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Standard Specification for Aluminum and Aluminum-Alloy Extruded Round Tubes for General-Purpose Applications[1]

This standard is issued under the fixed designation B491/B491M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. ~~Scope~~ Scope*

1.1 This specification covers aluminum and aluminum-alloy extruded round tubes either in coils or straight lengths, for general purpose applications such as refrigeration service, gas lines, oil lines, and instrument lines, in the alloys (Note 2) and tempers shown in Table 2 [Table 3], in outside diameters of 0.250 through 0.750 in. [6.00 through ~~20.00 mm].~~ 20.00 mm]. For diameters over 0.500 through 0.750 in. [over 12.50 through ~~20.00 mm],~~ 20.00 mm], the diameter and wall-thickness tolerances and eddy-current test parameters, if required, shall be agreed upon by the producer and the purchaser. Only tubes in aluminum 1200-H111 and 1235-H111 are sized after extrusion to minimize ovalness.

1.2 Alloy and temper designations are in accordance with ANSI ~~H35.1[H35.1M].~~H35.1/H35.1(M). The equivalent Unified Numbering System alloy designations are those of Table 1 preceded by A9 (for example, A91050 for aluminum ~~1050)~~1050), in accordance with Practice E527.

NOTE 1—For extruded tubes see Specification B221, and for drawn tubes for general-purpose applications see Specification B483.
NOTE 2—Throughout this specification the term *alloy* in the general sense includes aluminum as well as aluminum alloy.
NOTE 3—For inch-pound orders specify B491; for metric orders specify B491M. Do not mix units.

1.3 For acceptance criteria for inclusion of new aluminum and aluminum alloys in this specification, see Annex A2.

1.4 The values stated in either inch-pound or SI units are to be regarded separately as standards. The SI units are shown either in brackets or in separate tables. The values stated in each system are not exact equivalents; therefore, each system must be used independently of the other. Combining values from two systems will result in nonconformance with the specification.

2. Referenced Documents

2.1 The following documents of the issue in effect on the date of material purchase form a part of this specification to the extent referenced herein:

2.2 *ASTM Standards:*[2]

B557 Test Methods for Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products
B557M Test Methods for Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products (Metric)
B660 Practices for Packaging/Packing of Aluminum and Magnesium Products
B666/B666M Practice for Identification Marking of Aluminum and Magnesium Products
B881 Terminology Relating to Aluminum- and Magnesium-Alloy Products
B945 Practice for Aluminum Alloy Extrusions Press Cooled from an Elevated Temperature Shaping Process for Production of T1, T2, T5 and T10–Type Tempers
B985 Practice for Sampling Aluminum Ingots, Billets, Castings and Finished or Semi-Finished Wrought Aluminum Products for Compositional Analysis
E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
E34 Test Methods for Chemical Analysis of Aluminum and Aluminum-Base Alloys
~~E55 Practice for Sampling Wrought Nonferrous Metals and Alloys for Determination of Chemical Composition~~
E215 Practice for Standardizing Equipment for Electromagnetic Testing of Seamless Aluminum-Alloy Tube

[1] This specification is under the jurisdiction of ASTM Committee B07 on Light Metals and Alloys and is the direct responsibility of Subcommittee B07.03 on Aluminum Alloy Wrought Products.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard**

TABLE 1 Chemical Composition Limits[A,B,C,H]

Alloy	Silicon	Iron	Copper	Manganese	Magnesium	Chromium	Zinc	Vanadium	Titanium	Other Elements[D] Each	Other Elements[D] Total[E]	Aluminum
1050	0.25	0.40	0.05	0.05	0.05	...	0.05	0.05	0.03	0.03[G]	...	99.50[F]
1100	0.95 Si + Fe		0.05–0.20	0.05	...	...	0.10	...	...	0.05	0.15	99.00[F]
1200	1.00 Si + Fe		0.05	0.05	...	...	0.10	...	0.05	0.05	0.15	99.00[F]
1235	0.65 Si + Fe		0.05	0.05	0.05	...	0.10	0.05	0.06	0.03[G]	...	99.35[F]
3003	0.6	0.7	0.05–0.20	1.0–1.5	...	...	0.10	...	...	0.05	0.15	remainder
3102	0.40	0.7	0.10	0.05–0.40	...	...	0.30	...	0.10	0.05	0.15	remainder
6063	0.20–0.6	0.35	0.10	0.10	0.45–0.9	0.10	0.10	...	0.10	0.05	0.15	remainder

