Designation: B166 – 19

Standard Specification for Nickel-Chromium-Aluminum Alloy, Nickel-Chromium-Iron Alloys, Nickel-Chromium-Cobalt-Molybdenum Alloy, Nickel-Iron-Chromium-Tungsten Alloy, and Nickel-Chromium-Molybdenum-Copper Alloy Rod, Bar, and Wire[1]

This standard is issued under the fixed designation B166; 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 nickel-chromium-aluminum alloy, nickel-chromium-iron alloys,[3] nickel-chromium-cobalt-molybdenum alloy, nickel-iron-chromium-tungsten alloy, and nickel-chromim-molybdenum-copper alloy in the form of hot-finished and cold-worked rounds, squares, hexagons, rectangles, and cold-worked wire.

1.2 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.

1.3 The following precautionary caveat pertains only to the test methods 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.*

1.4 *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:*[4]

B168 Specification for Nickel-Chromium-Aluminum Alloys (UNS N06699), Nickel-Chromium-Iron Alloys (UNS N06600, N06601, N06603, N06690, N06693, N06025, N06045, and N06696), Nickel-Chromium-Cobalt-Molybdenum Alloy (UNS N06617), Nickel-Iron-Chromium-Tungsten Alloy (UNS N06674), Plate, Sheet, and Strip

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

E38 Methods for Chemical Analysis of Nickel-Chromium and Nickel-Chromium-Iron Alloys (Withdrawn 1989)[5]

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

E527 Practice for Numbering Metals and Alloys in the Unified Numbering System (UNS)

[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 application see related Specification SB-166 in Section II of that Code.

[3] Designation established in accordance with Practice E527 and SAE J1086, Practice for Numbering Metals and Alloys (UNS).

[4] 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.

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

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

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

2.2 *Federal Standards:*[6]
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:*[6]
MIL-STD-129 Marking for Shipment and Storage

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*
3.1.1 *bar, n*—material of rectangular (flats), hexagonal, or square solid section up to and including 10 in. (254 mm) in width and ⅛ in. (3.2 mm) and over in thickness in straight lengths.

3.1.2 *rod, n*—material of round solid section furnished in straight lengths.
3.1.2.1 *Discussion*—Hot-worked rectangular bar in widths 10 in. and under may be furnished as hot-rolled plate with sheared or cut edges in accordance with Specification B168, provided the mechanical property requirements of this specification are met.

3.1.3 *wire, n*—a cold-worked solid product of uniform round cross section along its whole length, supplied in coil form.

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 Name or UNS Number*—see Table 1,
4.1.2 *ASTM Designation,* including year of issue,
4.1.3 *Section*—Rod (round), bar (square, hexagonal, or rectangular), or wire (round),
4.1.4 *Condition* (see Table 2 and Table 3),
4.1.5 *Finish,*
4.1.6 *Dimensions,* including length (see Tables 4-8),
4.1.7 *Quantity*—feet or number of pieces,
4.1.8 *Certification*—State if certification is required,
4.1.9 *Samples for Product (Check) Analysis*—State whether samples for product (check) analysis shall be furnished, and
4.1.10 *Purchaser Inspection*—If purchaser wishes to witness tests or inspection of material at place of manufacture, the purchase order must so state indicating which test or inspections are to be witnessed.

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 variations in Specification B880.

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

6. Mechanical Properties and Other Requirements

6.1 *Mechanical Properties*—The material shall conform to the mechanical properties specified in Table 2 for rod and bar and Table 3 (UNS N06600 and N06690 only) for wire.

6.2 *Grain Size:*
6.2.1 Grain size for N06674 shall be 7 or coarser as determined in accordance with Test Methods E112.

7. Dimensions and Permissible Variations

7.1 *Diameter, Thickness, or Width*—The permissible variations from the specified dimensions as measured on the diameter or between parallel surfaces of cold-worked rod and bar shall be as prescribed in Table 4; of hot-worked rod and bar as prescribed in Table 5; and of wire as prescribed in Table 6.

7.2 *Out-of-Round*—Hot-worked rods and cold-worked rods (except "forging quality") all sizes, in straight lengths, shall not be out-of-round by more than one half the total permissible variations in diameter shown in Table 4 and Table 5, except for hot-worked rods ½ in. (12.7 mm) in diameter and under, which may be out-of-round by the total permissible variations in diameter shown in Table 5. Cold-worked wire shall not be out-of-round by more than one-half the total permissible variations in diameter shown in Table 6.

