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based on an elastic modulus of 30,000,000. However, when the degree of accuracy of this method is questionable the entire stress-strain diagram must be plotted and the yield strength determined from the 0.2 percent offset.

(iii) For the purpose of strain measurement, the initial strain must be set with the specimen under a stress of 12,000 p.s.i. and the strain indicator reading set at the calculated corresponding strain.

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

(4) Each impact specimen must be Charpy V-notch type size 10 mm × 10 mm taken in accordance with paragraph 11 of ASTM A 333 (IBR, see § 171.7 of this subchapter). When a reduced size specimen is used, it must be the largest size obtainable.

(k) *Acceptable physical test results.* Results of physical tests must conform to the following:

(1) The tensile strength may not exceed 155,000 p.s.i.

(2) The elongation must be at least 16 percent for a two-inch gage length.

(3) The Charpy V-notch impact properties for the three impact specimens which must be tested at 0 °F may not be less than the values shown as follows:

Size of specimen (mm)	Average value for acceptance (3 specimens)	Minimum value (1 specimen only of the 3)
10.0 × 10.0 .....	25.0 ft. lbs. ....	20.0 ft. lbs.
10.0 × 7.5 .....	21.0 ft. lbs. ....	17.0 ft. lbs.
10.0 × 5.0 .....	17.0 ft. lbs. ....	14.0 ft. lbs.

(4) After the final heat treatment, each vessel must be hardness tested on the cylindrical section. The tensile strength equivalent of the hardness number obtained may not be more than 165,000 p.s.i. (Rc 36). When the result of a hardness test exceeds the maximum permitted, two or more retests may be made; however, the hardness number

obtained in each retest may not exceed the maximum permitted.

(1) *Rejected cylinders.* Reheat treatment is authorized for rejected cylinders. However, each reheat treated cylinder must subsequently pass all the prescribed tests. Repair by welding is not authorized.

(m) *Markings.* Marking must be done by stamping into the metal of the cylinder. All markings must be legible and located on a shoulder.

(n) *Inspector's report.* In addition to the requirements of § 178.35, the inspector's report for the physical test report, must indicate the average value for three specimens and the minimum value for one specimen for each lot number.

[Amdt. 178–114, 61 FR 25942, May 23, 1996, as amended at 66 FR 45385, 43588, Aug. 28, 2001; 67 FR 51652, Aug. 8, 2002; 68 FR 48571, Aug. 14, 2003; 68 FR 75748, 75749, Dec. 31, 2003]

**§ 178.46 Specification 3AL seamless aluminum cylinders.**

(a) *Size and service pressure.* A DOT 3AL cylinder is a seamless aluminum cylinder with a maximum water capacity of 1000 pounds and minimum service pressure of 150 psig.

(b) *Authorized material and identification of material.* The material of construction must meet the following conditions:

(1) Starting stock must be cast stock or traceable to cast stock.

(2) Material with seams, cracks, laminations, or other defects likely to weaken the finished cylinder may not be used.

(3) Material must be identified by a suitable method that will identify the alloy, the aluminum producer's cast number, the solution heat treat batch number and the lot number.

(4) The material must be of uniform quality. Only the following heat treatable aluminum alloys in table 1 and 2 are permitted as follows:

TABLE 1—HEAT OR CAST ANALYSIS FOR ALUMINUM; SIMILAR TO “ALUMINUM ASSOCIATION”<sup>1</sup> ALLOY 6061

[CHEMICAL ANALYSIS IN WEIGHT PERCENT<sup>2</sup>]

Si min/ max	Fe max	Cu min/max	Mn max	Mg min/ max	Cr min/max	Zn max	Ti max	Pb max	Bi max	Other		A1
										each max	total max	
0.4/0.8	0.7	0.15/0.4	0.15	0.8/1.2	0.04/0.35	0.25	0.15	0.005	0.005	0.05	0.15	Bal.

<sup>1</sup>The “Aluminum Association” refers to “Aluminum Standards and Data 1993”, published by the Aluminum Association Inc.  
<sup>2</sup>Except for “Pb” and “Bi”, the chemical composition corresponds with that of Table 1 of ASTM B 221 (IBR, see § 171.7 of this subchapter) for Aluminum Association alloy 6061.