[A] Limits are in percent maximum unless shown as a range or otherwise stated.
[B] Analysis shall be made for the elements for which limits are shown in this table.
[C] For purposes of determining conformance to these limits, an observed value or a calculated value attained from analysis shall be rounded off to the nearest unit in the last right-hand place of figures used in expressing the specified limit, in accordance with the rounding method of Practice E29.
[D] *Others* includes listed elements for which no specific limit is shown as well as unlisted metallic elements. The producer may analyze samples for trace elements not specified in the specification. However, such analysis is not required and may not cover all metallic *Others* elements. Should any analysis by the producer or the purchaser establish that an *Others* element exceeds the limit of *Each* or that the aggregate of several *Others* elements exceeds the limit of *Total*, the material shall be considered nonconforming.
[E] *Other Elements—Total* shall be the sum of unspecified metallic elements 0.010 % or more, rounded to the second decimal before determining the sum.
[F] The aluminum content shall be calculated by subtracting from 100.00 % the sum of all metallic elements present in amounts of 0.010 % or more each, rounded to the second decimal before determining the sum.
[G] Vanadium 0.05%, maximum.
[H] In case there of a discrepancy in the values listed in Table 1 with those listed in the "International Alloy Designations and Chemical Composition Limits for Wrought Aluminum and Wrought Aluminum Alloys" (known as the "Teal Sheets"), the composition limits registered with the Aluminum Association and published in the "Teal Sheets" should be considered the controlling composition. The "Teal Sheets" are available at http://www.aluminum.org/tealsheets.

TABLE 2 Tensile Property Limits[A,B]

Alloy	Temper	Specified Wall Thickness, in.	Tensile Strength, ksi min	Tensile Strength, ksi max	Yield Strength (0.2 % Offset) min, ksi	Elongation in 2 in. min, %
1050[C]	H112	0.032–0.050	8.5	14.5	2.5	25
1100[C]	H112	0.032–0.050	11.0	17.0[D]	3.0	25
1200[C]	H111	0.032–0.050	11.0	17.0	9.5	25
	H112	0.032–0.050	10.0	16.0	3.0	25
1235[C]	H111	0.032–0.050	11.0	...	7.5	30
	H112	0.032–0.050	9.0	15.0	3.0	25
3003[C]	H112	0.032–0.050	14.0	20.0[D]	5.0	25
3102	H112	0.032–0.050	11.0	18.0	4.0	25
6063	T1	0.032–0.050	17.0	...	9.0	12

[A] The basis for establishment of mechanical property limits is shown in Annex A1.
[B] To determine conformance to this specification, each value for tensile strength and for yield strength shall be rounded to the nearest 0.1 ksi and each value for elongation to the nearest 0.5 %, both in accordance with the rounding method of Practice E29.
[C] Tubes in this alloy are also available in the F (as extruded) temper. Tensile properties for F temper are not specified or guaranteed.
[D] Maximum tensile strength for coils. No maximum limit for extruded lengths.

TABLE 3 Tensile Property Limits [SI Units]

Alloy	Temper	Specified Wall Thickness, mm	Tensile Strength, MPa min	Tensile Strength, MPa max	Yield Strength (0.2 % Offset) min, MPa	Elongation in 50 mm min, %
1050[A]	H112	0.80–1.30	60	100	15	25
1100[A]	H112	0.80–1.30	75	115[B]	20	25
1200[A]	H111	0.80–1.30	75	115	65	25
	H112	0.80–1.30	70	110	20	25
1235[A]	H111	0.80–1.30	75	...	50	30
	H112	0.80–1.30	60	105	20	25
3003[A]	H112	0.80–1.30	95	140[B]	35	25
3102	H112	0.80–1.30	95	125	30	25
6063	T1	0.80–1.30	115	...	60	12

[A] Tubes in this alloy are also available in the F (as extruded) temper. Tensile properties for F temper are not specified or guaranteed.
[B] Maximum tensile strength for coils. No maximum limit for extruded lengths.

E527 Practice for Numbering Metals and Alloys in the Unified Numbering System (UNS)
E607 Test Method for Atomic Emission Spectrometric Analysis Aluminum Alloys by the Point to Plane Technique Nitrogen Atmosphere (Withdrawn 2011)[3]

[3] The last approved version of this historical standard is referenced on www.astm.org.

