U.S. Department
of Transportation

**Pipeline and Hazardous
Materials Safety Administration**

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

DOT-SP 16320

EXPIRATION DATE: March 31, 2019

(FOR RENEWAL, SEE 49 CFR 107.109)

1. GRANTEE: Digital Wave Corporation
Centennial, CO

2. PURPOSE AND LIMITATION:

a. This special permit authorizes the extension of the service life of certain DOT-CFFC cylinders, which are subjected to the requalification and operational controls that are defined in this special permit. 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 alternative testing is authorized as provided herein.

5. BASIS: This special permit is based on the application of Digital Wave Corporation dated November 5, 2014 submitted in accordance with § 107.105, the public proceeding thereon, and additional information dated December 23, 2015 and October 11, 2016.

6. HAZARDOUS MATERIALS (49 CFR 172.101):

Hazardous Materials Description			
Proper Shipping Name	**Hazard Class/ Division**	**Identi-fication Number**	**Packing Group**
Air, compressed (breathing air containing up to 39% by volume oxygen)	2.2	UN1002	N/A

7. SAFETY CONTROL MEASURES:

a. Packaging -

(1) Packagings prescribed are limited to certain non-DOT specification composite cylinders made under the DOT-CFFC standard and manufactured under special permits, used exclusively in Self Contained Breathing Apparatus (SCBA) service and maintained under the standard operating procedure as described in the Digital Wave Corporation (DWC) special permit application on file with the Office of Hazardous Materials Safety Approvals and Permits Division (OHMSAPD).

(2) Cylinders may be considered for an extended service life not exceeding 30 years after the original manufacturing date of the cylinder.

(3) Each cylinder considered for extended service life must be requalified by Modal Acoustic Emission (MAE) in accordance with the procedures specified in the DWC application for special permit on file with the OHMSAPD and as prescribed in this special permit.

(4) Cylinders passing the MAE requalification may be marked "DOT-SP 16320" and authorized for an additional 5 years. Cylinders with the DOT-SP 16320 marking must be successfully requalified once every 5 years using MAE in order to remain in service for a maximum service life of 30 years from the date of manufacture.

b. MAE Equipment and Performance - The MAE testing system must include 1) broadband piezoelectric sensors, 2) preamplifiers, 3) high-pass and low-pass filters, 4) amplifiers, 5) A/D (analog-to-digital) converters, 6) a computer program for the collection of data, 7) computer and monitor for the display of data and 8) a computer program for analysis of data. The MAE technician must be capable of examining the waveforms (event by event) and the waveforms for each event must correspond precisely with the pressure and time data during the test. The MAE testing system must include a computer program capable of detecting the first arrival channel. The MAE testing system must include sensors and recording equipment with a current calibration sticker (yearly) or a current certificate of calibration. Sensors shall have a flat frequency response (+/- 6 dB amplitude response over the frequency range specified) from 50 kHz to 400 kHz. Deviation from flat response (signal coloration) must be corrected by using a sensitivity curve obtained with a Michelson Interferometer calibration system similar to the apparatus used by the National Institute for Standards and Technology. MAE sensors must have a diameter no greater than 0.5 inch for the active part of the sensor face. The aperture effect must be taken into account. Sensor sensitivity must be at least 0.1 V/nm. Preamplifiers and amplifiers will have a flat frequency response (+/- 1 dB) over the frequency range of interest. The MAE system must include a high-pass filter of 20 kHz. Additionally, a low-pass filter must be applied to prevent digital aliasing that occurs if frequencies higher than the Nyquist frequency (half the Sampling Rate) are in the signal. The MAE system must include the memory depth (wave window length) and sampling rate of the high speed analog-to-digital (A/D) converter and must be set for the MAE test requirements.

c. Standard References and Calibration -

(1) 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 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 micro-inch, 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 have lateral dimensions of 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 center (equator) of the ball impacts the center (mid-line) of the edge of the aluminum plate, as shown in Figure 1 below.

