

May 29, 2007



U.S. Department  
of Transportation

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

**Pipeline and Hazardous  
Materials Safety Administration**

DOT-SP 12706  
(SIXTH REVISION)

EXPIRATION DATE: April 30, 2011

(FOR RENEWAL, SEE 49 CFR § 107.109)

1. GRANTEE: RAGASCO AS  
Raufoss, Norway  
(U.S. Agent: RAGASCO North America, Inc.,  
West Palm Beach, FL)
2. PURPOSE AND LIMITATIONS:
  - a. This special permit authorizes the manufacture, marking, sale and use of a non-DOT specification fully-wrapped fiberglass composite cylinder with seamless, non-load sharing blow-molded thermoplastic liner for the transportation in commerce of the materials authorized by this special permit. This special permit provides no relief from the Hazardous Materials Regulations (HMR) other than as specifically stated herein.
  - b. The safety analyses performed in development of this special permit only considered the hazards and risks associated with transportation in commerce. The safety analyses did not consider the hazards and risks associated with consumer use, use as a component of a transport vehicle or other device, or other uses not associated with transportation in commerce.
3. REGULATORY SYSTEM AFFECTED: 49 CFR Parts 106, 107 and 171-180.
4. REGULATIONS FROM WHICH EXEMPTED: 49 CFR §§ 173.304a(a)(1) and 175.3 in that the use of a non-DOT specification packaging is not authorized therein except as specified herein.

5. BASIS: This special permit is based on the application of RAGASCO Composites AS dated May 26, 2007 submitted in accordance with § 107.109.
6. HAZARDOUS MATERIALS (49 CFR § 172.101):

| <b>Hazardous Material Description</b>                 |                               |                              |                      |
|---|-------------------------------|------------------------------|----------------------|
| <b>Proper Shipping Name</b>                           | <b>Hazard Class/ Division</b> | <b>Identification Number</b> | <b>Packing Group</b> |
| Butane <i>see also</i> Petroleum gases, liquefied     | 2.1                           | UN1011                       | N/A                  |
| Hydrocarbon gas mixture, liquefied n.o.s.             | 2.1                           | UN1965                       | N/A                  |
| Petroleum gases, liquefied or Liquefied petroleum gas | 2.1                           | UN1075                       | N/A                  |
| Propane <i>see also</i> Petroleum gases, liquefied    | 2.1                           | UN1978                       | N/A                  |
| Compressed gas, n.o.s. (Nitrogen)                     | 2.2                           | UN1956                       | N/A                  |

7. SAFETY CONTROL MEASURES:

a. PACKAGING - Packaging prescribed is a non-DOT specification fully-wrapped fiberglass composite cylinder with a one-piece thermoplastic liner. The cylinder has a permanently attached outer casing made of injection molded high density polyethylene (HDPE). Cylinders must be designed, manufactured, and tested in conformance with the following documents: RAC doc. 0141295-1200 "LPG Quality Assurance Program Plan", and drawings on file with the Office of Hazardous Materials Special Permits and Approvals (OHMSPA). Additionally, cylinders must be in conformance with the following:

(1) Type size and service pressure.

Maximum Volume: 24 Liters

Maximum service pressure: 294 psi (20 bars)

Minimum test pressure: 441 psi (30 bars)

Minimum burst pressure: 882 psi (60 bars)

(2) Inspection. Inspections and verifications required by this special permit must be performed by an independent inspection agency approved in writing by the Associate Administrator for Hazardous Materials Safety in accordance with Title 49, Code of Federal regulations, Subpart I.

(3) Duties of the inspector.

(i) Determine that all materials conform to the provisions of this special permit.

(ii) For each raw material batch, verify liner material to be within the specification in this special permit by analysis or obtaining the manufacturer's certified analyses. A certification from the manufacturer is acceptable when verified by check analyses on a sample from every raw material batch. Verify conformance of filament and resin system components with the requirements in the special permit.

(iii) Prior to the initial shipment of any specific cylinder design, verify that the design qualification tests prescribed in this special permit have been performed with acceptable results.

(iv) Verify conformance of the completed cylinder with all requirements, including marking, condition of inside, threads and relevant process parameters.

(v) Verify winding process to assure that composite material is uniform, of required thickness and pattern, and in accordance with the composite structure present in cylinders subjected to the design qualification tests.

(vi) Witness all tests and pressurizations, obtain copies of all test results and certifications; report volumetric capacity, and completed composite cylinder weight.

(vii) Furnish completed inspector's report to the manufacturer of the cylinder and upon request, to the purchaser.

(4) Authorized materials and identification of materials.

(i) Inner liner must be non-load sharing, seamless, blow moulded quality high density polyethylene (HDPE). The mass density at 23°C (73.4°F) must be per ISO 1133/ASTM D1505-85: 0.942 - 0.948 g/cm<sup>2</sup>; min/max. The melt flow rate (MFR) at a material temperature of 190°C with a driving force of 21.6kg, must be 5.3 - 8.0 g /10 minute; min/max.

(ii) Filament material must be commercial Type E-fiberglass. Filaments must be tested in accordance with ASTM D-2343-79 and have minimum strand strength of 200,000 psi.

(iii) Resin system must be thermoset vinylester based resin as described in the material specifications on file with the OHMSPA. Resin system must be tested on sample coupons representative of the composite overwrap in accordance with ASTM D-2344-67 for water boil test, and have minimum shear strength of 13.8MPa (2029 psi).

(iv) Threaded brass insert shall conform to the following chemical analysis (by weight %):

|         |                      |
|---------|----------------------|
| Cu:     | 57.0 - 59.0, min/max |
| Pb:     | 1.5 - 2.0, min/max   |
| Fe:     | 0.4, max             |
| Ni:     | 0.4, max             |
| Sn:     | 0.3, max             |
| Al:     | 0.9, max             |
| Others: | 0.2, max             |
| Zn:     | Remainder            |

(5) Manufacture.

(i) The thermoplastic liner shall be homogeneous, clean and correctly dimensioned. No defect that is likely to weaken the finisher liner function is authorized.

(ii) The composite cylinder must be manufactured from a thermoplastic liner fully overwrapped with resin impregnated continuous filament windings. The winding pattern must be "helical" or "in place and hoop" wrap, applied under controlled tension to develop the design composite thickness. After winding is complete, the composite must be cured by a controlled temperature profile. No defect that is likely to weaken the finished cylinder appreciably is acceptable.

(iii) Welding or brazing for any purpose whatsoever is prohibited.

(6) Lot size. A cylinder lot means a group of cylinders successively produced from qualified liners, having the same size and configuration, the same specified materials of construction, and the same process of manufacture to the same cylinder specification. In no case may the lot size exceed 200 cylinders; however, any cylinder processed for use in the required destructive tests need not be counted as one of the 200, but must have been processed with the lot.

(7) Wall thickness. Liner wall thickness shall be within tolerances specified in drawings on file. The minimum fiber stress ratio (fiber stress at design minimum burst pressure divided by the fiber stress at service pressure) must be 3.4.

(8) Openings. Openings are permitted on the heads only. The center line of openings must coincide with the longitudinal axis of the cylinder. Threads must be clean cut, even, without checks and to gauge.

(9) Pressure relief devices and valve protection.  
Cylinder must be equipped with a pressure relief device in accordance with § 173.301(f). Protection for valves and other connections must be in accordance with § 173.301(h).

(10) Production testing

(i) Each cylinder must be hydrostatically or pneumatically pressure tested to a pressure of at least 441 psig (30 bar) without measurement of expansion. The cylinder test pressure must be maintained for a sufficiently long period (at least 30 seconds) to ascertain that there are no leaks and no failure. The cylinder shall be rejected if there are leaks, failure to hold pressure, or visible permanent deformation after the cylinder is depressurized. (Note: Cracking of resin is not necessarily a sign of permanent deformation.) If leakage occurs in the piping or fittings, the cylinder may be retested after repairing such leakages. Only two such retests are authorized. The pressure gauge must permit reading to an accuracy of 1 percent in the range of 80 percent to 120 percent of test pressure. Cylinders rejected by the pressure test must not be placed in service.

(ii) One cylinder taken at random from each lot of 1,000 or less cylinders must be subjected to cycle testing in accordance with DOT FRP-1 §178.AA-12(b) (See Appendix B of this special permit). Acceptable results must be in accordance with §178.AA-13(c) and §178.AA-14(c).

(iii) One cylinder taken at random from each lot of 200 or less cylinders must be hydrostatically burst tested in accordance with DOT FRP-1 § 178.AA-12(c). Acceptable results must be in accordance with § 178.AA-13(d) and § 178.AA-14(d), except that the burst may initiate anywhere on the cylinder (dome or sidewall). The cylinder must remain in one piece. Leakage through the boss fusion joint is permitted, provided that the pressure at failure is at least 4 times the design service pressure.

(11) Inspector's reports & retention of report.

(i) The inspector must prepare a report that is clear, legible, and in accordance with DOT FRP-1 § 178.AA-16 except that testing and criteria relevant to aluminum liners must be replaced with that relevant to thermoplastic liners, and references to FRP-1 must be replaced with this special permit number.

(ii) The inspector's report must be retained for 15 years from the original test date on the cylinder by the manufacturer and by the inspector.

(12) Design qualification tests. Prior to initial shipment of any specific cylinder design, qualification tests must have been performed on representative cylinders with satisfactory results. All cylinders used for design qualification tests must be fabricated on the same equipment and subjected to the same processes as is used to produce cylinders intended for charging and shipment. All tests must be witnessed by an independent inspector. Test reports must be kept on file by the cylinder manufacturer and made available to the independent inspector and the OHMT upon request. Design changes must be as defined in DOT FRP-1 § 178.AA-18(b). Required testing for design changes must be as specified in DOT FRP-1 § 178.AA-18(c). The following design qualification tests must be performed:

(i) Vacuum Test. One cylinder shall be subjected to a vacuum test prior to the environmental cycle test. The cylinder shall be subjected to a series of cycles from atmospheric pressure to a vacuum. The contents (inert gas or air) shall be reduced from atmospheric pressure to a pressure of 0.2 bar absolute at ambient temperature. The vacuum shall be maintained at this level for at least one minute. The pressure in the cylinder shall be returned to atmospheric pressure. The total number of cycles shall be 50. After cycling, the interior of the liner shall be inspected for damage. Any evidence of disbonding, folding, or other damage shall be noted. If the

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cylinder then passes the environmental cycle test, it shall also be deemed to have passed the vacuum test.

