



# Standard Specification for Nickel-Chromium-Iron Alloys (UNS N06600, N06601, N06603, N06690, N06693, N06025, N06045, and N06696), Nickel- Chromium-Cobalt-Molybdenum Alloy (UNS N06617), and Nickel-Iron-Chromium-Tungsten Alloy (UNS N06674) Rod, Bar, and Wire<sup>1</sup>

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 reappraisal. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reappraisal.

*This standard has been approved for use by agencies of the U.S. Department of Defense.*

## 1. Scope\*

1.1 This specification<sup>2</sup> covers nickel-chromium-iron alloys (UNS N06600, N06601, N06603, N06690, N06693, N06025, N06045, and N06696),\* nickel-chromium-cobalt-molybdenum alloy (UNS N06617), and nickel-iron-chromium-tungsten (UNS N06674) 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 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.*

<sup>1</sup> 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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<sup>2</sup> For ASME Boiler and Pressure Vessel Code application see related Specification SB-166 in Section II of that Code.

\* Designation established in accordance with Practice E527 and SAE J1086, Practice for Numbering Metals and Alloys (UNS).

## 2. Referenced Documents

### 2.1 ASTM Standards:<sup>3</sup>

- B168 Specification for Nickel-Chromium-Iron Alloys (UNS N06600, N06601, N06603, N06690, N06693, N06025, N06045, and N06696), Nickel-Chromium-Cobalt-Molybdenum Alloy (UNS N06617), and 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 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)<sup>4</sup>
- 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)
- E1473 Test Methods for Chemical Analysis of Nickel,

<sup>3</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

<sup>4</sup> The last approved version of this historical standard is referenced on [www.astm.org](http://www.astm.org).

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

## Cobalt, and High-Temperature Alloys

### 2.2 Federal Standards:<sup>5</sup>

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:<sup>5</sup>

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 1/8 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.

<sup>5</sup> Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098, <http://www.dodssp.daps.mil>.

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. 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 1/2 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<sup>A</sup>**

| Element    | Composition Limits, % |                        |              |                        |              |                        |                        |              |                        |                        |  |
|------------|-----------------------|------------------------|--------------|------------------------|--------------|------------------------|------------------------|--------------|------------------------|------------------------|--|
|            | Alloy N06600          | Alloy N06601           | Alloy N06617 | Alloy N06674           | Alloy N06690 | Alloy N06693           | Alloy N06025           | Alloy N06045 | Alloy N06603           | Alloy N06696           |  |
| Nickel     | 72.0 min              | 58.0–63.0              | 44.5 min     | remainder <sup>B</sup> | 58.0 min     | remainder <sup>B</sup> | remainder <sup>B</sup> | 45.0 min     | remainder <sup>B</sup> | remainder <sup>B</sup> |  |
| 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              |  |
| Cobalt     | ...                   | ...                    | 10.0–15.0    | ...                    | ...          | ...                    | ...                    | ...          | ...                    | ...                    |  |
| Molybdenum | ...                   | ...                    | 8.0–10.0     | ...                    | ...          | ...                    | ...                    | ...          | ...                    | ...                    |  |
| Iron       | 6.0–10.0              | remainder <sup>B</sup> | 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               | 1.0–3.0                |  |
| 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               | 2.0–6.0                |  |
| Aluminum   | ...                   | 1.0–1.7                | 0.8–1.5      | ...                    | ...          | 2.5–4.0                | 1.8–2.4                | ...          | 2.4–3.0                | 1.0 max                |  |
| 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              | ...                    |  |
| 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               | 0.15 max               |  |
| 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               | 1.5–3.0                |  |
| 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              | 1.0–2.5                |  |
| Titanium   | ...                   | ...                    | 0.6 max      | 0.05–0.20              | ...          | 1.0 max                | 0.1–0.2                | ...          | 0.01–0.25              | 0.010 max              |  |
| Phosphorus | ...                   | ...                    | ...          | 0.030 max              | ...          | ...                    | 0.020 max              | 0.020 max    | 0.20 max               | 1.0 max                |  |
| Zirconium  | ...                   | ...                    | ...          | ...                    | ...          | ...                    | 0.01–0.10              | ...          | 0.01–0.10              | ...                    |  |
| Yttrium    | ...                   | ...                    | ...          | ...                    | ...          | ...                    | 0.05–0.12              | ...          | 0.01–0.15              | ...                    |  |
| Boron      | ...                   | ...                    | 0.006 max    | 0.0005–0.006           | ...          | ...                    | ...                    | ...          | ...                    | ...                    |  |
| Nitrogen   | ...                   | ...                    | ...          | 0.02 max               | ...          | ...                    | ...                    | ...          | ...                    | ...                    |  |
| Niobium    | ...                   | ...                    | ...          | 0.10–0.35              | ...          | 0.5–2.5                | ...                    | ...          | ...                    | ...                    |  |
| Cerium     | ...                   | ...                    | ...          | ...                    | ...          | ...                    | ...                    | ...          | ...                    | ...                    |  |
| Tungsten   | ...                   | ...                    | ...          | 6.0–8.0                | ...          | ...                    | ...                    | 0.03–0.09    | ...                    | ...                    |  |