7.3 *Corners*—Cold-worked bars will have practically exact angles and sharp corners.

7.4 *Machining Allowances for Hot-Worked Materials*—When the surfaces of hot-worked products are to be machined, the allowances prescribed in Table 7 are recommended for normal machining operations.

7.5 *Length*—The permissible variations in length of cold-worked and hot-worked rod and bar shall be as prescribed in Table 8.

7.5.1 Rods and bars ordered to random or nominal lengths will be furnished with either cropped or saw-cut ends; material ordered to cut lengths will be furnished with square saw-cut or machined ends.

7.6 *Straightness*—The permissible variations in straightness of cold-worked rod and bar as determined by the departure from straightness shall be as prescribed in Table 9.
7.6.1 The permissible variations in straightness of hot-worked rod and bar as determined by the departure from straightness shall be as specified in Table 10.

8. Workmanship, Finish, and Appearance

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

9. Sampling

9.1 *Lot—Definition:*
9.1.1 A lot for chemical analysis shall consist of one heat.
9.1.2 A lot for mechanical properties testing and other requirements shall consist of all material from the same heat, nominal diameter or thickness, and condition.

TABLE 1 Chemical Requirements[A]

Element	Composition Limits, %											
	Alloy N06600	Alloy N06601	Alloy N06617	Alloy N06674	Alloy N06690	Alloy N06693	Alloy N06025	Alloy N06045	Alloy N06603	Alloy N06696	Alloy N06699	Alloy N06235
Nickel	72.0 min	58.0–63.0	44.5 min	remainder[B]	58.0 min	remainder[B]	remainder[B]	45.0 min	remainder[B]	remainder[B]	remainder[B]	remainder[B]
Chromium	14.0–17.0	21.0–25.0	20.0–24.0	21.5–24.5	27.0–31.0	27.0–31.0	24.0-26.0	26.0-29.0	24.0-26.0	28.0-32.0	26.0-30.0	30.0-32.5
Cobalt	...	...	10.0–15.0	...	...	...	...	...	...	...	...	1.0 max
Molybdenum	...	...	8.0–10.0	...	...	...	...	...	...	1.0-3.0	...	5.0-6.2
Iron	6.0–10.0	remainder[B]	3.0 max	20.0–27.0	7.0–11.0	2.5–6.0	8.0–11.0	21.0-25.0	8.0-11.0	2.0-6.0	2.5 max	1.5 max
Manganese	1.0 max	1.0 max	1.0 max	1.50 max	0.5 max	1.0 max	0.15 max	1.0 max	0.15 max	1.0 max	0.50 max	0.3-0.65
Aluminum	...	1.0–1.7	0.8–1.5	...	...	2.5–4.0	1.8-2.4	...	2.4-3.0	...	1.9-3.0	0.2-0.4
Carbon	0.15 max	0.10 max	0.05–0.15	0.01 max	0.05 max	0.15 max	0.15-0.25	0.05-0.12	0.20-0.40	0.15 max	0.005-0.10	0.02-0.06
Copper	0.5 max	1.0 max	0.5 max	...	0.5 max	0.5 max	0.1 max	0.3 max	0.50 max	1.5-3.0	0.50 max	3.5-4.0
Silicon	0.5 max	0.5 max	1.0 max	1.0 max	0.5 max	0.5 max	0.5 max	2.5-3.0	0.50 max	1.0-2.5	0.50 max	0.2-0.6
Sulfur	0.015 max	0.015 max	0.015 max	0.015 max	0.015 max	0.01 max	0.010 max	0.010 max	0.010 max	0.010 max	0.01 max	0.015 max
Titanium	...	...	0.6 max	0.05–0.20	...	1.0 max	0.1-0.2	...	0.01-0.25	1.0 max	0.60 max	0.5 max
Phosphorus	...	...	...	0.030 max	...	...	0.020 max	0.020 max	0.20 max	...	0.02 max	0.03 max
Zirconium	...	...	...	...	...	...	0.01-0.10	...	0.01-0.10	...	0.10 max	...
Yttrium	...	...	...	...	...	...	0.05-0.12	...	0.01-0.15	...	...	...
Boron	...	...	0.006 max	0.0005–0.006	...	...	...	...	...	...	0.008 max	...
Nitrogen	...	...	...	0.02 max	...	...	...	...	...	...	0.05 max	...
Niobium	...	...	...	0.10–0.35	...	0.5–2.5	...	...	...	...	0.50 max	1.0 max
Cerium	...	...	...	...	...	...	...	0.03-0.09	...	...	...	...
Tungsten	...	...	...	6.0–8.0	...	...	...	...	...	...	...	0.60 max

[A] Where ellipses (...) appear in this table, there is no requirement, and the element need neither be analyzed for nor reported.
[B] Element shall be determined arithmetically by difference.

