9400 Fax: 201.387.0291
On the web at: www.micronmetals.com Email: info@micronmetals.com

Page 1 of 1

Figure D3: Product Certification for Fe_3O_4

ATLANTIC EQUIPMENT ENGINEERS
HIGH PURITY METALS AND COMPOUNDS

Certificate of Analysis
BLACK IRON OXIDE
FE-602

1.1 General

SOLD TO	PURCHASE ORDER #	SHIP DATE	DOCUMENT NUMBER
SAFETY MANAGEMENT SERVICES for COMMANDER TOOELE ARMY DEPOT	1526	9 MAR 2021	2101018
CATALOG NUMBER	LOT NUMBER	QUANTITY	CAS NUMBER
FE-602	2009517	1 LB	1317-61-6

2.1 Chemical Analysis (in percentage (%) unless otherwise stated)

Tint Strength	pH	FeO	Moisture
97.6	8.91	23.4	0.39
Water soluble Salts		Fe2O3	
0.16		99.9	

3.1 Screen Analysis (percent passing) / Other

Size	+325 mesh
1-5 microns	0.009

4.1 Notes

Very fine, black powder, manufactured in the USA.

5.1 Statement

The above analysis is carried out as part of our internal quality control testing and is based upon our analysis methods.

We do not assume any warranty, liability, or risk based on such findings. Our quality is warranted within the scope of our general sales conditions.

Please refer to SDS for material handling instructions.

Very Truly Yours,

M. Gerald, QA

24 Industrial Ave, Upper Saddle River, NJ 07458 Tel: 201.828.9400 Fax: 201.387.0291
On the web at: www.micronmetals.com Email: info@micronmetals.com

Page 1 of 1

Figure D4: Product Certification for Ti Metal Powder

ATLANTIC EQUIPMENT ENGINEERS
HIGH PURITY METALS AND COMPOUNDS

Certificate of Analysis
TITANIUM METAL POWDER
TI 101

1.1 General

SOLD TO	PURCHASE ORDER #	SHIP DATE	DOCUMENT NUMBER
SAFETY MANAGEMENT SERVICES for COMMANDER TOOELE ARMY DEPOT	1526	9 MAR 2021	2101018
CATALOG NUMBER	LOT NUMBER	QUANTITY	CAS NUMBER
TI 101	2012519	7 LBS	7440-32-6

2.1 Chemical Analysis (in percentage (%) unless otherwise stated)

Al	Cl	Cr	Fe	H	Mg	Mn
0.007	<0.025	0.004	0.028	0.51	<0.010	<0.005
Mo	Zr	Na	Ni	O	P	Pb & Cd
<0.005	<0.01	<0.001	0.006	0.91	<0.010	<0.002
Si	Sn	V	Ti			
0.007	<0.010	<0.005	99.8% min			

3.1 Screen Analysis (percent passing) / Other

Size	
< 20 microns	

4.1 Notes
99.8% min metals basis

5.1 Statement

The above analysis is carried out as part of our internal quality control testing and is based upon our analysis methods.

We do not assume any warranty, liability, or risk based on such findings. Our quality is warranted within the scope of our general sales conditions.

Please refer to SDS for material handling instructions.

Very Truly Yours,

M. Gerald, QA

24 Industrial Ave, Upper Saddle River, NJ 07458 Tel: 201.828.9400 Fax: 201.387.0291
On the web at: www.micronmetals.com Email: info@micronmetals.com

Page 1 of 1

Figure D5: Product Certification for MnO_2

AMERICAN ELEMENTS

World's Leading Manufacturer of Rare Earth and Advanced Material Products

A MERELEX CORPORATION • 10884 WEYBURN AVE. LOS ANGELES, CA 90024
TEL. 310-208-0551 • FAX 310-208-0351 • E-MAIL: customerservice@americanelements.com

CERTIFICATE OF COMPLIANCE

99+% (metals basis) Manganese Oxide Powder

MnO2

Product Code: MN-OX-021M-P.5UM

CAS #: 1313-13-9

LOT #: 1441516447-410

American Elements certifies that the materials listed below and shipped on 4/8/2021 meets the purity and dimensional requirements set forth in SMS Energetics, Inc. purchase order: DOT1-6265D.

99+% (metals basis) Manganese Oxide Powder
MnO2
APS: 5 um

AMERICAN ELEMENTS

By

AEC FORM 102:CA REV. APP. 2/3/99

Figure D6: Product Certification for Bi_2O_3

Figure D7: Product Certification for SnO_2

SIGMA-ALDRICH

sigma-aldrich.com

3050 Spruce Street, Saint Louis, MO 63103, USA
Website: www.sigmaaldrich.com
Email USA: techserv@sial.com
Outside USA: eurtechserv@sial.com

Certificate of Analysis

Product Name:
Tin(IV) oxide – −325 mesh, 99.9% trace metals basis

SnO_2

Product Number:	**244651**
Batch Number:	**MKBX0592V**
Brand:	ALDRICH
CAS Number:	18282-10-5
MDL Number:	MFCD00011244
Formula:	O2Sn
Formula Weight:	150.71 g/mol
Quality Release Date:	16 DEC 2015

Test	Specification	Result
Appearance (Color) Off-White to Grey	Conforms to Requirements	Light Grey
Appearance (Form)	Powder	Powder
X-Ray Diffraction	Conforms to Structure	Conforms
Loss on Ignition 1 Hour at 1000 Degrees Celsius	≤ 0.5 %	0.1 %
ICP Major Analysis Confirms Tin Component	Confirmed	Conforms
Purity 99.9% Based On Trace Metals Analysis	Conforms	Conforms
Trace Metal Analysis	≤ 1000.0 ppm	579.0 ppm
Silver (Ag)		9.0 ppm
Aluminum (Al)		4.4 ppm
Arsenic (As)		4.5 ppm
Bismuth (Bi)		16.0 ppm
Calcium (Ca)		35.0 ppm
Chromium (Cr)		2.2 ppm
Copper (Cu)		15.0 ppm
Iron (Fe)		120.0 ppm
Potassium (K)		2.0 ppm
Magnesium (Mg)		24.0 ppm
Manganese (Mn)		0.7 ppm
Sodium (Na)		11.0 ppm
Nickel (Ni)		1.9 ppm
Lead (Pb)		79.0 ppm
Antimony (Sb)		250.0 ppm
Titanium (Ti)		2.0 ppm
Zinc (Zn)		2.2 ppm
Zirconium (Zr)		0.1 ppm

Michael Grady, Manager
Quality Control
Milwaukee, WI US

Figure D8: Product Certification for Mg Metal Powder

SIGMA-ALDRICH

3050 Spruce Street, Saint Louis, MO 63103 USA
Email USA: techserv@sial.com Outside USA: eurtechserv@sial.com

Certificate of Analysis

Product Name:	MAGNESIUM powder, >= 99 %
Product Number:	13112
Batch Number:	STBH6715
Brand:	Aldrich
CAS Number:	7439-95-4
Formula:	Mg
Formula Weight:	24.31
Quality Release Date:	09 JUL 2018
Recommended Retest Date:	DEC 2021

TEST	SPECIFICATION	RESULT
APPEARANCE (COLOR)	WHITE TO GREY	LIGHT GREY
APPEARANCE (FORM)	POWDER	POWDER
ASSAY	≥ 99 %	100.7 %
INSOLUBLE MATTER	≤ 0.05 % (INSOLUBLE IN HCL)	< 0.05 %
IRON	≤ 0.05 %	< 0.05 %

Claudia Mayer
Manager Quality Control
Steinheim, Germany

Figure D9: Product Certification for NiO

Sigma-Aldrich.

3050 Spruce Street, Saint Louis, MO 63103, USA
Website: www.sigmaaldrich.com
Email USA: techserv@sial.com
Outside USA: eurtechserv@sial.com

Certificate of Analysis

Product Name:
Nickel(II) oxide - green, -325 mesh, 99%

Product Number:	**399523**
Batch Number:	**MKCN2758**
Brand:	ALDRICH
CAS Number:	1313-99-1
MDL Number:	MFCD00011145
Formula:	NiO
Formula Weight:	74.69 g/mol
Quality Release Date:	11 DEC 2020

NiO

Test	Specification	Result
Appearance (Color)	Green to Very Dark Green and Green-Brown and Brown-Green	Green
Appearance (Form)	Powder	Powder
X-Ray Diffraction	Conforms to Structure	Conforms
Nickel	77.4 - 79.8 %	77.9 %
Particle Size -325 Mesh	Confirmed	Confirmed

Michael Grady, Manager
Quality Control
Milwaukee, WI US

Sigma-Aldrich warrants, that at the time of the quality release or subsequent retest date this product conformed to the information contained in this publication. The current Specification sheet may be available at Sigma-Aldrich.com. For further inquiries, please contact Technical Service. Purchaser must determine the suitability of the product for its particular use. See reverse side of invoice or packing slip for additional terms and conditions of sale.

Version Number: 1 Page 1 of 1

Figure D10: Product Certification for MoO_3

STANFORD ADVANCED MATERIALS

Stanford Advanced Materials
23661 Birtcher Dr. Lake Forest, CA 92630, USA
Tel: (949) 407-8904 Fax: (949) 812-6690

Certificate of Analysis

Product Name:	Molybdenum Trioxide (MoO3) Powder
Purity:	≥99.5%
Particle Size:	-325mesh
Lot Number:	OC210201-12629-1
Date:	2/1/21

Purity (wt%)	99.5
C (wt%)	0.05
H (wt%)	0.02
O (wt%)	0.01
N (wt%)	0.01
Mg (wt%)	0.01
Al (wt%)	0.01
Si (wt%)	0.02
Ca (wt%)	0.01
Ti (wt%)	0.01
Fe (wt%)	0.08
Ni (wt%)	0.01
Cu (wt%)	0.02
Sn (wt%)	0.01
W (wt%)	0.03
Pb (wt%)	0.01

Stanford Advanced Materials

TEST REPORT

Examination of the 5-Minute Koenen Test Limit

DOT Contract # 693JK320C000005

U.S. Department of Transportation
Pipeline and Hazardous Materials Safety Administration
(PHMSA)

Attention: PHH-20
Hazardous Materials Technology
1200 New Jersey Avenue, SE
E21-317
Washington, DC 20590

Troy A. Gardner, PE, CSP
Jackson Zarbock

June 30, 2023

SMS-6265h-R1, Rev 0

1847 West 9000 South, Suite 205 • West Jordan, Utah 84088 • 801-567-0456 • www.smsenergetics.com

Test Report

Examination of the 5-minute Koenen Test Limit

June 30, 2023
SMS-6265h-R1, Rev 0

Troy A. Gardner, PE, CSP
Testing & Classifications Manager
Safety Management Services, Inc.

Jackson D. Zarbock
Project Engineer
Safety Management Services, Inc.

TABLE OF CONTENTS

TABLES

FIGURES

PHOTOS

1.0 STATEMENT OF WORK

DOT Contract # 693JK320C000005 with Safety Management Services, Inc. (SMS) of West Jordan, Utah defines that for Task 8, "Examination of 5-minute Koenen Test Limit for High-Temperature Energetic Materials", SMS shall perform extended-duration Koenen testing, instrumented with thermocouples, to characterize the extended duration heating profile and reaction violence of thirteen thermites.

2.0 SUMMARY AND CONCLUSIONS

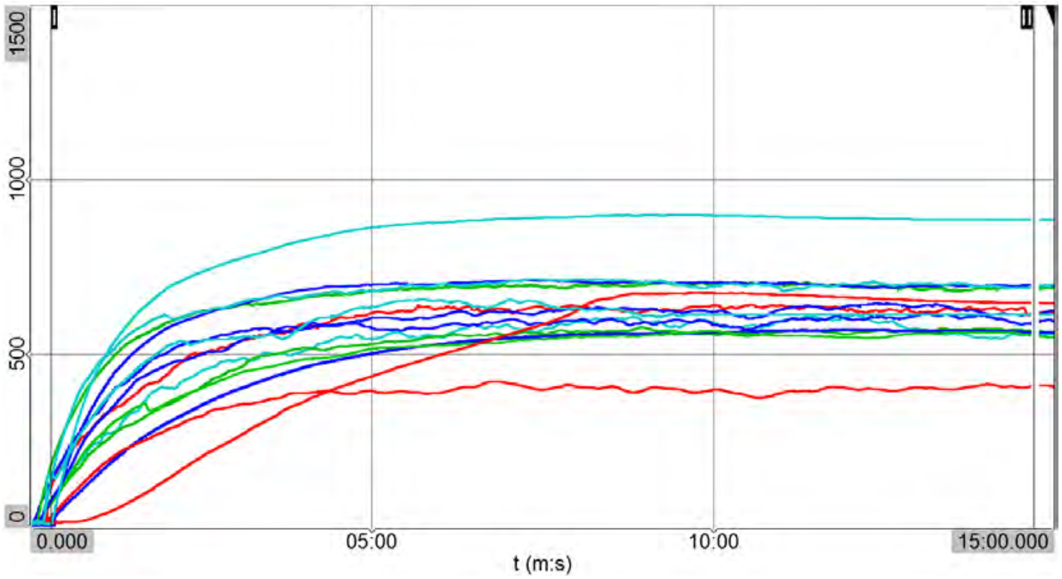
SMS performed extended-duration Koenen testing, instrumented with thermocouples, on the following fourteen thermites; a double underline designates thermites that exploded in these Koenen tests:

- LS #1 Al-Fe_2O_3^
- LS #2 Al-Fe_2O_3
- LS #4 Al-CuO
- LS #5 Al-CuO
- LS #7 Al-MnO_2*
- LS #8 Mg&Al-MoO_3-CuO*
- SS #4 Mg-MnO_2*
- SS #12 Al-Co_3O_4
- SS #19 Al-SnO_2*
- SS #24 Al-Bi_2O_3*
- SS #27 Al-Fe_3O_4*
- SS #29 Al-MnO
- SS #30 Al-NiO*
- SS #48 Ti-Bi_2O_3*

* Appears to explode in small quantities when unconfined.
^ Fast reacting in small quantities when unconfined.

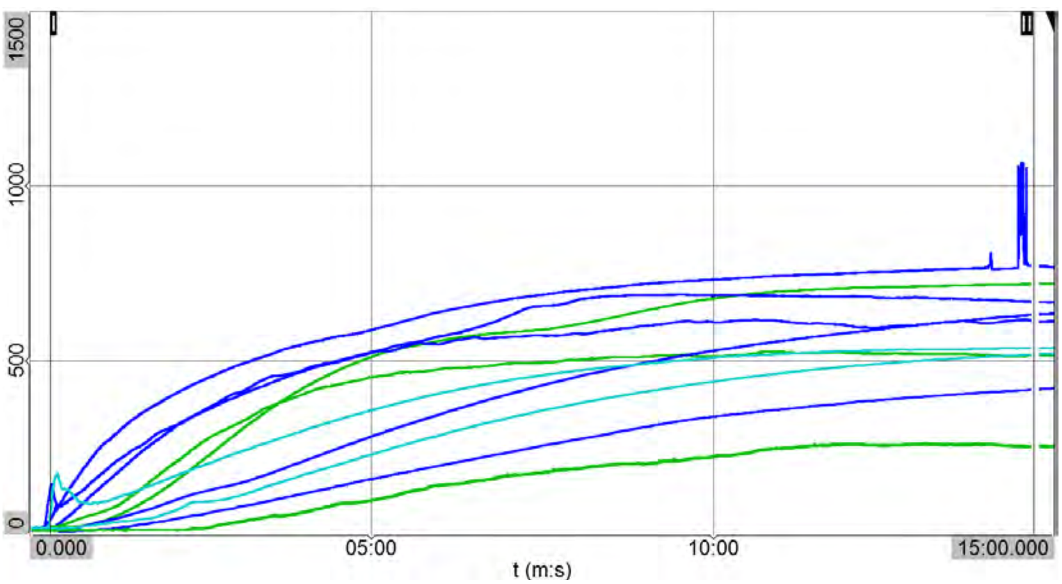
The tests were witnessed by Troy A. Gardner and Jason T. Ford. In general, the thermocouple in the bottom of the Koenen tube reached a temperature plateau around five minutes into the test, as shown in the following figure.

Figure 1: Sample Temperature in the Bottom of the Koenen Tube



Similarly, the temperature at the top or bottom third of the sample reached a temperature plateau around ten minutes into the test, as shown in the following figure.

Figure 2: Sample Temperature One-Third from the Top/Bottom in Koenen Trials



The following table summarizes the sample temperatures at five, ten and fifteen minutes into the test.

Table 1: Koenen Heating Profile for Thermites

Description of Measurement	Sample Temperature (°C)	
	Average	Standard Deviation
Bottom of sample		
Five minutes	591	116
Ten minutes	629	107
Fifteen minutes	622	103
Top/bottom third of sample		
Five minutes	373	163
Ten minutes	526	152
Fifteen minutes	565	143

On average, thermite test samples in the bottom of a Koenen tube reached 94% of their maximum temperature within the first five minutes; the top/bottom third of the sample reached 93% of their maximum temperature within ten minutes but it was around 100°C less than that achieved at the bottom. Further, there is greater variability in the temperature of the top/bottom third of the sample in comparison to that of the bottom.

Thermites with auto-ignition temperatures above these temperatures can pass the Koenen test with no reaction but still present an explosion or fast reaction hazard, such as LS #1 Al-Fe_2O_3, SS #19 Al-SnO_2, SS #27 Al-Fe_3O_4 or SS #30 Al-NiO. In this round of testing, some of the thermites ignited in each of the three trials; other thermites only ignited in one of the three trials (inconsistent and unpredictable results). Each ignition was within the standard five-minute Koenen test limit unlike the prior study where many thermite reactions were well after the standard five minutes.

3.0 ACKNOWLEDGEMENTS

Mixing of all thermites was performed by Derek M. Sutton, Jordan D. Dzubak and Jackson D. Zarbock. Testing was performed by Jackson D. Zarbock.

4.0 BACKGROUND

Historically, industry has offered traditional thermite formulations (containing only metal and metal oxides) for transport in Class 4 as flammable or water-reactive solids. The reaction produces a burst of heat, high temperature, and molten metal for various uses including joining steel railroad ties or copper transmission lines, metal refining, disabling munitions, etc. Traditional thermite formulations pass the UN Manual of Tests and Criteria, Appendix 6

"Screening Procedures" for substances which may have explosive properties as they do not contain any of the chemical groups listed in Table A6.1 that are associated with explosive properties. NOTE: The Appendix 6 Screening Procedures cannot be used for substances manufactured with the view to producing a practical explosive or pyrotechnic effect.

Newer "exotic" thermite formulations include those with additives such as plastics, oxidizers, nano materials, explosives, etc. to confer special compositions or actions upon use. Thermite research was needed to identify families of new and existing thermite compositions and to determine their hazards in transport and to transport vehicles.

Safety Management Services, Inc. (SMS) was contracted to perform research on thermite formulations in cooperation with Southwest Research Institute (SwRI) and the U.S. Department of Transportation (DOT) Pipeline and Hazardous Materials Safety Administration (PHMSA). This effort is considered to be Phase I of thermite testing. During Phase I, eight thermites for large-scale testing and fifteen thermite formulations were selected for small-scale testing. It was discovered that thermite mixtures exhibited hazards ranging from rapid reactions that were consistent with 1.3G materials to exploding when ignited in unconfined 5-gram quantities, similar to 1.1G flash powders. Two of the eight large-scale thermite mixtures and six of the fifteen small-scale thermite mixtures mixed by SMS also exploded in unconfined 5-gram quantities.

These findings prompted the request for SMS to perform additional testing to further research the energetic properties of thermite and develop the technical basis to base policies and decisions on thermite-based products.

The eight exploding thermites from Task 7 were selected for this extended-duration Koenen testing:

- LS #7 Al-MnO_2
- LS #8 Mg&Al-MoO_3-CuO
- SS #4 Mg-MnO_2
- SS #19 Al-SnO_2
- SS #24 Al-Bi_2O_3
- SS #27 Al-Fe_3O_4
- SS #30 Al-NiO
- SS #48 Ti-Bi_2O_3

Additionally, the following additional thermites were also tested:

- LS #1 Al-Fe_2O_3
- LS #2 Al-Fe_2O_3
- LS #4 Al-CuO
- LS #5 Al-CuO
- SS #12 Al-Co_3O_4
- SS #29 Al-MnO

5.0 DESCRIPTION OF THERMITE TEST SAMPLES

5.1 Fine Al-Fe_2O_3 Thermite – Large-Scale Mix ID #1 (SMS mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 25.26% aluminum (Al) and 74.74% ferric oxide (Fe_2O_3). The aluminum was 3N purity (99.9% pure), 1 - 5 micrometers (microns) in size, and offered for transport as a Division 4.1 flammable solid. The ferric oxide was 2N purity (99% pure), 1 - 5 microns in size, and offered for transport as non-regulated. This thermite was a fine, red powder when fully mixed.

Photo 1: Fine Al-Fe_2O_3 Thermite – Large-Scale Mix ID #1 (SMS mixed)

5.2 Coarse Al-Fe_2O_3 Thermite A – Large-Scale Mix ID #2 (Commercial)

SMS procured this thermite from a commercial supplier. This thermite contained approximately 25% aluminum (Al) and 75% iron(III)/ferric oxide (Fe_2O_3) by mass. The thermite was a coarse powder that was a mixture of black and light gray particles.

Photo 2: Coarse Al-Fe_2O_3 Thermite A – Large-Scale Mix ID #2 (Commercial)

5.3 Fine Al-CuO Thermite – Large-Scale Mix ID #4 (SMS mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 18.44% aluminum (Al) and 81.56% copper(II)/cupric oxide (CuO). The aluminum was 3N purity (99.9% pure), 1 - 5 micrometers (microns) in size, and offered for transport as a Division 4.1 flammable solid. The cupric oxide was 3N purity (99.9% pure), 1 - 5 microns in size, and offered for transport as Class 9. This thermite was a very fine, dark gray powder when fully mixed.

Photo 3: Fine Al-CuO Thermite – Large-Scale Mix ID #4 (SMS mixed)

5.4 Medium Al-CuO Thermite – Large-Scale Mix ID #5 (Commercial)

SMS procured this thermite from a commercial supplier. This thermite contains approximately 18% aluminum (Al) and 82% cupric oxide (CuO). The thermite was gray and silver speckled powder with medium-sized particles.

Photo 4: Medium Al-CuO Thermite – Large-Scale Mix ID #5 (Commercial)

5.5 Fine Al-MnO_2 Thermite – Large-Scale Mix ID #7 (SMS mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 29.27% aluminum (Al) and 70.73% manganese(IV) oxide (MnO_2). The aluminum was 3N purity (99.9% pure), 1 - 5 micrometers (microns) in size, and offered for transport as a Division 4.1 flammable solid. The manganese(IV) oxide was 2N purity (99% pure), 5 microns in size, and offered for transport as non-regulated. This thermite was a very fine, dark gray powder when fully mixed.

Photo 5: Fine Al-MnO_2 Thermite – Large-Scale Mix ID #7 (SMS mixed)

5.6 Fine Mg&Al-MoO_3-CuO Thermite – Large-Scale Mix ID #8 (SMS mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 25% magnalium (magnesium-aluminum), 34% molybdenum trioxide (MoO_3), and 41% copper(II)/cupric oxide (CuO). The magnalium was 2N purity (99% pure), 44 micrometers (microns) in size, and offered for transport as a Division 4.3 dangerous when wet substance with a subsidiary hazard of Division 4.2 spontaneously combustible. The molybdenum trioxide was 2N purity (99% pure), 44 microns in size, and offered for transport as a Division 6.1 toxic substance. The cupric oxide was 3N purity (99.9% pure), 1 - 5 microns in size, and offered for transport as Class 9. This thermite was a very fine, gray powder when fully mixed.

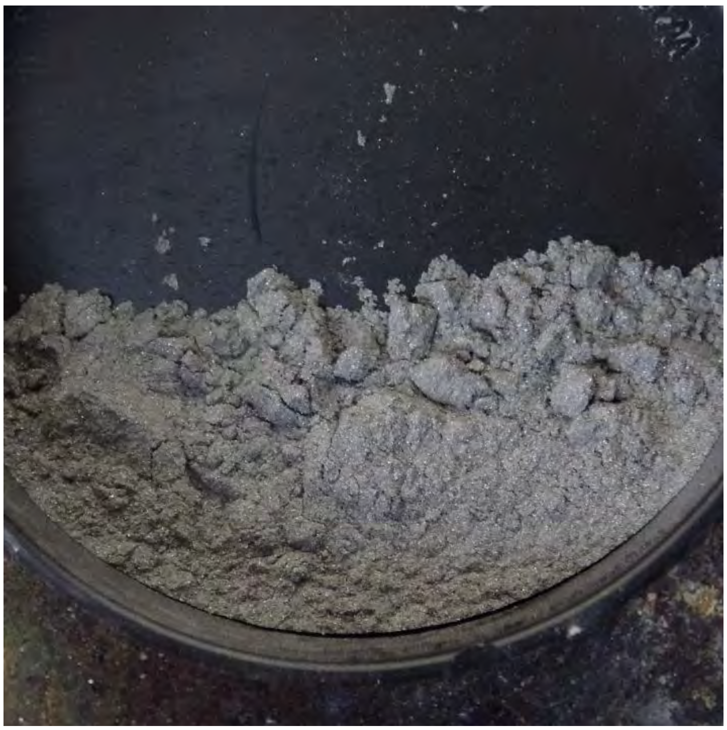


Photo 6: Fine Mg&Al-MoO_3-CuO Thermite – Large-Scale Mix ID #8 (SMS mixed)

5.7 Fine Mg-MnO_2 Thermite – Small-Scale Mix ID #4 (SMS mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 35.86% magnesium (Mg) and 64.14% manganese(IV) oxide (MnO_2). The manganese(IV) oxide was 2N purity (99% pure), 5 microns in size, and offered for transport as non-regulated. This thermite was a very fine, gray powder when fully mixed.

Photo 7: Fine Mg-MnO_2 Thermite – Small-Scale Mix ID #4 (SMS mixed)

5.8 Fine Al-Co_3O_4 Thermite – Small-Scale Mix ID #12 (SMS mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 23.01% aluminum (Al) and 76.99% cobalt oxide (Co_3O_4). The aluminum was 3N purity (99.9% pure), 1 - 5 micrometers (microns) in size, and offered for transport as a Division 4.1 flammable solid. This thermite was a very fine, dark gray powder when fully mixed.

Photo 8: Fine Al-Co_3O_4 Thermite – Small-Scale Mix ID #12 (SMS mixed)

5.9 Fine Al-SnO_2 Thermite – Small-Scale Mix ID #19 (SMS mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 19.27% aluminum (Al) and 80.73% tin(IV) oxide (SnO_2). The aluminum was 3N purity (99.9% pure), 1 - 5 micrometers (microns) in size, and offered for transport as a Division 4.1 flammable solid. This thermite was a very fine, off-white powder when fully mixed.

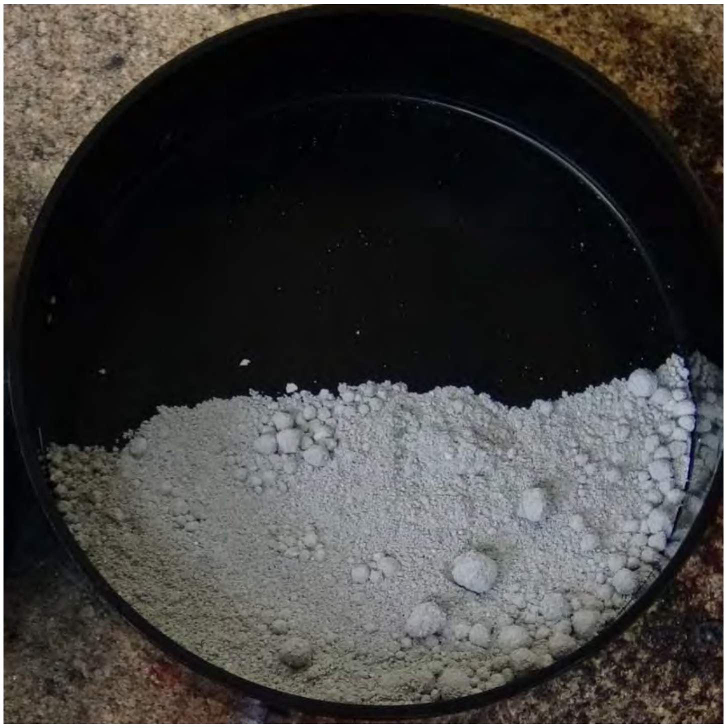


Photo 9: Fine Al-SnO_2 Thermite – Small-Scale Mix ID #19 (SMS mixed)

5.10 Fine Al-Bi_2O_3 Thermite – Small-Scale Mix ID #24 (SMS mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 10.38% aluminum (Al) and 89.62% bismuth oxide (Bi_2O_3). The aluminum was 3N purity (99.9% pure), 1 - 5 micrometers (microns) in size, and offered for transport as a Division 4.1 flammable solid. This thermite was a very fine, off-white powder when fully mixed.

Photo 10: Fine Al-Bi_2O_3 Thermite – Small-Scale Mix ID #24 (SMS mixed)

5.11 Fine Al-Fe_3O_4 – Small-Scale Mix ID #27 (SMS Mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 23.71% aluminum (Al) and 76.29% iron tetroxide (Fe_3O_4). The aluminum was 3N purity (99.9% pure), 1 - 5 micrometers (microns) in size, and offered for transport as a Division 4.1 flammable solid. The iron tetroxide was 3N purity (99.9% pure) and 1-5 micrometers (microns) in size. This thermite was a fine, dark gray powder when fully mixed.

Photo 11: Fine Al-Fe_3O_4 – Small-Scale Mix ID #27

5.12 Fine Al-MnO – Small-Scale Mix ID #29 (SMS Mixed)

Although not contractually required, SMS also procured and mixed the raw ingredients for this thermite for the instrumented Koenen tests only. The composition of this thermite by mass was 20.23% aluminum (Al) and 79.77% manganese oxide (MnO). The aluminum was 3N purity (99.9% pure), 1 - 5 micrometers (microns) in size, and offered for transport as a Division 4.1 flammable solid. The manganese oxide was 1N purity (99% pure) fine powder. This thermite was a fine green powder when fully mixed.

Photo 12: Fine Al-MnO – Small-Scale Mix ID #29

5.13 Fine Al-NiO – Small-Scale Mix ID #30 (SMS Mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 19.41% aluminum (Al) and 80.59% nickel oxide (NiO). The aluminum was 3N purity (99.9% pure), 1 - 5 micrometers (microns) in size, and offered for transport as a Division 4.1 flammable solid. The nickel oxide was 1N purity (99% pure) and 1 - 5 micrometers (microns) in size. This thermite was a fine light green powder when fully mixed.

Photo 13: Fine Al-NiO – Small-Scale Mix ID #30

5.14 Fine Ti-Bi_2O_3 – Small-Scale Mix ID #48 (SMS Mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 13.35% titanium (Ti) and 86.65% bismuth trioxide (Bi_2O_3). The titanium was 2N purity (99.9% pure), less than 20 micrometers in size, and offered for transport as a Division 4.1 flammable solid. The bismuth trioxide was 3N purity (99.9% pure) and 1- 5 micrometers (micron) in size. This thermite was a fine, light-yellow powder when fully mixed.

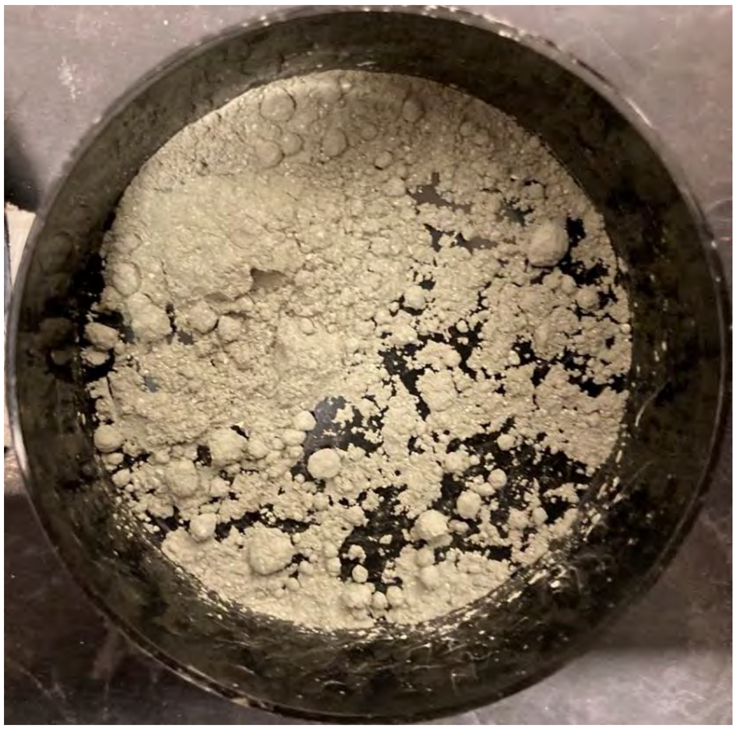


Photo 14: Fine Ti-Bi_2O_3 – Small-Scale Mix ID #48

6.0 TEST DESCRIPTIONS AND RESULTS

6.1 UN Series 2 (b) Koenen test

6.1.1 Test Description

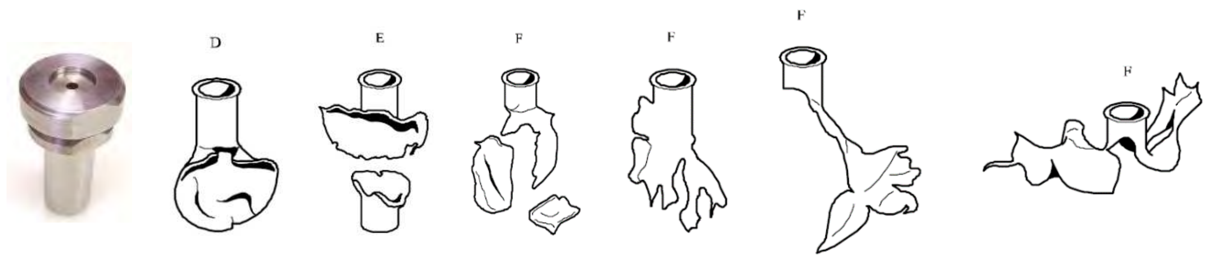
The Koenen test is used to determine the sensitiveness of solid and liquid substances to intense heat under high confinement. This test utilizes a steel tube to hold the sample. The tube is deep drawn from DC04, A620, or SPCEN sheet steel; 26.5 ± 1.5 grams mass, 75 °C 0.5mm length, 0.5 ± 0.05mm wall, and 30 ± 3 MPa quasi-static bursting pressure. The sample is loaded into the tubes in three equal increments with each increment tamped with an 80 N force applied to the total cross-section of the tube until the tube is filled to 60mm. Liquids are loaded into the tube to a height of 60mm. The tube is assembled into a reusable closing device (threaded nut and collar) and an orifice plate installed on the open end of the tube. Varying the orifice plate over the top of the sample tube changes the degree of confinement of the sample.

Photo 1: Koenen Tube, Orifice Plates, and Reusable Closing Device

The tube is placed in the heating and protective device, the test area vacated, burners remotely lit, providing a calibrated heating rate to the sample by propane burners located at four locations around the tube for at least five minutes or until the tube ruptures. NOTE: The heating rate is calibrated to 3.3 ± 0.3 K/sec using the time for 27 cm^3 of silicone oil of apparent density 0.96 ± 0.02 at 20°C and heat capacity 1.46 ± 0.02 J/(g·K) at 25°C to rise from 135°C to 285°C as measured by a 1mm thermocouple placed 43mm below the rim of the tube through a 1.5mm orifice plate (the rise time must be between 41.7 - 50.0 seconds).

After each trial the fragments of the tube, if any, are collected and weighed. The following effects are differentiated:

- "O": Tube unchanged;
- "A": Bottom of tube bulged out;
- "B": Bottom and wall of the tube bulged out;
- "C": Bottom of tube split;
- "D": Wall of tube split;
- "E": Tube split into two fragments;
- "F": Tube fragmented into three or more mainly large pieces which in some cases may be connected with each other by a narrow strip;
- "G": Tube fragmented into many mainly small pieces, closing device undamaged; and
- "H": Tube fragmented into many very small pieces, closing device bulged out or fragmented.



If a trial results in any of the effects "O" to "E", the result is regarded as "no explosion". If a trial gives the effect "F", "G" or "H", the result is evaluated as "explosion". The test is performed three times at the lowest orifice size that the result "no explosion" is observed. The limiting diameter (LD) is the largest orifice diameter at which the result "explosion" is obtained. The orifice sizes are reduced until an explosion effect occurs or the substance passes the test with the smallest orifice (1.0mm).

The result is considered positive for the UN Series 2 (b) test and the substance to show a violent effect on heating under confinement if the LD is 2.0mm or more. The result is considered negative for the UN Series 2 (b) test and the substance to show no violent effect on heating under confinement if the LD is less than 2.0mm.

6.1.2 Test Configuration

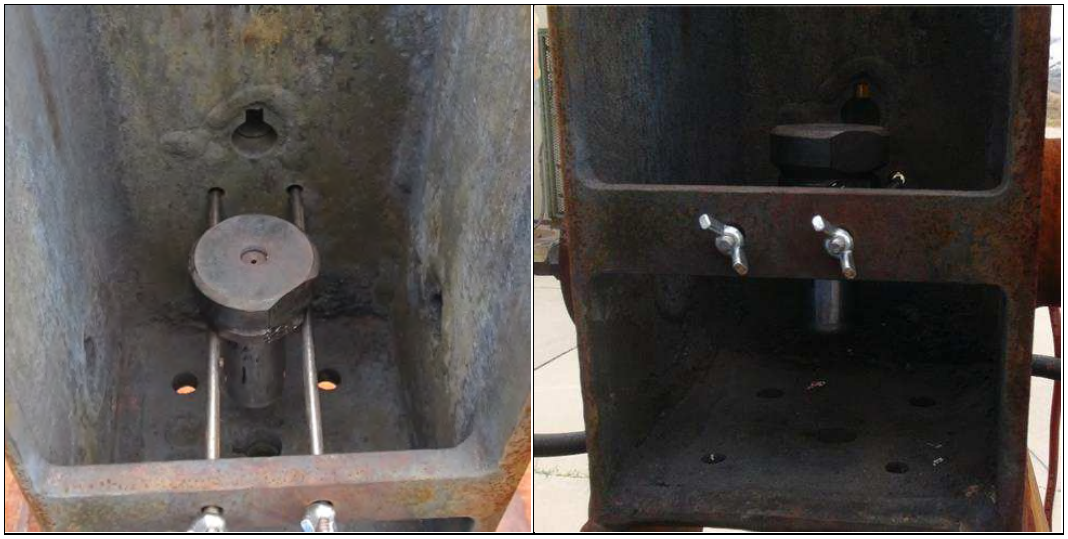
The quantity of sample in each tube, filled in three equal increments with 80 N tamping to a depth of 60mm, is listed in the following table.

Table 2: Sample Quantity Required to Fill Koenen Tubes to a Depth of 60mm

Item	Sample	Trial 1 Mass (g)	Trial 2 Mass (g)	Trial 3 Mass (g)
1	LS #1 Al-Fe_2O_3	39.98	40.40	38.26
2	LS #2 Al-Fe_2O_3	54.94	55.29	55.02
3	LS #4 Al-CuO	64.76	63.34	63.35
4	LS #5 Al-CuO	67.87	67.89	67.86
5	LS #7 Al-MnO_2	59.20	59.50	60.27
6	LS #8 Mg&Al-MoO_3-CuO	51.00	51.07	50.96
7	SS #4 Mg-MnO_2	49.40	51.50	48.05
8	SS #12 Al-Co_3O_4	61.40	61.60	61.52
9	SS #19 Al-SnO_2	58.52	58.32	58.29
10	SS #24 Al-Bi_2O_3	103.86	103.95	104.19
11	SS #27 Al-Fe_3O_4	49.20	50.35	49.86
12	SS #29 Al-MnO	50.76	49.13	51.64
13	SS #30 Al-NiO	88.59	87.09	87.90
14	SS #48 Ti-Bi_2O_3	113.71	113.75	113.05

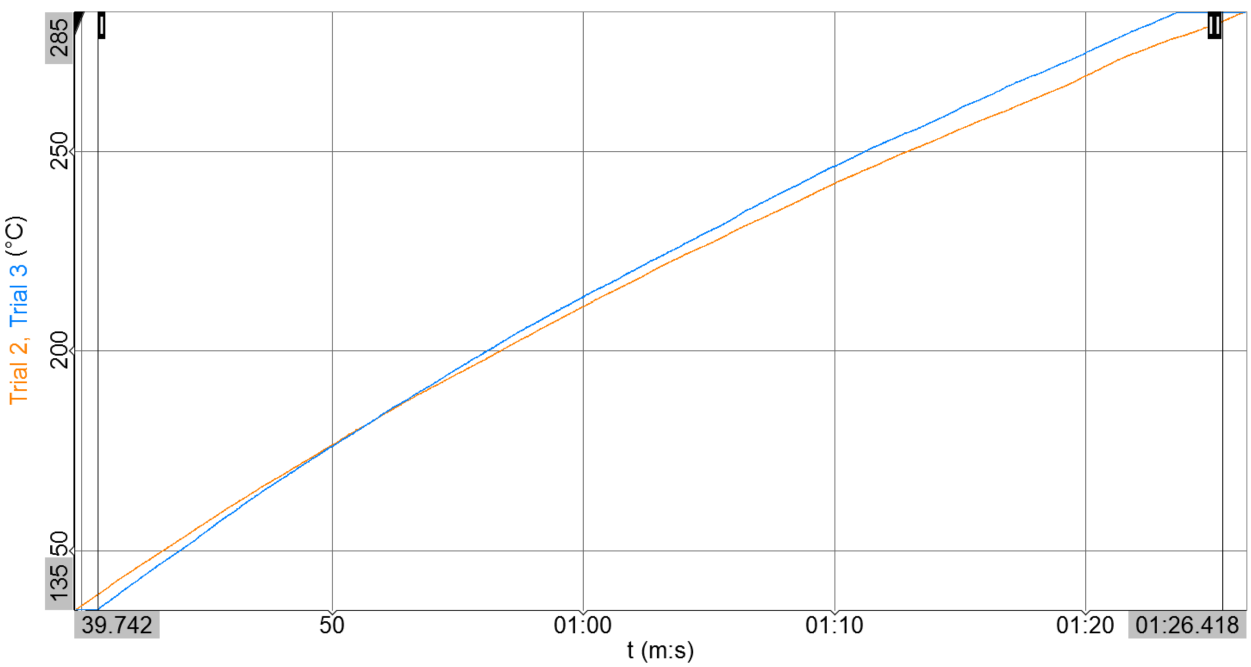
The orifice plates for these tests had a 2.5mm diameter hole to accommodate an Omega Model GG-K-30 (solid-wire, Type-K) thermocouple with glass wrap (nominally 0.9mm x 1.3mm), resulting in a vent area comparable to that for the 2.0mm orifice required by the UN Test Series 2 (b) test. The test tube was centered in the heating and protective device as shown in the following photo.

Photo 2: Koenen Tube Suspended in Heating and Protective Device



For the calibration trials, Sigma-Aldrich P/N 378364-1L silicone oil with a viscosity of 100 cSt (25°C) and a density of 0.96 g/mL at 25°C was utilized; the time for 27 cm³ of the silicone oil to rise from 135°C to 285°C measured by a 1mm thermocouple placed 43mm below the rim of the tube through a 1.5mm orifice plate was 43.1 and 46.6 seconds, which was within calibration.

Figure 3: Temperature of Silicone Oil for Koenen Calibration Trials



The first four thermites were tested with the thermocouple placed in the bottom of the tube and the thermite sample loaded on top of it. These first four tests show the variation in temperature at the bottom of the tube with various thermites. Subsequent thermites were tested with the thermocouple in the bottom of the tube for the first trial, at the bottom of the second increment for the second trial and at the bottom of the third increment for the third trial, to determine the thermal gradient/variation in each sample.

6.1.3 Test Results

The test results are summarized in the following table. When trials resulted in ignition of the thermite, the ignition temperature and time were listed in the table; otherwise, the plateau temperature and time were listed.

Table 3: Summary of Instrumented Koenen Test Results

Item	Sample	Trial	Thermocouple Placement	Ignition Temp (°C)	Time to Ignition (mm:ss)	Plateau Temp (°C)	Time to Plateau (min)	Effect Type
1	LS #1 Al-Fe_2O_3	1	Bottom of tube	-	-	400	4.3	O
		2	Bottom of tube	-	-	700	5.0	O
		3	Bottom of tube	-	-	700	5.0	O
2	LS #2 Al-Fe_2O_3	1	Bottom of tube	-	-	560	7.5	O
		2	Bottom of tube	-	-	560	6.0	O
		3	Bottom of tube	-	-	630	5.3	O
3	LS #4 Al-CuO	1	Bottom of tube	798	02:21	-	-	F
		2	1/3 from bottom	441	04:34	-	-	F
		3	1/3 from top	312	03:20	-	-	F
4	LS #5 Al-CuO	1	Bottom of tube	755	01:48	-	-	E
		2	1/3 from bottom	-	-	720	12.5	O
		3	1/3 from top	-	-	760	12.0	O
5	LS #7 Al-MnO_2	1	Bottom of tube	265	01:47	-	-	F
		2	Bottom of tube	-	-	550	7.2	O
		3	Bottom of tube	-	-	590	4.0	O
6	LS #8 Mg&Al-MoO_3-CuO	1	Bottom of tube	709	01:22	-	-	F
		2	1/3 from bottom	676	01:56	-	-	F
		3	1/3 from top	59	01:04	-	-	E
7	SS #4 Mg-MnO_2	1	Bottom of tube	514	01:07	-	-	F
		2	1/3 from bottom	356	01:05	-	-	F
		3	1/3 from top	156	01:04	-	-	F
8	SS #12 Al-Co_3O_4	1	Bottom of tube	-	-	670	8.5	O
		2	1/3 from bottom	-	-	520	14.0	O
		3	1/3 from top	-	-	680	8.0	O

Item	Sample	Trial	Thermocouple Placement	Ignition Temp (°C)	Time to Ignition (mm:ss)	Plateau Temp (°C)	Time to Plateau (min)	Effect Type
9	SS #19 Al-SnO_2	1	Bottom of tube	-	-	690	4.5	O
		2	1/3 from bottom	-	-	510	7.8	O
		3	1/3 from top	-	-	600	8.7	O
10	SS #24 Al-Bi_2O_3	1	Bottom of tube	505	01:38	-	-	F
		2	1/3 from bottom	317	02:42	-	-	F
		3	1/3 from top	217	01:28	-	-	F
11	SS #27 Al-Fe_3O_4	1	Bottom of tube	-	-	880	5.4	O
		2	1/3 from bottom	-	-	670	7.0	O
		3	1/3 from top	-	-	630	15.0	O
12	SS #29 Al-MnO	1	Bottom of tube	-	-	630	6.2	O
		2	Bottom of tube	-	-	570	5.3	O
		3	Bottom of tube	-	-	640	4.8	O
13	SS #30 Al-NiO	1	Bottom of tube	-	-	710	7.1	O
		2	1/3 from bottom	-	-	530	11.2	O
		3	1/3 from top	-	-	420	15:00	O
14	SS #48 Ti-Bi_2O_3	1	Bottom of tube	378	02:52	-	-	F
		2	1/3 from bottom	-	-	260	11:13	O
		3	1/3 from top	87	01:22	-	-	F

The temperature of each thermite in the Koenen trials is shown in the following figures accompanied by photos of the test results.

Figure 4: Temperature of LS #1 Al-Fe_2O_3 in Koenen Trials

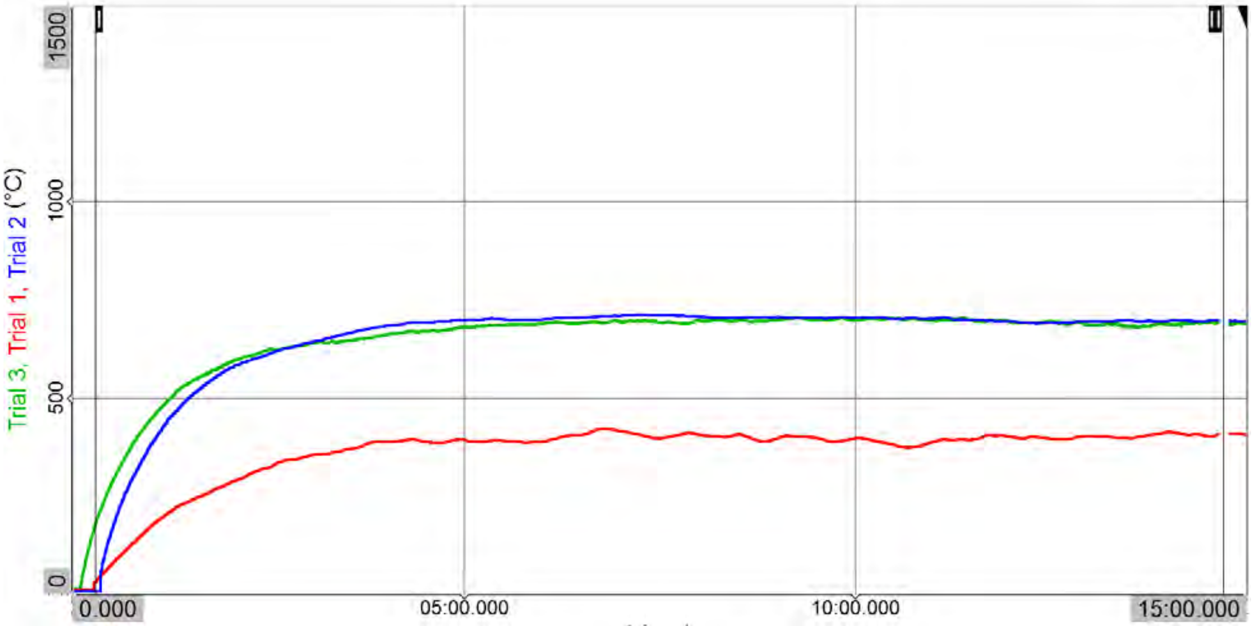


Photo 15: Koenen Test Results for LS #1 Al-Fe_2O_3, Trials 1 - 3 (left to right)

Figure 5: Temperature of LS #2 Al-Fe_2O_3 in Koenen Trials

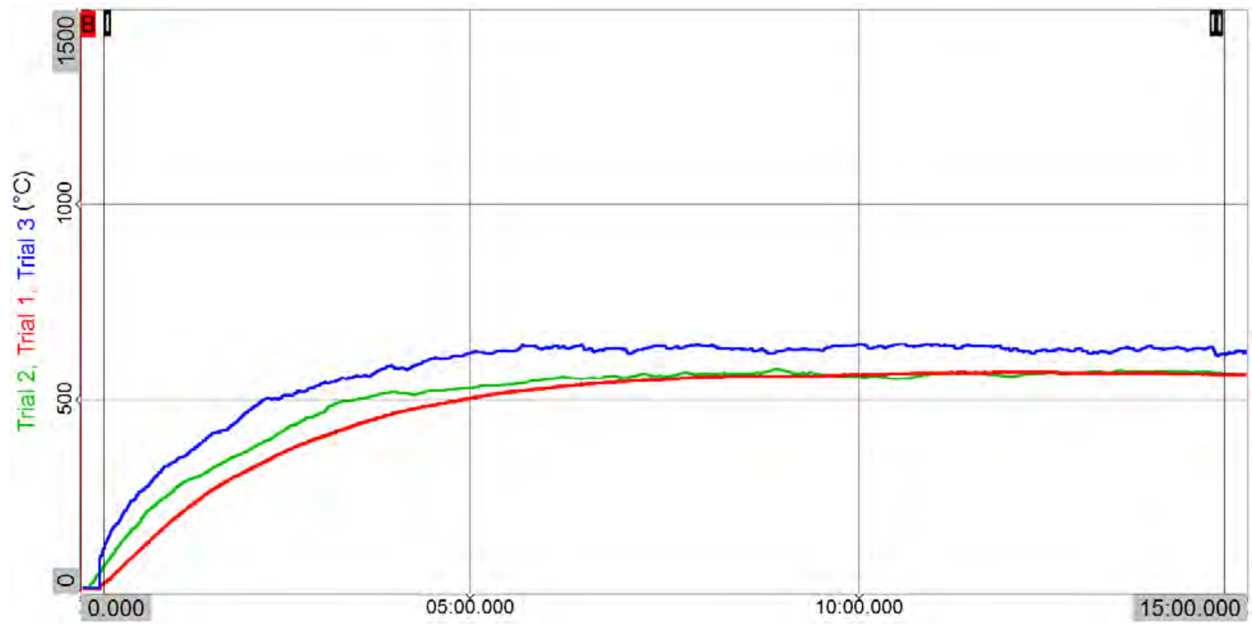


Photo 16: Koenen Test Results for LS #2 Al-Fe_2O_3, Trials 1 - 3 (left to right)

Figure 6: Temperature of LS #4 Al-CuO in Koenen Trials

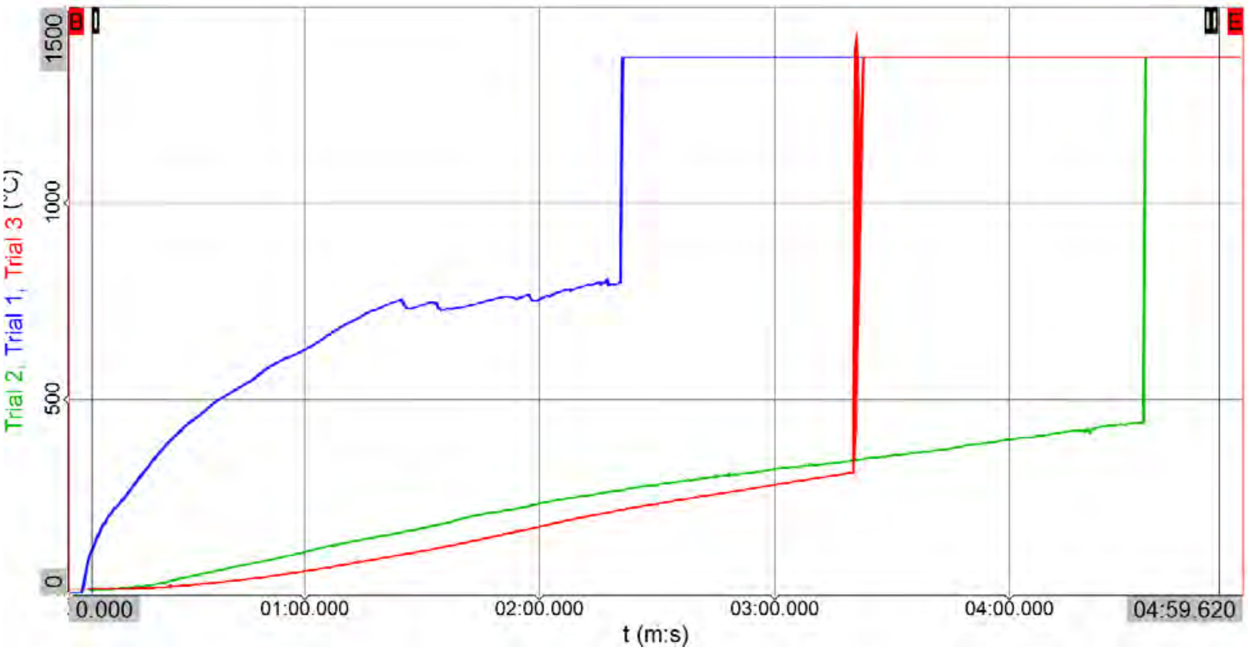


Photo 17: Koenen Test Results for LS #4 Al-CuO, Trials 1 - 3 (left to right)

