Designation: B163 – 22

Standard Specification for Seamless Nickel and Nickel Alloy Condenser and Heat-Exchanger Tubes[1]

This standard is issued under the fixed designation B163; 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.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope*

1.1 This specification[2] covers seamless tubes of nickel and nickel alloys, as shown in Table 1, for use in condenser and heat-exchanger service.

1.2 This specification covers outside diameter and average wall, or outside diameter and minimum wall tube.

1.2.1 The sizes covered by this specification are 3 in. (76.2 mm) and under in outside diameter with minimum wall thicknesses of 0.148 in. (3.76 mm) and under, and with average wall thicknesses of 0.165 in. (4.19 mm) and under.

1.3 Tube shall be furnished in the alloys and conditions as shown in Table 2. For small diameter and light wall tube (converter sizes), see Appendix X2.

1.4 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.5 The following safety hazards caveat pertains only to the test method portion, Section 12, of this specification. *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to become familiar with all hazards including those identified in the appropriate Safety Data Sheet (SDS) for this product/material as provided by the manufacturer, to establish appropriate safety, health, and environmental practices, and determine the applicability of regulatory limitations prior to use.*

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

B829 Specification for General Requirements for Nickel and Nickel Alloys Seamless Pipe and Tube

B880 Specification for General Requirements for Chemical Check Analysis Limits for Nickel, Nickel Alloys and Cobalt Alloys

E8/E8M Test Methods for Tension Testing of Metallic Materials

E18 Test Methods for Rockwell Hardness of Metallic Materials

E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

E76 Test Methods for Chemical Analysis of Nickel-Copper Alloys (Withdrawn 2003)[4]

E112 Test Methods for Determining Average Grain Size

E140 Hardness Conversion Tables for Metals Relationship Among Brinell Hardness, Vickers Hardness, Rockwell Hardness, Superficial Hardness, Knoop Hardness, Scleroscope Hardness, and Leeb Hardness

E1473 Test Methods for Chemical Analysis of Nickel, Cobalt and High-Temperature Alloys

2.2 *Federal Standards:*[5]

Fed. Std. No. 102 Preservation, Packaging and Packing Levels

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

Fed. Std. No. 182 Continuous Identification Marking of Nickel and Nickel-Base Alloys

2.3 *Military Standard:*[5]

MIL-STD-129 Marking for Shipment and Storage

[1] This specification is under the jurisdiction of ASTM Committee B02 on Nonferrous Metals and Alloys and is the direct responsibility of Subcommittee B02.07 on Refined Nickel and Cobalt and Their Alloys.

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[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SB-163 in Section II of that Code.

[3] 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.

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

[5] Available from DLA Document Services, Building 4/D, 700 Robbins Ave., Philadelphia, PA 19111-5094, http://quicksearch.dla.mil.

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

TABLE 1 Chemical Requirements[A]

Element	Composition, %									
	N02200	N02201	N04400	N06025	N06045	N06600	N06601	N06603	N06686	N06690
Nickel	99.0 min[B]	99.0 min[B]	63.0 min[B]	remainder[B]	45.0 min[B]	72.0 min[B]	58.0–63.0	remainder[B]	remainder[B]	58.0 min[B]
Copper	0.25	0.25	28.0 – 34.0	0.1	0.3	0.5	1.0	0.5	...	0.5
Molybdenum	...	...	...	...	...	...	...	...	15.0 – 17.0	...
Iron	0.40	0.40	2.5	8.0 – 11.0	21.0 – 25.0	6.0 – 10.0	remainder[B]	8.0 – 11.0	5.0	7.0 – 11.0
Manganese	0.35	0.35	2.0	0.15	1.0	1.0	1.0	0.15	0.75	0.5
Carbon	0.15	0.02	0.3	0.15 – 0.25	0.05 – 0.12	0.15	0.10	0.20 – 0.40	0.010	0.05
Silicon	0.35	0.35	0.5	0.5	2.5 – 3.0	0.5	0.5	0.5	0.08	0.5
Sulfur	0.01	0.01	0.024	0.010	0.010	0.015	0.015	0.010	0.02	0.015
Chromium	...	...	...	24.0 – 26.0	26.0 – 29.0	14.0 – 17.0	21.0 – 25.0	24.0 – 26.0	19.0 – 23.0	27.0 – 31.0
Aluminum	...	...	...	1.8 – 2.4	...	...	1.0 – 1.7	2.4 – 3.0	...	...
Titanium	...	...	...	0.1 – 0.2	...	...	...	0.01 – 0.25	0.02 – 0.25	...
Phosphorus	...	...	...	0.020	0.020	...	...	0.02	0.04	...
Cerium	...	...	...	...	0.03 – 0.09	...	...	...	...	...
Zirconium	...	...	...	0.01 – 0.10	...	...	...	0.01 – 0.10	...	...
Yttrium	...	...	...	0.05 – 0.12	...	...	...	0.01 – 0.15	...	...
Boron	...	...	...	...	...	...	...	...	...	...
Cobalt	...	...	...	...	...	...	...	...	...	...
Niobium[C]	...	...	...	...	...	...	...	...	...	...
Tungsten	...	...	...	...	...	...	...	...	3.0 – 4.4	...
Nitrogen	...	...	...	...	...	...	...	...	...	...

