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Standard Specification for Aluminum and Aluminum-Alloy Seamless Condenser and Heat-Exchanger Tubes with Integral Fins[1]

This standard is issued under the fixed designation B 404/B 404M; 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 externally helical, integrally finned aluminum and aluminum-alloy seamless tubes with finned or unfinned ends, with continuous fins, or with unfinned sections, in outside diameters (diameter over fins) up to 2 in. [50 mm] inclusive. See Table 1 and Table 2.

1.2 Alloy and temper designations are in accordance with ANSI H35.1 and H35.1M. The equivalent Unified Numbering System alloy designations are those of Table 1 preceded by A9, for example, A91060 for aluminum 1060 in accordance with Practice E 527.

NOTE 1—Throughout this specification the term alloy in the general sense includes aluminum as well as aluminum alloy.

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 units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

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

2.2 *ASTM Standards:*

B 557 Test Methods for Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products[2]

B 557M Test Methods for Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products [Metric][2]

B 597 Practice for Heat Treatment of Aluminum Alloys[2]

B 660 Practices for Packaging/Packing of Aluminum and Magnesium Products[2]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[3]

E 34 Test Methods for Chemical Analysis of Aluminum and Aluminum-Base Alloys[4]

E 55 Practice for Sampling Wrought Nonferrous Metals and Alloys for Determination of Chemical Composition[4]

E 227 Test Method for Optical Emission Spectrometric Analysis of Aluminum and Aluminum Alloys by the Point-to-Plane Technique[4]

E 527 Practice for Numbering Metals and Alloys (UNS)[5]

E 607 Test Method for Optical Emission Spectrometric Analysis of Aluminum and Aluminum Alloys by the Point-to-Plane Technique, Nitrogen Atmosphere[6]

E 716 Practices for Sampling Aluminum and Aluminum Alloys for Spectrochemical Analysis[6]

E 1251 Test Method for Optical Emission Spectrometric Analysis of Aluminum and Aluminum Alloys by the Argon Atmosphere, Point-to-Plane, Unipolar Self-Initiating Capacitor Discharge[6]

2.3 *ANSI Standards:*

H35.1 Alloy and Temper Designation Systems for Aluminum[2]

H35.1M Alloy and Temper Designation Systems for Aluminum [Metric][2]

2.4 *Federal Standards:*

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)[7]

2.5 *Military Standards:*

MIL-STD-129 Marking for Shipment and Storage[7]

3. Terminology

3.1 *Definitions:*

3.1.1 *round tube*—a hollow wrought product that is long in relation to its cross section, which is round and has a uniform wall thickness.

3.1.2 *drawn tube*—a tube brought to final dimensions by drawing through a die.

3.1.3 *seamless tube*—a tube which does not contain any line junctures resulting from the method of manufacture.

3.1.4 *alclad tube*—a composite tube product composed of

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[2] *Annual Book of ASTM Standards*, Vol 02.02.

[3] *Annual Book of ASTM Standards*, Vol 14.02.

[4] *Annual Book of ASTM Standards*, Vol 03.05.

[5] *Annual Book of ASTM Standards*, Vol 01.01.

[6] *Annual Book of ASTM Standards*, Vol 03.06.

[7] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

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

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

Alloy[D]	Silicon	Iron	Copper	Manganese	Magnesium	Chromium	Zinc	Titanium	Other Elements[E]		Aluminum
									Each	Total[F]	
1060[G]	0.25	0.35	0.05	0.03	0.03	...	0.05	0.03	0.03	...	99.60 min[H]
3003	0.6	0.7	0.05–0.20	1.0–1.5	...	...	0.10	...	0.05	0.15	remainder
Alclad 3003	3003 alloy clad with 7072 alloy										
5052	0.25	0.40	0.10	0.10	2.2–2.8	0.15–0.35	0.10	...	0.05	0.15	remainder
5454	0.25	0.40	0.10	0.50–1.0	2.4–3.0	0.05–0.20	0.25	0.20	0.05	0.15	remainder
6061	0.40–0.8	0.7	0.15–0.40	0.15	0.8–1.2	0.04–0.35	0.25	0.15	0.05	0.15	remainder
7072 Cladding	0.7 Si + Fe		0.10	0.10	0.10	...	0.8–1.3	...	0.05	0.15	remainder

[A] Limits are in percent maximum unless shown as a range or shown otherwise.
[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 obtained from analysis shall be rounded 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] These designations were established in accordance with ANSI H35.1.
[E] *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 non-conforming.
[F] *Other Elements*—Total shall be the sum of unspecified metallic elements 0.010 % or more, rounded to the second decimal before determining the sum.
[G] Vanadium 0.05 %, maximum.
[H] 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.

an aluminum-alloy core having on either the inside or outside surface a metallurgically bonded aluminum or aluminum-alloy coating that is anodic to the core, thus electrolytically protecting the core against corrosion.