(2) Each Sensor has a flat frequency response (+/- 6 dB amplitude response over the frequency range specified) and has a range of 50 kHz to 400 kHz and diameter less than or equal to 0.5 inch. Each sensor must be mounted on the inclined aluminum plate and tested separately via the rolling ball impact. The vertical position of the ball impact point must be adjusted gradually 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. The center frequency of the first cycle of the extensional mode plate wave (E wave) must be confirmed as 125 kHz ± 10 kHz. The energy value in joules of the first half cycle of the E wave, is defined as U^{AE}_{RBI}, the wave energy detected by the MAE system, and must be used to scale the fiber break energy, U_{FB}. This must be an "end-to-end" calibration meaning that the energy measured using the complete AE instrumentation (sensor, cables, preamplifiers, amplifiers, filters and digitizer) that is to be used in the actual testing situation. The energy linearity of the complete AE instrumentation (sensor, cables, preamplifiers, amplifiers, filters and digitizer) 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 start of the E wave must be from the first cycle of the waveform recognizable as the front end of the E wave to the end of the E wave which taken as 10 μs later (the time was calculated from the dispersion curves for the specified aluminum plate). The wave energy must be computed and

recorded from the digital waveform as described in DWC application on file with the OHMSAPD.

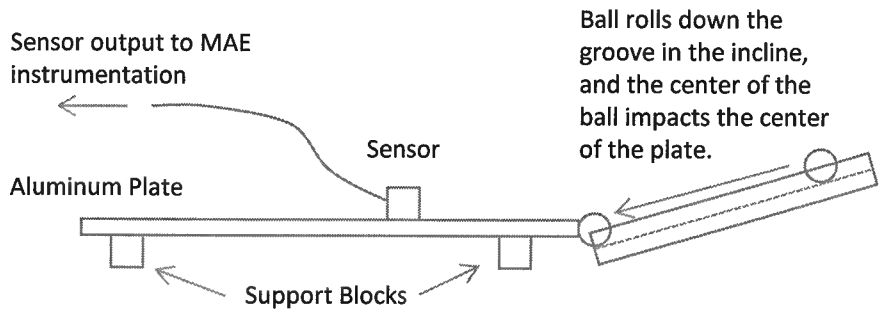

Figure 1. Inclined grooved Plate, impact balls, aluminum plate and sensor configuration

(3) Analog-to-Digital Converter Calibration - The sampling rate of the A/D 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 long tone burst with amplitude of 0.1 V at 100, 200, 300, and 400 kHz. The system must display an energy value of

$$U = (V^2 \times N \times T)/(2Z) \text{ joules}$$

at each frequency, where V = 0.1 volts, N = 20, Z is the preamplifier input impedance and T is the period of the cycle. If the measured values agree to within 15% of the theoretical values, the correct sampling rate has been set. These measurements must be performed at a system gain of 0 dB.

(4) Amplifier Gain Correction - All energies must be corrected for gain (e.g., 20 dB (x10) gain increases apparent energy 100 times and 40 dB (x100) gain increases apparent energy 10,000 times).

d. Visual Inspection - Prior to MAE testing, external and internal surfaces of each cylinder must be inspected in accordance with CGA Pamphlet C-6.2. Cylinders that do not meet the visual inspection criteria must be condemned.

e. MAE Test Procedure - After completion of MAE system calibration, the following test procedure must be completed:

(1) Sensor Mounting - A minimum of 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 from the dome-to-sidewall transition area and will be in-line along the axial direction of the vessel.

(2) System sensitivity - The sampling rate and memory depth settings for the MAE system are:

(i) Threshold: 52 dBAE (The sensitivity must be adjusted to account for the response of the sensors as measured from the rolling ball calibration);

(ii) Sampling Rate: 5 MHz; and

(iii) Memory Depth: 2048 Samples.

(3) Sensor Performance Checks - DWC must conduct sensor performance checks prior to each test to verify proper operation and good coupling to the vessel. For the coupling check, the E and F waveforms must be observed by breaking pencil lead at approximately 2 inches (5 cm) from each sensor along the axial direction of the vessel. The energy of the lead break waveforms must be 5×10^{-15} to 20×10^{-15} Joules. If this energy level is not met, the sensor coupling must be checked, or the sensor replaced. All calibration data must be recorded. Amplitude response performance checks must be carried out by pencil lead breaks (Pentel 2H, 0.3 mm) at a location centered along a line between the two sensors. Both sensors must 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. 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.

(4) Pressurization Procedure - Each cylinder must be subjected to a two-step hydraulic pressurization process from 0 psig to the cylinder's design test pressure (5/3 marked service pressure). During the first pressurization, the cylinder must be held at test pressure for at least five (5) minutes and up to 15 minutes. If no MAE activity is recorded after a five

(5) minute interval during the hold, the cylinder is stable and the pressure may be reduced to zero (0) psig. The pressure must be held at zero (0) psi for 100 seconds, then the step 1 pressurization must be repeated and held for a period of 100 seconds and depressurized as described above. The MAE event waveforms must be monitored and recorded during the two-step pressurizations process. Pressurization must be stopped, if the Background Energy Oscillation (BEO) exceeds two (2) times the quiescent background energy of that channel. The fill rate must be less than the rate at which flow noise first appears. If at any time during fill, the fill rate is too high in that it causes flow noise, the fill rate must be decreased until the flow noise disappears. A post-test system sensitivity check (lead breaks as described above) must be conducted and the data must be saved. The test temperature shall be between 50 °F (10 °C) and 120 °F (49 °C).

