U.S. Department of Transportation
Research and Special Programs Administration

MAY 27 1994

400 Seventh Street S.W.
Washington D.C. 20590

DOT-E 10847

EXPIRATION DATE: January 15, 1996

(FOR RENEWAL, SEE 49 CFR 107.105.)

1. GRANTEE: Brunswick Composites, Brunswick Corporation, Lincoln, Nebraska.

2. PURPOSE AND LIMITATIONS: This exemption authorizes the manufacture, mark and sale of a non-DOT specification, fiber reinforced plastic (FRP), hoop wrapped composite (HW) aluminum cylinder to be used for the transportation in commerce of Division 2.1 and Division 2.2 gases. This exemption provides no relief from any regulation other than as specifically stated herein.

3. REGULATORY SYSTEM AFFECTED: 49 CFR Parts 106, 107 and 171-180.

4. REGULATIONS FROM WHICH EXEMPTED: 49 CFR Sections 173.302(a)(1), 173.304(a) and (d), 175.3.

5. BASIS: This exemption is based on Brunswick Corporation's application dated June 30, 1992, supplemental information dated August 21, 1992 submitted in accordance with 49 CFR 107.103 and the public proceeding thereon.

6. HAZARDOUS MATERIALS (49 CFR 172.101):

Hazardous materials description/ proper shipping name	Hazard Class or Division	Identification Number	Packing Group
Air Compressed	Division 2.2	UN 1002	N/A
Argon, compressed	Division 2.2	UN 1006	N/A
Carbon Dioxide, compressed	Division 2.2	UN 1013	N/A
Helium, compressed	Division 2.2	UN 1046	N/A
Neon, compressed	Division 2.2	UN 1065	N/A
Nitrogen, compressed	Division 2.2	UN 1066	N/A
Natural Gas, compressed (Methane)	Division 2.1	UN 1971	N/A

7. PACKAGING(S) and SAFETY CONTROL MEASURES:

a. PACKAGING - Packaging prescribed is a non-DOT specification fiber reinforced plastic (FRP) hoop wrapped composite (HW) aluminum cylinder made in conformance with the following:

(a) Brunswick's drawings # 2400003 & 164284, dated 12-11-91, 174267 dated May 5, 1992, and the information provided in the report of Design Qualification Tests of Fiber Reinforced Plastic (FRP) Hoop Wrapped (HW) composite cylinder dated June 30, 1992 on file with the Office of Hazardous Materials Exemptions and Approvals (OHMEA), and

(b) DOT FRP-2 Standard, dated January 15, 1982,(178.BB) contained in Appendix A of this exemption, except as follows:

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

Type 3HW cylinder consisting of resin impregnated continuous filament windings in a near circuferential direction having a winding angle not less than 87 degrees over a seamless aluminum liner made in compliance with 178.BB-6; not over 250 pounds water capacity; and a service pressure of at least 900 psi but not greater than 3600 psi. Cylinders having an overall length exceeding 84 inches are not authorized.

178.BB-4 Duties of the Inspector.

(a) Verify conformance to the requirements in this exemption and to DOT FRP-2 Standard dated January 15, 1982.

(b) Verify conformance of aluminum liner with 178.BB-6. Verify conformance of the filament and resin system components with the requirements specified in 178.BB-5 of this exemption.
(c) thru (g) * * *.

178.BB-5 Authorized Materials and Identification of materials.

(a) Aluminum liner must be 6061 alloy of T6 temper made from seamless drawn tubing and must conform with DOT 3AL specification (§178.46) except that:

(1) Test specimens required by §178.46-12 and 178.46-13 may be obtained from test rings of same diameter and thickness of the finished cylinder. The length of the test ring shall not be less than 16 inches. The test ring must have the ends covered by welded end plates with appropriate openings to simulate the heat treatment of the production cylinders. The test ring must be heat treated along with the production cylinders.