<sup>A</sup> Where ellipses (...) appear in this table, there is no requirement, and the element need neither be analyzed for nor reported.

<sup>B</sup> Element shall be determined arithmetically by difference.

**TABLE 2 Mechanical Properties of Rods and Bars**

| Condition and Diameter or Distance<br>Between Parallel Surfaces, in. (mm)    | Tensile Strength,<br>min, psi (MPa) | Yield Strength (0.2 %<br>offset), min, psi (MPa) | Elongation in 2 in. or<br>50 mm or 4D, min,% |
|--|-------------------------------------|--|--|
| <i>UNS N06600:</i>   |                                     |  |  |
| Cold-worked (as worked):   |                                     |  |  |
| Rounds:  |                                     |  |  |
| Under ½ (12.7)   | 120 000 (825)                       | 90 000 (620)                                     | 7 <sup>A</sup>                               |
| 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 <sup>A</sup>                               |
| 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 <sup>B</sup>   | —                                   | —  | —  |
| Cold-worked (annealed) or hot-worked (annealed):                             |                                     |  |  |
| Rods and bars, all sizes   | 80 000 (550)                        | 35 000 (240)                                     | 30 <sup>A</sup>                              |
| Rings and disks <sup>C</sup>   | —                                   | —  | —  |
| Forging Quality:   |                                     |  |  |
| All sizes  | <i>D</i>                            | <i>D</i>   | <i>D</i>                                     |
| <i>UNS N06601:</i>   |                                     |  |  |
| Cold-worked (annealed) or hot-worked (annealed):                             |                                     |  |  |
| All products, all sizes  | 80 000 (550)                        | 30 000 (205)                                     | 30   |
| Forging Quality:   |                                     |  |  |
| All sizes  | <i>D</i>                            | <i>D</i>   | <i>D</i>                                     |
| <i>UNS N06617:</i>   |                                     |  |  |
| Cold-worked (annealed) or hot-worked (annealed):                             |                                     |  |  |
| All products, all sizes  | 95 000 (655)                        | 35 000 (240)                                     | 35   |
| Forging Quality:   |                                     |  |  |
| All sizes  | <i>D</i>                            | <i>D</i>   | <i>D</i>                                     |
| <i>UNS N06674</i>  |                                     |  |  |
| Cold-worked (annealed <sup>E</sup> ) or hot-worked (annealed <sup>E</sup> ): |                                     |  |  |
| All products, all sizes  | 86 000 (590)                        | 34 000 (235)                                     | 30   |
| Forging Quality:   |                                     |  |  |
| All sizes  | <i>D</i>                            | <i>D</i>   | <i>D</i>                                     |
| <i>UNS N06690:</i>   |                                     |  |  |
| Cold-worked (as worked):   |                                     |  |  |
| Rounds:  |                                     |  |  |
| Under ½ (12.7)   | 120 000 (825)                       | 90 000 (620)                                     | 7 <sup>A</sup>                               |
| 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 <sup>A</sup>                               |
| 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 <sup>B</sup>   | —                                   | —  | —  |
| Cold-worked (annealed) or hot-worked (annealed):                             |                                     |  |  |
| Rods and bars, all sizes   | 85 000 (586)                        | 35 000 (240)                                     | 30 <sup>A</sup>                              |
| Rings and disks <sup>C</sup>   | —                                   | —  | —  |
| Forging Quality:   |                                     |  |  |
| All sizes  | <i>D</i>                            | <i>D</i>   | <i>D</i>                                     |
| <i>UNS N06693:</i>   |                                     |  |  |
| Cold-worked (annealed) or hot-worked (annealed):                             |                                     |  |  |
| Rods and bars, all sizes   | 100 000 (690)                       | 50 000 (345)                                     | 30   |
| Forging Quality:   |                                     |  |  |
| All sizes  | <i>D</i>                            | <i>D</i>   | <i>D</i>                                     |
| <i>UNS N06603:</i>   |                                     |  |  |
| Cold-worked (annealed) or hot-worked (annealed):                             |                                     |  |  |
| All products, all sizes  | 94 000 (650)                        | 43 000 (300)                                     | 25   |
| Forging Quality:   |                                     |  |  |
| All sizes  | <i>D</i>                            | <i>D</i>   | <i>D</i>                                     |
| <i>UNS N06025:</i>   |                                     |  |  |
| Cold-worked (annealed) or hot-worked (annealed):                             |                                     |  |  |
| All products, all sizes  | 98 000 (680)                        | 39 000 (270)                                     | 30   |
| Forging Quality:   |                                     |  |  |
| All sizes  | <i>D</i>                            | <i>D</i>   | <i>D</i>                                     |
| <i>UNS N06045:</i>   |                                     |  |  |