E716 Practices for Sampling and Sample Preparation of Aluminum and Aluminum Alloys for Determination of Chemical Composition by Spectrochemical Analysis
E1251 Test Method for Analysis of Aluminum and Aluminum Alloys by Spark Atomic Emission Spectrometry

2.3 *ANSI Standards:*[4]
~~H35.1~~H35.1/H35.1(M) Alloy and Temper Designation Systems for Aluminum
~~H35.1M Alloy and Temper Designation Systems for Aluminum (Metric)~~
H35.2 Dimensional Tolerances for Aluminum Mill Products
H35.2M Dimensional Tolerances for Aluminum Mill Products (Metric)
2.4 *Federal Standard:*[5]
Fed. Std. No. 123 Marking for Shipment (Civil Agencies)
2.5 *Military Standard:*[5]
MIL-STD-129 Marking for Shipment and Storage
2.6 *CEN Standard:*[6]
EN 14242 Aluminium and Aluminium Alloys—Chemical Analysis—Inductively Coupled Plasma Optical Emission Spectral Analysis

3. Terminology

3.1 *Definitions*—Refer to Terminology B881

3.2 *Definitions of Terms Specific to This Standard:*
3.2.1 *capable of*—The term *capable of* as used in this specification means that the test need not be performed by the producer of the material. However, should testing by the purchaser establish that the material does not meet these requirements, the material shall be subject to rejection.

4. Ordering Information

4.1 Orders for material to this specification shall include the following information:
4.1.1 This specification designation (which includes the number, the year, and the revision letter, if applicable),

NOTE 4—For inch-pound orders specify B491, for metric orders specify B491M. Do not mix units.

4.1.2 Quantity in pieces or pounds [kilograms],
4.1.3 Alloy (Section 7),
4.1.4 Temper (Section 8),
4.1.5 Cross-sectional dimensions (outside diameter and wall thickness, or inside diameter and wall thickness),
4.1.6 Length, random or specific,
4.1.7 Nominal inside diameter of coils, and weight or maximum outside diameter, if applicable (18.3),

4.2 Additionally, orders for material to this specification shall include the following information when required by the purchaser:
4.2.1 Whether testing for leaks is required (Section 10), and frequency of testing required,
4.2.2 For aluminum 1200-H111 and 1235-H111, whether inside cleanliness test is required (11.2), and frequency of testing required,
4.2.3 Whether inspection or witness of inspection and tests by the purchaser's representative is required prior to material shipment (Section 14),
4.2.4 Whether certification is required (Section 16),
4.2.5 Whether marking for identification is required (Section 17), and
4.2.6 Whether Practices B660 applies and, if so, the levels of preservation packaging, and packing required (18.4).

5. Manufacture

5.1 The tubes covered by this specification shall be produced by the hot-extrusion method. The tube ends shall be crimped or otherwise sealed to avoid contamination during shipping. When sized tube in aluminum 1200-H111 or 1235-H111 is required the extruded tube may be lightly cold drawn.

6. Responsibility for Quality Assurance

6.1 *Responsibility for Inspection*— Unless otherwise specified in the contract or purchase order, the producer is responsible for the performance of all inspection and test requirements specified herein. Except as otherwise specified in the contract or order, the producer may use his own or any other suitable facilities for the performance of the inspection and test requirements specified herein, unless disapproved by the purchaser. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification where such inspections are deemed necessary to assure that material conforms to prescribed requirements.

6.2 *Lot Definition*—An inspection lot shall be defined as follows:

[4] Available from Aluminum Association, Inc., 1525 Wilson Blvd., Suite 600, Arlington, VA 22209, http://www.aluminum.org.
[5] Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098.
[6] Available from European Committee for Standardization (CEN), Avenue Marnix 17, B-1000, Brussels, Belgium, http://www.cen.eu.

6.2.1 For heat-treated tempers, an inspection lot shall consist of an identifiable quantity of material of the same mill form, alloy, temper, and nominal dimensions traceable to a heat-treated lot or lots, and subjected to inspection at one time.

6.2.2 For nonheat-treated tempers, an inspection lot shall consist of an identifiable quantity of material of the same mill form, alloy, temper, and nominal dimensions subjected to inspection at one time.

7. Chemical Composition

7.1 *Limits*—The ~~tubes~~extrusions shall conform to the chemical composition limits ~~specified~~ in Table 1. Conformance shall be determined by ~~analyzing samples taken at the time the~~the producer, by taking samples in accordance with Practices E716 when the ingots are poured and analyzing those samples in accordance with Test Methods E34, E607, E1251~~or samples taken from the finished or semifinished product.~~, or EN 14242. At least one sample shall be taken for each group of ingots poured simultaneously from the same source of molten metal. If the producer has determined the chemical composition ~~of the material during the course of manufacture he~~ during pouring of the ingots, they shall not be required to sample and ~~analzye~~analyze the finished product.