(ii) High Temperature Creep. Two cylinders shall be hydraulically pressurized to test pressure and shall be maintained at this pressure for at least 1,000 hours. The test shall be conducted at a minimum temperature of 70°C and a relative humidity of less than 50%. After this test, the cylinders shall be subjected to the leak test and the burst test. The cylinder shall not exhibit any visible deformation or loose (unravelling) fibers. The cylinder shall pass the leak test and the burst pressure shall be equal to or greater than 2 times the test pressure. Leak test. Acceptable methods for leakage testing include bubble testing using dry air or gas or measurement of trace gases using a mass spectrometer. Leak testing must be performed at service pressure. No leakage in excess of the permeation rate of 0.25 (ml/h/L water capacity) shall be permitted.

(iii) Permeability Test. Two cylinders shall be hydraulically pressure cycled 1000 cycles from zero to service pressure, and then weighed empty. The cylinders shall then be filled to service pressure with LPG at a temperature of 15°C. The cylinders shall be weighed after 1,7,14,21, and 28 days, emptied and weighed empty after testing. Requirement: Maximum loss of weight rate  $q < 0.25$  (ml/h/L water capacity). The calculation should be modified so that the difference between empty weight before and after the test is not integrated in the loss of weight rate.

(iv) Flawed Cylinder Test. Two cylinders shall be prepared with cuts into the composite approximately in the following manner: Two flaws on each cylinder: Width = 1mm, length = 5 times the composite thickness, depth = at least 40% of the composite thickness. One cut shall be longitudinal and the other transverse in the cylindrical part along two planes forming an angle of 120 degrees. One cylinder shall withstand the ambient pressure cycling test to 5000 cycles, while the other cylinder shall withstand the burst test to at least 4/3 times the test pressure.



(v) Drop Test. Two cylinder shall be filled with water to the weight equal to maximal service content. The cylinders shall be dropped from the height of 1.2m onto a smooth, un-yielding surface (steel, concrete, etc.) twice in the following five positions, giving a total of ten drops: (1) vertically onto the bottom end, (2) 45 degrees onto the bottom end, (3) horizontally, (4) 45 degrees onto the valve end, and (5) vertically onto the valve end. Visual damage shall be noted after each drop. After dropping, one cylinder shall withstand the ambient pressure cycling test, while the other cylinder shall withstand the burst test.

(vi) Torque test on cylinder neck boss. The cylinder shall be fitted with a valve and tightened to 150% of the maximum torque recommended by the manufacturer. The valve shall be removed after the first installation and the neck thread and boss inspected. The procedure shall then be repeated. A test for leaks in the cylinder neck or the permeability test shall be conducted at service pressure for at least 10 minutes. The neck thread and boss shall show no significant deformation and shall remain within drawing and gauge tolerance. Leakage greater than 1 bubble in 2 minutes in the bubble leak test or failure of the permeability test shall constitute a failure of the test.

(vii) The following design qualification tests must be performed in accordance with the procedures and accept/reject criteria of § 178.AA-18 of the DOT FRP-1 Standard (See Appendix B of this special permit):

- Pressure Cycling Tests (Ambient, Environmental, and Thermal)
- Hydraulic Burst Test, except that the burst may initiate as prescribed in 7.a.(10)(iii) of this special permit
- Gunfire Test
- Bonfire Test, except that venting may occur other than through the pressure relief device.

b. REQUALIFICATION TESTING - At least every 5 years, each cylinder must be visually inspected and proof pressure tested. The retest and inspection must be performed with the outer casing in place. Persons performing requalification functions must comply with § 180.205(b).

(1) Proof pressure testing must be to at least 30 bars test pressure in accordance with paragraph 7.a.(10)(i) of this special permit.

(2) Visual inspection must be performed on the outer casing and the non-protected composite areas only. A strong backlight shall be used. Visual inspection and acceptance criteria must be in accordance with Appendix A of this special permit. Repair of the cylinder is not authorized. Cylinders meeting the criteria for rejection must be scrapped.

(3) Removal or replacement of the outer casing may only be performed by personnel authorized by the manufacturer.

(4) Retest markings must be in accordance with 49 CFR 180.213(d) and (e). Retest markings must be applied on a label securely affixed to the exposed dome of the cylinder and overcoated with epoxy, near the original test date which is marked on the face of the cylinder boss. Metal stamping of the composite surface or the metal boss is prohibited.

c. OPERATIONAL CONTROLS -

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

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

(3) Cylinder service life may not exceed 15 years from the date of manufacture as marked on the cylinder.

(4) Filling requirements are subject to all terms contained in §§ 173.304 and 173.304a for DOT 4BA specification cylinders. Person refilling cylinders authorized by this special permit must follow manufacturer's recommendations for pre-fill inspections.

(5) Cylinders must be transported in well-ventilated motor vehicles.

d. MARKING -

(1) Each cylinder must be permanently marked as prescribed in DOT FRP-1 Standard "Basic Requirements for Fiber Reinforced Plastic (FRP) Type 3FC Composite Cylinders §178.AA-15, except that the markings must be made on the top face of the cylinder boss by laser etching or by engraving, and the size of the markings must be at least 1/8 inch in height.

(2) Each cylinder must be marked "DOT-SP 12706".

(3) Each cylinder must be permanently and legibly marked "CYLINDER MUST NOT BE STORED IN AN UNVENTILATED SPACE".

8. SPECIAL PROVISIONS:

a. In accordance with the provisions of Paragraph (b) of §173.22a, persons may use the packaging authorized by this special permit for the transportation of the hazardous materials specified in paragraph 6, only in conformance with the terms of this special permit.

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

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

d. Each packaging manufactured under the authority of this special permit must be either; (1) marked with the name of the manufacturer and location (city and state) of the facility at which it is manufactured; or (2) marked with a registration symbol designated by the Office of Hazardous Materials Special permits and Approvals for a specific manufacturing facility.

- e. A current copy of this special permit must be maintained at each facility where the package is manufactured under this special permit. It must be made available to a DOT representative upon request.
- f. The cylinders described in this special permit are authorized only for normal transportation as an article of commerce i.e., the movement of hazardous materials packages from consignor to consignee.
- g. No modifications may be made to the pressure vessel, or the Quality Assurance Program Plan used for its manufacture which would affect the performance of the pressure vessel or its compliance with the requirements of this special permit until such modifications have been reviewed, tested and certified by an Independent Inspector as meeting the requirements of this special permit.
- h. Packagings permanently marked "DOT-E 12706", prior to October 1, 2007 may continue to be used under this special permit for the remaining service life of the packaging or until the special permit is no longer valid. Packagings marked on or after October 1, 2007 must be marked "DOT-SP 12706".
- i. Shipping papers displaying "DOT-E 12706" may continue to be used until October 1, 2007 provided the special permit remains valid.
9. MODES OF TRANSPORTATION AUTHORIZED: Motor vehicle, rail freight, cargo vessel, and cargo aircraft only.
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

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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.:

A handwritten signature in blue ink that reads "Aiane LaValle". The signature is written in a cursive style and is positioned above a rectangular stamp area.

for Bob Richard  
Deputy Associate Administrator  
for Hazardous Materials Safety

Address all inquiries to: Associate Administrator for Hazardous Materials Safety, Pipeline and Hazardous Materials Safety Administration, Department of Transportation, Washington, D.C. 20590. Attention: PHH-31.

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](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: CWF/sln

**DOT FRP-2 STANDARD**

**DATE: Original: January 15, 1982**

**Revision 1: January 4, 1987**

**BASIC REQUIREMENTS FOR FIBER REINFORCED PLASTIC  
(FRP) TYPE 3HW COMPOSITE CYLINDERS**

**§ 178.BB** Fiber reinforced plastic (FRP) hoop wrapped composite (HW) cylinders made of definitely prescribed materials.

**§ 178.BB-1** General.

Each cylinder must conform with these basic requirements and the specific requirements of the applicable exemption.

**§ 178.BB-2** Type, size and service pressure.

Type 3HW hoop-wrapped cylinder consisting of resin impregnated continuous filament windings in the circumferential direction only over a seamless aluminum liner made in accordance with § 178.BB-6(a); not over 200 pounds water capacity; and service pressure at least 900 PSI but not greater than 5000 PSI.

**§ 178.BB-3** Inspection by whom and where.

Inspections and verifications must be performed by an independent inspection agency approved in writing by the Director for the Office of Hazardous Materials Transportation (OHMT), in accordance with 49 CFR 173.300a. Chemical analyses and tests must be made in the United States unless otherwise approved in writing by the Director for OHMT in accordance with 49 CFR 173.300b.

**§ 178.BB-4** Duties of the inspector.

(a) Determine that all materials conform with the provisions of this standard before releasing them for cylinder manufacture.

(b) Verify that aluminum liner conforms with § 178.BB-6(a). Verify that filament and resin system components conforms with the requirements specified in § 178.BB-5.

(c) Prior to initial shipment of any specific composite cylinder

design, verify that the design qualification tests prescribed in § 178.BB-18 have been performed with acceptable results.

(d) Verify that each completed cylinder conforms with all requirements including marking.

(e) Verify that winding process is proper to assure that composite material is uniform, of required thickness and pattern, and in accordance with the composite structure present in cylinders subjected to the design qualification tests.

(f) Witness all tests and pressurizations, obtain copies of all test results and certifications; report volumetric capacity, permanent expansion and completed composite cylinder weight.

(g) Furnish completed inspector's report (§ 178.BB-16) to the maker of the cylinder and upon request, to the purchaser. (See § 178.BB-17).

**§ 178.BB-5 Authorized material and identification of material.**

(a) Aluminum liner must be 6061 or 6351 alloy and T6 temper.