[A] Maximum unless range or minimum is given. Where ellipses (...) appear in this table, there is no requirement and analysis for the element need not be determined or reported.
[B] Element shall be determined arithmetically by difference.
[C] Columbium and niobium are interchangeable names for the same element and both names are acceptable for use in B02.07 specifications.

TABLE 1 Chemical Requirements[A] *(continued)*

Element	Composition, %									
	N06696	N06699	N06845	N08120	N08800	N08801	N08810	N08811	N08825	N08935
Nickel	remainder[B]	remainder[B]	44.0 – 50.0	35.0 – 39.0	30.0 – 35.0	30.0 – 34.0	30.0 – 35.0	30.0 – 35.0	38.0 – 46.0	34.0 – 36.0
Copper	1.5 – 3.0	0.50	2.0 – 4.0	0.50	0.75	0.50	0.75	0.75	1.5 – 3.0	0.4
Molybdenum	1.0 – 3.0	...	5.0 – 7.0	2.50	...	...	...	...	2.5 – 3.5	6.1 – 7.1
Iron	2.0 – 6.0	2.5	remainder[B]	remainder[B]	39.5 min[B]	39.5 min[B]	39.5 min[B]	39.5 min[B]	22.0 min[B]	remainder[B]
Manganese	1.0	0.50	0.5	1.5	1.5	1.50	1.5	1.5	1.0	1.2
Carbon	0.15	0.005 – 0.10	0.05	0.02 – 0.10	0.10	0.10	0.05 – 0.10	0.06 – 0.10	0.05	0.030
Silicon	1.0 – 2.5	0.50	0.5	1.0	1.0	1.00	1.0	1.0	0.5	0.5
Sulfur	0.010	0.01	0.010	0.03	0.015	0.015	0.015	0.015	0.03	0.020
Chromium	28.0 – 32.0	26.0 – 30.0	20.0 – 25.0	23.0 – 27.0	19.0 – 23.0	19.0 – 22.0	19.0 – 23.0	19.0 – 23.0	19.5 – 23.5	26.0 – 28.0
Aluminum	...	1.9 – 3.0	...	0.40	0.15 – 0.60	...	0.15 – 0.60	0.25 – 0.60[D]	0.2	...
Titanium	1.0	0.60	...	0.20	0.15 – 0.60	0.75 – 1.5	0.15 – 0.60	0.25 – 0.60[D]	0.6 – 1.2	...
Phosphorus	...	0.02	...	0.04	0.045	...	0.045	0.045	...	0.030
Cerium	...	...	...	...	...	...	...	...	...	...
Zirconium	...	0.10	...	...	...	...	...	...	...	...
Yttrium	...	...	...	...	...	...	...	...	...	...
Boron	...	0.008	...	0.010	...	...	...	...	...	...
Cobalt	...	...	...	3.0	...	...	...	...	...	...
Niobium[C]	...	0.50	...	0.4 – 0.9	...	...	...	...	...	...
Tungsten	...	...	2.0 – 5.0	2.50	...	...	...	...	...	...
Nitrogen	...	0.05	...	0.13 – 0.30	...	...	...	...	...	0.25 – 0.36

[A] Maximum unless range or minimum is given. Where ellipses (...) appear in this table, there is no requirement and analysis for the element need not be determined or reported.
[B] Element shall be determined arithmetically by difference.
[C] Columbium and niobium are interchangeable names for the same element and both names are acceptable for use in B02.07 specifications.
[D] Alloy UNS N08811: Al + Ti = 0.85 – 1.20.

