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

This standard is issued under the fixed designation B 865; 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 the standard. The values given in parentheses are for
information only.

2. Referenced Documents
2.1 ASTM Standards: 2
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 112 Test Methods for Determining the Average Grain
Size
E 140 Hardness Conversion Tables for Metals
E 602 Test Method for Sharp-Notch Tension Testing with
Cylindrical Specimens
E 1473 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
Mats

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 ½ 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 reforg-
ing,
4.1.7 Finish,
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 inspec-
tions are to be witnessed.

5. Chemical Composition
5.1 The material shall conform to the composition limits
specified in Table 1.
TABLE 1 Chemical Requirements

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

*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

<table>
<thead>
<tr>
<th>Specified Dimension, in. (mm)</th>
<th>Permissible Variations from Specified Dimensions, in. (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Plus</td>
</tr>
<tr>
<td>Rod and bar, hot worked:</td>
<td></td>
</tr>
<tr>
<td>1 (25.4) and under</td>
<td>0.016 (0.41)</td>
</tr>
<tr>
<td>Over 1 (25.4) to 2 (50.8), incl</td>
<td>0.031 (0.79)</td>
</tr>
<tr>
<td>Over 2 (50.8) to 4 (101.6), incl</td>
<td>0.047 (1.19)</td>
</tr>
<tr>
<td>Over 4 (101.6)</td>
<td>0.125 (3.18)</td>
</tr>
<tr>
<td>Rod, rough-turned or ground:</td>
<td></td>
</tr>
<tr>
<td>Under 1 (25.4)</td>
<td>0.005 (0.13)</td>
</tr>
<tr>
<td>1 (25.4) and over</td>
<td>0.031 (0.79)</td>
</tr>
<tr>
<td>Round rod, semi-smooth, machined:</td>
<td></td>
</tr>
<tr>
<td>Over 3 1/2 (88.9)</td>
<td>0.031 (0.79)</td>
</tr>
<tr>
<td>Round rod, smooth finished, machined:</td>
<td></td>
</tr>
<tr>
<td>Over 3 1/2 (88.9)</td>
<td>0</td>
</tr>
<tr>
<td>Forging quality bolt stock (rounds only):</td>
<td></td>
</tr>
<tr>
<td>1/4 (6.4), 5/16 (7.9)</td>
<td>0</td>
</tr>
<tr>
<td>5/32 (9.5), 1/8 (11.1), 1/8 (12.7)</td>
<td>0</td>
</tr>
<tr>
<td>3/32 (14.3), 1/16 (7.9), 1/16 (17.5), 1/16 (19.1), 1/16 (20.6), 1/16 (22.2)</td>
<td>0</td>
</tr>
<tr>
<td>1/8 (7.9), 1 (25.4)</td>
<td>0</td>
</tr>
<tr>
<td>1/16 to 1/8 (27.0 to 38.1), in 1/16 (1.6) increments</td>
<td>0</td>
</tr>
</tbody>
</table>

*Not applicable to forging stock.

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

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 1/2 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 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:
TABLE 5 Mechanical Properties—Age-Hardened<sup>d</sup> (Bar, Rod, and Forgings)

<table>
<thead>
<tr>
<th>Form, Condition</th>
<th>Tensile Strength, min, ksi (MPa)</th>
<th>Yield Strength&lt;sup&gt;b&lt;/sup&gt;, 0.2 % offset, min, ksi (MPa)</th>
<th>Elongation&lt;sup&gt;b&lt;/sup&gt; in 2 in. or 4D, min,%</th>
<th>Hardness&lt;sup&gt;c&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rounds, hexagons, squares, Hot-worked and age-hardened</td>
<td>140 (965)</td>
<td>100 (690)</td>
<td>20.0</td>
<td>265</td>
</tr>
<tr>
<td>Cold-worked and age-hardened</td>
<td>145 (1000)</td>
<td>110 (760)</td>
<td>15.0</td>
<td>300</td>
</tr>
<tr>
<td>Over 1 (25.4), incl</td>
<td>140 (965)</td>
<td>100 (690)</td>
<td>17.0</td>
<td>280</td>
</tr>
<tr>
<td>Over 3 (76.2), incl</td>
<td>135 (930)</td>
<td>95 (655)</td>
<td>20.0</td>
<td>255</td>
</tr>
<tr>
<td>Over 6 (151.6), incl</td>
<td>140 (965)</td>
<td>100 (690)</td>
<td>15.0</td>
<td>265</td>
</tr>
<tr>
<td>Hexagons, hexagons, squares, Cold-worked and age-hardened</td>
<td>140 (965)</td>
<td>90 (620)</td>
<td>20.0</td>
<td>250</td>
</tr>
<tr>
<td>Cold-worked and age-hardened</td>
<td>130 (895)</td>
<td>85 (585)</td>
<td>20.0</td>
<td>250</td>
</tr>
</tbody>
</table>

<sup>a</sup>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.)