Figure 7: Temperature of LS #5 Al-CuO in Koenen Trials

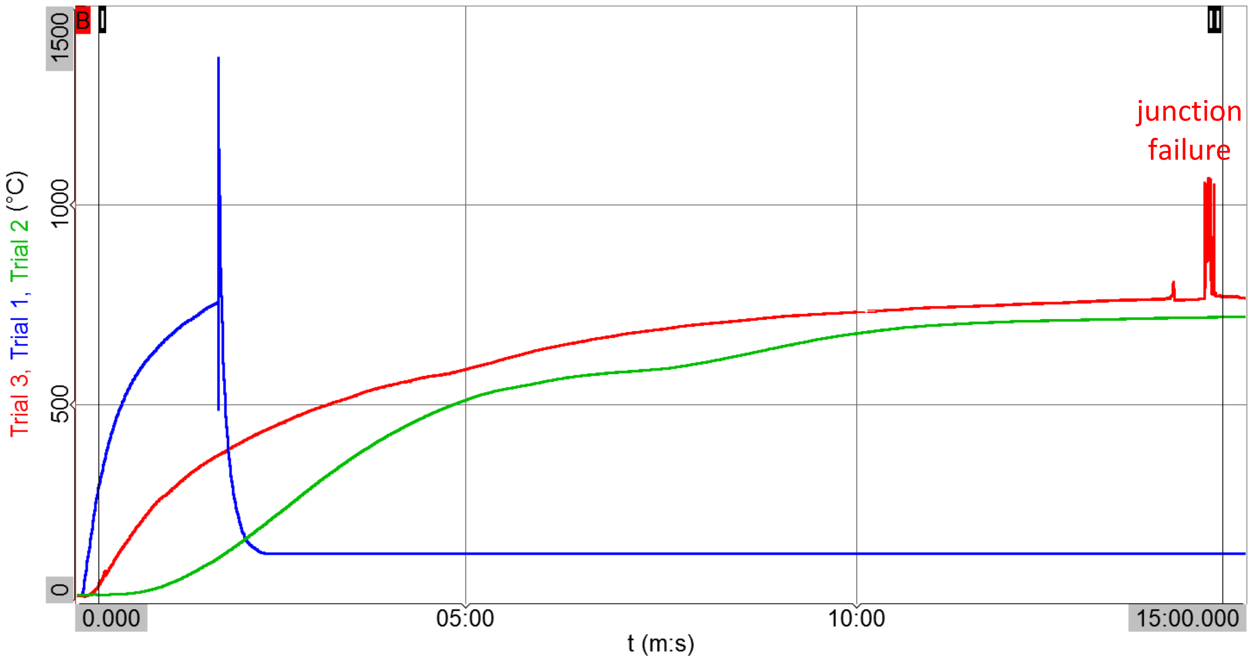


Photo 18: Koenen Test Results for LS #5 Al-CuO, Trials 1 - 3 (left to right)

Figure 8: Temperature of LS #7 Al-MnO_2 in Koenen Trials

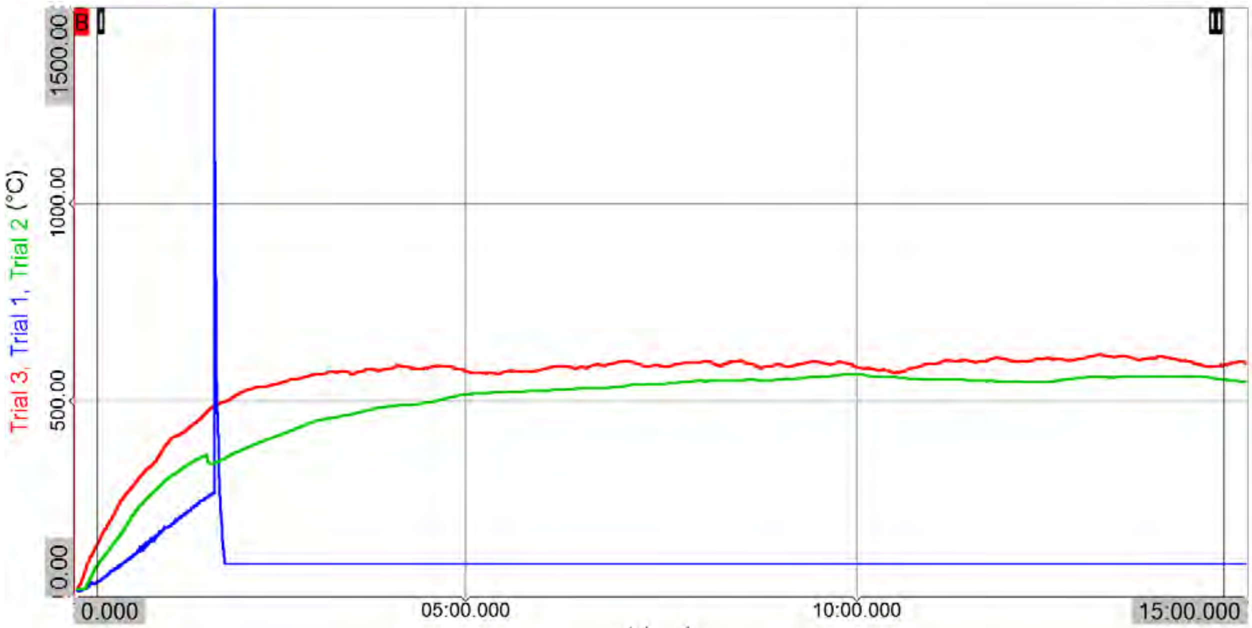


Photo 19: Koenen Test Results for LS #7 Al-MnO_2, Trials 1 - 3 (left to right)

Figure 9: Temperature of LS #8 Mg&Al-MoO_3-CuO in Koenen Trials

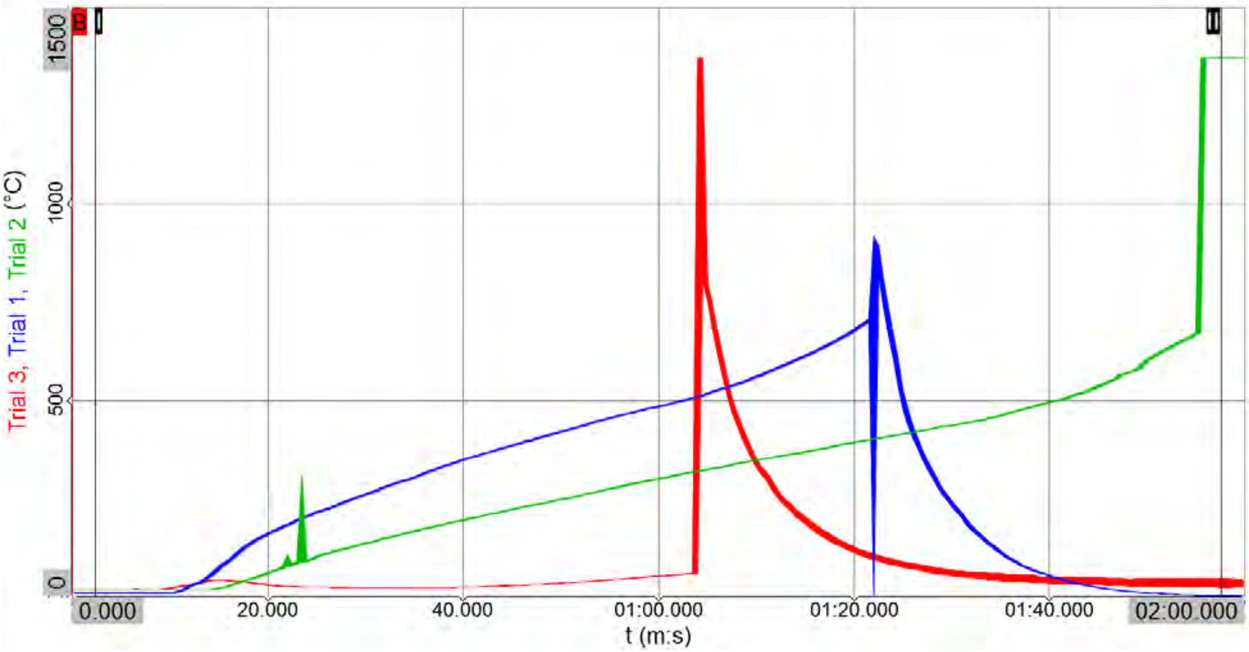


Photo 20: Koenen Test Results for LS #8 Mg&Al-MoO_3-CuO, Trials 1 - 3 (left to right)

Figure 10: Temperature of SS #4 Mg-MnO_2 in Koenen Trials

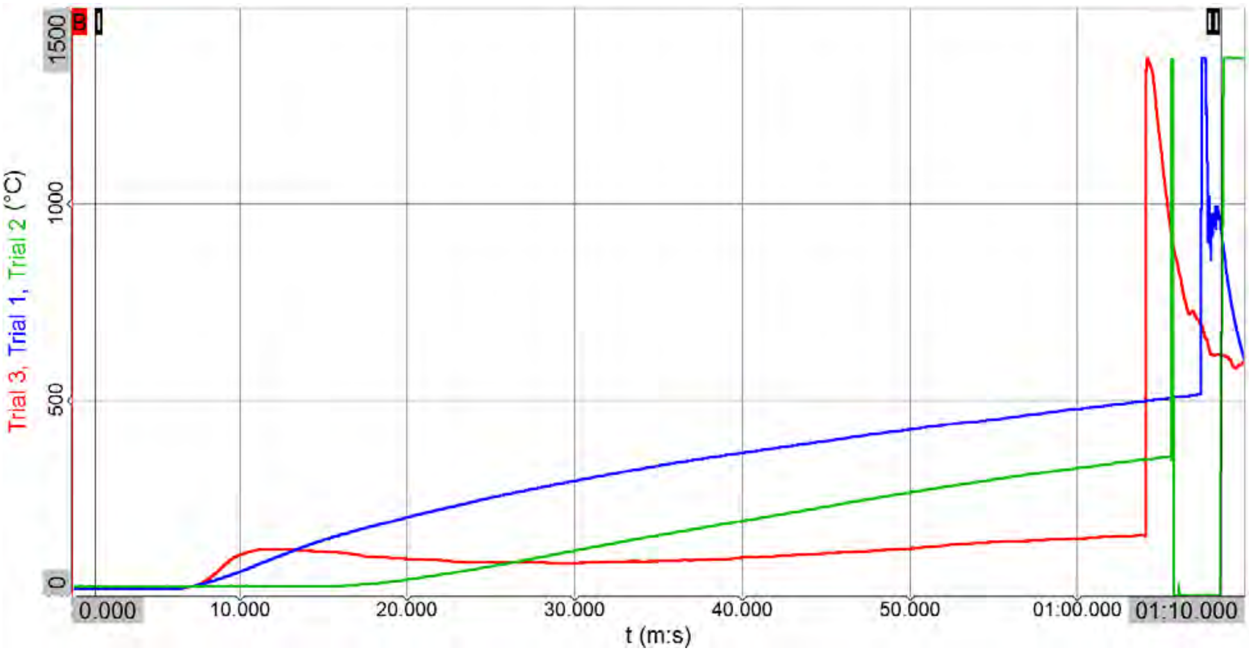


Photo 21: Koenen Test Results for SS #4 Mg-MnO_2, Trials 1 - 3 (left to right)

Figure 11: Temperature of SS #12 Al-Co_3O_4 in Koenen Trials

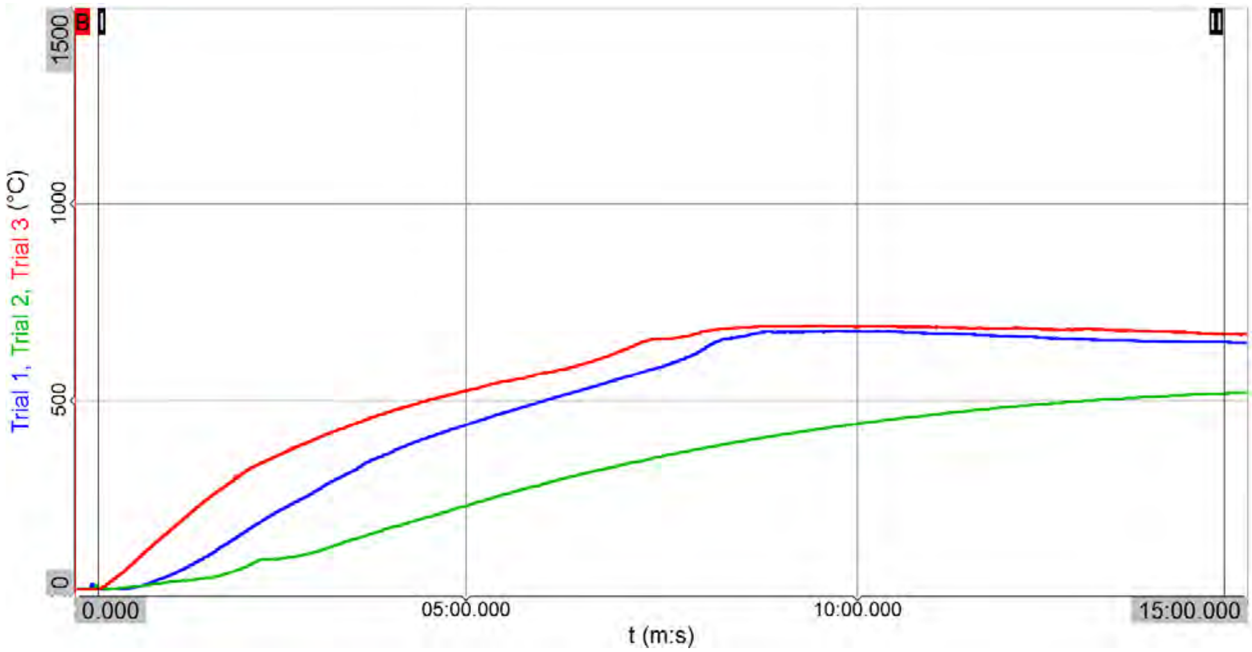


Photo 22: Koenen Test Results for SS #12 Al-Co_3O_4, Trials 1 - 3 (left to right)

Figure 12: Temperature of SS #19 Al-SnO_2 in Koenen Trials

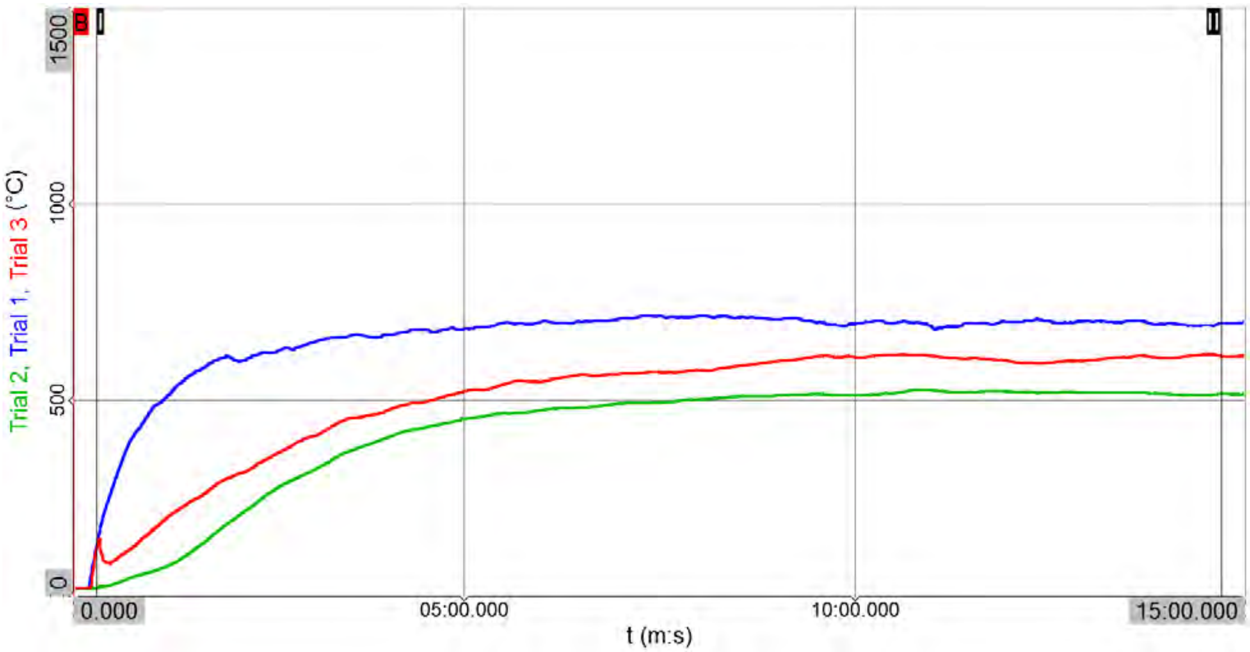


Photo 23: Koenen Test Results for SS #19 Al-SnO_2, Trials 1 - 3 (left to right)

Figure 13: Temperature of SS #24 Al-Bi_2O_3 in Koenen Trials

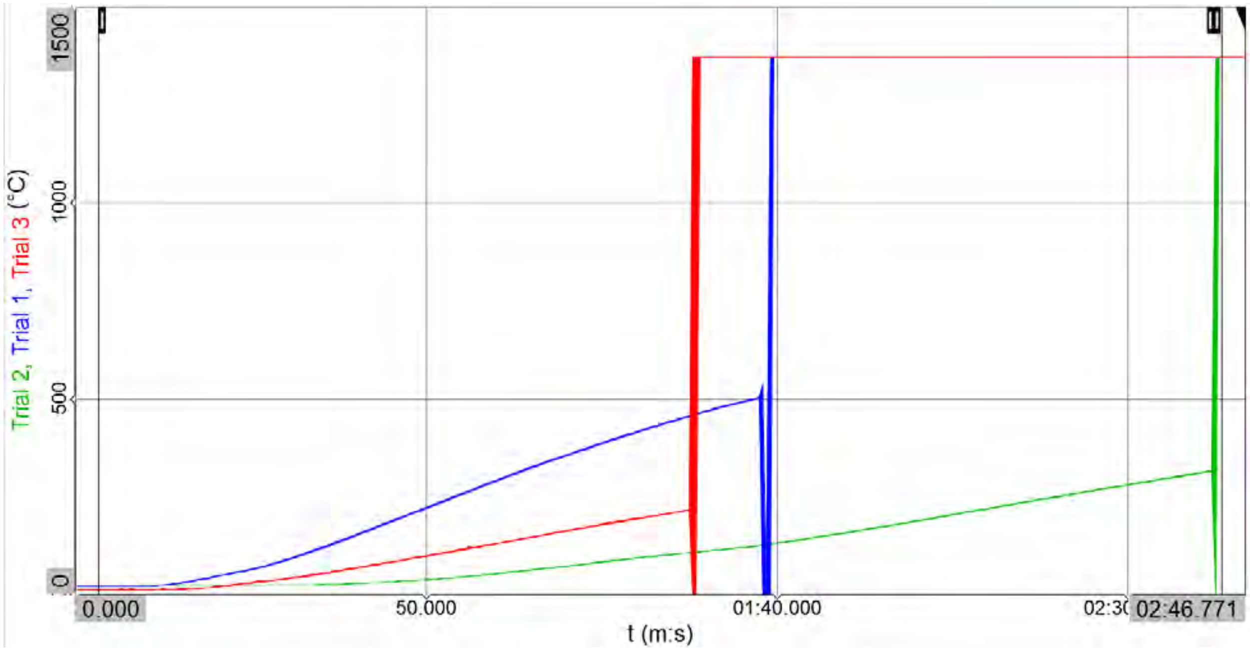


Photo 24: Koenen Test Results for SS #24 Al-Bi_2O_3, Trials 1 - 3 (left to right)

Figure 14: Temperature of SS #27 Al-Fe_3O_4 in Koenen Trials

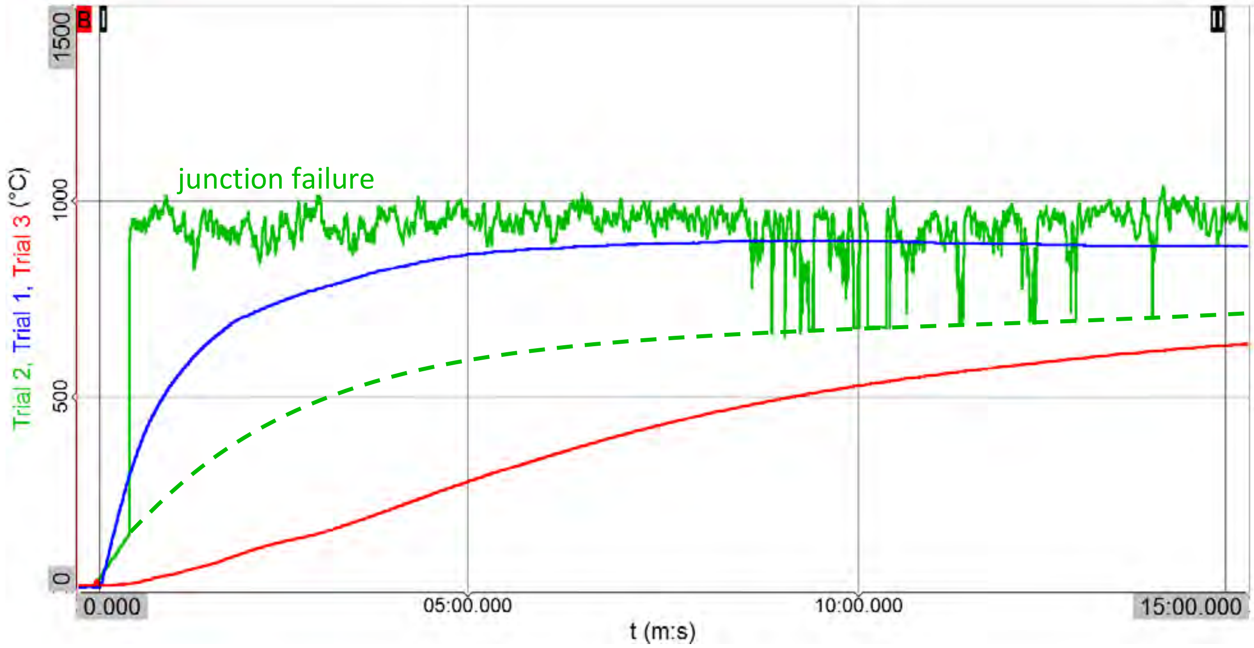


Photo 25: Koenen Test Results for SS #27 Al-Fe_3O_4, Trials 1 - 3 (left to right)

Figure 15: Temperature of SS #29 Al-MnO in Koenen Trials

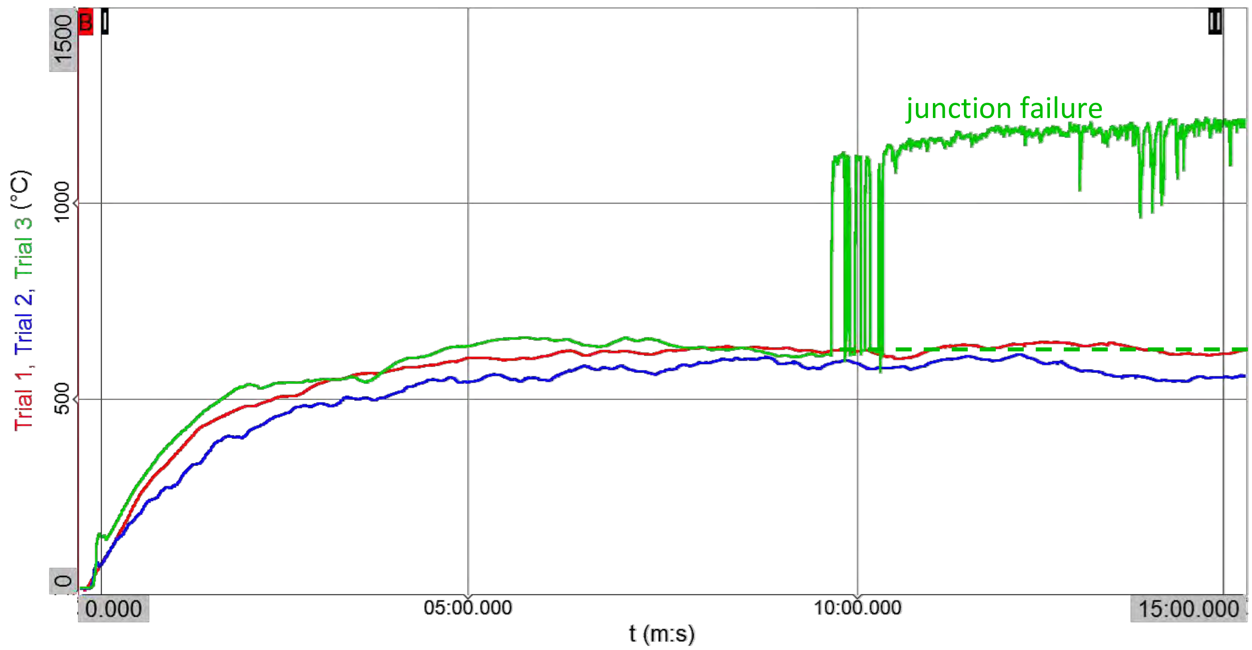


Photo 26: Koenen Test Results for SS #29 Al-MnO, Trials 1 - 3 (left to right)

Figure 16: Temperature of SS #30 Al-NiO in Koenen Trials

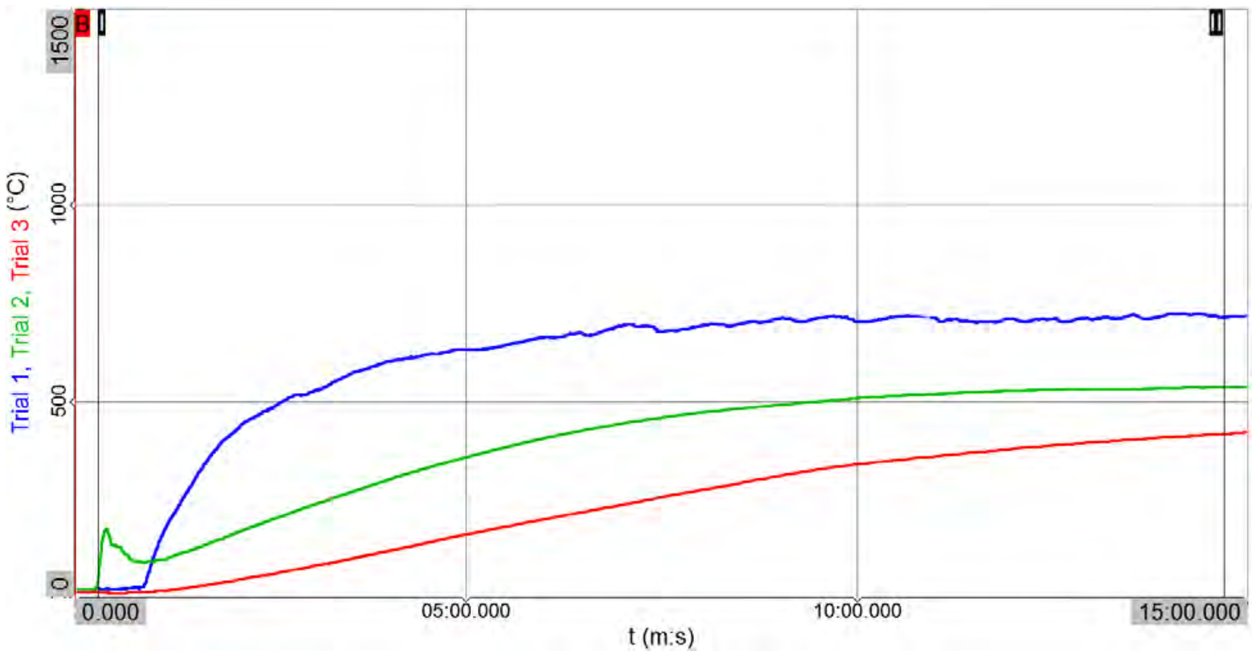


Photo 27: Koenen Test Results for SS #30 Al-NiO, Trials 1 - 3 (left to right)

Figure 17: Temperature of SS #48 Ti-Bi_2O_3 in Koenen Trials

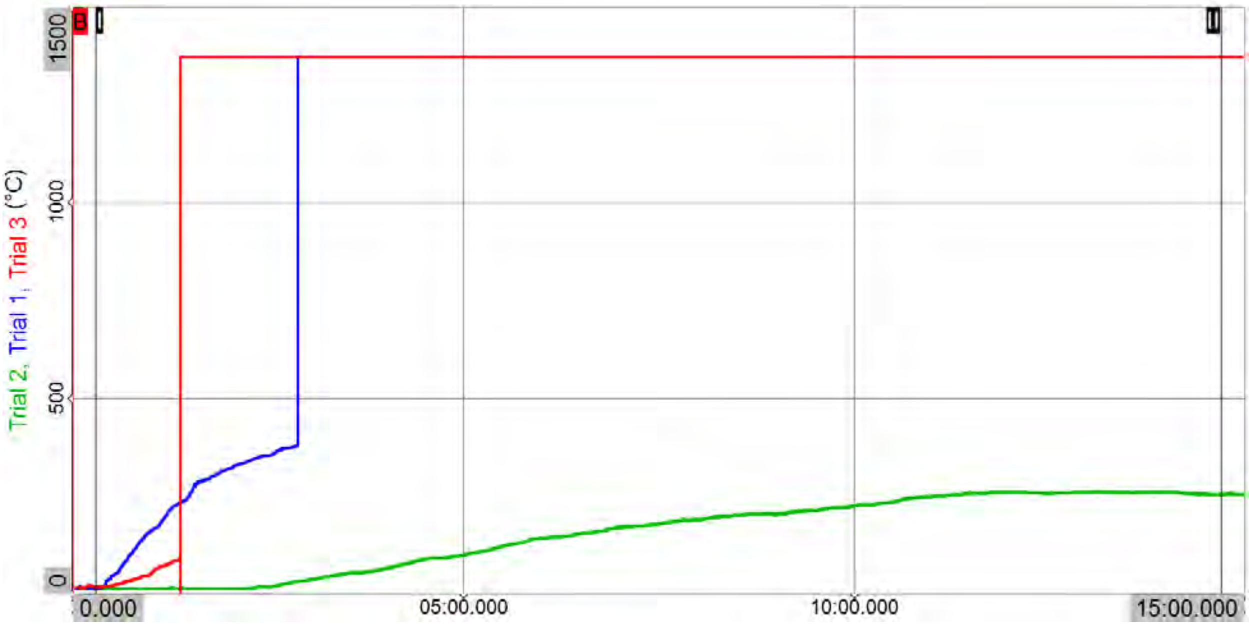
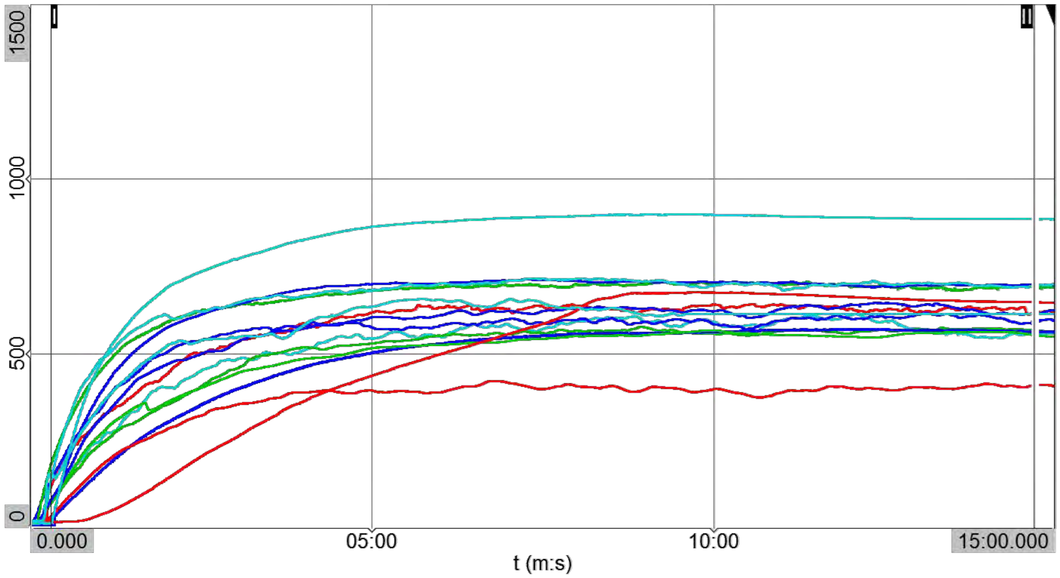


Photo 28: Koenen Test Results for SS #48 Ti-Bi_2O_3, Trials 1 - 3 (left to right)

6.1.4 Assessment of Test Results

In general, the thermocouple in the bottom of the Koenen tube reached a temperature plateau around five minutes into the test, as shown in the following figure. The following table summarizes the sample temperatures at five, ten and fifteen minutes into the test.

Figure 18: Sample Temperature in the Bottom of the Koenen Tube (without Ignitions)



The following table summarizes the sample temperatures at five, ten and fifteen minutes into the test.

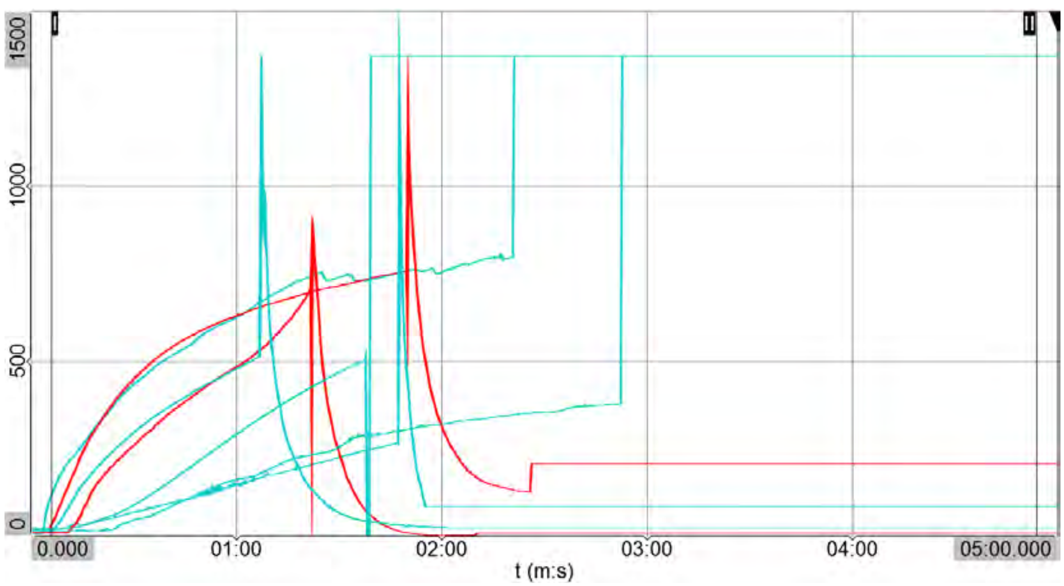
Table 4: Progression of Sample Temperatures in the Bottom of the Koenen Tube

Sample Temperature (°C)		
5 min	10 min	15 min
395	398	407
436	557	548
502	562	557
516	566	563
529	583	565
543	590	595
575	613	613
605	622	619
618	641	625
635	675	646
681	694	690
682	699	696
699	704	701
864	899	885
395	398	407
436	557	548

	Sample Temperature (°C)		
	5 min	**10 min**	**15 min**
	502	562	557
	516	566	563
	529	583	565
	543	590	595
	575	613	613
	605	622	619
	618	641	625
	635	675	646
Average	**591**	**629**	**622**
Std Dev	**116**	**107**	**103**

The following figure is a plot of the sample temperature in the bottom of the tube for the thermites that reacted in the Koenen test; the heating rates are similar to and consistent with those in the trials above that did not react.

Figure 19: Sample Temperature in the Bottom of the Koenen Tube (Ignitions only)



Similarly, the temperature at the top or bottom third of the sample reached a temperature plateau around ten minutes into the test, as shown in the following figure. The following table summarizes the sample temperatures at five, ten and fifteen minutes into the test.

Figure 20: Sample Temperature One-Third from the Top/Bottom in Koenen Trials (without Ignitions)

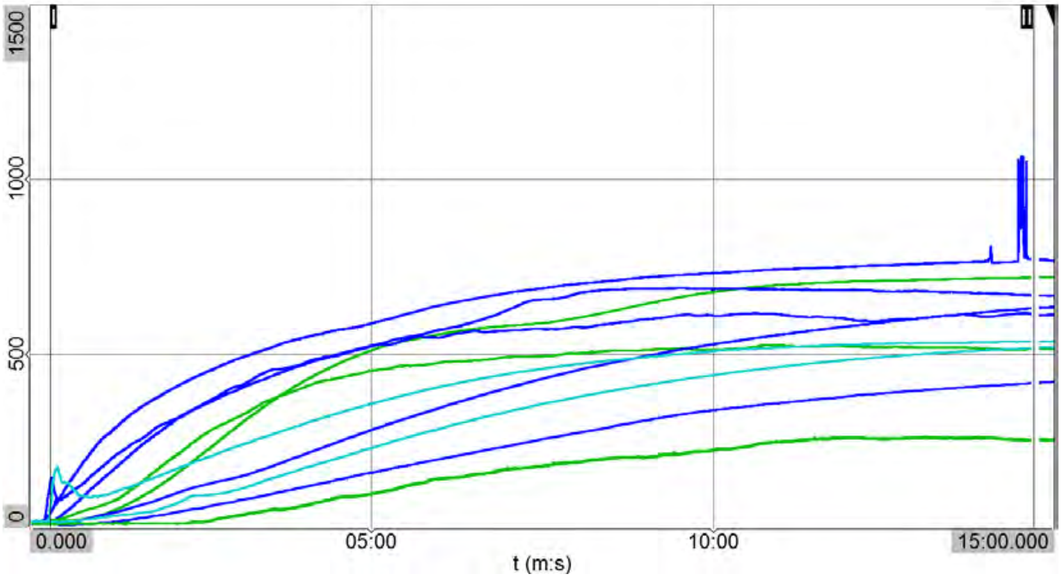


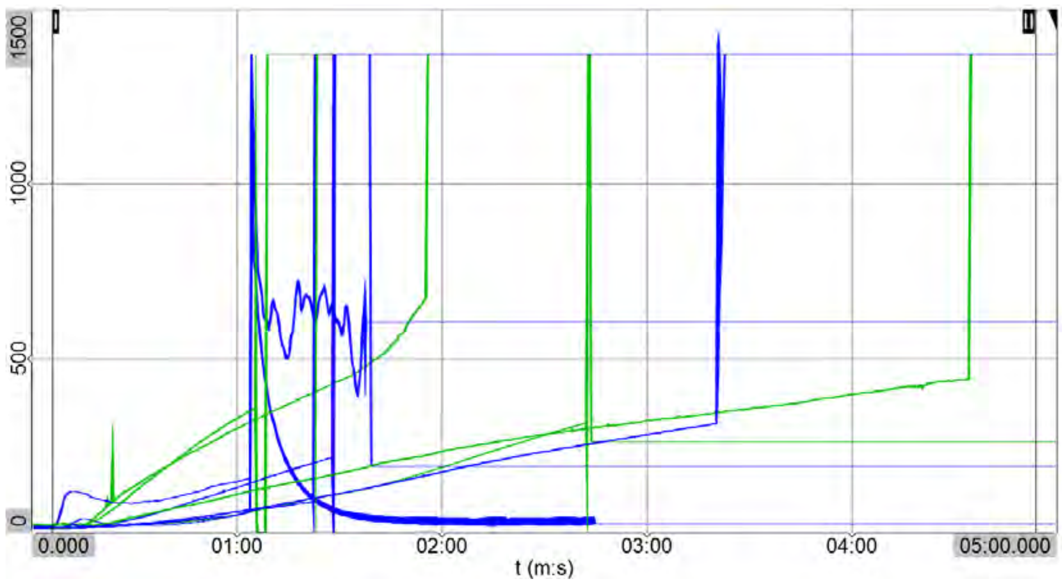
Table 5: Progression of Sample Temperatures One-Third from the Top/Bottom

Sample Temperature (°C)		
5 min	10 min	15 min
100	224	254
161	340	421
230	439	515
283	508	520
357	512	537
452	528	613
512	610	635
524	678	667
523	687	720
588	732	767
100	224	254
161	340	421
230	439	515
283	508	520
357	512	537
452	528	613
512	610	635
524	678	667
523	687	720

	Sample Temperature (°C)		
	5 min	10 min	15 min
	588	732	767
Average	**373**	**526**	**565**
Std Dev	**163**	**152**	**143**

The following figure is a plot of the sample temperature one-third from the top/bottom for the thermites that reacted in the Koenen test; the heating rates are similar to and consistent with those shown above that did not react.

Figure 21: Sample Temperature One-Third from the Top/Bottom in Koenen Trials (Ignitions Only)



7.0 CONCLUSIONS

On average, thermite test samples in the bottom of a Koenen tube reached 94% of their maximum temperature within the first five minutes; the top/bottom third of the sample reached 93% of their maximum temperature within ten minutes but it was around 100°C less than that achieved at the bottom. Further, there is greater variability in the temperature of the top/bottom third of the sample in comparison to that of the bottom.

Thermites with auto-ignition temperatures above these temperatures can pass the Koenen test with no reaction but still present an explosion or fast reaction hazard, such as LS #1 Al-Fe_2O_3, SS #19 Al-SnO_2, SS #27 Al-Fe_3O_4 or SS #30 Al-NiO. In this round of testing, some of the thermites ignited in each of the three trials; other thermites only ignited in one of the three trials (inconsistent and unpredictable results). Each ignition was within the standard five-minute

Koenen test limit unlike the prior study where many thermite reactions were well after the standard five minutes.

APPENDIX A

– PRODUCT CERTIFICATIONS

Figure D1: Product Certification for Al Metal Powder

ATLANTIC EQUIPMENT ENGINEERS
HIGH PURITY METALS AND COMPOUNDS

Certificate of Analysis
ALUMINUM METAL POWDER
AL-100

1.1 General

SOLD TO	PURCHASE ORDER #	SHIP DATE	DOCUMENT NUMBER
SAFETY MANAGEMENT SERVICES for COMMANDER TOOELE ARMY DEPOT	1526	9 MAR 2021	2101018
CATALOG NUMBER	LOT NUMBER	QUANTITY	CAS NUMBER
AL-100	2002510-6	173 LBS	7429-90-5

2.1 Chemical Analysis (in percentage (%) unless otherwise stated)

Al	Ti	Si	Fe
99.9%	<0.06	<0.10	<0.20

3.1 Screen Analysis (percent passing) / Other

Size	D 10	D 50	D 90
1-5 microns	1.6 microns	3.6 microns	9 microns

4.1 Notes

5.1 Statement

Shelf life is indefinite when material is stored in a tightly sealed container in a cool, dry place.

The above analysis is carried out as part of our internal quality control testing and is based upon our analysis methods.

We do not assume any warranty, liability, or risk based on such findings. Our quality is warranted within the scope of our general sales conditions.

Please refer to SDS for material handling instructions.

Very Truly Yours,

M. Gerald, QA

24 Industrial Ave, Upper Saddle River, NJ 07458 Tel: 201.828.9400 Fax: 201.387.0291
On the web at: www.micronmetals.com Email: info@micronmetals.com

Page 1 of 1

Figure D2: Product Certification for Co_3O_4

ATLANTIC EQUIPMENT ENGINEERS
HIGH PURITY METALS AND COMPOUNDS

Certificate of Analysis

COBALT OXIDE POWDER
CO 601

1.1 General

SOLD TO	PURCHASE ORDER #	SHIP DATE	DOCUMENT NUMBER
SAFETY MANAGEMENT SERVICES for COMMANDER TOOELE ARMY DEPOT	1526	9 MAR 2021	2101018
CATALOG NUMBER	LOT NUMBER	QUANTITY	CAS NUMBER
CO 601	2006516	1 LB	1309-06-1

2.1 Chemical Analysis (in percentage (%) unless otherwise stated)

Co	Ni	Fe	Ca	Cu	Pb
73.09	0.0007	0.0014	0.0029	0.0003	0.0005

3.1 Screen Analysis (percent passing) / Other

Size	D 50
-400 mesh	4.13 microns

4.1 Notes

5.1 Statement

The above analysis is carried out as part of our internal quality control testing and is based upon our analysis methods.

We do not assume any warranty, liability, or risk based on such findings. Our quality is warranted within the scope of our general sales conditions.

Please refer to SDS for material handling instructions.

Very Truly Yours,

M. Gerald, QA

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Page 1 of 1

Figure D3: Product Certification for CuO

ATLANTIC EQUIPMENT ENGINEERS
HIGH PURITY METALS AND COMPOUNDS

Certificate of Analysis
CUPRIC OXIDE
CU-602

1.1 General

SOLD TO	PURCHASE ORDER #	SHIP DATE	DOCUMENT NUMBER
SAFETY MANAGEMENT SERVICES for COMMANDER TOOELE ARMY DEPOT	1526	9 MAR 2021	2101018
CATALOG NUMBER	LOT NUMBER	QUANTITY	CAS NUMBER
CU-602	2102518	548 LBS	1317-38-0

2.1 Chemical Analysis (in percentage (%) unless otherwise stated)

Cu	CuO	Cu2O	Zn	Fe	Ca	Mg
75	94	3	0.3	0.02	0.01	0.002
Mn	Pb	Cd	As	Sb	Moisture	
0.001	0.05	0.01	0.01	0.01	0.2	

3.1 Screen Analysis (percent passing) / Other

Size	Specific Gravity	-325 mesh	Loose Bulk Density
1-5 microns	8.7 g/cc	99.9	80 lbs / ft³

4.1 Notes

5.1 Statement

The above analysis is carried out as part of our internal quality control testing and is based upon our analysis methods.

We do not assume any warranty, liability, or risk based on such findings. Our quality is warranted within the scope of our general sales conditions.

Please refer to SDS for material handling instructions.

Very Truly Yours,

M. Gerald, QA

24 Industrial Ave, Upper Saddle River, NJ 07458 Tel: 201.828.9400 Fax: 201.387.0291
On the web at: www.micronmetals.com Email: info@micronmetals.com

Page 1 of 1

Figure D4: Product Certification for Fe_2O_3

ATLANTIC EQUIPMENT ENGINEERS
HIGH PURITY METALS AND COMPOUNDS

Certificate of Analysis
RED IRON OXIDE POWDER
FE-601

1.1 General

SOLD TO	PURCHASE ORDER #	SHIP DATE	DOCUMENT NUMBER
SAFETY MANAGEMENT SERVICES for COMMANDER TOOELE ARMY DEPOT	1526	9 MAR 2021	2101018
CATALOG NUMBER	LOT NUMBER	QUANTITY	CAS NUMBER
FE-601	2102517-RD	282 LBS	1309-37-1

2.1 Chemical Analysis (in percentage (%) unless otherwise stated)

Tint strength	Moisture	Water soluble
100.4	0.60	0.10
Fe2O3	pH	
99 min	6.1	

3.1 Screen Analysis (percent passing) / Other

Size	+325 mesh
1-5 microns	0.012

4.1 Notes

5.1 Statement

The above analysis is carried out as part of our internal quality control testing and is based upon our analysis methods.

We do not assume any warranty, liability, or risk based on such findings. Our quality is warranted within the scope of our general sales conditions.

Please refer to SDS for material handling instructions.

Very Truly Yours,

M. Gerald, QA

24 Industrial Ave, Upper Saddle River, NJ 07458 Tel: 201.828.9400 Fax: 201.387.0291
On the web at: www.micronmetals.com Email: info@micronmetals.com

Page 1 of 1

Figure D5: Product Certification for Fe_3O_4

ATLANTIC EQUIPMENT ENGINEERS
HIGH PURITY METALS AND COMPOUNDS

Certificate of Analysis
BLACK IRON OXIDE
FE-602

1.1 General

SOLD TO	PURCHASE ORDER #	SHIP DATE	DOCUMENT NUMBER
SAFETY MANAGEMENT SERVICES for COMMANDER TOOELE ARMY DEPOT	1526	9 MAR 2021	2101018
CATALOG NUMBER	LOT NUMBER	QUANTITY	CAS NUMBER
FE-602	2009517	1 LB	1317-61-6

2.1 Chemical Analysis (in percentage (%) unless otherwise stated)

Tint Strength	pH	FeO	Moisture
97.6	8.91	23.4	0.39
Water soluble Salts		Fe2O3	
0.16		99.9	

3.1 Screen Analysis (percent passing) / Other

Size	+325 mesh
1-5 microns	0.009

4.1 Notes

Very fine, black powder, manufactured in the USA.

5.1 Statement

The above analysis is carried out as part of our internal quality control testing and is based upon our analysis methods.

We do not assume any warranty, liability, or risk based on such findings. Our quality is warranted within the scope of our general sales conditions.

Please refer to SDS for material handling instructions.

Very Truly Yours,

M. Gerald, QA

24 Industrial Ave, Upper Saddle River, NJ 07458 Tel: 201.828.9400 Fax: 201.387.0291
On the web at: www.micronmetals.com Email: info@micronmetals.com

Page 1 of 1

Figure D6: Product Certification for Ti Metal Powder

ATLANTIC EQUIPMENT ENGINEERS
HIGH PURITY METALS AND COMPOUNDS

Certificate of Analysis
TITANIUM METAL POWDER
TI 101

1.1 General

SOLD TO	PURCHASE ORDER #	SHIP DATE	DOCUMENT NUMBER
SAFETY MANAGEMENT SERVICES for COMMANDER TOOELE ARMY DEPOT	1526	9 MAR 2021	2101018
CATALOG NUMBER	LOT NUMBER	QUANTITY	CAS NUMBER
TI 101	2012519	7 LBS	7440-32-6

2.1 Chemical Analysis (in percentage (%) unless otherwise stated)

Al	Cl	Cr	Fe	H	Mg	Mn
0.007	<0.025	0.004	0.028	0.51	<0.010	<0.005
Mo	Zr	Na	Ni	O	P	Pb & Cd
<0.005	<0.01	<0.001	0.006	0.91	<0.010	<0.002
Si	Sn	V	Ti			
0.007	<0.010	<0.005	99.8% min			

3.1 Screen Analysis (percent passing) / Other

Size	
< 20 microns	

4.1 Notes
99.8% min metals basis

5.1 Statement

The above analysis is carried out as part of our internal quality control testing and is based upon our analysis methods.

We do not assume any warranty, liability, or risk based on such findings. Our quality is warranted within the scope of our general sales conditions.

Please refer to SDS for material handling instructions.

Very Truly Yours,

M. Gerald, QA

24 Industrial Ave, Upper Saddle River, NJ 07458 Tel: 201.828.9400 Fax: 201.387.0291
On the web at: www.micronmetals.com Email: info@micronmetals.com

Figure D7: Product Certification for MnO_2

AMERICAN ELEMENTS

World's Leading Manufacturer of Rare Earth and Advanced Material Products

A MERELEX CORPORATION • 10884 WEYBURN AVE. LOS ANGELES, CA 90024
TEL. 310-208-0551 • FAX 310-208-0351 • E-MAIL: customerservice@americanelements.com

CERTIFICATE OF COMPLIANCE

99+% (metals basis) Manganese Oxide Powder

MnO2

Product Code: MN-OX-021M-P.5UM

CAS #: 1313-13-9

LOT #: 1441516447-410

American Elements certifies that the materials listed below and shipped on 4/8/2021 meets the purity and dimensional requirements set forth in SMS Energetics, Inc. purchase order: DOT1-6265D.

99+% (metals basis) Manganese Oxide Powder
MnO2
APS: 5 um

AMERICAN ELEMENTS

By ____________

AEC FORM 102:CA REV. APP. 2/3/99

Figure D8: Product Certification for Bi_2O_3

Figure D9: Product Certification for SnO_2

SIGMA-ALDRICH

sigma-aldrich.com

3050 Spruce Street, Saint Louis, MO 63103, USA
Website: www.sigmaaldrich.com
Email USA: techserv@sial.com
Outside USA: eurtechserv@sial.com

Certificate of Analysis

Product Name:
Tin(IV) oxide - -325 mesh, 99.9% trace metals basis

SnO_2

Product Number:	**244651**
Batch Number:	**MKBX0592V**
Brand:	ALDRICH
CAS Number:	18282-10-5
MDL Number:	MFCD00011244
Formula:	O2Sn
Formula Weight:	150.71 g/mol
Quality Release Date:	16 DEC 2015

Test	Specification	Result
Appearance (Color) Off-White to Grey	Conforms to Requirements	Light Grey
Appearance (Form)	Powder	Powder
X-Ray Diffraction	Conforms to Structure	Conforms
Loss on Ignition 1 Hour at 1000 Degrees Celsius	≤ 0.5 %	0.1 %
ICP Major Analysis Confirms Tin Component	Confirmed	Conforms
Purity 99.9% Based On Trace Metals Analysis	Conforms	Conforms
Trace Metal Analysis	≤ 1000.0 ppm	579.0 ppm
Silver (Ag)		9.0 ppm
Aluminum (Al)		4.4 ppm
Arsenic (As)		4.5 ppm
Bismuth (Bi)		16.0 ppm
Calcium (Ca)		35.0 ppm
Chromium (Cr)		2.2 ppm
Copper (Cu)		15.0 ppm
Iron (Fe)		120.0 ppm
Potassium (K)		2.0 ppm
Magnesium (Mg)		24.0 ppm
Manganese (Mn)		0.7 ppm
Sodium (Na)		11.0 ppm
Nickel (Ni)		1.9 ppm
Lead (Pb)		79.0 ppm
Antimony (Sb)		250.0 ppm
Titanium (Ti)		2.0 ppm
Zinc (Zn)		2.2 ppm
Zirconium (Zr)		0.1 ppm

Michael Grady, Manager
Quality Control
Milwaukee, WI US

Figure D10: Product Certification for Mg Metal Powder

SIGMA-ALDRICH

3050 Spruce Street, Saint Louis, MO 63103 USA
Email USA: techserv@sial.com Outside USA: eurtechserv@sial.com

Certificate of Analysis

Product Name:	MAGNESIUM powder, >= 99 %
Product Number:	13112
Batch Number:	STBH6715
Brand:	Aldrich
CAS Number:	7439-95-4
Formula:	Mg
Formula Weight:	24.31
Quality Release Date:	09 JUL 2018
Recommended Retest Date:	DEC 2021

TEST	SPECIFICATION	RESULT
APPEARANCE (COLOR)	WHITE TO GREY	LIGHT GREY
APPEARANCE (FORM)	POWDER	POWDER
ASSAY	≥ 99 %	100.7 %
INSOLUBLE MATTER	≤ 0.05 % (INSOLUBLE IN HCL)	< 0.05 %
IRON	≤ 0.05 %	< 0.05 %

Claudia Mayer
Manager Quality Control
Steinheim, Germany

Figure D11: Product Certification for NiO

Sigma-Aldrich.

3050 Spruce Street, Saint Louis, MO 63103, USA
Website: www.sigmaaldrich.com
Email USA: techserv@sial.com
Outside USA: eurtechserv@sial.com

Certificate of Analysis

Product Name:
Nickel(II) oxide - green, -325 mesh, 99%

NiO

Product Number:	399523
Batch Number:	MKCN2758
Brand:	ALDRICH
CAS Number:	1313-99-1
MDL Number:	MFCD00011145
Formula:	NiO
Formula Weight:	74.69 g/mol
Quality Release Date:	11 DEC 2020

Test	Specification	Result
Appearance (Color)	Green to Very Dark Green and Green-Brown and Brown-Green	Green
Appearance (Form)	Powder	Powder
X-Ray Diffraction	Conforms to Structure	Conforms
Nickel	77.4 - 79.8 %	77.9 %
Particle Size -325 Mesh	Confirmed	Confirmed

Michael Grady, Manager
Quality Control
Milwaukee, WI US

Version Number: 1 Page 1 of 1

Figure D12: Product Certification for MoO_3

STANFORD ADVANCED MATERIALS

Stanford Advanced Materials
23661 Birtcher Dr. Lake Forest, CA 92630, USA
Tel: (949) 407-8904 Fax: (949) 812-6690

Certificate of Analysis

Product Name:	Molybdenum Trioxide (MoO3) Powder
Purity:	≥99.5%
Particle Size:	-325mesh
Lot Number:	OC210201-12629-1
Date:	2/1/21

Purity (wt%)	99.5
C (wt%)	0.05
H (wt%)	0.02
O (wt%)	0.01
N (wt%)	0.01
Mg (wt%)	0.01
Al (wt%)	0.01
Si (wt%)	0.02
Ca (wt%)	0.01
Ti (wt%)	0.01
Fe (wt%)	0.08
Ni (wt%)	0.01
Cu (wt%)	0.02
Sn (wt%)	0.01
W (wt%)	0.03
Pb (wt%)	0.01

Stanford Advanced Materials

TEST REPORT

Optimization of Base Thermite and Thermite-Additive Formulations

DOT Contract # 693JK320C000005

U.S. Department of Transportation
Pipeline and Hazardous Materials Safety Administration
(PHMSA)

Attention: PHH-20
Hazardous Materials Technology
1200 New Jersey Avenue, SE
E21-317
Washington, DC 20590

Troy A. Gardner, PE, CSP
Jackson D. Zarbock

September 13, 2023
SMS-6265k-R1, Rev 0

1847 West 9000 South, Suite 205 • West Jordan, Utah 84088 • 801-567-0456 • www.smsenergetics.com

Test Report

Optimization of Base Thermite and Thermite-Additive Formulations

September 13, 2023
SMS-6265k-R1, Rev 0

Troy A. Gardner, PE, CSP
Testing & Classifications Manager
Safety Management Services, Inc.