TABLE 2 Alloy and Conditions

Alloy	Condition
Nickel UNS N02200 and low-carbon nickel UNS N02201	annealed or stress-relieved
Nickel-copper alloy UNS N04400	annealed or stress-relieved
Nickel-chromium-iron-aluminum alloy UNS N06603	annealed
Nickel-chromium-iron-copper alloy UNS N06696	annealed
Nickel-chromium-iron-aluminum alloy UNS N06601	annealed
Nickel-chromium-iron alloy UNS N06600	annealed
Low-carbon nickel-chromium-molybdenum-tungsten alloy UNS N06686	annealed
Nickel-chromium-iron alloy UNS N06690	annealed
Nickel-chromium-iron alloy UNS N06045	annealed
Nickel-iron-chromium alloy UNS N08120[A]	annealed or cold-worked
Nickel-iron-chromium alloy UNS N08800[A]	annealed or cold-worked
Nickel-iron-chromium alloy UNS N08810[A]	annealed
Nickel-iron-chromium alloy UNS N08811[A]	annealed
Nickel-iron-chromium alloy UNS N08801	annealed
Nickel-iron-chromium-molybdenum alloy UNS N08935	annealed
Nickel-iron-chromium-molybdenum-copper alloy UNS N08825	annealed
Nickel-chromium-iron alloy UNS N06025	annealed
Nickel-iron-chromium-molybdenum-copper alloy UNS N06845	annealed
Nickel-chromium-aluminum alloy UNS N06699	annealed

[A] Alloy UNS N08800 is normally employed in service temperatures up to and including 1100 °F (593 °C). Alloys UNS N08810, UNS N08811, and UNS N08120 are normally employed in service temperatures above 1100 °F (539 °C) where resistance to creep and rupture is required, and it is annealed to develop controlled grain size for optimum properties in this temperature range.

3. Terminology

3.1 *Definitions:*

3.1.1 *average diameter, n*—average of the maximum and minimum outside diameters, as determined at any one cross section of the tube.

3.1.2 *tube, n*—hollow product of round or any other cross section having a continuous periphery.

4. Ordering Information

4.1 It is the responsibility of the purchaser to specify all requirements that are necessary for the safe and satisfactory performance of material ordered under this specification. Examples of such requirements include, but are not limited to, the following:

4.1.1 *Alloy* (Table 1).

4.1.2 *Condition (Temper)* Table 3 and Appendix X1 and Appendix X2.

4.1.2.1 If annealed ends for stress relieved tubing are desired, state length of end to be annealed and whether or not one end or both ends are to be annealed.

4.1.3 *Finish.*

4.1.4 *Dimensions*—Outside diameter, minimum or average wall thickness (in inches, not gage number), and length.

4.1.5 *Fabrication Operations:*

4.1.5.1 *Cold Bending or Coiling.*

4.1.5.2 *Packing.*

4.1.5.3 *Rolling or Expanding into Tube Sheets.*

4.1.5.4 *Welding or Brazing*—Process to be employed.

4.1.5.5 *Hydrostatic Test or Nondestructive Electric Test*—Specify type of test (6.5).

4.1.5.6 *Pressure Requirements*—If other than required by 6.5.

4.1.5.7 *Ends*—Plain ends cut and deburred will be furnished.

4.1.6 *Supplementary Requirements*—State nature and details.

4.1.7 *Certification*—State if certification is required (Section 15).

4.1.8 *Samples for Product (Check) Analysis*—Whether samples for product (check) analysis shall be furnished.

4.1.9 *Purchaser Inspection*—If purchaser wishes to witness tests or inspection of material at place of manufacture, the purchase order must so state indicating which tests or inspections are to be witnessed (Section 13).

4.1.10 *Small-Diameter and Light-Wall Tube (Converter Sizes)*—See Appendix X2.

5. Chemical Composition

5.1 The material shall conform to the composition limits specified in Table 1.

5.2 If a product (check) analysis is performed by the purchaser, the material shall conform to the product (check) analysis per Specification B880.

6. Mechanical Properties and Other Requirements

6.1 *Mechanical Properties*—The material shall conform to the mechanical properties specified in Table 3.