<sup>b</sup>Hardness values are given for information only and are not the basis for acceptance or rejection.

<sup>c</sup>Not applicable to subsize tensile specimens less than 0.250 in. (6.4 mm) in diameter.

<sup>d</sup>Applicable to both hot-worked and cold-worked material.

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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.

7.6.2 The permissible variations in straightness of hot-worked, cold-worked, rough-turned, and machined rod and bar as determined by the departure from straightness shall be as specified in Table 10.

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TABLE 6 Tensile Strength of Cold-Drawn Wire in Coils

<table>
<thead>
<tr>
<th>Condition and Size, in. (mm)</th>
<th>Tensile Strength, min, ksi (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold-worked, as-drawn, all sizes</td>
<td>110–155 (760–1070)&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Cold-worked and annealed, all sizes</td>
<td>110 (760)&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Cold-worked, spring temper, as-drawn 0.057 (1.45) and less&lt;sup&gt;c&lt;/sup&gt;</td>
<td>165 (1140)</td>
</tr>
<tr>
<td>Over 0.057 to 0.114 (1.45 to 2.90), incl</td>
<td>155 (1070)</td>
</tr>
<tr>
<td>Over 0.114 to 0.229 (2.90 to 5.82), incl</td>
<td>150 (1035)</td>
</tr>
<tr>
<td>Over 0.229 to 0.312 (5.82 to 7.92), incl</td>
<td>145 (1000)</td>
</tr>
<tr>
<td>Over 0.312 to 0.375 (7.92 to 9.52), incl</td>
<td>135 (930)</td>
</tr>
<tr>
<td>Over 0.375 to 0.437 (9.52 to 11.10), incl</td>
<td>125 (860)</td>
</tr>
<tr>
<td>Over 0.437 to 0.563 (11.10 to 14.30), incl</td>
<td>120 (825)</td>
</tr>
<tr>
<td>Cold-worked, annealed, and age-hardened&lt;sup&gt;d&lt;/sup&gt;, all sizes</td>
<td>130 (895)</td>
</tr>
<tr>
<td>Cold-worked, as drawn, age-hardened&lt;sup&gt;d&lt;/sup&gt;, all sizes</td>
<td>155 (1070)</td>
</tr>
<tr>
<td>Cold-worked, spring temper, and age-hardened&lt;sup&gt;d&lt;/sup&gt;</td>
<td>180 (1240)</td>
</tr>
<tr>
<td>Over 0.114 (2.90), incl</td>
<td>170 (1170)</td>
</tr>
<tr>
<td>Over 0.375 (9.52) to 5.92, incl</td>
<td>160 (1105)</td>
</tr>
</tbody>
</table>

<sup>a</sup>Maximum and minimum.

<sup>b</sup>Maximum.

<sup>c</sup>Applicable to material in coil. For material in straightened and cut lengths, deduct 15 ksi (105 MPa) from above values.

<sup>d</sup>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.)

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7.6.2.1 In determining straightness in the standard 42-in. (1.07-mm) distance between supports or, when specified, in determining straightness in length not in excess of those shown in Table 3, the rod shall be placed on a precision table equipped with ball bearing rollers and a micrometer or dial indicator. The rod then shall be rotated slowly against the indicator, and the deviation from straightness in any portion of the rod between the supports shall not exceed the permissible variations prescribed in Table 10. The deviation from straightness (throw in one revolution) is defined as the difference between the maximum and minimum readings of the dial indicator in one complete revolution of the rod.

7.7 Forging—Dimensions and tolerances shall be as specified on the order, sketch, or drawing.

7.8 Forging Stock—Dimensions and tolerances shall be as agreed upon between the purchaser and the manufacturer.
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 shall consist of all material from the same heat, same nominal cross-sectional or forgings size, and condition.

9.1.2.1 A lot for forging stock shall consist of one heat.

9.1.2.2 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.

9.2.3 Unaged Material—For material ordered in the unaged condition, one test specimen shall be taken from each lot as defined in 9.1.2. The specimen shall be obtained from the actual material to be shipped or from a forged test coupon when applicable. The specimen shall be aged, or annealed and aged, as required by either applicable Table 5 or Table 6. Tests need not be repeated when unaged material from the same heat can be identified with a lot that has been tested in the specified condition and found to meet the requirements of this specification.

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.