Jackson D. Zarbock
Project Engineer
Safety Management Services, Inc.

TABLE OF CONTENTS

TABLES

FIGURES

PHOTOS

1.0 STATEMENT OF WORK

DOT Contract # 693JK320C000005 with Safety Management Services, Inc. (SMS) of West Jordan, Utah defines that in conjunction with Tasks 11 - 14, SMS shall:

1) Reaction Optimization for Modified Al-Fe_2O_3 Thermite: Perform mixing (50 grams each) and Hotwire Explosion Screening tests for variations of Fine Al-Fe_2O_3 Thermite – Large-Scale Mix ID #1 (SMS mixed), modified with the stoichiometric substitution of magnalium (5 - 50% Mg, 50 - 95% Al) for aluminum, in six ±5% incremental changes.
2) Reaction Optimization for Modified Al-CuO Thermite: Perform mixing (50 grams each) and Hotwire Explosion Screening tests for variations of Fine Al-CuO Thermite – Large-Scale Mix ID #4 (SMS mixed), modified with the stoichiometric substitution of magnalium (5 - 50% Mg, 50 - 95% Al) for aluminum, in six ±5% incremental changes.
3) Effect of Additives upon Optimized MgAl-Fe_2O_3 Thermite: Perform mixing (800 grams each) and testing (sensitivity, one Large-scale UN Test N.1 screening trial, Bursting Tube Ranking Test) for an optimized Fine MgAl-Fe_2O_3 Thermite – Modified Large-Scale Mix ID #1 (SMS mixed), substituting three +10% incremental substitutions of four additives (as approved by PHMSA) for the metal oxide and/or metal powder.
4) Effect of Additives upon Optimized MgAl-CuO Thermite: Perform mixing (800 grams each) and testing (sensitivity, one Large-scale UN Test N.1 screening trial, Internal Ignition Ranking Test) for an optimized Fine MgAl-CuO Thermite – Modified Large-Scale Mix ID #4 (SMS mixed), substituting three +10% incremental substitutions of four additives (as approved by PHMSA) for the metal oxide and/or metal powder.
5) Provide the COR with a test report and video(s).

2.0 SUMMARY AND CONCLUSION

Magnalium alloy powder (50/50 magnesium/aluminum by weight) was substituted for aluminum powder in Fine Al-Fe_2O_3 Thermite – Large-Scale Mix ID #1 (SMS mixed) and Fine Al-CuO Thermite – Large-Scale Mix ID #4 (SMS mixed). The stoichiometric mixtures were calculated to be:

- Modified Large-Scale Mix ID #1: 27.98% magnalium and 72.02% Fe_2O_3, and
- Modified Large-Scale Mix ID #4: 20.63% magnalium and 79.37% CuO.

The modified thermite was mixed with six ±5% incremental changes to the baseline formulation; two 25-gram Hotwire Explosion Screening tests were performed on each mixture to determine which mixture had the quickest reaction. The original Large-Scale Mix ID #1 (Al-Fe_2O_3) had a burn time of 0.5 seconds in the large-scale N.1 Test; the optimized Large-Scale Mix ID #1-6 (38.0% MgAl, 62.0% Fe_2O_3) had a burn time of 0.6 seconds for a 25-gram pile (i.e., substitution of magnalium for aluminum appears to have slowed the thermite reaction).

In contrast, the original Large-Scale Mix ID #4 (Al-CuO) had a burn time of 2.1 seconds in the large-scale N.1 Test; 25-gram piles of optimized Large-Scale Mix ID #4-3 (15.6% MgAl, 84.4% CuO) through #4-7 (35.6% MgAl, 64.4% CuO) exploded upon ignition (variation in reaction violence between exploding samples was minor). Therefore, substitution of magnalium for aluminum dramatically increased the thermite reaction rate. Large-Scale Mix ID #4-5 (25.6% MgAl, 74.4% CuO) was selected as the optimized formulation.

The following thermite additives were selected:

- Additive A: Polytetrafluoroethylene (PTFE) or Teflon™ powder
- Additive B: Molybdenum trioxide (MoO_3) powder
- Additive C: Sodium nitrate ($NaNO_3$) powder
- Additive D: Calcium peroxide (CaO_2) powder

Thermite mixes were prepared with each of these additives substituting the metal oxide in 10%, 20%, and 30% by weight of the of the total mix. Thermite-additive formulations were identified by the additive (A, B, C, or D) and the percentage of the total mix it represented (10, 20 or 30). The thermite mixes were then subjected to the following tests in order to rank them by sensitivity and reactivity:

- MBOM Impact Sensitivity Test using the Bruceton Method
- ABL Friction Sensitivity Test using the Bruceton Method
- ABL ESD Sensitivity Test using the Bruceton Method
- Large-scale N.1 Flammable Solids Test
- Sasser-Koenen Ignition Burst Ranking Test

Results from the sensitivity tests are summarized in Table 1. In general, additives made the thermite formulations more sensitive to impact stimulus; mixes containing sodium nitrate had a marked increase in sensitivity in both base thermites for all quantities of sodium nitrate, with the 20% sodium nitrate formulations being most sensitive. Friction sensitivity increased for all thermite-additive formulations as additives were increased; the average H_{50} values for 10%, 20%, and 30% additive thermite formulations were 644.7, 526.4, and 410.8 lb_f, respectively.

Table 1: Bruceton H_{50} and Standard Deviations for Sensitivity Testing

Mix ID	Additive	Additive Content (wt%)	MBOM Impact (cm)		ABL Friction (lb_f)		ABL ESD (J)	
			H_{50}	σ	H_{50}	σ	H_{50}	σ
1-6	PTFE	10	>100	n/a	393.4	1.41	0.013	4.00E-06
1-6	PTFE	20	94.2	1.50	211.0	1.28	0.013	5.00E-06
1-6	PTFE	30	26.1	10.20	235.9	1.31	0.384	4.00E-06
4-5	PTFE	10	>100	n/a	287.6	1.18	0.038	2.00E-06
4-5	PTFE	20	>100	n/a	177.4	2.26	0.400	5.00E-06
4-5	PTFE	30	13.5	1.70	175.8	1.25	0.050	6.00E-06
1-6	MoO_3	10	>100	n/a	623.1	1.33	0.084	1.10E-05
1-6	MoO_3	20	>100	n/a	845.8	1.19	0.059	5.00E-06
1-6	MoO_3	30	>100	n/a	494.9	1.30	0.072	5.00E-06

Mix ID	Additive	Additive Content (wt%)	MBOM Impact (cm)		ABL Friction (lb_f)		ABL ESD (J)	
			H_{50}	σ	H_{50}	σ	H_{50}	σ
4-5	MoO_3	10	>100	n/a	>1000	N/A	0.058	3.00E-06
4-5	MoO_3	20	>100	n/a	370.1	1.22	0.039	4.00E-06
4-5	MoO_3	30	>100	n/a	308.1	1.74	0.027	6.00E-06
1-6	$NaNO_3$	10	42.9	66.60	635.2	2.33	0.021	3.00E-06
1-6	$NaNO_3$	20	26.5	1.80	808.1	1.12	0.013	8.00E-06
1-6	$NaNO_3$	30	32.2	1.70	643.3	1.42	0.020	7.00E-06
4-5	$NaNO_3$	10	52.6	2.00	963.2	1.38	0.140	7.00E-06
4-5	$NaNO_3$	20	30.5	5.70	813.4	1.11	0.054	1.00E-05
4-5	$NaNO_3$	30	40.0	7.40	762.9	1.27	0.091	4.00E-06
1-6	CaO_2	10	>100	n/a	855.2	1.10	0.014	7.00E-06
1-6	CaO_2	20	>100	n/a	555.7	1.46	0.012	2.10E-05
1-6	CaO_2	30	>100	n/a	416.8	1.51	0.015	1.10E-05
4-5	CaO_2	10	>100	n/a	399.8	1.56	0.054	1.60E-05
4-5	CaO_2	20	>100	n/a	429.5	6.40	0.049	1.10E-05
4-5	CaO_2	30	>100	n/a	248.3	1.70	0.045	1.30E-05

All formulations passed the Ignition Burst Ranking Test at the smallest 2.5mm orifice size with no significant damage to the steel Koenen tube. This result is very unique, illustrating that even as these thermites with additives explode, they are not exploding with the same power as other explosives, propellants and pyrotechnics. However, the following formulations exhibited faster burn rates or audible "wooshes", indicating more energetic reactions:

- LS #1-6-A30
- LS #4-5-A10
- LS #4-5-A20
- LS #4-5-A30
- LS #4-5-C20
- LS #4-5-C30
- LS #4-5-D30

The Large-scale UN Test N.1 Flammable Solids test was performed on each of the thermites with additives, as summarized in Table 2.

Table 2: Analysis of the Large-Scale N.1 Flammable Solids Test Results

Additive	LS #1-6 Test Results	LS #4-5 Test Results
PTFE	Burn rate increased from baseline and increased with more additive. Burn pressure decreased from baseline but did not change with more additive.	Burn rate decreased from baseline and decreased further with more additive. Burn pressure decreased from baseline but did not change with more additive.

Additive	LS #1-6 Test Results	LS #4-5 Test Results
MoO_3	Burn rate decreased from baseline but increase with more additive. Burn pressure decrease slightly from baseline and did not change with more additive.	Burn rate did not change from baseline and did not change with more additive. Blast pressure increased from baseline but did not change with more additive.
$NaNO_3$	Burn rate decreased from baseline but increased with more additive. Burn pressure increased with more additive.	Burn rate did not change from baseline and did not change with more additive. Blast pressure increased from baseline but did not change with more additive. Burn pressure decreased with more additive.
CaO_2	Burn rate increased with more additive. Burn pressure did not change with more additive.	Burn rate decreased from baseline and decreased with more additive. Blast pressure increased from baseline but did not change with more additive.

Based on these results, the six thermite-additive formulations listed in Table 3 were selected to undergo UN Series 1 and 2 and UN Series 6 (a) Single Package Testing.

Table 3: Thermite-Additive Formulations Selected for Task 15

Sample ID	Composition (wt%)				Additive Type
	MgAl	Fe_2O_3	CuO	Additive	
LS #1-6-A30	38%	32%	-	30%	PTFE
LS #1-6-C30	38%	32%	-	30%	$NaNO_3$
LS #4-5-A10	25%	-	65%	10%	PTFE
LS #4-5-A30	25%	-	45%	30%	PTFE
LS #4-5-C30	25%	-	45%	30%	$NaNO_3$
LS #4-5-D30	25%	-	45%	30%	CaO_2

Two of these six thermites, LS #1-6-A30 and LS #4-5-C30, were selected for full UN Series 6 (c) External fire (bonfire) tests.

3.0 ACKNOWLEDGEMENTS

The mixing of all thermites was performed by Derek M. Sutton. Testing was performed by Troy A. Gardner, Jason T. Ford, Collin L. Boren, and Jackson D. Zarbock.

4.0 BACKGROUND

Historically, industry has offered traditional thermite formulations (containing only metal and metal oxides) for transport in Class 4 as flammable or water-reactive solids. The reaction produces a burst of heat, high temperature, and molten metal for various uses including joining steel railroad ties or copper transmission lines, metal refining, disabling munitions, etc. Traditional thermite formulations pass the UN Manual of Tests and Criteria, Appendix 6 "Screening Procedures" for substances which may have explosive properties as they do not contain any of the chemical groups listed in Table A6.1 that are associated with explosive properties. NOTE: The Appendix 6 Screening Procedures cannot be used for substances manufactured with the view to producing a practical explosive or pyrotechnic effect.

Newer "exotic" thermite formulations include those with additives such as plastics, oxidizers, nano materials, explosives, etc. to confer special compositions or actions upon use. Additional research into the effect of additives was needed to identify families of new and existing thermite compositions and to determine their hazards in transport.

5.0 DESCRIPTION OF BASE THERMITE FORMULATIONS

5.1 Replacement of Aluminum (Al) with Magnalium (MgAl)

Two thermite formulations were selected for this study to determine the effect of thermite additives:

- Fine Al-Fe_2O_3 – Large-scale Mix ID #1 (LS #1)
- Fine Al-CuO – Large-scale Mix ID #4 (LS #4)

These thermites were selected because they represent the most common thermites utilized in the thermite industry; each of these thermites exhibited very energetic but not explosive reactions during UN Series 6 Testing and the Hotwire Explosion Screening Test.

To increase the reaction potential, the aluminum powder in the base thermite formulations was replaced with magnalium powder, a 50/50 by weight alloy of magnesium and aluminum (52.6% moles of magnesium and 47.4% moles of aluminum), 99% pure, and 1 - 5 micrometers (microns) in size. Because the constituents of the base thermite formulation were altered, the metal-to-metal-oxide ratios used in the original formulations no longer represented a stoichiometric mixture. As such, the stoichiometric ratio of magnalium to metal oxide was recalculated. The stoichiometric (molar) reaction for modified Large-Scale Mix #1 is:

$$1\,MgAl + 0.\ 412\,Fe_2O_3 \rightarrow 0.526\,MgO + 0.237\,Al_2O_3 + 0.824\,Fe \qquad (1)$$

The stoichiometric (molar) reaction for modified Large-Scale Mix #4 is:

$$1\,MgAl + 1.237\,CuO \rightarrow 0.526\,MgO + 0.237\,Al_2O_3 + 1.24\,Cu \qquad (1)$$

Based on these calculations, the thermite formulations were modified to that shown in Table 4.

Table 4: Modified Large-Scale Thermite Formulations

Thermite	Metal (wt%)	Metal Oxide (wt%)
Modified Large-Scale Mix ID #1 – MgAl-Fe_2O_3	27.98	72.02
Modified Large-Scale Mix ID #4 – MgAl-CuO	20.63	79.37

Descriptions of the base thermite formulations are provided in the following sections.

5.2 Fine MgAl-Fe_2O_3 Thermite – Modified Large-Scale Mix ID #1 (SMS mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 27.98% magnalium (50/50 wt% magnesium/aluminum alloy) and 72.02% ferric oxide (Fe_2O_3). The magnalium was 1 - 5 micrometers (microns) in size. The ferric oxide was 2N purity (99% pure), 1 - 5 microns in size, and offered for transport as non-regulated. This thermite was a fine, red powder when fully mixed.

Photo 1: Fine MgAl-Fe_2O_3 Thermite – Modified Large-Scale Mix ID #1 (SMS mixed)

5.3 Fine MgAl-CuO Thermite – Modified Large-Scale Mix ID #4 (SMS mixed)

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 20.63% magnalium (50/50 wt% magnesium/aluminum alloy) and 79.37% copper (II)/cupric oxide (CuO). The magnalium was 1 - 5 micrometers (microns) in size. The cupric oxide was 3N purity (99.9% pure), 1 - 5 microns in size, and offered for transport as Class 9. This thermite was a very fine, dark gray powder when fully mixed.

Photo 2: Fine MgAl-CuO Thermite – Modified Large-Scale Mix ID #4 (SMS mixed)

6.0 OPTIMIZATION OF BASE THERMITE FORMULATION

Once the stoichiometric recipe for each thermite was determined, the quantities of metal and metal oxide were then varied in five-percent increments, from 15% fuel-poor to 15% fuel-rich. The recipes of the base thermite prepared for optimization testing are given in Table 5.

Table 5: Base Thermite Optimization Recipes

Mix ID	Metal Variation (%)	Metal Oxide Variation (%)	Metal Weight (%)	Metal Type	Metal Oxide Weight (%)	Metal Oxide Type
1-1	-15%	+15%	13.0	MgAl	87.0	Fe_2O_3
1-2	-10%	+10%	18.0	MgAl	82.0	Fe_2O_3
1-3	-5%	+5%	23.0	MgAl	77.0	Fe_2O_3
1-4	0%	0%	28.0	MgAl	72.0	Fe_2O_3
1-5	+5%	-5%	33.0	MgAl	67.0	Fe_2O_3
1-6	+10%	-10%	38.0	MgAl	62.0	Fe_2O_3
1-7	+15%	-15%	43.0	MgAl	57.0	Fe_2O_3
4-1	-15%	+15%	5.6	MgAl	94.4	CuO
4-2	-10%	+10%	10.6	MgAl	89.4	CuO
4-3	-5%	+5%	15.6	MgAl	84.4	CuO

Mix ID	Metal Variation (%)	Metal Oxide Variation (%)	Metal Weight (%)	Metal Type	Metal Oxide Weight (%)	Metal Oxide Type
4-4	0%	0%	20.6	MgAl	79.4	CuO
4-5	+5%	-5%	25.6	MgAl	74.4	CuO
4-6	+10%	-10%	30.6	MgAl	69.4	CuO
4-7	+15%	-15%	35.6	MgAl	64.4	CuO

7.0 BASE THERMITE OPTIMIZATION TESTING

7.1 Hotwire Explosion Screening Test

7.1.1 Test Description

The base thermite recipes were tested to determine which metal-to-metal-oxide ratio yielded the most energetic reaction. To assess reaction violence, each thermite was subjected to the Hotwire Explosion Screening Test. This test was performed to ignite the thermite using a high temperature to assess burn rate and reaction violence. A 105-mm long, 18-gauge 80/20 nickel/chromium (ni-chrome) resistance heating wire (Type A) was attached to electrodes suspended just above an insulating clay-based firebrick. A 25-gram test sample was poured over the heating wire. The test setup is shown in Photo 3.

Photo 3: Hotwire Explosion Test Setup – Typical

The resistance heating wire could achieve a maximum test temperature of 1200°C. All thermite samples were tested at 10 volts and 21 amps. The test was conducted for two minutes or until the reaction was determined to be complete (i.e., sample was consumed, or reaction has stopped). High-speed video and HD video were used to record each reaction and determined burn rate. Burn rates were assessed from the time of first ignition to when the sample was consumed.

7.2 Test Results

Two 25-gram trials for each base thermite mix were completed. The burn rate and reaction assessment are listed in Table 6. Videos of each reaction are provided as SMS-6265k-V1.

Table 6: Hotwire Explosion Screening Test Results

Mix ID	Composition (wt%)			Burn Time (s)		Reaction Assessment
	MgAl	Fe_2O_3	CuO	Trial 1	Trial 2	
1-1	13.0	87.0	-	>60	>60	Thermite not consumed.
1-2	18.0	82.0	-	>60	>60	Thermite not consumed.
1-3	23.0	77.0	-	2.44	3.6	Sample burned rapidly.
1-4	28.0	72.0	-	1.64	1.48	Fast reaction, sample deflagrated.
1-5	33.0	67.0	-	1.04	0.96	Fast reaction, sample deflagrated.
1-6	38.0	62.0	-	0.68	0.6	Fast reaction, sample deflagrated.
1-7	43.0	57.0	-	0.84	0.96	Sample burned rapidly.
4-1	5.6	-	94.4	>60	>60	No reaction observed.
4-2	10.6	-	89.4	39.6	33.5	Thermite slowly consumed.
4-3	15.6	-	84.4	0.2	0.2	Sample exploded.
4-4	20.6	-	79.4	0.12	0.16	Sample exploded.
4-5	25.6	-	74.4	0.12	0.16	Sample exploded.
4-6	30.6	-	69.4	0.12	0.12	Sample exploded.
4-7	35.6	-	64.4	0.12	0.12	Sample exploded.

Based on the burn time and reaction violence results, it was determined that LS #1-6 was the optimized formulation for modified Large-scale Mix ID #1 MgAl-Fe_2O_3. For modified Large-scale Mix ID #4 MgAl-CuO, mixes 4-3 through 4-7 exploded for both trials. Differences in reaction violence and burn rate were very small. However, it was determined that LS #4-5 was consumed slightly faster than the other exploding mixes. NOTE: LS #4-5 is closely related to the exploding thermite formulation Large-scale Mix ID #8 – MgAl-MoO_3-CuO, missing only molybdenum trioxide (MoO_3).

8.0 SELECTION OF THERMITE ADDITIVES

Once the base thermite formulation was selected, four additives were selected based on their potential to be found in industry as ingredients in energetic mixtures and for the potential change they could have on the reactivity of the base thermite formulation. Additives with purities and particle sizes similar to the base thermite ingredients were found and purchased. The four additives selected for testing, the rationale for their selection, and their product specifications are listed in Table 7.

Table 7: Selected Additives and Rationale for Selection

ID	Additive	Rationale	Specification
A	Polytetrafluoroethylene (PTFE) or Teflon™	Common ingredient in pyrotechnics, flares and thermite mixtures.	Fine white powder, 6 - 9 micrometers (microns) particle size, high purity
B	Molybdenum trioxide (MoO_3)	Common metal oxide in other explosive thermite mixtures.	Fine off-white powder, 325 mesh (44 microns), 99.5% purity
C	Sodium nitrate ($NaNO_3$)	Weak nitrate (slower acting than other nitrates like potassium or barium); common ingredient in reactive mixtures.	Fine white powder, 98.5% purity, approximately 50 microns
D	Calcium peroxide (CaO_2)	Common oxidizer in various pyrotechnic mixtures.	Fine white powder, 81% purity, approximately 50 microns

Additives were introduced into the optimized base thermite recipes, replacing the metal oxide in 10% increments by weight from 10% to 30%. The recipes for each thermite-additive formulation are given in Table 8.

Table 8: Thermite-Additive Recipes

Mix ID	Additive	Quantity (wt%)			Additive Mix ID
		Metal	Metal Oxide	Additive	
1-6	A: PTFE	38%	52%	10%	LS #1-6-A10
1-6	A: PTFE	38%	42%	20%	LS #1-6-A20
1-6	A: PTFE	38%	32%	30%	LS #1-6-A30
4-5	A: PTFE	25%	65%	10%	LS #4-5-A10
4-5	A: PTFE	25%	55%	20%	LS #4-5-A20
4-5	A: PTFE	25%	45%	30%	LS #4-5-A30
1-6	B: MoO_3	38%	52%	10%	LS #1-6-B10
1-6	B: MoO_3	38%	42%	20%	LS #1-6-B20
1-6	B: MoO_3	38%	32%	30%	LS #1-6-B30
4-5	B: MoO_3	25%	65%	10%	LS #4-5-B10
4-5	B: MoO_3	25%	55%	20%	LS #4-5-B20

Mix ID	Additive	Quantity (wt%)			Additive Mix ID
		Metal	Metal Oxide	Additive	
4-5	B: MoO_3	25%	45%	30%	LS #4-5-B30
1-6	C: $NaNO_3$	38%	52%	10%	LS #1-6-C10
1-6	C: $NaNO_3$	38%	42%	20%	LS #1-6-C20
1-6	C: $NaNO_3$	38%	32%	30%	LS #1-6-C30
4-5	C: $NaNO_3$	25%	65%	10%	LS #4-5-C10
4-5	C: $NaNO_3$	25%	55%	20%	LS #4-5-C20
4-5	C: $NaNO_3$	25%	45%	30%	LS #4-5-C30
1-6	D: CaO_2	38%	52%	10%	LS #1-6-D10
1-6	D: CaO_2	38%	42%	20%	LS #1-6-D20
1-6	D: CaO_2	38%	32%	30%	LS #1-6-D30
4-5	D: CaO_2	25%	65%	10%	LS #4-5-D10
4-5	D: CaO_2	25%	55%	20%	LS #4-5-D20
4-5	D: CaO_2	25%	45%	30%	LS #4-5-D30

9.0 THERMITE-ADDITIVE OPTIMIZATION SENSITIVITY TESTING

Once the thermite-additive formulations were mixed, they were subjected to impact, friction, and ESD sensitivity testing to 1) determine whether the formulations were too sensitive for personnel to safely handle, and 2) determine the effect of the additive on the sensitivity of the substance. The following sensitivity tests were performed:

- MBOM Impact Sensitivity Test
- ABL Friction Sensitivity Test
- ABL ESD Sensitivity Test

9.1 Bruceton Method

The Bruceton "Up Down" Method was used to provide a relative ranking system between thermite formulations. Five exploratory trials are performed to establish a starting energy level in the relative middle of the at which half of trials will result in initiation. Once an initial energy level is established, a 25-trial "Up Down" Method is employed starting at the initial energy level. If a trial results in a "go", then the next trial is conducted at the next lower level. If a trial results in a "no go", the next trial is conducted at the next highest level. The fifty percent point is calculated in accordance with documented Bruceton methodology detailed in AOP-7 and MIL-STD-1751A.

9.2 MBOM Impact Sensitivity Test

9.2.1 Test Description

MBOM Impact tests are used to determine the response of an energetic material when it is impacted by a moving mass. This test simulates potential impact conditions in processing operations, wherein an energetic material is subjected to a collision between moving components of the processing equipment or inadvertent dropping of tools or equipment.

The Modified Bureau of Mines (MBOM) Test, shown in Figure 1, uses a 2-kg drop weight. The sample is placed on the impact anvil. The impact insert is positioned above the sample and the drop weight is raised to a predetermined height, between 1 and 100 cm, and dropped. Sample initiation is detected by audible or visual means.

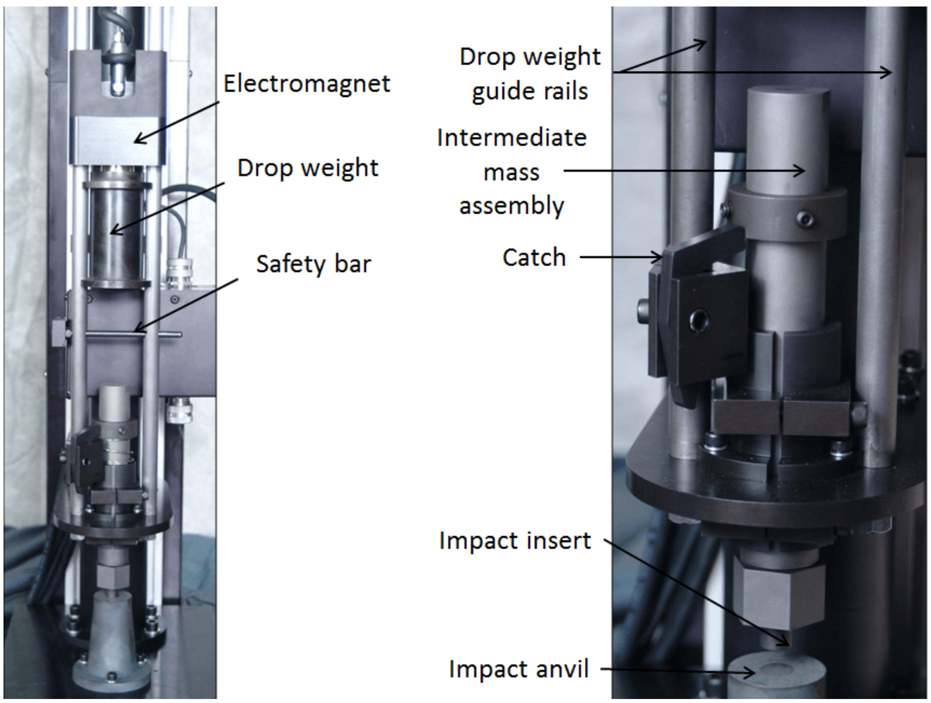


Figure 1: MBOM Impact Test Apparatus

9.2.2 Test Results

Impact sensitivity testing was complete on all thermite-additive formulations. Test results are summarized in Table 9. Raw data sheets and Bruceton calculations are given in the appendix.

Table 9: Summary of Impact Sensitivity Bruceton H_{50} Calculations

Large-Scale Thermite	Additive	Additive Content (wt%)	MBOM Impact (cm)	
			H_{50}	σ
1-6	PTFE	10	>100	N/A
1-6	PTFE	20	94.2	1.50
1-6	PTFE	30	26.1	10.20

Large-Scale Thermite	Additive	Additive Content (wt%)	MBOM Impact (cm)	
			H_{50}	σ
4-5	PTFE	10	>100	N/A
4-5	PTFE	20	>100	N/A
4-5	PTFE	30	13.5	1.70
1-6	MoO_3	10	>100	N/A
1-6	MoO_3	20	>100	N/A
1-6	MoO_3	30	>100	N/A
4-5	MoO_3	10	>100	N/A
4-5	MoO_3	20	>100	N/A
4-5	MoO_3	30	>100	N/A
1-6	$NaNO_3$	10	42.9	66.60
1-6	$NaNO_3$	20	26.5	1.80
1-6	$NaNO_3$	30	32.2	1.70
4-5	$NaNO_3$	10	52.6	2.00
4-5	$NaNO_3$	20	30.5	5.70
4-5	$NaNO_3$	30	40.0	7.40
1-6	CaO_2	10	>100	N/A
1-6	CaO_2	20	>100	N/A
1-6	CaO_2	30	>100	N/A
4-5	CaO_2	10	>100	N/A
4-5	CaO_2	20	>100	N/A
4-5	CaO_2	30	>100	N/A

For the formulations with molybdenum trioxide and calcium peroxide additives, impact sensitivity was not affected by any increase in additives for either base thermite formulation, with all Bruceton H_{50} calculations begin above 100 cm. The thermite formulations with PTFE powder saw no change in sensitivity at 10% or 20% additive PTFE, but a marked increase in sensitivity when the at 30% PTFE for both base thermites. Mixes containing sodium nitrate had a marked increase in sensitivity in both base thermites for all quantities of sodium nitrate, with the 20% sodium nitrate formulations being most sensitive. In general, additives made the thermite formulations more sensitive to impact stimulus.

9.3 ABL Friction Sensitivity Test

9.3.1 Test Description

Friction sensitivity tests determine the response of an energetic material sample when subjected to frictional forces at a given velocity. This test simulates friction conditions, which may occur in a process when an energetic material is subjected to a frictional force between moving components or during material handling.

In the ABL Friction Test, shown in Figure 2, the sample is placed on the friction anvil. The stationary friction wheel is lowered on the sample and a known force is applied hydraulically. A pendulum or motor drive is used to propel the sliding anvil at any of several standard velocities perpendicular to the downward force from the load. Sample initiation is detected by audible or visual means.

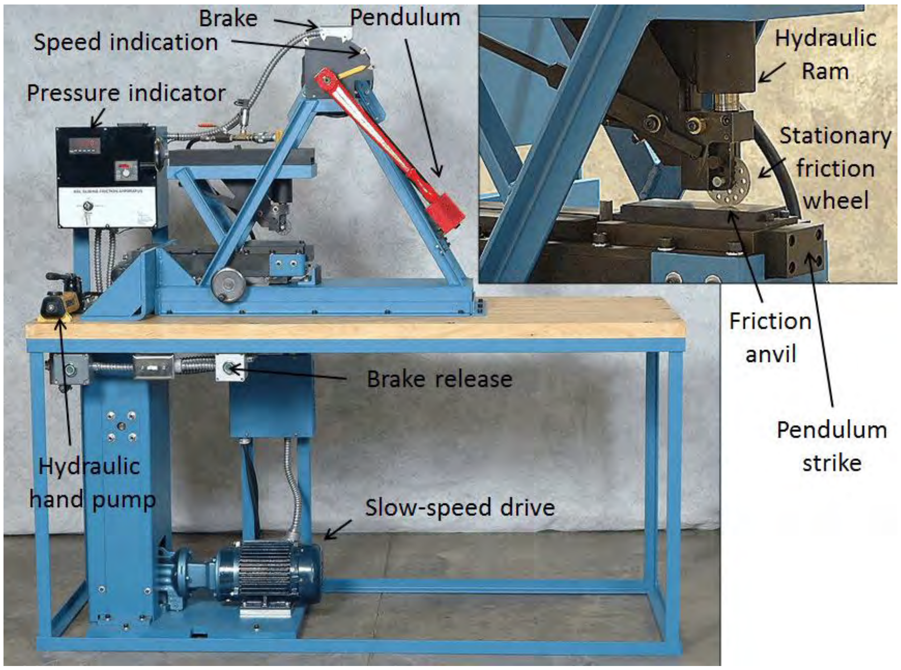


Figure 2: ABL Friction Test Apparatus

9.3.2 Test Results

Friction sensitivity testing was complete on all thermite-additive formulations. Test results are summarized in Table 10. Raw data sheets and Bruceton calculations are given in the appendix.

Table 10: Summary of Friction Sensitivity Bruceton H_{50} Calculations

Large-Scale Thermite	Additive	Additive Content (wt%)	ABL Friction (lb_f)	
			H50	σ
1-6	PTFE	10	393.4	1.41
1-6	PTFE	20	211.0	1.28
1-6	PTFE	30	235.9	1.31
4-5	PTFE	10	287.6	1.18
4-5	PTFE	20	177.4	2.26
4-5	PTFE	30	175.8	1.25

Large-Scale Thermite	Additive	Additive Content (wt%)	ABL Friction (lb_f)	
			H50	σ
1-6	MoO_3	10	623.1	1.33
1-6	MoO_3	20	845.8	1.19
1-6	MoO_3	30	494.9	1.30
4-5	MoO_3	10	>1000	N/A
4-5	MoO_3	20	370.1	1.22
4-5	MoO_3	30	308.1	1.74
1-6	$NaNO_3$	10	635.2	2.33
1-6	$NaNO_3$	20	808.1	1.12
1-6	$NaNO_3$	30	643.3	1.42
4-5	$NaNO_3$	10	963.2	1.38
4-5	$NaNO_3$	20	813.4	1.11
4-5	$NaNO_3$	30	762.9	1.27
1-6	CaO_2	10	855.2	1.10
1-6	CaO_2	20	555.7	1.46
1-6	CaO_2	30	416.8	1.51
4-5	CaO_2	10	399.8	1.56
4-5	CaO_2	20	429.5	6.40
4-5	CaO_2	30	248.3	1.70

In general, friction sensitivity increased for all thermite-additive formulations as additives were increased. The average H_{50} values for 10%, 20%, and 30% additive thermite formulations were 644.7, 526.4, and 410.8 lb_f, respectively.

9.4 ABL Electrostatic Discharge Sensitivity Test

9.4.1 Test Description

ESD testing is used to determine the response of an energetic material when subjected to various levels of electrostatic discharge energy. Electrostatic energy stored in a charged capacitor is discharged to the test sample. The ABL ESD Test Apparatus is shown in Figure 3. The sample is placed on a specialized electrode which assures the electrostatic discharge will pass through the sample. A capacitor is charged with a known volt potential (usually 5000 volts). The discharge needle is lowered until a spark is drawn through the sample. The approaching needle method is most commonly used because it best models the safety issues involved with ESD sensitivity. Sample initiation is detected by audible or visual means.

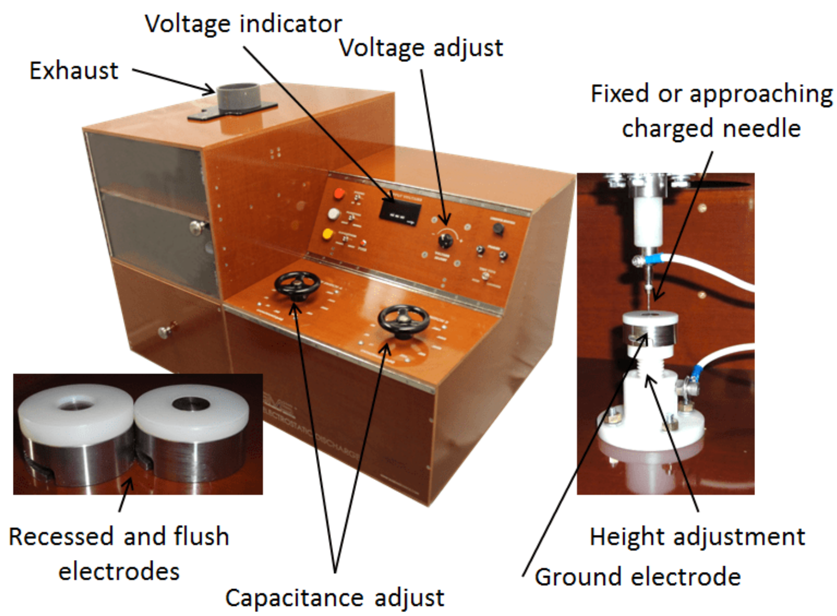


Figure 3: ABL ESD Test Apparatus

9.4.2 Test Results

ABL ESD testing was conducted on all thermite-additive formulations. The results are summarized in Table 11. Raw data sheets and Bruceton calculations are given in the appendix.

Table 11: Summary of ESD Sensitivity Bruceton H_{50} Calculations

Large-Scale Thermite	Additive	Additive Content (wt%)	ABL ESD (J)	
			H50	σ
1-6	PTFE	10	0.013	4.00E-06
1-6	PTFE	20	0.013	5.00E-06
1-6	PTFE	30	0.384	4.00E-06
4-5	PTFE	10	0.038	2.00E-06
4-5	PTFE	20	0.400	5.00E-06
4-5	PTFE	30	0.050	6.00E-06
1-6	MoO_3	10	0.084	1.10E-05
1-6	MoO_3	20	0.059	5.00E-06
1-6	MoO_3	30	0.072	5.00E-06
4-5	MoO_3	10	0.058	3.00E-06
4-5	MoO_3	20	0.039	4.00E-06
4-5	MoO_3	30	0.027	6.00E-06
1-6	$NaNO_3$	10	0.021	3.00E-06

Large-Scale Thermite	Additive	Additive Content (wt%)	ABL ESD (J)	
			H50	σ
1-6	$NaNO_3$	20	0.013	8.00E-06
1-6	$NaNO_3$	30	0.020	7.00E-06
4-5	$NaNO_3$	10	0.140	7.00E-06
4-5	$NaNO_3$	20	0.054	1.00E-05
4-5	$NaNO_3$	30	0.091	4.00E-06
1-6	CaO_2	10	0.014	7.00E-06
1-6	CaO_2	20	0.012	2.10E-05
1-6	CaO_2	30	0.015	1.10E-05
4-5	CaO_2	10	0.054	1.60E-05
4-5	CaO_2	20	0.049	1.10E-05
4-5	CaO_2	30	0.045	1.30E-05

Based on these results, significant fluctuations in sensitivity were seen for thermite with PTFE, with no distinct pattern detectable. Increasing amounts of molybdenum trioxide resulted in more ESD sensitivity. Additional sodium nitrate in LS #1-6 resulted in higher ESD sensitivity. The presence of additional sodium nitrate in thermite #4-5 did not affect ESD sensitivity. The presence of additional calcium peroxide did not affect ESD sensitivity.

10.0 THERMITE-ADDITIVE OPTIMIZATION REACTIVITY TESTING

Once sensitivity testing was complete and all mixes were deemed safe to handle, reactivity tests were conducted to determine the effect of additional additives on the reactivity of thermites. The Ignition Burst Ranking Test and the Large-Scale N.1 Flammable Solids Test were conducted in order to rank thermite-additive formulations based on their reactivity.

10.1 Bursting Tube Ranking Test

10.1.1 Test Description

The test is a modified UN Koenen Test. The test method uses the same tube, collar, and orifice plates as the UN Koenen Test. If samples are to be ranked by their limiting orifice diameters, a 5-gram sample of a substance is placed in a Koenen tube. No tamping is performed on the sample. The tube is placed inside a Koenen collar. An orifice plate is selected and placed on the tube. Standard orifice diameters are 5, 8, 10, 12, 15, 18, 20, and 22 mm. The nut is then screwed over the top of the orifice plate. The assembled test tube is placed in a protective fixture to catch any fragmentation. An electric match is placed through the orifice plate and into the material. See Figure 4 for the full test set up.

Figure 4: The Bursting Tube Ranking Test Setup

The overall concept for this test is that substances that are more energetic and have burn rates that are relatively fast will require orifices that are much larger to vent combustion gases than substances that have slower burn rates. If the venting or orifice hole is sufficiently large, then the material will burn within the Koenen tube and vent out the specified orifice hole. If the venting or orifice hole is insufficient, then the Koenen tube will rupture (fragment or burst). The confined powder ignites, burns, and bursts the shell open depending on its burn rate. Test trials are performed in an iterative fashion. An orifice size is selected, and the sample is tested. If the material ruptures the tube, a larger orifice size is selected. If the material does not rupture the tube, a smaller orifice size is selected.

Test trials are conducted until the limiting orifice diameter is determined. The limiting orifice diameter is the largest orifice size at which the Koenen tube is ruptured, with three trials resulting in no-gos at the next largest orifice size. For example, if a substance ruptured the Koenen tube at an orifice size of 15 mm but did not rupture the tube with an 18 mm orifice after three trials, the limiting orifice size for that substance is 15mm. Energetic powders can be ranked and compared based on their limiting orifice diameters.

10.1.2 Test Results

Testing was completed on all thermite-additive formulations. Additionally, testing was also performed on LS #1-6, LS #4-5, and exploding thermite SS #48 to provide a baseline to compare the thermite-additive test results against. All thermites tested, including the LS #1-6, LS #4-5, and SS #48 had passing results for three trials at an orifice diameter of 2.5mm. This indicates that additional confinement of thermite-additive formulations results in less energetic reactions. This is consistent with non-additive thermite behavior.

The baseline thermites were also tested at 20 mm, with LS #4-5 and SS #48 exhibiting faster reactions at the larger orifice size. Several thermite-additive formulations exhibited notably faster reaction behavior than other trials, producing an audible “whoosh”, or being consumed much faster than other formulations. These faster reacting formulations were the following:

- LS #1-6-A30
- LS #4-5-A10
- LS #4-5-A20
- LS #4-5-A30
- LS #4-5-C20
- LS #4-5-C30
- LS #4-5-D30

This reaction violence was observed visually and audibly.

10.1.3 Conclusions

While the Bursting Tube Ranking Test is effective at discerning between the relative quickness and bursting power of various explosives, propellants and pyrotechnics, each of the thermites passed the test at the smallest orifice size (unusual test result in comparison to other pyrotechnics and propellants), illustrating that even as these thermites with additives explode, they are not exploding with the same power as other explosives, propellants and pyrotechnics.

10.2 Large-scale N.1 Flammable Solids Test

10.2.1 Test Description

The Large-scale UN Test N.1 is used to determine the ability of a bulk substance to propagate combustion. The test may be performed with a powdered or granular substance. The substance is formed into an unbroken strip or powder train approximately 250 mm long by 80 mm wide by 10 mm high on a high-temperature ceramic fiber board that was 16 inches long, 5 7/8 inches wide, and 0.5 inches thick.

A 105-mm long, 18-gauge 80/20 nickel/chromium (ni-chrome) resistance heating wire (Type A) attached to electrodes was used as the high temperature heating source. The resistance heating wire could achieve a maximum test temperature of 1200°C. All thermite samples were tested at 10 volts and 21 amps. The test is performed six times using a clean cool board each time, unless a positive result is observed earlier. Powdered, granular or pasty substances are classified in Division 4.1 when the time of burning of one or more of the test runs is less than 45 seconds or the rate of burning is more than 2.2 mm/s. The test setup is shown in Photo 4.

Photo 4: Large-scale N.4 Test Setup – Typical

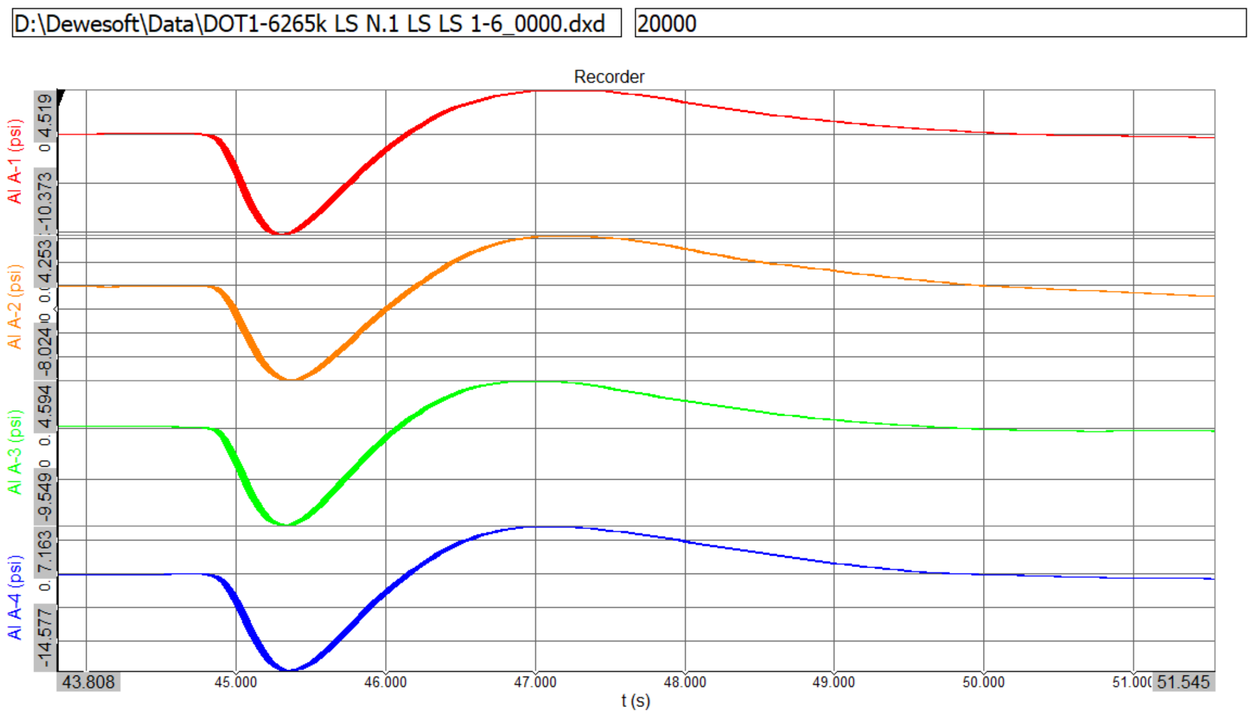
To measure the burn rate of the thermite, each test trial was recorded with high-definition (HD) video and high-speed video. Additionally, incident (side-on) overpressure was measured using four piezoelectric blast pressure probes placed 50-inches from the center of the base plate. The base plate was placed in the same location for each trial to minimize pressure variations.

10.3 Test Results

One trial of the Large-scale N.1 test was conducted on each thermite-additive formulation. One trial was also performed on LS #1-6 and LS #4-5 with no additives to provide a baseline for burn rate and overpressure. The test data is summarized in Table 12. Videos of each reaction are provided as SMS-6265k-V2. Example pictures of damage to the ceramic fiber board in the event of an explosion result are given in Photo 5.

The table column "LS N.1 Reaction" is the time in milliseconds for the fireball to reach its maximum width (since flame obscures direct observation of the sample). The burn pressure waveform was measured by the dynamic blast pressure probes as a characteristic negative pressure followed immediately by a positive pressure pulse. Figure 5 is an example of a typical burn pressure waveform for LS #1-6; it is characterized by a change from ambient pressure to peak negative pressure before a gradual rise to a peak positive pressure and then a decrease back to ambient pressure. It is observed simultaneously across all channels independent of distance but whose peak values diminishes with distance. The maximum peak pressure for the burn pressure waveforms is listed in the “Burn” column of Table 12.

Figure 5: Typical Burn Pressure Waveform



The thermite explosions were unlike a standard detonation shock wave that is characterized by an instantaneous rise from ambient pressure to a peak pressure that quickly decreases to ambient pressure and then a negative phase; rather, their pressure waveforms were characterized by the typical burn pressure waveform that was preceded by a small positive pressure pulse that traveled as a blast wave, arriving sequentially at inline pressure sensors, decreasing in peak value while increasing in duration with distance. Figure 6 is an example of a typical blast pressure waveform for LS #4-5, preceding the burn pressure waveform. The maximum peak pressure for the blast pressure waveforms is listed in the “Blast” column of Table 12.

Figure 6: Typical Blast Pressure Waveform

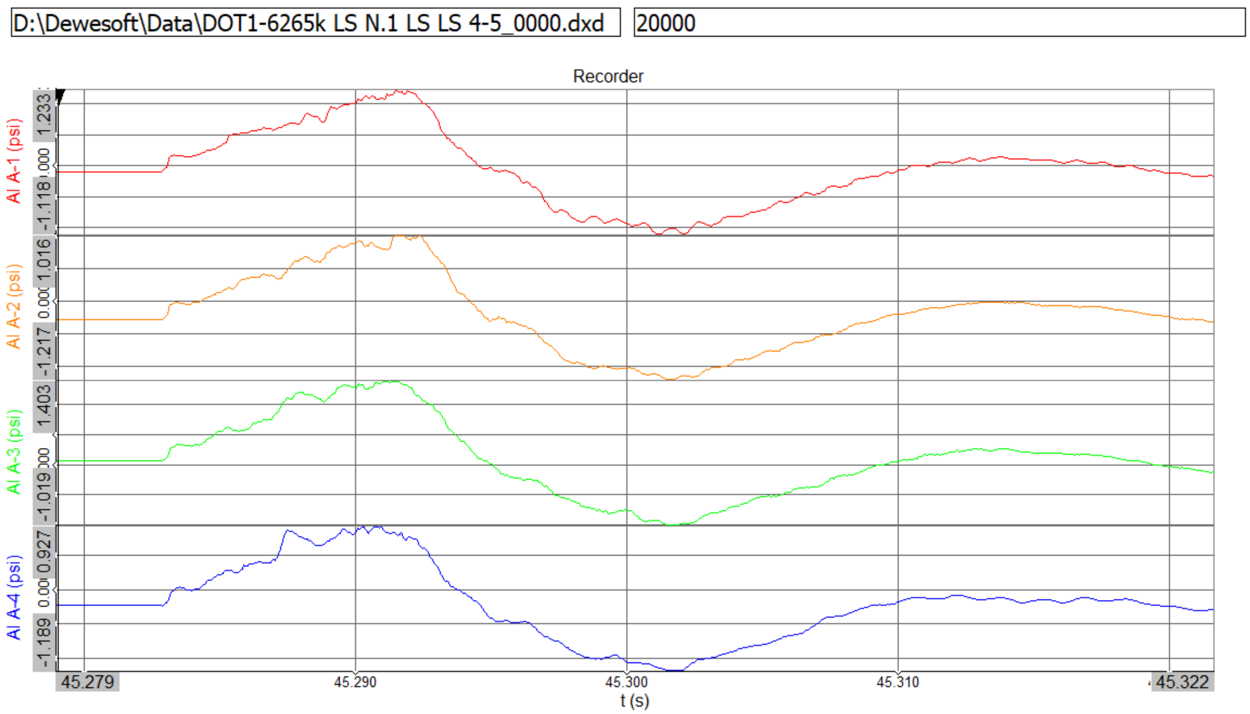


Table 12: Large-scale N.1 Flammable Solids Test Results

Mix ID	Additive	Additive Content (wt%)	Net Wt. (g)	LS N.1 Reaction (msec)	Pressure (psig)		Reaction Type	Insulator Plate Damage
					Burn	Blast		
1-6	None	None	181.4	170	5.1	0	Burn	Intact
4-5	None	None	485.8	16	17.9	1.1	Explosion	Fragmented
1-6	PTFE	10	199.6	84	4.5	0	Rapid burn	Intact
1-6	PTFE	20	151.2	69	3	0	Rapid burn	Intact
1-6	PTFE	30	191.8	45	4.4	0	Rapid burn	Intact
4-5	PTFE	10	243.4	99	4.2	0	Rapid burn	Intact
4-5	PTFE	20	241.4	105	5.2	0	Rapid burn	Intact
4-5	PTFE	30	214.6	190	5.2	0	Burn	Intact
1-6	MoO_3	10	225.2	-	3.3	0	Burn	Intact
1-6	MoO_3	20	221.2	283	3.6	0	Burn	Intact
1-6	MoO_3	30	229.8	152	3.7	0	Burn	Intact
4-5	MoO_3	10	399.8	15	13.1	1.4	Explosion	Fragmented
4-5	MoO_3	20	319.8	20	13.5	1.2	Explosion	Fragmented
4-5	MoO_3	30	287.0	20	8.1	1.1	Explosion	Fragmented
1-6	$NaNO_3$	10	257.6	522	3.3	0	Burn	Intact

Mix ID	Additive	Additive Content (wt%)	Net Wt. (g)	LS N.1 Reaction (msec)	Pressure (psig)		Reaction Type	Insulator Plate Damage
					Burn	Blast		
1-6	$NaNO_3$	20	318.6	308	6	0	Burn	Intact
1-6	$NaNO_3$	30	345.2	220	6.9	0	Burn	Intact
4-5	$NaNO_3$	10	334.0	18	20.2	1.5	Explosion	Fragmented
4-5	$NaNO_3$	20	342.2	16	10.7	1.6	Explosion	Fragmented
4-5	$NaNO_3$	30	319.6	18	9.2	1.2	Explosion	Fragmented
1-6	CaO_2	10	210.8	236	5.7	0	Burn	Intact
1-6	CaO_2	20	221.8	200	6	0	Burn	Intact
1-6	CaO_2	30	161.2	105	4.2	0	Rapid burn	Intact
4-5	CaO_2	10	290.8	23	7.9	1	Explosion	Fragmented
4-5	CaO_2	20	290.2	25	6.4	1.2	Explosion	Fragmented
4-5	CaO_2	30	288.2	44	4	0.3	Explosion	Intact

Intact after Reaction

Fragmented by Reaction

Photo 5: Example Ceramic Fiber Board Damage for the N.1 Flammable Solids Test

Analysis of the test results are provided in Table 2.

