

April 26, 2017



U.S. Department
of Transportation

East Building, PHH-30
1200 New Jersey Avenue S.E.
Washington, D.C. 20590

**Pipeline and Hazardous
Materials Safety Administration**

DOT-SP 16190
(FIRST REVISION)

EXPIRATION DATE: 2021-03-31

(FOR RENEWAL, SEE 49 CFR § 107.109)

1. GRANTEE: Digital Wave Corporation
Centennial, CO
2. PURPOSE AND LIMITATION:
 - a. This special permit authorizes the transportation in commerce of certain gases listed in section 6 in DOT-CFFC and DOT FRP-1 composite cylinders when Modal Acoustic Emission (MAE) is used as part of requalification in lieu of the hydrostatic retest required in § 180.205, as described in paragraph 7. This special permit provides no relief from the Hazardous Materials Regulations (HMR) other than as specifically stated herein. The most recent revision supersedes all previous revisions.
 - b. The safety analyses performed in the development of this special permit only considered the hazards and risks associated with the transportation in commerce.
 - c. No party status will be granted to this special permit.
3. REGULATORY SYSTEM AFFECTED: 49 CFR Parts 106, 107 and 171-180.
4. REGULATIONS FROM WHICH EXEMPTED: 49 CFR § 180.205(g) in that the MAE is performed in place of the hydrostatic test, as provided herein.
5. BASIS: This special permit is based on the application of Digital Wave Corporation dated March 28, 2017, submitted in accordance with § 107.109.

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6. HAZARDOUS MATERIALS (49 CFR § 172.101):

| Hazardous Materials Description | | | |
|---|------------------------------|------------------------------|----------------------|
| Proper Shipping Name | Hazard Class/Division | Identification Number | Packing Group |
| Air, compressed (containing up to 39% by volume oxygen) | 2.2 | UN1002 | N/A |
| Argon, compressed | 2.2 | UN1006 | N/A |
| Bromotrifluoromethane or Refrigerant Gas, R 13B1 | 2.2 | UN1009 | N/A |
| Carbon dioxide | 2.2 | UN1013 | N/A |
| Chlorodifluorobromomethane or Refrigerant Gas, R12B1 | 2.2 | UN1974 | N/A |
| Compressed gas, n.o.s. | 2.2 | UN1956 | N/A |
| Helium, compressed | 2.2 | UN1046 | N/A |
| Heptafluoropropane or Refrigerant Gas R 227 | 2.2 | UN3296 | N/A |
| Hydrogen, compressed | 2.1 | UN1049 | N/A |
| Methane, compressed or Natural gas, compressed (<i>with high methane content</i>) | 2.1 | UN1971 | N/A |
| Neon, compressed | 2.2 | UN1065 | N/A |
| Nitrogen, compressed | 2.2 | UN1066 | N/A |
| Nitrous oxide | 2.2 | UN1070 | N/A |

April 26, 20177. SAFETY CONTROL MEASURES:

a. PACKAGING - Packaging prescribed are limited to non-DOT specification composite cylinders manufactured under DOT-CFFC (BASIC REQUIREMENTS FOR FULLY WRAPPED CARBON-FIBER REINFORCED ALUMINUM LINED CYLINDERS, 5TH REVISION) and DOT FRP-1 (FIBER REINFORCED PLASTIC FULL WRAPPED COMPOSITE WITH ALUMINUM LINED CYLINDERS) standards that are subjected to periodic inspection and testing (requalification) and marking prescribed in § 180.205, § 180.209 and § 180.213 except that the cylinder is examined by a modal acoustic emission (MAE) method in lieu of the hydrostatic pressure test. Each cylinder must be retested in accordance with the procedures specified in the DWC application for special permit on file with the Approvals and Permits Division (APD) and as prescribed in this special permit.

b. TESTING (Requalification) - Each cylinder must be requalified once every five (5) years by an approved facility that has a DOT RIN from the OHMSAPD for requalification of DOT-CFFC and FRP-1 cylinders using Modal Acoustic Emission (MAE) testing in lieu of hydrostatic testing and in accordance with following:

- (1) Visual Examination - Each cylinder must receive an internal and external visual examination in accordance with CGA Pamphlet C-6.2 Standards for Visual Inspection and Requalification of Fiber Reinforced High Pressure Cylinders, 1996, Third Edition. Cylinders that do not meet the visual inspection criteria must be condemned.
- (2) Modal Acoustic Emission (MAE) Equipment - The MAE testing system must include:
 - a. Piezoelectric sensors
 - b. Pre-amplifiers
 - c. High and low pass filters
 - d. Amplifiers
 - e. Analog-to-digital (A/D) converters
 - f. A computer program for data collection
 - g. A computer and monitor for data display
 - h. A computer program for data analysis

The MAE technician must be capable of examining the waveforms (event by event), and the waveforms for each event must precisely correspond with the pressure and time data during the test.

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The MAE testing system must include sensors and recording equipment with a current (yearly) calibration sticker or certificate of calibration. Pre-amplifiers and amplifiers shall have a flat frequency response (± 1 dB) over the sensor frequency range specified. The MAE system shall include a high pass filter of 20 kHz, and a low pass filter with an appropriate roll-off frequency such that digital aliasing of frequencies higher than the Nyquist frequency that are contained in the signal does not occur.

(3) MAE Sensor Specification, Standard References and Calibration - The MAE sensors used shall have a flat with frequency response measured in an absolute sense (± 6 dB amplitude response from 50 kHz to 400 kHz), with a minimum sensitivity of 0.1 V/nm. Deviation from flat response (signal coloration) must be corrected using an absolute sensitivity curve obtained from an absolute surface wave calibration, similar to the calibration developed by the National Institute of Standards and Technology (NIST). MAE sensors shall have a diameter no greater than 0.5 inches, and the aperture effect must be taken into account in the data analysis.

The MAE system must be calibrated to detect and measure the wave energy of the test object (e.g., fiber breakage from a composite cylinder) by using a Rolling Ball Impactor and an Inclined Plate. The Rolling Ball Impactor must be used to create an acoustical impulse in the aluminum-inclined-plate. The impact setup includes a steel ball 1/2 inch in diameter. The ball impactor is made of chrome steel alloy hardened to R/C 63, ground and lapped to a surface finish of 1.5 microinch, within 0.0001 of actual size and roundness within 0.000025 inch. The calibration Inclined Plate is made of aluminum alloy 7075-T6, and must be at least 4' x 4' in size, and 0.125 inch (0.003 meters) in thickness and be supported by steel blocks. The inclined plate includes a machined square groove 3/8" wide which supports and guides the impact ball to the impact point. The length of groove and inclined angle must be 16" and 6° respectively. The grooved inclined plate must be positioned next to the edge of the aluminum plate such that the equator of the ball impacts the mid-plane of the edge of the aluminum plate, as shown in figure 1 below. The vertical

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position of the ball impact point must be gradually adjusted in order to "peak up" the acoustical signal, much as is done in ultrasonic testing where the angle is varied slightly to "peak up" the response.

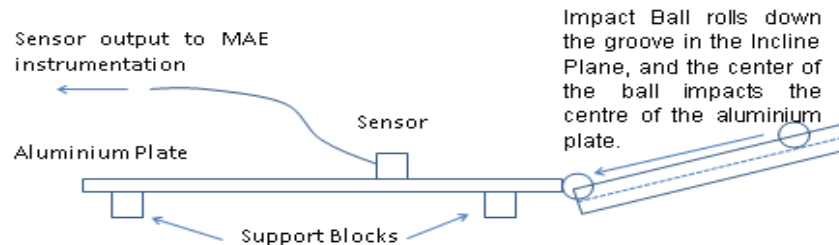


Figure 1 - Example of "Rolling Ball Impactor Energy Calibration" Setup

The start of the Extensional mode plate wave (E wave) shall be recognizable as the front end of the E wave, with the first full cycle ending 10 μ s later. The center frequency of the first cycle of the extensional mode plate wave (E wave) must be confirmed as 125 ± 10 kHz. The energy value (in Joules) of the first cycle of the E wave detected by the MAE system, defined as

U_{RBI}^{AE} , is used to scale the fiber break energy, U_{FB} .

