



Standard Specification for Aluminum and Aluminum-Alloy Extruded Round Tubes for General-Purpose Applications¹

This standard is issued under the fixed designation B 491/B 491M; 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

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]. For diameters over 0.500 through 0.750 in. [over 12.50 through 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**]. The equivalent Unified Numbering System alloy designations are those of **Table 1** preceded by A9 (for example, A91050 for aluminum 1050) in accordance with Practice **E 527**.

NOTE 1—For extruded tubes see Specification B 221, and for drawn tubes for general-purpose applications see Specification B 483.

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 B 491; for metric orders specify B 491M. 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

B 557 Test Methods for Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products

B 557M Test Methods for Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products (Metric)

B 660 Practices for Packaging/Packing of Aluminum and Magnesium Products

B 666/B 666M Practice for Identification Marking of Aluminum and Magnesium Products

B 881 Terminology Relating to Aluminum- and Magnesium-Alloy Products

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

E 34 Test Methods for Chemical Analysis of Aluminum and Aluminum-Base Alloys

E 55 Practice for Sampling Wrought Nonferrous Metals and Alloys for Determination of Chemical Composition

E 215 Practice for Standardizing Equipment for Electromagnetic Examination of Seamless Aluminum-Alloy Tube

E 527 Practice for Numbering Metals and Alloys in the Unified Numbering System (UNS)

E 607 Test Method for Atomic Emission Spectrometric Analysis Aluminum Alloys by the Point to Plane Technique Nitrogen Atmosphere

E 716 Practices for Sampling Aluminum and Aluminum Alloys for Spectrochemical Analysis

E 1251 Test Method for Analysis of Aluminum and Aluminum Alloys by Atomic Emission Spectrometry

2.3 ANSI Standards:

H35.1 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:

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.

TABLE 1 Chemical Composition Limits^{A,B,C}

Alloy	Silicon	Iron	Copper	Manganese	Magnesium	Chromium	Zinc	Vanadium	Titanium	Other Elements ^D		Aluminum
										Each	Total ^E	
1050	0.25	0.40	0.05	0.05	0.05	...	0.05	0.05	0.03	0.03	...	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	...	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 E 29.

^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.

TABLE 2 Tensile Property Limits^{A,B}

Alloy	Temper	Specified Wall Thickness, in.	Tensile Strength, ksi		Yield Strength (0.2 % Offset) min, ksi	Elongation in 2 in. min, %
			min	max		
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 E 29.

^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		Yield Strength (0.2 % Offset) min, MPa	Elongation in 50 mm min, %
			min	max		
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.

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)³

2.5 Military Standard:

MIL-STD-129 Marking for Shipment and Storage³

3. Terminology

3.1 Definitions: Refer to Terminology B 881

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

³ Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098.

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 B 491, for metric orders specify B 491M. 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 B 660 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:

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 shall conform to the chemical composition limits specified in Table 1. Conformance shall be determined by analyzing samples taken at the time the ingots are poured or samples taken from the finished or semifinished product. If the producer has determined the chemical composition of the material during the course of manufacture he shall not be required to sample and 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 E 55.

7.3.2 Sampling for spectrochemical analysis shall be in accordance with Practices E 716. Samples for other methods of analysis shall be suitable for the form of material being analyzed and the type of analytical method used.

7.4 *Methods of Analysis*—The determination of chemical composition shall be made in accordance with suitable chemical (Test Methods E 34), or spectrochemical (Test Methods E 607 and E 1251), methods. Other methods may be used only when no published ASTM method is available. In case of dispute the methods of analysis shall be agreed upon between the producer and purchaser.

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 [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 **B 557** [**B 557M**].

8.4 *Test Methods*—The tension tests shall be made in accordance with Test Methods **B 557** [**B 557M**].

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.

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 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 **E 215**. 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. [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 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 **E 215** 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 m²] (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. When specified by the purchaser at the time of placing the order, tube in the H111 temper shall meet the foregoing inside cleanliness requirement.

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] 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**].

TABLE 4 Diameter Tolerances

	Allowable Deviation of Mean Diameter ^A from Specified Diameter, plus and minus, in. [mm]	Allowable Deviation of Diameter at Any Point from Specified Diameter, plus and minus, in. [mm]
Extruded tube	0.004 [0.10]	0.006 [0.15]
Sized tube (1200-H111 and 1235-H111 only) ^B	0.004 [0.10]	0.004 [0.10]

^A Mean diameter is the average of two diameter measurements taken at right angles to each other at any point along the length.

^B Not applicable if inside diameter of the coil is less than 40 times the outside diameter of the tube.

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.

13.2 Each tube shall be examined to determine conformance to this specification with respect to general quality and identification marking. On approval of the purchaser however, the producer or supplier may use a system of statistical quality control for such examinations.

14. Source Inspection

14.1 If the purchaser desires that his representative inspect or witness the inspection and testing of the material prior to shipment, such agreement shall be made by the purchaser and producer as part of the purchase contract.

14.2 When such inspection or witness of inspection and testing is agreed upon, the producer shall afford the purchaser's representative all reasonable facilities to satisfy him that the material meets the requirements of this specification. Inspection and tests shall be conducted so there is no unnecessary interference with the producer's operations.

15. Retest and Rejection

15.1 If any material fails to conform to all of the applicable requirements of this specification, it shall be cause for rejection of the inspection lot.

