ASTM B865 / ASME SB865

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

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.

A. Chemical Composition :-

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

Table 1

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	0.2
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	0.03-0.04
Sulfur	0.010 max	0.003
Copper	27.0–33.0	0.15-0.20

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

B. Mechanical Properties :-

1. The material in the unaged condition shall conform to the mechanical properties specified in Table 2.
2. After aging the material shall conform to the mechanical properties specified in Table 3 and Table 4.

Table 2: 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:			
1⁄4 (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 for material ordered in the unaged condition.*

[B] *Rounds over 4(1/4) in. (108.0 mm) in diameter shall have hardness of 260 BHN, max.*

Table 3: 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	1⁄4 (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	1⁄4 (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 sub-size 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 41⁄4 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 4: 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.)

C. Length :-

1. The permissible variations in length of cold worked and hot-worked rod and bar shall be as prescribed in Table 5.

Table 5

Random mill lengths:	
Hot-worked	6 to 24 ft (1.83 to 7.31 m) long with not more than 25 weight % between 6 and 9 ft (1.83 and 2.74 m)[A]
Cold-worked	6 to 20 ft (1.83 to 6.1 m) long with not more than 25 weight % between 6 and 10 ft (1.83 and 3.05 m)
Multiple lengths	Furnished in multiples of a specified unit length, within the length limits indicated above. For each multiple, an allowance of 1⁄4 in. (6.4 mm) will be made for cutting, unless otherwise specified. At the manufacturer's option, individual specified unit lengths may be furnished.
Nominal lengths	Specified nominal lengths having a range of not less than 2 ft (610 mm) with no short lengths allowed[B]
Cut lengths	A specified length to which all rods and bars will be cut with a permissible variation of plus 1⁄8in. (3.2 mm), minus 0 for sizes 8 in. (203 mm) and less in diameter or distance between parallel surfaces. For larger sizes, the permissible variation shall be + 1⁄4 in. (6.4 mm), minus 0.

A For hot-worked sections weighing over 25 lb/ft (37 kg/m) and for smooth-forged products, all sections, short lengths down to 2 ft (610 mm) may be furnished.

B For cold-worked rods and bars under 1/2 in. (12.7 mm) in diameter or distance between parallel surfaces ordered to nominal or stock lengths with a 2 ft (610 mm) range, at least 93 % of such material shall be within the range specified; the balance may be in shorter lengths, but in no case shall lengths less than 4 ft (1220 mm) be furnished.

D. Test Methods :-

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:

Test	ASTM Designation
Chemical Analysis	E 1473
Tension	E 8
Rockwell Hardness	E 18
Hardness Conversion	E 140
Rounding Procedure	E 29

E. Supplementary Requirements :-

1. Chemical Composition:
   i. The chemical composition shall be per Table 1 plus modifications as per Table 6.

Table 6

Element	Composition Limits, %	Product (check) analysis variations, under min or over max, of the specified limit of element, %
Cobalt	0.25,max	0.03
Sulfur	0.006,max	0.003
Phosphorus	0.02,max	0.005
Zinc	0.02,max	0.003
Lead	0.006,max	0.002
Tin	0.006,max	0.002

2. Nondestructive Tests:
    i. When specified by the purchaser, each piece of each lot shall be inspected. The purchaser shall specify if one or both tests are required.
    ii. Ultrasonic Tests:
    Ultrasonic testing shall be performed in accordance with MIL Std. 271 and as per agreement between the purchaser and the supplier.
    iii. Liquid Penetrant Inspection:
    Liquid penetrant inspection shall be in accordance with MIL-STD-271.

3. Tension Test:
    i. The slow strain rate tensile test will determine if a lot of metal is susceptible to intergranular cracking.
    ii. The tensile test shall be conducted in accordance with Test Methods E 8 at a temperature to be agreed upon between the supplier and the purchaser. If no testing temperature is specified by the purchaser, then the sample shall be tested at 400°F (205°C).
    iii. The average grain size from the half of the slow strain rate tensile specimen not used for fracture surface analysis in accordance with point E.3.iv, shall be used for determination as specified in Test Methods E 112.
    iv. Fracture Surface Analysis— After fracture, the fracture surface of each specimen shall be examined and the fracture mode characterized as follows:
        a. Fracture Surface Photography.
        b. Determination of Intergranular Fracture Sites.
        c. Quantification of Intergranular Fracture Sites.

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