APPENDIX A

– TEST RESULTS AND PHOTOS

Table A 1: Black Powder Equivalency Test Results

Mix ID	Additive	Additive Amount (wt%)	Trial	Orifice Size	Result	Notes
1-6	None	None	1	2.5	Pass	Tube did not rupture, faster burn than 20 mm trial
1-6	None	None	2	20	Pass	Tube did not rupture, very slow burn
4-5	None	None	1	2.5	Pass	Tube did not rupture, slow reaction
4-5	None	None	2	20	Pass	Tube did not rupture, extremely fast reaction
SS 48	None	None	1	2.5	Pass	Tube did not rupture, slow reaction
SS 48	None	None	2	20	Pass	Tube did not rupture, audible "whoosh"
1-6	PTFE	10	1	8	Pass	Tube did not rupture, slow burn
1-6	PTFE	10	2	5	Pass	Tube did not rupture, slow burn
1-6	PTFE	10	3	3	Pass	Tube did not rupture, slow burn
1-6	PTFE	10	4	2.5	Pass	Tube did not rupture, slow burn
1-6	PTFE	10	5	2.5	Pass	Tube did not rupture, small burn hole in bottom of tube
1-6	PTFE	10	6	2.5	Pass	Tube did not rupture, small burn hole in bottom of tube
1-6	PTFE	20	1	2.5	Pass	Tube did not rupture, slow burn
1-6	PTFE	20	2	2.5	Pass	Tube did not rupture, molten metal in bottom of tube
1-6	PTFE	20	3	2.5	Pass	Tube did not rupture, small burn hole in bottom of tube
1-6	PTFE	30	1	2.5	Pass	Tube did not rupture, slow burn
1-6	PTFE	30	2	2.5	Pass	Tube did not rupture, fast reaction with audible "whoosh"
1-6	PTFE	30	3	2.5	Pass	Tube did not rupture, fast reaction with audible "whoosh"
4-5	PTFE	10	1	2.5	Pass	Tube did not rupture, small burn hole in side of tube
4-5	PTFE	10	2	2.5	Pass	Tube did not rupture, fast reaction
4-5	PTFE	10	3	2.5	Pass	Tube did not rupture, small burn hole in side of tube
4-5	PTFE	20	1	2.5	Pass	Tube did not rupture, fast reaction
4-5	PTFE	20	2	2.5	Pass	Tube did not rupture, fast reaction
4-5	PTFE	20	3	2.5	Pass	Tube did not rupture, fast reaction

Mix ID	Additive	Additive Amount (wt%)	Trial	Orifice Size	Result	Notes
4-5	PTFE	30	1	2.5	Pass	Tube did not rupture, fast reaction
4-5	PTFE	30	2	2.5	Pass	Tube did not rupture, fast reaction
4-5	PTFE	30	3	2.5	Pass	Tube did not rupture, fast reaction
1-6	MoO_3	10	1	2.5	Pass	Tube did not rupture, slow burn
1-6	MoO_3	10	2	2.5	Pass	Tube did not rupture, slow burn
1-6	MoO_3	10	3	2.5	Pass	Tube did not rupture, slow burn
1-6	MoO_3	20	1	2.5	Pass	Tube did not rupture, slow burn
1-6	MoO_3	20	2	2.5	Pass	Tube did not rupture, molten metal in bottom of tube
1-6	MoO_3	20	3	2.5	Pass	Tube did not rupture, slow burn
1-6	MoO_3	30	1	2.5	Pass	Tube did not rupture, slow burn
1-6	MoO_3	30	2	2.5	Pass	Tube did not rupture, slow burn
1-6	MoO_3	30	3	2.5	Pass	Tube did not rupture, small burn hole in bottom of tube
4-5	MoO_3	10	1	2.5	Pass	Tube did not rupture, small burn hole in bottom of tube
4-5	MoO_3	10	2	2.5	Pass	Tube did not rupture, small burn hole in bottom of tube
4-5	MoO_3	10	3	2.5	Pass	Tube did not rupture, small burn hole in bottom of tube
4-5	MoO_3	20	1	2.5	Pass	Tube did not rupture, small burn hole in bottom of tube
4-5	MoO_3	20	2	2.5	Pass	Tube did not rupture, small burn hole in bottom of tube
4-5	MoO_3	20	3	2.5	Pass	Tube did not rupture, small burn hole in bottom of tube
4-5	MoO_3	30	1	2.5	Pass	Tube did not rupture, small burn hole in bottom of tube
4-5	MoO_3	30	2	2.5	Pass	Tube did not rupture, small burn hole in bottom of tube
4-5	MoO_3	30	3	2.5	Pass	Tube did not rupture, small burn hole in bottom of tube
1-6	$NaNO_3$	10	1	2.5	Pass	Tube did not rupture, small burn hole in bottom of tube
1-6	$NaNO_3$	10	2	2.5	Pass	Tube did not rupture, weak sparks seen out of top
1-6	$NaNO_3$	10	3	2.5	Pass	Tube did not rupture, slow burn
1-6	$NaNO_3$	20	1	2.5	Pass	Tube did not rupture, slow burn

Mix ID	Additive	Additive Amount (wt%)	Trial	Orifice Size	Result	Notes
1-6	$NaNO_3$	20	2	2.5	Pass	Tube did not rupture, slow burn
1-6	$NaNO_3$	20	3	2.5	Pass	Tube did not rupture, slow burn
1-6	$NaNO_3$	30	1	2.5	Pass	Tube did not rupture, fast reaction
1-6	$NaNO_3$	30	2	2.5	Pass	Tube did not rupture, fast reaction
1-6	$NaNO_3$	30	3	2.5	Pass	Tube did not rupture, fast reaction
4-5	$NaNO_3$	10	1	2.5	Pass	Tube did not rupture, slow burn
4-5	$NaNO_3$	10	2	2.5	Pass	Tube did not rupture, slow burn
4-5	$NaNO_3$	10	3	2.5	Pass	Tube did not rupture, slow burn
4-5	$NaNO_3$	20	1	2.5	Pass	Tube did not rupture, fast reaction
4-5	$NaNO_3$	20	2	2.5	Pass	Tube did not rupture, fast reaction
4-5	$NaNO_3$	20	3	2.5	Pass	Tube did not rupture, fast reaction
4-5	$NaNO_3$	30	1	2.5	Pass	Tube did not rupture, fast reaction
4-5	$NaNO_3$	30	2	2.5	Pass	Tube did not rupture, fast reaction
4-5	$NaNO_3$	30	3	2.5	Pass	Tube did not rupture, fast reaction
1-6	CaO_2	10	1	2.5	Pass	Tube did not rupture, slow burn
1-6	CaO_2	10	2	2.5	Pass	Tube did not rupture, slow burn
1-6	CaO_2	10	3	2.5	Pass	Tube did not rupture, slow burn
1-6	CaO_2	20	1	2.5	Pass	Tube did not rupture, slow burn
1-6	CaO_2	20	2	2.5	Pass	Tube did not rupture, slow burn
1-6	CaO_2	20	3	2.5	Pass	Tube did not rupture, small burn hole in bottom of tube
1-6	CaO_2	30	1	2.5	Pass	Tube did not rupture, slow burn
1-6	CaO_2	30	2	2.5	Pass	Tube did not rupture, slow burn
1-6	CaO_2	30	3	2.5	Pass	Tube did not rupture, slow burn
4-5	CaO_2	10	1	2.5	Pass	Tube did not rupture, slow burn
4-5	CaO_2	10	2	2.5	Pass	Tube did not rupture, slow burn

Mix ID	Additive	Additive Amount (wt%)	Trial	Orifice Size	Result	Notes
4-5	CaO_2	10	3	2.5	Pass	Tube did not rupture, slow burn
4-5	CaO_2	20	1	2.5	Pass	Tube did not rupture, slow burn
4-5	CaO_2	20	2	2.5	Pass	Tube did not rupture, slow burn
4-5	CaO_2	20	3	2.5	Pass	Tube did not rupture, slow burn
4-5	CaO_2	30	1	2.5	Pass	Tube did not rupture, fast reaction
4-5	CaO_2	30	2	2.5	Pass	Tube did not rupture, fast reaction
4-5	CaO_2	30	3	2.5	Pass	Tube did not rupture, fast reaction

Photo A 1: LS #1-6 Test Results – Trials 1 - 2

Photo A 2: LS #4-5 Test Results – Trials 1 - 2

Photo A 3: SS #48 Test Results – Trials 1 - 2

Photo A 4: LS #1-6-A10 Test Results – Trials 1 - 3

Photo A 5: LS #1-6-A10 Test Results – Trials 4 - 6

Photo A 6: LS #1-6-A20 Test Results – Trials 1 - 3

Photo A 7: LS #1-6-A30 Test Results – Trials 1 - 3

Photo A 8: LS #1-6-B10 Test Results – Trials 1 - 3

Photo A 9: LS #1-6-B20 Test Results – Trials 1 - 3

Photo A 10: LS #1-6-B30 Test Results – Trials 1 - 3

Photo A 11: LS #1-6-C10 Test Results – Trials 1 - 3

Photo A 12: LS #1-6-C20 Test Results – Trials 1 - 3

Photo A 13: LS #1-6-C30 Test Results – Trials 1 - 3

Photo A 14: LS #1-6-D10 Test Results – Trials 1 - 3

Photo A 15: LS #1-6-D20 Test Results – Trials 1 - 3

Photo A 16: LS #1-6-D30 Test Results – Trials 1 - 3

Photo A 17: LS #4-5-A10 Test Results – Trials 1 - 3

Photo A 18: LS #4-5-A20 Test Results – Trials 1 - 3

Photo A 19: LS #4-5-A30 Test Results – Trials 1 - 3

Photo A 20: LS #4-5-B10 Test Results – Trials 1 - 3

Photo A 21: LS #4-5-B20 Test Results – Trials 1 - 3

Photo A 22: LS #4-5-B30 Test Results – Trials 1 - 3

Photo A 23: LS #4-5-C10 Test Results – Trials 1 - 3

Photo A 24: LS #4-5-C20 Test Results – Trials 1 - 3

Photo A 25: LS #4-5-C30 Test Results – Trials 1 - 3

Photo A 26: LS #4-5-D10 Test Results – Trials 1 - 3

Photo A 27: LS #4-5-D20 Test Results – Trials 1 - 3

Photo A 28: LS #4-5-D30 Test Results – Trials 1 - 3

APPENDIX B

– IMPACT, FRICTION, AND ESD BRUCETON H_{50} CALCULATIONS

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity

Sample: **LS1-6-A10**

$H_{50} = c + d\,(A/N_S \pm 0.5)$

NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	**log(cm)**	**+**	**-**
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
	SUM	**0**	**30**

CALCULATIONS USING NEGATIVES				
i	**n(-)**	**i(-)·n(-)**	**i^2(-)·n(-)**	**Interval**
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	**n(+)**	**i(+)·n(+)**	**i^2(+)·n(+)**	**Interval**
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#NAME?	log(cm)
#NAME?	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B 1: LS # 1-6-A10 – Bruceton H50 for MBOM Impact

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity

Sample: **LS1-6-A10**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

RSI Level		Frequency	
(cm)	log(lbf)	+	-
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	0	0
795.0	2.9	0	0
635.0	2.8	2	0
505.0	2.7	5	2
400.0	2.6	5	5
320.0	2.5	3	5
255.0	2.4	0	3
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0 0.000	0	0
	SUM	15	15

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
8	0	0	0	
7	0	0	0	0.094
6	0	0	0	0.107
5	0	0	0	0.100
4	0	0	0	0.098
3	2	6	18	0.099
2	5	10	20	0.101
1	5	5	5	0.097
0	3	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	N_S	A	B	d
2.407	15	21	43	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
7	0	0	0	
6	0	0	0	0.094
5	0	0	0	0.107
4	0	0	0	0.100
3	2	6	18	0.098
2	5	10	20	0.099
1	5	5	5	0.101
0	3	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	N_S	A	B	d
2.505	15	21	43	0.100

USE EITHER NEGATIVES OR POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.596 log(lbf)
394.2378 lbf
s (using negatives)
0.1510 log(lbf)
1.415644 lbf

H_{50} (using positives)
2.595 log(lbf)
393.3504 lbf
s (using positives)
0.1510 log(lbf)
1.415644 lbf

Figure B 2: LS # 1-6-A10 – Bruceton H_{50} for ABL Friction

Calculation of 50% initiation level from Bruceton data

ABL ESD Sensitivity

Sample: **LS1-6-A10**

Test voltage: 5 kV
Unit conversion: 1000000 pF / µF

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Nominal Capacitance (µF)	(pF)	log(pF)	Frequency +	Frequency -
0.750	750000	5.875	0	0
0.350	350000	5.544	0	0
0.250	250000	5.398	0	0
0.120	120000	5.079	0	0
0.060	60000	4.778	0	0
0.030	30000	4.477	0	0
0.015	15000	4.176	1	0
0.010	10000	4.000	1	0
0.0050	5000	3.699	2	0
0.0025	2500	3.398	7	1
0.0012	1200	3.079	4	6
0.0007	700	2.845	2	4
0.0003	300	2.477	0	2
0.0002	200	2.301	0	0
		SUM	**17**	**13**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
12	0	0	0	
11	0	0	0	0.331
10	0	0	0	0.146
9	0	0	0	0.319
8	0	0	0	0.301
7	0	0	0	0.301
6	0	0	0	0.301
5	0	0	0	0.176
4	0	0	0	0.301
3	1	3	9	0.301
2	6	12	24	0.319
1	4	4	4	0.234
0	2	0	0	0.368
FALSE	0	0	0	0.176
c	**N_S**	**A**	**B**	**d**
2.477	13	19	37	0.283

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
11	0	0	0	
10	0	0	0	0.331
9	0	0	0	0.146
8	0	0	0	0.319
7	0	0	0	0.301
6	0	0	0	0.301
5	1	5	25	0.301
4	1	4	16	0.176
3	2	6	18	0.301
2	7	14	28	0.301
1	4	4	4	0.319
0	2	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
c	**N_S**	**A**	**B**	**d**
2.845	17	33	91	0.283

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
3.033 log(pF)
1078 pF
0.0011 µF
0.013 J
s (using negatives)
0.3390 pF
0.004 mJ

H_{50} (using positives)
3.253 log(pF)
1791 pF
0.0018 µF
0.022 J
s (using positives)
0.7403 pF
0.009 mJ

Figure B 3: LS # 1-6-A10 – Bruceton H_{50} for ABL ESD

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity

Sample: **LS1-6-A20**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height (cm)	log(cm)	Frequency +	Frequency -
100	2.0	6	11
79.4	1.9	2	5
63.1	1.8	2	2
50.1	1.7	0	2
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
	SUM	**10**	**20**

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
3	11	33	99	
2	5	10	20	0.100
1	2	2	2	0.100
0	2	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
1.700	20	45	121	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
2	6	12	24	
1	2	2	2	0.100
0	2	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
1.800	10	14	26	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
1.974	log(cm)
94.2	cm
s (using negatives)	
0.1641	log(cm)
1.5	cm

H_{50} (using positives)	
1.890	log(cm)
77.6	cm
s (using positives)	
0.1080	log(cm)
1.3	cm

Figure B 4: LS # 1-6-A20 – Bruceton H50 for MBOM Impact

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity

Sample: **LS1-6-A20**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

RSI Level (cm)	log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	0	0
795.0	2.9	0	0
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	1	0
320.0	2.5	3	0
255.0	2.4	7	2
200.0	2.3	4	7
160.0	2.2	1	4
127.0	2.1	0	1
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0 0.000	0	0
	SUM	**16**	**14**

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
11	0	0	0	
10	0	0	0	0.094
9	0	0	0	0.107
8	0	0	0	0.100
7	0	0	0	0.098
6	0	0	0	0.099
5	0	0	0	0.101
4	0	0	0	0.097
3	2	6	18	0.099
2	7	14	28	0.106
1	4	4	4	0.097
0	1	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.104	14	24	50	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
10	0	0	0	
9	0	0	0	0.094
8	0	0	0	0.107
7	0	0	0	0.100
6	0	0	0	0.098
5	0	0	0	0.099
4	1	4	16	0.101
3	3	9	27	0.097
2	7	14	28	0.099
1	4	4	4	0.106
0	1	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.204	16	31	75	0.100

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.324 log(lbf)
211.0187 lbf
s (using negatives)
0.1067 log(lbf)
1.278635 lbf

H_{50} (using positives)
2.347 log(lbf)
222.4736 lbf
s (using positives)
0.1553 log(lbf)
1.429876 lbf

Figure B 5: LS # 1-6-A20 – Bruceton H_{50} for ABL Friction

Calculation of 50% initiation level from Bruceton data

ABL ESD Sensitivity

Sample: **LS1-6-A20**

Test voltage: 5 kV
Unit conversion: 1000000 pF / µF

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Nominal Capacitance			Frequency	
(µF)	(pF)	log(pF)	+	-
0.750	750000	5.875	0	0
0.350	350000	5.544	0	0
0.250	250000	5.398	0	0
0.120	120000	5.079	0	0
0.060	60000	4.778	0	0
0.030	30000	4.477	0	0
0.015	15000	4.176	1	0
0.010	10000	4.000	1	0
0.0050	5000	3.699	1	0
0.0025	2500	3.398	6	0
0.0012	1200	3.079	5	5
0.0007	700	2.845	3	4
0.0003	300	2.477	1	2
0.0002	200	2.301	0	1
		SUM	18	12

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
13	0	0	0	
12	0	0	0	0.331
11	0	0	0	0.146
10	0	0	0	0.319
9	0	0	0	0.301
8	0	0	0	0.301
7	0	0	0	0.301
6	0	0	0	0.176
5	0	0	0	0.301
4	0	0	0	0.301
3	5	15	45	0.319
2	4	8	16	0.234
1	2	2	2	0.368
0	1	0	0	0.176
c	N_S	A	B	d
2.301	12	25	63	0.283

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
12	0	0	0	
11	0	0	0	0.331
10	0	0	0	0.146
9	0	0	0	0.319
8	0	0	0	0.301
7	0	0	0	0.301
6	1	6	36	0.301
5	1	5	25	0.176
4	1	4	16	0.301
3	6	18	54	0.301
2	5	10	20	0.319
1	3	3	3	0.234
0	1	0	0	0.368
FALSE	0	0	0	0.176
c	N_S	A	B	d
2.477	18	46	154	0.283

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
3.033	log(pF)
1078	pF
0.0011	**µF**
0.013	**J**
s (using negatives)	
0.4306	**pF**
0.005	**mJ**

H_{50} (using positives)	
3.059	log(pF)
1146	pF
0.0011	**µF**
0.014	**J**
s (using positives)	
0.9421	**pF**
0.012	**mJ**

Figure B 6: LS # 1-6-A20 – Bruceton H_{50} for ABL ESD

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity

Sample: **LS1-6-A30**

$H_{50} = c + d\ (A/N_S \pm 0.5)$

NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	1	0
79.4	1.9	2	0
63.1	1.8	1	1
50.1	1.7	1	0
39.8	1.6	5	0
31.6	1.5	2	4
25.1	1.4	3	1
20.0	1.3	1	2
15.8	1.2	1	0
12.6	1.1	2	0
10.0	1.0	1	1
7.9	0.9	0	1
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
	SUM	20	10

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
11	0	0	0	
10	0	0	0	0.100
9	1	9	81	0.100
8	0	0	0	0.100
7	0	0	0	0.100
6	4	24	144	0.100
5	1	5	25	0.100
4	2	8	32	0.099
3	0	0	0	0.102
2	0	0	0	0.098
1	1	1	1	0.100
0	1	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
0.898	10	47	283	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
10	1	10	100	
9	2	18	162	0.100
8	1	8	64	0.100
7	1	7	49	0.100
6	5	30	180	0.100
5	2	10	50	0.100
4	3	12	48	0.100
3	1	3	9	0.099
2	1	2	4	0.102
1	2	2	2	0.098
0	1	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
1.000	20	102	668	0.100

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
1.416 log(cm) 26.1 cm
s (using negatives)
1.0072 log(cm) 10.2 cm

H_{50} (using positives)
1.458 log(cm) 28.7 cm
s (using positives)
1.1978 log(cm) 15.8 cm

Figure B 7: LS # 1-6-A30 – Bruceton H50 for MBOM Impact

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity

Sample: **LS1-6-A30**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

RSI Level		Frequency	
(cm)	log(lbf)	+	-
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	0	0
795.0	2.9	0	0
635.0	2.8	0	0
505.0	2.7	0	0
400.0	2.6	0	0
320.0	2.5	6	0
255.0	2.4	7	6
200.0	2.3	1	7
160.0	2.2	1	1
127.0	2.1	0	1
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0 0.000	0	0
	SUM	**15**	**15**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
11	0	0	0	
10	0	0	0	0.094
9	0	0	0	0.107
8	0	0	0	0.100
7	0	0	0	0.098
6	0	0	0	0.099
5	0	0	0	0.101
4	0	0	0	0.097
3	6	18	54	0.099
2	7	14	28	0.106
1	1	1	1	0.097
0	1	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.104	15	33	83	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
10	0	0	0	
9	0	0	0	0.094
8	0	0	0	0.107
7	0	0	0	0.100
6	0	0	0	0.098
5	0	0	0	0.099
4	0	0	0	0.101
3	6	18	54	0.097
2	7	14	28	0.099
1	1	1	1	0.106
0	1	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.204	15	33	83	0.100

USE EITHER NEGATIVES OR POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.373	log(lbf)
235.8808	lbf
s (using negatives)	
0.1165	log(lbf)
1.307785	lbf

H_{50} (using positives)	
2.373	log(lbf)
236.2764	lbf
s (using positives)	
0.1165	log(lbf)
1.307785	lbf

Figure B 8: LS # 1-6-A30 – Bruceton H_{50} for ABL Friction

Calculation of 50% initiation level from Bruceton data

ABL ESD Sensitivity

Sample: **LS1-6-A30**

Test voltage: 5 kV
Unit conversion: 1000000 pF / µF

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.
where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$
where $B = \Sigma i^2 \cdot n_i$

Nominal Capacitance			Frequency	
(µF)	(pF)	log(pF)	+	-
0.750	750000	5.875	0	0
0.350	350000	5.544	0	0
0.250	250000	5.398	0	0
0.120	120000	5.079	2	0
0.060	60000	4.778	6	2
0.030	30000	4.477	6	6
0.015	15000	4.176	1	6
0.010	10000	4.000	0	1
0.0050	5000	3.699	0	0
0.0025	2500	3.398	0	0
0.0012	1200	3.079	0	0
0.0007	700	2.845	0	0
0.0003	300	2.477	0	0
0.0002	200	2.301	0	0
		SUM	15	15

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
7	0	0	0	
6	0	0	0	0.331
5	0	0	0	0.146
4	0	0	0	0.319
3	2	6	18	0.301
2	6	12	24	0.301
1	6	6	6	0.301
0	1	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
c	N_S	A	B	d
4.000	15	24	48	0.283

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
6	0	0	0	
5	0	0	0	0.331
4	0	0	0	0.146
3	2	6	18	0.319
2	6	12	24	0.301
1	6	6	6	0.301
0	1	0	0	0.301
FALSE	0	0	0	0.176
FALSE	0	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
c	N_S	A	B	d
4.176	15	24	48	0.283

USE EITHER NEGATIVES OR POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
4.595	log(pF)
39322	pF
0.0393	**µF**
0.492	**J**
s (using negatives)	
0.3069	**pF**
0.004	**mJ**

H_{50} (using positives)	
4.488	log(pF)
30730	pF
0.0307	**µF**
0.384	**J**
s (using positives)	
0.3069	**pF**
0.004	**mJ**

Figure B 9: LS # 1-6-A30 – Bruceton H_{50} for ABL ESD

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity

Sample: **LS1-6-B10**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#NAME?	log(cm)
#NAME?	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B 10: LS # 1-6-B10 – Bruceton H50 for MBOM Impact

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity

Sample: **LS1-6-B10**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

RSI Level			Frequency	
(cm)	log(lbf)		+	-
1590	3.2		0	0
1280.0	3.1		0	0
1000.0	3.0		1	2
795.0	2.9		5	1
635.0	2.8		4	6
505.0	2.7		2	5
400.0	2.6		0	3
320.0	2.5		0	1
255.0	2.4		0	0
200.0	2.3		0	0
160.0	2.2		0	0
127.0	2.1		0	0
100.0	2.0		0	0
80.0	1.9		0	0
64.0	1.8		0	0
51.0	1.7		0	0
0.0000	0	0.000	0	0
	SUM		**12**	**18**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
7	0	0	0	
6	0	0	0	0.094
5	2	10	50	0.107
4	1	4	16	0.100
3	6	18	54	0.098
2	5	10	20	0.099
1	3	3	3	0.101
0	1	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.505	18	45	143	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
5	0	0	0	
4	0	0	0	0.094
3	1	3	9	0.107
2	5	10	20	0.100
1	4	4	4	0.098
0	2	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.703	12	17	33	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.804	log(lbf)
636.6714	lbf
s (using negatives)	
0.2780	log(lbf)
1.89692	lbf

H_{50} (using positives)	
2.795	log(lbf)
623.1331	lbf
s (using positives)	
0.1246	log(lbf)
1.332166	lbf

Figure B 11: LS # 1-6-B10 – Bruceton H_{50} for ABL Friction

Calculation of 50% initiation level from Bruceton data

ABL ESD Sensitivity

Sample: **LS1-6-B10**

Test voltage: 5 kV
Unit conversion: 1000000 pF / µF

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Nominal Capacitance			Frequency	
(µF)	(pF)	log(pF)	+	-
0.750	750000	5.875	0	0
0.350	350000	5.544	0	0
0.250	250000	5.398	0	0
0.120	120000	5.079	0	0
0.060	60000	4.778	0	0
0.030	30000	4.477	3	0
0.015	15000	4.176	4	3
0.010	10000	4.000	2	4
0.0050	5000	3.699	4	2
0.0025	2500	3.398	2	4
0.0012	1200	3.079	0	2
0.0007	700	2.845	0	0
0.0003	300	2.477	0	0
0.0002	200	2.301	0	0
		SUM	**15**	**15**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
10	0	0	0	
9	0	0	0	0.331
8	0	0	0	0.146
7	0	0	0	0.319
6	0	0	0	0.301
5	0	0	0	0.301
4	3	12	48	0.301
3	4	12	36	0.176
2	2	4	8	0.301
1	4	4	4	0.301
0	2	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
c	**N_S**	**A**	**B**	**d**
3.079	15	32	96	0.283

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
9	0	0	0	
8	0	0	0	0.331
7	0	0	0	0.146
6	0	0	0	0.319
5	0	0	0	0.301
4	3	12	48	0.301
3	4	12	36	0.301
2	2	4	8	0.176
1	4	4	4	0.301
0	2	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
c	**N_S**	**A**	**B**	**d**
3.398	15	32	96	0.283

USE EITHER NEGATIVES OR POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
3.825	log(pF)
6681	pF
0.0067	**µF**
0.084	**J**
s (using negatives)	
0.8614	**pF**
0.011	**mJ**

H_{50} (using positives)	
3.860	log(pF)
7252	pF
0.0073	**µF**
0.091	**J**
s (using positives)	
0.8614	**pF**
0.011	**mJ**

Figure B 12: LS # 1-6-B10 – Bruceton H_{50} for ABL ESD

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity

Sample: **LS1-6-B20**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height (cm)	log(cm)	Frequency +	Frequency -
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
	SUM	**0**	**30**

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.050 log(cm)
112.2 cm

s (using negatives)
0.0047 log(cm)
1.0 cm

H_{50} (using positives)
#NAME? log(cm)
#NAME? cm

s (using positives)
#DIV/0! log(cm)
#DIV/0! cm

Figure B 13: LS # 1-6-B20 – Bruceton H50 for MBOM Impact

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity

Sample: **LS1-6-B20**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

RSI Level (cm)	RSI Level log(lbf)		Frequency +	Frequency -
1590	3.2		0	0
1280.0	3.1		0	0
1000.0	3.0		7	11
795.0	2.9		0	8
635.0	2.8		1	1
505.0	2.7		0	2
400.0	2.6		0	0
320.0	2.5		0	0
255.0	2.4		0	0
200.0	2.3		0	0
160.0	2.2		0	0
127.0	2.1		0	0
100.0	2.0		0	0
80.0	1.9		0	0
64.0	1.8		0	0
51.0	1.7		0	0
0.0000	0	0.000	0	0
	SUM		**8**	**22**

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
5	0	0	0	
4	0	0	0	0.094
3	11	33	99	0.107
2	8	16	32	0.100
1	1	1	1	0.098
0	2	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.703	22	50	132	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
4	0	0	0	
3	0	0	0	0.094
2	7	14	28	0.107
1	0	0	0	0.100
0	1	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.803	8	14	28	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.979	log(lbf)
953.7247	lbf
s (using negatives)	
0.1393	log(lbf)
1.378305	lbf

H_{50} (using positives)	
2.927	log(lbf)
845.7837	lbf
s (using positives)	
0.0753	log(lbf)
1.189219	lbf

Figure B 14: LS # 1-6-B20 – Bruceton H_{50} for ABL Friction

Calculation of 50% initiation level from Bruceton data

ABL ESD Sensitivity

Sample: **LS1-6-B20**

Test voltage: 5 kV
Unit conversion: 1000000 pF / µF

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Nominal Capacitance			Frequency	
(µF)	(pF)	log(pF)	+	-
0.750	750000	5.875	0	0
0.350	350000	5.544	0	0
0.250	250000	5.398	0	0
0.120	120000	5.079	0	0
0.060	60000	4.778	0	0
0.030	30000	4.477	0	0
0.015	15000	4.176	4	0
0.010	10000	4.000	4	3
0.0050	5000	3.699	5	5
0.0025	2500	3.398	2	5
0.0012	1200	3.079	0	2
0.0007	700	2.845	0	0
0.0003	300	2.477	0	0
0.0002	200	2.301	0	0
		SUM	15	15

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
10	0	0	0	
9	0	0	0	0.331
8	0	0	0	0.146
7	0	0	0	0.319
6	0	0	0	0.301
5	0	0	0	0.301
4	0	0	0	0.301
3	3	9	27	0.176
2	5	10	20	0.301
1	5	5	5	0.301
0	2	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
c	N_S	A	B	d
3.079	15	24	52	0.283

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
9	0	0	0	
8	0	0	0	0.331
7	0	0	0	0.146
6	0	0	0	0.319
5	0	0	0	0.301
4	0	0	0	0.301
3	4	12	36	0.301
2	4	8	16	0.176
1	5	5	5	0.301
0	2	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
c	N_S	A	B	d
3.398	15	25	57	0.283

USE EITHER NEGATIVES OR POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
3.674 log(pF)
4719 pF
0.0047 µF
0.059 J
s (using negatives)
0.4292 pF
0.005 mJ

H_{50} (using positives)
3.728 log(pF)
5349 pF
0.0053 µF
0.067 J
s (using positives)
0.4822 pF
0.006 mJ

Figure B 15: LS # 1-6-B20 – Bruceton H_{50} for ABL ESD

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity

Sample: **LS1-6-B30**

$H_{50} = c + d\ (A/N_S \pm 0.5)$

NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height (cm)	log(cm)	Frequency +	Frequency -
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#NAME?	log(cm)
#NAME?	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B 16: LS # 1-6-B30 – Bruceton H50 for MBOM Impact

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity

Sample: **LS1-6-B30**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

RSI Level			Frequency	
(cm)	log(lbf)		+	-
1590	3.2		0	0
1280.0	3.1		0	0
1000.0	3.0		0	0
795.0	2.9		1	0
635.0	2.8		6	1
505.0	2.7		5	7
400.0	2.6		2	6
320.0	2.5		0	2
255.0	2.4		0	0
200.0	2.3		0	0
160.0	2.2		0	0
127.0	2.1		0	0
100.0	2.0		0	0
80.0	1.9		0	0
64.0	1.8		0	0
51.0	1.7		0	0
0.0000	0	0.000	0	0
	SUM		**14**	**16**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
7	0	0	0	
6	0	0	0	0.094
5	0	0	0	0.107
4	0	0	0	0.100
3	1	3	9	0.098
2	7	14	28	0.099
1	6	6	6	0.101
0	2	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	N_S	A	B	d
2.505	16	23	43	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
6	0	0	0	
5	0	0	0	0.094
4	0	0	0	0.107
3	1	3	9	0.100
2	6	12	24	0.098
1	5	5	5	0.099
0	2	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	N_S	A	B	d
2.602	14	20	38	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.698	log(lbf)
499.0024	lbf
s (using negatives)	
0.1049	log(lbf)
1.273156	lbf

H_{50} (using positives)	
2.695	log(lbf)
494.92	lbf
s (using positives)	
0.1133	log(lbf)
1.29817	lbf

Figure B 17: LS # 1-6-B30 – Bruceton H_{50} for ABL Friction

Calculation of 50% initiation level from Bruceton data

ABL ESD Sensitivity

Sample: LS1-6-B30

Test voltage: 5 kV
Unit conversion: 1000000 pF / µF

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Nominal Capacitance			Frequency	
(µF)	(pF)	log(pF)	+	-
0.750	750000	5.875	0	0
0.350	350000	5.544	0	0
0.250	250000	5.398	0	0
0.120	120000	5.079	0	0
0.060	60000	4.778	0	0
0.030	30000	4.477	0	0
0.015	15000	4.176	4	0
0.010	10000	4.000	4	5
0.0050	5000	3.699	5	5
0.0025	2500	3.398	1	5
0.0012	1200	3.079	0	1
0.0007	700	2.845	0	0
0.0003	300	2.477	0	0
0.0002	200	2.301	0	0
		SUM	14	16

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
10	0	0	0	
9	0	0	0	0.331
8	0	0	0	0.146
7	0	0	0	0.319
6	0	0	0	0.301
5	0	0	0	0.301
4	0	0	0	0.301
3	5	15	45	0.176
2	5	10	20	0.301
1	5	5	5	0.301
0	1	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
c	N_S	A	B	d
3.079	16	30	70	0.283

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
9	0	0	0	
8	0	0	0	0.331
7	0	0	0	0.146
6	0	0	0	0.319
5	0	0	0	0.301
4	0	0	0	0.301
3	4	12	36	0.301
2	4	8	16	0.176
1	5	5	5	0.301
0	1	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
c	N_S	A	B	d
3.398	14	25	57	0.283

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
3.752	log(pF)
5645	pF
0.0056	**µF**
0.071	**J**
s (using negatives)	
0.4075	**pF**
0.005	**mJ**

H_{50} (using positives)	
3.762	log(pF)
5781	pF
0.0058	**µF**
0.072	**J**
s (using positives)	
0.4182	**pF**
0.005	**mJ**

Figure B 18: LS # 1-6-B30 – Bruceton H_{50} for ABL ESD

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity

Sample: **LS1-6-C10**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	3	4
79.4	1.9	1	2
63.1	1.8	1	0
50.1	1.7	1	0
39.8	1.6	1	0
31.6	1.5	3	0
25.1	1.4	4	2
20.0	1.3	2	4
15.8	1.2	0	2
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
	SUM	**16**	**14**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
8	4	32	256	
7	2	14	98	0.100
6	0	0	0	0.100
5	0	0	0	0.100
4	0	0	0	0.100
3	0	0	0	0.100
2	2	4	8	0.100
1	4	4	4	0.099
0	2	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
1.199	14	54	366	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
7	3	21	147	
6	1	6	36	0.100
5	1	5	25	0.100
4	1	4	16	0.100
3	1	3	9	0.100
2	3	6	12	0.100
1	4	4	4	0.100
0	2	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
1.301	16	49	249	0.100

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	**H_{50} (using positives)**
1.633 log(cm)	1.556 log(cm)
42.9 cm	36.0 cm
s (using negatives)	**s (using positives)**
1.8234 log(cm)	1.0030 log(cm)
66.6 cm	10.1 cm

Figure B 19: LS # 1-6-C10 – Bruceton H50 for MBOM Impact

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity

Sample: **LS1-6-C10**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

RSI Level			Frequency	
(cm)	log(lbf)		+	-
1590	3.2		0	0
1280.0	3.1		0	0
1000.0	3.0		2	18
795.0	2.9		0	3
635.0	2.8		0	1
505.0	2.7		2	1
400.0	2.6		0	3
320.0	2.5		0	0
255.0	2.4		0	0
200.0	2.3		0	0
160.0	2.2		0	0
127.0	2.1		0	0
100.0	2.0		0	0
80.0	1.9		0	0
64.0	1.8		0	0
51.0	1.7		0	0
0.0000	0	0.000	0	0
	SUM		**4**	**26**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
6	0	0	0	
5	0	0	0	0.094
4	18	72	288	0.107
3	3	9	27	0.100
2	1	2	4	0.098
1	1	1	1	0.099
0	3	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	N_S	A	B	d
2.602	26	84	320	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
5	0	0	0	
4	0	0	0	0.094
3	2	6	18	0.107
2	0	0	0	0.100
1	0	0	0	0.098
0	2	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	N_S	A	B	d
2.703	4	6	18	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.974 log(lbf)
941.0259 lbf
s (using negatives)
0.3063 log(lbf)
2.024619 lbf

H_{50} (using positives)
2.803 log(lbf)
635.1552 lbf
s (using positives)
0.3677 log(lbf)
2.331732 lbf

Figure B 20: LS # 1-6-C10 – Bruceton H_{50} for ABL Friction

Calculation of 50% initiation level from Bruceton data

ABL ESD Sensitivity

Sample: **LS1-6-C10**

Test voltage: 5 kV
Unit conversion: 1000000 pF / µF

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Nominal Capacitance			Frequency	
(µF)	(pF)	log(pF)	+	-
0.750	750000	5.875	0	0
0.350	350000	5.544	0	0
0.250	250000	5.398	0	0
0.120	120000	5.079	0	0
0.060	60000	4.778	0	0
0.030	30000	4.477	0	0
0.015	15000	4.176	0	0
0.010	10000	4.000	0	1
0.0050	5000	3.699	3	1
0.0025	2500	3.398	8	3
0.0012	1200	3.079	3	8
0.0007	700	2.845	0	3
0.0003	300	2.477	0	0
0.0002	200	2.301	0	0
		SUM	14	16

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
11	0	0	0	
10	0	0	0	0.331
9	0	0	0	0.146
8	0	0	0	0.319
7	0	0	0	0.301
6	0	0	0	0.301
5	0	0	0	0.301
4	1	4	16	0.176
3	1	3	9	0.301
2	3	6	12	0.301
1	8	8	8	0.319
0	3	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
c	N_S	A	B	d
2.845	16	21	45	0.283

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
10	0	0	0	
9	0	0	0	0.331
8	0	0	0	0.146
7	0	0	0	0.319
6	0	0	0	0.301
5	0	0	0	0.301
4	0	0	0	0.301
3	0	0	0	0.176
2	3	6	12	0.301
1	8	8	8	0.301
0	3	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
c	N_S	A	B	d
3.079	14	14	20	0.283

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
3.358	log(pF)
2282	pF
0.0023	**µF**
0.029	**J**
s (using negatives)	
0.5132	**pF**
0.006	**mJ**

H_{50} (using positives)	
3.221	log(pF)
1663	pF
0.0017	**µF**
0.021	**J**
s (using positives)	
0.2099	**pF**
0.003	**mJ**

Figure B 21: LS # 1-6-C10 – Bruceton H_{50} for ABL ESD

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity

Sample: **LS1-6-C20**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	**log(cm)**	**+**	**-**
100	2.0	1	0
79.4	1.9	1	0
63.1	1.8	1	0
50.1	1.7	2	0
39.8	1.6	4	1
31.6	1.5	3	3
25.1	1.4	4	2
20.0	1.3	2	4
15.8	1.2	0	2
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
	SUM	**18**	**12**

CALCULATIONS USING NEGATIVES				
i	**n(-)**	**i(-)·n(-)**	**i^2(-)·n(-)**	**Interval**
8	0	0	0	
7	0	0	0	0.100
6	0	0	0	0.100
5	0	0	0	0.100
4	1	4	16	0.100
3	3	9	27	0.100
2	2	4	8	0.100
1	4	4	4	0.099
0	2	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
1.199	12	21	55	0.100

CALCULATIONS USING POSITIVES				
i(+)	**n(+)**	**i(+)·n(+)**	**i^2(+)·n(+)**	**Interval**
7	1	7	49	
6	1	6	36	0.100
5	1	5	25	0.100
4	2	8	32	0.100
3	4	12	36	0.100
2	3	6	12	0.100
1	4	4	4	0.100
0	2	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
1.301	18	48	194	0.100

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
1.423 log(cm)
26.5 cm
s (using negatives)
0.2502 log(cm)
1.8 cm

H_{50} (using positives)
1.517 log(cm)
32.9 cm
s (using positives)
0.5966 log(cm)
4.0 cm

Figure B 22: LS # 1-6-C20 – Bruceton H50 for MBOM Impact

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity

Sample: LS1-6-C20

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

RSI Level		Frequency	
(cm)	log(lbf)	+	-
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	4	14
795.0	2.9	3	4
635.0	2.8	0	3
505.0	2.7	0	1
400.0	2.6	0	1
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0 0.000	0	0
	SUM	7	23

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
6	0	0	0	
5	0	0	0	0.094
4	14	56	224	0.107
3	4	12	36	0.100
2	3	6	12	0.098
1	1	1	1	0.099
0	1	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	N_S	A	B	d
2.602	23	75	273	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
3	0	0	0	
2	0	0	0	0.094
1	4	4	4	0.107
0	3	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	N_S	A	B	d
2.900	7	4	4	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.977 log(lbf)
947.5436 lbf
s (using negatives)
0.2041 log(lbf)
1.600052 lbf

H_{50} (using positives)
2.907 log(lbf)
808.1288 lbf
s (using positives)
0.0442 log(lbf)
1.107105 lbf

Figure B 23: LS # 1-6-C20 – Bruceton H_{50} for ABL Friction

Calculation of 50% initiation level from Bruceton data

ABL ESD Sensitivity

Sample: **LS1-6-C20**

Test voltage: 5 kV
Unit conversion: 1000000 pF / µF

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Nominal Capacitance			Frequency	
(µF)	(pF)	log(pF)	+	-
0.750	750000	5.875	0	0
0.350	350000	5.544	0	0
0.250	250000	5.398	0	0
0.120	120000	5.079	0	0
0.060	60000	4.778	0	0
0.030	30000	4.477	0	0
0.015	15000	4.176	0	0
0.010	10000	4.000	0	0
0.0050	5000	3.699	1	0
0.0025	2500	3.398	7	0
0.0012	1200	3.079	2	7
0.0007	700	2.845	3	2
0.0003	300	2.477	2	3
0.0002	200	2.301	1	2
		SUM	16	14

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
13	0	0	0	
12	0	0	0	0.331
11	0	0	0	0.146
10	0	0	0	0.319
9	0	0	0	0.301
8	0	0	0	0.301
7	0	0	0	0.301
6	0	0	0	0.176
5	0	0	0	0.301
4	0	0	0	0.301
3	7	21	63	0.319
2	2	4	8	0.234
1	3	3	3	0.368
0	2	0	0	0.176
c	N_S	A	B	d
2.301	14	28	74	0.283

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
13	0	0	0	
12	0	0	0	0.331
11	0	0	0	0.146
10	0	0	0	0.319
9	0	0	0	0.301
8	0	0	0	0.301
7	0	0	0	0.301
6	0	0	0	0.176
5	1	5	25	0.301
4	7	28	112	0.301
3	2	6	18	0.319
2	3	6	12	0.234
1	2	2	2	0.368
0	1	0	0	0.176
c	N_S	A	B	d
2.301	16	47	169	0.283

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
3.009 log(pF)
1021 pF
0.0010 µF
0.013 J
s (using negatives)
0.6031 pF
0.008 mJ

H_{50} (using positives)
2.991 log(pF)
980 pF
0.0010 µF
0.012 J
s (using positives)
0.9003 pF
0.011 mJ

Figure B 24: LS # 1-6-C20 – Bruceton H_{50} for ABL ESD

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity

Sample: **LS1-6-C30**

$H_{50} = c + d\,(A/N_S \pm 0.5)$

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	1	0
79.4	1.9	1	0
63.1	1.8	0	0
50.1	1.7	4	0
39.8	1.6	4	4
31.6	1.5	2	5
25.1	1.4	2	3
20.0	1.3	1	2
15.8	1.2	0	1
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
	SUM	15	15

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
8	0	0	0	
7	0	0	0	0.100
6	0	0	0	0.100
5	0	0	0	0.100
4	4	16	64	0.100
3	5	15	45	0.100
2	3	6	12	0.100
1	2	2	2	0.099
0	1	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
1.199	15	39	123	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
7	1	7	49	
6	1	6	36	0.100
5	0	0	0	0.100
4	4	16	64	0.100
3	4	12	36	0.100
2	2	4	8	0.100
1	2	2	2	0.100
0	1	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
1.301	15	47	195	0.100

USE EITHER NEGATIVES OR POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
1.508 log(cm)
32.2 cm
s (using negatives)
0.2372 log(cm)
1.7 cm

H_{50} (using positives)
1.563 log(cm)
36.6 cm
s (using positives)
0.5184 log(cm)
3.3 cm

Figure B 25: LS # 1-6-C30 – Bruceton H50 for MBOM Impact

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity

Sample: **LS1-6-C30**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

RSI Level		Frequency	
(cm)	log(lbf)	+	-
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	2	10
795.0	2.9	2	3
635.0	2.8	4	2
505.0	2.7	1	4
400.0	2.6	0	2
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0 0.000	0	0
	SUM	**9**	**21**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
6	0	0	0	
5	0	0	0	0.094
4	10	40	160	0.107
3	3	9	27	0.100
2	2	4	8	0.098
1	4	4	4	0.099
0	2	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.602	21	57	199	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
5	0	0	0	
4	0	0	0	0.094
3	2	6	18	0.107
2	2	4	8	0.100
1	4	4	4	0.098
0	1	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.703	9	14	30	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.922 log(lbf)
835.922 lbf
s (using negatives)
0.3449 log(lbf)
2.212613 lbf

H_{50} (using positives)
2.808 log(lbf)
643.2985 lbf
s (using positives)
0.1521 log(lbf)
1.419285 lbf

Figure B 26: LS # 1-6-C30 – Bruceton H_{50} for ABL Friction

Calculation of 50% initiation level from Bruceton data

ABL ESD Sensitivity

Sample: **LS1-6-C30**

Test voltage: 5 kV
Unit conversion: 1000000 pF / µF

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.
where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$
where $B = \Sigma i^2 \cdot n_i$

Nominal Capacitance			Frequency	
(µF)	(pF)	log(pF)	+	-
0.750	750000	5.875	0	0
0.350	350000	5.544	0	0
0.250	250000	5.398	0	0
0.120	120000	5.079	0	0
0.060	60000	4.778	0	0
0.030	30000	4.477	0	0
0.015	15000	4.176	0	0
0.010	10000	4.000	2	0
0.0050	5000	3.699	5	1
0.0025	2500	3.398	5	4
0.0012	1200	3.079	4	4
0.0007	700	2.845	1	3
0.0003	300	2.477	0	1
0.0002	200	2.301	0	0
		SUM	17	13

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
12	0	0	0	
11	0	0	0	0.331
10	0	0	0	0.146
9	0	0	0	0.319
8	0	0	0	0.301
7	0	0	0	0.301
6	0	0	0	0.301
5	0	0	0	0.176
4	1	4	16	0.301
3	4	12	36	0.301
2	4	8	16	0.319
1	3	3	3	0.234
0	1	0	0	0.368
FALSE	0	0	0	0.176
c	**N_S**	**A**	**B**	**d**
2.477	13	27	71	0.283

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
11	0	0	0	
10	0	0	0	0.331
9	0	0	0	0.146
8	0	0	0	0.319
7	0	0	0	0.301
6	0	0	0	0.301
5	0	0	0	0.301
4	2	8	32	0.176
3	5	15	45	0.301
2	5	10	20	0.301
1	4	4	4	0.319
0	1	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
c	**N_S**	**A**	**B**	**d**
2.845	17	37	101	0.283

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
3.207 log(pF)
1610 pF
0.0016 µF
0.020 J
s (using negatives)
0.5399 pF
0.007 mJ

H_{50} (using positives)
3.320 log(pF)
2088 pF
0.0021 µF
0.026 J
s (using positives)
0.5657 pF
0.007 mJ

Figure B 27: LS # 1-6-C30 – Bruceton H_{50} for ABL ESD

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity

Sample: **LS1-6-D10**

$H_{50} = c + d\,(A/N_S \pm 0.5)$

NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#NAME?	log(cm)
#NAME?	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B 28: LS # 1-6-D10 – Bruceton H50 for MBOM Impact

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity

Sample: LS1-6-D10

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

RSI Level		Frequency	
(cm)	log(lbf)	+	-
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	9	6
795.0	2.9	2	9
635.0	2.8	0	2
505.0	2.7	0	1
400.0	2.6	0	1
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0 0.000	0	0
	SUM	**11**	**19**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
6	0	0	0	
5	0	0	0	0.094
4	6	24	96	0.107
3	9	27	81	0.100
2	2	4	8	0.098
1	1	1	1	0.099
0	1	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.602	19	56	186	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
3	0	0	0	
2	0	0	0	0.094
1	9	9	9	0.107
0	2	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.900	11	9	9	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.945 log(lbf)
881.8163 lbf
s (using negatives)
0.1825 log(lbf)
1.522466 lbf

H_{50} (using positives)
2.932 log(lbf)
855.1738 lbf
s (using positives)
0.0287 log(lbf)
1.068264 lbf

Figure B 29: LS # 1-6-D10 – Bruceton H_{50} for ABL Friction

Calculation of 50% initiation level from Bruceton data

ABL ESD Sensitivity

Sample: **LS1-6-D10**

Test voltage: 5 kV
Unit conversion: 1000000 pF / µF

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Nominal Capacitance			Frequency	
(µF)	(pF)	log(pF)	+	-
0.750	750000	5.875	0	0
0.350	350000	5.544	0	0
0.250	250000	5.398	0	0
0.120	120000	5.079	0	0
0.060	60000	4.778	0	0
0.030	30000	4.477	0	0
0.015	15000	4.176	0	0
0.010	10000	4.000	0	0
0.0050	5000	3.699	2	0
0.0025	2500	3.398	3	2
0.0012	1200	3.079	6	3
0.0007	700	2.845	4	5
0.0003	300	2.477	1	3
0.0002	200	2.301	0	1
		SUM	16	14

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
13	0	0	0	
12	0	0	0	0.331
11	0	0	0	0.146
10	0	0	0	0.319
9	0	0	0	0.301
8	0	0	0	0.301
7	0	0	0	0.301
6	0	0	0	0.176
5	0	0	0	0.301
4	2	8	32	0.301
3	3	9	27	0.319
2	5	10	20	0.234
1	3	3	3	0.368
0	1	0	0	0.176
c	N_S	A	B	d
2.301	14	30	82	0.283

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
12	0	0	0	
11	0	0	0	0.331
10	0	0	0	0.146
9	0	0	0	0.319
8	0	0	0	0.301
7	0	0	0	0.301
6	0	0	0	0.301
5	0	0	0	0.176
4	2	8	32	0.301
3	3	9	27	0.301
2	6	12	24	0.319
1	4	4	4	0.234
0	1	0	0	0.368
FALSE	0	0	0	0.176
c	N_S	A	B	d
2.477	16	33	87	0.283

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
3.049	log(pF)
1120	pF
0.0011	**µF**
0.014	**J**
s (using negatives)	
0.5937	**pF**
0.007	**mJ**

H_{50} (using positives)	
2.920	log(pF)
831	pF
0.0008	**µF**
0.010	**J**
s (using positives)	
0.5562	**pF**
0.007	**mJ**

Figure B 30: LS # 1-6-D10 – Bruceton H_{50} for ABL ESD

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity

Sample: **LS1-6-D20**

$H_{50} = c + d\,(A/N_S \pm 0.5)$

NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.050 log(cm)
112.2 cm
s (using negatives)
0.0047 log(cm)
1.0 cm

H_{50} (using positives)
#NAME? log(cm)
#NAME? cm
s (using positives)
#DIV/0! log(cm)
#DIV/0! cm

Figure B 31: LS # 1-6-D20 – Bruceton H50 for MBOM Impact

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity

Sample: **LS1-6-D20**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

RSI Level			Frequency	
(cm)	log(lbf)		+	-
1590	3.2		0	0
1280.0	3.1		0	0
1000.0	3.0		1	0
795.0	2.9		3	1
635.0	2.8		6	3
505.0	2.7		4	6
400.0	2.6		1	4
320.0	2.5		0	1
255.0	2.4		0	0
200.0	2.3		0	0
160.0	2.2		0	0
127.0	2.1		0	0
100.0	2.0		0	0
80.0	1.9		0	0
64.0	1.8		0	0
51.0	1.7		0	0
0.0000	0	0.000	0	0
	SUM		15	15

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
7	0	0	0	
6	0	0	0	0.094
5	0	0	0	0.107
4	1	4	16	0.100
3	3	9	27	0.098
2	6	12	24	0.099
1	4	4	4	0.101
0	1	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	N_S	A	B	d
2.505	15	29	71	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
6	0	0	0	
5	0	0	0	0.094
4	1	4	16	0.107
3	3	9	27	0.100
2	6	12	24	0.098
1	4	4	4	0.099
0	1	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	N_S	A	B	d
2.602	15	29	71	0.100

USE EITHER NEGATIVES OR POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.747	log(lbf)
559.0902	lbf
s (using negatives)	
0.1653	log(lbf)
1.463171	lbf

H_{50} (using positives)	
2.745	log(lbf)
555.6527	lbf
s (using positives)	
0.1653	log(lbf)
1.463171	lbf

Figure B 32: LS # 1-6-D20 – Bruceton H_{50} for ABL Friction

Calculation of 50% initiation level from Bruceton data

ABL ESD Sensitivity

Sample: **LS1-6-D20**

Test voltage: 5 kV
Unit conversion: 1000000 pF / µF

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Nominal Capacitance			Frequency	
(µF)	(pF)	log(pF)	+	-
0.750	750000	5.875	0	0
0.350	350000	5.544	0	0
0.250	250000	5.398	0	0
0.120	120000	5.079	0	0
0.060	60000	4.778	0	0
0.030	30000	4.477	0	0
0.015	15000	4.176	0	0
0.010	10000	4.000	2	0
0.0050	5000	3.699	5	1
0.0025	2500	3.398	1	4
0.0012	1200	3.079	2	0
0.0007	700	2.845	2	1
0.0003	300	2.477	5	2
0.0002	200	2.301	0	5
		SUM	17	13

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
13	0	0	0	
12	0	0	0	0.331
11	0	0	0	0.146
10	0	0	0	0.319
9	0	0	0	0.301
8	0	0	0	0.301
7	0	0	0	0.301
6	0	0	0	0.176
5	1	5	25	0.301
4	4	16	64	0.301
3	0	0	0	0.319
2	1	2	4	0.234
1	2	2	2	0.368
0	5	0	0	0.176
c	N_S	A	B	d
2.301	13	25	95	0.283

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
12	0	0	0	
11	0	0	0	0.331
10	0	0	0	0.146
9	0	0	0	0.319
8	0	0	0	0.301
7	0	0	0	0.301
6	0	0	0	0.301
5	2	10	50	0.176
4	5	20	80	0.301
3	1	3	9	0.301
2	2	4	8	0.319
1	2	2	2	0.234
0	5	0	0	0.368
FALSE	0	0	0	0.176
c	N_S	A	B	d
2.477	17	39	149	0.283

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.987	log(pF)
971	pF
0.0010	**µF**
0.012	**J**
s (using negatives)	
1.6690	**pF**
0.021	**mJ**

H_{50} (using positives)	
2.985	log(pF)
966	pF
0.0010	**µF**
0.012	**J**
s (using positives)	
1.6196	**pF**
0.020	**mJ**

Figure B 33: LS # 1-6-D20 – Bruceton H_{50} for ABL ESD

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity

Sample: **LS1-6-D30**

$H_{50} = c + d\,(A/N_S \pm 0.5)$

NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i²(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i²(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#NAME?	log(cm)
#NAME?	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B 34: LS # 1-6-D30 – Bruceton H50 for MBOM Impact

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity

Sample: **LS1-6-D30**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

RSI Level			Frequency	
(cm)	log(lbf)		+	-
1590	3.2		0	0
1280.0	3.1		0	0
1000.0	3.0		0	0
795.0	2.9		0	0
635.0	2.8		4	0
505.0	2.7		4	4
400.0	2.6		6	3
320.0	2.5		2	5
255.0	2.4		0	2
200.0	2.3		0	0
160.0	2.2		0	0
127.0	2.1		0	0
100.0	2.0		0	0
80.0	1.9		0	0
64.0	1.8		0	0
51.0	1.7		0	0
0.0000	0	0.000	0	0
	SUM		16	14

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
8	0	0	0	
7	0	0	0	0.094
6	0	0	0	0.107
5	0	0	0	0.100
4	0	0	0	0.098
3	4	12	36	0.099
2	3	6	12	0.101
1	5	5	5	0.097
0	2	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	N_S	A	B	d
2.407	14	23	53	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
7	0	0	0	
6	0	0	0	0.094
5	0	0	0	0.107
4	0	0	0	0.100
3	4	12	36	0.098
2	4	8	16	0.099
1	6	6	6	0.101
0	2	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	N_S	A	B	d
2.505	16	26	58	0.100

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.620	log(lbf)
416.8157	lbf
s (using negatives)	
0.1800	log(lbf)
1.513579	lbf

H_{50} (using positives)	
2.617	log(lbf)
414.178	lbf
s (using positives)	
0.1635	log(lbf)
1.457106	lbf

Figure B 35: LS # 1-6-D30 – Bruceton H_{50} for ABL Friction

Calculation of 50% initiation level from Bruceton data

ABL ESD Sensitivity

Sample: **LS1-6-D30**

Test voltage: 5 kV
Unit conversion: 1000000 pF / µF

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.
where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$
where $B = \Sigma i^2 \cdot n_i$