This calibration must be an end-to-end calibration, meaning that the energy measured using the complete MAE instrumentation (sensor, cables, pre-amplifiers, amplifiers, filters, and digitizer) that are to be used during the actual MAE requalification test. The energy linearity of the complete MAE instrumentation must be measured by using different roll lengths of 8, 12, and 16 inches. A mechanism (manual or automated) must be used to release the ball down the inclined plane. The wave energy must be computed and recorded from the digital waveform as described in DWC application on file with OHMSAPD.

a. Analog-to-Digital Converter Calibration - The sampling rate of the A/D converter must be such that aliasing does not occur. The recording system (consisting of all amplifiers, filters, and digitizers beyond the sensor) must be calibrated by using a 20 cycle tone burst with amplitude of 0.1 V at 100, 200, 300, and 400 kHz. The system must measure an energy value of

$$U = \frac{V^2 \cdot N \cdot T}{2Z} \text{ Joules}$$

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at each frequency, where $V = 0.1$ Volts, $N = 20$, T is the period of a single cycle at the given frequency, and Z is the pre-amplifier input impedance. If the measured values agree within 15% of the theoretical values, a proper sampling rate has been set. The measurements must be performed at a system gain of 0 dB.

b. Amplifier Gain Correction - All energies must be corrected for gain (e.g., 20 dB increases apparent amplitude 10x and apparent energy 100x, 40 dB increases apparent amplitude 100x and apparent energy 10,000 x).

(4) MAE Test Procedure - After completion of the MAE system calibration, the following test procedure must be completed:

a. Sensor Mounting - Two (2) sensors must be mounted on each cylinder, one sensor installed at each end of a cylinder. The sensors are located within two inches of the dome-to-sidewall transition area and will be in-line along the axial direction of the vessel.

b. System settings - The system's settings shall be as follows:

i. Threshold: The system's trigger threshold shall be at least 52 dB_{AE} (adjusted to account for the sensor's absolute sensitivity response)

ii. Sampling Rate: 5 MHz

iii. Memory Depth: 2048 points

c. Sensor Coupling Checks - Sensor coupling checks must be performed prior to each test to verify proper system operation, and sensor coupling to the vessel. For the coupling check, the E and F waveforms shall be observed by breaking pencil lead (Pentel 2H, 0.3 mm) at approximately 2 inches from each sensor along the axial direction of the vessel. The energy of the lead break waveforms

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shall be at least 5×10^{-15} Joules. If this energy level is not met, the sensor coupling shall be checked, or the sensor replaced. All calibration data shall be recorded.

An amplitude response performance check shall be carried out by a pencil lead break at a location centered along a line between the two sensors. Both sensors shall have a maximum amplitude response within 3 dB of each other. The gain settings for the calibration must be such that the signal does not saturate either the amplifiers or the A/D converter. If so, repeat the lead breaks at a system gain that does not saturate the system. Prior to pressurization, reset the gain to the test gain.

d. Pressurization Procedure - Each cylinder must be pressurized from 0 psig to the cylinder's design test pressure (5/3 marked service pressure). During the pressurization, the cylinder must be held at test pressure for at least 5 minutes and up to 15 minutes. If no MAE activity is recorded after a 5 minute interval during the test pressure hold, the cylinder is stable and the pressure may be reduced to 0 psig.

MAE waveforms are to be monitored and recorded during the entire pressurization procedure. Pressurization must be stopped if Background Energy Oscillations greater than a factor of 2 occur on either channel. The fill rate must be less than the rate at which flow noise first appears. Conduct a post-test system sensitivity check (lead breaks as described in 7.b.4.c) and save the data. The test temperature shall be between 50 °F (10 °C) and 120 °F (49 °C).

In case of malfunction of the test equipment, the test may be repeated up to two times.

WARNING: Pressurizing a cylinder to test pressure comes with associated risk and appropriate measures shall be taken to ensure safe operation and to contain any energy that may be released as a result of a cylinder rupturing during pressurization.