6.2 *Hardness*—When annealed ends are specified for tubing in the stress-relieved condition (see Table 3), the hardness of the ends after annealing shall not exceed the values specified in Table 3.

6.3 *Flare*—A flare test shall be made on one end of 1 % of the number of finished tube lengths from each lot. For less than 100 tubes in a lot, a flare test shall be made on one end of one tube length in the lot. In the case of stress relieved tubing with annealed ends, the test shall be made prior to, or subsequent to, annealing of the ends at the option of the manufacturer.

6.3.1 The flare test shall consist of flaring a test specimen with an expanding tool having an included angle of 60° until the specified outside diameter has been increased by 30 %. The flared specimen shall not exhibit cracking through the wall.

6.4 *Grain Size*—A transverse sample representing full-wall thickness of annealed alloys UNS N08120, UNS N08810 and UNS N08811 shall conform to an average grain size of ASTM No. 5 or coarser.

TABLE 3 Mechanical Properties of Tubes

Material and Condition	Tensile Strength, min, ksi (MPa)	Yield Strength (0.2 % Offset), min, ksi (MPa)	Elongation in 2 in. or 50 mm (or 4 *D*) min, %	Rockwell Hardness (or equivalent) for annealed ends[A]
Nickel UNS N02200:				
Annealed	55 (379)	15 (103)	40	...
Stress-relieved	65 (448)	40 (276)	15	B65 max
Low-carbon nickel UNS N02201:				
Annealed	50 (345)	12 (83)	40	...
Stress-relieved	60 (414)	30 (207)	15	B62 max
Nickel-copper alloy UNS N04400:				
Annealed	70 (483)	28 (193)	35	...
Stress-relieved	85 (586)	55 (379)	15	B75 max
Nickel-chromium-iron alloys:				
Annealed alloy UNS N06600	80 (552)	35 (241)	30	...
Annealed alloy UNS N06601	80 (552)	30 (207)	30	...
Annealed alloy UNS N06690	85 (586)	35 (241)	30	...
Annealed alloy UNS N06045	90 (620)	35 (240)	35	...
Annealed alloy UNS N06025	98 (680)	39 (270)	30	...
Annealed alloy UNS N06603	94 (650)	43 (300)	25	...
Annealed alloy UNS N06696	85 (586)	35 (240)	30	...
Low-carbon nickel-chromium-molybdenum-tungsten alloy:				
Annealed UNS N06686	100 (690)	45 (310)	45	...
Nickel-iron-chromium alloys:				
Annealed alloy UNS N08120	90 (620)	40 (276)	30	...
Annealed alloy UNS N08800	75 (517)	30 (207)	30	...
Annealed alloy UNS N08801	65 (448)	25 (172)	30	...
Cold-worked alloy UNS N08800	83 (572)	47 (324)	30	...
Annealed alloy UNS N08810	65 (448)	25 (172)	30	...
Annealed alloy UNS N08811	65 (448)	25 (172)	30	...
Nickel-iron-chromium-molybdenum alloy:				
Annealed alloy UNS N08935	109 (750)	62 (425)	35	...
Nickel-iron-chromium-molybdenum-copper alloys:				
Annealed UNS N08825	85 (586)	35 (241)	30	...
Annealed UNS N06845	100 (690)	40 (276)	30	...
Nickel-chromium-aluminum alloys:				
Annealed UNS N06699	89 (610)	35 (240)	40	...

[A] Rockwell or equivalent hardness values apply only to the annealed ends of stress-relieved tubing. Caution should be observed in using the Rockwell test on thin material, as the results may be affected by the thickness of specimen. For thickness under 0.050 in. (1.27 mm) the use of the Rockwell superficial or the Vickers hardness test is suggested. For hardness conversions for nickel and high-nickel alloys see Hardness Conversion Tables E140.

6.5 *Hydrostatic or Nondestructive Electric Test*—Each tube shall be subjected to either the hydrostatic test or the nondestructive electric test. The type of test to be used shall be at the option of the manufacturer, unless otherwise specified in the purchase order.

