



Designation: B 166 – 04

Standard Specification for Nickel-Chromium-Iron Alloys (UNS N06600, N06601, N06603, N06690, N06693, N06025, and N06045)* and Nickel- Chromium-Cobalt-Molybdenum Alloy (UNS N06617) Rod, Bar, and Wire¹

This standard is issued under the fixed designation B 166; 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 specification² covers nickel-chromium-iron alloys (UNS N06600, N06601, N06603, N06690, N06693, N06025, and N06045)* and nickel-chromium-cobalt-molybdenum alloy (UNS N06617) 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 the standard. The values given in parentheses are for information only.

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 establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 ASTM Standards:³

B 168 Specification for Nickel-Chromium-Iron Alloys (UNS N06600, N06601, N06603, N06690, N06693, N06025, and N06045) and Nickel-Chromium-Cobalt-Molybdenum Alloy (UNS N06617) Plate, Sheet, and Strip
B 880 Specification for General Requirements for Chemical Check Analysis Limits for Nickel, Nickel Alloys and Cobalt Alloys

E 8 Test Methods for Tension Testing of Metallic Materials
E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials
E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
E 38 Methods for Chemical Analysis of Nickel-Chromium and Nickel-Chromium-Iron Alloys⁴
E 140 Hardness Conversion Tables for Metals
E 527 Practice for Numbering Metals and Alloys (UNS)
E 1473 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

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 *bar*—material of rectangular (flats), hexagonal, or square solid section up to and including 10 in. (254 mm) in width and 1/8 in. (3.2 mm) and over in thickness in straight lengths.

3.1.2 *rod*—material of round solid section furnished in straight lengths.

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 B 168, provided the mechanical property requirements of this specification are met.

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

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.

* New designation established in accordance with Practice E 527 and SAE J1086, Practice for Numbering Metals and Alloys (UNS).

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 Withdrawn.

⁵ Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098

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 B 880.

6. Mechanical Properties

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.

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.

TABLE 1 Chemical Requirements

Element	Composition Limits, %							
	Alloy N06600	Alloy N06601	Alloy N06617	Alloy N06690	Alloy N06693	Alloy N06025	Alloy N06045	Alloy N06603
Nickel	72.0 min	58.0–63.0	44.5 min	58.0 min	remainder ^A	remainder ^A	45.0 min	remainder ^A
Chromium	14.0–17.0	21.0–25.0	20.0–24.0	27.0–31.0	27.0–31.0	24.0–26.0	26.0–29.0	24.0–26.0
Cobalt	...	...	10.0–15.0	...	...	...	...	...
Molybdenum	...	...	8.0–10.0	...	...	...	...	...
Iron	6.0–10.0	remainder ^A	3.0 max	7.0–11.0	2.5–6.0	8.0–11.0	21.0–25.0	8.0–11.0
Manganese	1.0 max	1.0 max	1.0 max	0.5 max	1.0 max	0.15 max	1.0 max	0.15 max
Aluminum	...	1.0–1.7	0.8–1.5	...	2.5–4.0	1.8–2.4	...	2.4–3.0
Carbon	0.15 max	0.10 max	0.05–0.15	0.05 max	0.15 max	0.15–0.25	0.05–0.12	0.20–0.40
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
Silicon	0.5 max	0.5 max	1.0 max	0.5 max	0.5 max	0.5 max	2.5–3.0	0.50 max
Sulfur	0.015 max	0.015 max	0.015 max	0.015 max	0.01 max	0.010 max	0.010 max	0.010 max
Titanium	...	...	0.6 max	...	1.0 max	0.1–0.2	...	0.01–0.25
Phosphorus	...	...	...	...	...	0.020 max	0.020 max	0.20 max
Zirconium	...	...	...	...	...	0.01–0.10	...	0.01–0.10
Yttrium	...	...	...	...	...	0.05–0.12	...	0.01–0.15
Boron	...	...	0.006 max	...	...	...	...	...
Nitrogen	...	...	...	...	...	...	...	...
Niobium	...	...	...	...	0.5–2.5	...	...	...
Cerium	...	...	...	...	...	...	0.03–0.09	...