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(5) Accept/Reject Criteria - Prior to the evaluation of any acceptance/rejection criteria, any external noise such as electromagnetic interference (EMI), mechanical rubbing, flow noise, etc. must be filtered out. Identify noise events by their shape, spectral characteristics, or other information known about the test such as a temporally associated disturbance due to the pressurization system or test fixture.

a. Rejection due to Fiber Break Energy - Events that occur at the higher loads during pressurization having significant energy in the frequency range $f > 300$ kHz are due to fiber bundle, or partial fiber bundle breaks. These should not be present at normal operating pressure (working pressure) in a cylinder that has been tested to a much higher pressure and is now operated at working pressure. For fiber bundles to break while holding at operating pressure the cylinder must possess a severe stress concentration. Such a cylinder shall be removed from service.

In order to determine if fiber bundle breakage has occurred during the filling operation, the frequency spectra of the direct E and F waves shall be examined and the energies in certain frequency ranges shall be computed as given below.

i. Energies (U) in the ranges are defined as

$$U_0: 50 - 400 \text{ kHz}$$

$$U_1: 100 - 200 \text{ kHz}$$

$$U_2: 250 - 400 \text{ kHz}$$

ii. The criteria for determining if fiber breaks have occurred is given by the following formulas:

$$\text{Criteria 1: } U_0 \geq U_{FBB}^{AE}$$

$$\text{Criteria 2: } \frac{U_2}{(U_1 + U_2)} \geq 15\%$$

$$\text{Criteria 3: } \frac{U_2}{U_0} \geq 10\%$$

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iii. The value of U_{FBB}^{AE} for DOT-CFFC and DOT FRP-1 cylinders are:

$$U_{FBB}^{AE} \text{ for DOT-CFFC} = 2.7 \times 10^{-16} \text{ Joules}$$

$$U_{FBB}^{AE} \text{ for DOT FRP-1} = 1.5 \times 10^{-15} \text{ Joules}$$

NOTE: These values are sensor and system specific, and need to be adjusted properly, based upon the Rolling Ball Impact Calibration for the given sensor/system configuration.

Rejection - A cylinder must be rejected if all three energy conditions (Criteria 1, Criteria 2, and Criteria 3) in Paragraph 7.b.(5)(a)(ii) have occurred.

b. Rejection due to Single Event Energy - The energy from the waveform of all events is measured from the recorded MAE data.

Rejection - A cylinder must be rejected if a measured MAE event energy is greater than 2.7×10^{-14} Joules for DOT-CFFC cylinders, and 1.5×10^{-13} Joules for DOT-FRP1 cylinders.

c. Rejection due to Background Energy - During pressurization, the background energy of any channel shall not rise above the quiescent background energy level by more than a factor of 2. Further, if an oscillation in the background energy greater than a factor of 2 (difference between adjacent maxima and minima values of an N point moving average of the background energy values) occurs at any time during the test, the vessel shall be depressurized immediately.

Rejection - Any cylinder which violates the rise in the background energy level, or exhibits background energy oscillations greater than a factor of 2 shall be rejected.

(6) Action for Rejected Cylinders - When a cylinder is rejected, the requalifier must securely affix to the cylinder a label with the word "CONDEMNED" over coated with epoxy near, but not obscuring, the original

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manufacturer's label. Alternatively, at the direction of the cylinder owner, the requalifier may render the cylinder incapable of holding pressure.

c. MARKING - Retest markings must be applied on a label securely affixed to the cylinder and over coated with epoxy, near the original test date. The retest markings must include the retest date, requalifiers RIN, and "MAE" as the requalification test procedure. The marking of the RIN number on the cylinder certifies compliance with all terms and conditions of this special permit.

d. REPORT - A report must be generated for each cylinder listing all cylinders that were examined. The MAE reports must include the following:

1. RIN
2. MAE equipment, model and serial number
3. Cylinder manufacture date, serial number, special permit number, type and marked service pressure
4. MAE technicians' name and certification level
5. Test date
6. Decay rate *B* values
7. Event energies exceeding the fiber bundle failure criteria
8. Event energies exceeding the FRAE requirement
9. Background energy oscillation pressure
10. Visual inspection results (Pass/Fail/NA)
11. Acceptance/rejection results

The MAE reports must be on file at the test site, and made available to a DOT representative when requested.

e. PERSONNEL QUALIFICATION - Each person who performs retesting or who evaluates or certifies retest results must meet the following requirements:

- (1) Project Manager - is the senior manager of a Digital Wave Corporation (DWC) responsible for compliance with DOT regulations including this special permit. Additionally, the project manager must ensure that each operator and senior review technologist maintain the required certifications described herein.