3.1.5 *finned tube*—a tube which has integral fins or projections protruding from its outside surface.

3.1.6 *producer*—the primary manufacturer of the material.

3.1.7 *supplier*—includes only the category of jobbers and distributors as distinct from producers.

3.2 *Definition of Term 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),

4.1.2 Quantity of each size (number of pounds [pieces]),

4.1.3 Alloy and temper (Sections 7 and 8),

4.1.4 Description of tube ends (plain or finned),

4.1.5 Dimensions: outside diameter, wall thickness, length of unfinned ends (if applicable), root diameter and wall thickness of finned section, number of fins per unit length, fin geometry, and total tube length (Section 5),

4.2 Additionally, orders for material to this specification shall include the following information when required by the purchaser:

4.2.1 Whether identification marking is required (Section 17),

4.2.2 Whether inspection or witness of inspection and tests by the purchaser's representative is required prior to material shipment (Section 14),

4.2.3 Whether certification is required (Section 16), and

4.2.4 Whether Practices B 660 applies and, if so, the levels of preservation, packaging, and packing required (18.3).

5. Manufacture

5.1 The fins shall be produced by the cold forming of aluminum alloy drawn seamless tubes so that the fins are integral with the tube.

5.2 The fin geometry and number of fins per unit length shall be as agreed upon between the manufacturer and the purchaser (Fig. 1). The finned tubes shall normally be furnished with unfinned ends, but may be furnished with finned ends or stripped ends from which the fins have been removed by machining.

6. Responsibility for Quality Assurance

6.1 *Responsibility for Inspection and Tests*—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 all the material of the same mill form, alloy, temper, and nominal dimensions traceable to a heat-treat lot or lots, and subjected to inspection at one time.

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

7. Chemical Composition

7.1 *Limits*—The finned tubes shall conform to the chemical composition limits prescribed in Table 1. Conformance shall be determined by the producer by analyzing samples taken at the time the ingots are poured, or samples taken from the finished or semifinished product. If the producer of the drawn seamless

TABLE 2 Tensile Property Limits[A,B]

