DOT FRP - 1 STANDARD

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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-frettaged 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-frettaged 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-frettage, 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 thee 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-frettage 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-frettage 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 nor 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's 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 (Serial Numbers)	Chemical Analyses										
	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Others Ea.	Others 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 _____ 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 _____ psig.

Weight - pounds (without valve)	Hydrostatic test	
		Perma-

Serial number	Liner	Composite	Total Volume cu.in	Autofrettage pressure psig	Total expansion cu.in	Permanent expansion cu.in	Ratio of PE to TE percent	Actual test pressure psig

LOT CYCLING AND BURST TESTS

Type of test	Serial Number of cylinder	Number of pressurizations to service pressure	Number of pressurizations to test pressure	Burst pressure (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:

	ORIGINAL DESIGN	DESIGN CHANGE				
		Material	Diameter or Service pressure		Water capacity	
Type of test		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 form 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 from 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 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 liquified 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
	X	-		-		-
Zero	-	X				
	X	-		-		-
Service	-	X				

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

*Based on §178.AA-7