(b) Filament material must be E-Glass conforming to MIL Specification MIL-R-60346 or an equivalent National Standard. The filaments must be tested in accordance with ASTM-D2343 for strand strength and must have a minimum average roving strength of 270,000 psi.

For roving denier determination, the filament material must be tested in accordance with ASTM D3317-74 and must be of at least 90% of the specified nominal value for the rovings. A manufacturer's certified test results for the rovings used in production may be used in lieu of testing.

(c) thru (e) * * *

b. TESTING - Design qualification tests must be submitted prior to production for approval by the Associate Administrator for Hazardous Materials safety (AAHMS) for cylinders of size different from that authorized in this exemption.

8. SPECIAL PROVISIONS:

a. Offerors for transportation of the hazardous materials specified in this exemption may use the packaging described in this exemption for the transportation of such hazardous materials so long as no modifications or changes are made to the packages, all terms of this exemption are complied with, and a copy of the current exemption is maintained at each facility from which offering occurs.

b. Shippers using the packaging covered by this exemption must comply with all provisions of this exemption, and all other applicable requirements contained in 49 CFR Parts 171-180.

c. Cylinders may not be used for underwater breathing purposes.

d. Cylinders used in oxygen service must conform with 49 CFR 173.302(a)(5)(i) through (a)(5)(iv).

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

f. Each cylinder must be reinspected and hydrostatically retested every three years in accordance with 49 CFR 173.34(e)(13), as prescribed for DOT 3HT specification cylinders, except that the rejection elastic expansion does not apply and the permanent volumetric expansion may not exceed 5 percent of the total volumetric expansion at test pressure. Retest dates must be stamped on the exposed metallic surface of the cylinder neck or marked on a label securely affixed to the cylinder and overcoated with epoxy near the original test date. Reheat treatment or repair of rejected cylinders is not authorized. When a hydrostatic retest is repeated as provided for in 49 CFR 173.34(e)(3), only two such retests are permitted.

g. No person may perform inspection and testing of cylinders subject to this exemption unless that person (1) holds a current copy of this exemption at the location of such inspection and testing, and (2) complies with all the terms and conditions of this exemption. The marking of the retester's symbol on the cylinders certifies compliance with all of the terms and conditions of this exemption.

h. A cylinder that has been subjected to fire may not be returned to service.

i. Transportation of methane by cargo aircraft only is limited to 150 kilograms (330 pounds).

j. Cylinders must be packaged in accordance with 49 CFR 173.301(k).

k. A copy of this exemption, in its current status, must be maintained at each manufacturing facility at which this packaging is manufactured and must be made available to a DOT representative upon request.

l. Each packaging manufactured under the authority of this exemption 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 for a specific manufacturing facility.

m. The cylinders described in this exemption are authorized only for normal transportation as an article of commerce i.e., the movement of hazardous materials packages from consignor to consignee. No cylinder may be transported in a partially filled condition other than full or empty per 49 CFR 173.29, unless it is equipped with a pressure relief device designed, mnufactured and tested for partially filled cylinders.

n. Filling requirements are subject to all terms contained in 49 CFR 173.302 for 3AL specification cylinders.

9. MODES OF TRANSPORTATION AUTHORIZED. Motor vehicle, rail freight, and cargo-aircraft only. (See paragraph 8(i) of this exemption.)

10. MODAL REQUIREMENTS: A copy of this exemption must be carried aboard each aircraft used to transport packages covered by this exemption. In accordance with the provisions of 49 CFR Part 107, Appendix B to Subpart B, paragraph 3, the shipper shall furnish a copy of this exemption 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 exemption and penalties prescribed by the Hazardous Materials Transportation Act:

- All terms and conditions prescribed in this exemption and the Hazardous Materials Regulations, Parts 171-180.
- Registration required by 49 CFR 107.601 et seq., when applicable.

No person may use or apply this exemption, including display of its number, when the exemption has expired or is otherwise no longer in effect unless a regulation has been amended making the exemption no longer necessary.