**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,% |
|--|----------------------------------|---|---|
| Cold-worked (annealed) or hot-worked (annealed):<br>All products, all sizes                                      | 90 000 (620)                     | 35 000 (240)                                  | 35  |
| Hot-worked (Annealed): <sup>F</sup><br>Rods and bars, all sizes  | 75 000 (517)                     | 30 000 (207)                                  | 30  |
| Forging Quality:<br>All sizes<br><i>UNS N06696</i>   | <sup>D</sup>                     | <sup>D</sup>                                  | <sup>D</sup>                              |
| Cold-worked (annealed and water quenched) or hot-worked (annealed and water quenched)<br>All products, all sizes | 85 000 (586)                     | 35 000 (240)                                  | 30  |

<sup>A</sup> Not applicable to diameters or cross sections under 3/32 in. (2.4 mm).

<sup>B</sup> Hardness B75 to B100, or equivalent.

<sup>C</sup> Hardness B75 to B95, or equivalent.

<sup>D</sup> Forging quality is furnished to chemical requirements and surface inspection only. No mechanical properties are required.

<sup>E</sup> Solution annealed at a minimum temperature of 2150°F (1175°C) followed by a water quench or rapidly cooled by other means.

<sup>F</sup> High-temperature annealed condition.

**TABLE 3 Mechanical Properties of Cold-Worked Wire in Coil (Alloys N06600 and N06690 Only)<sup>A</sup>**

| 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:<br>(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.<br>(2) For spring temper wire over 0.229 in. (5.82 mm): Twice the diameter of wire. |
| 0.032 (0.81) and over                   | 80 000 (552)                | 105 000 (724)  |   |
| Cold-worked, regular temper, all sizes  | 120 000 (827)               |                | The wire shall withstand the wrapping test without fracture or development of a pebbled or orange-peel surface.   |
| 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)               | ...            |   |

<sup>A</sup> Properties are not applicable to wire after straightening and cutting.

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.

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.

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

| Specified Dimension, in. (mm) <sup>A</sup> | Permissible Variations From Specified Dimension, in. (mm) |              |
|--|---|--------------|
|  | +   | -            |
| <b>Rounds:</b>                             |   |              |
| 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) |
| <b>Hexagons, squares, rectangles:</b>      |   |              |
| 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) |

<sup>A</sup> Dimensions apply to diameter of rounds, to distance between parallel surfaces of hexagons and squares, and separately to width and thickness of rectangles.

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

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

| Specified Dimension, in. (mm) <sup>A</sup> | 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: <sup>B</sup>          |  |              |
| Under 1 (25.4)                             | 0.005 (0.13)   | 0.005 (0.13) |
| 1 (25.4) and over                          | 0.031 (0.79)   | 0            |

<sup>A</sup> Dimensions apply to diameter of rods, to distance between parallel surfaces of hexagons and squares, and separately to width and thickness of rectangles.