Nominal Capacitance			Frequency	
(µF)	(pF)	log(pF)	+	-
0.750	750000	5.875	0	0
0.350	350000	5.544	0	0
0.250	250000	5.398	0	0
0.120	120000	5.079	0	0
0.060	60000	4.778	0	0
0.030	30000	4.477	0	0
0.015	15000	4.176	0	0
0.010	10000	4.000	2	0
0.0050	5000	3.699	4	1
0.0025	2500	3.398	3	3
0.0012	1200	3.079	3	2
0.0007	700	2.845	5	2
0.0003	300	2.477	1	4
0.0002	200	2.301	0	0
		SUM	**18**	**12**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
12	0	0	0	
11	0	0	0	0.331
10	0	0	0	0.146
9	0	0	0	0.319
8	0	0	0	0.301
7	0	0	0	0.301
6	0	0	0	0.301
5	0	0	0	0.176
4	1	4	16	0.301
3	3	9	27	0.301
2	2	4	8	0.319
1	2	2	2	0.234
0	4	0	0	0.368
FALSE	0	0	0	0.176
c	**N_S**	**A**	**B**	**d**
2.477	12	19	53	0.283

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
12	0	0	0	
11	0	0	0	0.331
10	0	0	0	0.146
9	0	0	0	0.319
8	0	0	0	0.301
7	0	0	0	0.301
6	0	0	0	0.301
5	2	10	50	0.176
4	4	16	64	0.301
3	3	9	27	0.301
2	3	6	12	0.319
1	5	5	5	0.234
0	1	0	0	0.368
FALSE	0	0	0	0.176
c	**N_S**	**A**	**B**	**d**
2.477	18	46	158	0.283

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
3.067 log(pF)
1167 pF
0.0012 µF
0.015 J
s (using negatives)
0.8893 pF
0.011 mJ

H_{50} (using positives)
3.059 log(pF)
1146 pF
0.0011 µF
0.014 J
s (using positives)
1.0440 pF
0.013 mJ

Figure B 36: LS # 1-6-D30 – Bruceton H_{50} for ABL ESD

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity

Sample: **LS4-5-A10**

$H_{50} = c + d\ (A/N_S \pm 0.5)$

NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	27
79.4	1.9	0	1
63.1	1.8	0	1
50.1	1.7	0	1
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
3	27	81	243	
2	1	2	4	0.100
1	1	1	1	0.100
0	1	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
1.700	30	84	248	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.029	log(cm)
106.8	cm
s (using negatives)	
0.0736	log(cm)
1.2	cm

H_{50} (using positives)	
#NAME?	log(cm)
#NAME?	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B 37: LS # 4-5-A10 – Bruceton H_{50} for MBOM Impact

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity

Sample: **LS4-5-A10**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

RSI Level (lbf)	log(lbf)		Frequency +	Frequency -
1590	3.2		0	0
1280.0	3.1		0	0
1000.0	3.0		1	0
795.0	2.9		1	0
635.0	2.8		1	0
505.0	2.7		1	0
400.0	2.6		4	0
320.0	2.5		8	3
255.0	2.4		2	7
200.0	2.3		0	2
160.0	2.2		0	0
127.0	2.1		0	0
100.0	2.0		0	0
80.0	1.9		0	0
64.0	1.8		0	0
51.0	1.7		0	0
0.0000	0	0.000	0	0
SUM			18	12

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
9	0	0	0	
8	0	0	0	0.094
7	0	0	0	0.107
6	0	0	0	0.100
5	0	0	0	0.098
4	0	0	0	0.099
3	0	0	0	0.101
2	3	6	12	0.097
1	7	7	7	0.099
0	2	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	N_S	A	B	d
2.301	12	13	19	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
8	0	0	0	
7	0	0	0	0.094
6	1	6	36	0.107
5	1	5	25	0.100
4	1	4	16	0.098
3	1	3	9	0.099
2	4	8	16	0.101
1	8	8	8	0.097
0	2	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	N_S	A	B	d
2.407	18	34	110	0.100

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.459	log(lbf)
287.549	lbf
s (using negatives)	
0.0708	log(lbf)
1.177011	lbf

H_{50} (using positives)	
2.545	log(lbf)
350.6368	lbf
s (using positives)	
0.4150	log(lbf)
2.600059	lbf

Figure B 38: LS # 4-5-A10 – Bruceton H_{50} for ABL Friction

Calculation of 50% initiation level from Bruceton data

ABL ESD Sensitivity

Sample: **LS4-5-A10**

Test voltage: 5 kV
Unit conversion: 1000000 pF / µF

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.
where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$
where $B = \Sigma i^2 \cdot n_i$

Nominal Capacitance			Frequency	
(µF)	(pF)	log(pF)	+	-
0.750	750000	5.875	0	0
0.350	350000	5.544	0	0
0.250	250000	5.398	0	0
0.120	120000	5.079	0	0
0.060	60000	4.778	0	0
0.030	30000	4.477	0	0
0.015	15000	4.176	1	0
0.010	10000	4.000	3	0
0.0050	5000	3.699	9	2
0.0025	2500	3.398	4	8
0.0012	1200	3.079	0	3
0.0007	700	2.845	0	0
0.0003	300	2.477	0	0
0.0002	200	2.301	0	0
		SUM	**17**	**13**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
10	0	0	0	
9	0	0	0	0.331
8	0	0	0	0.146
7	0	0	0	0.319
6	0	0	0	0.301
5	0	0	0	0.301
4	0	0	0	0.301
3	0	0	0	0.176
2	2	4	8	0.301
1	8	8	8	0.301
0	3	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
c	**N_S**	**A**	**B**	**d**
3.079	13	12	16	0.283

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
9	0	0	0	
8	0	0	0	0.331
7	0	0	0	0.146
6	0	0	0	0.319
5	0	0	0	0.301
4	0	0	0	0.301
3	1	3	9	0.301
2	3	6	12	0.176
1	9	9	9	0.301
0	4	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
c	**N_S**	**A**	**B**	**d**
3.398	17	18	30	0.283

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
3.482 log(pF)
3035 pF
0.0030 µF
0.038 J
s (using negatives)
0.1870 pF
0.002 mJ

H_{50} (using positives)
3.556 log(pF)
3599 pF
0.0036 µF
0.045 J
s (using positives)
0.3085 pF
0.004 mJ

Figure B 39: LS # 4-5-A10 – Bruceton H_{50} for ABL ESD

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity

Sample: **LS4-5-A20**

$H_{50} = c + d\ (A/N_S \pm 0.5)$

NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height (cm)	log(cm)	Frequency +	Frequency -
100	2.0	3	24
79.4	1.9	0	3
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
	SUM	3	27

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
1	24	24	24	
0	3	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
1.900	27	24	24	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
0	3	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.000	3	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.038	log(cm)
109.2	cm
s (using negatives)	
0.0206	log(cm)
1.0	cm

H_{50} (using positives)	
1.950	log(cm)
89.2	cm
s (using positives)	
0.0047	log(cm)
1.0	cm

Figure B 40: LS # 4-5-A20 – Bruceton H_{50} for MBOM Impact

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity

Sample: **LS4-5-A20**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

RSI Level (lbf)	RSI Level log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	0	0
795.0	2.9	0	0
635.0	2.8	1	0
505.0	2.7	2	0
400.0	2.6	1	1
320.0	2.5	1	0
255.0	2.4	3	0
200.0	2.3	5	2
160.0	2.2	4	4
127.0	2.1	1	4
100.0	2.0	0	1
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0 0.000	0	0
	SUM	18	12

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
12	0	0	0	
11	0	0	0	0.094
10	0	0	0	0.107
9	0	0	0	0.100
8	0	0	0	0.098
7	0	0	0	0.099
6	1	6	36	0.101
5	0	0	0	0.097
4	0	0	0	0.099
3	2	6	18	0.106
2	4	8	16	0.097
1	4	4	4	0.100
0	1	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	N_S	A	B	d
2.000	12	24	74	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
11	0	0	0	
10	0	0	0	0.094
9	0	0	0	0.107
8	0	0	0	0.100
7	1	7	49	0.098
6	2	12	72	0.099
5	1	5	25	0.101
4	1	4	16	0.097
3	3	9	27	0.099
2	5	10	20	0.106
1	4	4	4	0.097
0	1	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	N_S	A	B	d
2.104	18	51	213	0.100

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.249 log(lbf)
177.4072 lbf
s (using negatives)
0.3542 log(lbf)
2.260654 lbf

H_{50} (using positives)
2.336 log(lbf)
216.8586759 lbf
s (using positives)
0.6186 log(lbf)
4.155674675 lbf

Figure B 41: LS # 4-5-A20 – Bruceton H_{50} for ABL Friction

Calculation of 50% initiation level from Bruceton data

ABL ESD Sensitivity

Sample: **LS4-5-A20**

Test voltage: 5 kV
Unit conversion: 1000000 pF / µF

$H_{50} = c + d\,(A/N_S \pm 0.5)$

NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Nominal Capacitance (µF)	(pF)	log(pF)	Frequency +	-
0.750	750000	5.875	1	0
0.350	350000	5.544	0	0
0.250	250000	5.398	0	0
0.120	120000	5.079	0	0
0.060	60000	4.778	0	0
0.030	30000	4.477	0	0
0.015	15000	4.176	2	0
0.010	10000	4.000	3	1
0.0050	5000	3.699	7	2
0.0025	2500	3.398	4	6
0.0012	1200	3.079	0	4
0.0007	700	2.845	0	0
0.0003	300	2.477	0	0
0.0002	200	2.301	0	0
		SUM	**17**	**13**

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
10	0	0	0	
9	0	0	0	0.331
8	0	0	0	0.146
7	0	0	0	0.319
6	0	0	0	0.301
5	0	0	0	0.301
4	0	0	0	0.301
3	1	3	9	0.176
2	2	4	8	0.301
1	6	6	6	0.301
0	4	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
c	**N_S**	**A**	**B**	**d**
3.079	13	13	23	0.283

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
9	1	9	81	
8	0	0	0	0.331
7	0	0	0	0.146
6	0	0	0	0.319
5	0	0	0	0.301
4	0	0	0	0.301
3	2	6	18	0.301
2	3	6	12	0.176
1	7	7	7	0.301
0	4	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
c	**N_S**	**A**	**B**	**d**
3.398	17	28	118	0.283

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
3.504	log(pF)
3191	pF
0.0032	**µF**
0.040	**J**
s (using negatives)	
0.3662	**pF**
0.005	**mJ**

H_{50} (using positives)	
3.723	log(pF)
5281	pF
0.0053	**µF**
0.066	**J**
s (using positives)	
1.9530	**pF**
0.024	**mJ**

Figure B 42: LS # 4-5-A20 – Bruceton H_{50} for ABL ESD

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity

Sample: **LS4-5-A30**

$H_{50} = c + d\ (A/N_S \pm 0.5)$

NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height (cm)	Drop Height log(cm)	Frequency +	Frequency -
100	2.0	1	0
79.4	1.9	1	0
63.1	1.8	1	0
50.1	1.7	1	0
39.8	1.6	1	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	3	1
15.8	1.2	4	3
12.6	1.1	3	4
10.0	1.0	2	3
7.9	0.9	0	2
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
	SUM	17	13

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
11	0	0	0	
10	0	0	0	0.100
9	0	0	0	0.100
8	0	0	0	0.100
7	0	0	0	0.100
6	0	0	0	0.100
5	0	0	0	0.100
4	1	4	16	0.099
3	3	9	27	0.102
2	4	8	16	0.098
1	3	3	3	0.100
0	2	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
0.898	13	24	62	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
10	1	10	100	
9	1	9	81	0.100
8	1	8	64	0.100
7	1	7	49	0.100
6	1	6	36	0.100
5	0	0	0	0.100
4	0	0	0	0.100
3	3	9	27	0.099
2	4	8	16	0.102
1	3	3	3	0.098
0	2	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
1.000	17	60	376	0.100

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
1.131 log(cm)
13.5 cm
s (using negatives)
0.2244 log(cm)
1.7 cm

H_{50} (using positives)
1.302 log(cm)
20.0 cm
s (using positives)
1.5644 log(cm)
36.7 cm

Figure B 43: LS # 4-5-A30 – Bruceton H_{50} for MBOM Impact

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity

Sample: **LS4-5-A30**

$H_{50} = c + d\,(A/N_S \pm 0.5)$

NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height (cm)	log(cm)	Frequency +	Frequency -
100	2.0	1	0
79.4	1.9	1	0
63.1	1.8	1	0
50.1	1.7	1	0
39.8	1.6	1	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	3	1
15.8	1.2	4	3
12.6	1.1	3	4
10.0	1.0	2	3
7.9	0.9	0	2
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
	SUM	17	13

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
11	0	0	0	
10	0	0	0	0.100
9	0	0	0	0.100
8	0	0	0	0.100
7	0	0	0	0.100
6	0	0	0	0.100
5	0	0	0	0.100
4	1	4	16	0.099
3	3	9	27	0.102
2	4	8	16	0.098
1	3	3	3	0.100
0	2	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
0.898	13	24	62	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
10	1	10	100	
9	1	9	81	0.100
8	1	8	64	0.100
7	1	7	49	0.100
6	1	6	36	0.100
5	0	0	0	0.100
4	0	0	0	0.100
3	3	9	27	0.099
2	4	8	16	0.102
1	3	3	3	0.098
0	2	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
1.000	17	60	376	0.100

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
1.131 log(cm)	13.5 cm
s (using negatives)	
0.2244 log(cm)	1.7 cm

H_{50} (using positives)	
1.302 log(cm)	20.0 cm
s (using positives)	
1.5644 log(cm)	36.7 cm

Figure B 44: LS # 4-5-A30 – Bruceton H_{50} for ABL Friction

Calculation of 50% initiation level from Bruceton data

ABL ESD Sensitivity

Sample: **LS4-5-A30**

Test voltage: 5 kV
Unit conversion: 1000000 pF / µF

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.
where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$
where $B = \Sigma i^2 \cdot n_i$

Nominal Capacitance			Frequency	
(µF)	(pF)	log(pF)	+	-
0.750	750000	5.875	1	0
0.350	350000	5.544	0	0
0.250	250000	5.398	0	0
0.120	120000	5.079	0	0
0.060	60000	4.778	0	0
0.030	30000	4.477	0	0
0.015	15000	4.176	3	0
0.010	10000	4.000	4	2
0.0050	5000	3.699	5	4
0.0025	2500	3.398	3	5
0.0012	1200	3.079	0	3
0.0007	700	2.845	0	0
0.0003	300	2.477	0	0
0.0002	200	2.301	0	0
		SUM	**16**	**14**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
10	0	0	0	
9	0	0	0	0.331
8	0	0	0	0.146
7	0	0	0	0.319
6	0	0	0	0.301
5	0	0	0	0.301
4	0	0	0	0.301
3	2	6	18	0.176
2	4	8	16	0.301
1	5	5	5	0.301
0	3	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
c	**N_S**	**A**	**B**	**d**
3.079	14	19	39	0.283

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
9	1	9	81	
8	0	0	0	0.331
7	0	0	0	0.146
6	0	0	0	0.319
5	0	0	0	0.301
4	0	0	0	0.301
3	3	9	27	0.301
2	4	8	16	0.176
1	5	5	5	0.301
0	3	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
c	**N_S**	**A**	**B**	**d**
3.398	16	31	129	0.283

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
3.605	log(pF)
4028	pF
0.0040	**µF**
0.050	**J**
s (using negatives)	
0.4463	**pF**
0.006	**mJ**

H_{50} (using positives)	
3.805	log(pF)
6382	pF
0.0064	**µF**
0.080	**J**
s (using positives)	
1.9897	**pF**
0.025	**mJ**

Figure B 45: LS # 4-5-A30 – Bruceton H_{50} for ABL ESD

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity

Sample: **LS4-5-B10**

$H_{50} = c + d\,(A/N_S \pm 0.5)$

NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height (cm)	Drop Height log(cm)	Frequency +	Frequency -
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
	SUM	**0**	**30**

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.050 log(cm)
112.2 cm
s (using negatives)
0.0047 log(cm)
1.0 cm

H_{50} (using positives)
#NAME? log(cm)
#NAME? cm
s (using positives)
#DIV/0! log(cm)
#DIV/0! cm

Figure B 46: LS # 4-5-B10 – Bruceton H_{50} for MBOM Impact

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity

Sample: **LS4-5-B10**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

RSI Level (lbf)	RSI Level log(lbf)	Frequency +	Frequency -
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	6	15
795.0	2.9	1	7
635.0	2.8	0	1
505.0	2.7	0	0
400.0	2.6	0	0
320.0	2.5	0	0
255.0	2.4	0	0
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0 0.000	0	0
	SUM	**7**	**23**

CALCULATIONS USING NEGATIVES				
i	**n(-)**	**i(-)·n(-)**	**i^2(-)·n(-)**	**Interval**
4	0	0	0	
3	0	0	0	0.094
2	15	30	60	0.107
1	7	7	7	0.100
0	1	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.803	23	37	67	0.100

CALCULATIONS USING POSITIVES				
i(+)	**n(+)**	**i(+)·n(+)**	**i^2(+)·n(+)**	**Interval**
3	0	0	0	
2	0	0	0	0.094
1	6	6	6	0.107
0	1	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.900	7	6	6	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
3.013	log(lbf)
1029.854	lbf
s (using negatives)	
0.0571	log(lbf)
1.140604	lbf

H_{50} (using positives)	
2.936	log(lbf)
862.8483	lbf
s (using positives)	
0.0244	log(lbf)
1.057874	lbf

Figure B 47: LS # 4-5- B10 – Bruceton H_{50} for ABL Friction

Calculation of 50% initiation level from Bruceton data

ABL ESD Sensitivity

Sample: **LS4-5-B10**

Test voltage: 5 kV
Unit conversion: 1000000 pF / µF

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.
where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$
where $B = \Sigma i^2 \cdot n_i$

Nominal Capacitance			Frequency	
(µF)	(pF)	log(pF)	+	-
0.750	750000	5.875	0	0
0.350	350000	5.544	0	0
0.250	250000	5.398	0	0
0.120	120000	5.079	0	0
0.060	60000	4.778	0	0
0.030	30000	4.477	0	0
0.015	15000	4.176	2	0
0.010	10000	4.000	8	1
0.0050	5000	3.699	5	7
0.0025	2500	3.398	1	5
0.0012	1200	3.079	0	1
0.0007	700	2.845	0	0
0.0003	300	2.477	0	0
0.0002	200	2.301	0	0
		SUM	**16**	**14**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
10	0	0	0	
9	0	0	0	0.331
8	0	0	0	0.146
7	0	0	0	0.319
6	0	0	0	0.301
5	0	0	0	0.301
4	0	0	0	0.301
3	1	3	9	0.176
2	7	14	28	0.301
1	5	5	5	0.301
0	1	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
c	**N_S**	**A**	**B**	**d**
3.079	14	22	42	0.283

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
9	0	0	0	
8	0	0	0	0.331
7	0	0	0	0.146
6	0	0	0	0.319
5	0	0	0	0.301
4	0	0	0	0.301
3	2	6	18	0.301
2	8	16	32	0.176
1	5	5	5	0.301
0	1	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
c	**N_S**	**A**	**B**	**d**
3.398	16	27	55	0.283

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
3.666 log(pF)
4632 pF
0.0046 µF
0.058 J
s (using negatives)
0.2567 pF
0.003 mJ

H_{50} (using positives)
3.734 log(pF)
5422 pF
0.0054 µF
0.068 J
s (using positives)
0.2839 pF
0.004 mJ

Figure B 48: LS # 4-5- B10 – Bruceton H_{50} for ABL ESD

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity

Sample: **LS4-5-B20**

$H_{50} = c + d\ (A/N_S \pm 0.5)$

NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
	SUM	**0**	**30**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#NAME?	log(cm)
#NAME?	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B 49: LS # 4-5-B20 – Bruceton H_{50} for MBOM Impact

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity

Sample: **LS4-5-B20**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

RSI Level			Frequency	
(cm)	log(lbf)		+	-
1590	3.2		0	0
1280.0	3.1		0	0
1000.0	3.0		0	0
795.0	2.9		0	0
635.0	2.8		0	0
505.0	2.7		5	0
400.0	2.6		7	5
320.0	2.5		3	7
255.0	2.4		0	3
200.0	2.3		0	0
160.0	2.2		0	0
127.0	2.1		0	0
100.0	2.0		0	0
80.0	1.9		0	0
64.0	1.8		0	0
51.0	1.7		0	0
0.0000	0	0.000	0	0
	SUM		15	15

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
8	0	0	0	
7	0	0	0	0.094
6	0	0	0	0.107
5	0	0	0	0.100
4	0	0	0	0.098
3	0	0	0	0.099
2	5	10	20	0.101
1	7	7	7	0.097
0	3	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	N_S	A	B	d
2.407	15	17	27	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
7	0	0	0	
6	0	0	0	0.094
5	0	0	0	0.107
4	0	0	0	0.100
3	0	0	0	0.098
2	5	10	20	0.099
1	7	7	7	0.101
0	3	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	N_S	A	B	d
2.505	15	17	27	0.100

USE EITHER NEGATIVES OR POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.569	log(lbf)
370.8526	lbf
s (using negatives)	
0.0879	log(lbf)
1.224207	lbf

H_{50} (using positives)	
2.568	log(lbf)
370.0178	lbf
s (using positives)	
0.0879	log(lbf)
1.224207	lbf

Figure B 50: LS # 4-5- B20 – Bruceton H_{50} for ABL Friction

Calculation of 50% initiation level from Bruceton data

ABL ESD Sensitivity

Sample: **LS4-5-B20**

Test voltage: 5 kV
Unit conversion: 1000000 pF / µF

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Nominal Capacitance			Frequency	
(µF)	(pF)	log(pF)	+	-
0.750	750000	5.875	0	0
0.350	350000	5.544	0	0
0.250	250000	5.398	0	0
0.120	120000	5.079	0	0
0.060	60000	4.778	0	0
0.030	30000	4.477	0	0
0.015	15000	4.176	1	0
0.010	10000	4.000	3	1
0.0050	5000	3.699	7	2
0.0025	2500	3.398	3	6
0.0012	1200	3.079	2	3
0.0007	700	2.845	0	2
0.0003	300	2.477	0	0
0.0002	200	2.301	0	0
		SUM	16	14

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
11	0	0	0	
10	0	0	0	0.331
9	0	0	0	0.146
8	0	0	0	0.319
7	0	0	0	0.301
6	0	0	0	0.301
5	0	0	0	0.301
4	1	4	16	0.176
3	2	6	18	0.301
2	6	12	24	0.301
1	3	3	3	0.319
0	2	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
c	N_S	A	B	d
2.845	14	25	61	0.283

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
10	0	0	0	
9	0	0	0	0.331
8	0	0	0	0.146
7	0	0	0	0.319
6	0	0	0	0.301
5	0	0	0	0.301
4	1	4	16	0.301
3	3	9	27	0.176
2	7	14	28	0.301
1	3	3	3	0.301
0	2	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
c	N_S	A	B	d
3.079	16	30	74	0.283

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
3.492 log(pF)
3107 pF
0.0031 µF
0.039 J
s (using negatives)
0.5493 pF
0.007 mJ

H_{50} (using positives)
3.469 log(pF)
2941 pF
0.0029 µF
0.037 J
s (using positives)
0.5222 pF
0.007 mJ

Figure B 51: LS # 4-5- B20 – Bruceton H_{50} for ABL ESD

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity

Sample: **LS4-5-B30**

$H_{50} = c + d\ (A/N_S \pm 0.5)$

NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height (cm)	Drop Height log(cm)	Frequency +	Frequency -
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
	SUM	**0**	**30**

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#NAME?	log(cm)
#NAME?	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B 52: LS # 4-5-B30 – Bruceton H_{50} for MBOM Impact

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity

Sample: **LS4-5-B30**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i{\cdot}n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2{\cdot}n_i$

RSI Level		Frequency	
(cm)	log(lbf)	+	-
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	0	0
795.0	2.9	0	0
635.0	2.8	1	0
505.0	2.7	2	1
400.0	2.6	6	1
320.0	2.5	4	4
255.0	2.4	4	3
200.0	2.3	0	4
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0 0.000	0	0
	SUM	**17**	**13**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
9	0	0	0	
8	0	0	0	0.094
7	0	0	0	0.107
6	0	0	0	0.100
5	0	0	0	0.098
4	1	4	16	0.099
3	1	3	9	0.101
2	4	8	16	0.097
1	3	3	3	0.099
0	4	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.301	13	18	44	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
8	0	0	0	
7	0	0	0	0.094
6	0	0	0	0.107
5	0	0	0	0.100
4	1	4	16	0.098
3	2	6	18	0.099
2	6	12	24	0.101
1	4	4	4	0.097
0	4	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.407	17	26	62	0.100

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.489 log(lbf)
308.1172 lbf

s (using negatives)
0.2414 log(lbf)
1.743525 lbf

H_{50} (using positives)
2.509 log(lbf)
322.8923 lbf

s (using positives)
0.2157 log(lbf)
1.643221 lbf

Figure B 53: LS # 4-5- B30 – Bruceton H_{50} for ABL Friction

Calculation of 50% initiation level from Bruceton data

ABL ESD Sensitivity

Sample: **LS4-5-B30**

Test voltage: 5 kV
Unit conversion: 1000000 pF / µF

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.
where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$
where $B = \Sigma i^2 \cdot n_i$

Nominal Capacitance			Frequency	
(µF)	(pF)	log(pF)	+	-
0.750	750000	5.875	0	0
0.350	350000	5.544	0	0
0.250	250000	5.398	0	0
0.120	120000	5.079	0	0
0.060	60000	4.778	0	0
0.030	30000	4.477	0	0
0.015	15000	4.176	0	0
0.010	10000	4.000	3	0
0.0050	5000	3.699	4	2
0.0025	2500	3.398	5	3
0.0012	1200	3.079	4	5
0.0007	700	2.845	0	4
0.0003	300	2.477	0	0
0.0002	200	2.301	0	0
		SUM	16	14

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
11	0	0	0	
10	0	0	0	0.331
9	0	0	0	0.146
8	0	0	0	0.319
7	0	0	0	0.301
6	0	0	0	0.301
5	0	0	0	0.301
4	0	0	0	0.176
3	2	6	18	0.301
2	3	6	12	0.301
1	5	5	5	0.319
0	4	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
c	N_S	A	B	d
2.845	14	17	35	0.283

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
10	0	0	0	
9	0	0	0	0.331
8	0	0	0	0.146
7	0	0	0	0.319
6	0	0	0	0.301
5	0	0	0	0.301
4	0	0	0	0.301
3	3	9	27	0.176
2	4	8	16	0.301
1	5	5	5	0.301
0	4	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
c	N_S	A	B	d
3.079	16	22	48	0.283

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
3.331	log(pF)
2141	pF
0.0021	**µF**
0.027	**J**
s (using negatives)	
0.4837	**pF**
0.006	**mJ**

H_{50} (using positives)	
3.327	log(pF)
2123	pF
0.0021	**µF**
0.027	**J**
s (using positives)	
0.5222	**pF**
0.007	**mJ**

Figure B 54: LS # 4-5- B30 – Bruceton H_{50} for ABL ESD

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity

Sample: **LS4-5-C10**

$H_{50} = c + d\,(A/N_S \pm 0.5)$

NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height (cm)	Drop Height log(cm)	Frequency +	Frequency -
100	2.0	2	0
79.4	1.9	2	2
63.1	1.8	3	3
50.1	1.7	4	4
39.8	1.6	3	3
31.6	1.5	0	3
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
	SUM	14	15

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
5	0	0	0	
4	2	8	32	0.100
3	3	9	27	0.100
2	4	8	16	0.100
1	3	3	3	0.100
0	3	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
1.500	15	28	78	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
4	2	8	32	
3	2	6	18	0.100
2	3	6	12	0.100
1	4	4	4	0.100
0	3	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
1.600	14	24	66	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
1.736 log(cm)
54.4 cm
s (using negatives)
0.2816 log(cm)
1.9 cm

H_{50} (using positives)
1.721 log(cm)
52.6 cm
s (using positives)
0.2913 log(cm)
2.0 cm

Figure B 55: LS # 4-5-C10 – Bruceton H_{50} for MBOM Impact

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity

Sample: **LS4-5-C10**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

RSI Level (cm)	log(lbf)		Frequency +	Frequency -
1590	3.2		0	0
1280.0	3.1		0	0
1000.0	3.0		5	11
795.0	2.9		4	4
635.0	2.8		2	3
505.0	2.7		0	1
400.0	2.6		0	0
320.0	2.5		0	0
255.0	2.4		0	0
200.0	2.3		0	0
160.0	2.2		0	0
127.0	2.1		0	0
100.0	2.0		0	0
80.0	1.9		0	0
64.0	1.8		0	0
51.0	1.7		0	0
0.0000	0	0.000	0	0
	SUM		**11**	**19**

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
5	0	0	0	
4	0	0	0	0.094
3	11	33	99	0.107
2	4	8	16	0.100
1	3	3	3	0.098
0	1	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.703	19	44	118	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
4	0	0	0	
3	0	0	0	0.094
2	5	10	20	0.107
1	4	4	4	0.100
0	2	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.803	11	14	24	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.984 log(lbf)
963.189 lbf
s (using negatives)
0.1414 log(lbf)
1.384944 lbf

H_{50} (using positives)
2.880 log(lbf)
758.1034 lbf
s (using positives)
0.0953 log(lbf)
1.245505 lbf

Figure B 56: LS # 4-5- C10 – Bruceton H_{50} for ABL Friction

Calculation of 50% initiation level from Bruceton data

ABL ESD Sensitivity

Sample: **LS4-5-C10**

Test voltage: 5 kV
Unit conversion: 1000000 pF / µF

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Nominal Capacitance			Frequency	
(µF)	(pF)	log(pF)	+	-
0.750	750000	5.875	0	0
0.350	350000	5.544	0	0
0.250	250000	5.398	0	0
0.120	120000	5.079	0	0
0.060	60000	4.778	1	0
0.030	30000	4.477	3	1
0.015	15000	4.176	5	3
0.010	10000	4.000	4	5
0.0050	5000	3.699	2	4
0.0025	2500	3.398	0	2
0.0012	1200	3.079	0	0
0.0007	700	2.845	0	0
0.0003	300	2.477	0	0
0.0002	200	2.301	0	0
		SUM	15	15

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
9	0	0	0	
8	0	0	0	0.331
7	0	0	0	0.146
6	0	0	0	0.319
5	0	0	0	0.301
4	1	4	16	0.301
3	3	9	27	0.301
2	5	10	20	0.176
1	4	4	4	0.301
0	2	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
c	N_S	A	B	d
3.398	15	27	67	0.283

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
8	0	0	0	
7	0	0	0	0.331
6	0	0	0	0.146
5	0	0	0	0.319
4	1	4	16	0.301
3	3	9	27	0.301
2	5	10	20	0.301
1	4	4	4	0.176
0	2	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
c	N_S	A	B	d
3.699	15	27	67	0.283

USE EITHER NEGATIVES OR POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
4.049 log(pF)
11200 pF
0.0112 µF
0.140 J
s (using negatives)
0.5760 pF
0.007 mJ

H_{50} (using positives)
4.067 log(pF)
11670 pF
0.0117 µF
0.146 J
s (using positives)
0.5760 pF
0.007 mJ

Figure B 57: LS # 4-5- C10 – Bruceton H_{50} for ABL ESD

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity

Sample: **LS4-5-C20**

$H_{50} = c + d\,(A/N_S \pm 0.5)$

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	1	1
79.4	1.9	1	0
63.1	1.8	2	0
50.1	1.7	2	1
39.8	1.6	2	1
31.6	1.5	4	2
25.1	1.4	2	4
20.0	1.3	1	3
15.8	1.2	1	1
12.6	1.1	0	1
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
	SUM	**16**	**14**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
9	1	9	81	
8	0	0	0	0.100
7	0	0	0	0.100
6	1	6	36	0.100
5	1	5	25	0.100
4	2	8	32	0.100
3	4	12	36	0.100
2	3	6	12	0.099
1	1	1	1	0.102
0	1	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
1.100	14	47	223	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
8	1	8	64	
7	1	7	49	0.100
6	2	12	72	0.100
5	2	10	50	0.100
4	2	8	32	0.100
3	4	12	36	0.100
2	2	4	8	0.100
1	1	1	1	0.099
0	1	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
1.199	16	62	312	0.100

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
1.485 log(cm)
30.5 cm
s (using negatives)
0.7567 log(cm)
5.7 cm

H_{50} (using positives)
1.535 log(cm)
34.3 cm
s (using positives)
0.7287 log(cm)
5.4 cm

Figure B 58: LS # 4-5-C20 – Bruceton H_{50} for MBOM Impact

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity

Sample: **LS4-5-C20**

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.
where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$
where $B = \Sigma i^2 \cdot n_i$

RSI Level			Frequency	
(cm)	log(lbf)		+	-
1590	3.2		0	0
1280.0	3.1		0	0
1000.0	3.0		3	19
795.0	2.9		2	4
635.0	2.8		0	2
505.0	2.7		0	0
400.0	2.6		0	0
320.0	2.5		0	0
255.0	2.4		0	0
200.0	2.3		0	0
160.0	2.2		0	0
127.0	2.1		0	0
100.0	2.0		0	0
80.0	1.9		0	0
64.0	1.8		0	0
51.0	1.7		0	0
0.0000	0	0.000	0	0
	SUM		5	25

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	$i^2(-)\cdot n(-)$	Interval
4	0	0	0	
3	0	0	0	0.094
2	19	38	76	0.107
1	4	4	4	0.100
0	2	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	N_S	A	B	d
2.803	25	42	80	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	$i^2(+)\cdot n(+)$	Interval
3	0	0	0	
2	0	0	0	0.094
1	3	3	3	0.107
0	2	0	0	0.100
FALSE	0	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	N_S	A	B	d
2.900	5	3	3	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
3.020	log(lbf)
1046.831	lbf
s (using negatives)	
0.0656	log(lbf)
1.163049	lbf

H_{50} (using positives)	
2.910	log(lbf)
813.4408	lbf
s (using positives)	
0.0434	log(lbf)
1.105093	lbf

Figure B 59: LS # 4-5- C20 – Bruceton H_{50} for ABL Friction

Calculation of 50% initiation level from Bruceton data

ABL ESD Sensitivity

Sample: **LS4-5-C20**

Test voltage: 5 kV
Unit conversion: 1000000 pF / µF

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.
where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$
where $B = \Sigma i^2 \cdot n_i$

Nominal Capacitance			Frequency	
(µF)	(pF)	log(pF)	+	-
0.750	750000	5.875	0	0
0.350	350000	5.544	0	0
0.250	250000	5.398	0	0
0.120	120000	5.079	0	0
0.060	60000	4.778	0	0
0.030	30000	4.477	0	0
0.015	15000	4.176	2	0
0.010	10000	4.000	6	1
0.0050	5000	3.699	7	5
0.0025	2500	3.398	1	7
0.0012	1200	3.079	0	0
0.0007	700	2.845	0	0
0.0003	300	2.477	0	0
0.0002	200	2.301	0	1
		SUM	**16**	**14**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
13	0	0	0	
12	0	0	0	0.331
11	0	0	0	0.146
10	0	0	0	0.319
9	0	0	0	0.301
8	0	0	0	0.301
7	0	0	0	0.301
6	1	6	36	0.176
5	5	25	125	0.301
4	7	28	112	0.301
3	0	0	0	0.319
2	0	0	0	0.234
1	0	0	0	0.368
0	1	0	0	0.176
c	**N_S**	**A**	**B**	**d**
2.301	14	59	273	0.283

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
9	0	0	0	
8	0	0	0	0.331
7	0	0	0	0.146
6	0	0	0	0.319
5	0	0	0	0.301
4	0	0	0	0.301
3	2	6	18	0.301
2	6	12	24	0.176
1	7	7	7	0.301
0	1	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
c	**N_S**	**A**	**B**	**d**
3.398	16	25	49	0.283

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
3.636 log(pF)
4324 pF
0.0043 µF
0.054 J
s (using negatives)
0.8114 pF
0.010 mJ

H_{50} (using positives)
3.699 log(pF)
4998 pF
0.0050 µF
0.062 J
s (using positives)
0.2982 pF
0.004 mJ

Figure B 60: LS # 4-5- C20 – Bruceton H_{50} for ABL ESD

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity

Sample: **LS4-5-C30**

$H_{50} = c + d\ (A/N_S \pm 0.5)$

NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	1	1
79.4	1.9	2	0
63.1	1.8	4	1
50.1	1.7	2	3
39.8	1.6	3	0
31.6	1.5	4	1
25.1	1.4	2	3
20.0	1.3	1	1
15.8	1.2	0	1
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
	SUM	19	11

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
8	1	8	64	
7	0	0	0	0.100
6	1	6	36	0.100
5	3	15	75	0.100
4	0	0	0	0.100
3	1	3	9	0.100
2	3	6	12	0.100
1	1	1	1	0.099
0	1	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
1.199	11	39	197	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
7	1	7	49	
6	2	12	72	0.100
5	4	20	100	0.100
4	2	8	32	0.100
3	3	9	27	0.100
2	4	8	16	0.100
1	2	2	2	0.100
0	1	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
1.301	19	66	298	0.100

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
1.602 log(cm)
40.0 cm
s (using negatives)
0.8666 log(cm)
7.4 cm

H_{50} (using positives)
1.597 log(cm)
39.6 cm
s (using positives)
0.5887 log(cm)
3.9 cm

Figure B 61: LS # 4-5-C30 – Bruceton H_{50} for MBOM Impact

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity

Sample: **LS4-5-C30**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

RSI Level			Frequency	
(cm)	log(lbf)		+	-
1590	3.2		0	0
1280.0	3.1		0	0
1000.0	3.0		5	12
795.0	2.9		3	5
635.0	2.8		2	2
505.0	2.7		0	1
400.0	2.6		0	0
320.0	2.5		0	0
255.0	2.4		0	0
200.0	2.3		0	0
160.0	2.2		0	0
127.0	2.1		0	0
100.0	2.0		0	0
80.0	1.9		0	0
64.0	1.8		0	0
51.0	1.7		0	0
0.0000	0	0.000	0	0
	SUM		**10**	**20**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
5	0	0	0	
4	0	0	0	0.094
3	12	36	108	0.107
2	5	10	20	0.100
1	2	2	2	0.098
0	1	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.703	20	48	130	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
4	0	0	0	
3	0	0	0	0.094
2	5	10	20	0.107
1	3	3	3	0.100
0	2	0	0	0.098
FALSE	0	0	0	0.099
FALSE	0	0	0	0.101
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.803	10	13	23	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.992	log(lbf)
981.9693	lbf
s (using negatives)	
0.1241	log(lbf)
1.330655	lbf

H_{50} (using positives)	
2.882	log(lbf)
762.8594	lbf
s (using positives)	
0.1031	log(lbf)
1.26792	lbf

Figure B 62: LS # 4-5- C30 – Bruceton H_{50} for ABL Friction

Calculation of 50% initiation level from Bruceton data

ABL ESD Sensitivity

Sample: **LS4-5-C30**

Test voltage: 5 kV
Unit conversion: 1000000 pF / µF

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Nominal Capacitance			Frequency	
(µF)	(pF)	log(pF)	+	-
0.750	750000	5.875	0	0
0.350	350000	5.544	0	0
0.250	250000	5.398	0	0
0.120	120000	5.079	0	0
0.060	60000	4.778	0	0
0.030	30000	4.477	0	0
0.015	15000	4.176	5	0
0.010	10000	4.000	5	4
0.0050	5000	3.699	4	6
0.0025	2500	3.398	0	4
0.0012	1200	3.079	0	1
0.0007	700	2.845	0	0
0.0003	300	2.477	0	0
0.0002	200	2.301	0	1
		SUM	**14**	**16**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
13	0	0	0	
12	0	0	0	0.331
11	0	0	0	0.146
10	0	0	0	0.319
9	0	0	0	0.301
8	0	0	0	0.301
7	0	0	0	0.301
6	4	24	144	0.176
5	6	30	150	0.301
4	4	16	64	0.301
3	1	3	9	0.319
2	0	0	0	0.234
1	0	0	0	0.368
0	1	0	0	0.176
c	**N_S**	**A**	**B**	**d**
2.301	16	73	367	0.283

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
8	0	0	0	
7	0	0	0	0.331
6	0	0	0	0.146
5	0	0	0	0.319
4	0	0	0	0.301
3	0	0	0	0.301
2	5	10	20	0.301
1	5	5	5	0.176
0	4	0	0	0.301
FALSE	0	0	0	0.301
FALSE	0	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
c	**N_S**	**A**	**B**	**d**
3.699	14	15	25	0.283

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
3.735	log(pF)
5427	pF
0.0054	**µF**
0.068	**J**
s (using negatives)	
0.9863	**pF**
0.012	**mJ**

H_{50} (using positives)	
3.861	log(pF)
7257	pF
0.0073	**µF**
0.091	**J**
s (using positives)	
0.3059	**pF**
0.004	**mJ**

Figure B 63: LS # 4-5- C30 – Bruceton H_{50} for ABL ESD

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity

Sample: **LS4-5-D10**

$H_{50} = c + d\,(A/N_S \pm 0.5)$

NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height (cm)	Drop Height log(cm)	Frequency +	Frequency -
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
	SUM	**0**	**30**

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#NAME?	log(cm)
#NAME?	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B 64: LS # 4-5-D10 – Bruceton H_{50} for MBOM Impact

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity

Sample: **LS4-5-D10**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

RSI Level		Frequency	
(cm)	log(lbf)	+	-
1590	3.2	0	0
1280.0	3.1	0	0
1000.0	3.0	1	0
795.0	2.9	1	0
635.0	2.8	3	0
505.0	2.7	7	2
400.0	2.6	1	6
320.0	2.5	4	1
255.0	2.4	0	4
200.0	2.3	0	0
160.0	2.2	0	0
127.0	2.1	0	0
100.0	2.0	0	0
80.0	1.9	0	0
64.0	1.8	0	0
51.0	1.7	0	0
0.0000	0 0.000	0	0
	SUM	17	13

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
8	0	0	0	
7	0	0	0	0.094
6	0	0	0	0.107
5	0	0	0	0.100
4	0	0	0	0.098
3	2	6	18	0.099
2	6	12	24	0.101
1	1	1	1	0.097
0	4	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	N_S	A	B	d
2.407	13	19	43	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
7	0	0	0	
6	0	0	0	0.094
5	1	5	25	0.107
4	1	4	16	0.100
3	3	9	27	0.098
2	7	14	28	0.099
1	1	1	1	0.101
0	4	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	N_S	A	B	d
2.505	17	33	97	0.100

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.602	log(lbf)
399.8405	lbf
s (using negatives)	
0.1937	log(lbf)
1.562055	lbf

H_{50} (using positives)	
2.649	log(lbf)
445.3224	lbf
s (using positives)	
0.3173	log(lbf)
2.076332	lbf

Figure B 65: LS # 4-5- D10 – Bruceton H_{50} for ABL Friction

Calculation of 50% initiation level from Bruceton data

ABL ESD Sensitivity

Sample: **LS4-5-D10**

Test voltage: 5 kV
Unit conversion: 1000000 pF / µF

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.
where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$
where $B = \Sigma i^2 \cdot n_i$

Nominal Capacitance			Frequency	
(µF)	(pF)	log(pF)	+	-
0.750	750000	5.875	0	0
0.350	350000	5.544	0	0
0.250	250000	5.398	0	0
0.120	120000	5.079	0	0
0.060	60000	4.778	0	0
0.030	30000	4.477	2	0
0.015	15000	4.176	3	2
0.010	10000	4.000	3	3
0.0050	5000	3.699	4	3
0.0025	2500	3.398	1	4
0.0012	1200	3.079	1	1
0.0007	700	2.845	1	1
0.0003	300	2.477	0	1
0.0002	200	2.301	0	0
		SUM	**15**	**15**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
12	0	0	0	
11	0	0	0	0.331
10	0	0	0	0.146
9	0	0	0	0.319
8	0	0	0	0.301
7	0	0	0	0.301
6	2	12	72	0.301
5	3	15	75	0.176
4	3	12	48	0.301
3	4	12	36	0.301
2	1	2	4	0.319
1	1	1	1	0.234
0	1	0	0	0.368
FALSE	0	0	0	0.176
c	**N_S**	**A**	**B**	**d**
2.477	15	54	236	0.283

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
11	0	0	0	
10	0	0	0	0.331
9	0	0	0	0.146
8	0	0	0	0.319
7	0	0	0	0.301
6	2	12	72	0.301
5	3	15	75	0.301
4	3	12	48	0.176
3	4	12	36	0.301
2	1	2	4	0.301
1	1	1	1	0.319
0	1	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
c	**N_S**	**A**	**B**	**d**
2.845	15	54	236	0.283

USE EITHER NEGATIVES OR POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
3.638	log(pF)
4346	pF
0.0043	**µF**
0.054	**J**
s (using negatives)	
1.2855	**pF**
0.016	**mJ**

H_{50} (using positives)	
3.723	log(pF)
5283	pF
0.0053	**µF**
0.066	**J**
s (using positives)	
1.2855	**pF**
0.016	**mJ**

Figure B 66: LS # 4-5- D10 – Bruceton H_{50} for ABL ESD

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity

Sample: **LS4-5-D20**

$H_{50} = c + d\ (A/N_S \pm 0.5)$

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height (cm)	log(cm)	Frequency +	Frequency -
100	2.0	1	27
79.4	1.9	0	1
63.1	1.8	0	0
50.1	1.7	0	1
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
	SUM	**1**	**29**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
3	27	81	243	
2	1	2	4	0.100
1	0	0	0	0.100
0	1	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	**N_S**	**A**	**B**	**d**
1.700	29	83	247	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
0	1	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	**N_S**	**A**	**B**	**d**
2.000	1	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
2.035 log(cm)
108.4 cm
s (using negatives)
0.0573 log(cm)
1.1 cm

H_{50} (using positives)
1.950 log(cm)
89.2 cm
s (using positives)
0.0047 log(cm)
1.0 cm

Figure B 67: LS # 4-5-D20 – Bruceton H_{50} for MBOM Impact

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity

Sample: **LS4-5-D20**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

RSI Level (cm)	log(lbf)		Frequency +	-
1590	3.2		0	0
1280.0	3.1		0	0
1000.0	3.0		4	0
795.0	2.9		1	3
635.0	2.8		3	0
505.0	2.7		2	2
400.0	2.6		2	1
320.0	2.5		4	1
255.0	2.4		2	3
200.0	2.3		0	2
160.0	2.2		0	0
127.0	2.1		0	0
100.0	2.0		0	0
80.0	1.9		0	0
64.0	1.8		0	0
51.0	1.7		0	0
0.0000	0	0.000	0	0
	SUM		18	12

CALCULATIONS USING NEGATIVES

i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
9	0	0	0	
8	0	0	0	0.094
7	0	0	0	0.107
6	3	18	108	0.100
5	0	0	0	0.098
4	2	8	32	0.099
3	1	3	9	0.101
2	1	2	4	0.097
1	3	3	3	0.099
0	2	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	N_S	A	B	d
2.301	12	34	156	0.100

CALCULATIONS USING POSITIVES

i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
8	0	0	0	
7	0	0	0	0.094
6	4	24	144	0.107
5	1	5	25	0.100
4	3	12	48	0.098
3	2	6	18	0.099
2	2	4	8	0.101
1	4	4	4	0.097
0	2	0	0	0.099
FALSE	0	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	N_S	A	B	d
2.407	18	55	247	0.100

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.633	log(lbf)
429.5281	lbf
s (using negatives)	
0.8069	log(lbf)
6.410084	lbf

H_{50} (using positives)	
2.661	log(lbf)
458.1883	lbf
s (using positives)	
0.7123	log(lbf)
5.155309	lbf

Figure B 68: LS # 4-5- D20 – Bruceton H_{50} for ABL Friction

Calculation of 50% initiation level from Bruceton data

ABL ESD Sensitivity

Sample: **LS4-5-D20**

Test voltage: 5 kV
Unit conversion: 1000000 pF / µF

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.
where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\,d\,((N_S B - A^2)/N_S^2 + 0.029)$
where $B = \Sigma i^2 \cdot n_i$

Nominal Capacitance			Frequency	
(µF)	(pF)	log(pF)	+	-
0.750	750000	5.875	0	0
0.350	350000	5.544	0	0
0.250	250000	5.398	0	0
0.120	120000	5.079	0	0
0.060	60000	4.778	0	0
0.030	30000	4.477	1	0
0.015	15000	4.176	3	1
0.010	10000	4.000	2	2
0.0050	5000	3.699	5	1
0.0025	2500	3.398	4	5
0.0012	1200	3.079	1	4
0.0007	700	2.845	0	1
0.0003	300	2.477	0	0
0.0002	200	2.301	0	0
		SUM	**16**	**14**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
11	0	0	0	
10	0	0	0	0.331
9	0	0	0	0.146
8	0	0	0	0.319
7	0	0	0	0.301
6	0	0	0	0.301
5	1	5	25	0.301
4	2	8	32	0.176
3	1	3	9	0.301
2	5	10	20	0.301
1	4	4	4	0.319
0	1	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
c	**N_S**	**A**	**B**	**d**
2.845	14	30	90	0.283

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
10	0	0	0	
9	0	0	0	0.331
8	0	0	0	0.146
7	0	0	0	0.319
6	0	0	0	0.301
5	1	5	25	0.301
4	3	12	48	0.301
3	2	6	18	0.176
2	5	10	20	0.301
1	4	4	4	0.301
0	1	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
c	**N_S**	**A**	**B**	**d**
3.079	16	37	115	0.283

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
3.593 log(pF)
3922 pF
0.0039 µF
0.049 J
s (using negatives)
0.8559 pF
0.011 mJ

H_{50} (using positives)
3.592 log(pF)
3912 pF
0.0039 µF
0.049 J
s (using positives)
0.8573 pF
0.011 mJ

Figure B 69: LS # 4-5- D20 – Bruceton H_{50} for ABL ESD

Calculation of 50% initiation level from Bruceton data

MBOM Impact Sensitivity

Sample: **LS4-5-D30**

$H_{50} = c + d\ (A/N_S \pm 0.5)$

NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

Drop Height		Frequency	
(cm)	log(cm)	+	-
100	2.0	0	30
79.4	1.9	0	0
63.1	1.8	0	0
50.1	1.7	0	0
39.8	1.6	0	0
31.6	1.5	0	0
25.1	1.4	0	0
20.0	1.3	0	0
15.8	1.2	0	0
12.6	1.1	0	0
10.0	1.0	0	0
7.9	0.9	0	0
6.3	0.8	0	0
5.0	0.7	0	0
4.0	0.6	0	0
3.2	0.5	0	0
	SUM	0	30

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
0	30	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	
c	N_S	A	B	d
2.000	30	0	0	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
FALSE	0	0	0	
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.100
FALSE	0	0	0	0.099
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.102
FALSE	0	0	0	0.098
FALSE	0	0	0	0.100
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.000
c	N_S	A	B	d
#NAME?	0	0	0	0.100

USE POSITIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.050	log(cm)
112.2	cm
s (using negatives)	
0.0047	log(cm)
1.0	cm

H_{50} (using positives)	
#NAME?	log(cm)
#NAME?	cm
s (using positives)	
#DIV/0!	log(cm)
#DIV/0!	cm

Figure B 70: LS # 4-5-D30 – Bruceton H_{50} for MBOM Impact

Calculation of 50% initiation level from Bruceton data

ABL Friction Sensitivity

Sample: **LS4-5-D30**

$H_{50} = c + d\,(A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.

where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\, d\, ((N_S B - A^2)/N_S^2 + 0.029)$

where $B = \Sigma i^2 \cdot n_i$

RSI Level			Frequency	
(cm)	log(lbf)		+	-
1590	3.2		0	0
1280.0	3.1		0	0
1000.0	3.0		1	0
795.0	2.9		1	0
635.0	2.8		1	0
505.0	2.7		2	0
400.0	2.6		2	1
320.0	2.5		4	1
255.0	2.4		4	3
200.0	2.3		3	4
160.0	2.2		0	3
127.0	2.1		0	0
100.0	2.0		0	0
80.0	1.9		0	0
64.0	1.8		0	0
51.0	1.7		0	0
0.0000	0	0.000	0	0
	SUM		18	12

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
10	0	0	0	
9	0	0	0	0.094
8	0	0	0	0.107
7	0	0	0	0.100
6	0	0	0	0.098
5	0	0	0	0.099
4	1	4	16	0.101
3	1	3	9	0.097
2	3	6	12	0.099
1	4	4	4	0.106
0	3	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	
c	N_S	A	B	d
2.204	12	17	41	0.100

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
9	0	0	0	
8	0	0	0	0.094
7	1	7	49	0.107
6	1	6	36	0.100
5	1	5	25	0.098
4	2	8	32	0.099
3	2	6	18	0.101
2	4	8	16	0.097
1	4	4	4	0.099
0	3	0	0	0.106
FALSE	0	0	0	0.097
FALSE	0	0	0	0.100
FALSE	0	0	0	0.104
FALSE	0	0	0	0.097
FALSE	0	0	0	0.097
FALSE	0	0	0	0.099
FALSE	0	0	0	0.000
c	N_S	A	B	d
2.301	18	44	180	0.100

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)	
2.395	log(lbf)
248.3121	lbf
s (using negatives)	
0.2321	log(lbf)
1.70653	lbf

H_{50} (using positives)	
2.495	log(lbf)
312.3735	lbf
s (using positives)	
0.6540	log(lbf)
4.50812	lbf

Figure B 71: LS # 4-5- D30 – Bruceton H_{50} for ABL Friction

Calculation of 50% initiation level from Bruceton data

ABL ESD Sensitivity

Sample: **LS4-5-D30**

Test voltage: 5 kV
Unit conversion: 1000000 pF / µF

$H_{50} = c + d\ (A/N_S \pm 0.5)$ NOTE: If negative results are used, the sign inside the brackets is positive; it is negative if positive results are used.
where c is the lowest test level, d is the test level interval, $A = \Sigma i \cdot n_i$, and $N_S = \Sigma n_i$

$s = 1.62\ d\ ((N_S B - A^2)/N_S^2 + 0.029)$
where $B = \Sigma i^2 \cdot n_i$

Nominal Capacitance			Frequency	
(µF)	(pF)	log(pF)	+	-
0.750	750000	5.875	1	0
0.350	350000	5.544	0	0
0.250	250000	5.398	0	0
0.120	120000	5.079	1	0
0.060	60000	4.778	1	0
0.030	30000	4.477	1	0
0.015	15000	4.176	2	1
0.010	10000	4.000	3	1
0.0050	5000	3.699	4	2
0.0025	2500	3.398	3	3
0.0012	1200	3.079	2	3
0.0007	700	2.845	0	2
0.0003	300	2.477	0	0
0.0002	200	2.301	0	0
		SUM	**18**	**12**

CALCULATIONS USING NEGATIVES				
i	n(-)	i(-)·n(-)	i^2(-)·n(-)	Interval
11	0	0	0	
10	0	0	0	0.331
9	0	0	0	0.146
8	0	0	0	0.319
7	0	0	0	0.301
6	0	0	0	0.301
5	1	5	25	0.301
4	1	4	16	0.176
3	2	6	18	0.301
2	3	6	12	0.301
1	3	3	3	0.319
0	2	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
c	**N_S**	**A**	**B**	**d**
2.845	12	24	74	0.283

CALCULATIONS USING POSITIVES				
i(+)	n(+)	i(+)·n(+)	i^2(+)·n(+)	Interval
10	1	10	100	
9	0	0	0	0.331
8	0	0	0	0.146
7	1	7	49	0.319
6	1	6	36	0.301
5	1	5	25	0.301
4	2	8	32	0.301
3	3	9	27	0.176
2	4	8	16	0.301
1	3	3	3	0.301
0	2	0	0	0.319
FALSE	0	0	0	0.234
FALSE	0	0	0	0.368
FALSE	0	0	0	0.176
c	**N_S**	**A**	**B**	**d**
3.079	18	56	288	0.283

USE NEGATIVES

NOTE: Calculations are performed using positives or negatives, whichever has the smaller total. If equal, either may be used.