12. REPORTING REQUIREMENTS. The carrier is required to report any incident involving loss of packaging contents or packaging failure to the AAHMS as soon as practicable. (49 CFR 171.15 and 171.16 apply to any activity undertaken under the authority of this exemption.) In addition, the holder of this exemption must inform the AAHMS, in writing, of any incidents involving the package and shipments made under the terms of this exemption.

Issued at Washington, D.C.:

MAY 27 1994

Alan I. Roberts
Associate Administrator
for Hazardous Materials Safety

(DATE)

MAY 27 1994

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

The original of this exemption is on file at the above office. Photo reproductions and legible reductions of this exemption are permitted. Any alteration of this exemption is prohibited.

Dist: FHWA, FRA, FAA.

U.S. Department of Transportation
Research and Special Programs Administration

APPENDIX A

DATE: January 15, 1982

BASIC REQUIREMENTS

FOR

FRP TYPE 3HW COMPOSITE CYLINDERS

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

178.BB-1 Compliance. Cylinders must be in compliance with these basic requirements and the specific requirements of the applicable exemption.

178.BB-2 Type size and service pressure. Type 3HW cylinder consisting of resin impregnated continuous filament windings in the circumferential direction only over a seamless aluminum liner made in compliance with §178.BB-6(a); not over 200 pounds water capacity; and service pressure at least 900 PSI but not greater than 5,000 PSI.

178.BB-3 Inspection by whom and where.

Inspection and verifications must be performed by an independent inspection agency approved in writing by the Associate Director for OHMR, in accordance with §173.300a of this subchapter. Chemical analyses and tests as specified must be made within the United States unless otherwise approved in writing by the Associate Director for OHMR in accordance with §173.300b of this subchapter.

178.BB-4 Duties of Inspector

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

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

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

DOT FRP-2 STANDARD MAY 27 1994

DATE: January 15, 1982

(d) Verify compliance of completed cylinders with all requirements including marking.

(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 pressurizations, obtain copies of all test results and certification; report volumetric capacity, permanent expansion and completed composite cylinder weight.

(g) Furnish complete 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 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-2343-67 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 shall be tested on a sample coupon representative of the composite overwrap in accordance with ASTM D-2344-76 for water boil shear test, and have a minimum shear strength of 5,000 PSI.

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

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

178.BB-6 Manufacture

(a) Liner. Aluminum liner without overwrap must be suitable for a marked service pressure of at least 50 percent of the service pressure marked on the composite cylinder, and must be in full compliance with DOT 3AL specification (49 CFR 178.46) except:

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

(2) Hydrostatic test prior to applying the filament wrap is not authorized.

(b) Composite Cylinder. The composite cylinder must be fabricated from an aluminum liner circumferentially wrapped over the entire cylindrical portion with resin impregnated continuous filament windings. Winding pattern to 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 autofrettaged by pressurizing to not less than 105 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 only. A "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 only. A "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 autofrettaged 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 shall 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 (178.BB-18(h)) and be such that after autofrettage, 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 §178.46-13 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% of the yield strength.

(b) The maximum filament stress at service pressure must not exceed 40% 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 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 in heads only. Centerline of openings must coincide with the longitudinal axis of the cylinder.

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

(c) Tapered threads are not permitted.

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

178.BB-9 Thermal Treatment.

(a) The resin must be cured at the temperature specified and by the process set forth in the cylinder manufacturer's specifications and noted in the Inspector's report. Curing temperature and process must correspond with that applied to the cylinders subjected to 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.

(a) Pressure relief devices and protection for valves and other connections must be in compliance with 49 CFR 173.34(d), and 173.301(g), except that the adequacy of the pressure relieving 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 accuracy 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.

(i) 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 autofrettage and previous to the official test must not exceed 90 percent of the test pressure. If, due to failure of the test apparatus, the test pressure cannot be maintained, the test may be repeated at a pressure increased by 10 percent or 100 pounds per square inch, whichever is the 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 autofrettage pressure.

178.BB-12 Destructive tests

(a) Cycling test.