<sup>B</sup> Spot 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.

**TABLE 6 Permissible Variations in Diameter of Cold-Worked Wire**

| Diameter, in. (mm)                          | Permissible Variations, in. (mm) |  |
|---|----------------------------------|--|
|   | + or -                           |  |
| Up to 0.0044 (0.112), incl                  | 0.0002 (0.005)                   |  |
| Over 0.0044 (0.112) to 0.0079 (0.201), incl | 0.00025 (0.006)                  |  |
| Over 0.0079 (0.201) to 0.0149 (0.378), incl | 0.0003 (0.008)                   |  |
| Over 0.0149 (0.378) to 0.0199 (0.505), incl | 0.0004 (0.010)                   |  |
| Over 0.0199 (0.505) to 0.031 (0.79), incl   | 0.0005 (0.013)                   |  |
| Over 0.031 (0.79) to 0.045 (1.14), incl     | 0.0006 (0.015)                   |  |
| Over 0.045 (1.14) to 0.079 (2.01), incl     | 0.0007 (0.018)                   |  |
| Over 0.079 (2.01) to 0.1875 (4.76), incl    | 0.001 (0.025)                    |  |
| Over 0.1875 (4.76) to 0.3125 (7.93), incl   | 0.002 (0.051)                    |  |
| Over 0.3125 (7.93) to 0.563 (14.3), incl    | 0.003 (0.076)                    |  |

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.

11.1.1 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 E8 shall be used. Longitudinal strip specimens shall be prepared in accordance with Test Methods E8 for rectangular bar up to ½ in. (12.7 mm), inclusive, in thicknesses that are too wide to be pulled full size.

11.2 Hardness test and grain size 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 procedure is suggested as follows:

(1) For rod, under ½ in. (12.7 mm) in diameter, hardness readings shall be taken on a flat surface prepared by filing or grinding approximately ¼ in. (1.6 mm) from the outside surface of the rod.

(2) For rod, ½ in. 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 methods:

| Test                | ASTM Designation        |
|---------------------|-------------------------|
| Chemical Analysis   | E38, <sup>A</sup> E1473 |
| Tension             | E8                      |
| Rockwell Hardness   | E18                     |
| Hardness Conversion | E140                    |
| Grain Size          | E112                    |
| Rounding Procedure  | E29                     |

<sup>A</sup> Methods E38 are to be used only for elements not covered by Test Methods E1473.

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 E29 as follows:

| Test  | Rounded Unit for Observed or Calculated Value   |
|---|---|
| Chemical composition, hardness, and tolerances (when expressed in decimals) | Nearest unit in the last righthand place of figures of the specified limit. If two 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. |
| Tensile strength and yield strength   | nearest 1000 psi (6.9 MPa)  |
| Elongation  | nearest 1 %   |

## 13. Inspection

13.1 Inspection of the material shall be made 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 producer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier may make claim for a rehearing.

## 15. Certification

15.1 When specified in the purchase order or contract, manufacturer's certification shall be furnished to the purchaser stating that 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: the name of the material or UNS Number, heat number, condition (temper), this specification number, the size, gross, tare, and net weight, consignor and consignee address, contract or order number, or such other information as may be defined in the contract or order.