TABLE 2—MECHANICAL PROPERTY LIMITS

Alloy and temper	Tensile strength—PSI		Elongation—percent minimum for 2” or 4D <sup>1</sup> size specimen
	Ultimate—minimum	Yield—minimum	
6061—T6	38,000	35,000	<sup>2</sup> 14

<sup>1</sup>“D” represents specimen diameters. When the cylinder wall is greater than 3/16 inch thick, a retest without reheat treatment using the 4D size specimen is authorized if the test using the 2 inch size specimen fails to meet elongation requirements.  
<sup>2</sup>When cylinder wall is not over 3/16-inch thick, 10 percent elongation is authorized when using a 24t x 6t size test specimen.

(5) All starting stock must be 100 percent ultrasonically inspected, along the length at right angles to the central axis from two positions at 90° to one another. The equipment and continuous scanning procedure must be capable of detecting and rejecting internal defects such as cracks which have an ultrasonic response greater than that of a calibration block with a 5/64-inch diameter flat bottomed hole.

(6) Cast stock must have uniform equiaxed grain structure not to exceed 500 microns maximum.

(7) Any starting stock not complying with the provisions of paragraphs (b)(1) through (b)(6) of this section must be rejected.

(c) *Manufacture.* Cylinders must be manufactured in accordance with the following requirements:

(1) Cylinder shells must be manufactured by the backward extrusion method and have a cleanliness level adequate to ensure proper inspection. No fissure or other defect is acceptable that is likely to weaken the finished cylinder below the design strength requirements. A reasonably smooth and uniform surface finish is required. If not originally free from such defects, the surface may be machined or otherwise conditioned to eliminate these defects.

(2) Thickness of the cylinder base may not be less than the prescribed minimum wall thickness of the cylindrical shell. The cylinder base must

have a basic torispherical, hemispherical, or ellipsoidal interior base configuration where the dish radius is no greater than 1.2 times the inside diameter of the shell. The knuckle radius may not be less than 12 percent of the inside diameter of the shell. The interior base contour may deviate from the true torispherical, hemispherical or ellipsoidal configuration provided that—

(i) Any areas of deviation are accompanied by an increase in base thickness;

(ii) All radii of merging surfaces are equal to or greater than the knuckle radius;

(iii) Each design has been qualified by successfully passing the cycling tests in this paragraph (c); and

(iv) Detailed specifications of the base design are available to the inspector.

(3) For free standing cylinders, the base thickness must be at least two times the minimum wall thickness along the line of contact between the cylinder base and the floor when the cylinders are in the vertical position.

(4) Welding or brazing is prohibited.

(5) Each new design and any significant change to any acceptable design must be qualified for production by testing prototype samples as follows:

(i) Three samples must be subjected to 100,000 pressure reversal cycles between zero and service pressure or 10,000 pressure reversal cycles between zero and test pressure, at a rate not in

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excess of 10 cycles per minute without failure.

(ii) Three samples must be pressurized to destruction and failure may not occur at less than 2.5 times the marked cylinder service pressure. Each cylinder must remain in one piece. Failure must initiate in the cylinder sidewall in a longitudinal direction. Rate of pressurization may not exceed 200 psig per second.

(6) In this specification "significant change" means a 10 percent or greater change in cylinder wall thickness, service pressure, or diameter; a 30 percent or greater change in water capacity or base thickness; any change in material; over 100 percent increase in size of openings; or any change in the number of openings.

(d) *Wall thickness.* The minimum wall thickness must be such that the wall stress at the minimum specified test pressure will not exceed 80 percent of the minimum yield strength nor exceed 67 percent of the minimum ultimate tensile strength as verified by physical tests in paragraph (i) of this section. The minimum wall thickness for any cylinder with an outside diameter greater than 5 inches must be 0.125 inch. Calculations must be made by the following formula:

$$S = [P(1.3D^2 + 0.4d^2)] / (D^2 - d^2)$$

Where:

- S = Wall stress in psi;
- P = Prescribed minimum test pressure in psig (see paragraph (g) of this section);
- D = Outside diameter in inches; and
- d = Inside diameter in inches.