(b) Filament material must be commercial Type-S or commercial Type-E fiberglass. Filaments must be tested in accordance with ASTM D-2343-67 and have minimum strand strength as follows:

(1) Type-S Glass ---- 400,000 PSI.

(2) Type-E Glass ---- 200,000 PSI.

(c) Resin system must be epoxy or modified epoxy type. Resin system must be tested on sample coupons representative of the composite over-wrap in accordance with ASTM D-2344-67 for water boil shear test, and have a minimum shear strength of 5,000 PSI.

(d) Materials must be identified by a suitable method during manufacture.

(e) Materials must be of uniform quality. Materials with injurious defects are not authorized.

**§ 178.BB-6 Manufacture.**



(a) **Liner.** Aluminum liner without over-wrap must be designed for a service pressure of at least 50 percent of the service pressure marked on the composite cylinder, and must conform with DOT 3AL specification (49 CFR 178.46) except:

(1) No marking is to be applied to the cylinder except as specified in § 178.BB-15; and

(2) Hydrostatic test of any cylinder prior to applying filament is not authorized.

(b) **Composite cylinder.** The composite cylinder must be made from an aluminum liner circumferentially wrapped over the entire cylindrical portion with resin impregnated continuous filament winding. Winding pattern must be "hoop" wrap applied under controlled tension to develop the design composite thickness. After winding is complete, the composite must be cured by a controlled temperature profile, and auto-frettagged by pressurizing to not less than 105 percent and not greater than 115 percent of the prescribed minimum test pressure. No defect is acceptable that is likely to weaken the finished cylinder appreciably.

(c) **Welding or brazing.** Welding or brazing for any purpose whatsoever is prohibited.

(d) **Lot size.**

(1) **Liner lot size.** A "liner lot" means a group of cylinders successively produced in one (up to 10 hour) shift having the same:

(i) size and configuration;

(ii) specified material of construction;

(iii) process of manufacture and heat treatment;

(iv) equipment of manufacture and heat treatment; and

(v) conditions of time, temperature and atmosphere during heat treatment.

(2) **Composite cylinder lot size.** A "composite cylinder lot" means a group of cylinders successively produced from qualified liners,

having:

- (i) the same size and configuration;
- (ii) the same specified materials of construction;
- (iii) the same process of manufacture to the same cylinder specification; and
- (iv) auto-frettagged under the same conditions of time, temperature and pressure.

(3) In no case may the "lot" size exceed 200 units; however, any unit processed for use in the required destructive tests need not be counted as one of the 200, but must have been processed with the lot.

(e) **Design qualification tests.** Prior to initial shipment of any specific cylinder design, qualification tests as prescribed in § 178.BB-18 must have been performed with satisfactory results.

§ 178.BB-7 **Wall thickness.**

(a) Minimum thickness of the liner must be at least equal to the minimum design thickness and be such that after auto-frettaging, the compressive stress in the sidewall of the liner at zero pressure will not exceed 95 percent of the minimum yield strength of the aluminum as determined in 49 CFR 178.46-13 or 95 percent of the minimum design yield strength shown in § 178.BB-18(h). The maximum tensile stress of the liner at operating pressure must not exceed 60 percent of its yield strength.

(b) The maximum filament stress at service pressure must not exceed 40 percent of the filament stress at the virgin burst pressure of the lot test cylinder.

(c) The end design must incorporate added materials to assure the stresses in the areas not supported by the hoop wrap are less than the stresses found in the cylindrical portion.

(d) Stresses shall be computed from Computer Code NASA CF-72124 "Computer Program for the Analysis of Filament-Wound Reinforced Metal Shell Pressure Vessels" May 1966, or other suitable analysis techniques.

§ 178.BB-8 **Openings.**

(a) Openings are permitted on the heads only. Centerline of openings must coincide with the longitudinal axis of the cylinder.

(b) Threads are required. Threads must be clean cut, even, without checks and to gauge.

(c) Tapered threads are not permitted.

(d) Any straight thread conforming with National Gas Straight (NGS) thread standard is authorized. The thread must conform with the requirements of Federal Standard (FED-STD) H28-1978. Other straight threads having at least 6 engaged threads are authorized provided that the calculated shear strength is at least 10 times the test pressure of the cylinder.

§ 178.BB-9 **Thermal treatment.**

The resin must be cured at the temperature specified and by the process set forth in the cylinder manufacturer's specification and noted in the Inspector's report. Curing temperature and process must correspond with that applied to the cylinders subjected to the qualification tests. The curing temperature must not exceed 350 ° F.

§ 178.BB-10 **Pressure relief devices and protection for valves, relief devices, and other connections.**

Pressure relief devices and protection for valves and other connections must conform with 49 CFR 173.34(d) and 173.301(g), except that the adequacy of the pressure relief devices for each design may be verified in accordance with § 178.BB-18(g).

§ 178.BB-11 **Nondestructive tests.**

(a) **Hydrostatic test.**

(1) By water-jacket, operated so as to obtain accurate data. Pressure gauge must permit reading to accuracy of 1 percent in the range of 80 percent to 120 percent of test pressure. Expansion gauge must permit reading of total expansion to an accuracy of either 1 percent or 0.1 cubic centimeter.

(2) The accuracy of the test equipment must be maintained by periodic recalibration. Records must be maintained to verify that the test equipment is calibrated on a regular basis. A calibration cylinder capable of verifying the equipment accuracy for the material, size and test pressure of the cylinders to be tested must be used for checking the equipment at the beginning of each day.

(3) Pressure must be maintained for 30 seconds and sufficiently longer to insure complete expansion. Any internal pressure applied after auto-fretting and previous to the official test must not exceed 90 percent of the test pressure. If, due to failure of test apparatus, the test pressure can not be maintained, the test may be repeated at a pressure increased by 10 percent or 100 PSI, whichever is lower. Not more than 2 such repeated tests are permitted.

(4) Each cylinder must be tested to at least 5/3 times service pressure. In no case may the test pressure exceed the auto-fretting pressure.

#### § 178.BB-12 **Destructive tests.**

(a) **Cycling test.** One cylinder taken at random out of each lot of 200 cylinders or less must be subjected to cyclic pressurization test by hydrostatically pressurizing the cylinder between approximately zero PSI and the designated pressure at a rate not to exceed 4 cycles per minute. Adequate recording instrumentation must be provided if the equipment is to be left unattended for periods of time. All cylinders used in the cycle test must be destroyed.

(b) **Burst test.** One cylinder taken at random out of each lot of 200 cylinders or less shall be hydrostatically pressurized to failure as follows: pressure shall be increased at a uniform rate up to minimum prescribed burst pressure; this pressure to be held for at least 60 seconds; then the pressure shall be further increased to failure. The rate of pressurization must not exceed 200 PSI per second. The cylinder cycle-tested in paragraph (b)(1) above may be used for this burst test.

(c) **Physical test.** Applies to aluminum liner only. If composite cylinder is from DOT 3AL stock, the DOT 3AL required tests may be used for this test.

#### § 178.BB-13 **Acceptable results of tests.**

(a) **Hydrostatic test.**

(1) The permanent volumetric expansion of the cylinder must not exceed 5 percent of the total volumetric expansion at test pressure.

(2) All cylinders failing to pass the hydrostatic test must be rejected.

(b) **Physical test.** Applies to aluminum liner only.

(1) Elongation must be at least 14 percent; except that an elongation of 10 percent is acceptable when the authorized specimen size is 24t x 6t.

(2) When the test results fail to meet requirements, the lot must be rejected.

(3) A retest of a rejected lot is authorized if an improper test was made due to the presence of a defect in the specimen or if the equipment or procedure was faulty. The retest must be performed on specimens taken from the same cylinder liner.

(c) **Cycling test.**

(1) Each test cylinder must withstand at least 10,000 pressurizations between approximately zero and service pressure followed by at least 30 pressurizations between zero and test pressure, without evidence of distortion or failure.

(2) When the test cylinder fails to withstand the cycle test, the lot represented must be rejected.

(d) **Burst test.**

(1) Burst pressure shall be at least 2-1/2 times the service pressure and in no case less than the value necessary to meet the stress criteria of § 178.BB-7(a). Failure must initiate in the cylinder sidewall. Cylinders with marked service pressure not exceeding 2,200 PSI must remain in one piece. Actual burst pressure must be recorded.

(2) When the test cylinder fails to withstand the minimum prescribed burst pressure, the lot represented must be rejected.

§ 178. BB-14 **Rejected liners and cylinders.**

(a) **Physical test.** Reheat treatment of aluminum liners that failed the physical test is authorized. Subsequent thereto, acceptable liners must pass all prescribed tests.

(b) **Hydrostatic test.** Cylinders rejected by the hydrostatic test must not be placed in service.

(c) **Cycle test.** Cylinders of lots rejected by the cycle test must not be placed in service.

(d) **Burst test.** Cylinders of lots rejected by the burst test must not be placed in service.

§ 178. BB-15 **Marking.**

(a) Each cylinder must be permanently marked by a method other than stamping in the composite wrap on the side near the end of the cylinder containing the valve outlet.

(b) Required markings are as follows:

(1) DOT-E \*\*\*\*-YYYY (where \*\*\*\* = Exemption number and YYYY = service pressure in PSIG).

(2) A serial number and an identifying symbol (letters); location of serial number to be just below or immediately following the DOT mark; location of symbol to be just below or immediately following the serial number. The symbol and serial number must be those of the maker. The symbol must be registered with the Director for OHMT; duplications not authorized.

(3) The Inspector's official mark must be placed near the serial number.

(4) Date of test (month and year).

(5) Examples of cylinder marking:

DOT-E \*\*\*\*-2000    or:            DOT-E \*\*\*\*-2000-1234-XY-AB-3-81  
1234-XY

AB  
3-81

(c) Size of marks must be at least 1/4 inch high if space permits.

(d) Additional markings are permitted in the composite, or may be stamped in low stress areas of the aluminum liner, other than the sidewall, provided the markings are not of a size and depth that will create harmful stress concentrations.

(e) Retest dates may be stamped in low stress areas of the top head. [Should be transferred to 49 CFR 173.34(e) at rulemaking.]