Warning: Appropriate measures shall be taken to ensure safe operation and to contain any energy that may be released as a result of a cylinder rupture during pressurization, regardless of hydraulic or pneumatic pressurization.

f. Accept/Reject Criteria - Each cylinder must be evaluated during MAE testing for the following four (4) Criteria:

(1) Stability - For each channel, the cumulative events versus time plot or event decay rate (B) must be measured.

Rejection - a cylinder must be rejected if the value of B does not meet the following:

$$-0.1 \leq B \leq -0.0001, \; R^2 \geq 0.80$$

R^2 = coefficient of determination used in regression calculation.

(2) Fiber Breakage - To determine if fiber bundle breakage has occurred during the second pressurization, the frequency spectra of the direct E and F waves in the digital signal must be examined as follows:

(i) Energy Measurement - The energies, U, for the following frequency ranges must be measured and recorded:

U0: 50 - 400 kHz

U1: 100 - 200 kHz

U2: 250 - 400 kHz

(ii) Energy Conditions - The criteria for determining if high frequency spectrum events have occurred, the following conditions must be calculated:

A- $U0 \geq U^{AE}_{FBB}$ Joules; and

B- $U2 / (U1 + U2) \geq 30\%$; and

C- $U2 / U0 \geq 30\%$

(iii) The values of U^{AE}_{FBB} for DOT-CFFC (Carbon Fiber) cylinders are:

U^{AE}_{FBB} for DOT CFFC = 2.7×10^{-16} Joules

Note: These values are sensor and system specific, and must be determined for each monitoring system configuration.

Rejection - A cylinder must be rejected if all three criteria (A, B and C) have occurred.

(3) Friction between Fracture Surfaces - The energy from friction between fracture surfaces is measured from the recorded MAE events.

Rejection - A cylinder must be rejected if a measured MAE event (energy) is greater than 2.7×10^{-14} Joules for carbon fiber cylinders.

(4) Background Energy Oscillation (BEO) - the background energy oscillation of each MAE channel must be measured and recorded during pressurization.

Rejection - A cylinder must be rejected if the BEO exceeds two (2) times the quiescent background energy of that channel at any time during pressurization.

Warning - If BEO with a difference in amplitude is greater than two (2) between minima and maxima, the pressure of the cylinder must be reduced immediately.

g. Action for Rejected Cylinders - When a cylinder is rejected, the retester must securely affix to the cylinder a label with the word "CONDEMNED" overcoated with epoxy near, but not obscuring, the original cylinder manufacturer's label. Alternatively, at the direction of the owner, the requalifier may render the cylinder incapable of holding pressure.

h. Marking - Each cylinder that has passed the requalification described in this special permit for extended service life must be marked "DOT-SP 16320". The new "DOT-SP 16320" marking must cover the current special permit marking by using epoxy, and then epoxy coated to ensure it is permanently attached to the cylinder. All markings, including requalification date (month/year), must be permanently placed on the cylinder as specified in § 180.213. The marking of the RIN symbol on the cylinder certifies compliance with all of the terms and conditions of this special permit.

i. Report - A report must be generated for each cylinder that was tested. 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 and marked service pressure;
(4) MAE technicians' name and certification level;
(5) Test date;
(6) Event energies exceeding the fiber bundle failure criteria, if any;
(7) Event energies exceeding the fretting emission energy allowable criteria, if any;
(8) Background energy oscillation pressure;

(9) Visual inspection results (Pass/Fail); and
(10) Acceptance/rejection results. If the cylinder is rejected, include each cause of rejection criteria as described in 7.f.

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

j. Personnel Qualification - Each person who performs retesting or who evaluates or certifies retest results must meet the following requirements:

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

(2) MAE Tester - The personnel responsible for performing cylinder retesting under this special permit must be qualified to an appropriate Level (Level I, II or III) in 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:

(i) 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 have been provided by a Senior Review Technologist. Based on written criteria, the Level II Operator may authorize cylinders that pass the retest to be marked in accordance with paragraph 7.h. 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.