NOTE 5—It is standard practice in the United States aluminum industry to determine conformance to the chemical composition limits prior to further processing of ingots into wrought products. Due to the continuous nature of the process, it is not practical to keep a specific ingot analysis identified with a specific quantity of finished material.

~~7.2 *Number of Samples*—The number of samples taken for determination of chemical composition shall be as follows:~~

~~7.2.1 When samples are taken at the time the ingots are poured, at least one sample shall be taken for each group of ingots poured simultaneously from the same source of molten metal.~~

~~7.2.2 When samples are taken from the finished or semifinished product, a sample shall be taken to represent each 4000 lb [2000 kg] or fraction thereof in the lot, except that not more than one sample shall be required per piece.~~

~~7.3 *Methods of Sampling*—Samples for determination of chemical composition shall be taken in accordance with one of the following methods:~~

~~7.3.1 Samples for chemical analysis shall be taken from the material by drilling, sawing, milling, turning, or clipping a representative piece or pieces to obtain a prepared sample of not less than 75 g. Sampling shall be in accordance with Practice E55.~~

~~7.3.2 Sampling for spectrochemical analysis shall be in accordance with Practices E716. Samples for other methods of analysis shall be suitable for the form of material being analyzed and the type of analytical method used.~~

7.2 ~~*Methods of Analysis*—The determination of chemical composition shall be made in accordance with suitable chemical (Test Methods~~If it becomes necessary to analyze the finished or semi-finished product for conformance to chemical ~~E34), or spectrochemical (Test Methods~~ composition limits, the ~~E607 and E1251), methods. Other methods may be used only when no published ASTM method is available. In case of dispute the~~methods of sampling and methods of analysis shall be ~~agreed upon between the producer and purchaser.~~as provided in the following:

7.2.1 *Methods of Sampling*—Samples for chemical analysis shall be taken in accordance with Practice B985.

7.2.2 *Methods of Analysis*—Analysis shall be performed in accordance with Test Methods E34, E607, or E1251, or CEN EN 14242 (ICP Method).

8. Tensile Properties

8.1 *Limits*—Tubes shall conform to the tensile property requirements specified in Table 2 [Table 3].

8.2 *Number of Specimens:*

8.2.1 One tension test specimen shall be taken for each ~~1000 lb~~ 1000 lb [500 kg] or fraction thereof in a lot.

8.2.2 Other procedures for selecting samples may be employed if agreed upon by the producer and the purchaser.

8.3 *Test Specimens*—The tension test specimens shall be as specified in Test Methods B557 [B557M].

8.4 *Test Methods*—The tension tests shall be made in accordance with Test Methods B557 [B557M].

9. Heat Treatment

9.1 Tubes produced in alloy 6063–T1 shall be cooled from an elevated temperature shaping process and naturally aged to a substantially stable ~~condition.~~condition in accordance with Practice B945.

10. Test for Leaks

10.1 When specified by the purchaser at the time of placing the order, tubes shall be tested for leaks by one of the following methods, at the option of the producer:

10.1.1 *Method 1*—Tubes shall be tested pneumatically at not less than 60 psig [400 kPa] air pressure while immersed in water or other suitable liquid. Any evidence of leakage shall be cause for rejection.

10.1.2 *Method 2*—Tubes shall be tested pneumatically at not less than 90 psig [600 kPa] air pressure with a ~~gage~~gauge which will indicate loss of pressure. There shall not be any loss of pressure during a test period of at least 15-s duration.

10.1.3 *Method 3*—Tubes of 0.250 through 0.500-in. [6.00 through 12.50 mm] diameter shall be subjected to an eddy-current test in accordance with the procedures described in Practice E215. Reference standards or secondary standards having equivalent

eddy-current response shall serve to define acceptance-rejection limits. For tubes over 0.500 through ~~0.750 in.~~ 0.750 in. [over 12.50 through 20.00 mm] in diameter eddy-current test parameters, if required, shall be agreed upon between the producer and the purchaser.