(e) *Openings.* Openings must comply with the following requirements:

- (1) Openings are permitted in heads only.
- (2) The size of any centered opening in a head may not exceed one-half the outside diameter of the cylinder.
- (3) Other openings are permitted in the head of a cylinder if:
  - (i) Each opening does not exceed 2.625 inches in diameter, or one-half the outside diameter of the cylinder; whichever is less;
  - (ii) Each opening is separated from each other by a ligament; and
  - (iii) Each ligament which separates two openings must be at least three

times the average of the diameters of the two openings.

- (4) All openings must be circular.
- (5) All openings must be threaded. Threads must comply with the following:
  - (i) Each thread must be clean cut, even, without checks, and to gauge.
  - (ii) Taper threads, when used, must conform to one of the following:
    - (A) American Standard Pipe Thread (NPT) type, conforming to the requirements of NBS Handbook H-28 (IBR, see § 171.7 of this subchapter);
    - (B) National Gas Taper Thread (NGT) type, conforming to the requirements of NBS Handbook H-28; or
    - (C) Other taper threads conforming to other standards may be used provided the length is not less than that specified for NPT threads.
  - (iii) Straight threads, when used, must conform to one of the following:
    - (A) National Gas Straight Thread (NGS) type, conforming to the requirements of NBS Handbook H-28;
    - (B) Unified Thread (UN) type, conforming to the requirements of NBS Handbook H-28;
    - (C) Controlled Radius Root Thread (UN) type, conforming to the requirements of NBS Handbook H-28; or
    - (D) Other straight threads conforming to other recognized standards may be used provided that the requirements in paragraph (e)(5)(iv) of this section are met.
  - (iv) All straight threads must have at least 6 engaged threads, a tight fit, and a factor of safety in shear of at least 10 at the test pressure of the cylinder. Shear stress must be calculated by using the appropriate thread shear area in accordance with NBS Handbook H-28.
  - (f) *Heat treatment.* Prior to any test, all cylinders must be subjected to a solution heat treatment and aging treatment appropriate for the aluminum alloy used.
  - (g) *Hydrostatic test.* Each cylinder must be subjected to an internal test pressure using the water jacket equipment and method or other suitable equipment and method and comply with the following requirements:
    - (1) The testing apparatus must be operated in a manner so as to obtain accurate data. The pressure gauge used

must permit reading to an accuracy of one percent. The expansion gauge must permit reading the total expansion to an accuracy of either one percent or 0.1 cubic centimeter.

(2) The test pressure must be maintained for a sufficient period of time to assure complete expansion of the cylinder. In no case may the pressure be held less than 30 seconds. If, due to failure of the test apparatus, the required test pressure cannot be maintained, the test may be repeated at a pressure increased by 10 percent or 100 psig, whichever is lower. If the test apparatus again fails to maintain the test pressure, the cylinder being tested must be rejected. Any internal pressure applied to the cylinder before any official test may not exceed 90 percent of the test pressure.

(3) The minimum test pressure is the greatest of the following:

(i) 450 psig regardless of service pressure;

(ii) Two times the service pressure for cylinders having service pressure less than 500 psig; or

(iii) Five-thirds times the service pressure for cylinders having a service pressure of at least 500 psig.

(4) Permanent volumetric expansion may not exceed 10 percent of total volumetric expansion at test pressure.

(h) *Flattening test.* One cylinder taken at random out of each lot must be subjected to a flattening test as follows:

(1) The test must be between knife edges, wedge shaped, having a 60° included angle, and rounded in accordance with the following table. The longitudinal axis of the cylinder must be at an angle 90° to the knife edges during the test. The flattening test table is as follows:

TABLE 3—FLATTENING TEST TABLE

Cylinder wall thickness in inches	Radius in inches
Under .150 .....	.500
.150 to .249 .....	.875
.250 to .349 .....	1.500
.350 to .449 .....	2.125
.450 to .549 .....	2.750
.550 to .649 .....	3.500
.650 to .749 .....	4.125

(2) An alternate bend test in accordance with ASTM E 290 using a mandrel diameter not more than 6 times the

wall thickness is authorized to qualify lots that fail the flattening test of this section without reheat treatment. If used, this test must be performed on two samples from one cylinder taken at random out of each lot of 200 cylinders or less.

