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Standard Specification for Precipitation Hardening Nickel-Copper-Aluminum Alloy (UNS N05500) Bar, Rod, Wire, Forgings, and Forging Stock[1]

This standard is issued under the fixed designation B865; 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 nickel-copper-aluminum alloy (UNS N05500) in the form of rounds, squares, hexagons, or rectangles, and forgings and forging stock, manufactured either by hot working or cold working, 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 *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:*[2]

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

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

E602 Test Method for Sharp-Notch Tension Testing with Cylindrical Specimens (Withdrawn 2010)[3]

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

2.2 *Federal Standards:*

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 Standards:*

MIL-STD-129 Marking for Shipment and Storage

MIL-STD-271 Nondestructive Testing Requirements for Metals

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.

3.1.3 *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 Orders for material to this specification should include the following information:

4.1.1 ASTM designation and year of issue,

4.1.2 Alloy name or UNS number (see Table 1),

4.1.3 Shape—rod (round) or bar (square, hexagonal, or rectangular),

4.1.3.1 Forging (sketch or drawing),

4.1.4 Dimensions, including length, (see Tables 2 and 3),

4.1.5 Condition (see Table 4, Table 5, and Table 6),

4.1.6 Forging stock—Specify if material is stock for reforging,

4.1.7 Finish,

[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 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.

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

TABLE 1 Chemical Requirements

Element	Composition Limits, %	Product (check) analysis variations, under min or over max, of the specified limit of element, %
Nickel[A]	63.0 min	0.45
Aluminum	2.30–3.15	0.20
Carbon	0.18 max	0.01
Iron	2.0 max	0.05
Manganese	1.5 max	0.04
Silicon	0.50 max	0.03
Titanium	0.35–0.85	0.03 min
		0.04 max
Sulfur	0.010 max	0.003
Copper	27.0–33.0	0.15 min
		0.20 max

[A] The nickel content shall be determined arithmetically by difference.

TABLE 2 Permissible Variations in Diameter or Distance Between Parallel Surfaces of Hot-Worked Rod and Bar[A]

Specified Dimension,[B] in. (mm)	Permissible Variations from Specified Dimensions, in. (mm)	
	Plus	Minus
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
Round rod, semi-smooth, machined:		
Over 3½ (88.9)	0.031 (0.79)	0
Round rod, smooth finished, machined:		
Over 3½ (88.9)	0	0.005 (0.13)
Forging quality bolt stock (rounds only):		
¼ (6.4), 5⁄16 (7.9)	0	0.0062 (0.16)
⅜ (9.5), 7⁄16 (11.1), ½ (12.7)	0	0.0066 (0.17)
9⁄16 (14.3), ⅝ (7.9), 11⁄16 (17.5), ¾ (19.1), 13⁄16 (20.6), ⅞ (22.2)	0	0.0082 (0.21)
5⁄16 (7.9), 1 (25.4)	0	0.0098 (0.25)
1 1⁄16 to 1½ (27.0 to 38.1), in 1⁄16 (1.6) increments	0	0.0112 (0.28)

[A] Not applicable to forging stock.
[B] Dimensions apply to diameter of rods, to distance between parallel surfaces of hexagons and squares, and separately to width and thickness of rectangles.

TABLE 3 Permissible Variations in Straightness of Precision Straightened Cold-Worked Shafting

Specified Dimension, in. (mm)	Standard Distance Between Supports, in. (mm)	Permissible Variations Throw In One Revolution From Straightness, in. (mm)
½ (12.7) to 15⁄16 (23.8), incl	42 (1070)	0.005 (0.13)
Over 15⁄16 (23.8) to 1 15⁄16 (49.2), incl	42 (1070)	0.006 (0.15)
Over 1 15⁄16 (49.2) to 2½ (63.5), incl	42 (1070)	0.007 (0.18)
Over 2½ (63.5) to 4 (101.6), incl	42 (1070)	0.008 (0.20)
¾ (19.0) to 15⁄16 (23.8), incl	Specified lengths of 3 to 10 ft (0.91 to 3.05 m)	0.004 (0.10) plus 0.0025 (0.064) for each foot, or fraction thereof, in excess of 3 ft (0.91 m)
Over 15⁄16 (23.8) to 4 (101.6), incl	Specified lengths of 20 ft (6.10 m) and less	0.005 (0.13) plus 0.0015 (0.038) for each foot, or fraction thereof, in excess of 3 ft (0.91 m)