§178. BB-16 **Inspector's report.**

(a) The inspector must prepare a report that is clear, legible and in accordance with the following:

**REPORT OF MANUFACTURE OF FIBER REINFORCED PLASTIC (FRP) 3HW HOOP WRAPPED COMPOSITE (HW) ALUMINUM LINED COMPRESSED GAS CYLINDER.**

(Place) \_\_\_\_\_

(Date) \_\_\_\_\_

(Exemption number) \_\_\_\_\_

Manufactured for \_\_\_\_\_

Located at \_\_\_\_\_

Manufactured by \_\_\_\_\_

Located at \_\_\_\_\_

Consigned to \_\_\_\_\_

Located at \_\_\_\_\_

Quantity \_\_\_\_\_ Size \_\_\_\_\_ inches outside diameter by \_\_\_\_\_ inches long

Marks placed on the \_\_\_\_\_ of the cylinder are:

DOT-E \_\_\_\_\_

Serial numbers \_\_\_\_\_ to \_\_\_\_\_ inclusive.

Identifying symbol (Registered) \_\_\_\_\_  
Inspector's mark (Registered) \_\_\_\_\_  
Test date(s) \_\_\_\_\_  
Other marks (if any) \_\_\_\_\_

Each composite cylinder was made by circumferentially overwrapping a seamless aluminum liner with resin impregnated continuous filament reinforcement. Composite overwrap was made by winding resin impregnated continuous filament over this liner in the circumferential direction only, followed by curing the resin at controlled temperature. The liner conforms with § 178.BB-6(a) for unwrapped cylinders having a service pressure of \_\_\_\_PSIG. Conformance of the liner with § 178.BB-6(a) was verified by performance of the prescribed tests or by obtaining the report of the inspector performing the prescribed tests.

Filament and resin were certified by the manufacturer and identified by package number. Strand strength of filament was verified. Shear strength of composite was verified. After wrapping, composite was cured per manufacturers' s specification.

Prescribed auto-frettage and hydrostatic tests were made in the presence of the inspector. All cylinders accepted conform with the specification requirements.

Tensile stress on the aluminum liner is calculated to be \_\_\_\_ PSI at service pressure. Filament stress is calculated to be \_\_\_\_ PSI at service pressure.

I hereby certify that all of these cylinders proved satisfactory in every way and conform with the requirements of DOT-E \_\_; except as follows:

Exceptions taken to any reporting or testing requirements of this exemption are: \_\_\_\_\_

(Signed) \_\_\_\_\_  
(Inspector)

### RECORD OF CHEMICAL ANALYSES OF MATERIAL FOR LINER

Place \_\_\_\_\_

Date \_\_\_\_\_

Exemption number \_\_\_\_\_

Serial numbers \_\_\_\_\_ to \_\_\_\_\_ inclusive.



Size \_\_\_\_\_ inches outside diameter by \_\_\_\_\_ inches long.  
 Made by \_\_\_\_\_ Company.  
 For \_\_\_\_\_ Company.  
 Material description \_\_\_\_\_.

NOTE: Any omission of analyses by heats, if authorized, must be accounted for by notation herein reading "The prescribed certificate of the manufacturer of material has been secured, found satisfactory, and placed on file." or by attaching a copy of the certificate.

| Alloy Designation | Cylinders Represented (Serial Nos.) | Chemical analyses |    |    |    |    |    |    |    |            |          |
|-------------------|-------------------------------------|-------------------|----|----|----|----|----|----|----|------------|----------|
|                   |                                     | Si                | Fe | Cu | Mn | Mg | Cr | Zn | Ti | Others Ea. | Total Al |
|                   |                                     |                   |    |    |    |    |    |    |    |            |          |
|                   |                                     |                   |    |    |    |    |    |    |    |            |          |
|                   |                                     |                   |    |    |    |    |    |    |    |            |          |

Material was manufactured and mill analyses made by \_\_\_\_\_  
 Originals of the certified mill analyses reports are in files of the material manufacturer.

(Signed) \_\_\_\_\_  
 (Inspector)

**RECORD OF PHYSICAL TESTS OF MATERIAL FOR LINERS.**

Place \_\_\_\_\_  
 Date \_\_\_\_\_  
 Exemption Number \_\_\_\_\_  
 Serial numbers \_\_\_\_\_ to \_\_\_\_\_ inclusive.  
 Size \_\_\_\_\_ inches outside diameter by \_\_\_\_\_ inches long.  
 Made by \_\_\_\_\_ Company.  
 For \_\_\_\_\_ Company.  
 Test specimen description \_\_\_\_\_

| Lot Code | Cylinders Represented by Test. (Serial Nos) | Yield Strength at 0.2 percent Offset (pounds per square inch) | Tensile Strength (pounds per square inch) | Elongation (percent) |
|----------|---|---|---|----------------------|
|          |   |   |   |                      |
|          |   |   |   |                      |
|          |   |   |   |                      |

(Signed) \_\_\_\_\_  
(Inspector)

**REPORT OF COMPOSITE ANALYSES**

Place \_\_\_\_\_  
Date \_\_\_\_\_  
Exemption number \_\_\_\_\_  
Materials \_\_\_\_\_  
Manufactured by \_\_\_\_\_ Company.  
For \_\_\_\_\_ Company.  
Numbered \_\_\_\_\_  
Filament specification and designation \_\_\_\_\_  
Manufactured by \_\_\_\_\_

| Manufacturing<br>package number | Tensile strength | Inter-laminar<br>shear strength |
|---------------------------------|------------------|---------------------------------|
|                                 |                  |                                 |
|                                 |                  |                                 |
|                                 |                  |                                 |
|                                 |                  |                                 |

**RESIN SYSTEM COMPONENTS  
MANUFACTURING BATCH NUMBERS**

| Resin        |      | Curing agent |      | Accelerator  |      |
|--------------|------|--------------|------|--------------|------|
| Batch number | Type | Batch number | Type | Batch number | Type |
|              |      |              |      |              |      |
|              |      |              |      |              |      |
|              |      |              |      |              |      |
|              |      |              |      |              |      |

Signed \_\_\_\_\_  
Inspector

**REPORT OF HYDROSTATIC TEST FOR FRP TYPE 3HW CYLINDERS**

Place \_\_\_\_\_  
 Date \_\_\_\_\_  
 Exemption number \_\_\_\_\_  
 Manufactured by \_\_\_\_\_  
 Located at \_\_\_\_\_  
 Manufactured for \_\_\_\_\_  
 Located at \_\_\_\_\_  
 Serial numbers \_\_\_\_\_ to \_\_\_\_\_ inclusive.  
 Symbol \_\_\_\_\_  
 Minimum prescribed test pressure \_\_\_\_\_ psig.

| <u>Weight - pounds</u><br>(without valve) |                              | <u>Hydrostatic test</u>       |   |  |  |   |   |
|---|------------------------------|-------------------------------|---|--|--|---|---|
| <u>Serial number</u>                      | <u>Compo-<br/>Liner site</u> | <u>Volume<br/>Total cu.in</u> | <u>Auto-<br/>frettage<br/>pressure<br/>psig</u> | <u>Total<br/>expan-<br/>sion<br/>cu.in</u> | <u>Perma-<br/>nent<br/>expan-<br/>sion<br/>cu.in</u> | <u>Actual<br/>Ratio<br/>of PE<br/>to TE<br/>percent</u> | <u>test<br/>pres-<br/>sure<br/>psig</u> |
|   |                              |                               |   |  |  |   |   |
|   |                              |                               |   |  |  |   |   |
|   |                              |                               |   |  |  |   |   |

**LOT CYCLING AND BURST TESTS**

| <u>Serial</u> | <u>Number of pressurizations</u> | <u>Burst</u> |
|---------------|----------------------------------|--------------|
|               |                                  |              |

| Type of test | Number of cylinder | to service pressure | to test pressure | pressure (psi g) |
|--------------|--------------------|---------------------|------------------|------------------|
| Cycling      |                    |                     |                  |                  |
| Virgin       |                    |                     |                  |                  |
| Burst        |                    |                     |                  |                  |

**§ 178.BB-17 Retention of inspector's report.**

The inspector's report (§ 178.BB-16) must be retained for 15 years from the original test date on the cylinder by the maker and the inspector.

**§ 178.BB-18 Design qualification tests.**

(a) **General.** Except as authorized in § 178.BB-10(a), qualification tests as prescribed in this paragraph shall have been performed on representative cylinders of each specific design prior to any initial shipment. All cylinders used for design qualification tests must be fabricated on the same equipment and subjected to the same processes as is used to produce cylinders intended for charging and shipment. All tests must be witnessed by an independent inspector. Test reports must be kept on file by the cylinder maker and made available to the independent inspector and the OHMT upon request.

(b) **Design changes.** For purposes of this standard, a design change is:

- (1) any change in material;
- (2) a 10 percent or greater change in diameter or service pressure; or
- (3) a 30 percent or greater change in water capacity.

(c) **Test requirements.** Each cylinder design or any design change to an approved cylinder design must be qualified by subjecting representative cylinders to the tests prescribed in the following table:

| Type of test          | ORIGINAL DESIGN | DESIGN CHANGE |                              |                                |                         |                                |
|-----------------------|-----------------|---------------|------------------------------|--------------------------------|-------------------------|--------------------------------|
|                       |                 | Material      | Diameter or Service pressure |                                | Water capacity          |                                |
|                       |                 | Any change    | 10 to 20 percent change      | Greater than 20 percent change | 30 to 50 percent change | Greater than 50 percent change |
| Cycling-Ambient       | X               | X             | X                            | X                              | X                       | X                              |
| Cycling-Environmental | X               | X             | -                            | X                              | -                       | X                              |
| Cycling-Thermal       | X               | X             | -                            | X                              | -                       | X                              |
| Hydraulic burst       | X               | X             | X                            | X                              | X                       | X                              |
| Gunfire               | X               | X             | X                            | X                              | X                       | X                              |
| Bonfire               | X               | X             | X                            | X                              | X                       | X                              |

(d) **Pressure cycling tests.** All cycling tests shall be performed by hydrostatically pressurizing the cylinder between approximately zero and designated pressure at a rate not in excess of 4 cycles per minute. All cylinders used in cycle tests must be destroyed. Adequate recording instrumentation must be provided if equipment is to be left unattended for periods of time.