TABLE 2 Mechanical Properties of Rods and Bars

Condition and Diameter or Distance Between Parallel Surfaces, in. (mm)	Tensile Strength, min, psi (MPa)	Yield Strength (0.2 % offset), min, psi (MPa)	Elongation in 2 in. or 50 mm or 4*D*, min,%
UNS N06600:			
Cold-worked (as worked):			
Rounds:			
Under ½ (12.7)	120 000 (825)	90 000 (620)	7[A]
½ to 1 (12.7 to 25.4), incl	110 000 (760)	85 000 (585)	10
Over 1 to 2½ (25.4 to 63.5), incl	105 000 (725)	80 000 (550)	12
Squares, hexagons, and rectangles:			
¼ (6.4) and under	100 000 (690)	80 000 (550)	5[A]
Over ¼ to ½ (6.4 to 12.7), excl	95 000 (655)	70 000 (480)	7
Hot worked (as worked):			
Rounds:			
¼ to ½ (6.4 to 12.7), incl	95 000 (655)	45 000 (310)	20
Over ½ to 3 (12.7 to 76.2), incl	90 000 (620)	40 000 (275)	25
Over 3 (76.2)	85 000 (585)	35 000 (240)	30
Squares, hexagons, and rectangles:			
All sizes	85 000 (585)	35 000 (240)	20
Rings and disks[B]	—	—	—
Cold-worked (annealed) or hot-worked (annealed):			
Rods and bars, all sizes	80 000 (550)	35 000 (240)	30[A]
Rings and disks[C]	—	—	—
Forging Quality:			
All sizes	*D*	*D*	*D*
UNS N06601:			
Cold-worked (annealed) or hot-worked (annealed):			
All products, all sizes	80 000 (550)	30 000 (205)	30
Forging Quality:	*D*	*D*	*D*
UNS N06617:			
Cold-worked (annealed) or hot-worked (annealed):			
All products, all sizes	95 000 (655)	35 000 (240)	35
Forging Quality:	*D*	*D*	*D*
UNS N06674			
Cold-worked (annealed[E]) or hot-worked (annealed[E])	86 000 (590)	34 000 (235)	30
All products, all sizes			
Forging Quality:	*D*	*D*	*D*
UNS N06690:			
Cold-worked (as worked):			
Rounds:			
Under ½ (12.7)	120 000 (825)	90 000 (620)	7[A]
½ to 1 (12.7 to 25.4), incl	110 000 (760)	85 000 (585)	10
Over 1 to 2½ (25.4 to 63.5), incl	105 000 (725)	80 000 (550)	12
Squares, hexagons, and rectangles:			
¼ (6.4) and under	100 000 (690)	80 000 (550)	5[A]
Over ¼ to ½ (6.4 to 12.7), excl	95 000 (655)	70 000 (480)	7
Hot worked (as worked):			
Rounds:			
¼ to ½ (6.4 to 12.7), incl	95 000 (655)	45 000 (310)	20
Over ½ to 3 (12.7 to 76.2), incl	90 000 (620)	40 000 (275)	25
Over 3 (76.2)	85 000 (585)	35 000 (240)	30
Squares, hexagons, and rectangles:			
All sizes	85 000 (585)	35 000 (240)	20
Rings and disks[B]	—	—	—
Cold-worked (annealed) or hot-worked (annealed):			
Rods and bars, all sizes	85 000 (586)	35 000 (240)	30[A]
Rings and disks[C]	—	—	—
Forging Quality:			
All sizes	*D*	*D*	*D*
UNS N06693:			
Cold-worked (annealed) or hot-worked (annealed):			
Rods and bars, all sizes	100 000 (690)	50 000 (345)	30
Forging Quality:	*D*	*D*	*D*
All sizes			
UNS N06603:			
Cold-worked (annealed) or hot-worked (annealed):			
All products, all sizes	94 000 (650)	43 000 (300)	25
Forging Quality:			
All sizes	*D*	*D*	*D*
UNS N06025:			
Cold-worked (annealed) or hot-worked (annealed):			
All products, all sizes	98 000 (680)	39 000 (270)	30
Forging Quality:	*D*	*D*	*D*
All sizes			
UNS N06045:			
Cold-worked (annealed) or hot-worked (annealed):			