TABLE 4 Mechanical Properties—Unaged[A] (Bar, Rod, Forgings)

Form	Condition	Hardness	
		Brinell 3000 kg, max	Rockwell, max
Rounds,[B] hexagons, squares, rectangles, and forgings	Hot-worked	245	C23
Hexagons	Cold-worked	260	C26
Rounds:			
¼ (6.4 mm) to 1 in. (25.4 mm), incl	Cold-worked	280	C29
Over 1 (25.4 mm) to 3 in. (76.2 mm), incl	Cold-worked	260	C26
Over 3 (76.2 mm) to 4 in. (101.6 mm), incl	Cold-worked	240	C22
Rounds, hexagons, squares, rectangles, and forgings	Hot-worked or cold-worked and annealed	185	B90

[A] No tensile tests are required except as provided for in 9.2.3.
[B] Rounds over 4¼ in. (108.0 mm) in diameter shall have hardness of 260 BHN, max.

4.1.8 Quantity—feet or number of pieces, and

4.1.9 Certification—State if certification or a report of test results is required (Section 15),

4.1.10 Samples for product (check) analysis—State whether samples for product (check) analysis should be furnished, and

4.1.11 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 Table 1.

6. Mechanical Properties

6.1 *Mechanical Properties*—The material in the unaged condition shall conform to the mechanical properties specified in Table 4. After aging the material shall conform to the mechanical properties specified in Table 5 and Table 6.

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 7; of hot-worked rod and bar as prescribed in Table 2; and of wire as prescribed in Table 7.

7.2 *Out-of-Round*—Hot-worked rods and cold-worked rods (except "forging quality") of 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 2 and Table 7, except for hot-worked rods ½ in. (12.7 mm) in diameter and under, which may be cut-of-round by the total permissible variations in diameter shown in Table 2. Cold-worked wire shall not be

TABLE 5 Mechanical Properties—Age-Hardened[A] (Bar, Rod, and Forgings)

Form	Condition	Maximum Section Thickness, in. (mm)	Tensile Strength, min, ksi (MPa)	Yield Strength[B], 0.2 % offset, min, ksi (MPa)	Elongation[B] in 2 in. or 4D, min,%	Hardness[C]	
						Brinell 3000 kg, min	Rockwell C, min
Rounds,[D] hexagons, squares, rectangles, and forgings[E]	Hot-worked and age-hardened	All sizes	140 (965)	100 (690)	20.0	265	27
Rounds	Cold-worked and age-hardened	¼ (6.4) to 1 (25.4), incl	145 (1000)	110 (760)	15.0	300	32
		over 1 (25.4) to 3 (76.2), incl	140 (965)	100 (690)	17.0	280	29
		over 3 (76.2) to 4 (101.6), incl	135 (930)	95 (655)	20.0	255	25
Hexagons	Cold-worked and age-hardened	¼ (6.4) to 2 (50.8), incl	140 (965)	100 (690)	15.0	265	27
Rounds, hexagons, squares, rectangles, and forgings	Annealed and age-hardened[F]	Up to 1 (25.4)	130 (895)	90 (620)	20.0	250	24
		1 (25.4) and over	130 (895)	85 (585)	20.0	250	24

[A] Age hardening heat treatment:

Age hardening shall be accomplished by holding at an aim temperature of 1100°F (595°C) for 8 to 16 h followed by furnace cooling to 900°F (480°C) at a rate of 15 to 25°F (10 to 15°C) per hour and then air cooling. An alternate procedure consists of holding at 1100°F (595°C) for up to 16 h, furnace cooling to 1000°F (540°C), holding for approximately 6 h, furnace cooling to 900°F (480°C), holding for approximately 8 h, and air cooling to room temperature.

(Mill age-hardened products have been precipitation heat treated by the manufacturer and further thermal treatment normally is not required. Hot-worked, cold-worked, or annealed material is normally age hardened by the purchaser after forming or machining.)

[B] Not applicable to subsize tensile specimens less than 0.250 in. (6.4 mm) in diameter.

[C] Hardness values are given for information only and are not the basis for acceptance or rejection.

[D] Rounds over 4¼ in. (108.0 mm) in diameter shall have an elongation in 2 in. (50.8 mm) or 4D of 17 %, min.

[E] When specified, for forged rings and discs, hardness measurements may be utilized in lieu of tensile test.

[F] Applicable to both hot-worked and cold-worked material.