6.5.1 *Hydrostatic Test:*

6.5.1.1 Each tube with an outside diameter ⅛ in. (3.2 mm) and larger and tubes with wall thickness of 0.015 in. (0.38 mm) and over shall be tested by the manufacturer to an internal hydrostatic pressure of 1000 psi (6.9 MPa) provided that the fiber stress calculated in accordance with the following equation does not exceed the allowable fiber stress, *S*, indicated below. The tube shall show no evidence of leakage.

$$P = 2St/D$$

where:

- P = hydrostatic test pressure, psi (MPa),
- S = allowable fiber stress for material in the condition furnished, as follows:
- t = minimum wall thickness, in. (mm); equal to the specified average wall minus the permissible "minus" wall tolerance, Table 4 and Table X2.2, or the specified minimum wall thickness, and
- D = outside diameter of the tube, in. (mm).

	psi	MPa
Annealed low-carbon nickel UNS N02201	8 000	55.2
Stress-relieved low-carbon nickel UNS N02201	15 000	103.4
Annealed nickel UNS N02200	10 000	68.9
Stress-relieved nickel UNS N02200	16 200	111.7
Annealed nickel-copper alloy UNS N04400	17 500	120.6
Stress-relieved nickel-copper alloy UNS N04400	21 200	146.2
Annealed nickel-chromium-aluminum alloy UNS N06699	22 100	152
Annealed nickel-chromium-iron alloy UNS N06600	20 000	137.9
Annealed nickel-chromium-iron alloy UNS N06601	20 000	137.9
Annealed nickel-chromium-iron alloy UNS N06690	21 200	146
Annealed nickel-chromium-iron alloy UNS N06045	22 500	155
Annealed nickel-chromium-iron alloy UNS N06025	24 500	169
Solution annealed low-carbon nickel-chromium-molybdenum-tungsten alloy UNS N06686	25 000	172
Annealed nickel-chromium-iron-aluminum alloy UNS N06603	24 000	165
Annealed nickel-chromium-iron-copper alloy UNS N06696	21 200	146
Annealed nickel-iron-chromium alloy UNS N08120	22 500	155
Annealed nickel-iron-chromium alloy UNS N08800	18 700	128.9
Annealed nickel-iron-chromium alloy UNS N08810	16 600	114.4
Annealed nickel-iron-chromium alloy UNS N08811	16 600	114.4
Annealed nickel-iron-chromium alloy UNS N08801	16 600	114.4
Annealed nickel-iron-chromium-molybdenum alloy UNS N08935	27 200	187.5
Annealed nickel-iron-chromium-molybdenum copper alloy UNS N08825	21 000	144.8
Annealed nickel-iron-chromium-molydenum-copper alloy UNS N06845	21 200	146.2
Cold-worked nickel-iron-chromium alloy UNS N08800	20 700	142.7

TABLE 4 Permissible Variations in Outside Diameter and Wall Thickness of Condenser and Heat Exchanger Tubes

NOTE 1—The tolerances in the table apply to individual measurements of outside diameter and include out-of-roundness (ovality), and apply to all materials and all conditions, except that for thin wall tubes having a nominal wall of 3 % or less of the outside diameter, the mean outside diameter shall comply with the permissible variations of the above table and individual measurements (including ovality) shall conform to the plus and minus values of the table with the values increased by ½ % of the nominal outside diameter.

NOTE 2—*Eccentricity*—The variation in wall thickness in any one cross section of any one tube shall not exceed plus or minus 10 % of the actual (measured) average wall of that section. The actual average wall is defined as the average of the thickest and thinnest wall of that section.

NOTE 3—For tolerances of small diameter and light wall tube (converter sizes) see Appendix X2 (Table X2.2).

Material	Nominal Outside Diameter, in. (mm)	Permissible Variations[A]					
		Outside Diameter, in. (mm)		Wall Thickness,%			
				Average Wall		Minimum Wall	
		+	−	+	−	+	−
UNS N02200, UNS N02201, and UNS N04400	½ to ⅝ (12.7 to 15.9), excl	0.005 (0.13)	0	12.5	12.5	25.0	0
	⅝ to 1½ (15.9 to 38.1), incl	0.005 (0.13)	0.005 (0.13)	10.0	10.0	20.0	0
	over 1½ to 3 (38.1 to 76.2), incl	0.010 (0.25)	0.010 (0.25)	10.0	10.0	22.0	0
UNS N06600, UNS N06601, UNS N06690, UNS N06045, UNS N06025, UNS N06603, UNS N06696, UNS N08800, UNS N06699 UNS N08810, UNS N08811, UNS N08801, UNS N08935 UNS N08825, UNS N06845, and UNS N08120	½ to ⅝ (12.7 to 15.9), excl	0.005 (0.13)	0.005 (0.13)	12.5	12.5	25.0	0
UNS N06686	⅝ to 1½ (15.9 to 38.1), incl	0.0075 (0.19)	0.0075 (0.19)	10.0	10.0	20.0	0
	over 1½ to 3 (38.1 to 76.2), incl	0.010 (0.25)	0.010 (0.25)	10.0	10.0	22.0	0

[A] Wall variations as indicated above are applicable only to the wall as ordered, for instance, to minimum or to average wall, but not to both.