11. Specimen Preparation

11.1 Rod and Bar:

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

11.1.2 All rod, bar, and wire shall be tested in full cross section size when possible. When a full cross section size test cannot be performed, the largest possible round specimen shown in Test Methods E 8 shall be used. Longitudinal strip
specimens shall be prepared in accordance with Test Methods E 8 for rectangular bar up to \( \frac{1}{2} \) in. (12.7 mm), inclusive, in thicknesses that are too wide to be pulled full size.

11.1.3 Forging stock test specimens shall be taken from a forged-down coupon or a sample taken directly from stock.

11.2 Forgings:

11.2.1 The tension test specimen representing each lot shall be taken from a forging or from a test prolongation.

11.2.2 The axis of the specimen shall be located at any point midway between the center and the surface of solid forgings and at any point midway between the inner and outer surfaces of the wall of hollow forgings, and shall be parallel to the direction of greatest metal flow.

11.2.3 The specimens shall be the largest possible round type as prescribed in Test Methods E 8.

11.3 Hardness test specimens shall be taken from material in the final condition.

**Note 1**—In order that the hardness determinations may be in reasonably close agreement, the following procedures are recommended:

1. For rod less than \( \frac{1}{2} \) in. (12.7 mm) in diameter, hardness readings shall be taken on a flat surface prepared by filing or grinding approximately \( \frac{1}{16} \) in. (1.6 mm) from the outside surface of the rod.

2. For rod \( \frac{1}{2} \) in. (12.7 mm) in diameter and larger, and for hexagonal, square, and rectangular bar, all sizes, hardness readings shall be taken on a cross section midway between the surface and center of the section.

12. Test Methods

12.1 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:

<table>
<thead>
<tr>
<th>Test</th>
<th>ASTM Designation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical Analysis</td>
<td>E 1473</td>
</tr>
<tr>
<td>Tension</td>
<td>E 8</td>
</tr>
<tr>
<td>Rockwell Hardness</td>
<td>E 18</td>
</tr>
<tr>
<td>Hardness Conversion</td>
<td>E 140</td>
</tr>
<tr>
<td>Rounding Procedure</td>
<td>E 29</td>
</tr>
</tbody>
</table>

12.2 For purposes of determining compliance with the specified limits for requirements of the properties listed in the following table, an observed value or a calculated value shall be rounded in accordance with the rounding method of Practice E 29 as follows:

<table>
<thead>
<tr>
<th>Test</th>
<th>Rounded Unit for Observed or Calculated Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical composition, hardness,</td>
<td>Nearest unit in the last right-hand place and tolerances (when expressed in figures of the specified limit. If two decimals)</td>
</tr>
<tr>
<td>and tolerances (when expressed in</td>
<td>choices are possible, as when the digits dropped are exactly a 5 or a 5 followed only by zeros, choose the one ending in an even digit, with zero defined as an even digit.</td>
</tr>
<tr>
<td>Tensile strength and yield strength</td>
<td>nearest 1000 psi (6.9 MPa)</td>
</tr>
<tr>
<td>Elongation</td>
<td>nearest 1%</td>
</tr>
</tbody>
</table>

13. Inspection

13.1 Inspection of the material shall be conducted as agreed upon between the manufacturer and the purchaser as part of the purchase contract.

14. Rejection and Rehearing

14.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the manufacturer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the manufacturer or supplier may make claim for a rehearing.

15. Certification

15.1 When specified in the purchase order or contract, a manufacturer’s certification shall be furnished to the purchaser stating that the material has been manufactured, tested, and inspected in accordance with this specification, and that the test results on representative samples meet specification requirements. When specified in the purchase order or contract, a report of the test results shall be furnished.

16. Product Marking

16.1 The following shall be marked on the material or included on the package, or on a label or tag attached thereto:

16.1.1 The name of the material or UNS Number,
16.1.2 Heat number,
16.1.3 Condition (temper),
16.1.4 This specification number and year of issue,
16.1.5 The size,
16.1.6 Gross, tare, and net weights,
16.1.7 Consignor and consignee address, and
16.1.8 Contract or order number or such other information as may be defined in the contract or order.

17. Keywords

17.1 bar; forgings; precipitation; rod; UNS N05500; wire
S1. Special End Uses

S1.1 When material is intended for nuclear applications or other critical end uses, or when any special requirements are to apply, the manufacturer shall be notified at the time of placement of the inquiry or order to determine if material of quality and inspection procedures normally employed for commercial material to this specification is adequate. In the event that more critical quality or more rigid inspection standards than those called out in this specification are indicated, the manufacturer and the purchaser shall agree upon such standards prior to production.