Temper[C]	Specified Wall Thickness, in. [mm]	Tensile Strength, ksi [MPa]		Yield Strength (0.2% Offset), min, ksi [MPa]	Elongation in 2 in. [50 mm] or 4× Diameter,[D] min, %		
		min	max		Full Section Specimen in 50 mm	Cut-Out Specimen	
						in 50 mm	In 5 × Diameter ($5.65\sqrt{A}$)[E]
			Aluminum 1060[C]				
O	0.018–0.500 [0.45–12.50]	8.5 [60]	13.5 [95]	2.5 [15]	...	...	...
H14	0.018–0.500	12.0 [85]	... [...]	10.0 [70]	...	...	...
			Alloy 3003[C]				
O	0.010–0.024 [0.25–0.63]	14.0 [95]	19.0 [130]	5.0 [35]	...	...	...
	0.025–0.049 [0.63–1.20]	14.0 [95]	19.0 [130]	5.0 [35]	30	20	...
	0.050–0.259 [1.20–6.30]	14.0 [95]	19.0 [130]	5.0 [35]	35	25	...
	0.260–0.500 [6.30–12.50]	14.0 [95]	19.0 [130]	5.0 [35]	...	30	27
H14	0.010–0.024 [0.25–0.63]	20.0 [140]	... [...]	17.0 [115]	3	...	...
	0.025–0.049 [0.63–1.20]	20.0 [140]	... [...]	17.0 [115]	5	3	...
	0.050–0.259 [1.20–6.30]	20.0 [140]	... [...]	17.0 [115]	8	4	...
	0.260–0.500 [6.30–12.50]	20.0 [140]	... [...]	17.0 [115]	...	...	...
H25	0.010–0.500 [0.25–12.50]	22.0 [150]	... [...]	19.0 [130]	...	...	...
			Alloy Alclad 3003[C]				
O	0.010–0.500 [0.25–12.50]	13.0 [90]	19.0 [130]	4.5 [30]	...	...	...
H14	0.010–0.024 [0.25–0.63]	19.0 [130]	...	16.0 [110]	...	...	...
	0.025–0.049 [0.63–1.20]	19.0 [130]	...	16.0 [110]	5	...	...
	0.050–0.259 [1.20–6.30]	19.0 [130]	...	16.0 [110]	8	4	...
	0.260–0.500 [6.30–12.50]	19.0 [130]	...	16.0 [110]	...	...	...
H25	0.010–0.500 [0.25–12.50]	21.0 [145]	...	18.0 [125]	...	...	...
			Alloy 5052[C]				
O	0.018–0.450 [0.45–11.50]	25.0 [170]	35.0 [240]	10.0 [70]	...	...	...
H32	0.018–0.450 [0.45–11.50]	31.0 [215]	...	23.0 [160]	...	...	...
H34	0.018–0.450 [0.45–11.50]	34.0 [235]	...	26.0 [180]	...	...	...
			Alloy 5454[C]				
O	0.010–0.200 [0.25–5.00]	31.0 [215]	...	12.0 [85]	...	...	...
H32	0.010–0.050 [0.25–1.20]	36.0 [250]	...	26.0 [180]	...	5	...
	0.051–0.200 [1.20–5.00]	36.0 [250]	...	26.0 [180]	...	8	...
H34	0.010–0.050 [0.25–1.20]	39.0 [270]	...	29.0 [200]	...	4	...
	0.051–0.200 [1.20–5.00]	39.0 [270]	...	29.0 [200]	...	6	...
			Alloy 6061[C]				
O	0.018–0.500 [0.45–12.50]	...	22.0 [150]	14.0 max [95 max]	15[F]	15[F]	13
T4	0.025–0.049 [0.63–1.20]	30.0 [205]	...	16.0 [110]	16[F]	14[F]	...
	0.050–0.259 [1.20–6.30]	30.0 [205]	...	16.0 [110]	18[F]	16[F]	16
	0.260–0.500 [6.30–12.50]	30.0 [205]	...	16.0 [110]	20[F]	18[F]	...
T6	0.025–0.049 [0.63–1.20]	42.0 [290]	...	35.0 [240]	10[F]	8[F]	...
	0.050–0.259 [1.20–6.30]	42.0 [290]	...	35.0 [240]	12[F]	10[F]	10
	0.260–0.500 [6.30–12.50]	42.0 [290]	...	35.0 [240]	14[F]	12[F]	...

[A] See 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 [1 MPa] and each value for elongation to the nearest 0.5 %, both in accordance with the rounding method of Practice E 29.

[C] These alloy and temper designations were established in accordance with ANSI H35.1.

[D] Elongations in 50 mm apply for tube tested in full-section, for sheet type specimens, for tubes having a flat wall, and for similar curved specimens for tubes having a curved wall, up to a maximum wall thickness of 12.50 mm. Elongations in 5 D ($5.65\sqrt{A}$), where D and A are diameter and cross-sectional area of the specimens, respectively, apply to round test specimens machined from wall thicknesses over 6.30 mm.

[E] Elongation of full-section and cut-out sheet-type specimens is measured in 2 in.; of cut-out round specimens in 4 × specimen diameter.

[F] The test for elongation is not required when specimens are machined from the finned portion of tube.

tubes from which the finned tubes may be produced, or the producer of the finned tubes, has determined the chemical composition of the material during the course of manufacture, sampling and analysis of the finished product shall not be required.

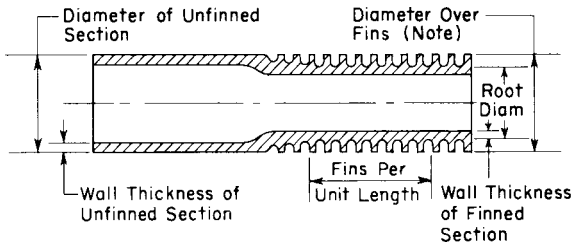
NOTE 2—It is standard practice in the United States aluminum industry to determine conformance to the chemical composition limits prior to further processing of ingots into wrought products. Due to the continuous nature of the process, it is not practical to keep a specific ingot analysis identified with a specific quantity of finished material.