(1) 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 equipment is to be left unattended for periods of time. All cylinders used in the cycle test must be destroyed.

(c) Burst test.

(1) 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.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 liner 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. Failure must initiate in the cylinder sidewall. Cylinders with a marked service pressure not exceeding 2200 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.BB-14 Rejected liners and cylinders.

(a) Physical test.

(1) Reheat treatment of aluminum liner is authorized subsequent thereto, acceptable liners must pass all prescribed tests.

(b) Hydrostatic test.

(1) Rejected cylinders must not be placed in service.

(c) Cycle test.

(1) Cylinders of rejected lots must not be placed in service.

(d) Burst test.

(1) Cylinders of rejected lots must not be placed in service.

178.BB-15 Marking.

(a) Each cylinder must be permanently marked (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 Y = service pressure in psig.)

(2) A serial number and an identifying symbol (letters); location of 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 numbers must be those of the maker. The symbol must be registered with the Associate Director for OHMR; duplications unauthorized.

(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
1234 - XY
AB
3-81

or; DOT-E **** 2000-1234-XY-AB-3-81

(c) Size of marks to be at least 1/4" 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.

178.BB-16 Inspector's Report

(a) Required to be clear, legible and in accordance with the following form:

REPORT OF MANUFACTURE OF FIBER
REINFORCED PLASTIC (FRP) 3HW HOOP WRAPPED COMPOSITE (HW)
ALUMINUM-LINED COMPRESSED GAS CYLINDERS

(Place) _____
(Date) _____
(Exemption number) _____
Manufactured For _____
Location at _____
Manufactured by _____
Location at _____
Consigned to _____
Location at _____
Quantity _____ Size _____ inches outside diameter by _____ inches long.

Marks placed on _____ of the cylinder are:

DOT-E _____
Serial Numbers _____ to _____ inclusive _____
Identifying Symbol (Registered) _____
Inspector's Mark _____
Test Date _____
Other Marks (if any) _____

Each composite cylinder was made by circumferentially overwrapping a seamless aluminum liner with resin impregnated 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 liners are in compliance with §178.BB-6(a) of this exemption for unwrapped cylinders having a service pressure of _____ psig. Compliance of the liners 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 manufacturers, identified by package number. Filament was verified as to strand strength. Composite was verified as to shear strength. After wrapping composite was cured in the manufacturer's specification.

DOT FRP-2 STANDARD

DATE: January 15, 1982

Autofrettage and hydrostatic test, as precribed, were made in the presence of the inspector. All cylinders accepted are in compliance with 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 comply with the requirements of DOT-E _ _ _ _; except as follows:

Exceptions taken to any reporting or testing requirement of this section are:

_____

_____

_____

(Signed) _____
Inspector

DATE: January 15, 1982

RECORD OF CHEMICAL ANALYSIS OF MATERIAL FOR CYLINDER LINER

(Place) _____
(Date) _____
(Exemption number) _____
Numbered _____ 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 hereon 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.

Mill Heat Code	Heat No.	Check Analysis No.	Cylinders Represented (Serial Numbers)	Chemical Analysis						
				Cu	Si	Fe	Mn	Zn	Ti	Other

Material was manufactured and mill analysis made by _____.
Originals of the certified mill analysis reports are in files of the manufacturer.

(Signed) _____
Inspector

RECORD OF PHYSICAL TESTS OF MATERIAL FOR CYLINDER LINERS

(Place) _____
(Date) _____
Exemption number) _____
Numbered _____ to _____ inclusive.
Size _____ inches outside diameter by _____ inches long.
Made by _____ Company.
For _____ Company.
Test Specimen Description _____

Lot Code	Cylinders Represented by test (Serial Numbers)	Yield strength at 0.2 Percent Offset (pounds per square inch)	Tensile Strength (pounds per square inch)	Elongation (percent)

(Signed) _____
Inspector

DATE: January 15, 1982

MAY 27 1994

REPORT OF COMPOSITE ANALYSIS

(Place) _____
(Date) _____
(Exemption number) _____
Materials _____
Manufactured by _____
For _____
Numbered _____
Filament designation and specification _____
Manufactured by _____