- (1) **Cycling test at ambient temperature.** One representative cylinder shall be cycle tested at ambient temperature without showing

evidence of distortion, deterioration or failure, as follows: pressurize from approximately zero to service pressure for 10,000 cycles; then pressurize from approximately zero to test pressure for 30 cycles. After successfully passing this test the cylinder must be pressurized to burst in accordance with paragraph (e)(1) of this section and the burst pressure recorded.

(2) **Environmental cycling test.** One representative cylinder free of any protective coating shall be cycle tested without showing evidence of distortion, deterioration or failure as follows. Any cylinder subjected to this cycling test must be destroyed.

(i) Condition the cylinder for 48 hours at zero pressure, 140 °F. or higher and 95 percent or greater relative humidity.

(ii) Pressurize from zero to service pressure for 5,000 cycles at 140 ° F. or higher and 95 percent or greater relative humidity.

(iii) Stabilize at zero pressure and ambient conditions.

(iv) Then pressurize from zero to service pressure for 5,000 cycles at -60 ° F. or lower.

(v) Stabilize at zero pressure and ambient temperature conditions.

(vi) Then pressurize from zero to test pressure for 30 cycles at ambient temperature.

(3) **Thermal cycling test.** One representative cylinder shall be tested without showing evidence of distortion, deterioration or failure as follows:

(i) Cycle test at ambient temperature by performing 10,000 pressurizations from approximately zero to service pressure and 30 pressurizations from zero to test pressure.

(ii) Then hydrostatically pressurize to service pressure; and submerge the pressurized cylinder in 200 ° F fluid, soak for 10 minutes; transfer and submerge in -60 ° F fluid and soak for 10 minutes. Subject cylinder to 20 such cycles restricting the

transfer time to at least one minute but not more than 3 minutes. The pressure in the cylinder may be controlled so that it does not exceed test pressure nor less than marked service pressure.

(4) After successfully passing this test, the cylinder must be pressurized to burst in accordance with paragraph (e)(1) of this section and burst pressure recorded.

(e) **Hydraulic burst test.**

(1) One representative cylinder shall be hydrostatically pressurized to failure as follows: pressure shall be increased at a uniform rate up to minimum prescribed burst pressure; this pressure to be held for at least 60 seconds; then pressure will be further increased to failure. The pressurization rate throughout the test must not exceed 200 psi per second.

(2) Burst pressure must be at least 2.5 times the marked service pressure, and in no case less than the value necessary to meet the stress criteria of § 178.BB-7(b). Failure must initiate in the sidewall. Cylinders with marked service pressure not exceeding 2200 psi must remain in one piece. Actual burst pressure must be recorded.

(e) **Gunfire Test.** One representative cylinder charged with air or nitrogen to service pressure shall be impacted by a 0.30 caliber armor-piercing projectile having a velocity of approximately 2800 feet per second. The cylinder shall be positioned so that the projectile impact point is in the cylinder sidewall having hoop winding, at approximately 45 degree angle and aimed to exit at the cylinder sidewall. Distance from firing location to test cylinder must not exceed 50 yards. Tested cylinder shall reveal no evidence of fragmentation failure. Approximate size of entrance and exit openings must be recorded.

(f) **Bonfire test.** Test cylinders must be fitted with pressure relief devices in accordance with §178.BB-10 and charged with the intended lading to the prescribed filling pressure or density. Charging with nitrogen or air to service pressure is authorized only if cylinders are to be charged only with non-liquefied gases. Fire for test shall be generated by kerosine-soaked wood, gasoline or JP-4 fuel. The lowest part of the cylinder shall be approximately 4 inches above the base of the fire when wood fire is used or shall be approximately 4 inches above the liquid surface if gasoline or JP-4 fuel is used. Test cylinder shall be exposed to fire until completely vented.

Time-pressure readings must be recorded at 30 second intervals from start of fire until venting is completed. Test results are not acceptable if contents vent from any location other than through a pressure relief device. After successfully passing the fire test, each cylinder must be pressurized to burst and burst pressure recorded. Tests must be performed as follows:

(1) **Vertical test.** Place test cylinder in its upright position and subject to total fire engulfment but in no case shall the flame be allowed to impinge directly on any relief device. Shielding of pressure relief devices with a metal plate may be used but is not a requirement. For cylinders equipped with relief devices on both ends, the bottom relief devices must be shielded from any flame impingement.

(2) **Horizontal tests.** Place test cylinder in its upright position and subject the entire length to flame impingement except that the flame must not be allowed to impinge directly on any relief device. Shielding of the pressure relief devices with a metal plate may be used but is not a requirement.

(3) **Cylinders for liquefied gas service.** At least one representative cylinder must be subjected to the horizontal test and two to the vertical test.

(4) **Cylinders for non-liquefied gas service only.** At least 2 cylinders must be subjected to the vertical test. Horizontal test is not required.

(h) **Qualification test results.** A report of all tests for each design qualification, describing test setup, procedure and results must be submitted to the OHMT. This report must include at least the following basic information on each cylinder design tested.

**BASIC CYLINDER DESIGN INFORMATION**

Dimension, material and pressure data.

(Date) ..... \_\_\_\_\_  
 (Exemption number) ..... \_\_\_\_\_  
 Service pressure ..... \_\_\_\_\_ PSIG  
 Auto-frettage pressure (Note 1) ..... \_\_\_\_\_ PSIG



Test pressure ..... \_\_\_\_\_ PSIG  
 Minimum prescribed burst pressure ..... \_\_\_\_\_ PSIG  
 Calculated burst pressure ..... \_\_\_\_\_ PSIG  
 Volume ..... \_\_\_\_\_ cu. in.  
 Inside diameter ..... \_\_\_\_\_ inches  
 Outside diameter of cylinder ..... \_\_\_\_\_ inches  
 Liner material and temper ... \_\_\_\_\_  
 Filament material ..... \_\_\_\_\_  
 Resin material ..... \_\_\_\_\_  
 Total weight of cylinder ..... \_\_\_\_\_ pounds  
 Weight of liner ..... \_\_\_\_\_ pounds  
 Weight of composite material ..... \_\_\_\_\_ pounds  
 Minimum wall thickness of liner (Qual. test cyl) \_\_\_\_\_ inch  
 Minimum design wall thickness of liner ..... \_\_\_\_\_ inch  
 Yield strength of liner (Qual. test cyl) ..... \_\_\_\_\_ psi  
 Minimum design yield strength of liner ..... \_\_\_\_\_ psi  
 Nominal thickness of overwrap ..... \_\_\_\_\_ inch  
 Minimum strand strength of filament ..... \_\_\_\_\_ psi  
 Minimum shear strength of resin ..... \_\_\_\_\_ psi

Note 1. For each qualification test cylinder, the total and permanent volumetric expansion readings obtained in the auto-frettage pressurizations must be recorded.

### DESIGN STRESSES AND LOAD DISTRIBUTION

|          | S T R E S S |                    |       |                  | L O A D |          |
|----------|-------------|--------------------|-------|------------------|---------|----------|
|          | Direction   | Distribution (psi) |       | Distribution (%) |         |          |
| Pressure | Long.       | Circ.              | Liner | Overwrap         | Liner   | Overwrap |
|          | X           | -                  |       | -                |         | -        |
| Zero     | -           | X                  |       |                  |         |          |
|          | X           | -                  |       | -                |         | -        |
| Service  | -           | X                  |       |                  |         |          |
|          | X           | -                  |       | -                |         | -        |
| Test     | -           | X                  |       |                  |         |          |
| *Minimum | X           | -                  |       | -                |         | -        |
| Burst    | -           | X                  |       |                  |         |          |

\*Based on §178. BB-7



**DOT FRP - 1 STANDARD**

DATE: Original; July 1, 1981

Revision 1; March 15, 1982

Revision 2; February 15, 1987

**BASIC REQUIREMENTS FOR FIBER REINFORCED PLASTIC (FRP)  
TYPE 3FC COMPOSITE CYLINDERS**

§ 178.AA **Fiber reinforced plastic (FRP) full (wrapped) composite (FC) cylinders made of definitely prescribed materials.**

§ 178.AA-1 **General.**

Each cylinder must conform with these basic requirements and the specific requirements of the applicable exemption.

§ 178.AA-2 **Type, size and service pressure.**

Type 3FC cylinder consisting of resin impregnated continuous filament windings in both longitudinal and circumferential directions only over a seamless aluminum liner; not over 200 pounds water capacity; and service pressure at least 900 PSI but not greater than 5000 PSI.

§ 178.AA-3 **Inspection by whom and where.**

Inspections and verifications must be performed by an independent inspection agency approved in writing by the Director for the Office of Hazardous Materials Transportation (OHMT), in accordance with 49 CFR 173.300a. Chemical analyses and tests must be made in the United States unless otherwise approved in writing by the Director for OHMT in accordance with 49 CFR 173.300b.

§ 178.AA-4 **Duties of the inspector.**

(a) Determine that all materials conform with the provisions of this standard before releasing them for cylinder manufacture.

(b) Verify chemical analysis of each heat of liner material by analysis or by obtaining producers certified analysis. A certification from the manufacturer indicating conformance with this requirement is acceptable when verified by check analysis on one sample taken from one cylinder liner

out of each inspection lot of 200 cylinders or less. Verify conformance of filament and resin system components with the requirements specified in § 178.AA-5.

(c) Prior to the initial shipment of any specific composite cylinder design, verify that the design qualification tests prescribed in § 178.AA-18 have been performed with acceptable results.

(d) Verify conformance of completed cylinder with all requirements including marking, condition of inside, heat treatment, and threads. Report minimum thickness of liner wall noted.

(e) Verify winding process to assure that composite material is uniform, of required thickness and pattern, and in accordance with the composite structure present in cylinders subjected to the design qualification tests.