H_{50} (using negatives)
3.553 log(pF)
3573 pF
0.0036 µF
0.045 J
s (using negatives)
1.0072 pF
0.013 mJ

H_{50} (using positives)
3.819 log(pF)
6585 pF
0.0066 µF
0.082 J
s (using positives)
2.9129 pF
0.036 mJ

Figure B 72: LS # 4-5- D30 – Bruceton H_{50} for ABL ESD

APPENDIX C

– IMPACT, FRICTION, AND ESD SENSTIVITY TESTING DATA SHEETS

Material: LS1-6-A10 **Operator:** JAK
Date: 30 May 2023 **Relative Humidty:** 36% **Temperature:** 67°F **Project:** DOT1-6265k

ERL Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI																																	
Level	100	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: LS1-6-A10 **Operator:** JDZ
Date: 31 May 2023 **Relative Humidty:** 39% **Temperature:** 70°F **Project:** DOT1-6265k

ABL ESD	μF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		A																															
Level	0.015 [0.19]	S																														1	0
RSI			A																														
Level	0.010 [0.13]		S																													1	0
RSI				Z																		A											
Level	0.0050 [0.063]			S																		S										2	0
RSI					Z				Z		Z												Z		Z				A		A		
Level	0.0025 [0.031]				S				S		S										F		S		S				S		S	7	1
RSI						Z						Z		Z												Z							
Level	0.0012 [0.015]					S		F		F		S		S						F				F		S		F		F		4	6
RSI															Z		Z																
Level	0.0007 [0.0088]						F						F		S		S		F								F					2	4
RSI																																	
Level	0.0003 [0.0038]															F		F														0	2

Material: LS1-6-A10 **Operator:** DMS
Date: 18 May 2023 **Relative Humidty:** 42% **Temperature:** 64'°F **Project:** DOT1-6265k

ABL Friction	lbf (8ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI												B		BX																			
Level	635											S		S																		2	0
RSI															B		BX		B				B								B		
Level	505										F		F		S		S		S				S								S	5	2
RSI		B						B												B				Z				B					
Level	400	S						S		F						F		F		S		F		S				S		F		5	5
RSI			B		B																				B								
Level	320		S		S		F		F												F				S		F		F			3	5
RSI																																	
Level	255			F		F																				F						0	3

Number indicates amount
<u>of sample consumption</u>
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

<u>Reaction Severity Index (RSI)</u>
T = Flame Trace
M = Smoke
Z = Spark
A = Flame
B = Flash
X = Sample Consumed
L = Loud Report or Explosion
H = Hardware Damage
P = Pop or Small Explosion
HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure C 1: LS # 1-6-A10 Sensitivity Testing Data Sheets

Material: LS1-6-A20 **Operator:** JAK
Date: 30 May 2023 **Relative Humidty:** 37% **Temperature:** 68°F **Project:** DOT1-6265k

ERL Impac	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI				Z									Z			Z								A2		B2					Z		
Level	100	F	F	S		F	F	F	F	F	F	F	S		F	S								S		S				F	S	6	11
RSI																	Z										Z						
Level	79.4				F									F			S						F		F		S		F			2	5
RSI																		Z		B1													
Level	63.1																	S		S		F						F				2	2
RSI																																	
Level	50.1																		F		F											0	2

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: LS1-6-A20 **Operator:** JDZ
Date: 31 May 2023 **Relative Humidty:** 39% **Temperature:** 70°F **Project:** DOT1-6265k

ABL ESD	μF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		A																															
Level	0.015 [0.19]	S																														1	0
RSI			A																														
Level	0.010 [0.13]		S																													1	0
RSI				A																													
Level	0.0050 [0.063]			S																												1	0
RSI					Z				Z		Z				A												Z		Z				
Level	0.0025 [0.031]				S				S		S				S												S		S			6	0
RSI						Z						Z				Z		Z												Z			
Level	0.0012 [0.015]					S		F		F		S		F		S		S								F		F		S		5	5
RSI																			Z				Z								Z		
Level	0.0007 [0.0088]						F						F				F		S				S		F						S	3	4
RSI																				Z													
Level	0.0003 [0.0038]																			S		F		F								1	2
RSI																																	
Level	0.0002 [0.0025]																				F											0	1

Material: LS1-6-A20 **Operator:** DMS
Date: 18 May 2023 **Relative Humidty:** 40% **Temperature:** 65°F **Project:** DOT1-6265k

ABL Fricti	lbf (8ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		Z																															
Level	400	S																														1	0
RSI			Z				Z																		Z								
Level	320		S				S																		S							3	0
RSI				Z				Z								Z				Z						B		B		Z			
Level	255			S		F		S								S				S				F		S		S		S		7	2
RSI									Z		Z						B				Z												
Level	200				F				S		S				F		S		F		S		F				F		F		F	4	7
RSI												Z																					
Level	160									F		S		F				F				F										1	4
RSI																																	
Level	127												F																			0	1

Number indicates amount of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace
M = Smoke
Z = Spark
A = Flame
B = Flash
X = Sample Consumed
L = Loud Report or Explosion
H = Hardware Damage
P = Pop or Small Explosion
HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure C 2: LS # 1-6-A20 Sensitivity Testing Data Sheets

Material: LS1-6-A30 **Operator:** JAK
Date: 31 May 2023 **Relative Humidty:** 38% **Temperature:** 65°F **Project:** DOT1-6265k

ERL Impac	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		Z																															
Level	100	S																														1	0
RSI			Z		B3																												
Level	79.4		S		S																											2	0
RSI						B3																											
Level	63.1			F		S																										1	1
RSI							B2																										
Level	50.1						S																									1	0
RSI								Z								B2		A2		B1		B2											
Level	39.8							S								S		S		S		S										5	0
RSI									B1														B2										
Level	31.6								S						F		F		F		F		S									2	4
RSI										B1		B1												Z									
Level	25.1									S		S		F										S								3	1
RSI																									Z								
Level	20.0										F		F												S							1	2
RSI																										Z							
Level	15.8																									S						1	0
RSI																											B1		B1				
Level	12.6																										S		S			2	0
RSI																														B1			
Level	10.0																											F		S		1	1
RSI																																	
Level	7.9																														F	0	1

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: LS1-6-A30 **Operator:** JDZ
Date: 23 May 2023 **Relative Humidty:** 39% **Temperature:** 68°F **Project:** DOT1-6265k

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI								B																				BX					
Level	0.120 [1.50]							S																				S				2	0
RSI					B				B		B		A												BX				B				
Level	0.060 [0.75]				S		F		S		S		S												S		F		S			6	2
RSI														Z		B		B		Z		Z								Z			
Level	0.030 [0.38]			F		F				F		F		S		S		S		S		S		F		F				S		6	6
RSI																															Z		
Level	0.015 [0.19]		F												F		F		F		F		F								S	1	6
RSI																																	
Level	0.010 [0.13]	F																														0	1

Material: LS1-6-A30 **Operator:** DMS
Date: 18 May 2023 **Relative Humidty:** 39% **Temperature:** 66°F **Project:** DOT1-6265k

ABL Fricti	lbf (8ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		Z		Z		Z				Z				Z																Z			
Level	320	S		S		S				S				S																S		6	0
RSI							Z				Z				Z						Z		Z		Z		Z						
Level	255		F		F		S		F		S		F		S						S		S		S		S		F		F	7	6
RSI																Z																	
Level	200							F				F				S				F		F		F		F		F				1	7
RSI																	Z3																
Level	160																S		F													1	1
RSI																																	
Level	127																	F														0	1

Number indicates amount of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace
M = Smoke
Z = Spark
A = Flame
B = Flash
X = Sample Consumed
L = Loud Report or Explosion
H = Hardware Damage
P = Pop or Small Explosion
HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure C 3: LS # 1-6-A30 Sensitivity Testing Data Sheets

Material: LS1-6-B10 **Operator:** JAK
Date: 30 May 2023 **Relative Humidty:** 39% **Temperature:** 65°F **Project:** DOT1-6265k

ERL Impac	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI																																	
Level	100	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: LS1-6-B10 **Operator:** JDZ
Date: 30 May 2023 **Relative Humidty:** 39% **Temperature:** 68°F **Project:** DOT1-6265k

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI				Z		Z																								A			
Level	0.030 [0.38]			S		S																								S		3	0
RSI							Z		BX														BZ								ZA		
Level	0.015 [0.19]		F		F		S		S														S						F		S	4	3
RSI										Z														Z									
Level	0.010 [0.13]	F						F		S												F		S				F				2	4
RSI											Z				Z		Z								Z								
Level	0.0050 [0.063]										S				S		S				F				S		F					4	2
RSI												Z						Z															
Level	0.0025 [0.031]											S		F		F		S		F						F						2	4
RSI																																	
Level	0.0012 [0.015]												F						F													0	2

Material: LS1-6-B10 **Operator:** DMS
Date: 18 May 2023 **Relative Humidty:** 36% **Temperature:** 68°F **Project:** DOT1-6265k

ABL Fricti	lbf (8ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI																									B								
Level	1000																						F	F	S							1	2
RSI								B										Z		B						Z				Z			
Level	795							S										S		S		F				S				S		5	1
RSI									Z		Z				Z												Z						
Level	635						F		S		S				S		F		F		F						S		F		F	4	6
RSI				Z								Z																					
Level	505			S		F				F		S		F		F												F				2	5
RSI																																	
Level	400		F		F								F																			0	3
RSI																																	
Level	320	F																														0	1

Number indicates amount of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace
M = Smoke
Z = Spark
A = Flame
B = Flash
X = Sample Consumed
L = Loud Report or Explosion
H = Hardware Damage
P = Pop or Small Explosion
HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure C 4: LS # 1-6-B10 Sensitivity Testing Data Sheets

Material: LS1-6-B20 **Operator:** JAK
Date: 31 May 2023 **Relative Humidty:** 40% **Temperature:** 66°F **Project:** DOT1-6265k

ERL Impa(	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI																																	
Level	100	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: LS1-6-B20 **Operator:** JDZ
Date: 30 May 2023 **Relative Humidty:** 39% **Temperature:** 68°F **Project:** DOT1-6265k

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		BX																					B		BX						BX		
Level	0.015 [0.19]	S																					S		S						S	4	0
RSI				BX		B																				Z		B					
Level	0.010 [0.13]			S		S																F		F		S		S		F		4	3
RSI							Z		Z		B				Z				B														
Level	0.0050 [0.063]		F		F		S		S		S				S				S		F						F		F			5	5
RSI												Z				B																	
Level	0.0025 [0.031]							F		F		S		F		S		F		F												2	5
RSI																																	
Level	0.0012 [0.015]												F				F															0	2

Material: LS1-6-B20 **Operator:** DMS
Date: 18 May 2023 **Relative Humidty:** 37% **Temperature:** 69°°F **Project:** DOT1-6265k

ABL Fricti	lbf (8ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI							B			B				B			A							Z		Z		Z					
Level	1000						S		F	S		F	F	S		F	S		F	F	F	F	F	S		S		S		F	F	7	11
RSI																																	
Level	795					F		F			F				F			F							F		F		F			0	8
RSI			B																														
Level	635		S		F																											1	1
RSI																																	
Level	505	F		F																												0	2

Number indicates amount
of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace
M = Smoke
Z = Spark
A = Flame
B = Flash
X = Sample Consumed
L = Loud Report or Explosion
H = Hardware Damage
P = Pop or Small Explosion
HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure C 5: LS # 1-6-B20 Sensitivity Testing Data Sheets

Material: LS1-6-B30 **Operator:** JAK
Date: 30 May 2023 **Relative Humidty:** 39% **Temperature:** 69°F **Project:** DOT1-6265k

ERL Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI																																	
Level	100	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: LS1-6-B30 **Operator:** JDZ
Date: 30 May 2023 **Relative Humidty:** 39% **Temperature:** 68°F **Project:** DOT1-6265k

ABL ESD	μF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI						B								BX						BX										AX			
Level	0.015 [0.19]					S								S						S										S		4	0
RSI			AX				BX								Z						AX												
Level	0.010 [0.13]		S		F		S						F		S				F		S								F		F	4	5
RSI								Z								Z						Z		Z		Z							
Level	0.0050 [0.063]	F		F				S				F				S		F				S		S		S		F				5	5
RSI									Z																								
Level	0.0025 [0.031]								S		F						F						F		F		F					1	5
RSI																																	
Level	0.0012 [0.015]									F																						0	1

Material: LS1-6-B30 **Operator:** DMS
Date: 31 May 2023 **Relative Humidty:** 38% **Temperature:** 65'°F **Project:** DOT1-6265k

ABL Friction	lbf (8ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI																															B		
Level	795																														S	1	0
RSI								B				Z				Z		Z								Z		Z					
Level	635							S				S				S		S								S		S		F		6	1
RSI									Z				B						Z		B		Z										
Level	505						F		S		F		S		F		F		S		S		S		F		F		F			5	7
RSI		Z		B																													
Level	400	S		S		F				F				F						F		F		F								2	6
RSI																																	
Level	320		F		F																											0	2

Number indicates amount
<u>of sample consumption</u>
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

<u>Reaction Severity Index (RSI)</u>
T = Flame Trace — X = Sample Consumed
M = Smoke — L = Loud Report or Explosion
Z = Spark — H = Hardware Damage
A = Flame — P = Pop or Small Explosion
B = Flash — HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure C 6: LS # 1-6-B30 Sensitivity Testing Data Sheets

Material: LS1-6-C10 **Operator:** JAK
Date: 31 May 2023 **Relative Humidty:** 42% **Temperature:** 66°F **Project:** DOT1-6265k

ERL Impac	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI					A3		B3			B3																							
Level	100	F	F	F	S		S		F	S																						3	4
RSI											B3																						
Level	79.4					F		F			S																					1	2
RSI												B2																					
Level	63.1											S																				1	0
RSI													B2																				
Level	50.1												S																			1	0
RSI														B2																			
Level	39.8													S																		1	0
RSI															Z												Z		Z				
Level	31.6														S												S		S			3	0
RSI																A1				Z		A1								B1			
Level	25.1															S				S		S				F		F		S		4	2
RSI																	B1						Z										
Level	20.0																S		F		F		S		F						F	2	4
RSI																																	
Level	15.8																	F						F								0	2

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: LS1-6-C10 **Operator:** JDZ
Date: 30 May 2023 **Relative Humidty:** 39% **Temperature:** 68°F **Project:** DOT1-6265k

ABL ESD	μF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI																																	
Level	0.010 [0.13]																														F	0	1
RSI		Z				AZ																		Z									
Level	0.0050 [0.063]	S				S																		S						F		3	1
RSI			Z				Z		Z		Z								BZ		Z				Z		Z						
Level	0.0025 [0.031]		S		F		S		S		S								S		S		F		S		S		F			8	3
RSI												Z		Z		AZ																	
Level	0.0012 [0.015]			F				F		F		S		S		S		F		F		F				F		F				3	8
RSI																																	
Level	0.0007 [0.0088]												F		F		F															0	3

Material: LS1-6-C10 **Operator:** DMS
Date: 31 May 2023 **Relative Humidty:** 37% **Temperature:** 70°F **Project:** DOT1-6265k

ABL Fricti	lbf (8ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI																						Z				Z							
Level	1000									F	F	F	F	F	F	F	F	F	F	F	F	S		F	F	S		F	F	F	F	2	18
RSI																																	
Level	795								F														F				F					0	3
RSI																																	
Level	635							F																								0	1
RSI			Z		Z																												
Level	505		S		S		F																									2	1
RSI																																	
Level	400	F		F		F																										0	3

Number indicates amount
<u>of sample consumption</u>
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction

F = No-Go or No Reaction

<u>Reaction Severity Index (RSI)</u>
T = Flame Trace X = Sample Consumed
M = Smoke L = Loud Report or Explosion
Z = Spark H = Hardware Damage
A = Flame P = Pop or Small Explosion
B = Flash HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure C 7: LS # 1-6-C10 Sensitivity Testing Data Sheets

Material: LS1-6-C20 **Operator:** JAK
Date: 31 May 2023 **Relative Humidty:** 45% **Temperature:** 67°F **Project:** DOT1-6265k

ERL Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		Z																															
Level	100	S																														1	0
RSI			Z																														
Level	79.4		S																													1	0
RSI				Z																													
Level	63.1			S																												1	0
RSI					Z																								B2				
Level	50.1				S																								S			2	0
RSI						B5		Z																Z						Z			
Level	39.8					S		S																S				F		S		4	1
RSI									B2																Z						Z		
Level	31.6						F		S														F		S		F				S	3	3
RSI										B1				B1				B1		Z													
Level	25.1									S				S				S		S		F				F						4	2
RSI											B1				B1																		
Level	20.0										S		F		S		F		F		F											2	4
RSI																																	
Level	15.8											F				F																0	2

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: LS1-6-C20 **Operator:** JDZ
Date: 30 May 2023 **Relative Humidty:** 39% **Temperature:** 68°F **Project:** DOT1-6265k

ABL ESD	μF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		Z																															
Level	0.0050 [0.063]	S																														1	0
RSI			Z		Z						Z													Z		AX		Z		Z			
Level	0.0025 [0.031]		S		S						S													S		S		S		S		7	0
RSI						Z						Z																					
Level	0.0012 [0.015]			F		S				F		S											F		F		F		F		F	2	7
RSI							Z						A							Z													
Level	0.0007 [0.0088]						S		F				S							S		F										3	2
RSI														A		Z																	
Level	0.0003 [0.0038]							F						S		S			F		F											2	3
RSI																	Z																
Level	0.0002 [0.0025]														F		S	F														1	2

Material: LS1-6-C20 **Operator:** DMS
Date: 31 May 2023 **Relative Humidty:** 40% **Temperature:** 66°F **Project:** DOT1-6265k

ABL Friction	lbf (8ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI									Z			B									Z				Z								
Level	1000							F	S		F	S				F	F	F	F	F	S		F	F	S		F	F	F	F	F	4	14
RSI					Z								Z		Z																		
Level	795				S		F			F			S		S							F				F						3	4
RSI																																	
Level	635			F		F								F																		0	3
RSI																																	
Level	505		F																													0	1
RSI																																	
Level	400	F																														0	1

Number indicates amount
of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction

F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace X = Sample Consumed
M = Smoke L = Loud Report or Explosion
Z = Spark H = Hardware Damage
A = Flame P = Pop or Small Explosion
B = Flash HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure C 8: LS # 1-6-C20 Sensitivity Testing Data Sheets

Material: LS1-6-C30 **Operator:** JAK
Date: 31 May 2023 **Relative Humidty:** 46% **Temperature:** 68°F **Project:** DOT1-6265k

ERL Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		B5																															
Level	100	S																														1	0
RSI			B5																														
Level	79.4		S																													1	0
RSI																																	
Level	63.1																															0	0
RSI													A3		A5		B5														A5		
Level	50.1												S		S		S														S	4	0
RSI						B5		Z		Z								A5															
Level	39.8					S		S		S		F		F		F		S												F		4	4
RSI																			A5								Z						
Level	31.6				F		F		F		F								S								S		F			2	5
RSI																				B5		Z											
Level	25.1			F																S		S				F		F				2	3
RSI																							A3										
Level	20.0																				F		S		F							1	2
RSI																																	
Level	15.8																							F								0	1

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: LS1-6-C30 **Operator:** JDZ
Date: 30 May 2023 **Relative Humidty:** 39% **Temperature:** 67°F **Project:** DOT1-6265k

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		Z		Z																													
Level	0.010 [0.13]	S		S																												2	0
RSI					Z										Z		AX		Z						Z								
Level	0.0050 [0.063]		F		S										S		S		S						S							5	1
RSI						Z						AX								AZ						AX		Z					
Level	0.0025 [0.031]					S						S		F		F		F		S				F		S		S				5	4
RSI							Z														AX								AX		AX		
Level	0.0012 [0.015]						S				F		F								S		F				F		S		S	4	4
RSI								Z																									
Level	0.0007 [0.0088]							S		F												F								F		1	3
RSI																																	
Level	0.0003 [0.0038]								F																							0	1

Material: LS1-6-C30 **Operator:** DMS
Date: 31 May 2023 **Relative Humidty:** 43% **Temperature:** 66°F **Project:** DOT1-6265k

ABL Friction	lbf (8ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI																B					Z												
Level	1000															S		F	F	F	S		F	F	F	F	F	F	F			2	10
RSI									B																					B			
Level	795								S						F		F					F								S		2	3
RSI						Z				Z		Z																			Z		
Level	635					S		F		S		S		F																	S	4	2
RSI			Z																														
Level	505		S		F		F				F		F																			1	4
RSI																																	
Level	400	F		F																												0	2

Number indicates amount
of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace
M = Smoke
Z = Spark
A = Flame
B = Flash
X = Sample Consumed
L = Loud Report or Explosion
H = Hardware Damage
P = Pop or Small Explosion
HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure C 9: LS # 1-6-C30 Sensitivity Testing Data Sheets

Material: LS1-6-D10 **Operator:** JAK
Date: 31 May 2023 **Relative Humidty:** 44% **Temperature:** 67°F **Project:** DOT1-6265k

ERL Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI																																	
Level	100	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: LS1-6-D10 **Operator:** JDZ
Date: 30 May 2023 **Relative Humidty:** 39% **Temperature:** 67°F **Project:** DOT1-6265k

ABL ESD	μF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI										Z																Z							
Level	0.0050 [0.063]									S																S						2	0
RSI							AZ				Z																Z						
Level	0.0025 [0.031]						S		F		S														F		S					3	2
RSI		Z										Z		Z		Z		Z										Z					
Level	0.0012 [0.015]	S				F		F				S		S		S		S						F				S				6	3
RSI			Z																Z		Z								Z				
Level	0.0007 [0.0088]		S		F								F		F		F		S		S		F						S			4	5
RSI																														Z			
Level	0.0003 [0.0038]			F																F		F								S		1	3
RSI																																	
Level	0.0002 [0.0025]																														F	0	1

Material: LS1-6-D10 **Operator:** DMS
Date: 31 May 2023 **Relative Humidty:** 45% **Temperature:** 67°F **Project:** DOT1-6265k

ABL Friction	lbf (8ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI						Z					Z		Z				Z		Z		B		Z				B			B			
Level	1000					S		F	F	F	S		S				S		S		S		S		F	F	S		F	S		9	6
RSI							Z							Z																			
Level	795				F		S					F		S		F		F		F		F		F				F			F	2	9
RSI																																	
Level	635			F											F																	0	2
RSI																																	
Level	505		F																													0	1
RSI																																	
Level	400	F																														0	1

Number indicates amount
of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction

F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace
M = Smoke
Z = Spark
A = Flame
B = Flash
X = Sample Consumed
L = Loud Report or Explosion
H = Hardware Damage
P = Pop or Small Explosion
HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure C 10: LS # 1-6-D10 Sensitivity Testing Data Sheets

Material: LS1-6-D20 **Operator:** JAK
Date: 31 May 2023 **Relative Humidty:** 38% **Temperature:** 70°F **Project:** DOT1-6265k

ERL Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI																																	
Level	100	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: LS1-6-D20 **Operator:** JDZ
Date: 30 May 2023 **Relative Humidty:** 39% **Temperature:** 68°F **Project:** DOT1-6265k

ABL ESD	μF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		Z										AX																					
Level	0.010 [0.13]	S										S																				2	0
RSI			Z		Z		Z		Z				Z																				
Level	0.0050 [0.063]		S		S		S		S		F		S																			5	1
RSI														Z																			
Level	0.0025 [0.031]			F		F		F		F				S																		1	4
RSI															Z												Z						
Level	0.0012 [0.015]														S												S					2	0
RSI																Z												Z					
Level	0.0007 [0.0088]															S										F		S				2	1
RSI																	Z		Z		Z		Z						Z				
Level	0.0003 [0.0038]																S		S		S		S		F				S		F	5	2
RSI																																	
Level	0.0002 [0.0025]																	F		F		F		F						F		0	5

Material: LS1-6-D20 **Operator:** DMS
Date: 31 May 2023 **Relative Humidty:** 40% **Temperature:** 70°F **Project:** DOT1-6265k

ABL Friction	lbf (8ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI																B																	
Level	1000															S																1	0
RSI																	Z				Z								Z				
Level	795														F		S				S								S			3	1
RSI		Z										Z						Z				Z		Z						Z			
Level	635	S										S		F				S		F		S		S				F		S		6	3
RSI			Z				Z		Z																Z								
Level	505		S				S		S		F		F						F				F		S		F				F	4	6
RSI				X																													
Level	400			S		F		F		F																F						1	4
RSI																																	
Level	320				F																											0	1

Number indicates amount of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace
M = Smoke
Z = Spark
A = Flame
B = Flash
X = Sample Consumed
L = Loud Report or Explosion
H = Hardware Damage
P = Pop or Small Explosion
HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure C 11: LS # 1-6-D20 Sensitivity Testing Data Sheets

Material: LS1-6-D30 **Operator:** JAK
Date: 31 May 2023 **Relative Humidty:** 39% **Temperature:** 70°F **Project:** DOT1-6265k

ERL Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI																																	
Level	100	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: LS1-6-D30 **Operator:** JDZ
Date: 30 May 2023 **Relative Humidty:** 38% **Temperature:** 67°F **Project:** DOT1-6265k

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		Z		AZ																													
Level	0.010 [0.13]	S		S																												2	0
RSI					A		Z		Z		Z																						
Level	0.0050 [0.063]		F		S		S		S		S																					4	1
RSI												Z														AZ		Z					
Level	0.0025 [0.031]					F		F		F		S														S		S				3	3
RSI													Z						Z										Z				
Level	0.0012 [0.015]												S						S						F		F		S			3	2
RSI														Z		Z				Z		Z								Z			
Level	0.0007 [0.0088]													S		S		F		S		S		F						S		5	2
RSI																															Z		
Level	0.0003 [0.0038]														F		F				F		F								S	1	4

Material: LS1-6-D30 **Operator:** DMS
Date: 31 May 2023 **Relative Humidty:** 44% **Temperature:** 67°F **Project:** DOT1-6265k

ABL Friction	lbf (8ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI					Z								B		Z		Z																
Level	635				S								S		S		S															4	0
RSI		Z				Z												Z												B			
Level	505	S		F		S						F		F		F		S												S		4	4
RSI							Z												Z				Z		Z		Z				Z		
Level	400		F				S				F								S				S		S		S		F		S	6	3
RSI								Z												Z													
Level	320							S		F										S		F		F		F		F				2	5
RSI																																	
Level	255								F												F											0	2

Number indicates amount
of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace
M = Smoke
Z = Spark
A = Flame
B = Flash
X = Sample Consumed
L = Loud Report or Explosion
H = Hardware Damage
P = Pop or Small Explosion
HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure C 12: LS # 1-6-D30 Sensitivity Testing Data Sheets

Material: LS4-5-A10 **Operator:** JDZ
Date: 23 May 2023 **Relative Humidty:** 42% **Temperature:** 68°F **Project:** DOT1-6265k

ERL Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI																																	
Level	100				F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	27
RSI																																	
Level	79.4			F																												0	1
RSI																																	
Level	63.1		F																													0	1
RSI																																	
Level	50.1	F																														0	1

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: LS4-5-A10 **Operator:** JDZ
Date: 25 May 2023 **Relative Humidty:** 49% **Temperature:** 67°F **Project:** DOT1-6265k

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		Z																															
Level	0.015 [0.19]	S																														1	0
RSI			Z						Z		B																						
Level	0.010 [0.13]		S						S		S																					3	0
RSI				Z		B						B		Z		Z		Z								B		Z		BZ			
Level	0.0050 [0.063]			S		S		F		F		S		S		S		S								S		S		S		9	2
RSI																			B		Z		B								B		
Level	0.0025 [0.031]				F		F						F		F		F		S		S		S		F		F		F		S	4	8
RSI																																	
Level	0.0012 [0.015]																			F		F		F								0	3

Material: LS4-5-A10 **Operator:** DMS
Date: 25 May 2023 **Relative Humidty:** 49% **Temperature:** 67°F **Project:** DOT1-6265k

ABL Friction	lbf (8ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		Z																															
Level	1000	S																														1	0
RSI			Z																														
Level	795		S																													1	0
RSI				Z																													
Level	635			S																												1	0
RSI					Z																												
Level	505				S																											1	0
RSI						Z						Z		Z		Z																	
Level	400					S						S		S		S																4	0
RSI							Z		Z								Z		Z		Z		Z				Z				Z		
Level	320						S		S		F		F		F		S		S		S		S				S				S	8	3
RSI																								Z				Z					
Level	255							F		F								F		F		F		S		F		S		F		2	7
RSI																																	
Level	200																								F				F			0	2

Number indicates amount
<u>of sample consumption</u>
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

<u>Reaction Severity Index (RSI)</u>
T = Flame Trace
M = Smoke
Z = Spark
A = Flame
B = Flash
X = Sample Consumed
L = Loud Report or Explosion
H = Hardware Damage
P = Pop or Small Explosion
HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure C 13: LS # 4-5-A10 Sensitivity Testing Data Sheets

Material: LS4-5-A20 **Operator:** JDZ
Date: 23 May 2023 **Relative Humidty:** 42% **Temperature:** 68°F **Project:** DOT1-6265k

ERL Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI								Z													Z		Z										
Level	100	F	F	F	F	F	F	S		F	F	F	F	F	F	F	F	F	F	F	S		S		F	F	F	F	F	F	F	3	24
RSI																																	
Level	79.4								F													F		F								0	3

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: LS4-5-A20 **Operator:** JDZ
Date: **Relative Humidty:** % **Temperature:** °F **Project:** DOT1-6265k

ABL ESD	μF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI			Z																				Z										
Level	0.015 [0.19]		S																				S									2	0
RSI				Z																				Z						Z			
Level	0.010 [0.13]			S																		F		S						S		3	1
RSI					Z		Z		B		BZ						B								B						B		
Level	0.0050 [0.063]				S		S		S		S						S				F				S				F		S	7	2
RSI												B		Z				Z								Z							
Level	0.0025 [0.031]					F		F		F		S		S		F		S		F						S		F				4	6
RSI																																	
Level	0.0012 [0.015]												F		F				F								F					0	4

Material: LS4-5-A20 **Operator:** DMS
Date: **Relative Humidty:** % **Temperature:** °F **Project:** DOT1-6265k

ABL Friction	lbf (8ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		Z																															
Level	635	S																														1	0
RSI			Z		Z																												
Level	505		S		S																											2	0
RSI						Z																											
Level	400			F		S																										1	1
RSI							B																										
Level	320						S																									1	0
RSI								B												Z		Z											
Level	255							S												S		S										3	0
RSI									B		Z												Z		Z				Z				
Level	200								S		S								F		F		S		S				S			5	2
RSI												B				Z										Z				Z			
Level	160									F		S				S		F						F		S		F		S		4	4
RSI													B																				
Level	127												S		F		F										F				F	1	4
RSI																																	
Level	100													F																		0	1

Number indicates amount
of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction

F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace
M = Smoke
Z = Spark
A = Flame
B = Flash
X = Sample Consumed
L = Loud Report or Explosion
H = Hardware Damage
P = Pop or Small Explosion
HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure C 14: LS # 4-5-A20 Sensitivity Testing Data Sheets

Material: LS4-5-A30 **Operator:** JDZ
Date: 23 May 2023 **Relative Humidty:** 42% **Temperature:** 68°F **Project:** DOT1-6265k

ERL Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		Z																															
Level	100	S																														1	0
RSI			ZP																														
Level	79.4		S																													1	0
RSI				ZP																													
Level	63.1			S																												1	0
RSI					B																												
Level	50.1				S																											1	0
RSI						Z																											
Level	39.8					S																										1	0
RSI																																	
Level	31.6																															0	0
RSI																																	
Level	25.1																															0	0
RSI							Z1		Z1																				B3				
Level	20.0						S		S																				S		F	3	1
RSI										B3								Z1		BP5		BP5											
Level	15.8							F		S								S		S		S						F		F		4	3
RSI											Z		Z1										Z1										
Level	12.6										S		S				F		F		F		S				F					3	4
RSI														Z1										Z1									
Level	10.0											F		S		F								S		F						2	3
RSI																																	
Level	7.9														F										F							0	2

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: LS4-5-A30 **Operator:** JDZ
Date: **Relative Humidty:** % **Temperature:** °F **Project:** DOT1-6265k

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI			Z																Z												Z		
Level	0.015 [0.19]		S																S												S	3	0
RSI				Z		Z														Z						Z							
Level	0.010 [0.13]			S		S												F		S						S				F		4	2
RSI							B		Z												B		B				B						
Level	0.0050 [0.063]				F		S		S								F				S		S		F		S		F			5	4
RSI										Z		BZ		Z																			
Level	0.0025 [0.031]							F		S		S		S		F						F		F				F				3	5
RSI																																	
Level	0.0012 [0.015]										F		F		F																	0	3

Material: LS4-5-A30 **Operator:** DMS
Date: **Relative Humidty:** % **Temperature:** °F **Project:** DOT1-6265k

ABL Friction	lbf (8ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		Z																															
Level	505	S																														1	0
RSI			Z																														
Level	400		S																													1	0
RSI				Z																													
Level	320			S																												1	0
RSI					Z								Z		Z		Z																
Level	255				S								S		S		S															4	0
RSI						Z		Z		Z								Z		Z		Z											
Level	200					S		S		S		F		F		F		S		S		S										6	3
RSI																							Z		Z		Z		Z		Z		
Level	160						F		F		F								F		F		S		S		S		S		S	5	5
RSI																																	
Level	127																							F		F		F		F		0	4

Number indicates amount
of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace
M = Smoke
Z = Spark
A = Flame
B = Flash
X = Sample Consumed
L = Loud Report or Explosion
H = Hardware Damage
P = Pop or Small Explosion
HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure C 15: LS # 4-5-A30 Sensitivity Testing Data Sheets

Material: LS4-5-B10 **Operator:** JDZ
Date: 23 May 2023 **Relative Humidty:** 42% **Temperature:** 68°F **Project:** DOT1-6265k

ERL Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI																																	
Level	100	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: LS4-5-B10 **Operator:** JDZ
Date: 30 May 2023 **Relative Humidty:** 42% **Temperature:** 65°F **Project:** DOT1-6265k

ABL ESD	μF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		Z														Z																	
Level	0.015 [0.19]	S														S																2	0
RSI			Z				Z		Z								Z						Z				Z		Z		Z		
Level	0.010 [0.13]		S				S		S						F		S						S				S		S		S	8	1
RSI				Z						Z		Z						Z						Z									
Level	0.0050 [0.063]			S		F		F		S		S		F				S				F		S		F		F		F		5	7
RSI																			Z														
Level	0.0025 [0.031]				F						F		F						S		F				F							1	5
RSI																																	
Level	0.0012 [0.015]																			F												0	1
RSI																																	
Level	0.0007 [0.0088]																															0	0
RSI																																	
Level	0.0003 [0.0038]																															0	0
RSI																																	
Level	0.0002 [0.0025]																															0	0

Material: LS4-5-B10 **Operator:** DMS
Date: 24 May 2023 **Relative Humidty:** 45% **Temperature:** 69'°F **Project:** DOT1-6265k

ABL Friction	lbf (8ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI			X		X				X		X		X													X							
Level	1000		S		S		F	F	S		S		S		F	F	F	F	F	F	F	F	F	F	F	S				F	F	6	15
RSI																											X						
Level	795	F		F		F				F		F		F													S		F			1	7
RSI																																	
Level	635																											F				0	1

Number indicates amount
of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace
M = Smoke
Z = Spark
A = Flame
B = Flash
X = Sample Consumed
L = Loud Report or Explosion
H = Hardware Damage
P = Pop or Small Explosion
HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure C 16: LS # 4-5-B10 Sensitivity Testing Data Sheets

Material: LS4-5-B20 **Operator:** JAK
Date: 23 May 2023 **Relative Humidty:** 39% **Temperature:** 66°F **Project:** DOT1-6265k

ERL Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI																																	
Level	100	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: LS4-5-B20 **Operator:** JDZ
Date: 30 May 2023 **Relative Humidty:** 41% **Temperature:** 66°F **Project:** DOT1-6265k

ABL ESD	μF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI																							B										
Level	0.015 [0.19]																						S									1	0
RSI		Z												B										Z									
Level	0.010 [0.13]	S												S								F		S								3	1
RSI			Z												Z				Z						Z		Z		Z		Z		
Level	0.0050 [0.063]		S										F		S				S		F				S		S		S		S	7	2
RSI				Z		Z										Z																	
Level	0.0025 [0.031]			S		S						F				S		F		F						F		F		F		3	6
RSI							Z		Z																								
Level	0.0012 [0.015]				F		S		S		F						F															2	3
RSI																																	
Level	0.0007 [0.0088]							F		F																						0	2

Material: LS4-5-B20 **Operator:** DMS
Date: 23 May 2023 **Relative Humidty:** 41% **Temperature:** 69°°F **Project:** DOT1-6265k

ABL Friction	lbf (8ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI							BX												BX		Z						Z				BX		
Level	505						S												S		S						S				S	5	0
RSI		Z						B				B				Z						Z		Z				Z					
Level	400	S				F		S				S				S		F		F		S		S		F		S		F		7	5
RSI			BX						Z				Z																				
Level	320		S		F				S		F		S		F		F						F		F				F			3	7
RSI																																	
Level	255			F						F				F																		0	3

Number indicates amount
<u>of sample consumption</u>
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction

F = No-Go or No Reaction

<u>Reaction Severity Index (RSI)</u>
T = Flame Trace X = Sample Consumed
M = Smoke L = Loud Report or Explosion
Z = Spark H = Hardware Damage
A = Flame P = Pop or Small Explosion
B = Flash HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure C 17: LS # 4-5-B20 Sensitivity Testing Data Sheets

Material: LS4-5-B30 **Operator:** JF
Date: 24 May 2023 **Relative Humidty:** 53% **Temperature:** 69°F **Project:** DOT1-6265k

ERL Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI																																	
Level	100	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: LS4-5-B30 **Operator:** JDZ
Date: 30 May 2023 **Relative Humidty:** 39% **Temperature:** 65°F **Project:** DOT1-6265k

ABL ESD	μF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		Z																		Z		BX											
Level	0.010 [0.13]	S																		S		S										3	0
RSI			Z														BX						Z				Z						
Level	0.0050 [0.063]		S														S		F		F		S				S					4	2
RSI				Z				Z																Z				Z		Z			
Level	0.0025 [0.031]			S				S								F		F						S		F		S		S		5	3
RSI					Z				Z		Z		Z																				
Level	0.0012 [0.015]				S		F		S		S		S		F										F				F		F	4	5
RSI																																	
Level	0.0007 [0.0088]					F				F		F		F																		0	4

Material: LS4-5-B30 **Operator:** DMS
Date: 24 May 2023 **Relative Humidty:** 45% **Temperature:** 69°F **Project:** DOT1-6265k

ABL Friction	lbf (8ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI																									BX								
Level	635																								S							1	0
RSI		BX																								Z							
Level	505	S																						F		S						2	1
RSI			Z						BX										BX								Z		BZ		B		
Level	400		S						S										S				F				S		S		S	6	1
RSI				Z						BX										Z										Z			
Level	320			S				F		S								F		S		F						F		S		4	4
RSI					BX						BX		Z		Z																		
Level	255				S		F				S		S		S		F				F											4	3
RSI																																	
Level	200					F						F		F		F																0	4

Number indicates amount
of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction

F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace
M = Smoke
Z = Spark
A = Flame
B = Flash
X = Sample Consumed
L = Loud Report or Explosion
H = Hardware Damage
P = Pop or Small Explosion
HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure C 18: LS # 4-5-B30 Sensitivity Testing Data Sheets

Material: LS4-5-C10 **Operator:** JDZ
Date: 23 May 2023 **Relative Humidty:** 43% **Temperature:** 67°F **Project:** DOT1-6265k

ERL Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI							BZ					BP																					
Level	100						S					S																				2	0
RSI													BP																BP				
Level	79.4					F		BP			F		S																S			2	2
RSI			Z					S						BP																BP			
Level	63.1		S		F					F				S														F		S		3	3
RSI															Z				BP		PZ										Z		
Level	50.1	F		F					F						S				S		S						F				S	4	4
RSI																BP						Z		ZP									
Level	39.8															S		F		F		S		S		F						3	3
RSI																																	
Level	31.6																F						F		F							0	3

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: LS4-5-C10 **Operator:** JDZ
Date: 24 May 2023 **Relative Humidty:** 52% **Temperature:** 68°F **Project:** DOT1-6265k

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI																				Z													
Level	0.060 [0.75]																			S												1	0
RSI					Z																BX		BX										
Level	0.030 [0.38]				S														F		S		S									3	1
RSI		BX				BX								Z										Z		Z							
Level	0.015 [0.19]	S		F		S								S				F				F		S		S						5	3
RSI							Z				Z				Z												Z						
Level	0.010 [0.13]		F				S				S		F		S		F								F		S				F	4	5
RSI								Z																				Z					
Level	0.0050 [0.063]							S		F		F				F												S		F		2	4
RSI																																	
Level	0.0025 [0.031]								F																				F			0	2

Material: LS4-5-C10 **Operator:** DMS
Date: 22 May 2023 **Relative Humidty:** 35% **Temperature:** 69°F **Project:** DOT1-6265k

ABL Friction	lbf (8ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI			Z					Z								BX					BX						Z						
Level	1000	F	S		F	F	F	S								S		F	F	F	S		F	F	F	F	S					5	11
RSI									Z				Z															Z		Z			
Level	795			F					S				S		F		F					F						S		S		4	4
RSI										Z																					Z		
Level	635									S		F		F															F		S	2	3
RSI																																	
Level	505										F																					0	1

Number indicates amount
<u>of sample consumption</u>
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

<u>Reaction Severity Index (RSI)</u>
T = Flame Trace X = Sample Consumed
M = Smoke L = Loud Report or Explosion
Z = Spark H = Hardware Damage
A = Flame P = Pop or Small Explosion
B = Flash HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure C 19: LS # 4-5-C10 Sensitivity Testing Data Sheets

Material: LS4-5-C20 **Operator:** JDZ
Date: 23 May 2023 **Relative Humidty:** 43% **Temperature:** 66°F **Project:** DOT1-6265k

ERL Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI			B																														
Level	100	F	S																													1	1
RSI				Z																													
Level	79.4			S																												1	0
RSI					BP							BP																					
Level	63.1				S							S																				2	0
RSI						BP							Z																				
Level	50.1					S					F		S																			2	1
RSI														Z																BP			
Level	39.8									F				S																S		2	1
RSI															BP		BP										BP				Z		
Level	31.6								F						S		S										S		F		S	4	2
RSI																		BP		Z													
Level	25.1							F								F		S		S						F		F				2	4
RSI																					BP												
Level	20.0						F												F		S				F							1	3
RSI																						Z											
Level	15.8																					S		F								1	1
RSI																																	
Level	12.6																						F									0	1

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: LS4-5-C20 **Operator:** JDZ
Date: 24 May 2023 **Relative Humidty:** 50% **Temperature:** 68°F **Project:** DOT1-6265k

ABL ESD	μF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		Z																				BX											
Level	0.015 [0.19]	S																				S										2	0
RSI					Z				Z				Z				BX						BX		Z								
Level	0.010 [0.13]				S				S				S				S				F		S		S							6	1
RSI						B				Z				Z				Z								Z		Z		Z			
Level	0.0050 [0.063]					S		F		S		F		S		F		S		F				F		S		S		S		7	5
RSI																															Z		
Level	0.0025 [0.031]			F			F				F				F				F								F		F		S	1	7

Material: LS4-5-C20 **Operator:** DMS
Date: 23 May 2023 **Relative Humidty:** 42% **Temperature:** 68°F **Project:** DOT1-6265k

ABL Friction	lbf (8ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI																																	
Level	1590																															0	0
RSI																																	
Level	1280																															0	0
RSI							Z										Z													Z			
Level	1000				F	F	S				F	F	F	F	F	F	S		F	F	F	F	F	F	F	F	F	F	F	S		3	19
RSI		Z						Z																									
Level	795	S		F				S		F								F													F	2	4
RSI																																	
Level	635		F						F																							0	2

Number indicates amount
of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace
M = Smoke
Z = Spark
A = Flame
B = Flash
X = Sample Consumed
L = Loud Report or Explosion
H = Hardware Damage
P = Pop or Small Explosion
HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure C 20: LS # 4-5-C20 Sensitivity Testing Data Sheets

Material: LS4-5-C30 **Operator:** JDZ
Date: 22 May 2023 **Relative Humidty:** 38% **Temperature:** 70°F **Project:** DOT1-6265k

ERL Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI			BX																														
Level	100	F	S																													1	1
RSI				Z						BX																							
Level	79.4			S						S																						2	0
RSI					ZP		Z				Z								BX														
Level	63.1				S		S		F		S								S													4	1
RSI												BX								B													
Level	50.1					F		F				S						F		S												2	3
RSI													LBX				ZP				B												
Level	39.8												S				S				S											3	0
RSI														ZP								BP		BP		BP							
Level	31.6													S		F						S		S		S						4	1
RSI																											Z				Z		
Level	25.1														F								F		F		S				S	2	3
RSI																												Z					
Level	20.0																											S		F		1	1
RSI																																	
Level	15.8																												F			0	1

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: LS4-5-C30 **Operator:** JDZ
Date: 24 May 2023 **Relative Humidty:** 50% **Temperature:** 68°F **Project:** DOT1-6265k

ABL ESD	μF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		BX							Z				BX																BX		BX		
Level	0.015 [0.19]	S							S				S																S		S	5	0
RSI						BX				BX				BX		BX								BX									
Level	0.010 [0.13]					S		F		S		F		S		S								S				F		F		5	4
RSI																	BX		BX		BX				Z								
Level	0.0050 [0.063]				F		F				F				F		S		S		S		F		S		F					4	6
RSI																																	
Level	0.0025 [0.031]																	F		F		F				F						0	4
RSI																																	
Level	0.0012 [0.015]			F																												0	1

Material: LS4-5-C30 **Operator:** DMS
Date: 23 May 2023 **Relative Humidty:** 43% **Temperature:** 66°F **Project:** DOT1-6265k

ABL Friction	lbf (8ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI								Z						Z				Z					Z						Z				
Level	1000						F	S		F	F	F	F	S		F	F	S		F	F	F	S				F	F	S			5	12
RSI		Z																						Z						Z			
Level	795	S				F			F						F				F					S		F				S		3	5
RSI			Z																												Z		
Level	635		S		F																				F						S	2	2
RSI																																	
Level	505			F																												0	1

Number indicates amount
of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction

F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace
M = Smoke
Z = Spark
A = Flame
B = Flash
X = Sample Consumed
L = Loud Report or Explosion
H = Hardware Damage
P = Pop or Small Explosion
HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure C 21: LS # 4-5-C30 Sensitivity Testing Data Sheets

Material: LS4-5-D10 **Operator:** CLB
Date: 18 May 2023 **Relative Humidty:** 45% **Temperature:** 68°F **Project:** DOT1-6265k

ERL Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI																																	
Level	100	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: LS4-5-D10 **Operator:** JDZ
Date: 24 May 2023 **Relative Humidty:** 48% **Temperature:** 69°F **Project:** DOT1-6265k

ABL ESD	μF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI																							Z		B								
Level	0.030 [0.38]																						S		S							2	0
RSI																				B						B		B					
Level	0.015 [0.19]																			S		F		F		S		S				3	2
RSI											Z				B														B				
Level	0.010 [0.13]										S				S				F		F						F		S			3	3
RSI		Z										Z				B														B			
Level	0.0050 [0.063]	S								F		S		F		S		F												S		4	3
RSI			Z																														
Level	0.0025 [0.031]		S						F				F				F														F	1	4
RSI				Z																													
Level	0.0012 [0.015]			S				F																								1	1
RSI					Z																												
Level	0.0007 [0.0088]				S		F																									1	1
RSI																																	
Level	0.0003 [0.0038]					F																										0	1

Material: LS4-5-D10 **Operator:** DMS
Date: 18 May 2023 **Relative Humidty:** 45% **Temperature:** 68°F **Project:** DOT1-6265k

ABL Friction	lbf (8ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		BX																															
Level	1000	S																														1	0
RSI			Z																														
Level	795		S																													1	0
RSI				BX																								Z		Z			
Level	635			S																								S		S		3	0
RSI					Z		Z		Z		BX		BX												Z						Z		
Level	505				S		S		S		S		S												S		F		F		S	7	2
RSI														Z																			
Level	400					F		F		F		F		S										F		F						1	6
RSI															Z		Z		Z		Z												
Level	320														S		S		S		S		F									4	1
RSI																																	
Level	255															F		F		F		F										0	4

Number indicates amount
<u>of sample consumption</u>
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

<u>Reaction Severity Index (RSI)</u>
T = Flame Trace
M = Smoke
Z = Spark
A = Flame
B = Flash
X = Sample Consumed
L = Loud Report or Explosion
H = Hardware Damage
P = Pop or Small Explosion
HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure C 22: LS # 4-5-D10 Sensitivity Testing Data Sheets

Material: LS4-5-D20 **Operator:** CLB
Date: 18 May 2023 **Relative Humidty:** 47% **Temperature:** 65°F **Project:** DOT1-6265k

ERL Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		Z																															
Level	100	S			F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	1	27
RSI																																	
Level	79.4			F																												0	1
RSI																																	
Level	63.1																															0	0
RSI																																	
Level	50.1		F																													0	1

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: LS4-5-D20 **Operator:** JDZ
Date: 24 May 2023 **Relative Humidty:** 47% **Temperature:** 68°F **Project:** DOT1-6265k

ABL ESD	μF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI					Z																												
Level	0.030 [0.38]				S																											1	0
RSI		Z				Z												Z															
Level	0.015 [0.19]	S		F		S												S														3	1
RSI							Z												Z														
Level	0.010 [0.13]		F				S										F		S													2	2
RSI								Z		Z		Z		Z						Z													
Level	0.0050 [0.063]							S		S		S		S		F				S												5	1
RSI																					Z				Z		Z				Z		
Level	0.0025 [0.031]								F		F		F		F						S				S		S		F		S	4	5
RSI																						Z											
Level	0.0012 [0.015]																					S		F		F		F		F		1	4
RSI																																	
Level	0.0007 [0.0088]																						F									0	1

Material: LS4-5-D20 **Operator:** DMS
Date: 18 May 2023 **Relative Humidty:** 45% **Temperature:** 68°°F **Project:** DOT1-6265k

ABL Friction	lbf (8ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		Z		BX		BX		Z																									
Level	1000	S		S		S		S																								4	0
RSI									B																								
Level	795		F		F		F		S																							1	3
RSI										Z												B		Z									
Level	635									S												S		S								3	0
RSI											Z														Z								
Level	505										S										F		F		S							2	2
RSI												Z														Z							
Level	400											S								F						S						2	1
RSI													Z				Z										Z				Z		
Level	320												S				S		F								S				S	4	1
RSI														Z														Z					
Level	255													S		F		F										S		F		2	3
RSI																																	
Level	200														F														F			0	2

Number indicates amount
of sample consumption
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

Reaction Severity Index (RSI)
T = Flame Trace
M = Smoke
Z = Spark
A = Flame
B = Flash
X = Sample Consumed
L = Loud Report or Explosion
H = Hardware Damage
P = Pop or Small Explosion
HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure C 23: LS # 4-5-D20 Sensitivity Testing Data Sheets

Material: LS4-5-D30 **Operator:** CLB
Date: 22 May 2023 **Relative Humidty:** 36% **Temperature:** 66°F **Project:** DOT1-6265k

ERL Impact	cm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI																																	
Level	100	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	0	30

Type 12: 1.5 kg intermediate mass with a 1.0, 1.5, 1.8, or 2.0 kg drop mass; 2.0 kg intermediate mass with a 1.0 or 2.0 kg drop mass; **2.5 kg intermediate mass** with a **2.5** or 5.0 **kg drop mass**

Material: LS4-5-D30 **Operator:** JDZ
Date: 24 May 2023 **Relative Humidty:** 54% **Temperature:** 67°F **Project:** DOT1-6265k

ABL ESD	µF [J] @ 5000V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI			BX																														
Level	0.750 [9.38]		S																													1	0
RSI																																	
Level	0.350 [4.38]																															0	0
RSI																																	
Level	0.200 [2.50]																															0	0
RSI				B																													
Level	0.120 [1.50]			S																												1	0
RSI					A																												
Level	0.060 [0.75]				S																											1	0
RSI						Z																											
Level	0.030 [0.38]					S																										1	0
RSI							Z		Z																								
Level	0.015 [0.19]	F					S		S																							2	1
RSI										Z		Z						Z															
Level	0.010 [0.13]							F		S		S						S														3	1
RSI													Z						Z		Z										Z		
Level	0.0050 [0.063]										F		S				F		S		S										S	4	2
RSI														Z								Z		Z									
Level	0.0025 [0.031]													S		F				F		S		S						F		3	3
RSI																									Z		Z						
Level	0.0012 [0.015]														F								F		S		S		F			2	3
RSI																																	
Level	0.0007 [0.0088]																									F		F				0	2

Material: LS4-5-D30 **Operator:** DMS
Date: 18 May 2023 **Relative Humidty:** 35% **Temperature:** 68°F **Project:** DOT1-6265k

ABL Friction	lbf (8ft/sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	+	-
RSI		Z																															
Level	1000	S																														1	0
RSI			Z																														
Level	795		S																													1	0
RSI				Z																													
Level	635			S																												1	0
RSI					Z																				BX								
Level	505				S																				S							2	0
RSI						Z																				Z							
Level	400					S																		F		S						2	1
RSI							Z		Z								Z										Z						
Level	320						S		S								S						F				S					4	1
RSI										Z				Z				Z										Z					
Level	255							F		S				S		F		S				F						S				4	3
RSI											Z								Z										Z				
Level	200										S		F		F				S		F								S		F	3	4
RSI																																	
Level	160											F								F										F		0	3

Number indicates amount <u>of sample consumption</u>
0 - None
1 - Little
2 - One-quarter
3 - One-half (SIGNIFICANT)
4 - Three-quarters
5 - Most/ All

S = Go or Reaction
F = No-Go or No Reaction

<u>Reaction Severity Index (RSI)</u>
T = Flame Trace
M = Smoke
Z = Spark
A = Flame
B = Flash
X = Sample Consumed
L = Loud Report or Explosion
H = Hardware Damage
P = Pop or Small Explosion
HV = High-speed Video, 28,000 fps, modified Rev. 2 algorithm

Figure C 24: LS # 4-5-D30 Sensitivity Testing Data Sheets

APPENDIX D

– PRODUCT CERTIFICATIONS

ATLANTIC EQUIPMENT ENGINEERS
HIGH PURITY METALS AND COMPOUNDS

Certificate of Analysis
RED IRON OXIDE POWDER
FE-601

1.1 General

CATALOG NUMBER	LOT NUMBER	CAS NUMBER
FE-601	2304511	1309-37-1

2.1 Chemical Analysis (in percentage (%) unless otherwise stated)

Tint strength	Moisture	Water soluble
99.5	0.40	0.12
Fe2O3	pH	
99 min	6.7	

3.1 Screen Analysis (percent passing) / Other

Size	+325 mesh
1-5 microns	0.012

4.1 Notes

5.1 Statement

The above analysis is carried out as part of our internal quality control testing and is based upon our analysis methods.

We do not assume any warranty, liability, or risk based on such findings. Our quality is warranted within the scope of our general sales conditions.

Please refer to SDS for material handling instructions.

Very Truly Yours,

M. Gerald, QA

24 Industrial Ave, Upper Saddle River, NJ 07458 Tel: 201.828.9400 Fax: 201.387.0291
On the web at: www.micronmetals.com Email: info@micronmetals.com

Page 1 of 1

Figure D1: Product Certification for Fe_2O_3

ATLANTIC EQUIPMENT ENGINEERS
HIGH PURITY METALS AND COMPOUNDS

Certificate of Analysis
CUPRIC OXIDE
CU-602

1.1 General

CATALOG NUMBER	LOT NUMBER	CAS NUMBER
CU-602	2304510	1317-38-0

2.1 Chemical Analysis (in percentage (%) unless otherwise stated)

Cu	CuO	Cu2O	Zn	Fe	Ca	Mg
75	94	3	0.3	0.02	0.01	0.002
Mn	Pb	Cd	As	Sb	Moisture	
0.001	0.05	0.01	0.01	0.01	0.2	

3.1 Screen Analysis (percent passing) / Other

Size	Specific Gravity	-325 mesh	Loose Bulk Density
1-5 microns	6.7 g/cc	99.9	80 lbs. / ft³

4.1 Notes

5.1 Statement

The above analysis is carried out as part of our internal quality control testing and is based upon our analysis methods.