(3) Each test cylinder must withstand flattening to nine times the wall thickness without cracking. When the alternate bend test is used, the test specimens must remain uncracked when bent inward around a mandrel in the direction of curvature of the cylinder wall until the interior edges are at a distance apart not greater than the diameter of the mandrel.

(i) *Mechanical properties test.* Two test specimens cut from one cylinder representing each lot of 200 cylinders or less must be subjected to the mechanical properties test, as follows:

(1) The results of the test must conform to at least the minimum acceptable mechanical property limits for aluminum alloys as specified in paragraph (b) of this section.

(2) Specimens must be 4D bar or gauge length 2 inches with width not over 1½ inch taken in the direction of extrusion approximately 180° from each other; provided that gauge length at least 24 times thickness with width not over 6 times thickness is authorized, when cylinder wall is not over 3/16 inch thick. The specimen, exclusive of grip ends, may not be flattened. Grip ends may be flattened to within one inch of each end of the reduced section. When the size of the cylinder does not permit securing straight specimens, the specimens may be taken in any location or direction and may be straightened or flattened cold 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 forbidden.

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

(i) The yield strength must be determined by either the "offset" method or the "extension under load" method as prescribed in ASTM B 557 (IBR, see §171.7 of this subchapter).

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(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 must be based on an elastic modulus of 10,000,000 psi. In the event of controversy, the entire stress-strain diagram must be plotted and the yield strength determined from the 0.2 percent offset.

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

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

(j) *Rejected cylinder.* Reheat treatment of rejected cylinders is authorized one time. Subsequent thereto, cylinders must pass all prescribed tests to be acceptable.

(k) *Duties of inspector.* In addition to the requirements of §178.35, the inspector shall:

(1) Verify compliance with the provisions of paragraph (b) of this section by:

(i) Performing or witnessing the performance of the chemical analyses on each melt or cast lot or other unit of starting material; or

(ii) Obtaining a certified chemical analysis from the material or cylinder manufacturer for each melt, or cast of material; or

(iii) Obtaining a certified check analysis on one cylinder out of each lot of 200 cylinders or less, if a certificate containing data to indicate compliance with the material specification is obtained.

(2) The inspector must verify ultrasonic inspection of all material by inspection or by obtaining the material producer’s certificate of ultrasonic inspection. Ultrasonic inspection must be performed or verified as having been performed in accordance with paragraph (b)(5) of this section.

(3) The inspector must also determine that each cylinder complies with this specification by:

(i) Selecting the samples for check analyses performed by other than the material producer;

(ii) Verifying that the prescribed minimum thickness was met by measuring or witnessing the measurement of the wall thickness; and

(iii) Verifying that the identification of material is proper.

(4) Prior to initial production of any design or design change, verify that the design qualification tests prescribed in paragraph (c)(6) of this section have been performed with acceptable results.

(1) *Definitions.* (1) In this specification, a “lot” means a group of cylinders successively produced 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) In no case may the lot size exceed 200 cylinders, but any cylinder processed for use in the required destructive physical testing need not be counted as being one of the 200.

(m) *Inspector’s report.* In addition to the information required by §178.35, the record of chemical analyses must also include the alloy designation, and applicable information on iron, titanium, zinc, magnesium and any other applicable element used in the construction of the cylinder.

[Amdt. 178–114, 61 FR 25942, May 23, 1996, as amended at 66 FR 45386, Aug. 28, 2001; 67 FR 51652, Aug. 8, 2002; 68 FR 75749, Dec. 31, 2003; 77 FR 60943, Oct. 5, 2012]

**§ 178.47 Specification 4DS welded stainless steel cylinders for aircraft use.**

(a) *Type, size, and service pressure.* A DOT 4DS cylinder is either a welded stainless steel sphere (two seamless hemispheres) or circumferentially welded cylinder both with a water capacity of not over 100 pounds and a