6.5.1.2 When so agreed upon between the manufacturer and the purchaser, tube may be tested to 1½ times the above allowable fiber stress.

6.5.1.3 When stress-relieved tubes with annealed ends are to be tested hydrostatically, such pressure testing shall be done prior to annealing of the ends of the tube.

6.5.2 *Nondestructive Electric Test*—Each tube shall be examined with a nondestructive electric test as prescribed in Specification B829.

7. Dimensions and Permissible Variations

7.1 *Outside Diameter and Wall Thickness*—The permissible variations in the outside diameter and wall thickness of tube shall not exceed those prescribed in Table 4 and Table X2.2, as applicable. (See also Table 5 and Table 6.)

7.2 *Length*—When tube is ordered cut-to-length, the length shall not be less than that specified, but a variation of plus ⅛ in. (3.2 mm) will be permitted, except that for lengths over 30 ft (9.1 m), a variation of plus ¼ in. (6.4 mm) will be permitted.

7.3 *Straightness*—Material shall be reasonably straight and free of bends or kinks.

8. Workmanship, Finish, and Appearance

8.1 The material shall be uniform in quality and temper, smooth, commercially straight, and free of injurious imperfections.

9. Sampling

9.1 *Lot*—Definition:

9.1.1 A lot for chemical analysis shall consist of one heat.

TABLE 5 Alloy,[A] Condition, Tube Size, and Bend Radii Limitations

Tube OD, in. (mm)	Average Tube Wall, in. (mm)[B]	Minimum Bend Radius, in. (mm)	
		Annealed Condition	Stress-Relieved Condition
Up to ½ (12.7), incl	0.046 to 0.057 (1.17 to 1.45), incl	1 3/16 (30.2)	1¼ (31.8)
Up to ½ (12.7), incl	Over 0.057 to 0.120 (1.45 to 3.05), incl	1 (25.4)	1⅛ (28.6)
Over ½ to ⅝ (12.7 to 15.9), incl	0.037 to 0.057 (0.94 to 1.45), incl	1 3/16 (30.2)	1¼ (31.8)
Over ½ to ⅝ (12.7 to 15.9), incl	Over 0.057 to 0.120 (1.45 to 3.05), incl	1 (25.4)	1 3/16 (30.2)
Over ⅝ to ¾ (15.9 to 19.0), incl	0.049 to 0.057 (1.24 to 1.45), incl	1¼ (31.8)	1½ (38.1)
Over ⅝ to ¾ (15.9 to 19.0), incl	Over 0.057 to 0.109 (1.45 to 2.77), incl	1 3/16 (30.2)	1¼ (31.8)
Over ¾ to 1 (19.0 to 25.4), incl	0.049 to 0.058 (1.24 to 1.47), incl	2 (50.8)	4 (101.6)
Over ¾ to 1 (19.0 to 25.4), incl	Over 0.058 to 0.109 (1.47 to 2.77), incl	1¾ (44.5)	2¼ (57.2)

[A] Applies for all alloys except alloy UNS N08810, alloy UNS N08801, and UNS N08811.

[B] To determine the bend radius applicable to minimum wall tubing, compute the corresponding average wall from the wall tolerances in Table 4, then use Table 5.