We do not assume any warranty, liability, or risk based on such findings. Our quality is warranted within the scope of our general sales conditions.

Please refer to SDS for material handling instructions.

Very Truly Yours,

M. Gerald, QA

24 Industrial Ave, Upper Saddle River, NJ 07458 Tel: 201.828.9400 Fax: 201.387.0291
On the web at: www.micronmetals.com Email: info@micronmetals.com

Page 1 of 1

Figure D2: Product Certification for CuO

GoodFellow
innovation, delivered

PTFE Powder 6-9 micron

PTFE

Product Code: FP30-PD-000110

Mean Particle Size: 6-9

Figure D3: Product Certification for PTFE (PTFE Powder)

STANFORD ADVANCED MATERIALS

Stanford Advanced Materials
23661 Birtcher Dr. Lake Forest, CA 92630, USA
Tel: (949) 407-8904 Fax: (949) 812-6690

Certificate of Analysis

Product Name:	Molybdenum Trioxide (MoO3) Powder
Purity:	≥99.5%
Particle Size:	-325mesh
Lot Number:	OC210201-12629-1
Date:	2/1/21

Purity (wt%)	99.5
C (wt%)	0.05
H (wt%)	0.02
O (wt%)	0.01
N (wt%)	0.01
Mg (wt%)	0.01
Al (wt%)	0.01
Si (wt%)	0.02
Ca (wt%)	0.01
Ti (wt%)	0.01
Fe (wt%)	0.08
Ni (wt%)	0.01
Cu (wt%)	0.02
Sn (wt%)	0.01
W (wt%)	0.03
Pb (wt%)	0.01

Stanford Advanced Materials

Figure D4: Product Certification for Molybdenum Trioxide (MoO_3)

Kingsfield Inc.

1 Dewolf Road, Suite 210 Old Tappan, N.J. 07675,
Tel: (201) 767-0414 Fax: (201)767-0743
www.kingsfieldinc.com

CERTIFICATE OF ANALYSIS

Product Name: Calcium Peroxide Powder
Quantity: 16,000KGS
Packing: 25kg bag
Lot#: 20200722

We certify that the quality of the above material is as follows;

Item	Specification	Test result
Appearance	White or yellowish powder	Pass
Cao2 content, %	Min75.0	81.24
Active Oxygen, %	/	17.8728
Bulk Density, g/L	500-650	524
PO_4, %	Max.2.0	1.28
PH, %	≈ 12	12.04
Ferric, %	Max.0.05	0.0314
Pb, %	Max.0.002	0.00088

Ryan Choi/ President of USA Office

Figure D5: Product Certification for Calcium Peroxide (CaO_2)

Reagents

PO Box 788
Belmont, NC 28012
+1.800.732.8484 F: +1.888.843.4384
Reagents.com

CERTIFICATE OF ANALYSIS

Product: **Sodium Nitrate, Purified**

Date of Manufacture: 7/25/2023

Expiration Date: September 2027

Intended Use: General Laboratory Reagent/Chemical.

Recommended Storage: 15 to 25 °C (59 to 77 °F)

Product Code: C2320500 C2320500

Lot Number: **8307537**

CAS Number: 7631-99-4

Test	Specification	Result
Assay	Report	98.5%
Chloride (Cl)	Report	0.27%
Insoluble Matter	Report	0.01%
Nitrite (NO_2)	Report	0.001%
Sulfate (SO_4)	Report	0.34%
Water (H_2O)	Report	0.01%

Balances are calibrated regularly with weights certified traceable to the NIST national mass standard. All products are prepared according to master documents that assure manufacture according to validated methods. Batch records document traceability and production history for each lot manufactured.

Figure D6: Product Certification for Sodium Nitrate ($NaNO_3$)

TEST REPORT

UN Series Testing on Select Thermite-Additive Formulations

DOT Contract # 693JK320C000005

U.S. Department of Transportation
Pipeline and Hazardous Materials Safety Administration
(PHMSA)

Attention: PHH-20
Hazardous Materials Technology
1200 New Jersey Avenue, SE
E21-317
Washington, DC 20590

Troy A. Gardner, PE, CSP
Jackson Zarbock

September 28, 2023
SMS-6265k-R2, Rev 1

1847 West 9000 South, Suite 205 • West Jordan, Utah 84088 • 801-567-0456 • www.smsenergetics.com

Test Report

UN Series Testing on Select Thermite-Additive Formulations

September 28, 2023
SMS-6265k-R2, Rev 1

Troy A. Gardner, PE, CSP
Testing & Classifications Manager
Safety Management Services, Inc.

Jackson D. Zarbock
Project Engineer
Safety Management Services, Inc.

TABLE OF CONTENTS

TABLES

FIGURES

PHOTOS

1.0 STATEMENT OF WORK

DOT Contract # 693JK320C000005 with Safety Management Services, Inc. (SMS) of West Jordan, Utah defines that in conjunction with Tasks 15, SMS shall:

1) Perform mixing and classification testing (UN Series 1 and 2, UN Series 6 (a) Single Package) on six of the COR-approved optimized thermites with specific quantities of additives.
2) Perform mixing and full UN Series 6 (c) External bonfire testing on two of the COR-approved optimized thermites with specific quantities of additives.
3) Provide the COR with a test report and videos.

2.0 SUMMARY AND CONCLUSIONS

Once the base thermite and thermite-additive formulations were optimized and tested (Tasks 11 - 14), six thermite formulations were selected to undergo UN Series 1, 2, and 6 (a) Single Package testing. The selected formulations are given in Table 1. For additional detail regarding the optimization and testing of the base thermite formulations and thermite-additive formulations, see SMS-6265k-R1.

Table 1: Thermite-Additive Formulations Selected for Task 15

Sample ID	Composition (wt%)			Additive Type
	MgAl	Fe_2O_3	Additive	
LS #1-6-A30	38%	32%	30%	PTFE
LS #1-6-C30	38%	32%	30%	$NaNO_3$
Sample ID	**Composition (wt%)**			**Additive Type**
	MgAl	**CuO**	**Additive**	
LS #4-5-A10	25%	65%	10%	PTFE
LS #4-5-A30	25%	45%	30%	PTFE
LS #4-5-C30	25%	45%	30%	$NaNO_3$
LS #4-5-D30	25%	45%	30%	CaO_2

The-thermite additive formulations were subjected to the following tests:

- UN Series 1 and 2 (a) UN Gap Test
- UN Series 1 and 2 (b) Koenen Test
- UN Series 1 and 2 (c) (i) Time/Pressure Test
- UN Series 1 and 2 (c) (ii) Internal Ignition Test
- UN Series 6 (a) Single Package Test

The results for these tests are summarized in Table 2.

Table 2: UN Series 1, 2, and 6 (a) Test Results Summary

Sample ID	UN Series 1 and 2				UN Series 6
	Zero Gap	Koenen	Internal Ignition	Time Pressure	Single Package
LS #1-6-A30	Pass, no hole in witness plate, pipe did not fragment.	Positive Result at 2.0 mm	Pass, pipe did not fragment. Extremely energetic reaction observed.	Fail, time to rise from 100 to 300 psi less than 30 ms.	Mass dispersion of sand, audible report, detonation waveform measured. No damage to the witness plate.
LS #1-6-C30	Pass, no hole in witness plate, pipe did not fragment.	Negative Result for 3 trials at 1.0 mm	Pass, pipe did not fragment. Extremely energetic reaction observed.	Fail, time to rise from 100 to 300 psi less than 30 ms.	Mass dispersion of sand, audible report, positive pressure pulse measured. No damage to witness plate.
LS #4-5-A10	Pass, no hole in witness plate, pipe did not fragment.	Positive Result at 2.0 mm	Pass, pipe did not fragment. Extremely energetic reaction observed.	Fail, time to rise from 100 to 300 psi less than 30 ms.	Mass dispersion of sand, audible report, detonation waveform measured. No damage to the witness plate.
LS #4-5-A30	Pass, no hole in witness plate, pipe did not fragment.	Positive Result at 2.0 mm	Pass, pipe did not fragment. Extremely energetic reaction observed.	Fail, time to rise from 100 to 300 psi less than 30 ms.	Mass dispersion of sand, audible report, positive pressure pulse measured. No damage to witness plate.
LS #4-5-C30	Pass, no hole in witness plate, pipe did not fragment.	Positive Result at 2.0 mm	Pass, pipe did not fragment. Extremely energetic reaction observed.	Fail, time to rise from 100 to 300 psi less than 30 ms.	Mass dispersion of sand, audible report, detonation waveform measured. No damage to the witness plate.
LS #4-5-D30	Pass, no hole in witness plate, pipe did not fragment.	Positive Result at 1.5 mm	Pass, pipe did not fragment. Extremely energetic reaction observed.	Fail, time to rise from 100 to 300 psi less than 30 ms.	Mass dispersion of sand, audible report, detonation waveform measured. No damage to the witness plate.

No formulation was shown to be shock sensitive. Four of the six formulations were considered Class 1 explosives based on the Koenen test results. No formulation fragmented the confining media during Internal Ignition Test. However, very violent reactions were observed. All formulations exhibited hazards consistent with a mass explosion during the single package test.

The following thermite-additive formulations were selected to undergo a full-scale UN Series 6 (c) External Fire Test:

- 1-6-A30
- 4-5-C30

Both formulations exhibited overpressure and burn rate characteristic consistent with Division 1.1, with the material being consumed instantaneously, resulting in a mass explosion and massive fireball with a radius greater than 4 meters. Thermal flux hazards exceeded mass-scaled thermal flux values typical from Hazard Division 1.3 type materials.

Based on these results and those detailed in SMS-6265k-R1, the additives studied can result in formulations that are more sensitive to impact, friction, and thermal stimulus than base thermite formulations. Reaction rate and overall reaction violence can increase or decrease with the additives, depending on the base thermite formulation. All tested thermite-additive formulations displayed Class 1 hazard characteristics when either heated or ignited.

3.0 ACKNOWLEDGEMENTS

The mixing of all thermites was performed by Derek M. Sutton. Testing was performed by Troy A. Gardner, Jason T. Ford, Collin L. Boren, and Jackson D. Zarbock.

4.0 BACKGROUND

Historically, industry has offered traditional thermite formulations (containing only metal and metal oxides) for transport in Class 4 as flammable or water-reactive solids. The reaction produces a burst of heat, high temperature, and molten metal for various uses including joining steel railroad ties or copper transmission lines, metal refining, disabling munitions, etc. Traditional thermite formulations pass the UN Manual of Tests and Criteria, Appendix 6 “Screening Procedures” for substances which may have explosive properties as they do not contain any of the chemical groups listed in Table A6.1 that are associated with explosive properties. NOTE: The Appendix 6 Screening Procedures cannot be used for substances manufactured with the view to producing a practical explosive or pyrotechnic effect.

Newer “exotic” thermite formulations include those with additives such as plastics, oxidizers, nano materials, explosives, etc. to confer special compositions or actions upon use. Additional research into the effect of additives was needed to identify families of new and existing thermite compositions and to determine their hazards in transport and to transport vehicles.

5.0 DESCRIPTION THERMITE-ADDITIVE FORMULATIONS

Six thermite-additive formulations were to undergo testing. These formulations were selected based on the results detailed in SMS-6265k-R1. Descriptions of the thermite-additive formulations are given below.

5.1 Large-Scale #1-6-A30 – MgAl-Fe_2O_3-PTFE Thermite

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 38% magnalium (50/50 wt% magnesium/aluminum alloy), 32% ferric oxide (Fe_2O_3), and 30% polytetrafluoroethylene (PTFE), or Teflon powder. The magnalium was 1 - 5 micrometers (microns) in size. The ferric oxide was 2N purity (99% pure), 1 - 5 microns in size, and offered for transport as non-regulated. The Teflon powder was 6-9 microns in size and offered for transport as non-regulated. This thermite was a fine, red powder when fully mixed.

Photo 1: Fine MgAl-Fe_2O_3-PTFE Thermite – Large-Scale #1-6-A30

5.2 Large-Scale #1-6-C30 – MgAl-Fe_2O_3-$NaNO_3$ Thermite

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 38% magnalium (50/50 wt% magnesium/aluminum alloy), 32% ferric oxide (Fe_2O_3), and 30% polytetrafluoroethylene (PTFE), or Teflon powder. The magnalium was 1 - 5 micrometers (microns) in size. The ferric oxide was 2N purity (99% pure), 1 - 5 microns in size, and offered for transport as non-regulated. The Sodium Nitrate ($NaNO_3$) powder was 98.5% pure, less than 50 microns in size, and offered for transport as non-regulated. This thermite was a fine, red powder when fully mixed.

Photo 2: Fine MgAl-Fe_2O_3-PTFE Thermite – Large-Scale #1-6-A30

5.3 Large Scale #4-5-A10 – MgAl-CuO-PTFE Thermite

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 25% magnalium (50/50 wt% magnesium/aluminum alloy), 65% copper (II)/cupric oxide (CuO), and 10% polytetrafluoroethylene (PTFE), or Teflon powder. The magnalium was 1 - 5 micrometers (microns) in size. The cupric oxide was 3N purity (99.9% pure), 1 - 5 microns in size, and offered for transport as Class 9. The Teflon powder was 6-9 microns in size and offered for transport as non-regulated. This thermite was a very fine, dark gray powder when fully mixed.

Photo 3: Fine MgAl-CuO-PTFE Thermite – Large-Scale #4-5-A10

5.4 Large Scale #4-5-A30 – MgAl-CuO-PTFE Thermite

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 25% magnalium (50/50 wt% magnesium/aluminum alloy), 45% copper (II)/cupric oxide (CuO), and 30% polytetrafluoroethylene (PTFE), or Teflon powder. The magnalium was 1 - 5 micrometers (microns) in size. The cupric oxide was 3N purity (99.9% pure), 1 - 5 microns in size, and offered for transport as Class 9. The Teflon powder was 6-9 microns in size and offered for transport as non-regulated. This thermite was a very fine, dark gray powder when fully mixed.

Photo 4: Fine MgAl-CuO-PTFE Thermite – Large-Scale #4-5-A30

5.5 Large Scale #4-5-C30 – MgAl-CuO-$NaNO_3$ Thermite

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 25% magnalium (50/50 wt% magnesium/aluminum alloy), 45% copper (II)/cupric oxide (CuO), and 30% sodium nitrate ($NaNO_3$) powder. The magnalium was 1 - 5 micrometers (microns) in size. The cupric oxide was 3N purity (99.9% pure), 1 - 5 microns in size, and offered for transport as Class 9. The Sodium Nitrate ($NaNO_3$) powder was 98.5% pure, less than 50 microns in size, and offered for transport as non-regulated. This thermite was a very fine, dark gray powder when fully mixed.

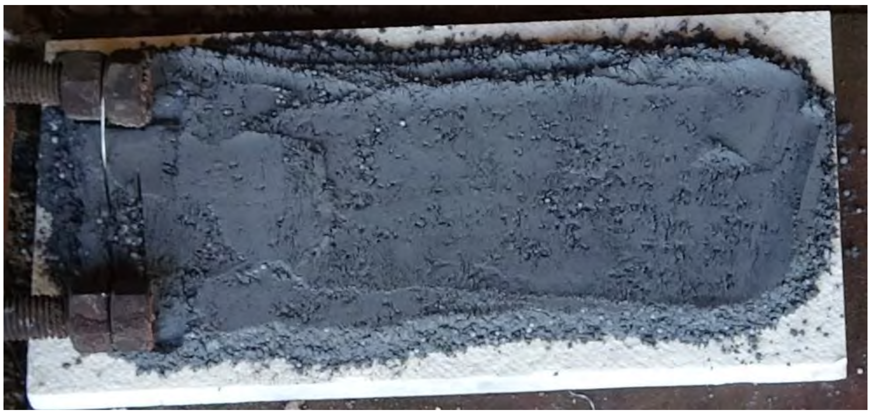


Photo 5: Fine MgAl-CuO- $NaNO_3$ Thermite – Large-Scale #4-5-C30

5.6 Large Scale #4-5-D30 – MgAl-CuO-CaO_2 Thermite

SMS procured and mixed the raw ingredients for this thermite. The composition of this thermite by mass was 25% magnalium (50/50 wt% magnesium/aluminum alloy), 45% copper (II)/cupric oxide (CuO), and 30% calcium peroxide (CaO_2) powder. The magnalium was 1 - 5 micrometers (microns) in size. The cupric oxide was 3N purity (99.9% pure), 1 - 5 microns in size, and offered for transport as Class 9. The calcium peroxide (CaO_2) powder was 81% pure, less than 50 microns in size, and offered for transport as non-regulated. This thermite was a very fine, light gray powder when fully mixed.

Photo 6: Fine MgAl-CuO- CaO_2 Thermite – Large-Scale #4-5-D30

6.0 TEST DESCRIPTIONS AND RESULTS

6.1 UN Series 1 (a) Zero Gap Test

6.1.1 Test Description

This test is used to measure the ability of a substance under confinement to propagate a detonation by subjecting it to a shock impulse from a booster charge. The sample is loaded to the top of a cold-drawn, seamless, carbon steel tube (48.0 ± 2 mm outer diameter, 4 ± 1 mm wall, and 400 ± 5 mm long). Solid samples are loaded to the density attained by tapping the tube until further settling becomes imperceptible. The sample mass is determined and, if solid, the apparent density calculated.

A 160-gram RDX/wax (95/5) or PETN/TNT (50/50) booster of 50 mm diameter and approximately 50mm length is used to provide a shock source placed directly on the tube. The tube is placed over a 150 ± 10mm (6-in) square, 3.2 ± 0.2mm (1/8-in) thick steel witness plate and separated from it by 1.6 ± 0.2mm (1/16-in) thick spacers. An air gap of at least 50 mm (2 in) is provided between the witness plate and the ground. The booster is initiated by a standard detonator.

The test is performed two times unless a positive result is observed during the first trial. The test result is considered positive and the substance sensitive to shock if the tube is fragmented completely or the witness plate is holed. Any other result is considered negative.

The result is considered positive and the substance sensitive to shock for the UN Series 2 (a) test if the tube is fragmented completely or the witness plate is holed. Any other result is considered negative and the substance not sensitive to detonative shock for the UN Series 2 (a) test.

6.1.2 Test Configuration

A PETN/TNT (50/50) booster was utilized for these tests. The dimensions of the steel tubes were 48 mm outer diameter, 4 mm wall (36 mm ID), and 400 mm long. The quantity of material required to fill each tube is listed in Table 3; the apparent density was calculated using a calculated internal volume of 503 cm^3.

Table 3: UN Series 1 (a) Zero Gap Weights and Densities

Sample ID	Trial	Weight (lb)	Weight (g)	Density (g/cm³)
LS #1-6-A30	1	0.6916	314	0.62
	2	0.6920	314	0.62
LS #1-6-C30	1	0.9016	409	0.81
	2	0.9020	409	0.81

Sample ID	Trial	Weight (lb)	Weight (g)	Density (g/cm³)
LS #4-5-A10	1	1.2616	572	1.14
	2	1.2621	572	1.14
LS #4-5-A30	1	0.8916	404	0.80
	2	0.8918	405	0.80
LS #4-5-C30	1	1.5416	699	1.39
	2	1.5421	699	1.39
LS #4-5-D30	1	1.2160	552	1.10
	2	1.2200	553	1.10

The tubes were filled and centered over the witness plate. A typical setup is shown in Photo 7.

Photo 7: UN Series (a) Zero Gap Test Setup – typical

6.1.3 Test Results

The test results are given in Table 4. Photos of test results are given in Photo 8 through Photo 13.

Table 4: UN Series (a) Zero Gap Test Results

Sample ID	Trial	Results	Assessment
LS #1-6-A30	1	Pass, plate bent but was not punctured. Majority of pipe intact.	Negative (NOT sensitive to detonative shock)
	2	Pass, plate bent but was not punctured. Majority of pipe intact.	
LS #1-6-C30	1	Pass, plate bent but was not punctured. Pipe split into two large pieces.	Negative (NOT sensitive to detonative shock)
	2	Pass, plate bent but was not punctured. Pipe split into two large pieces.	
LS #4-5-A10	1	Pass, plate bent but was not punctured. Majority of pipe intact, with large pieces.	Negative (NOT sensitive to detonative shock)
	2	Pass, plate bent but was not punctured. Majority of pipe intact, with large pieces.	
LS #4-5-A30	1	Pass, plate bent but was not punctured. Pipe split into two large pieces.	Negative (NOT sensitive to detonative shock)
	2	Pass, plate bent but was not punctured. Pipe split into two large pieces.	
LS #4-5-C30	1	Pass, plate slightly bent but was not punctured. Pipe split into three large pieces.	Negative (NOT sensitive to detonative shock)
	2	Pass, plate slightly bent but was not punctured. Pipe split into three large pieces.	
LS #4-5-D30	1	Pass, plate slightly bent but was not punctured. Pipe split into three large pieces.	Negative (NOT sensitive to detonative shock)
	2	Pass, plate slightly bent but was not punctured. Pipe split into three large pieces.	

Trial 1	Trial 2

Photo 8: Large-Scale #1-6-A30 UN 1 (a) Zero Gap Test Results

Trial 1	Trial 2

Photo 9: Large-Scale #1-6-C30 UN 1 (a) Zero Gap Test Results

Trial 1	Trial 2

Photo 10: Large-Scale #4-5-A10 UN 1 (a) Zero Gap Test Results

Trial 1	Trial 2

Photo 11: Large-Scale #4-5-A30 UN 1 (a) Zero Gap Test Results

Trial 1	Trial 2

Photo 12: Large-Scale #4-5-C30 UN 1 (a) Zero Gap Test Results

Trial 1	Trial 2

Photo 13: Large-Scale #4-5-D30 UN 1 (a) Zero Gap Test Results

6.2 UN Series 1 & 2 (b) Koenen Test

6.2.1 Test Description

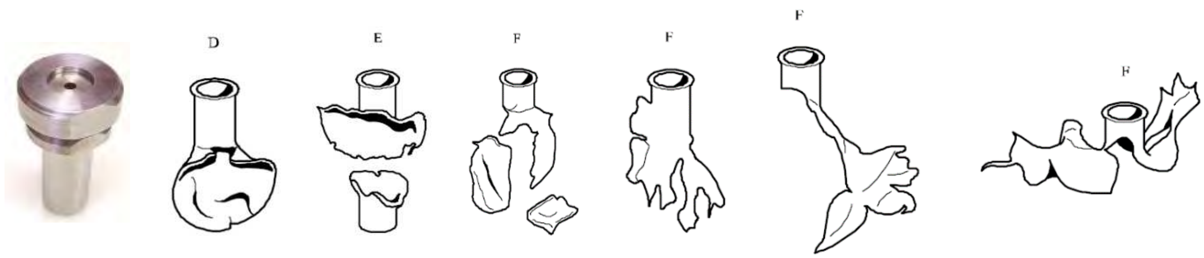
The Koenen test is used to determine the sensitiveness of solid and liquid substances to intense heat under high confinement. This test utilizes a steel tube to hold the sample. The tube is deep drawn from DC04, A620, or SPCEN sheet steel; 26.5 ± 1.5 grams mass, 75 °C 0.5mm length, 0.5 ± 0.05mm wall, and 30 ± 3 MPa quasi-static bursting pressure. The sample is loaded typically loaded into the tubes in three equal increments with each increment tamped with an 80 N force applied to the total cross-section of the tube until the tube is filled to 60mm. However, because compacting and confining thermites typically deaden the reaction violence, the samples were loaded into the tube and tapped until settled. The tube is assembled into a reusable closing device (threaded nut and collar) and an orifice plate installed on the open end of the tube. Varying the orifice plate over the top of the sample tube changes the degree of confinement of the sample.

Figure 1: Koenen Tube, Orifices, Plate, and Reusable Closing Device

The tube is placed in the heating and protective device, the test area vacated, burners remotely lit, providing a calibrated heating rate to the sample by propane burners located at four locations around the tube for at least 5 minutes or until the tube ruptures. NOTE: The heating rate is calibrated to 3.3 ± 0.3°K/sec using the time for 27 cm^3 of dibutyl phthalate to rise from 135°C to 285°C as measured by a 1mm thermocouple placed 43mm below the rim of the tube through a 1.5mm orifice plate (the rise time must be between 41.7 - 50.0 seconds).

After each trial the fragments of the tube, if any, are collected. The following effects are differentiated:

"O": Tube unchanged;
"A": Bottom of tube bulged out;
"B": Bottom and wall of the tube bulged out;
"C": Bottom of tube split;
"D": Wall of tube split;
"E": Tube split into two fragments;
"F": Tube fragmented into three or more mainly large pieces which in some cases may be connected with each other by a narrow strip;
"G": Tube fragmented into many mainly small pieces, closing device undamaged; and
"H": Tube fragmented into many very small pieces, closing device bulged out or fragmented.



If a trial results in any of the effects "O" to "E", the result is regarded as "no explosion". If a trial gives the effect "F", "G" or "H", the result is evaluated as "explosion". The test is performed three times at the lowest orifice size that the result "no explosion" is observed. The limiting diameter (LD) is the largest orifice diameter at which the result "explosion" is obtained. The orifice sizes are reduced until an explosion effect occurs or the substance passes the test with the smallest orifice (1.0mm).

The result is considered positive for the UN Series 2 (b) test if the substance exhibits an explosion when heated under confinement at an LD of 2.0mm. The result is considered negative for the UN Series 2 (b) test but positive for the UN Series 1 (b) test if exhibits an explosion when heated under confinement at an LD of greater than or equal to 1.0mm. The result is considered negative if the substance does not exhibit an explosion at an LD of 1.0mm. Three trials are performed to confirm the size above the LD does not result in an explosion.

6.2.2 Test Configuration

Samples were initially tested at 2.0mm orifice size. If the trial resulted in an explosion, then the formulation results were considered positive for the UN Series 2 (b) test. If the trial resulted in a no explosion, two more trials were conducted at 2.0mm. If all trials at 2.0mm resulted in no explosions, then the samples were tested at 1.0mm. If the trial resulted in a no explosion, two more trials were conducted at 1.0mm. If all trials resulted in no explosions, then the formulation results were considered negative for the UN Serie 1 (b) test. If the trial at 1.0mm resulted at 1.0mm resulted in an explosion, then the sample was tested three times at 1.5mm.

The formulations were loaded into the Koenen tubes and tapped until visible settling was negligible. The tube was then placed in a collar and an orifice plate was installed and tightened. The test tube was centered in the heating and protective device as shown in Photo 14. The material weights for each trial are given in Table 5.

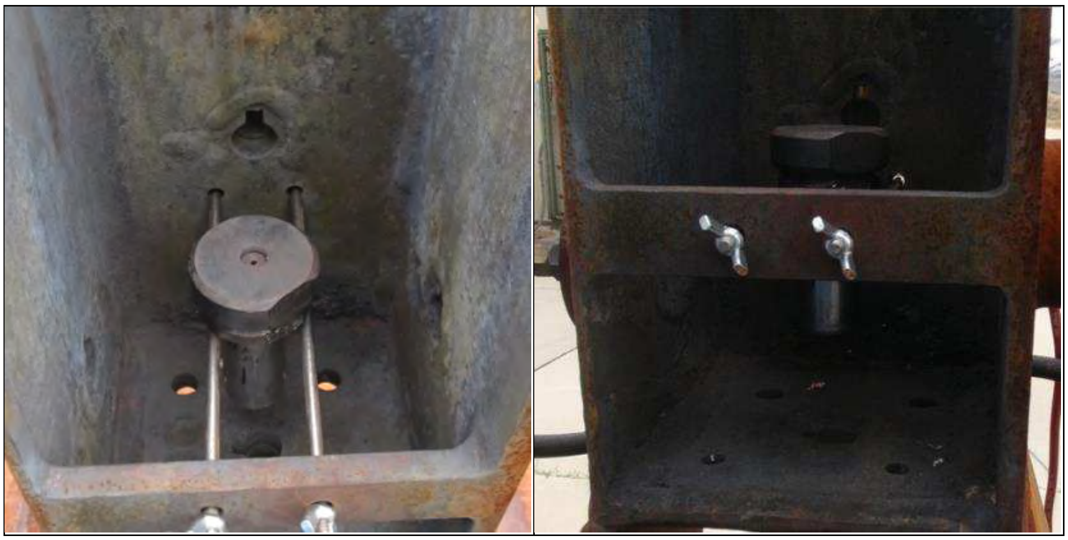


Photo 14: Koenen Tube Suspended in Heating and Protective Device

For the calibration trials, Sigma-Aldrich P/N 378364-1L silicone oil with a viscosity of 100 cSt (25°C) and a density of 0.96 g/mL at 25°C was utilized; the time for 27 cm^3 of the silicone oil to rise from 135°C to 285°C measured by a 1mm thermocouple placed 43mm below the rim of the tube through a 1.5mm orifice plate was 43.1 and 46.6 seconds, which was within calibration.

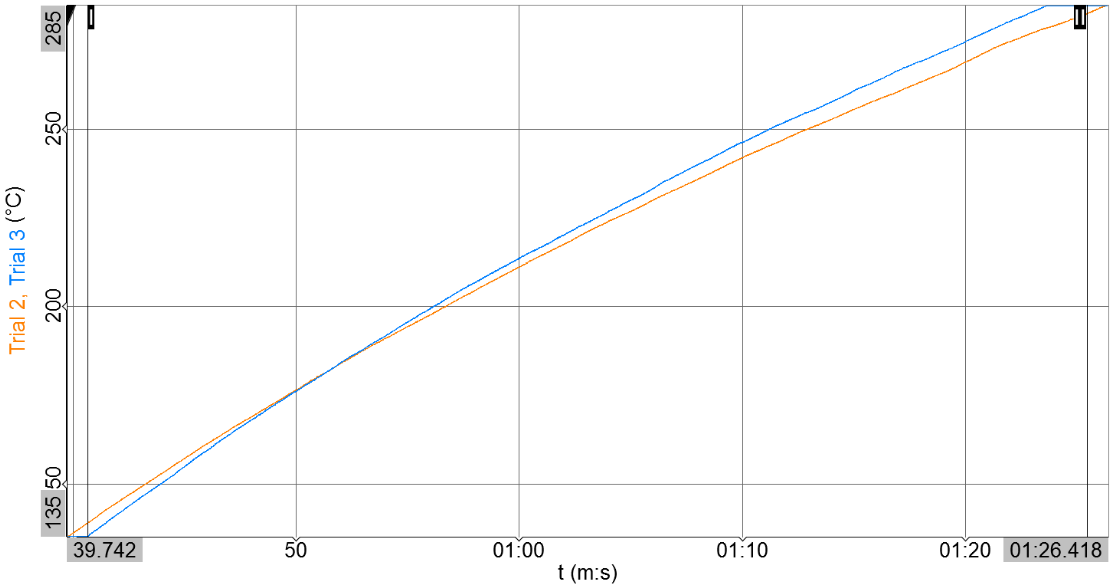


Figure 2: Calibration of Koenen Heating Rate with Silicone Oil

6.2.3 Test Results

The test results for all Koenen trials are given below. Photos of test results are provided in the Appendix.

Table 5: UN Series 1/2 (b) Koenen Test Results and Details

Sample ID	Trial	Material Mass	Orifice (mm)	Result	Reaction Time
1-6-A30	1	16.19	2.0	(+), type "F"	00:52.8
1-6-C30	1	24.31	2.0	(+), type "F"	00:29.3
	2	25.52	2.0	(+), type "F"	01:07.5
	3	24.40	2.0	(-), type "A"	00:49.8
	4	24.35	1.0	(-), type "A"	00:45.5
	5	25.53	1.0	(-), type "A"	00:47.6
	6	25.53	1.0	(+), type "F"	00:15.6
4-5-A10	1	35.19	2.0	(+), type "F"	00:39.6
4-5-A30	1	27.45	2.0	(+), type "F"	00:53.4
4-5-C30	1	39.35	2.0	(-), type "A"	00:57.6
4-5-D30	1	27.09	2.0	(-), type "A"	00:35.4
	2	27.03	2.0	(-), type "A"	00:44.8
	3	27.03	2.0	(-), type "A"	00:41.8
	4	27.92	1.0	(-), type "E"	00:54.8
	5	27.91	1.5	(-), type "D"	01:02.6

6.3 UN Series 1 & 2 (c) (i) Time/Pressure Test

6.3.1 Test Description

The Time/Pressure Test is used to determine whether igniting a substance under confinement will result in a deflagration with explosive violence. The Time/Pressure Test is used in both Test 1 (c) and Test 2 (c) to determine if a substance displays explosive violence when ignited under confinement. The test apparatus is shown in Figure 3.

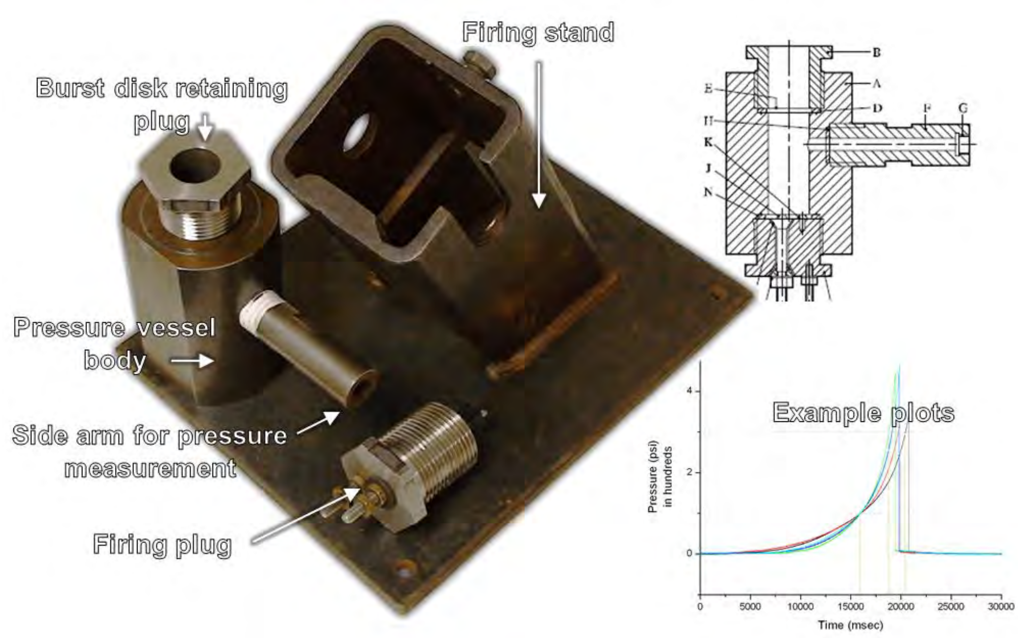


Figure 3: Time/Pressure Test Apparatus

A five-gram sample is placed inside the pressure vessel body. The firing plug is fitted with a 13mm square piece of primed cambric (linen fabric coated on both sides with a potassium nitrate/ silicon/ sulphurless gunpowder pyrotechnic composition) or equivalent and screwed into the bottom of the housing. A burst disk is fitted into the top opening of the pressure vessel body with a lead washer to provide an airtight seal. The burst disk retaining plug is inserted into the top of the pressure vessel and screwed into place. A pressure transducer is screwed into the pressure vessel body to monitor the pressure over time.

The Time/Pressure test is used in both Test 1 (c) and Test 2 (c). In UN Test 1 (c) the pressure is monitored to see if it reaches 2070 kPa (300 psig) whereas in UN Test 2 (c) the pressure is monitored to see if it transitions from 690-2070 kPa (100-300 psig) in less than 30 msec. Three trials are typically performed.

6.3.2 Test Configuration

Five-gram samples of each thermite-additive formulation were weighed and placed into the apparatus. The device was fitted with a high temperature pyrogen match. The ignition source and typical setup are shown in Photo 15.

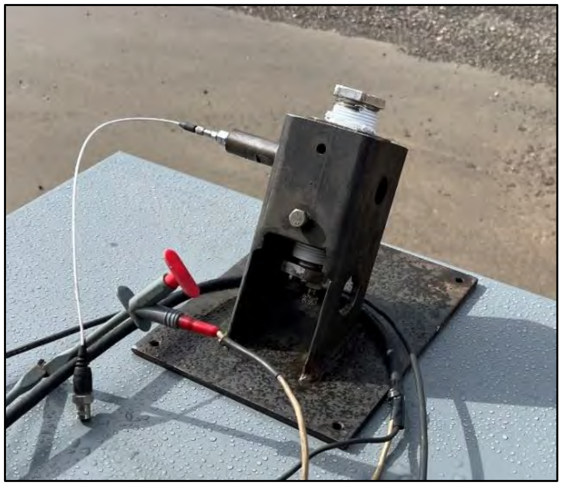


Photo 15: Time/Pressure Ignition Source and Test Setup - typical

6.3.3 Test Results

The Time/Pressure Test was conducted on all six thermite-additive formulations. The test results are summarized in Table 6. All test formulations displayed explosive behavior when ignited under confinement.

Table 6: UN Series 1/2 (c) (i) Time/Pressure Test Results

Thermite ID	Time to rise from 100 to 300 psi (ms)	Result
LS #1-6-A30	0.67	(+), formulation exhibits explosive hazards when ignited under confinement and is accepted into Class 1.
LS #1-6-C30	4.27	(+), formulation exhibits explosive hazards when ignited under confinement and is accepted into Class 1.
LS #4-5-A10	1.19	(+), formulation exhibits explosive hazards when ignited under confinement and is accepted into Class 1.
LS #4-5-A30	0.45	(+), formulation exhibits explosive hazards when ignited under confinement and is accepted into Class 1.
LS #4-5-C30	0.28	(+), formulation exhibits explosive hazards when ignited under confinement and is accepted into Class 1.
LS #4-5-D30	0.21	(+), formulation exhibits explosive hazards when ignited under confinement and is accepted into Class 1.

6.4 UN Series 1 & 2 (c) (ii) Internal Ignition Test

6.4.1 Test Description

The Internal Ignition Test is used to determine if a substance will transition from deflagration to detonation when ignited under confinement. The substance is loaded into a 3-inch schedule 40 carbon steel (A53 Grade B) pipe, 74 mm ID, 7.6 mm wall thickness, 45.7 cm (18 inches) that is capped at one end with a 3,000-pound forged steel end cap. Solid samples are loaded to the density attained by tapping the tube until further settling becomes imperceptible.

When the pipe is filled halfway, an igniter is placed at the center of the tube through an orifice in the wall. For UN Series 1 (c) (ii), a 20-gram black powder bag igniter is typically used. For UN Series 2 (c) (ii) a 10-gram black powder bag igniter is typically used. Sample is then loaded around the bag igniter until the tube is full. The tube is capped at the other end with a second 3,000-pound forged steel end cap. The figure below shows a typical test set-up. The test is considered positive if the pipe or either end cap fragment into at least two distance pieces. Three trials are performed unless a positive result is achieved in an earlier trial.

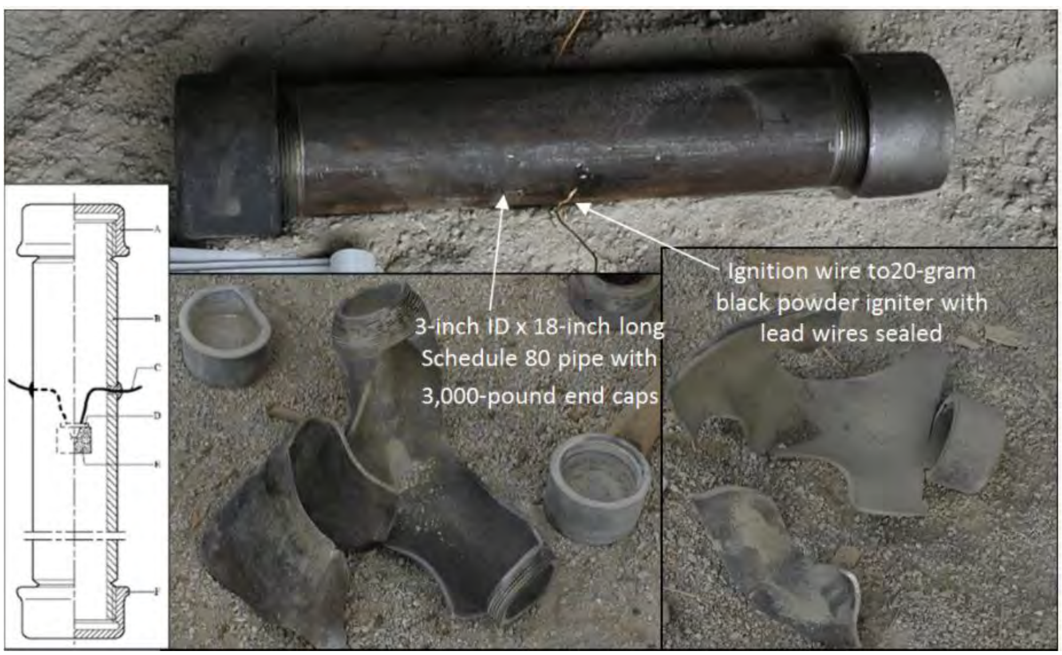


Figure 4: Typical Internal Ignition Test Set-up

6.4.2 Test Configuration

The thermite was loaded into the pipe and tamped until material settling was negligible. A 20-gram black powder bag igniter was used. The weights of all trials are given in Table 7. An example test setup is shown in Photo 16. All trials were placed below a large fragment table to restrain any fragments for collection.

Table 7: Sample Weights for UN Series 1/2 (c) (ii) Internal Ignition Test

Sample ID	Weights (lb)		
	Trial 1	Trial 2	Trial 3
LS #1-6-A30	2.97	2.50	2.70
LS #1-6-C30	3.70	3.70	3.92
LS #4-5-A10	5.07	5.10	5.30
LS #4-5-A30	3.50	3.80	3.70
LS #4-5-C30	6.60	6.30	6.60
LS #4-5-D30	5.00	5.10	5.00

Photo 16: UN Series 1/2 (c) (ii) Internal Ignition Test Setup – typical

6.4.3 Test Results

The test results are summarized in Table 8. Test result photos are given in the appendix. Videos of all tests are provided in SMS-6265k-V3.

Table 8: UN Series 1/2 (c) (ii) Internal Ignition Test Results

Sample ID	Results		
	Trial 1	Trial 2	Trial 3
LS #1-6-A30	Pass, pipe not fragmented or endcap. Orifice enlarged to 1-inch diameter.	Pass, pipe not fragmented or endcap. Orifice enlarged to 1-inch diameter.	Pass, pipe not fragmented or endcap. Orifice enlarged to 1-inch diameter.
LS #1-6-C30	Pass, pipe not fragmented or endcap. Orifice enlarged to 1-inch diameter.	Pass, pipe not fragmented or endcap. Orifice enlarged to 1-inch diameter.	Pass, pipe not fragmented or endcap. Orifice enlarged to 1-inch diameter.
LS #4-5-A10	Pass, pipe not fragmented. End cap was blown off. Orifice enlarged to 5-inch dimeter.	Pass, pipe not fragmented. End cap was blown off and dented top of fragment table.	Pass, pipe not fragmented. End cap was blown off and dented top of fragment table.
LS #4-5-A30	Pass, pipe not fragmented. End cap was blown off and found 60 yards away.	Pass, pipe not fragmented. End cap was blown off and dented top of fragment table.	Pass, pipe not fragmented. End cap was blown off and dented top of fragment table.
LS #4-5-C30	Pass, pipe not fragmented. End cap blown off and pipe was pushed 18 inches into the ground.	Pass, pipe not fragmented. End cap blown off and pipe was pushed 6 inches into the ground	Pass, pipe did not fragment but turned into projectile, punching a clean hole through the fragment table.
LS #4-5-D30	Pass, pipe and end caps not fragmented. Orifice enlarged to 1-inch diameter.	Pass, pipe and end caps not fragmented. Orifice enlarged to 1-inch diameter.	Pass, pipe and end caps not fragmented. Orifice enlarged to 1-inch diameter.

Based on these results, thermite-additive formulations exhibit extremely energetic reactions without fragmenting robust confining media. This indicates that test parameters for the Series 1 and 2 (c) (ii) Internal Ignition Test, misrepresent the hazards of thermites and thermite-additive formulations with known explosive characteristics. Thermite-additive formulations that are known to have highly energetic and explosive characteristics currently pass the Internal Ignition Test, per the test result indicators, namely fragmentation of the pipe and end caps.

7.0 UN SERIES 6 TEST DESCRIPTIONS AND RESULTS

7.1 Confined UN Series 6 (a) Single Package Test

7.1.1 Test Description

This test is applied to a packaged substance in the condition and form in which it will be offered for transport to determine whether there is a mass explosion of the package contents. Typically, substances intended to function by detonation are tested with a standard detonator inserted into the top of the substance; substances intended to function by deflagration are tested with an igniter located in the center of the substance in the package that is just sufficient (but not more than 30 grams of black powder) to ensure ignition of the substance. For this testing, thermites were ignited using a 10-gram sample of magnesium-based thermite starter mix with an electric match, or an insulated Nichrome hotwire igniter.

The package is placed on a 3mm-thick mild steel witness plate on the ground. Sand (bagged, boxed, or piled) is placed as closely as possible around the test package to a minimum thickness of confinement, in every direction of 0.5 meters for a package not exceeding 0.15 m³ and 1.0 meter for a package greater than 0.15 m³. The igniter is functioned and observations made on the following: evidence of thermal effects, projection effects, detonation, deflagration or explosion of the total contents of the package. The test is performed three times unless a decisive result occurs earlier (e.g. explosion of the total contents). Evidence of a mass explosion (a crater at the test site, damage to the witness plate beneath the package, measurement of a blast, and disruption and scattering of the confining material) indicates a candidate for Division 1.1.

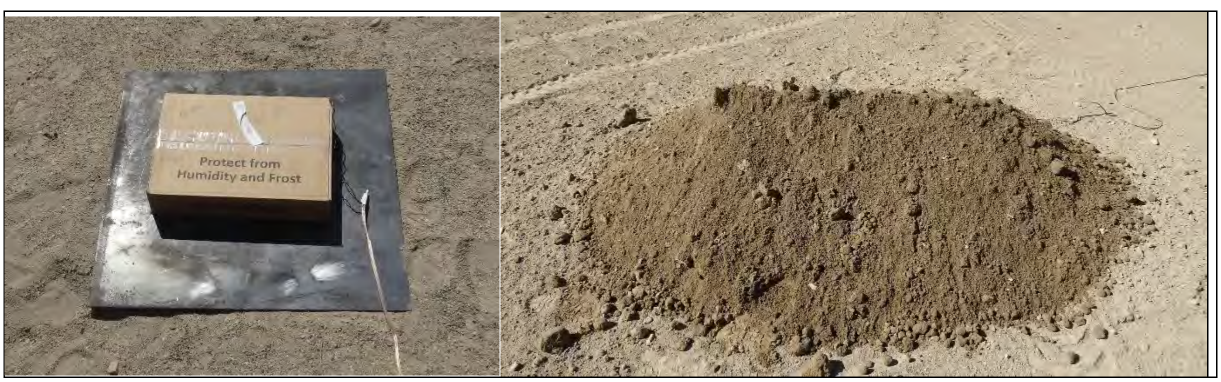


Photo 17: UN Series 6 (a) Single Package Test Setup - typical

7.1.2 Test Configuration

All trials were conducted with 25-pound quantities of thermite placed inside a thick conductive plastic bag within a fiberboard box. All LS #1-6 thermite-additive formulations were placed in boxes that were 14-inches long, 10 inches wide, and 6 inches tall. All LS #4-5 thermite-additive formulations were placed in boxes that were 14-inches long, 10 inches wide, and 8 inches tall.

Trial 1 for each formulation was ignited using an insulated Nichrome hotwire igniter (see Photo 18). Trial 2 for each formulation was ignited using a 10-gram thermite starter mix bag igniter (see Photo 19). Once it was established that the ignition source did not result in a different outcome with tests, Trial 3 was conducted using insulated Nichrome hotwire igniters.

Photo 18: Insulated Nichrome Hotwire Igniter – typical

Photo 19: Placement of Thermite Starter Mix Bag Igniter - typical

Three blast probes were placed at 18, 22, and 31 feet from the witness plate to assess whether 1) a true detonation or positive pressure pulse occurred, and 2) pressure differences between each of the trials. Data was acquired at 100,000 Hz. The sensors used at each distance and their calibration values are given in Table 10.

Table 9: Sensor Details for the UN Series 6 (a) Single Package Test

Distance (ft)	Sensor Type	Model Number	Range (psi)	Serial Number	Calibration Value (psi/mV)
18	ICP Blast Overpressure Probe	137A23	0-50	9880	0.0105
22	ICP Blast Overpressure Probe	137A23	0-50	9882	0.0106
31	ICP Blast Overpressure Probe	137A23	0-50	9883	0.0106

7.1.3 Test Results

Test results are summarized in Table 10. Test result photos and pressure pulses are given in the appendix. The test videos are provided in SMS-6265k-V4. Maximum pressures are given to display a ranking system between trials and formulations.

Table 10: Summary of UN Series 6 (a) Single Package Test Results

Sample ID	Trial	Confining Media	Witness Plate	Blast Measurement	Assessment
LS #1-6-A30	1	Mass dispersion	Undamaged	Audible report. True detonation waveform. Pressure measurement: 0.495 - 0.560 psi	Explosion
	2	Mass dispersion	Undamaged	Audible report. True detonation waveform. Pressure measurement: 0.200 – 0.280 psi	Explosion
	3	Mass dispersion	Undamaged	Audible report. True detonation waveform. Pressure measurement: 0.240 – 0.340 psi	Explosion
LS #1-6-C30	1	Mass dispersion	Undamaged	Audible report. Positive pressure pulse. Pressure measurement: 0.090 psi – 0.210	Explosion
	2	Mass dispersion	Undamaged	Audible report. Positive pressure pulse. Pressure measurement: 0.020 – 0.045 psi	Explosion
	3	Mass dispersion	Undamaged	Faint audible report. Positive pressure pulse. Pressure measurement: 0.030 -0.050 psi	Explosion
LS #4-5-A10	1	Mass dispersion	Undamaged	Audible report. Deflagration waveform. Pressure measurement: 0.428 – 0.630 psi	Explosion
	2	Mass dispersion	Undamaged	Audible report. Deflagration waveform. Pressure measurement: 0.300 - 0.510 psi	Explosion
	3	Mass dispersion	Undamaged	Audible report. Deflagration waveform. Pressure measurement: 0.150 - 0.300 psi	Explosion
LS #4-5-A30	1	Mass dispersion	Undamaged	Audible report, deflagration waveform. Pressure measurement: 0.378 - 0.887 psi	Explosion
	2	Mass dispersion	Undamaged	Audible report, detonation waveform. Pressure measurement: 0.450 – 0.600 psi	Explosion
	3	Mass dispersion	Undamaged	Audible report, detonation waveform. Pressure measurement: 0.300 – 0.500 psi	Explosion

Sample ID	Trial	Confining Media	Witness Plate	Blast Measurement	Assessment
LS #4-5-C30	1	Mass dispersion	Undamaged	Audible report, detonation waveform. Pressure measurement: 0.970 – 1.30 psi	Explosion
	2	Mass dispersion	Undamaged	Audible report, detonation waveform. Pressure measurement: 1.10 – 1.20 psi	Explosion
	3	Mass dispersion	Undamaged	Audible report, detonation waveform. Pressure measurement: 1.70 – 2.20 psi	Explosion
LS #4-5-D30	1	Mass dispersion	Undamaged	Audible report, detonation waveform. Pressure measurement: 0.330 – 0.520 psi	Explosion
	2	Mass dispersion	Undamaged	Audible report, detonation waveform. Pressure measurement: 0.630 – 0.940 psi	Explosion
	3	Mass dispersion	Undamaged	Audible report. Positive pressure pulse. Pressure measurement: 0.180 - 0.500 psi	Explosion

All samples completely dispersed the confining medium, with at most a small ring surrounding the witness plate. In several trials, the witness plate was slightly bent, but no trials resulted in damage or perforation of the witness plate.

7.1.4 Conclusions

Based on maximum pressure values recorded during testing, the most violent LS #1-6 additive formulation was LS #1-6-A30 and the most violent LS #4-5 formulation was LS #4-5-C30. As such, these were the formulations selected to undergo full-scale UN Series 6 (c) Testing.

7.2 UN Series 6 (c) External Fire Test

7.2.1 Test Description

This test demonstrates the reaction of packaged substances or articles when exposed to a fire. The test is performed on a stack of packages in the condition and form in which they will be offered for transport. A stack of packages with a total volume of at least 0.15 m³ with a minimum of three packages is placed in the center of a non-combustible surface (steel grate) above sufficient quantity of fuel to provide a thirty-minute fire. Three 200-cm × 200-cm × 0.2-cm aluminum witness screens or witness screen frames are placed four meters from the edge of the stack to serve as visible distance markers. The fuel is ignited simultaneously on at least two sides and the material is observed for a) evidence of detonation, deflagration, or explosion of the total contents; b) potentially hazardous projections; and c) thermal effects (i.e. rate of burn, size of any fireball, etc.). The test is recorded using regular video with audio from two angles and visual distance marking devices; additionally, air-blast gauges and/or radiometers may also be utilized.

7.2.2 Test Configuration

All trials were conducted with 25-pound quantities of thermite placed inside a thick conductive plastic bag within a fiberboard box. Based on densities relative to commercially available thermites, LS #1-6-A30 was packaged in boxes that were 14-inches long, 10 inches wide, and 6 inches tall, LS #4-5-C30 was packaged in boxes that were 14-inches long, 10 inches wide, and 8 inches tall. A minimum number of packages required to achieve a total volume of 0.15 m^3 were prepared for each formulation. The total number of packages, total out volume, and total weight for each test is given in Table 11.

Table 11: Summary of UN Series 6 (c) External Fire Test Volumes and Weights

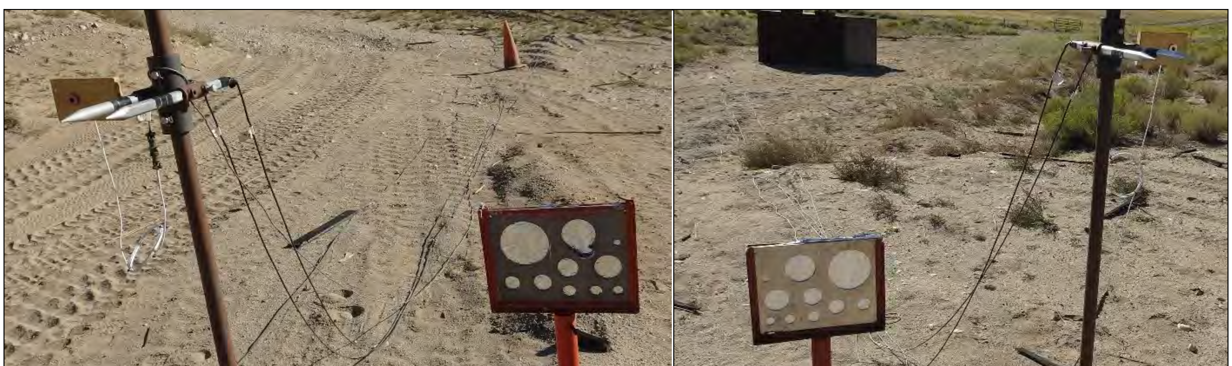
Sample ID	Package Dimensions (in)	Number of Packages	Total Volume	Total Weight (lbs)
LS #1-6-A30	14 x 10 x 8	9	0.165	225
LS #4-5-C30	14 x 10 x 6	11	0.151	275

The packages were placed at the center of the fuel source, with the base layer that was two packages wide. The top layer was one package wide, running along the middle of the base layer. The test setup for each trial is shown in Photo 20 and Photo 21.