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(2) The personnel responsible for performing cylinder retesting under this special permit shall be qualified to an appropriate Level (Level I, II or III) in modal acoustic emission (MAE) testing in accordance with the American Society for Nondestructive Testing (ASNT) Recommended Practice SNT-TC-1A-1996 depending upon the assigned responsibility as described below:

As a minimum, a Level II Operator must perform system startup, calibrate the system, and review and certify the test results when written acceptance and rejection criteria for cylinders has been provided by a Senior Review Technologist. Based written criteria, the Level II Operator may authorize cylinders that pass the retest to be marked in accordance with paragraph 7. (c) of this special permit. However, a person with Level I certification may perform a system startup, check calibration, and perform MAE under the direct guidance and supervision of a Senior Review Technologist or a Level II Operator, either of whom must be physically present at the test site so as to be able to observe examinations conducted under this special permit.

(3) Senior Review Technologist (SRT) - is a person who provides written MAE procedure, supervisory training and examinations (Level I and II), technical guidance to operators and reviews and verifies the retest results. An SRT must have a thorough understanding of the DOT Regulations (49 CFR) pertaining to the requalification and reuse of DOT cylinders authorized under this special permit and ASNT Recommended Practice SNT-TC-1A and possess either:

i. A Level III certificate from ASNT in Acoustic Emission, with a documented experience for a minimum of 2 years of experience in Non-Destructive Evaluation (NDE) of pressure vessels or pipelines using the Modal Acoustic Emission techniques;

ii. A Professional Engineer (PE) License with a documented experience for a minimum of 2 years of experience in Non-Destructive Evaluation (NDE) of pressure vessels or pipelines using the Modal Acoustic Emission techniques; or,

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iii. A PhD degree in Engineering/Physics with documented evidence of experience in Non-Destructive Evaluation (NDE) of pressure vessels or pipelines, using the modal acoustic emission technique or research/thesis work and authoring/co-authoring of technical papers published, in recognized technical journals, in the fields of modal acoustic emission testing methods.

iv. The SRT must prepare and submit the reports required in the paragraphs 7.d. and annually verify that the MAE program is being operated in accordance with the requirements of this special permit.

The most recent copies of certification (e.g. ASNT Level III or PE license) must be available for inspection at each requalification facility.

f. OPERATIONAL CONTROLS - Following operational controls applies to this special permit:

(1) No person may perform inspection and testing of cylinders subject to this special permit unless:

i. That person is an employee of Digital Wave Corporation and has a current copy of this special permit at the location of such inspection and testing, and

ii. Complies with all the terms and conditions of this special permit.

(2) Each facility approved by OHMSPA to test cylinders under the terms of this special permit must have a resident operator with at least a Level II Certification in MAE.

(3) Cylinders requalified under this special permit are not authorized for use fifteen (15) years after the manufacture date.

(4) Cylinders may not be used for underwater breathing purposes.

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(5) A cylinder that has been subjected to fire may not be returned to service.

(6) Cylinders used in oxygen service or in nitrous oxide service must conform with § 173.302(b)(1)-(3). A cylinder that has been subjected to fire may not be returned to service.

(7) Transportation of flammable gases is not authorized aboard passenger-carrying aircraft or cargo vessel.

(8) Transportation of oxygen is only authorized when in accordance with § 175.501.

(9) Cylinders must be packaged in accordance with § 173.301(a)(9).

8. SPECIAL PROVISIONS:

- a. The designated SRT must review the MAE program annually. The designated SRT must submit a letter to OHMSPA verifying that the MAE program is meeting the terms and requirements of this special permit.
- b. The total number of cylinders tested under this special permit must be reported by special permit number and age. These results must be summarized and reported to DOT on an annual basis. A summary of the test results at each facility must be reported (electronic or paper) to the Associate Administrator for Hazardous Materials Safety annually to assess the effectiveness of the test program. The summary must include the total number of cylinders tested under this special permit grouped by type or special permit number, size and age. The summary must include the number of cylinders accepted, rejected or condemned. For any rejected or condemned cylinder, the defect causing the rejection/condemnation must be fully characterized and profiled (i.e., cuts, abrasions, impacts, fiber failures, chemical damage, heat damage, etc.) and the specific size of the defect should be determined (i.e., length, depth, width, etc.). The cylinders that were condemned at visual inspection (prior to MAE) shall also be included in the report.

