Designation: B639 – 02 (Reapproved 2013)

Standard Specification for Precipitation Hardening Cobalt-Containing Alloys (UNS R30155 and UNS R30816) Rod, Bar, Forgings, and Forging Stock for High-Temperature Service[1]

This standard is issued under the fixed designation B639; 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 hot- and cold-worked precipitation hardenable cobalt-containing alloys (UNS R30155 and UNS R30816) rod, bar, forgings, and forging stock for high-temperature service.

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]

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

E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

E139 Test Methods for Conducting Creep, Creep-Rupture, and Stress-Rupture Tests of Metallic Materials

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

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *bar, n*—material of rectangular (flats), hexagonal, octagonal, or square solid section in straight lengths.

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

4. Ordering Information

4.1 It is the responsibility of the purchaser to specify all requirements that are necessary for 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 *Condition* (temper) (Table 4).

4.1.4 *Section*—Rod or bar (round, rectangle, square, hexagon, octagon).

4.1.4.1 *Forging* (sketch or drawing).

4.1.5 *Dimensions,* including length.

4.1.6 *Quantity* (mass or number of pieces).

4.1.7 *Forging stock*—Specify if material is stock for reforging.

4.1.8 *Finish.*

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*—Whether samples for product (check) analysis should be furnished (9.2).

4.1.11 *Purchaser Inspection*—If the purchaser wishes to witness the tests or inspection of material at the place of manufacture, the purchase order must so state indicating which tests or inspections are to be witnessed (Section 13).

5. Chemical Composition

5.1 The material shall conform to the chemical 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 per Specification B880.

[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.

* New designation established in accordance with Practices E527 and SAE J1086. Practice for Numbering Metals and Alloys (UNS).

Current edition approved Feb. 1, 2013. Published February 2013. Originally approved in 1970. Last previous edition approved in 2008 as B639 – 02 (2008). DOI: 10.1520/B0639-02R13.

[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.

TABLE 1 Chemical Requirements

Element	Composition Limits, %	Composition Limits, %
	UNS R30155 (Formerly Grade 661)	UNS R30816 (Formerly Grade 671)
Carbon	0.08 to 0.16	0.32 to 0.42
Manganese	1.00 to 2.00	1.00 to 2.00
Silicon	1.00 max	1.00 max
Phosphorus	0.040 max	0.040 max
Sulfur	0.030 max	0.030 max
Chromium	20.00 to 22.50	19.00 to 21.00
Nickel	19.00 to 21.00	19.00 to 21.00
Molybdenum	2.50 to 3.50	3.50 to 4.50
Tungsten	2.00 to 3.00	3.50 to 4.50
Columbium + tantalum	0.75 to 1.25	3.50 to 4.50
Iron	remainder[A]	5.00 max
Cobalt	18.50 to 21.00	40.00 min
Nitrogen	0.20 max	...

[A] Element shall be determined arithmetically by difference.

TABLE 2 Tensile and Hardness Requirements[A]

Alloy	Heat Treatment	Tensile Strength, min, psi (MPa)	Yield Strength (0.2 % offset), min, psi (MPa)	Elongation in 2 in. or 50.8 mm or 4 *D*, min, %	Reduction of Area, min, %	Brinell Hardness, min
R30155	solution + precipitation harden	110 000 (760)	50 000 (345)	30	30	192
R30816	solution + precipitation harden	130 000 (895)	60 000 (415)	20	20	248

[A] The supplier shall demonstrate that the material will meet fully heat-treated properties after full heat treatment in accordance with Table 4.

TABLE 3 Stress-Rupture Requirements[A]

Alloy	Heat Treatment	Test Temperature, °F (°C)	Stress, psi (MPa)[B]	Minimum, h	Elongation in 2 in. or 50.8 mm, or 4*D*, min, %
R30155	solution + precipitation harden	1350 (732)	24 000 (165)	100	10
R30816	solution + precipitation harden	1350 (732)	38 000 (260)	100	8

[A] The supplier shall demonstrate that material will meet fully heat-treated properties after full heat treatment in accordance with Table 4.
[B] Test specimens meeting minimum requirements may be overloaded to produce rupture in a reasonable and practical time period.

TABLE 4 Heat Treatment[A]

Alloy	Recommended Solution Treatment	Precipitation Hardening Treatment
R30155	2125 to 2175°F (1162 to 1190°C) hold 30 min, minimum, water quench	1475 to 1525°F (801 to 829°C) hold 4 h, air cool or furnace cool
R30816	2130 to 2170°F (1165 to 1187°C), hold 1 h, water quench	1390 to 1410°F (754 to 765°C) hold 12 h, air cool or furnace cool

[A] The purchaser shall designate on the purchase order or inquiry any partial stage of heat treatment required on the material to be shipped.