Photo 20: LS #1-6-A30 UN Series 6 (c) External Fire Test Setup

Photo 21: LS #4-5-C30 UN Series 6 (c) External Fire Test Setup

Two sensor stations were deployed to measure blast overpressure and thermal flux. Each station was equipped with two ICP blast overpressure pencil probes and one thermal flux radiometer. The stations were placed 15 meters from the edge of the stack, at a ninety-degree angle. Additionally, Bikini gages were placed at the same locations as the sensor stations. The sensors stations and Bikini gages are shown in Photo 22. Details on the sensors used are given in Table 12.



Station 1	Station 2

Photo 22: UN Series 6 (c) External Fire Sensor Stations

Table 12: Sensor Details for the UN Series 6 (c) External Fire Test

Sensor Station	Sensor Type	Model Number	Range	Serial Number	Calibration Value
Blast Overpressure					
1	ICP Blast Overpressure Probe	137A23	0-50 psi	9880	0.0105 psi/mV
1	ICP Blast Overpressure Probe	137A23	0-50 psi	9882	0.0106 psi/mV
2	ICP Blast Overpressure Probe	137A23	0-50 psi	1911	0.0105 psi/mV
2	ICP Blast Overpressure Probe	137A23	0-50 psi	1913	0.0089 psi/mV
Heat Flux					
1	Hukseflux Radiometer	SBG01-005	0-5 kW/m^2	13320	1927 kW/m^2/V
2	Hukseflux Radiometer	SBG01-005	0-5 kW/m^2	13325	1942 kW/m^2/V

7.2.3 Test Results

7.2.3.1 LS #1-6-A30 UN Series 6 (c) External Fire

The formulation ignited approximately one minute and thirty seconds after ignition of the fire. The enter stack reacted instantaneously, producing an audible report and a fire ball that completely engulfed the witness screen frames. The height of the reaction is shown in Photo 23. The test video is provided as SMS-6265k-V5.

Photo 23: LS #1-6-A30 UN Series 6 (c) External Fire Reaction

The reaction produced a deflagration curve with a small positive pressure pulse preceding it. Maximum pressures for the small pressure pulse were measured at 0.7 psi at station 1 and 0.67 psi at station 2. The deflagration curve resulted in a maximum pressure between 7.8 and 16.5

psi at station 1 and 9.4 and 10.5 psi at station 2. Images of the pressure pulse and deflagration curve are shown in Figure 5 and Figure 6.

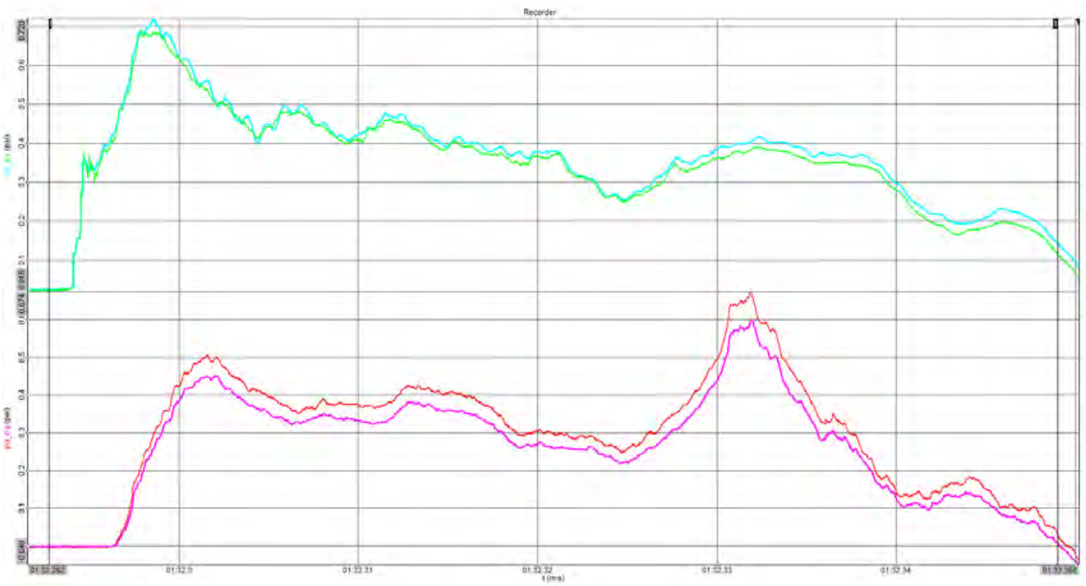


Figure 5: LS #1-6-A30 External Fire Positive Pressure Pulse (zoomed in)

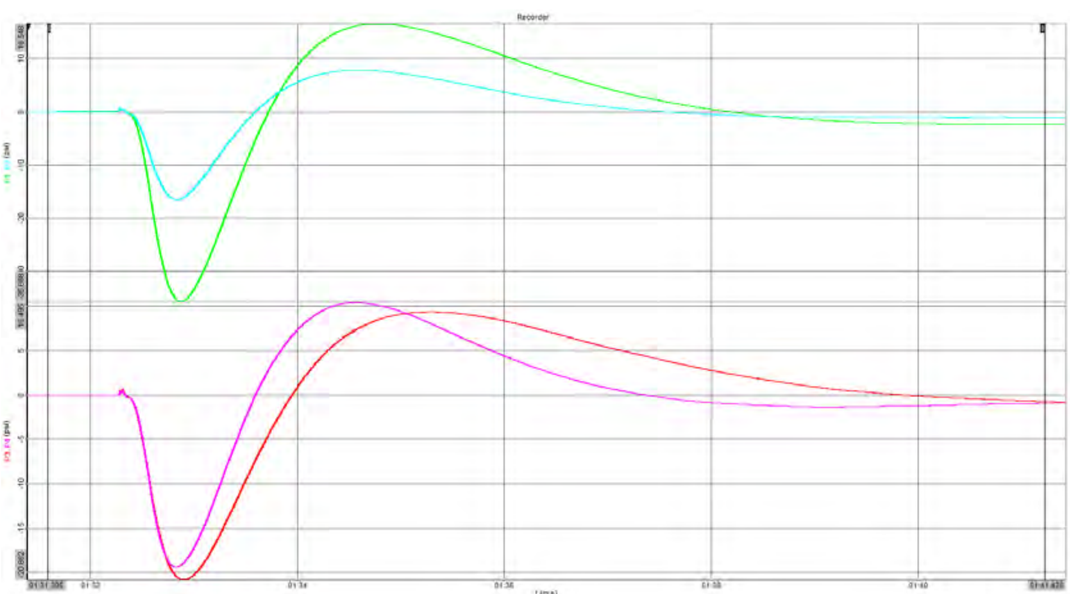


Figure 6: LS #1-6-A30 External Fire Deflagration Curve (zoomed out)

The blast did not rupture any of the holes in the Bikini gages (rupture pressure less than 2.2 psi). The blast scattered the wood lattice around the test area as shown in Photo 24; the remains in the burn pan are shown in Photo 25.

Photo 24: Wood Lattice Scattered by Explosion

Photo 25: Post-Test Steel Grating in Burn Pan

7.2.3.2 LS # 4-5-C30 UN Series 6 (c) External Fire

The formulation ignited within approximately thirty seconds of ignition of the fire. The enter stack reacted instantaneously, producing an audible report and a fire ball that completely engulfed the witness screen frames. The height of the reaction is shown in Photo 26. The test video is provided as SMS-6265k-V5.

Photo 26: LS #4-5-C30 UN Series 6 (c) External Fire Reaction

The reaction produced a deflagration curve with a true detonation curve preceding it. Maximum detonation pressures were measured at 3.76 psi at station 1 and 3.72 psi at station 2. The deflagration curve resulted in a maximum pressure between 4.8 and 13.0 psi at station 1 and 5.8 and 6.8 psi at station 2. Images of the detonation and deflagration curves are shown in Figure 7 and Figure 8.

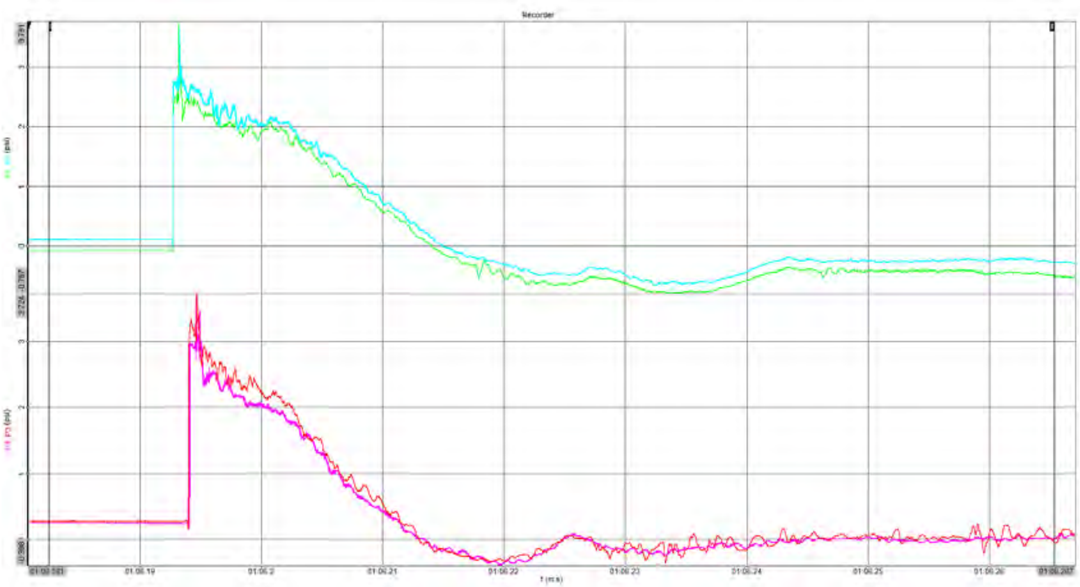


Figure 7: LS #4-5-C30 External Fire Positive Pressure Pulse

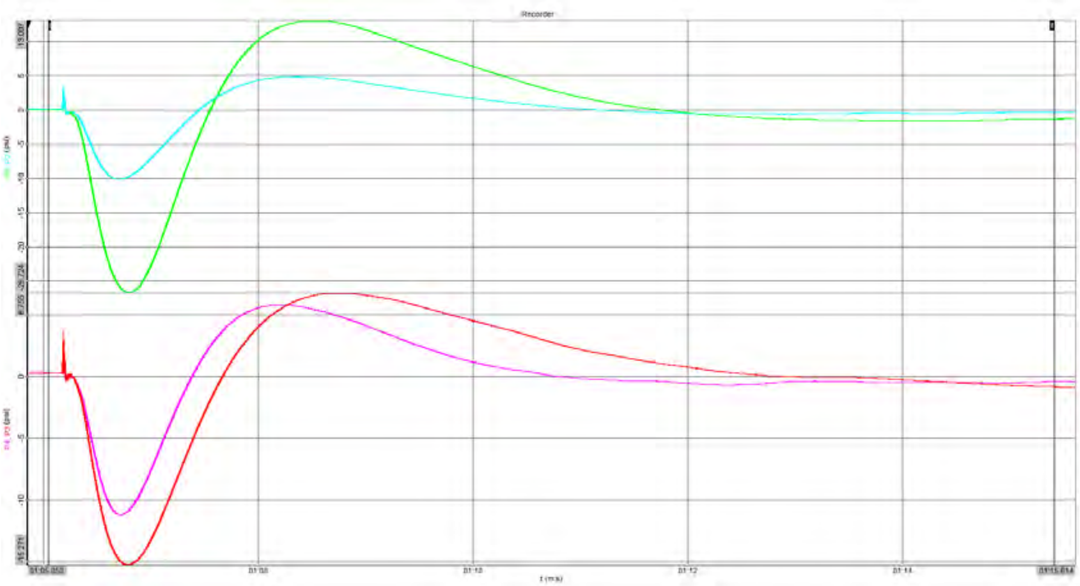


Figure 8: LS #4-5-C30 External Fire Deflagration Curve

The blast ruptured the two largest holes in the Bikini gage (greater than 3.0 psi, less than 3.7 psi), as shown in Photo 27. For conversion of holes to rupture pressure, please refer to SMS-6265f-R2, Section 5.3, "Instrumentation".

Photo 27: Bikini Gages Ruptured by the Blast of LS #4-5-C30 (two largest holes)

The blast scattered the wood lattice around the test area as shown in Photo 28; the remains in the burn pan are shown in Photo 29.

Photo 28: Wood Lattice Scattered by Explosion

Photo 29: Post-Test Steel Grating in Burn Pan

7.2.3.3 Thermal Flux Hazards

Maximum heat flux values recorded at each station for each event are given in Table 13. Heat flux data graphs for LS #1-6-A3- and LS #4-5-C30 are given in Figure 9 and Figure 10, respectively.

Table 13: Maximum Heat Flux Values for UN Series 6 (c) External Fire Tests

Sample ID	Maximum Heat Flux (kw/m^2)	
	Station 1	Station 2
LS #1-6-A30	66.5	85.6
LS #4-5-C30	40.0	50.3

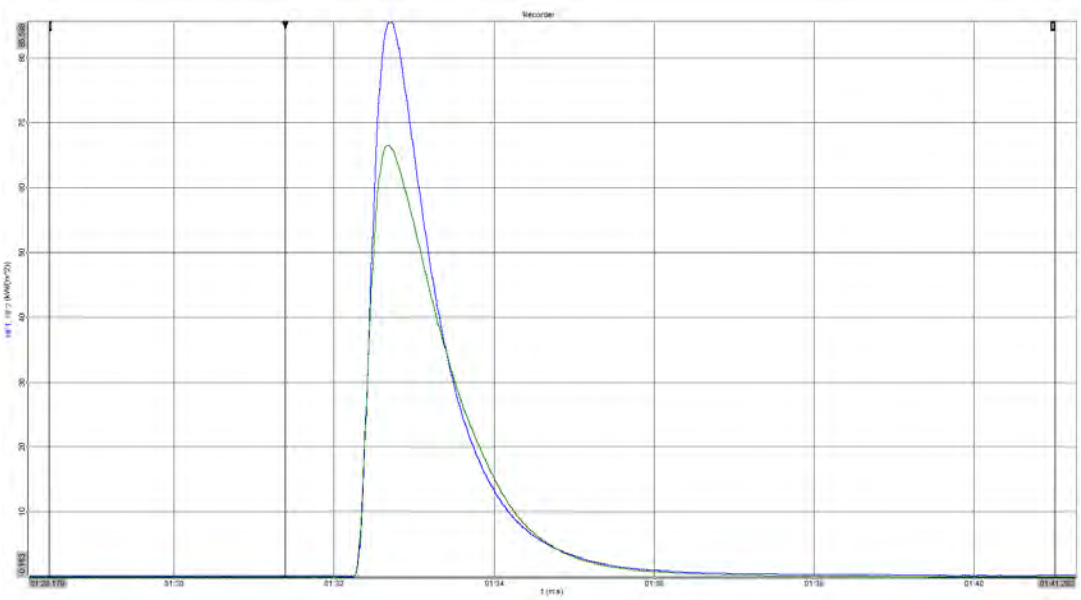


Figure 9: LS #1-6-A30 External Fire Measured Heat Flux

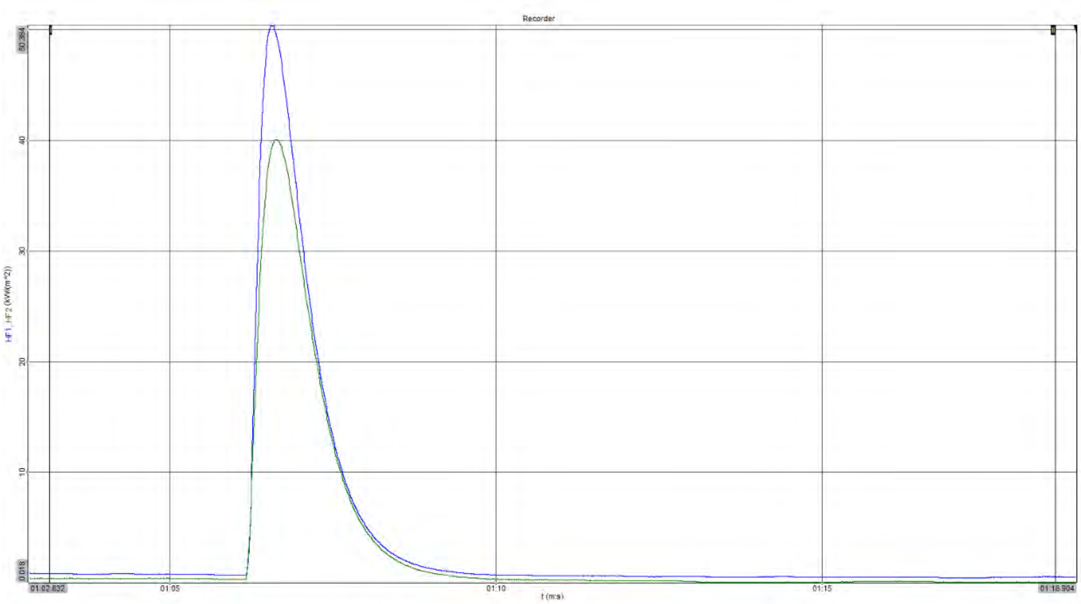


Figure 10: LS #4-5-C30 External Fire Measured Heat Flux

Section 16.6.2.4.4 (c) of the UN Manual of Tests and Criteria states that the material should be assigned to Division 1.3 if "the irradiance of the burning product exceeds that of the fire by more than 4 kW/m² [for 100 kg] at a distance of 15 m from the edge of the packages of unpackaged articles. The irradiance is measured over 5 seconds, during the period of maximum output". Table 16.2 details how thermal flux values at 15 meters are scaled for varying masses of HD 1.3/1.4 type materials. Comparative thermal flux is scaled by mass with the following equation.

$$F = F_0 \left(\frac{m}{m_0}\right)^{\frac{2}{3}}$$

Where, F_o is the expected thermal heat flux at 15 meters for 1.3/1.4 materials and 5 meters for 1.4/1.4S materials (4 kW/m²). *m* is the mass of the material being tested, and m_o is the comparative mass (100 kg).

Table 14 shows the scaled thermal flux based on the above equation and the maximum thermal flux values measured at 15 meters during the period of highest thermal output. The irradiance of the bonfire measured before the event was less than 0.1 kW/m^2. The amount of time each reaction emitted thermal flux that exceed the scaled thermal flux value is given in Table 14.

Table 14: Scaled Thermal Flux Values and Measured Thermal Flux for the External Fire Tests

Sample ID	Mass (kg)	Scaled Thermal Flux from Table 16.2	Maximum Thermal Flux Measured at 15 m	Time Above Scaled Thermal Flux (s)
LS #1-6-A30	102	4.05	85.6	2.51
LS #4-5-C30	125	4.64	60.3	1.83

It can be determined from the calculations above that the thermal flux difference measured at 15 meters for both formulations exceed the scaled thermal flux calculated for their corresponding mass. As such, these materials emit thermal heat flux consistent with Division 1.3 type materials.

Both tested thermite additive formulations exhibited Hazard Division 1.1 type reactions during the external fire test.

8.0 CONCLUSIONS AND RECOMMENDATIONS

The presence of additives did not result in any shock sensitive formulations. The presence additives did result in formulations that react more violently to heating under confinement with four of the six thermites failing UN Series 2 (a) Koenen Test displayed explosive characteristics, and one of the six failing UN Series 1 (a) Koenen Test. All tested formulations displayed extremely energetic reactions during the Internal Ignition test. However, because the confining media was not fragmented, all formulations passed. When these formulations were subjected to the Time/Pressure Test, all samples failed. This further indicates that the test parameters of the Internal Ignition test misrepresent the hazards of both traditional thermite and thermite-additive formulations. The differing results between UN Series 1 and 2 (c) (i) Time/pressure tests and the UN Series 1 and 2 (c) (ii) Internal ignition tests also indicate that the these tests may not be equivalent when certain materials are tested. Materials that pass Internal Ignition may not pass the Time/Pressure Test, and vice versa.

Formulations subjected to UN Series 6 tests displayed reaction characteristics consistent with HD 1.1 type materials both in the 6 (a) Single Package and the 6 (c) External Fire Tests. Overall, the introduction of additives to traditional metal-metal oxide thermites can result in formulations that display hazard characteristics consistent with Class 1 explosives and Hazard Division 1.1 explosives.

APPENDIX A

– UN SERIES 1 & 2 (b) KOENEN TEST RESULTS

Trial 1

Photo A 1: LS #1-6-A30 Koenen Test Results

Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6

Photo A 2: LS #1-6-C30 Koenen Test Results

Trial 1

Photo A 3: LS #4-5-A10 Koenen Test Results

Trial 1

Photo A 4: LS #4-5-A30 Koenen Test Results

Trial 1

Photo A 5: LS #4-5-C30 Koenen Test Results

Trial 1	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**

Photo A 6: LS #4-5-D30 Koenen Test Results

APPENDIX B

– UN SERIES 1 & 2 C (i) TIME/PRESSURE TEST RESULTS

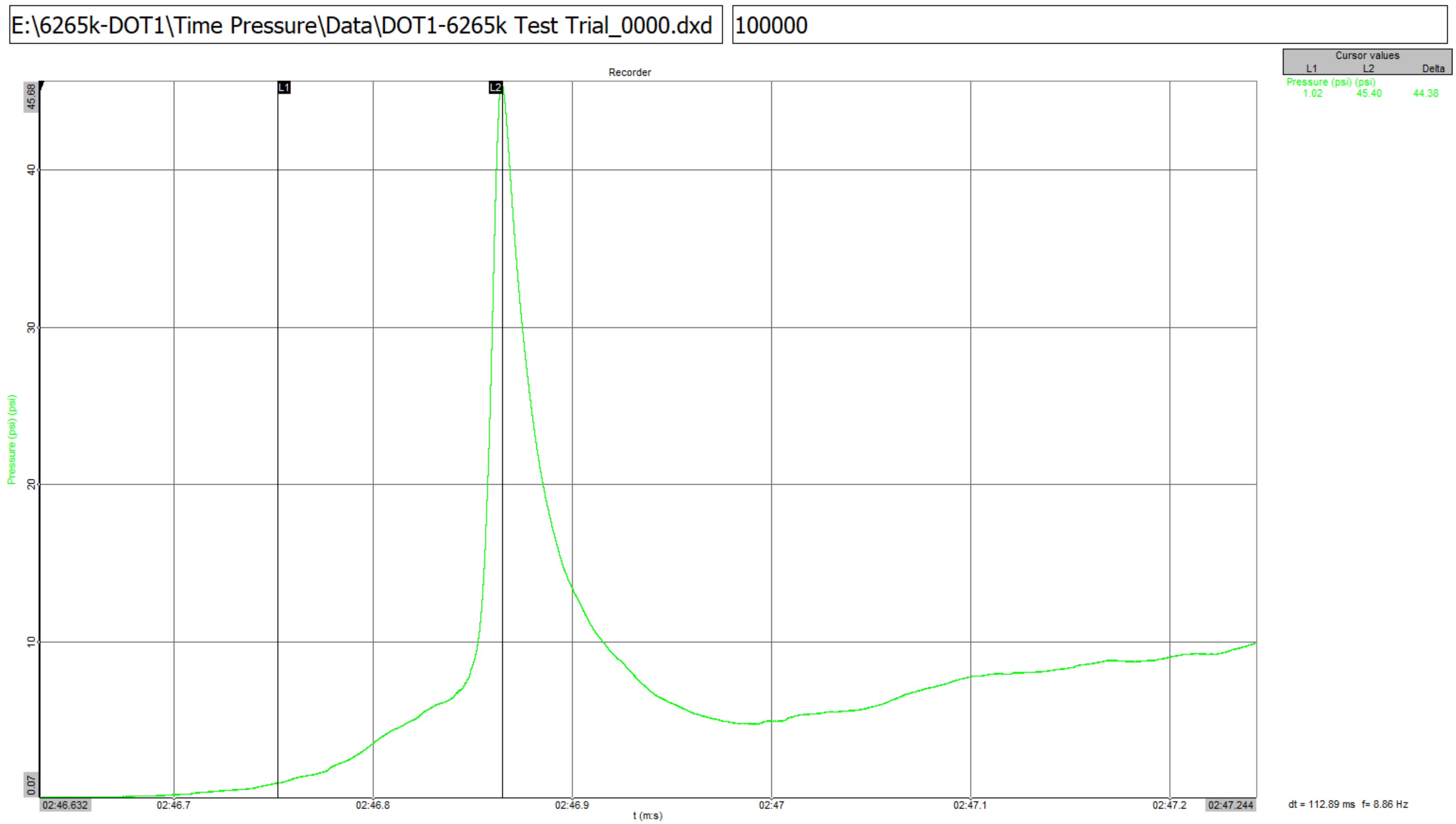


Figure B 1: Igniter Only Time/Pressure Test Data – Trial 1

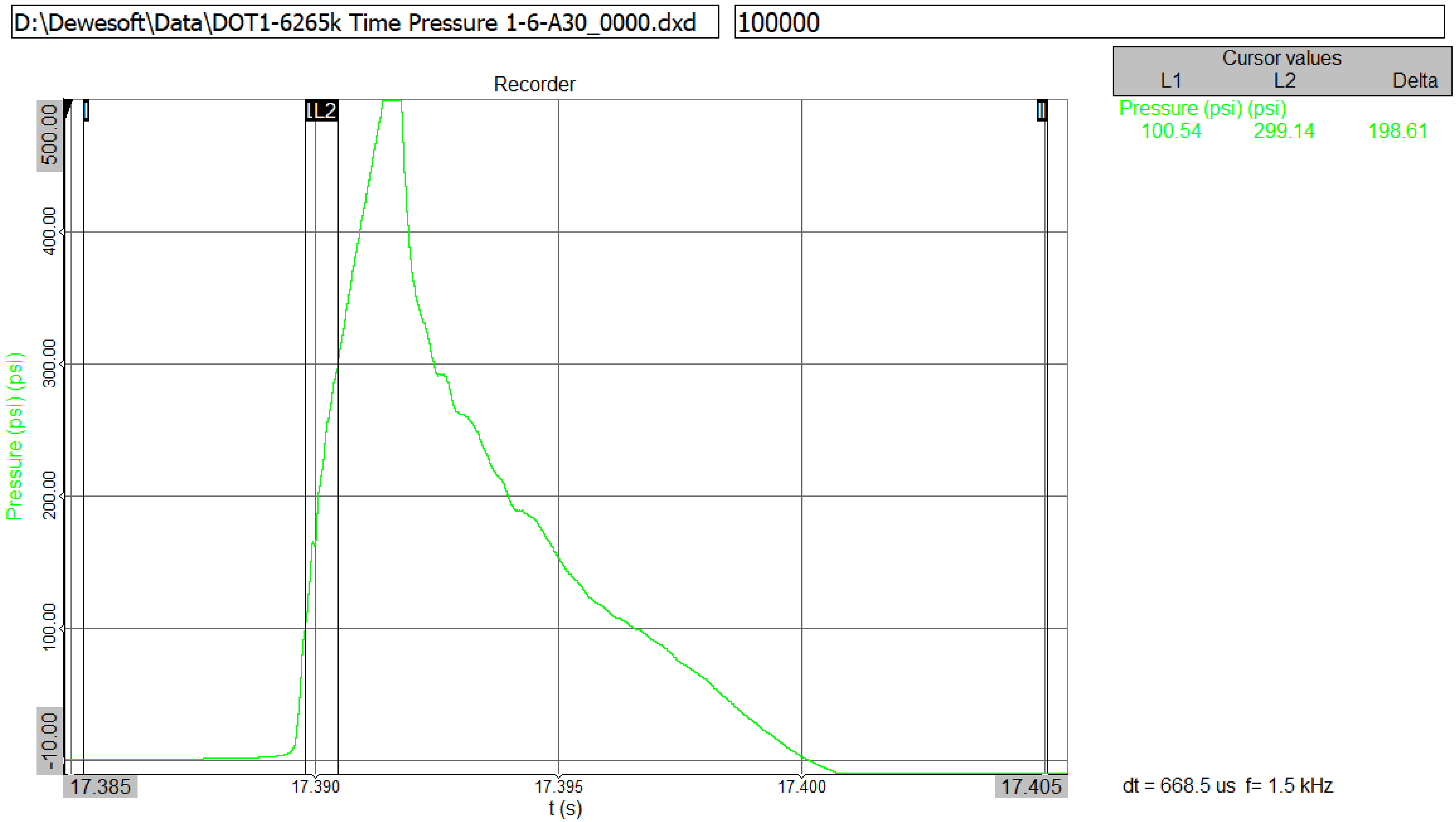


Figure B 2: LS #1-6-A30 Time/Pressure Test Data – Trial 1

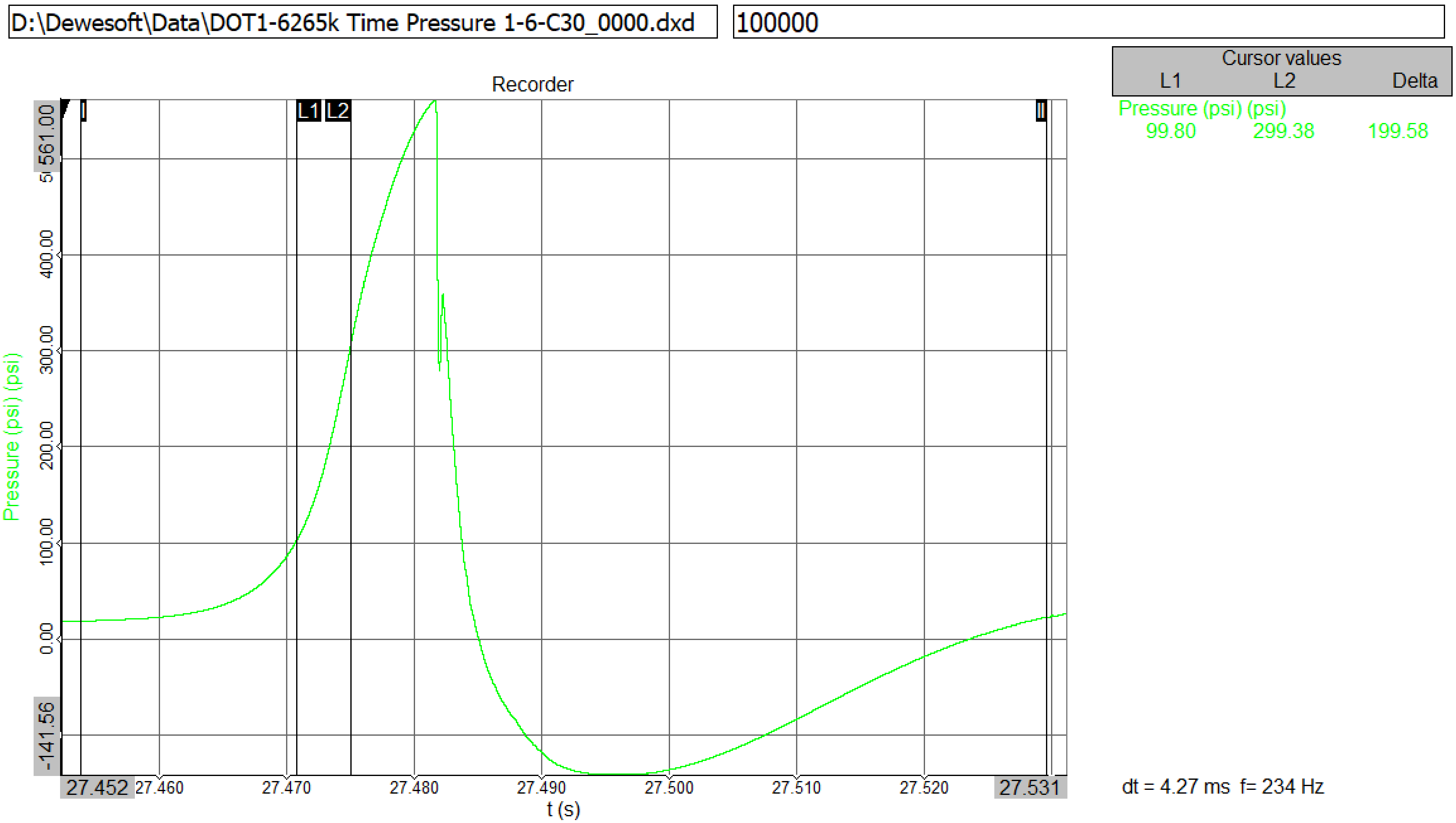


Figure B 3: LS #1-6-C30 Time/Pressure Test Data – Trial 1

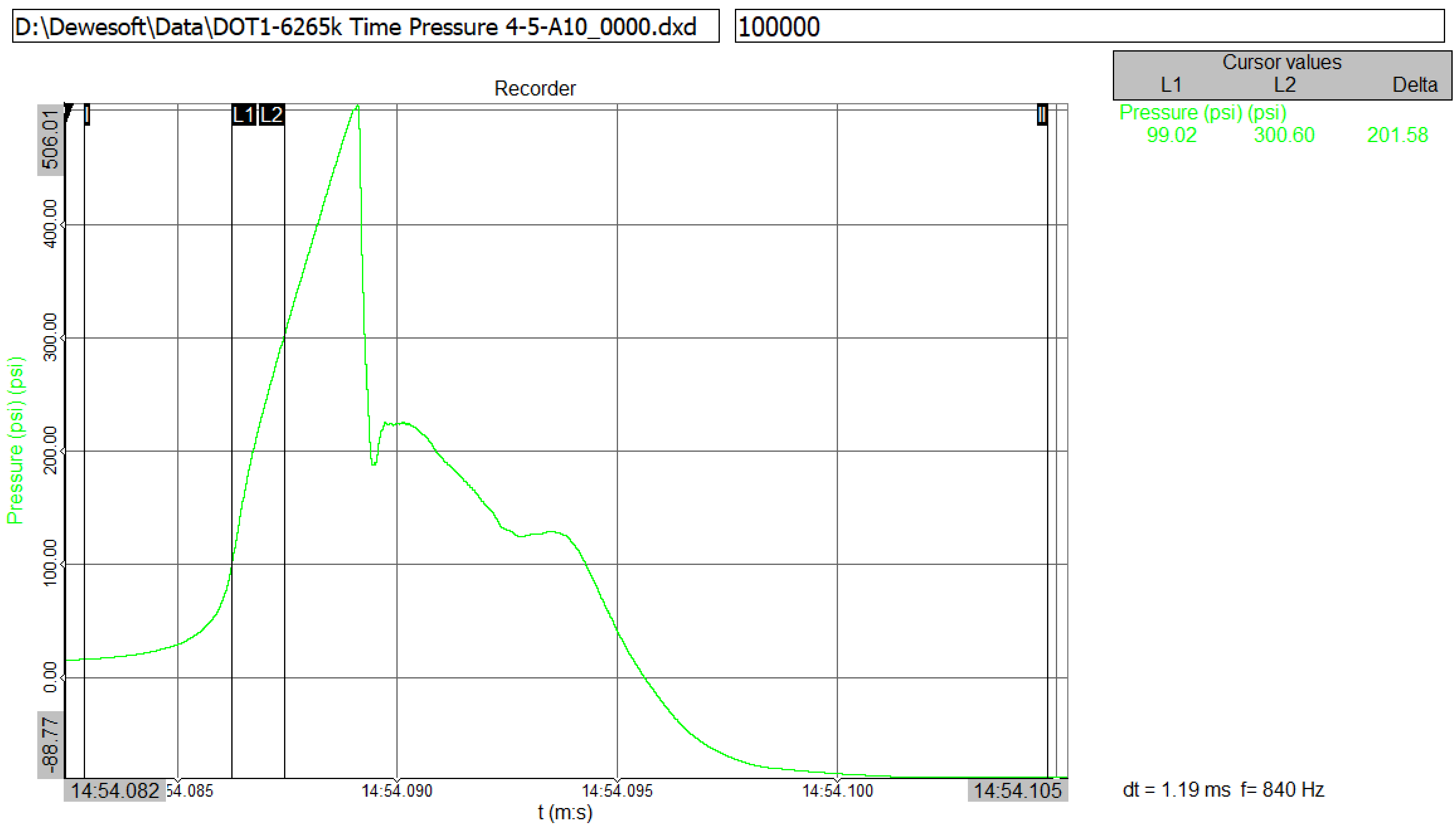


Figure B 4: LS #4-5-A10 Time/Pressure Test Data – Trial 1

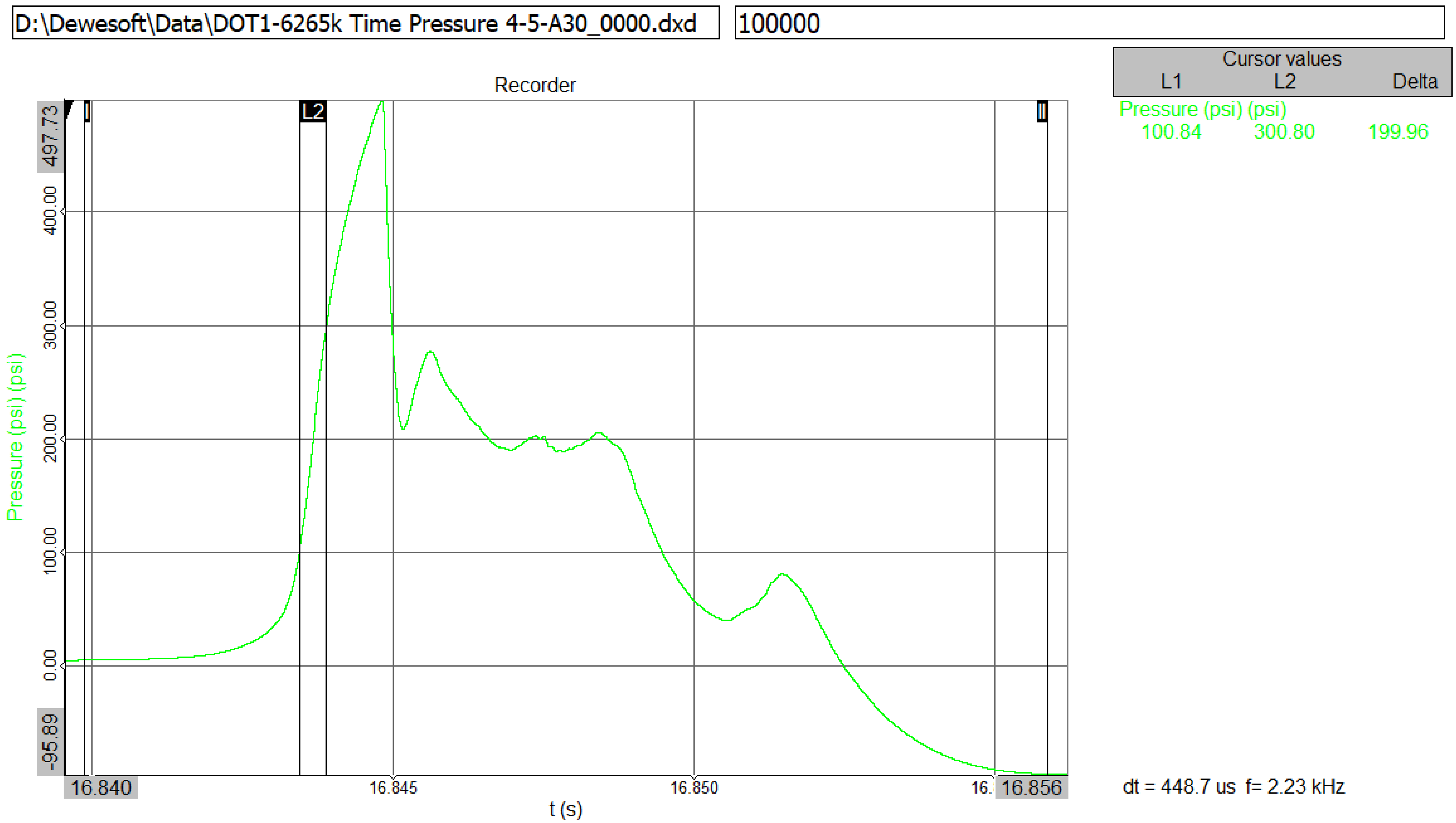


Figure B 5: LS #4-5-A30 Time/Pressure Test Data – Trial 1

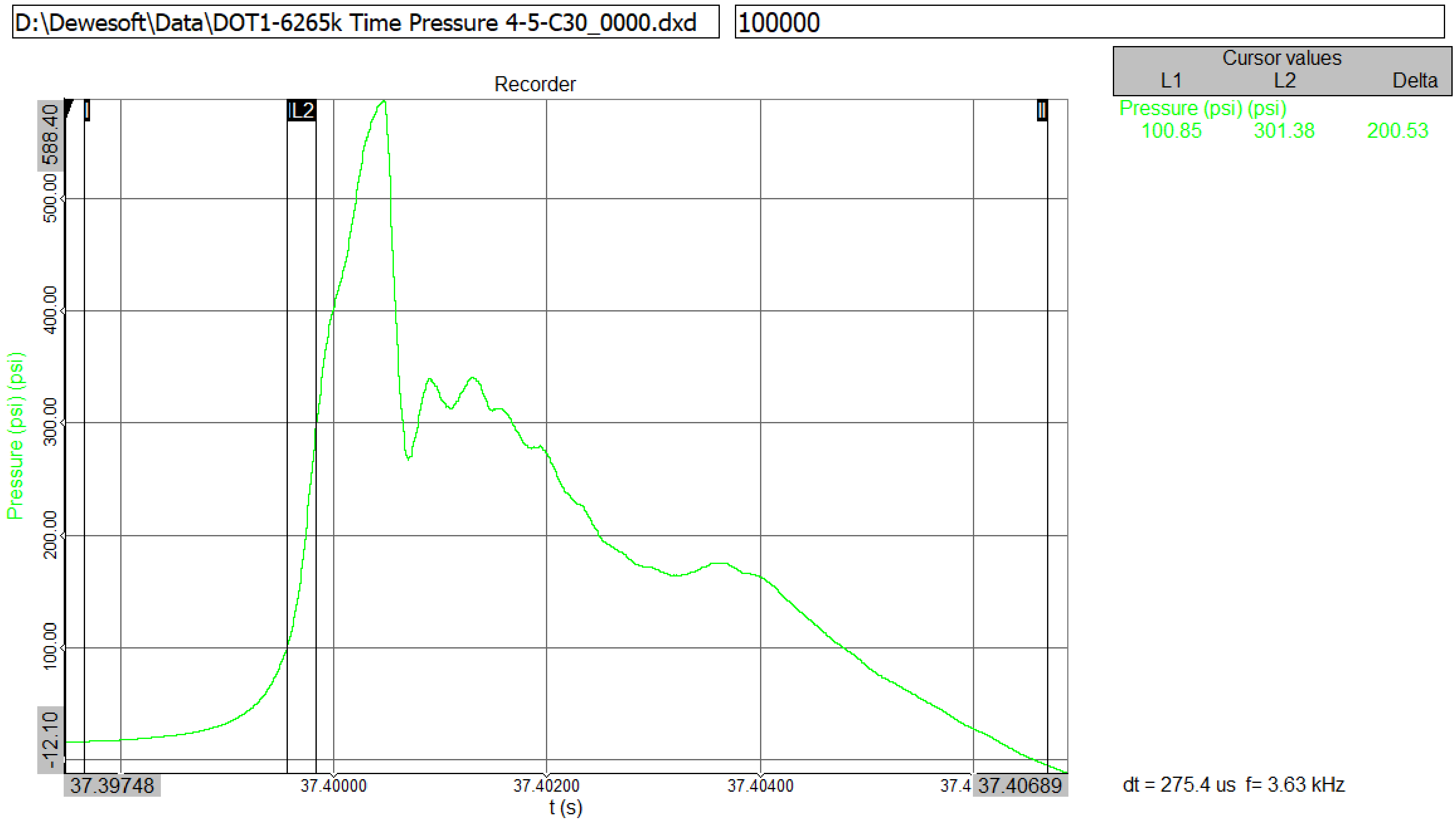


Figure B 6: LS #1-6-C30 Time/Pressure Test Data – Trial 1

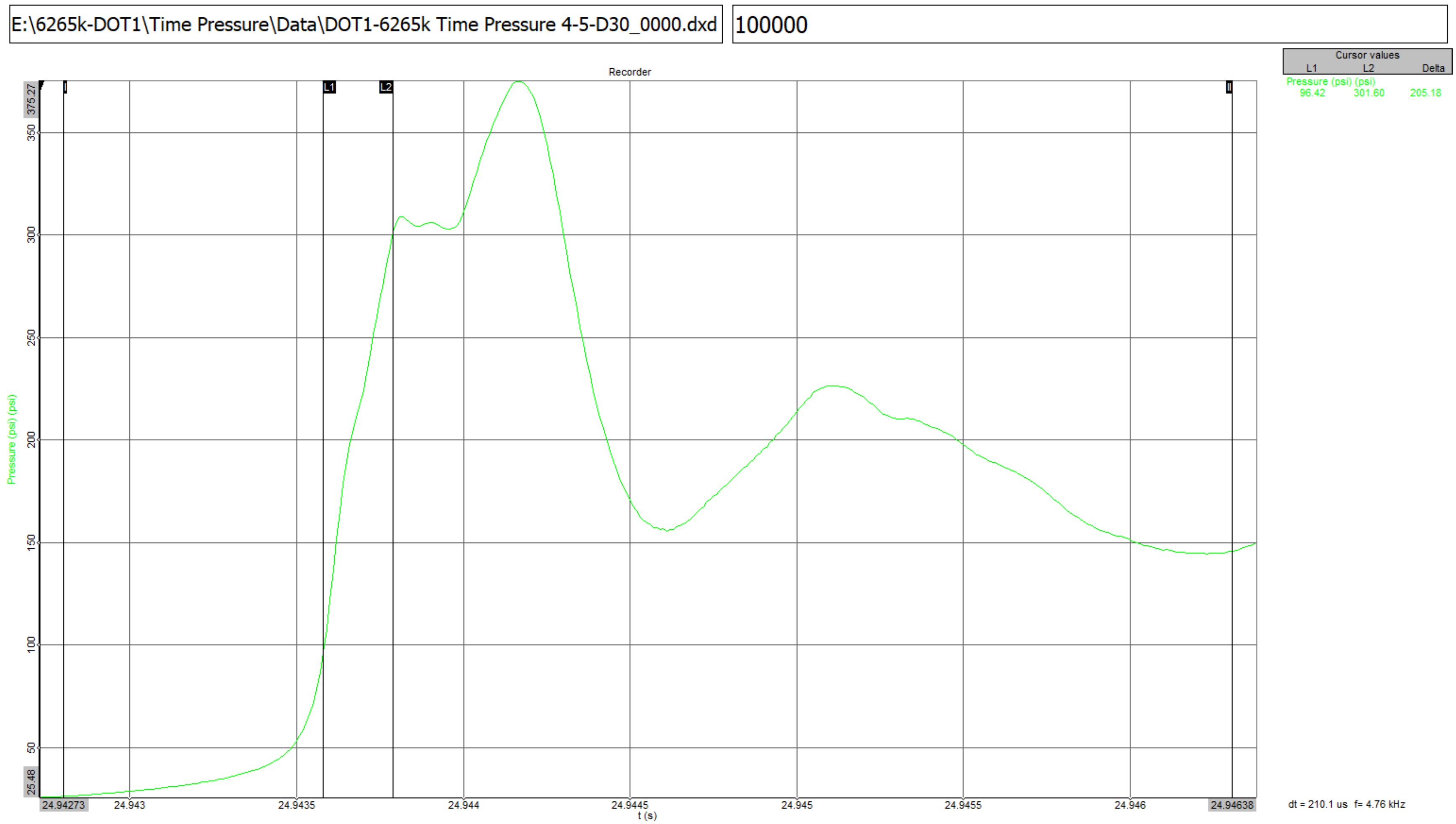


Figure B 7: LS #4-5-D30 Time/Pressure Test Data – Trial 1

APPENDIX C

– UN SERIES 1 & 2 C (ii) INTERNAL IGNITION TEST RESULTS

Trial 1	Trial 2	Trial 3

Photo C 1: LS #1-6-A30 Internal 1/2 (c) (ii) Internal Ignition Test Results

Trial 1	Trial 2	Trial 3

Photo C 2: LS #1-6-C30 Internal 1/2 (c) (ii) Internal Ignition Test Results

Photo C 3: LS #4-5-A10 Internal 1/2 (c) (ii) Internal Ignition Test Results

Trial 1	Trial 2	Trial 3

Photo C 4: LS #4-5-A30 Internal 1/2 (c) (ii) Internal Ignition Test Results

Trial 1	Trial 2	Trial 3

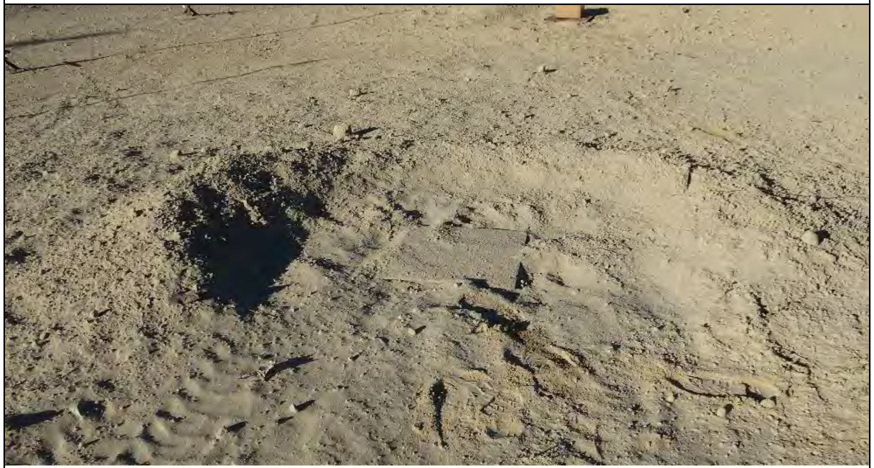
Photo C 5: LS #4-5-C30 Internal 1/2 (c) (ii) Internal Ignition Test Results

Photo C 6: LS #4-5-D30 Internal 1/2 (c) (ii) Internal Ignition Test Results

APPENDIX D

– UN SERIES 6 (a) SINGLE PACKAGE TEST RESULTS

Trial 1



Trial 2

Trial 3

Photo D 1: LS #1-6-A30 Single Package Test Results

Trial 1

Trial 2

Trial 3

Photo D 2: LS #1-6-C30 Single Package Test Results

Trial 1

Trial 2

Trial 3

Photo D 3: LS #4-5-A10 Single Package Test Results

Trial 1

Trial 2

Trial 3

Photo D 4: LS #4-5-A30 Single Package Test Results

Trial 1

Trial 2

Trial 3

Photo D 5: LS #4-5-C30 Single Package Test Results

Trial 1

Trial 2

Trial 3

Photo D 6: LS #4-5-D30 Single Package Test Results

APPENDIX E

– PRODUCT CERTIFICATIONS

ATLANTIC EQUIPMENT ENGINEERS
HIGH PURITY METALS AND COMPOUNDS

Certificate of Analysis

RED IRON OXIDE POWDER
FE-601

1.1 General

CATALOG NUMBER	LOT NUMBER	CAS NUMBER
FE-601	2304511	1309-37-1

2.1 Chemical Analysis (in percentage (%) unless otherwise stated)

Tint strength	Moisture	Water soluble
99.5	0.40	0.12
Fe2O3	pH	
99 min	6.7	

3.1 Screen Analysis (percent passing) / Other

Size	+325 mesh
1-5 microns	0.012

4.1 Notes

5.1 Statement

The above analysis is carried out as part of our internal quality control testing and is based upon our analysis methods.

We do not assume any warranty, liability, or risk based on such findings. Our quality is warranted within the scope of our general sales conditions.

Please refer to SDS for material handling instructions.

Very Truly Yours,

M. Gerald, QA

24 Industrial Ave, Upper Saddle River, NJ 07458 Tel: 201.828.9400 Fax: 201.387.0291
On the web at: www.micronmetals.com Email: info@micronmetals.com

Page 1 of 1

Figure E 1: Product Certification for Fe_2O_3

ATLANTIC EQUIPMENT ENGINEERS
HIGH PURITY METALS AND COMPOUNDS

Certificate of Analysis
CUPRIC OXIDE
CU-602

1.1 General

CATALOG NUMBER	LOT NUMBER	CAS NUMBER
CU-602	2304510	1317-38-0

2.1 Chemical Analysis (in percentage (%) unless otherwise stated)

Cu	CuO	Cu2O	Zn	Fe	Ca	Mg
75	94	3	0.3	0.02	0.01	0.002
Mn	Pb	Cd	As	Sb	Moisture	
0.001	0.05	0.01	0.01	0.01	0.2	

3.1 Screen Analysis (percent passing) / Other

Size	Specific Gravity	-325 mesh	Loose Bulk Density
1-5 microns	6.7 g/cc	99.9	80 lbs. / ft^3

4.1 Notes

5.1 Statement

The above analysis is carried out as part of our internal quality control testing and is based upon our analysis methods.

We do not assume any warranty, liability, or risk based on such findings. Our quality is warranted within the scope of our general sales conditions.

Please refer to SDS for material handling instructions.

Very Truly Yours,

M. Gerald, QA

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Page 1 of 1

Figure E 2: Product Certification for CuO

GoodFellow
innovation, delivered

PTFE Powder 6-9 micron

PTFE

Product Code: FP30-PD-000110

Mean Particle Size: 6-9

Figure E 3: Product Certification for PTFE (Teflon Powder)

STANFORD ADVANCED MATERIALS

Stanford Advanced Materials
23661 Birtcher Dr. Lake Forest, CA 92630, USA
Tel: (949) 407-8904 Fax: (949) 812-6690

Certificate of Analysis

Product Name:	Molybdenum Trioxide (MoO3) Powder
Purity:	≥99.5%
Particle Size:	-325mesh
Lot Number:	OC210201-12629-1
Date:	2/1/21

Purity (wt%)	99.5
C (wt%)	0.05
H (wt%)	0.02
O (wt%)	0.01
N (wt%)	0.01
Mg (wt%)	0.01
Al (wt%)	0.01
Si (wt%)	0.02
Ca (wt%)	0.01
Ti (wt%)	0.01
Fe (wt%)	0.08
Ni (wt%)	0.01
Cu (wt%)	0.02
Sn (wt%)	0.01
W (wt%)	0.03
Pb (wt%)	0.01

Stanford Advanced Materials

Figure E 4: Product Certification for Molybdenum Trioxide (MoO_3)

Kingsfield Inc.

1 Dewolf Road, Suite 210 Old Tappan, N.J. 07675,
Tel: (201) 767-0414 Fax: (201)767-0743
www.kingsfieldinc.com

CERTIFICATE OF ANALYSIS

Product Name: Calcium Peroxide Powder
Quantity: 16,000KGS
Packing: 25kg bag
Lot#: 20200722

We certify that the quality of the above material is as follows;

Item	Specification	Test result
Appearance	White or yellowish powder	Pass
Cao2 content, %	Min75.0	81.24
Active Oxygen, %	/	17.8728
Bulk Density, g/L	500-650	524
PO_4, %	Max.2.0	1.28
PH, %	≈ 12	12.04
Ferric, %	Max.0.05	0.0314
Pb, %	Max.0.002	0.00088

Ryan Choi/ President of USA Office

Figure E 5: Product Certification for Calcium Peroxide (CaO_2)

Reagents

PO Box 788
Belmont, NC 28012
+1.800.732.8484 F: +1.888.843.4384
Reagents.com

CERTIFICATE OF ANALYSIS

Product: **Sodium Nitrate, Purified**

Date of Manufacture: 7/25/2023

Expiration Date: September 2027

Intended Use: General Laboratory Reagent/Chemical.

Recommended Storage: 15 to 25 °C (59 to 77 °F)

Product Code: C2320500
C2320500

Lot Number: **8307537**

CAS Number: 7631-99-4

Test	Specification	Result
Assay	Report	98.5%
Chloride (Cl)	Report	0.27%
Insoluble Matter	Report	0.01%
Nitrite (NO_2)	Report	0.001%
Sulfate (SO_4)	Report	0.34%
Water (H_2O)	Report	0.01%

Balances are calibrated regularly with weights certified traceable to the NIST national mass standard. All products are prepared according to master documents that assure manufacture according to validated methods. Batch records document traceability and production history for each lot manufactured.

Figure E 6: Product Certification for Sodim Nitrate ($NaNO_3$)