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- c. A statement of qualifications, for each "qualified MAE tester" used under this special permit and information in support thereof, must be maintained by Digital Wave Corporation. The location of this statement, for each "qualified MAE tester", must be identified to OHMSPA.
 - d. A current copy of this special permit must be maintained at each facility where the package is offered or reoffered for transportation.
 - e. A current copy of the DOT special permit for the cylinders listed in this special permit must be maintained at each facility where retesting is performed.
 - f. Shippers (offerors) may use the cylinders specified and tested in accordance with the provisions of this special permit for the transportation in commerce of those hazardous materials specified herein, provided no modifications or changes are made to the cylinders. All terms of this special permit and other applicable requirements contained in 49 CFR Parts 100-185 must be met.
 - g. Motor carriers operating under the terms of this special permit must have a "Satisfactory" or "Conditional" safety rating as prescribed in 49 CFR Part 385.
 - h. Transportation of Division 2.1 (flammable gases) and Division 2.3 (gases which are poisonous by inhalation) materials are not authorized aboard cargo vessel or cargo aircraft only unless specifically authorized in the Hazardous Materials Table (§ 172.101).
9. MODES OF TRANSPORTATION AUTHORIZED: Motor vehicle, rail freight, cargo vessel, passenger-carrying aircraft, and cargo only aircraft.
10. MODAL REQUIREMENTS: A current copy of this special permit must be carried aboard each cargo vessel or aircraft used to transport packages covered by this special permit. The shipper must furnish a current copy of this special permit to the air carrier before or at the time the shipment is tendered.

11. COMPLIANCE: Failure by a person to comply with any of the following may result in suspension or revocation of this special permit and penalties prescribed by the Federal hazardous materials transportation law, 49 U.S.C. 5101 et seq:

- o All terms and conditions prescribed in this special permit and the Hazardous Materials Regulations, 49 CFR Parts 171-180.
- o Persons operating under the terms of this special permit must comply with the security plan requirement in Subpart I of Part 172 of the HMR, when applicable.
- o Registration required by § 107.601 et seq., when applicable.

Each "Hazmat employee", as defined in § 171.8, who performs a function subject to this special permit must receive training on the requirements and conditions of this special permit in addition to the training required by §§ 172.700 through 172.704.

No person may use or apply this special permit, including display of its number, when this special permit has expired or is otherwise no longer in effect.

Under Title VII of the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU)—"The Hazardous Materials Safety and Security Reauthorization Act of 2005" (Pub. L. 109-59), 119 Stat. 1144 (August 10, 2005), amended the Federal hazardous materials transportation law by changing the term "exemption" to "special permit" and authorizes a special permit to be granted up to two years for new special permits and up to four years for renewals.

12. REPORTING REQUIREMENTS: Shipments or operations conducted under this special permit are subject to the Hazardous Materials Incident Reporting requirements specified in 49 CFR §§ 171.15 Immediate notice of certain hazardous materials incidents, and 171.16 Detailed hazardous materials

incident reports. In addition, the grantee(s) of this special permit must notify the Associate Administrator for Hazardous Materials Safety, in writing, of any incident involving a package, shipment or operation conducted under terms of this special permit.

Issued in Washington, D.C.:



for William Schoonover
Associate Administrator for Hazardous Materials Safety

Address all inquiries to: Associate Administrator for Hazardous Materials Safety, Pipeline and Hazardous Material Safety Administration, U.S. Department of Transportation, East Building PHH-30, 1200 New Jersey Avenue, Southeast, Washington, D.C. 20590.

Copies of this special permit may be obtained by accessing the Hazardous Materials Safety Homepage at http://hazmat.dot.gov/sp_app/special_permits/spec_perm_index.htm. Photo reproductions and legible reductions of this special permit are permitted. Any alteration of this special permit is prohibited.

PO: Toughiry/SG