7.2 *Number of Samples*—The number of samples taken for determining the 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 semifinished or finished product, a sample shall be taken to represent each 4000 lb [2000 kg] or fraction thereof of material in the lot, except that not more than one sample shall be required per piece.

7.3 *Methods of Sampling*—Samples for determination of



NOTE 1—The diameter over the fins shall not exceed the diameter of the unfinned section unless otherwise specified.

FIG. 1 Finned Tube Nomenclature

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 weight of prepared sample 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 taken by methods 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 227, 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.

NOTE 3—It is difficult to obtain a reliable analysis of each of the components of clad materials using material in its finished state. A reasonably accurate determination of the core composition can be made if the cladding is substantially removed prior to analysis. The cladding composition is more difficult to determine because of the relatively thin layer and because of diffusion of core elements to the cladding. The correctness of cladding alloy used can usually be verified by a combination of a metallographic examination and a spectrochemical analysis of the surface at several widely separated points.

8. Tensile Properties

8.1 *Limits*—The tubes (before finning for O, H14, H25, H32, H34, and T4 tempers and after finning for T6 temper) shall conform to the tensile property requirements of Table 2.

NOTE 4—Tubes in the O, H14, H25, H32, H34, and T4 tempers before finning will have (after finning) in the finned areas, tensile and yield strengths somewhat higher and elongations slightly lower than those specified in Table 2 because of the cold work introduced by the finning process. Tubes can be furnished in the annealed (O) temper, and Alloy 6061 can be furnished in the solution heat-treated and aged (T6) temper after finning.

8.2 *Number of Specimens*:

8.2.1 For tubes having a nominal weight of less than 1 lb/linear ft [1.7 kg/linear m], one tension test specimen shall be taken for each 1000 lb [500 kg] or fraction thereof in a lot.

8.2.2 For tubes having a nominal weight of 1 lb or more/linear ft, [1.7 kg or more/linear m] one tension test specimen shall be taken for each 1000 ft [300 m] or fraction thereof in a lot.

8.2.3 If the lot contains tubes of more than one alloy, temper, or size, only those tubes of the same alloy, temper, and size shall be grouped for the purpose of selecting tension test specimens. Other procedures for selecting samples may be employed if agreed upon by the producer and the purchaser.

8.3 *Test Specimens*:

8.3.1 Tension test specimens shall be the full-tube section before finning for O, H14, H25, H32, H34, and T4 tempers, and from the unfinned ends or with the fins machined off the finned tube for T6 temper, unless the limits of the testing machine preclude the use of such specimens.

8.3.2 When it is not possible to test the full section, refer to Test Methods B 557 [B 557M] for specimen geometry.

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

9. Leak Test

9.1 *Limits*—The tubes after finning shall withstand an internal air gage pressure of 250 psi [1700 kPa], minimum, without showing evidence of leakage.

9.2 *Number of Specimens*—Each tube shall be tested.

9.3 *Test Method*—The tubes shall be subjected to an internal air pressure for 5 s, minimum, while they are immersed in water or other suitable fluid. Air bubbles emerging through the immersing fluid shall be evidence of leakage.

10. Expansion Test

10.1 *Limits*—The tube ends shall be capable of being flared until the inside diameter at the ends has been expanded at least 20 % without developing cracks or ruptures visible to the unaided eye corrected for normal vision.

10.2 *Number of Tests*—The test frequency shall be at the discretion of the producer, but the number of tests conducted shall be sufficient to provide reasonable assurance that the tubes will meet the expansion requirement.

10.3 *Test Specimens*—When expansion tests are conducted the test specimens shall be taken at random from representative tubes and their length shall be at least three times the inside diameter of the tube.

10.4 *Test Method*—One end of the test specimen shall be expanded by forcing a smoothly machined steel pin having a taper of 1½ in./ft [1 mm/8 mm] into the tube end.

11. Cladding Thickness

11.1 The aluminum-alloy coating of Alclad 3003 tubes shall comprise the inside surface only and its thickness before finning shall be approximately 10 % of the total wall thickness.

11.2 *Measurement*—The number of measurements shall be at the discretion of the manufacturer but it shall be such as to provide reasonable assurance that the coating thickness does not vary to an unreasonable extent.

11.3 *Specimens*—When measurements are made, transverse cross sections of 3 or more tubes per each 1000 lb [500 kg] or fraction thereof in the lot shall be taken and polished for examination with a metallurgical microscope.