(f) Witness all tests and pressurization, obtain copies of all test results and certifications; report volumetric capacity, permanent expansion and completed composite cylinder weight.

(g) Furnish completed inspector's report (§ 178.AA-16) to the maker of the cylinder and upon request, to the purchaser. (See § 178.AA-17).

§ 178.AA-5 **Authorized material and identification of material.**

(a) Aluminum liner must be 6351 or 6061 alloy and T6 temper.

(b) Filament material must be commercial Type-S or commercial Type-E fiberglass. Filaments must be tested in accordance with ASTM D-2343-79 and have minimum strand strength as follows:

(1) Type-S Glass ---- 400,000 PSI.

(2) Type-E Glass ---- 200,000 PSI.

(c) Resin system must be epoxy or modified epoxy type. Resin system must be tested on sample coupons representative of the composite over-wrap in accordance with ASTM D-2344-67 for water boil shear test, and have a minimum shear strength of 5,000 PSI.

(d) Materials must be identified by a suitable method during

manufacture.

(e) Materials must be of uniform quality. Materials with injurious defects are not authorized.

§ 178.AA-6 **Manufacture.**

(a) **Liner.** Aluminum liner must have dirt and scale removed as necessary to afford proper inspection; no defect that is likely to weaken the finished liner appreciably is authorized; reasonably smooth and uniform surface finish is required. No interior folding in the neck area is permitted; smooth gathering of the material in the neck in which there are no sharp rooted folds is acceptable. If not originally free from such defect, the liner surface may be machined or otherwise treated to eliminate these defects provided the required minimum wall thickness is maintained. Liner end contour must be concave to pressure.

(b) **Composite cylinder.** The composite cylinder must be fabricated from an aluminum liner fully overwrapped with resin impregnated continuous filament windings. Winding pattern must be "helical" or "in plane and hoop" wrap, applied under controlled tension to develop the design composite thickness. After winding is complete, the composite must be cured by a controlled temperature profile, and auto-fretted by pressurizing to not less than 105 and not greater than 115 percent of the prescribed minimum test pressure. No defect that is likely to weaken the finished cylinder appreciably is acceptable.

(c) **Welding or brazing.** Welding or brazing for any purpose whatsoever is prohibited.

(d) **Lot size.**

(1) **Liner lot size.** A "liner lot" means a group of liners successively produced having the same: size and configuration; specified material of construction; process of manufacture and heat treatment; equipment of manufacture and heat treatment; and conditions of time, temperature and atmosphere during heat treatment.

(2) **Composite cylinder lot size.** A "composite cylinder lot" means a group of cylinders successively produced from qualified liners, having the same size and configuration, the same specified materials of construction, the same process of manufacture to the same cylinder specification and auto-frettagged under the same conditions of temperature, time and pressure.

(3) In no case may the lot size exceed 200 units; however, any unit processed for use in the required destructive tests need not be counted as one of the 200, but must have been processed with the lot.

(e) **Design qualification tests.** Prior to initial shipment of any specific cylinder design, qualification tests as prescribed in § 178.AA-18 must have been performed with satisfactory results.

§ 178.AA-7 **Wall thickness.**

(a) Minimum thickness of the liner must be such that after auto-frettagage, the compressive stress in the sidewall of the liner at zero pressure will not exceed 95 percent of the minimum yield strength of the aluminum as determined in § 178.AA-12(a) or 95 percent of the minimum design yield strength shown in § 178.AA-18(h). The maximum tensile stress of the liner at operating pressure must not exceed 60 percent of the yield strength.

(b) The maximum filament stress at service pressure must not exceed 30 percent of the filament stress at the virgin burst pressure of the lot test cylinder.

(c) The end designs must incorporate added materials to assure the stresses in these areas are less than the stresses found in the cylindrical portion.

(d) Stresses shall be computed from Computer Code NASA CF-72124 "Computer Program for the Analysis of Filament-Wound Reinforced Metal Shell Pressure Vessels" May 1966, or other suitable analysis techniques.

§ 178.AA-8 **Openings.**

(a) Openings are permitted on the heads only. Center line of openings must coincide with the longitudinal axis of the cylinder.

(b) Threads are required. Threads must be clean cut, even, without

checks and to gauge.

(c) Tapered threads are not permitted.

(d) Straight threads conforming with National Gas Straight (NGS) thread standard are authorized. These threads must conform to the requirements of Federal Standard (FED-STD)-H28 (1978). Other straight threads having at least 6 engaged threads are authorized provided that the calculated shear strength is at least 10 times the test pressure of the cylinder.

**§ 178.AA-9 Thermal treatment.**

(a) The aluminum liner must be solution heat treated and aged to the T-6 temper after all forming operations and prior to pressurizing and overwrapping.

(b) The resin must be cured at the temperature specified and by the process set forth in the cylinder manufacturer's specification and noted in the Inspector's report. Curing temperature and process must correspond with that applied to the cylinders subjected to the qualification tests. The curing temperature must not exceed 350 ° F.

**§ 178.AA-10 Pressure relief devices and protection for valves, relief devices, and other connections.**

Pressure relief devices and protection for valves and other connections must conform with 49 CFR 173.34(d) and 173.301(g), except that the adequacy of the pressure relief devices for each design may be verified in accordance with § 178.AA-18(g).

**§ 178.AA-11 Nondestructive tests.**

(a) **Hydrostatic test.**

(1) By water-jacket, operated so as to obtain accurate data. Pressure gauge must permit reading to accuracy of 1 percent in the range of 80 percent to 120 percent of test pressure. Expansion gauge must permit reading of total expansion to an accuracy of either 1 percent or 0.1 cubic centimeter.

(2) The accuracy of the test equipment must be maintained by

periodic recalibration. Records must be maintained to verify that the test equipment is calibrated on a regular basis. A calibration cylinder capable of verifying the equipment accuracy for the material, size and test pressure of the cylinders to be tested must be used for checking the equipment at the beginning of each day.

(3) Pressure must be maintained for 30 seconds and sufficiently longer to insure complete expansion. Any internal pressure applied after auto-fretting and previous to the official test must not exceed 90 percent of the test pressure. If, due to failure of test apparatus, the test pressure can not be maintained, the test may be repeated at a pressure increased by 10 percent or 100 PSI, whichever is lower. Not more than 2 such repeated tests are permitted.

(4) Each cylinder must be tested to at least  $5/3$  times service pressure. In no case may the test pressure exceed the auto-fretting pressure.

#### § 178.AA-12 **Destructive tests.**

(a) **Physical tests.** To determine yield strength, tensile strength and elongation of the aluminum liner material. Applies to aluminum liner only.

(1) Required on 2 specimens cut from one liner taken at random out of each lot of 200 liners or less.

(2) Specimens must be: gauge length of 2 inches with width not over 1-1/2 inches; or gauge length of 4 times the specimen diameter (4D bar), provided that a specimen with gauge length at least 24 times thickness with width not over 6 times thickness is authorized when liner wall is not over 3/16 inch thick. The specimen, exclusive of grip ends, must not be flattened. Grip ends may be flattened to within one inch of each end of the reduced section. When size of liner does not permit securing straight specimens, the specimens may be taken in any location or direction and may be straightened or flattened cold and by pressure only, not by blows. When such specimens are used, the inspector's report must show that the specimens were so taken and prepared. Heating of specimens for any purpose is not authorized.

(3) The yield strength in tension shall be the stress corresponding to a permanent strain of 0.2 percent of the gauge length.

(i) The yield strength shall be determined by either the



"offset" method or the "extension under load" method as prescribed by ASTM Standard E8-78.

(ii) In using the "extension under load" method, the total strain or "extension under load" corresponding to the stress at which the 0.2 percent permanent strain occurs may be determined with sufficient accuracy by calculating the elastic extension of the gauge length under appropriate load and adding thereto 0.2 percent of the gauge length. Elastic extension calculations shall be based on an elastic modulus of 10,000,000. In the event of controversy, the entire stress-strain diagram shall be plotted and the yield strength determined from the 0.2 percent offset.

(iii) For the purpose of strain measurement, the initial strain shall be set while the specimen is under a stress of 6,000 pounds per square inch, the strain indicator reading being set at the calculated corresponding strain.

(iv) Cross-head speed of the testing machine shall not exceed 1/8 inch per minute during yield strength determination.

(b) **Cycling test.** One cylinder taken at random out of each lot of 200 cylinders must be subjected to cyclic pressurization test by hydrostatically pressurizing the cylinder between approximately zero PSIG and the designated pressure at a rate not to exceed 4 cycles per minute. Adequate recording instrumentation must be provided if the equipment is to be left unattended for periods of time. All cylinders used in the cycle test must be destroyed.

(c) **Burst test.** One cylinder taken at random out of each lot of cylinders shall be hydrostatically tested to destruction by pressurizing at a uniform rate up to minimum prescribed burst pressure, holding the pressure constant at minimum burst pressure for 60 seconds; and increasing the pressure to failure. The rate of pressurization must not exceed 200 PSI per second. The cylinder cycle tested in paragraph (b)(1) above may be used for this burst test.

§ 178.AA-13 **Acceptable results of tests.**

(a) **Hydrostatic test.**

(1) The permanent volumetric expansion of the cylinder must not exceed 5 percent of the total volumetric expansion at test pressure.

(2) All cylinders failing to pass the hydrostatic test must be rejected.

(b) **Physical test.** Applies to aluminum liner only.

(1) Elongation must be at least 14 percent; except that an elongation of 10 percent is acceptable when the authorized specimen size is 24t x 6t.

(2) When the test results fail to meet requirements, the lot must be rejected.

(3) A retest of a rejected lot is authorized if an improper test was made due to the presence of a defect in the specimen or if the equipment or procedure was faulty. The retest must be performed on specimens taken from the same cylinder liner.

(c) **Cycling test.**

(1) Each test cylinder must withstand at least 10,000 pressurization between approximately zero and service pressure followed by at least 30 pressurizations between zero and test pressure, without evidence of distortion or failure.

(2) When the test cylinder fails to withstand the cycle test, the lot represented must be rejected.