TABLE 6 Alloys, Size Ranges, and Yield Strength for Higher Yield Strength Tubes

Alloys	Size Range, in. (mm)		0.2 % Yield Strength, ksi (MPa)	
	OD	Wall Thickness	Minimum	Maximum
Nickel-chromium-iron Alloy UNS N06600	¼ to ⅞ (6.35 to 22.23)	Up to 0.100 (2.54)	40 (276)	65 (448)
Nickel-chromium-iron Alloy UNS N06601	¼ to ⅞ (6.35 to 22.23)	Up to 0.100 (2.54)	40 (276)	65 (449)
Nickel-iron-chromium Alloy UNS N08800	¼ to ⅞ (6.35 to 22.23)	Up to 0.100 (2.54)	40 (276)	65 (448)
Nickel-chromium-iron Alloy UNS N06690	¼ to ⅞ (6.35 to 22.23)	Up to 0.100 (2.54)	40 (276)	65 (448)

9.1.2 A lot for mechanical properties, hardness, flaring, and grain size testing shall consist of all material from the same heat, nominal size (except length), and condition (temper).

9.1.2.1 Where material cannot be identified by heat, a lot shall consist of not more than 500 lb (230 kg) of material in the same condition (temper) and size.

9.2 *Test Material Selection:*

9.2.1 *Chemical Analysis*—Representative samples shall be taken during pouring or subsequent processing.

9.2.1.1 Product (check) analysis shall be wholly the responsibility of the purchaser.

9.2.2 *Mechanical Properties, Hardness, and Grain Size*—Samples of the material to provide test specimens for mechanical properties, hardness, and grain size shall be taken from such locations in each lot as to be representative of that lot.

10. Number of Tests

10.1 *Chemical Analysis*—One test per lot.

10.2 *Mechanical Properties*—One test per lot.

10.3 *Hardness*—A representative sample consisting of 3 % of each lot of tubes with annealed ends (see 9.1.2).

10.4 *Grain Size*—One test per lot.

10.5 *Flare*—A representative sample consisting of 1 % of the number of tube lengths in each lot, with a minimum of one tube per lot.

11. Specimen Preparation

11.1 *Tension Test:*

11.1.1 Tension test specimens shall be taken from material in the final condition (temper) and tested in the direction of fabrication.

11.1.2 Whenever possible, all tubes shall be tested in full tubular size. When testing in full tubular size is not possible, longitudinal strip specimens, or the largest possible round specimen, shall be used. In the event of disagreement when full tubular testing is not possible, a longitudinal strip specimen with reduced gage length as contained in Test Methods E8/E8M shall be used.

11.1.3 In the case of stress-relieved tubes furnished with annealed ends, the tension test shall be made on the stress-relieved tubes prior to annealing the ends.

11.2 *Hardness Test:*

11.2.1 *Stress-Relieved Tubing with Annealed Ends*—The hardness test may be made on the inside of the tube near the end or on a specimen cut from the end, at the option of the manufacturer. The test shall be made on the inside of the specimen.

12. Test Methods

12.1 The chemical composition, mechanical, and other properties of the material as enumerated in this specification shall be determined, in case of disagreement, in accordance with the following methods:

Test	ASTM Designation
Chemical Analysis	E76, E1473
Tension	E8/E8M
Rounding Procedure	E29
Rockwell Hardness	E18
Grain Size	E112
Hardness Conversion	E140

12.2 The measurement of average grain size may be carried out by the planimetric method, the comparison method, or the intercept method described in Test Methods E112. In case of dispute the "referee" method for determining average grain size shall be the planimetric method.

12.3 For purposes of determining compliance with the specified limits for requirements of the properties listed in the following table, an observed value or a calculated value shall be rounded as indicated below, in accordance with the rounding method of Practice E29:

Test	Rounded Unit for Observed or Calculated Value
Chemical composition, hardness, and tolerances (when expressed in decimals)	nearest unit in the last right-hand place of figures of the specified limit
Tensile strength, yield strength	nearest 1000 psi (6.9 MPa)
Elongation	nearest 1 %
Grain size:	
0.0024 in. (0.060 mm) or larger	nearest multiple of 0.0002 in. (0.005 mm)
less than 0.0024 in. (0.060 mm)	nearest multiple of 0.0001 in. (0.002 mm)

13. Inspection

13.1 Inspection of the material shall be made as agreed upon between the manufacturer and the purchaser as part of the purchase contract.

14. Rejection and Rehearing

14.1 Material not conforming to this specification or to authorized modifications will be subject to rejection.

14.2 Samples tested in accordance with this specification that represent rejected material shall be preserved for not less than three weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

15. Certification

15.1 When specified in the purchase order or contract, a manufacturer's certification shall be furnished to the purchaser stating that material has been manufactured, tested, and inspected in accordance with this specification, and that the test