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

HYDROSTATIC TEST DATA FOR FRP TYPE 3HW COMPRESSED GAS CYLINDERS

(Place) _____

(Date) _____

(Exemption number) _____

Manufactured by: _____

For: _____

Numbered: _____

Symbol: _____

Minimum Prescribed Test Pressure _____ (psig)

Serial Number	WEIGHT-lbs (without valve)			Volume (cu.in)	Auto-Frettage Pressure (psig)	HYDROSTATIC TEST			
	Liner	Composite	Total			Total Expansion (cu.in.)	Permament Expansion (cu.cm.)	Ratio of Permanent to total (percent)	Actual Test Pressure (psig)

LOT CYCLING AND BURST TESTS				
Type of Test	Serial Number of Cylinder	Number of Pressurizations		Burst Pressure (psig)
		To Service Pressure	To Test Pressure	
Cycling				
Virgin Burst				

Signed: _____

Inspector

178.BB.17 Retention of inspector's reports

(a) The inspector's report (178.BB-16) must be retained for 15 years from the original test date on the cylinders 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 the 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 OHMR upon request.

(b) Design Changes - For purposes of this section a design change is any change in material; a 10 percent or greater change in diameter or service pressure; or a 30 percent or greater change in water capacity.

(c) Test Requirements - Cylinders representative of each design and design change must be subjected to tests as 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 Temp.	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 psig and the 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 0 to service pressure for 10,000 cycles; then pressurize from 0 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:

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

(ii) Pressurize from zero to service pressure for 5000 cycles at 140°F or higher and 95% or greater relative humidity.

(iii) Stabilize at zero pressure and ambient conditions.

(iv) Then pressurize from zero to service pressure for 5000 cycles at -60°F or lower.

(v) Stabilize at zero pressure and ambient conditions.

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

Any cylinder subjected to this cycling test must be destroyed.

(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 0 to service pressure and 30 pressurizations from 0 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 the cylinder to 20 such cycles restricting the transfer time to at least one minute but not more than three minutes. The pressure in the cylinder may be controlled so that it does not exceed test pressure nor be less than marked service pressure.

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, held constant at minimum burst pressure for 60 seconds; and 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 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.

(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 so positioned that the projectile impact point is in the cylinder sidewall having hoop winding, at approximately 45° angle and aimed to exit at the cylinder side wall. Distance from firing location to test cylinder not to exceed 50 yards. Tested cylinder shall reveal no evidence of a fragmentation failure. Approximate size of entrance and exit openings must be recorded.

DATE: January 15, 1982

BASIC CYLINDER DESIGN INFORMATION

Dimensional, material and pressure data

(Date) _____

(Exemption number) _____

Service pressure..... _____ psig
Autofrettage pressure (NOTE 1)..... _____ psig
Test pressure..... _____ psig
Minimum prescribed burst pressure..... _____ psig
Calculated burst pressure..... _____ psig

Volume..... _____ cu.in.
Inside diameter..... _____ inch
Outside diameter of cylinder..... _____ inch
Liner material and temper - _____
Filament material - _____
Resin material - _____

Total weight of cylinder..... _____ pounds
Weight of liner..... _____ pounds
Weight of composite materia..... _____ pounds

Minimum sidewall thickness of liner (Qual. Test cyl) _____ psig
Minimum design wall thickness of liner..... _____ psig
Yield strength of liner (Qual. test cylinder) _____ 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 autofrettage pressurizations, must be recorded.

DESIGN STRESSES AND LOAD DISTRIBUTION

	Stress				Load	
	Direction		Distribution (PSI)		Distribution (%)	
Pressure	Long.	Circ.	Liner	Overwrap	Liner	Overwrap
Zero	x	-				
	-	x				
Service	x	-				
	-	x				
Test	x	-				
	-	x				
*Minimum Burst	x	-				
	-	x				

*Based on 178.BB-7