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

Specified Dimension, in. (mm)[A]	Permissible Variations from Specified Dimension, in. (mm)	
	+	−
Rods:		
1/16 to 3/16 (1.59 to 4.76), excl	0	0.002 (0.051)
3/16 to 1/2 (4.76 to 12.70), excl	0	0.003 (0.076)
1/2 to 15/16 (12.70 to 23.81), incl	0.001 (0.025)	0.002 (0.051)
Over 15/16 to 1 15/16 (23.81 to 49.2), incl	0.0015 (0.038)	0.003 (0.076)
Over 1 15/16 to 2 1/2 (49.2 to 63.5), incl	0.002 (0.051)	0.004 (0.102)
Bars:		
1/16 to 3/16 (1.59 to 4.76), excl	0	0.002 (0.051)
3/16 to 1/2 (4.76 to 12.7), excl	0	0.003 (0.076)

[A] Dimensions apply to the diameter of rods, to the distance between parallel surfaces of hexagonal, octagonal, and square bar, and separately to the width and thickness of rectangular bar.

6. Mechanical Requirements

6.1 *Tensile and Hardness Requirements*—The material shall conform to the requirements for tensile and hardness properties in Table 2.

6.2 *Stress-Rupture Requirements*—The material shall conform to the requirements for stress-rupture properties in Table 3.

7. Dimensions and Permissible Variations

7.1 *Diameter, Thickness, or Width*—The permissible variations from the specified dimensions of cold-worked rod and bar shall be as prescribed in Table 5, and of hot-worked rod and bar as prescribed in Table 6.

7.1.1 *Out-of-Round*—Cold-worked and hot-worked rod, 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 5 and Table 6, except for hot-worked rod ½ in. (12.7 mm) and under, which may be out-of-round by the total permissible variations in diameter shown in Table 6.

7.1.2 *Corners*—Cold-worked bar shall have practically exact angles and sharp corners.

TABLE 6 Permissible Variations in Diameter or Distance Between Parallel Surfaces of Hot-Worked Rods and Bars

Specified Dimension, in. (mm)[A]	Permissible Variations from Specified Dimension, in. (mm)	
	+	–
Rod and bar, hot-finished:		
1 (25.4) and under	0.016 (0.41)	0.016 (0.41)
Over 1 to 2 (25.4 to 50.8), incl	0.031 (0.79)	0.016 (0.41)
Over 2 to 4 (50.8 to 101.6), incl	0.047 (1.19)	0.031 (0.79)
Over 4 (101.6)	0.125 (3.18)	0.063 (1.60)
Rod, hot-finished and 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

[A] Dimensions apply to the diameter of rods, to the distance between parallel surfaces of hexagonal, octagonal, and square bar, and separately to the width and thickness of rectangular bar.

7.1.3 *Cut Lengths*—A specified length to which all rod and bar will be cut with a permissible variation of + ⅛ in. (3.18 mm), – 0 for sizes 8 in. (203 mm) and less in diameter or distance between parallel surfaces. For larger sizes, the permissible variation shall be + ¼ in. (6.35 mm), – 0.

7.1.4 *Straightness for Cold-Worked and Hot-Worked Rod and Bar*—The maximum curvature (depth of chord) shall not exceed 0.050 in. multiplied by the length in feet (0.04 mm multiplied by the length in centimetres). Material under ½ in. (12.7 mm) in diameter or distance between parallel surfaces shall be reasonably straight and free of sharp bends and kinks.

7.1.5 For forgings, dimensions and tolerances shall be as specified on the order, sketch, or drawing.

7.1.6 Dimensions and tolerances for forging stock shall be as agreed upon between the purchaser and the supplier.

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 *Mechanical Properties*—A lot for tension, hardness, and stress-rupture testing shall consist of all material from the same heat, nominal diameter or thickness, or forging size, and condition (temper).

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 (temper).

9.2 *Test Material Selection:*

9.2.1 *Chemical Analysis*—Representative samples shall be taken during pouring or subsequent processing.

9.2.1.1 *Product (Check) Analysis* shall be wholly the responsibility of the purchaser.

9.2.2 *Mechanical Properties*—Samples of the material to provide test specimens for mechanical properties shall be taken from such locations in each lot as to be representative of that lot.

10. Number of Tests

10.1 *Chemical Analysis*—One test per lot.

10.2 *Tension*—One test per lot.

10.3 *Hardness*—One test per lot.

10.4 *Stress-Rupture*—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 (temper) and tested in the direction of fabrication.

11.1.2 All rod and bar 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 thickness, which 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 shown in Test Methods E8.

11.3 Stress-rupture specimens shall be the same as tension specimens except modified as necessary for stress-rupture testing in accordance with Test Methods E139.

12. Test Methods

12.1 Determine the chemical composition, mechanical and other properties of the material as enumerated in this specification, in case of disagreement, in accordance with the following methods:

Test	ASTM Designation
Chemical analysis	E1473
Tension	E8
Rounding procedure	E29
Stress rupture	E139

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 as indicated, in accordance with the rounding method of Practice E29.

Test	Rounded Unit for Observed or Calculated Value
Chemical composition, hardness, and tolerances (when expressed in decimals)	nearest unit in the last right-hand 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 %
Rupture Life	1 h

13. Inspection

13.1 Inspection of the material shall be as agreed upon between the purchaser and the supplier 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, a 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.

17. Keywords

17.1 bar; forgings; rod; R30155; R30816