(d) **Burst test.**

(1) Burst pressure shall be at least 3 times the service pressure and in no case less than the value necessary to meet the stress criteria of § 178.AA-7(b). Failure must initiate in the cylinder sidewall. Cylinders with marked service pressure not exceeding 2,200 PSI must remain in one piece. Actual burst pressure must be recorded.

(2) When the test cylinder fails to withstand pressure up to the minimum prescribed burst pressure, the lot represented must be rejected.

§ 178. AA-14 **Rejected liners and cylinders.**

(a) **Physical test.** Reheat treatment of aluminum liners that failed the physical test is authorized. Subsequent thereto, acceptable liners must pass all prescribed tests.

(b) **Hydrostatic test.** Cylinders rejected by the hydrostatic test must not be placed in service.

(c) **Cycle test.** Cylinders of lots rejected by the cycle test must not be placed in service.

(d) **Burst test.** Cylinders of lots rejected by the burst test must not be placed in service.

§ 178. AA-15 **Marking.**

(a) Each cylinder must be permanently marked (other than stamping in the filament wrap) in the epoxy coating on the side near the end of the cylinder containing the valve outlet.

(b) Required markings are as follows:

(1) DOT-E \*\*\*\*-YYYY (where \*\*\*\*=Exemption number, and YYYY = service pressure in PSIG).

(2) A serial number and an identifying symbol (letters); location of serial number to be just below or immediately following the DOT mark; location of symbol to be just below or immediately following the number. The symbol and number must be those of the maker. The symbol must be registered with the Director for OHMT; duplications not authorized.

(3) The Inspector's official mark must be placed near the serial number.

(4) Date of test (month and year) so placed that dates of subsequent tests can be easily added.

(5) Examples of cylinder marking:

DOT-E \*\*\*\*-2000  
1234-XY  
AB  
3-81

or;

DOT-E \*\*\*\*-2000-1234-XY-AB-3-81

(c) Size of marks must be at least 1/4 inch high if space permits.

(d) Additional markings are permitted (in the epoxy coating).

§ 178.AA-16 **Inspector's report.**

(a) The inspector must prepare a report that is clear, legible and in accordance with the following form:

**REPORT OF MANUFACTURE OF FIBER REINFORCED PLASTIC (FRP) TYPE 3FC  
FULL COMPOSITE (FC) ALUMINUM LINED COMPRESSED GAS CYLINDER.**

(Place) \_\_\_\_\_

(Date) \_\_\_\_\_

(Exemption number) \_\_\_\_\_

Manufactured for \_\_\_\_\_ Company.  
 Located at \_\_\_\_\_  
 Manufactured by \_\_\_\_\_ Company.  
 Located at \_\_\_\_\_  
 Consigned to \_\_\_\_\_ Company.  
 Located at \_\_\_\_\_  
 Quantity \_\_\_\_\_ Size \_\_\_\_\_ inches outside diameter by \_\_\_\_\_ inches long

Marks placed on the \_\_\_\_\_ of the cylinder are:

DOT-E \_\_\_\_\_  
 Serial numbers \_\_\_\_\_ to \_\_\_\_\_ inclusive.  
 Identifying symbol (Registered) \_\_\_\_\_  
 Inspector's mark (Registered) \_\_\_\_\_  
 Test date(s) \_\_\_\_\_  
 Other marks (if any) \_\_\_\_\_

Each composite cylinder was made by completely overwrapping a seamless aluminum liner with resin impregnated filament reinforcement. Composite overwrap was made by winding resin impregnated \_\_\_\_\_ continuous filament over this liner in both longitudinal and circumferential directions, followed by curing the resin at controlled temperature.

The aluminum was identified by heat numbers and verified as to chemical analysis, record thereof is attached hereto. Liners fabricated from the aluminum were solution heat treated and artificially aged to T-6 temper. Physical tests were made in the presence of the inspector and report of test results is attached hereto.

Each liner was inspected before and after closing in the ends. All that were inspected were found to be free from seams, cracks, lamination and other defects which might prove injurious to the strength of the cylinder.

Liner walls were measured and the minimum thickness noted was at least equal to the minimum design thickness. The outside diameter was found by a close approximation to be \_\_\_\_\_ inches.

Filament and resin were certified by the manufacturers, and identified by package number. Filament was verified as to strand strength. Composite was verified as to shear strength. After wrapping, composite was cured per manufacturers' specification.

Prescribed auto-frettage and hydrostatic tests were made in the presence of the inspector. All cylinders accepted conform with the specification requirements. Results of auto-frettage and hydrostatic tests are attached hereto.

Tensile stress on the aluminum liner is calculated to be \_\_\_ PSI at service pressure. Filament stress is calculated to be \_\_\_ PSI in the hoop direction and \_\_\_ PSI in the longitudinal direction at service pressure.

I hereby certify that all of these cylinders proved satisfactory in every way and conform with the requirements of DOT-E \_\_\_ ; except as follows:

Exceptions taken to any reporting or testing requirements of this exemption are: \_\_\_\_\_  
\_\_\_\_\_

(Signed) \_\_\_\_\_  
(Inspector)

**RECORD OF CHEMICAL ANALYSES OF MATERIAL FOR LINER**

(Place) \_\_\_\_\_

(Date) \_\_\_\_\_

(Exemption number) \_\_\_\_\_

Serial numbers \_\_\_\_\_ to \_\_\_\_\_ inclusive.

Size \_\_\_\_\_ inches outside diameter by \_\_\_\_\_ inches long.

Made by \_\_\_\_\_ Company.

For \_\_\_\_\_ Company.

Material description \_\_\_\_\_  
\_\_\_\_\_

NOTE: Any omission of analyses by heats, if authorized, must be accounted for by notation herein reading "The prescribed certificate of the manufacturer of material has been secured, found satisfactory, and placed on file." or by attaching a copy of the certificate.

Alloy      Cylinders

| Designation Represented<br>(Serial Numbers) | Chemical Analyses |    |    |    |    |    |    |    |        |       |    |
|---|-------------------|----|----|----|----|----|----|----|--------|-------|----|
|   | Si                | Fe | Cu | Mn | Mg | Cr | Zn | Ti | Others |       | Al |
|   |                   |    |    |    |    |    |    |    | Ea.    | Total |    |
|   |                   |    |    |    |    |    |    |    |        |       |    |
|   |                   |    |    |    |    |    |    |    |        |       |    |

Material was manufactured and mill analyses made by \_\_\_\_\_.  
 Originals of the certified mill analyses reports are in files of the material manufacturer.

(Signed) \_\_\_\_\_  
 (Inspector)

**RECORD OF PHYSICAL TESTS OF MATERIAL FOR LINERS.**

(Place) \_\_\_\_\_  
 (Date) \_\_\_\_\_  
 (Exemption Number) \_\_\_\_\_  
 Serial numbers \_\_\_\_\_ to \_\_\_\_\_ inclusive.  
 Size \_\_\_\_\_ inches outside diameter by \_\_\_\_\_ inches long.  
 Made by \_\_\_\_\_ Company  
 For \_\_\_\_\_ Company  
 Test specimen description \_\_\_\_\_.

| Lot Code | Cylinders Represented by Test. (Serial Nos) | Yield Strength at 0.2 percent Offset (pounds per square inch) | Tensile Strength (pounds per square inch) | Elongation (percent) |
|----------|---|---|---|----------------------|
|          |   |   |   |                      |

(Signed) \_\_\_\_\_  
 (Inspector)

**REPORT OF COMPOSITE ANALYSES**

(Place) \_\_\_\_\_  
 (Date) \_\_\_\_\_  
 (Exemption number) \_\_\_\_\_  
 Materials \_\_\_\_\_  
 Manufactured by \_\_\_\_\_ Company  
 For \_\_\_\_\_ Company  
 Numbered \_\_\_\_\_  
 Filament specification and designation \_\_\_\_\_

Manufactured by \_\_\_\_\_ Company

| Manufacturing package number | Tensile strength | Inter-laminar shear strength |
|------------------------------|------------------|------------------------------|
|                              |                  |                              |
|                              |                  |                              |
|                              |                  |                              |
|                              |                  |                              |

**RESIN SYSTEM COMPONENTS  
MANUFACTURING BATCH NUMBERS**

| Resin        |      | Curing agent |      | Accelerator  |      |
|--------------|------|--------------|------|--------------|------|
| Batch number | Type | Batch number | Type | Batch number | Type |
|              |      |              |      |              |      |
|              |      |              |      |              |      |
|              |      |              |      |              |      |
|              |      |              |      |              |      |

Signed \_\_\_\_\_  
Inspector

**REPORT OF HYDROSTATIC TEST FOR FRP TYPE 3FC CYLINDERS**

(Place) \_\_\_\_\_

(Date) \_\_\_\_\_

(Exemption number) \_\_\_\_\_

Manufactured by: \_\_\_\_\_

Located at: \_\_\_\_\_

Manufactured for: \_\_\_\_\_

Located at: \_\_\_\_\_

Serial numbers: \_\_\_\_\_ to \_\_\_\_\_ inclusive.

Symbol \_\_\_\_\_

Minimum prescribed test pressure \_\_\_\_\_ psi g.

|  |                  |
|--|------------------|
| <u>Weight - pounds</u><br><u>(without valve)</u> | Hydrostatic test |
|--|------------------|

Perma-



| Serial number | Compo-<br>Liner site | Volume<br>Total cu.in | Auto-<br>frettage<br>pressure<br>psig | Total<br>expan-<br>sion<br>cu.in | ment<br>expan-<br>sion<br>cu.in | Ratio<br>of PE<br>to TE<br>percent | Actual<br>test<br>sure<br>psig |
|---------------|----------------------|-----------------------|---------------------------------------|----------------------------------|---------------------------------|------------------------------------|--------------------------------|
|               |                      |                       |                                       |                                  |                                 |                                    |                                |
|               |                      |                       |                                       |                                  |                                 |                                    |                                |
|               |                      |                       |                                       |                                  |                                 |                                    |                                |
|               |                      |                       |                                       |                                  |                                 |                                    |                                |

**LOT CYCLING AND BURST TESTS**

| Type of<br>test | Serial<br>Number of<br>cylinder | Number of<br>pressurizations<br>to service<br>pressure |  | Burst<br>to test<br>pressure<br>(psig) |
|-----------------|---------------------------------|--|--|--|
| Cycling         |                                 |  |  |  |
| Virgin Burst    |                                 |  |  |  |

**§ 178.AA-17 Retention of inspector's report.**

The inspector's report (§ 178.AA-16) must be retained for 15 years from the original test date on the cylinder by the maker and the inspector.