(ii) Senior Review Technologist (SRT) - A person who provides the written MAE procedure, supervisory training and examinations (Level I and II), technical guidance to operators and reviews and verifies the test results. The SRT must prepare and submit the reports required in paragraph 7.i. and annually verify that the MAE program is being operated in accordance with the requirements of this special permit. 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:

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

(B) A Professional Engineer (PE) License with a documented minimum of 2 years of experience in Non-Destructive Evaluation (NDE) of pressure vessels or pipelines using the Modal Acoustic Emission test method; or

(C) 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 test method or research/thesis work and authoring/co-authoring of technical papers published, in recognized technical journals, in the field of Modal Acoustic Emission testing methods.

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

k. OPERATIONAL CONTROLS -

(1) The cylinders that are requalified for service life extension under this special permit are limited to DOT-CFFC cylinders that are exclusively used in SCBA service.

(2) Each cylinder covered by the terms of this special permit must have a prominent warning label on the external surface of the cylinder that indicates "The Cylinder must be externally inspected per CGA C6.2 prior to every fill".

(3) A cylinder that has been dropped in a fire may not be returned to service.

(4) Each cylinder that is requalified for service life extension under this special permit must be identified by special permit designation, serial number, the cylinder's owner (e.g., Fire station), and MAE requalification results (fail/pass);

(5) The original special permit marking of each cylinder that is requalified for service life extension under this special permit must be covered and replaced with "DOT-SP 16320" as described in paragraph 7.d. of this special permit.

(6) Record Keeping - Prior to marking a cylinder with "DOT-SP 16320" (designation for extended service life), the identification of each cylinder as described in paragraph 8.c. of this special permit must be submitted to the OHMSAPD.

(7) Revalidation Plan - All cylinders marked with "DOT-SP 16320" are subject to the in-service life extension (Revalidation Plan). The Revalidation Plan is described in paragraph 8.a. of this special permit.

(8) Maximum Service Life - Cylinders requalified under this special permit are authorized for an additional 5 year service life extension. The maximum service life of any cylinder that was qualified under this special permit is 30 years from the date of manufacture.

8. SPECIAL PROVISIONS:

a. Revalidation Plan - DWC must formulate a plan for all the cylinders that are marked "DOT-SP 16320" for the additional service life extension. The plan must be submitted to the OHMSAPD within 12 months of the issuance of this special permit and must include:

(1) A detailed procedure for obtaining the DOT-CFFC cylinders from the field and design qualification testing of each design type;

(2) A procedure for the random selection of a minimum of 5 cylinders which have been in service for 18, 21, 24 and 27 years;

(3) All randomly selected cylinders from the field must be tested in accordance with Sections 8.5.4, 8.5.5, 8.5.7 and 8.5.8 of ISO 11119-2:2002. Acceptance criteria must be as defined in ISO 11119-2; and

(4) The complete MAE test report, including the original test data, must be submitted to the Associate Administrator for Hazardous Materials Safety for assessment within 30 days of completion of the test. Failure to meet the acceptance criteria specified in this special permit may result in the design being restricted to a maximum life of 15 years.

b. The designated SRT must review the MAE program annually. The designated SRT must submit a letter to the OHMSAPD, on January 7th each year that this special permit is effective, verifying that the MAE program is meeting the terms and requirements of this special permit.

c. The total number of cylinders tested under this special permit must be reported by special permit number, type (e.g., CFFC), serial 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) must also be included in the report.

d. A statement of qualifications and supporting documentation, for each "qualified MAE tester" used under this special permit and information in support thereof, must be maintained by DWC. The location of this statement, for each "qualified MAE tester", must be identified to the OHMSAPD.

e. A person who is not a holder of this special permit who receives a package covered by this special permit may reoffer it for transportation provided no modification or change is made to the package and it is reoffered for transportation in conformance with this special permit and the HMR.

f. A current copy of this special permit must be maintained at each facility where the package is offered or reoffered for transportation.

g. A current copy of the DOT special permit for the cylinders listed in paragraph 7.a. of this special permit must be maintained at each facility where retesting is performed.

9. MODES OF TRANSPORTATION AUTHORIZED: Motor vehicle, cargo vessel, passenger-carrying aircraft, cargo aircraft and rail freight.

10. MODAL REQUIREMENTS: A current copy of this special permit must be carried aboard each cargo vessel, aircraft, or motor vehicle used to transport packages covered by this special permit. The shipper must furnish a 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:

- All terms and conditions prescribed in this special permit and the Hazardous Materials Regulations, 49 CFR Parts 171-180.

- 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.

- 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.:

April 21, 2017

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: MT