15.2 When there is evidence that a failed specimen was not representative of the inspection lot and when no other sampling plan is provided or approved by the purchaser through the contract or purchaser order, at least two additional specimens shall be selected to replace each test specimen that failed. All

specimens so selected for retest shall meet the requirements of the specification or the lot shall be subject to rejection.

15.3 Material in which defects are discovered subsequent to inspection may be rejected.

15.4 If material is rejected by the purchaser, the producer or supplier is responsible only for replacement of material to the purchaser. As much as possible of the rejected material shall be returned to the producer or supplier.

16. Certification

16.1 The producer or supplier shall, on request, furnish to the purchaser a certificate stating that the material has been sampled, tested, and inspected in accordance with this specification, and has met the requirements.

17. Identification Marking of Product

17.1 When specified on the purchase order or contract, all material shall be marked in accordance with Practice B 666 [B 666M].

18. Packaging and Package Marking

18.1 Unless otherwise specified in the contract or purchase order, the material shall be packaged to provide adequate protection during normal handling and transportation. Each package shall contain only one size, alloy, and temper of material unless otherwise agreed. The type of packing and gross weight of containers shall, unless otherwise agreed, be at the producer's discretion, provided they are such as to ensure acceptance by common or other carriers for safe transportation at the lowest rate to the delivery point.

18.2 Each shipping container shall be marked with the purchase order number, material size, specification number, alloy and temper, gross and net weights, and the producer's name or trademark.

18.3 The inside diameter of coils, normally 22 in. [550 mm] or greater, and the weight and outside diameter of coils shall be at the producer's discretion unless otherwise agreed.

18.4 When specified in the contract or purchase order, material shall be preserved, packaged, and packed in accordance with the requirements of Practices B 660. The application levels shall be as specified in the contract or order. Marking for shipment of such material shall be in accordance with **Fed. Std. No. 123** for civil agencies and **MIL-STD-129** for military agencies.

19. Keywords

19.1 aluminum alloy; extruded round tubes

ANNEXES

(Mandatory Information)

A1. BASIS FOR INCLUSION OF PROPERTY LIMITS

A1.1 Limits are established at a level at which a statistical evaluation of the data indicates that 99 % of the population obtained from all standard material meets the limit with 95 % confidence. For the products described, mechanical property limits for the respective size ranges are based on the analyses of at least 100 data from standard production material with no more than ten data from a given lot. All tests are performed in accordance with the appropriate ASTM test methods. For

informational purposes, refer to “Statistical Aspects of Mechanical Property Assurance” in the Related Material section of the *Annual Book of ASTM Standards*, Vol 02.02. Mechanical property limits in SI units were derived from the inch-pound system limits that were developed under the above principles. As test data on metric dimensioned specimens are accumulated, some refinement of limits, particularly for elongations measured in 5D, can be anticipated.

A2. ACCEPTANCE CRITERIA FOR INCLUSION OF NEW ALUMINUM AND ALUMINUM ALLOYS IN THIS SPECIFICATION

A2.1 Prior to acceptance for inclusion in this specification, the composition of wrought or cast aluminum or aluminum alloy shall be registered in accordance with ANSI H35.1 or H35.1M. The Aluminum Association⁴ holds the Secretariat of ANSI H35 Committee and administers the criteria and procedures for registration.

A2.2 If it is documented that the Aluminum Association could not or would not register a given composition, an alternative procedure and the criteria for acceptance shall be as follows:

A2.2.1 The designation submitted for inclusion does not utilize the same designation system as described in ANSI H35.1 or H35.1M. A designation not in conflict with other designation systems or a trade name is acceptable.

A2.2.2 The aluminum or aluminum alloy has been offered for sale in commercial quantities within the prior twelve months to at least three identifiable users.

A2.2.3 The complete chemical composition limits are submitted.

A2.2.4 The composition is, in the judgment of the responsible subcommittee, significantly different from that of any other aluminum or aluminum alloy already in the specification.

A2.2.5 For codification purposes, an alloying element is any element intentionally added for any purpose other than grain refinement and for which minimum and maximum limits are specified. Unalloyed aluminum contains a minimum of 99.00 % aluminum.

A2.2.6 Standard limits for alloying elements and impurities are expressed to the following decimal places:

Less than 0.001 %	0.000X
0.001 to but less than 0.01 %	0.00X
0.01 to but less than 0.10 %	
Unalloyed aluminum made by a refining process	0.0XX
Alloys and unalloyed aluminum not made by a refining process	0.0X
0.10 through 0.55 %	0.XX
(It is customary to express limits of 0.30 through 0.55 % as 0.X0 or 0.X5.)	
Over 0.55 %	0.X, X.X, etc.
(except that combined Si + Fe limits for 99.00 % minimum aluminum must be expressed as 0.XX or 1.XX)	

A2.2.7 Standard limits for alloying elements and impurities are expressed in the following sequence: Silicon; Iron; Copper; Manganese; Magnesium; Chromium; Nickel; Zinc (Note A2.1); Titanium; Other Elements, Each; Other Elements, Total; Aluminum (Note A2.2).

NOTE A2.1—Additional specified elements having limits are inserted in alphabetical order of their chemical symbols between zinc and titanium, or are specified in footnotes.

NOTE A2.2—Aluminum is specified as *minimum* for unalloyed aluminum and as a *remainder* for aluminum alloys.

⁴ The Aluminum Association, Inc., 1525 Wilson Boulevard, Suite 600, Arlington, VA 22209.

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