^AElement 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 4D, 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 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	85 000 (586)	40 000 (275)	30
Forging Quality:			
	D	D	D
UNS N06603:			
Cold-worked (annealed) or hot-worked (annealed):			
All products, all sizes	94 000 (650)	43 000 (300)	25
Forging Quality:			
	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
UNS N06045:			
Cold-worked (annealed) or hot-worked (annealed):			
All products, all sizes	90 000 (620)	35 000 (240)	35
Hot-worked (Annealed): ^E			
Rods and bars, all sizes	75 000 (517)	30 000 (207)	30

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 4D, min, %
Forging Quality: All sizes	D	D	D

^ANot applicable to diameters or cross sections under 3/32 in. (2.4 mm).

^BHardness B75 to B100, or equivalent.

^CHardness B75 to B95, or equivalent.

^DForging quality is furnished to chemical requirements and surface inspection only. No mechanical properties are required.

^EHigh-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)	...	

^AProperties are not applicable to wire after straightening and cutting.

TABLE 4 Permissible Variations in Diameter or Distance Between Parallel Surfaces of Cold-Worked Rod and Bar

Specified Dimension, in. (mm) ^A	Permissible Variations From Specified Dimension, in. (mm)	
	+	-
Rounds:		
1/16 (1.6) to 3/16 (4.8), excl	0	0.002 (0.05)
3/16 (4.8) to 1/2 (12.7), excl	0	0.003 (0.08)
1/2 (12.7) to 15/16 (23.8), incl	0.001 (0.03)	0.002 (0.05)
over 15/16 (23.8) to 1 1/16 (49.2), incl	0.0015 (0.04)	0.003 (0.08)
over 1 1/16 (49.2) to 2 1/2 (63.5), incl	0.002 (0.05)	0.004 (0.10)
Hexagons, squares, rectangles:		
1/2 (12.7) and less	0	0.004 (0.10)
over 1/2 (12.7) to 7/8 (22.2), incl	0	0.005 (0.13)
over 7/8 (22.2) to 1 1/4 (31.8), incl	0	0.007 (0.18)
over 1 1/4 (31.8) to 2 (50.8), incl	0	0.009 (0.23)

^ADimensions apply to diameter of rounds, to distance between parallel surfaces of hexagons and squares, and separately to width and thickness of rectangles.

TABLE 5 Permissible Variations in Diameter or Distance Between Parallel Surfaces of Hot-Worked Rod and Bar

Specified Dimension, in. (mm) ^A	Permissible Variations from Specified Dimensions, in. (mm)	
	+	-
Rod and bar, hot-worked:		
1 (25.4) and under	0.016 (0.41)	0.016 (0.41)
over 1 (25.4) to 2 (50.8), incl	0.031 (0.79)	0.016 (0.41)
over 2 (50.8) to 4 (101.6), incl	0.047 (1.19)	0.031 (0.79)
over 4 (101.6)	0.125 (3.18)	0.063 (1.60)
Rod, rough-turned or ground:		
under 1 (25.4)	0.005 (0.13)	0.005 (0.13)
1 (25.4) and over	0.031 (0.79)	0
Forging quality rod:^B		
Under 1 (25.4)	0.005 (0.13)	0.005 (0.13)
1 (25.4) and over	0.031 (0.79)	0

^ADimensions apply to diameter of rods, to distance between parallel surfaces of hexagons and squares, and separately to width and thickness of rectangles.

^BSpot grinding is permitted to remove minor surface imperfections. The depth of these spot ground areas shall not exceed 3 % of the diameter of the rod.

9.1.2 A lot for mechanical properties testing shall consist of all material from the same heat, nominal diameter or thickness, and condition.

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*—Samples of the material to provide test specimens for mechanical properties 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.