**TABLE 7 Normal Machining Allowances for Hot-Worked Material**

| Finished-Machined Dimensions for Finishes as Indicated Below, in. (mm) <sup>A</sup> | Normal Machining Allowance, in. (mm) |   |                     |            |
|---|--------------------------------------|---|---------------------|------------|
|   | On Diameter, for Rods                | Distance Between Parallel Surfaces for Hexagonal and Square Bar | For Rectangular Bar |            |
|   |                                      |   | On Thickness        | On Width   |
| Hot-worked: <sup>B</sup>  |                                      |   |                     |            |
| Up to 7/8 (22.2), incl  | 1/8 (3.2)                            | 1/8 (3.2)   | 1/8 (3.2)           | 3/16 (4.8) |
| Over 7/8 to 1 1/8 (22.2 to 47.6), incl  | 1/8 (3.2)                            | 3/16 (4.8)  | 1/8 (3.2)           | 3/16 (4.8) |
| Over 1 1/8 to 2 1/8 (47.6 to 73.0), incl  | 3/16 (4.8)                           | 1/4 (6.4)   | ...                 | 3/16 (4.8) |
| Over 2 1/8 to 3 1/16 (73.0 to 96.8), incl   | 1/4 (6.4)                            | ...   | ...                 | 3/16 (4.8) |
| Over 3 1/16 (96.8)  | 1/4 (6.4)                            | ...   | ...                 | 3/8 (9.5)  |
| Hot-worked rods:  |                                      |   |                     |            |
| Rough-turned or rough-ground: <sup>C</sup>  |                                      |   |                     |            |
| 1 5/16 to 4 (23.8 to 101.6), incl in diameter                                       | 1/16 (1.6)                           | ...   | ...                 | ...        |
| Over 4 to 12 (101.6 to 304.8), incl in diameter                                     | 1/8 (3.2)                            | ...   | ...                 | ...        |

<sup>A</sup> Dimensions apply to diameter of rods, to distance between parallel surfaces of hexagonal and square bar, and separately to width and thickness of rectangular bar.  
<sup>B</sup> The allowances for hot-worked material in Table 5 are recommended for rods machined in lengths of 3 ft (0.91 m) or less and for bars machined in lengths of 2 ft (0.61 m) or less. Hot-worked material to be machined in longer lengths should be specified showing the finished cross-sectional dimension and the length in which the material will be machined in order that the manufacturer may supply material with sufficient oversize, including allowance for out-of-straightness.  
<sup>C</sup> Applicable to 3 ft (0.91 m) max length.

**TABLE 8 Permissible Variations in Length of Rods and Bars**

|                      |   |
|----------------------|---|
| 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). <sup>A</sup>  |
| 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. <sup>B</sup>   |
| Cut lengths          | A specified length to which all rods and bars will be cut with a permissible variation of plus 1/8 in. (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), - 0. |

<sup>A</sup> 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.  
<sup>B</sup> 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.

**TABLE 9 Permissible Variations in Straightness of Cold-Worked Rods and Bars**

| Specified Diameter or Distance Between Parallel Surfaces, in. (mm) <sup>A</sup> | Permissible Variations in Lengths Indicated, in. (mm) |
|---|---|
| Rounds:   | Depth of Chord:                                       |
| 1/2 (12.7) to 2 1/2 (63.5), incl  | 0.030 (0.76) per ft (305 mm) of length                |
| Hexagons, squares, rectangles:  |   |
| 1/2 (12.7) to 2 (50.8), incl  | 0.030 (0.76) per ft (305 mm) of length                |

<sup>A</sup> Material under 1/2 in. (12.7 mm) shall be reasonably straight and free of sharp bends and kinks.

**TABLE 10 Permissible Variations in Straightness of Hot-Worked Rods and Bars<sup>A</sup>**

| Finish   | Permissible Variations, in./ft (mm/m) <sup>B</sup> |
|--|--|
| Rods and bars, hot-worked                        | 0.050 (4.2) <sup>C</sup>                           |
| Rounds hot-worked, rough-ground, or rough-turned | 0.050 (4.2) <sup>C</sup>                           |

<sup>A</sup> Not applicable to forging quality.  
<sup>B</sup> Material under 1/2 in. (12.7 mm) shall be reasonably straight and free of sharp bends and kinks.  
<sup>C</sup> The maximum curvature (depth of chord) shall not exceed the values indicated multiplied by the length in feet.

## 17. Keywords

17.1 bar; rod; wire; UNS N06025; UNS N06045; UNS N06600; UNS N06601; UNS N06603; UNS N06617; UNS

N06674; UNS N06690; UNS N06693; UNS N06696

## SUPPLEMENTARY REQUIREMENTS

### SUPPLEMENTARY REQUIREMENTS FOR SPECIAL END USES

#### 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.

### SUPPLEMENTARY REQUIREMENTS FOR U.S. GOVERNMENT

The following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, or order for agencies of the U.S. Government.

#### S2. Referenced Documents

S2.1 The following documents of the issue in effect on date of material purchased form a part of this specification to the extent referenced herein: Federal Standards 102, 123, and 182 and Military Standard MIL-STD-129.