10.1.3.1 For coiled tube, secondary standards having an equivalent eddy-current response to No. 70 (0.028-in. [0.70-mm] diameter) and No. 60 (0.040-in. [1.00-mm] diameter) drill holes shall be used to standardize the equipment. Tubes that produce eddy-current indications less than those from the ~~No. 60~~ No. 60 hole of the secondary standard shall be acceptable. Any tube that produces an indication equal to or greater than those from the No. 60 hole of the secondary standard shall be rejected. Setup procedures shall include a check to ensure that tubes containing defects which give responses equal to or greater than that from a No. 60 hole are rejected at the speed of inspection. Tubes in long coils may contain up to a specified number of defects per coil when agreed between the producer and purchaser. In cases where a specified number of defects per coil are allowed, the need for marking such defects in a coil shall be handled as agreed upon by the producer and purchaser.

10.1.3.2 For tube of straight lengths reference standards described in Appendixes X1 and X2 of Practice E215 shall be used to standardize the equipment. Tubes that produce eddy-current indications less than those from the 2A holes of the applicable reference standard or an equivalent secondary standard shall be acceptable. Any tube having a discontinuity that produces an eddy-current indication equal to or greater than those from the 2A holes of the applicable reference standard or an equivalent secondary standard shall be rejected.

11. Special Requirements for Coiled Tube

11.1 *Expansion Test*—The ends of tubes in the H111, H112, and F tempers only shall be capable of being expanded by forcing a steel pin having an included angle of 60° into the tube until the outside diameter has been increased 40 % without signs of cracks, ruptures, or other defects clearly visible by normal vision.

NOTE 6—Other expansion test capabilities may be required in special cases but shall be the subject of negotiation between the producer and the purchaser.

11.2 *Inside Cleanliness Requirements and Test*—Tube in the H112, T1, and F tempers shall be capable of meeting an inside cleanliness requirement of not more than 0.002 g/ft [0.02 g/m] of residue of internal surface when a test sample having a minimum internal area of 375 in.^{2} [0.240 m^2] (except that no more than 50 ft [15 m] of length is required) is washed with inhibited 1,1,1-trichloroethane or trichloroethylene or ~~equivalent.~~ equivalent (Note 7). When specified by the purchaser at the time of placing the order, tube in the H111 temper shall meet the foregoing inside cleanliness requirement.

NOTE 7—Products that are considered equivalent to inhibited 1,1,1-trichloroethane or trichloroethylene, for the purposes of the Inside Cleanliness Test, include, but are not limited to, n-propyl bromide, dichloromethane, acetone, and others, as agreed between the producer and the purchaser.

11.2.1 To perform the test a measured quantity of the solvent should be pulled through the tube into a flask which is, in turn, attached to an aspirator or vacuum pump. The solvent shall then be transferred to a weighed container (crucible, evaporating dish, or beaker). The solvent in the container shall be evaporated to dryness on a low-temperature hot plate or steam bath. Overheating of the container should be avoided to prevent charring of the residue. The container shall then be dried in an oven at 100 to 110°C for 10 min, cooled in a desiccator, and weighed. A blank determination shall be run on the measured quantity of solvent, and the gain in weight for the blank shall be subtracted from the weight of the residue sample. The corrected weight shall then be calculated in grams of residue per internal area of tube.

11.2.2 The quantity of the solvent used may vary with the size of tube being examined. A minimum quantity of 100 mL should be used for diameters up to 0.500 in. [12.50 mm] and should be increased proportionately for larger sizes. The quantity of solvent used for the blank run shall be the same as that used for the actual examination of the tube sample.

11.2.3 In performing the test, care must be exercised to clean the outside surface of the end of the sample to be immersed in the solvent. The sample must be prepared in such a manner as to prevent the inclusion in the residue of aluminum chips or dust, resulting from the cutting of the sample.

12. Dimensional Tolerances

12.1 *Diameter*—The variation in diameter of tubes 0.250 through 0.625 in. [6.00 through 16.00 mm] in specified outside diameter shall not exceed the values given in Table 4.

12.2 *Wall Thickness*—The deviation in wall thickness at any point from the specified wall thickness of tubes with a specified wall thickness of 0.032 through 0.050 in. [0.80 through ~~1.30 mm]~~ 1.30 mm] shall not exceed ±0.004 in. [±0.10 mm].

12.3 *Length*—The variations in length shall not exceed those prescribed in Table 12.6 of ANSI H35.2 [H35.2M].

12.4 *Sampling for Inspection*—Examination for dimensional conformance shall be made to ensure conformance to the tolerances specified.

13. General Quality

13.1 Unless otherwise specified, the tubes shall be supplied in the mill finish and shall be uniform as defined by the requirements of this specification and shall be commercially sound. Any requirement not so covered is subject to negotiation between the producer and purchaser.