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Standard Specification for Seamless Nickel and Nickel Alloy (UNS N06845) 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 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.

~~1.4The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.~~

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 Material Safety Data Sheet (MSDS) for this product/material as provided by the manufacturer, to establish appropriate safety and health practices, and determine the applicability of regulatory limitations prior to use.*

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

2.2 *Federal Standards:*[4]

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

[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] Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098, http://www.dodssp.daps.mil.

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

TABLE 1 Chemical Requirements[A]

Alloy	Nickel02200	CopperN02201	Molyb-denumN04400	IronN06025	Manga-nese, maxN06045	Carbon[A]N06600	Silicon[A]N06601	Sulfur, maxN06603	Chro-miumN06686	Alum-inum	Titan-ium
Nickel UNS N02200	99.0 min[B]	0.25 max	—	0.40 max	0.35	0.15 max	0.35	0.01	...	...	...
Nickel Low-carbon Nickel UNS N02201	99.0 min[B]	0.25 max	—	0.40 max	0.35	0.15 max	0.35	0.01	...	...	...
Nickel-copper alloy UNS N04400	99.0 min[B]	0.25 max	—	0.40 max	0.35	0.02 max	0.35	0.01	...	...	...
Nickel-copper alloy UNS N04400	63.0 min[B]	28.0 to 34.0	...	2.5 max	2.0	0.3max	0.5	0.024	...	...	...
Nickel-chromium-iron alloy UNS N06600	72.0 min[B]	remainder[B]	45.0 min[B]	72.0 min[B]	58.0–63.0	remainder[B]	remainder[B]	0.024	...	...	...
Nickel-chromium-iron alloy UNS N06600	58.0 min[B]	—	6.0 to 10.0	1.0	0.15 max	0.5	0.015	14.0 to 17.0	...	...5	
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	...	
Nickel-chromium-iron alloy UNS N06601	58.0 to 63.0	1.0 max	—	8.0–11.0	21.0–25.0	6.0–10.0	remainder[A]	1.0	0.10	0.50	
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	0.015	21.0 to 25.0	1.0 to 1.7	...	...	...	...	...	...	...	...
Manganese	0.35	0.35	2.0	0.15	1.0	1.0	1.0	0.15	0.75	0...	...
Nickel-chromium-iron alloy UNS N06690	58.0 min[B]	0.5 max	—	7.0 to 11.0	0.5	0.05 max	0.5	0.015	27.0 to 31.0	...05	
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	...	...	...	...	...	...	...	...	...	...	
Silicon	0.35	0.35	0.5	0.5	2.5–3.0	0.5	0.5	0.5	0.08	0.5	
Nickel-chromium-iron alloy UNS N06025	remainder[B]	0.1 max	—	8.0 to11.0	0.15	0.15 to0.25	0.5	0.010	24.0 to 26.0	1.8 t015	
Sulfur	0.01	0.01	0.024	0.010	0.010	0.015	0.015	0.010	0.02	0.015	

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

	N06696	N06845	N08120	N08800	N08801	N08810	N08811	N08825
Nickel	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
Copper	1.5–3.0	2.0–4.0	0.50	0.75	0.50	0.75	0.75	1.5–3.0
Molybdenum	1.0–3.0	5.0–7.0	2.50	...	...	...	...	2.5–3.5
Iron	2.0–6.0	remainder[B]	remainder[B]	39.5 min[B]	39.5 min[B]	39.5 min[B]	39.5 min[B]	22.0 min[B]
Manganese	1.0	0.5	1.5	1.5	1.50	1.5	1.5	1.0
Carbon	0.15	0.05	0.02–0.10	0.10	0.10	0.05–0.10	0.06–0.10	0.05
Silicon	1.0–2.5	0.5	1.0	1.0	1.00	1.0	1.0	0.5
Sulfur	0.010	0.010	0.03	0.015	0.015	0.015	0.015	0.03
Chromium	28.0–32.0	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
Aluminum	...	...	0.40	0.15–0.60	...	0.15–0.60	0.15–0.60[C]	0.2
Titanium	1.0	...	0.20	0.15–0.60	0.75–1.5	0.15–0.60	0.15–0.60[C]	0.6–1.2
Phosphorus	...	...	0.04	...	...	...	...	...
Cerium	...	...	...	...	...	...	...	...
Zirconium	...	...	...	...	...	...	...	...
Yttrium	...	...	...	...	...	...	...	...
Boron	...	...	0.010	...	...	...	...	...
Cobalt	...	...	3.0	...	...	...	...	...
Columbium (Nb)	...	...	0.4–0.9	...	...	...	...	...
Tungsten	...	2.0–5.0	2.50	...	...	...	...	...
Nitrogen	...	...	0.13–0.30	...	...	...	...	...

[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] 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-copper alloy UNS N08825	annealed
Nickel-chromium-iron alloy UNS N06025	annealed
Nickel-iron-chromium-molybdenum-copper alloy UNS N06845	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.

2.3 *Military Standard:*[4]
MIL-STD-129 Marking for Shipment and Storage

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).

TABLE 3 Mechanical Properties of Tubes

Material and Condition	Tensile Strength, min, ksi (MPa)	Yield Strength (0.2 % Offset), min, psi (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-copper-alloy:*~~				
Nickel-iron-chromium-molybdenum-copper-alloys:				
Annealed UNS N08825	85 (586)	35 (241)	30	...
Annealed UNS N06845	100 (690)	40 (276)	30	...

[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.

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).~~ State if certification is required (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.

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.

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 N08810, UNS N08811, UNS N08801, ~~UNS N08825, and UNS N08120~~ 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 *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.