TABLE 2 *Continued*

Condition and Diameter or Distance Between Parallel Surfaces, in. (mm)	Tensile Strength, min, psi (MPa)	Yield Strength (0.2 % offset), min, psi (MPa)	Elongation in 2 in. or 50 mm or 4*D*, min,%
All products, all sizes	90 000 (620)	35 000 (240)	35
Hot-worked (Annealed):[F]			
Rods and bars, all sizes	75 000 (517)	30 000 (207)	30
Forging Quality:	[D]	[D]	[D]
All sizes			
UNS N06696			
Cold-worked (annealed and water quenched) or hot-worked (annealed and water quenched)	85 000 (586)	35 000 (240)	30
All products, all sizes			
UNS N06699:			
Cold-worked (annealed) or hot-worked (annealed):	89 000 (610)	35 000 (240)	40
All products, all sizes			
Forging Quality:	[D]	[D]	[D]
All sizes			
UNS N06235			
Cold-worked (annealed) or hot-worked (annealed):	90 000 (620)	35 000 (240)	35
All products, all sizes			
Forging Quality:	[D]	[D]	[D]
All sizes			

[A] Not applicable to diameters or cross sections under 3⁄32 in. (2.4 mm).
[B] Hardness B75 to B100, or equivalent.
[C] Hardness B75 to B95, or equivalent.
[D] Forging quality is furnished to chemical requirements and surface inspection only. No mechanical properties are required.
[E] Solution annealed at a minimum temperature of 2150°F (1175°C) followed by a water quench or rapidly cooled by other means.
[F] High-temperature annealed condition.

TABLE 3 Mechanical Properties of Cold-Worked Wire in Coil (Alloys N06600 and N06690 Only)[A]

Condition and Size, in, (mm)	Tensile Strength, psi (MPa)		Wrapping Test
	Min	Max	
Annealed			
Under 0.032 (0.81)	80 000 (552)	115 000 (793)	The wire shall be wrapped eight consecutive turns in a closed helix (pitch approximately equal to the diameter of the wire) around a mandrel as follows: (*1*) For all annealed and regular temper wire and for spring temper wire 0.229 in. (5.82 mm) and less: Same as diameter of wire. (*2*) For spring temper wire over 0.229 in. (5.82 mm): Twice the diameter of wire. The wire shall withstand the wrapping test without fracture or development of a pebbled or orange-peel surface.
0.032 (0.81) and over	80 000 (552)	105 000 (724)	
Cold-worked, regular temper, all sizes	120 000 (827)		
Cold-worked, spring temper		165 000 (1138)	
Up to 0.057 (1.45), incl	185 000 (1276)	...	
Over 0.057 (1.45) to 0.114 (2.90), incl	175 000 (1207)	...	
Over 0.114 (2.90) to 0.229 (5.82), incl	170 000 (1172)	...	
Over 0.229 (5.82) to 0.329 (8.36), incl	165 000 (1138)	...	
Over 0.329 (8.36) to 0.375 (9.53), incl	160 000 (1103)	...	
Over 0.375 (9.53) to 0.500 (12.7), incl	155 000 (1069)	...	
Over 0.500 (12.7) to 0.563 (14.3), incl	140 000 (965)	...	

[A] Properties are not applicable to wire after straightening and cutting.

9.1.2.1 Where material cannot be identified by heat, a lot shall consist of not more than 500 lb (227 kg) of material in the same size and condition.

9.2 *Test Material Selection:*

9.2.1 *Chemical Analysis*—Representative samples from each lot 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 and Other Requirements*—Samples of the material to provide test specimens for mechanical properties and other requirements 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 *Tension*—One test per lot.

10.3 *Hardness*—One test per lot (when required by Footnotes B or C in Table 2).

10.4 *Grain Size*—One test from one end of one bar or rod from each lot. See 9.1.2.

11. Specimen Preparation

11.1 Tension test specimens shall be taken from material in the final condition and tested in the direction of fabrication.