**§ 178.AA-18 Design qualification tests.**

(a) **General** - Except as authorized in § 178.AA-10(a), the

qualification tests as prescribed in this paragraph shall have been performed on representative cylinders of each specific design prior to any initial shipment. All cylinders used for design qualification tests must be fabricated on the same equipment and subjected to the same processes as is used to produce cylinders intended for charging and shipment. All tests must be witnessed by an independent inspector. Test reports must be kept on file by the cylinder maker and made available to the independent inspector and the OHMT upon request.

(b) **Design changes.** For purposes of this standard, a design change is: (1) any change in material; (2) a 10 percent or greater change in diameter or service pressure; or (3) a 30 percent or greater change in water capacity.

(c) **Test requirements.** Each cylinder design or any design change to an approved cylinder design must be qualified by subjecting representative cylinders to the tests prescribed in the following table:

| Type of test          | ORIGINAL DESIGN | DESIGN CHANGE |                              |                                |                         |                                |
|-----------------------|-----------------|---------------|------------------------------|--------------------------------|-------------------------|--------------------------------|
|                       |                 | Material      | Diameter or Service pressure |                                | Water capacity          |                                |
|                       |                 | Any change    | 10 to 20 percent change      | Greater than 20 percent change | 30 to 50 percent change | Greater than 50 percent change |
| Cycling-Ambient       | X               | X             | X                            | X                              | X                       | X                              |
| Cycling-Environmental | X               | X             | -                            | X                              | -                       | X                              |
| Cycling-Thermal       | X               | X             | -                            | X                              | -                       | X                              |
| Hydraulic burst       | X               | X             | X                            | X                              | X                       | X                              |
| Gunfire               | X               | X             | X                            | X                              | X                       | X                              |
| Bonfire               | X               | X             | X                            | X                              | X                       | X                              |

(d) **Pressure cycling tests.** All cycling tests shall be performed by hydrostatically pressurizing the cylinder between approximately zero and designated pressure at a rate not in excess of 4 cycles per minute. All cylinders used in cycle tests must be destroyed. Adequate recording

instrumentation must be provided if equipment is to be left unattended for periods of time.

(1) **Cycling test at ambient temperature.** One representative cylinder shall be cycle tested at ambient temperature without showing evidence of distortion, deterioration or failure, as follows: pressurize from approximately zero to service pressure for 10,000 cycles; then pressurize from approximately zero to test pressure for at least 30 cycles. After successfully passing this test the cylinder must be pressurized to burst in accordance with paragraph (e)(1) of this section and the burst pressure recorded.

(2) **Environmental cycling test.** One representative cylinder free of any protective coating shall be cycle tested without showing evidence of distortion, deterioration or failure as follows. Any cylinder subjected to this cycling test must be destroyed.

(i) Condition the cylinder for 48 hours at zero pressure, 140 °F. or higher and 95 percent or greater relative humidity.

(ii) Pressurize from zero to service pressure for 5,000 cycles at 140 °F. or higher and 95 percent or greater relative humidity.

(iii) Stabilize at zero pressure and ambient conditions.

(iv) Then pressurize from zero to service pressure for 5,000 cycles at -60 °F. or lower.

(v) Stabilize at zero pressure and ambient temperature conditions.

(vi) Then pressurize from zero to test pressure for 30 cycles at ambient temperature.

(3) **Thermal cycling test.** One representative cylinder shall be tested without showing evidence of distortion, deterioration or failure as follows. After successfully passing this test, the cylinder must be pressurized to burst in accordance with paragraph (e)(1) of this section and burst pressure recorded.

(i) Cycle test at ambient temperature by performing 10,000

pressurizations from approximately zero to service pressure and at least 30 pressurizations from zero to test pressure.

(ii) Then hydrostatically pressurize to service pressure; and submerge the pressurized cylinder in 200 °F. fluid, soak for 10 minutes; transfer and submerge in -60 °F. fluid and soak for 10 minutes. Subject cylinder to 20 such cycles restricting the transfer time to at least one minute but not more than 3 minutes. The pressure in the cylinder may be controlled so that it does not exceed test pressure nor less than marked service pressure.

(e) **Hydraulic burst test.**

(1) One representative cylinder shall be hydrostatically pressurized to failure as follows: pressure shall be increased at a uniform rate up to minimum prescribed burst pressure; this pressure to be held for at least 60 seconds; then pressure will be further increased to failure. The pressurization rate throughout the test must not exceed 200 psi per second.

(2) Burst pressure must be at least 3 times the marked service pressure, and in no case less than the value necessary to meet the stress criteria of § 178.AA-7(b). Failure must initiate in the sidewall. Cylinders with marked service pressure not exceeding 2200 psi must remain in one piece. Actual burst pressure must be recorded.

(f) **Gunfire Test.** One representative cylinder charged with air or nitrogen to service pressure shall be impacted by a 0.30 caliber armor-piercing projectile having a velocity of approximately 2800 feet per second. Cylinder shall be positioned so that the projectile impact point is in the cylinder sidewall having hoop winding, at approximately 45 degree angle and aimed to exit at the cylinder sidewall. Distance from firing location to test cylinder must not exceed 50 yards. Tested cylinder shall reveal no evidence of a fragmentation failure. Approximate size of entrance and exit openings must be recorded.

(g) **Bonfire test.** Test cylinders must be fitted with pressure relief devices in accordance with § 178.AA-10 and charged with the intended lading to the prescribed filling pressure or density. Charging with nitrogen or air to service pressure is authorized only if cylinders are to be charged only with non-liquefied gases. Fire for the test shall be generated by kerosine-soaked wood, gasoline or JP-4 fuel. The lowest part of the cylinder

shall be approximately 4 inches above the base of the fire when wood fire is used or shall be approximately 4 inches above the liquid surface if gasoline or JP-4 fuel is used. Test cylinder shall be exposed to fire until completely vented. Time-pressure readings must be recorded at 30 second intervals from start of fire until venting is completed. Test results are not acceptable if contents vent from any location other than through a pressure relief device. After successfully passing the fire test, each cylinder must be pressurized to burst and burst pressure recorded. Tests must be performed as follows:

(1) **Vertical test.** Place test cylinder in its upright position and subject to total fire engulfment but in no case shall the flame be allowed to impinge directly on any relief device. Shielding of pressure relief devices with a metal plate may be used but is not a requirement. For cylinders equipped with relief devices on both ends, the bottom relief devices must be shielded from any flame impingement.

(2) **Horizontal tests.** Place test cylinder in its upright position and subject the entire length to flame impingement except that the flame must not be allowed to impinge directly on any relief device. Shielding of the pressure relief devices with a metal plate may be used but is not a requirement.

(3) **Cylinders for liquefied gas service.** At least one representative cylinder must be subjected to the horizontal test and two to the vertical test.

(4) **Cylinders for non-liquefied gas service only.** At least 2 cylinders must be subjected to the vertical test. Horizontal test is not required.

(h) **Qualification test results.** A report of all tests for each design qualification, describing test setup, procedure and results must be submitted to the OHMT. This report must include at least the following basic information on each cylinder design tested.

**BASIC CYLINDER DESIGN INFORMATION**

**Dimension, material and pressure data.**

(Date) ..... \_\_\_\_\_  
 (Exemption number) ..... \_\_\_\_\_

Cylinder:

Service pressure ..... \_\_\_\_\_ PSIG  
 Volume ..... \_\_\_\_\_ cu. in.  
 Outside diameter of cylinder ..... \_\_\_\_\_ inches  
 Total weight of cylinder ..... \_\_\_\_\_ pounds  
 Auto-frettage pressure (Note 1) ..... \_\_\_\_\_ PSIG  
 Test pressure ..... \_\_\_\_\_ PSIG  
 Minimum prescribed burst pressure ..... \_\_\_\_\_ PSIG  
 Calculated burst pressure ..... \_\_\_\_\_ PSIG  
 Nominal thickness of overwrap ..... \_\_\_\_\_ inch  
 Minimum strand strength of filament ..... \_\_\_\_\_ psi  
 Minimum shear strength of resin ..... \_\_\_\_\_ psi  
 Weight of composite material ..... \_\_\_\_\_ pounds

Liner:

Weight of liner ..... \_\_\_\_\_ pounds  
 Inside diameter ..... \_\_\_\_\_ inches  
 Liner material and temper ... \_\_\_\_\_  
 Filament material ..... \_\_\_\_\_  
 Resin material ..... \_\_\_\_\_  
 Minimum wall thickness of liner (Qual. test cyl). \_\_\_\_\_ inch  
 Minimum design wall thickness of liner ..... \_\_\_\_\_ inch  
 Yield strength of liner (Qual. test cyl) ..... \_\_\_\_\_ psi  
 Minimum design yield strength of liner ..... \_\_\_\_\_ psi

Note 1. For each qualification test cylinder, the total and permanent volumetric expansion readings obtained in the auto-frettage pressurizations must be recorded.

**DESIGN STRESSES AND LOAD DISTRIBUTION**

|          | STRESS    |       |                    |          | LOAD             |          |
|----------|-----------|-------|--------------------|----------|------------------|----------|
|          | Direction |       | Distribution (psi) |          | Distribution (%) |          |
| Pressure | Long.     | Circ. | Liner              | Overwrap | Liner            | Overwrap |
| Zero     | X         | -     |                    | -        |                  | -        |
| Service  | -         | X     |                    |          |                  |          |

|          |   |   |   |   |
|----------|---|---|---|---|
|          | X | - | - | - |
| Test     | - | X |   |   |
| *Minimum | X | - | - | - |
| Burst    | - | X |   |   |

\*Based on §178.AA-7