TABLE 6 Tensile Strength of Cold-Drawn Wire in Coils

Condition and Size, in. (mm)	Tensile Strength, min, ksi (MPa)
Cold-worked, as-worked, all sizes	110–155 (760–1070)[A]
Cold-worked and annealed, all sizes	110 (760)[B]
Cold-worked, spring temper, as-drawn 0.057 (1.45) and less[C]	165 (1140)
Over 0.057 to 0.114 (1.45 to 2.90), incl	155 (1070)
Over 0.114 to 0.229 (2.90 to 5.82), incl	150 (1035)
Over 0.229 to 0.312 (5.82 to 7.92), incl	145 (1000)
Over 0.312 to 0.375 (7.92 to 9.52), incl	135 (930)
Over 0.375 to 0.437 (9.52 to 11.10), incl	125 (860)
Over 0.437 to 0.563 (11.10 to 14.30), incl	120 (825)
Cold-worked, annealed, and age-hardened,[D] all sizes	130 (895)
Cold-worked, as drawn, age-hardened,[D] all sizes	155 (1070)
Cold-worked, spring temper, and age-hardened[D]	
Up to 0.114 (2.90), incl	180 (1240)
Over 0.114 to 0.375 (2.90 to 9.52), incl	170 (1170)
Over 0.375 to 0.563 (9.52 to 14.30), incl	160 (1105)

[A] Maximum and minimum.

[B] Maximum.

[C] Applicable to material in coil. For material in straightened and cut lengths, deduct 15 ksi (105 MPa) from above values.

[D] Age hardening heat treatment:

Age hardening shall be accomplished by holding at an aim temperature of 1100°F (595°C) for 8 to 16 h followed by furnace cooling to 900°F (480°C) at a rate of 15 to 25°F (10 to 15°C) per hour and then air cooling. An alternate procedure consists of holding at 1100°F (595°C) for up to 16 h, furnace cooling to 1000°F (540°C), holding for approximately 6 h, furnace cooling to 900°F (480°C), holding for approximately 8 h, and air cooling to room temperature.

(Mill age-hardened products have been precipitation heat treated by the manufacturer and further thermal treatment is not normally required. Hot-worked, cold-worked, or annealed material is normally age hardened by the purchaser after forming or machining.)

TABLE 7 Permissible Variations in Diameter or Distance Between Parallel Surfaces of Cold-Worked Rod and Bar

Specified Dimension,[A] in. (mm)	Permissible Variations From Specified Dimension, in. (mm)	
	Plus	Minus
Rounds:		
1/16 (1.6) to 3/16 (4.8), excl	0	0.002 (0.05)
3/16 (4.8) to ½ (12.7), excl	0	0.003 (0.08)
½ (12.7) to 15/16 (23.8), incl	0	0.002 (0.05)[B]
Over 15/16 (23.8) to 1 15/16 (49.2), incl	0	0.003 (0.08)[B]
Over 1 15/16 (49.2) to 2½ (63.5), incl	0	0.004 (0.10)[B]
Over 2½ (63.5) to 3 (76.2), incl	0	0.005 (0.13)[B]
Over 3 (76.2) to 3½ (88.9), incl	0	0.006 (0.15)[B]
Over 3½ (88.9) to 4 (101.6), incl	0	0.007 (0.18)[B]
Hexagons, squares, rectangles:		
½ (12.7) and less	0	0.004 (0.10)
Over ½ (12.7) to ⅞ (22.2), incl	0	0.005 (0.13)
Over ⅞ (22.2) to 1¼ (31.8), incl	0	0.007 (0.18)
Over 1¼ (31.8) to 2 (50.8), incl	0	0.009 (0.23)

[A] Dimensions apply to diameter of rounds, to distance between parallel surfaces of hexagons and squares, and separately to width and thickness of rectangles.

[B] For cold-worked, age-hardened, bright finish shafting, an additional minus 0.002 (0.05) tolerance will be permitted.

out-of-round by more than one-half the total permissible variations in diameter shown in Table 7.

7.3 *Edges*—Square, rectangular, and hexagonal bar and rod shall have angles and corners consistent with commercial practice.

7.4 *Machining Allowances for Hot-Worked Materials*—When the surfaces of hot-worked products are to be machined, the allowances prescribed in Table 8 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 9.

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:*

7.6.1 The permissible variations in straightness of precision-straightened cold-worked rod and bar as determined by the departure from straightness shall be as specified in Table 3.