#### S3. Quality Assurance

##### S3.1 *Responsibility for Inspection:*

S3.1.1 Unless otherwise specified in the contract or purchase order, the manufacturer is responsible for the performance of all inspection and test requirements specified. Except as otherwise specified in the contract or purchase order, the manufacturer may use his own or any other suitable facilities for the performance of the inspection and test requirements unless disapproved by the purchaser at the time the order is placed. The purchaser shall have the right to perform any of the inspections or tests set forth when such inspections and tests are deemed necessary to ensure that the material conforms to prescribed requirements.

#### S4. Identification Marking

S4.1 All material shall be properly marked for identification in accordance with Fed. Std. No. 182, except that the ASTM specification number and the alloy number shall be used.

#### S5. Preparation for Delivery

##### S5.1 *Preservation, Packaging, Packing:*

S5.1.1 *Military Agencies*—The material shall be separated by size, composition, grade, or class and shall be preserved and packaged, level A or C, packed level A, B, or C as specified in the contract or purchase order.

S5.1.2 *Civil Agencies*—The requirements of Fed. Std. No. 102 shall be referenced for definitions of the various levels of packaging protection.

##### S5.2 *Marking:*

S5.2.1 *Military Agencies*—In addition to any special marking required by the contract or purchase order, marking for shipment shall be in accordance with MIL-STD-129.

S5.2.2 *Civil Agencies*—In addition to any special marking required by the contract or purchase order, marking for shipment shall be in accordance with Fed. Std. No. 123.



**APPENDIX**
**(Nonmandatory Information)**
**X1. PROCURABLE CONDITIONS AND FINISHES**

X1.1 The various conditions and finishes in which rod and bar are procurable are as follows:

X1.1.1 *Hot-Worked*— With a tightly adherent, dark oxide surface.

X1.1.2 *Hot-Worked, Rough-Ground*—Similar to X1.1.1 except rough-ground.

X1.1.3 *Hot-Worked, Rough-Turned*—Similar to X1.1.1 except rough-turned with a broad-nosed tool similar to a bar peeling operation and thus may not be straight. Intended generally for machining where an overhauled surface is desired, essentially for machined step down shafts or parts machined in short lengths of 3 ft (0.91 m) or less.

X1.1.4 *Hot-Worked, Forging Quality*—Rough-turned and spot-ground, as necessary, for sizes 1 in. (25.4 mm) in diameter and over; rough ground and spot ground for sizes under 1 in. in diameter. Material is selected from heats of known, good hot malleability.

NOTE X1.1—For sizes 2½ in. (63.5 mm) in diameter and less,

coldworked rod may be used also for forging by virtue of the fact that such rod has been overhauled for removal of mechanical surface defects prior to cold-working. In such cases, the user should run pilot forging tests to ensure himself that such material has the desired hot malleability range.

X1.1.5 *Hot-Worked, Annealed*—Soft, with a tightly adherent dark oxide.

X1.1.6 *Hot-Worked, Annealed, and Pickled*—Same as X1.1.5 except descaled for removal of mill oxide. Provides for better surface inspection than does hot-worked material and often employed where welding is involved where removal of mill oxide is desired.

NOTE X1.2—Annealing prior to pickling may be required in order to reduce the mill oxide since uniform pickling of an unreduced oxide is difficult.

X1.1.7 *Cold-Worked, As Worked*—Hot-worked, overhauled, cold-worked, and straightened with a smooth, bright finish.

X1.1.8 *Cold-Worked, Annealed, and Pickled*—Hot-worked, overhauled, cold-worked, annealed, descaled, and straightened. Annealed for softness and with a dull matte finish.

**SUMMARY OF CHANGES**

Committee B02 has identified the location of selected changes to this standard since the last issue (B166 - 08) that may impact the use of this standard. (Approved October 1, 2011.)

(1) Added UNS N06674 to Title, 1.1, Section 17, Table 1, and Table 2.

(2) Added Test Methods E112 to 2.1; revised Section 6, added

6.2; revised 9.1 and 9.2.2; added 10.4; revised 11.2; and revised 12.1, all to address grain size of N06674.

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