11.4 *Test Method*—Using a magnification of 100×, the coating thickness at four points, 90° apart, in each sample shall be measured and the average of the 12 measurements shall be taken as the thickness. If the tube diameter is larger than can

properly be mounted for polishing and examination, each of the portions of the cross section may consist of an arc about ½ in. (12 mm) in length.

12. Dimensional Tolerances

12.1 *Outside Diameter*—Tube ordered to the requirements of this specification, in Alloys 1060, 3003, alclad 3003, 5052, and 5454, and measured by the use of "go" and "no-go" ring gages, shall not vary from the specified outside diameter by an amount greater than is specified in Table 3. Tube in Alloy 6061 shall not vary from specified outside diameter by an amount greater than that specified in Table 4. Unless otherwise specified the diameter over the fins shall at no point exceed the diameter of the unfinned ends.

12.2 *Wall Thickness*—The wall thickness, at any point, shall not be less than the specified wall thickness.

12.3 *Length*—The length shall not be less than that specified when measured at 68°F [20°C] but may exceed that specified by an amount no greater than prescribed in Table 5.

12.4 *Squareness of Cut Ends*—The cut ends of the tube shall not vary from squareness with the longitudinal axis of the tube by more than 1°.

12.5 *Number of Samples*—Examination for dimensional conformance shall be made to ensure conformance to the tolerance 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 producer and purchaser.

13.2 Surface discoloration that is characteristic of proper solution heat treatment shall not be cause for rejection.

NOTE 5—Procedures for proper solution heat treatment are described in Practice B 597.

13.3 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.

TABLE 3 Outside Diameter Tolerances for Tube in Alloys 1060, 3003, Alclad 3003, 5052, and 5454

Specified Diameter,[A] in. [mm]	Tolerance,[B] in. [mm], plus and minus
Up through 0.500 [12.50]	0.002 [0.05]
0.501–0.749 [12.50–18.00]	0.0025 [0.06]
0.750–1.000 [18.00–25.00]	0.003 [0.08]
1.001–1.250 [25.00–30.00]	0.0035 [0.09]
1.251–2.000 [30.00–50.00]	0.004 [0.10]

[A] Intermediate thicknesses shall be rounded to the third decimal place in accordance with Practice E 29.
[B] As measured by the use of "Go" and "No-Go" ring gages.

TABLE 4 Outside Diameter Tolerances for Tube in Alloy 6061

Specified Diameter,[A] in. [mm]	Tolerance,[B] in. [mm], plus and minus
Up through 0.500 [12.50]	0.003 [0.08]
0.501–1.000 [12.50–25.00]	0.004 [0.10]
1.001–1.500 [25.00–40.00]	0.005 [0.13]
1.501–2.000 [40.00–50.00]	0.006 [0.15]

[A] Intermediate thicknesses shall be rounded to the third decimal place in accordance with Practice E 29.
[B] As measured by the use of "Go" and "No-Go" ring gages.

TABLE 5 Length Tolerances for All Tubes

Specified Length, ft [mm]	Tolerance, in. [mm], plus
Up through 15 [5000]	3/32 [2.5]
Over 15 through 20 [5000 through 6000]	1/8 [3]
Over 20 through 30 [6000 through 10 000]	3/16 [5]

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 purchase 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 so specified in the purchase order, each tube ½ in. [12.5 mm] or larger in outside diameter shall be marked near one end with the producer's name or trademark and the alloy and temper. Identification characters shall have a minimum height of ⅛ in. [3 mm] and the marking material shall have adequate resistance to obliteration during normal handling and shall be removable by normal cleaning methods; however, ghost images of the characters may remain. Tubes smaller than ½ in. [12.5 mm] in diameter may be either tagged (in bundles) or marked as individual pieces with the above information.

18. Packaging and Package Marking

18.1 The material shall be packaged to provide adequate protection during normal handling and transportation and each package shall contain only one size and alloy of material unless otherwise agreed. The type of packaging 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 purchase order number, material size, specification number, alloy and temper, gross and net weights, and the producer's name or trademark.

18.3 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 applicable 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; condenser tubes; heat-exchanger 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 analysis 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 this metric issue were derived from 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 Association[8] 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

[8] The Aluminum Association, 900 19th St., NW, Washington, DC 20006.

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.

SUMMARY OF CHANGES

This section identifies the principal changes to this standard that have been incorporated since the last issue.

(1) Deleted references to Test Method E 101.