SAE Aerospace
An SAE International Group

AEROSPACE MATERIAL SPECIFICATION

SAE AMS4650 | REV. L

Issued 1939-12
Revised 2004-03
Reaffirmed 2012-04

Superseding AMS4650K

Copper-Beryllium Alloy, Bars, Rods, Shapes, and Forgings
98Cu - 1.9Be
Solution Heat Treated TB00 (A)
(Composition similar to UNS C17200)

RATIONALE

AMS4650L has been reaffirmed to comply with the SAE five-year review policy.

1. SCOPE:

This specification covers a copper-beryllium alloy in the form of bars, rods, shapes, and forgings.

1.2 Application:

These products have been used typically for parts after aging requiring a combination of high strength, good wear resistance, and corrosion resistance and where electrical conductivity or low magnetic susceptibility may be important, but usage is not limited to such applications.

1.3 Safety - Hazardous Materials:

While the materials, methods, applications, and processes described or referenced in this specification may involve the use of hazardous materials, this specification does not address the hazards which may be involved in such use. It is the sole responsibility of the user to ensure familiarity with the safe and proper use of any hazardous materials and to take necessary precautionary measures to ensure the health and safety of all personnel involved.

2. APPLICABLE DOCUMENTS:

The issue of the following documents in effect on the date of the purchase order forms a part of this specification to the extent specified herein. The supplier may work to a subsequent revision of a document unless a specific document issue is specified. When the referenced document has been cancelled and no superseding document has been specified, the last published issue of that document shall apply.

TO PLACE A DOCUMENT ORDER: Tel: 877-606-7323 (inside USA and Canada)
Tel: +1 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: CustomerService@sae.org
SAE WEB ADDRESS: http://www.sae.org

2.1 SAE Publications:

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001 or www.sae.org.

AMS 2221	Tolerances, Copper and Copper Alloy Bars and Rods
AMS 2750	Pyrometry
AMS 2808	Identification, Forgings

2.2 ASTM Publications:

Available from ASTM, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959 or www.astm.org.

ASTM B 249	Specification for General Requirements for Wrought Copper and Copper-Alloy Rod, Bar, Shapes, and Forgings
ASTM B 249M	Specification for General Requirements for Wrought Copper and Copper-Alloy Rod, Bar, Shapes, and Forgings (Metric)
ASTM E 3	Practice for Preparation of Metallographic Specimens
ASTM E 8	Test Methods for Tension Testing of Metallic Materials
ASTM E 8M	Test Methods for Tension Testing of Metallic Materials (Metric)
ASTM E 18	Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials
ASTM E 106	Chemical Analysis of Copper-Beryllium Alloys
ASTM E 112	Test Methods for Determining Average Grain Size
ASTM E 478	Chemical Analysis of Copper Alloys

3. TECHNICAL REQUIREMENTS:

3.1 Composition:

Shall conform to the percentages by weight shown in Table 1, determined by wet chemical methods in accordance with ASTM E 106 or ASTM E 478, by spectrochemical methods, or by other analytical methods acceptable to purchaser.

TABLE 1 - Composition

Element	min	max
Beryllium	1.80	2.00
Nickel plus Cobalt	0.20	--
Nickel plus Cobalt plus Iron	--	0.6
Aluminum	--	0.20
Silicon	--	0.20
Copper (3.1.2)	remainder	
Sum of Named Elements (3.1.3)	99.5	--

3.1.1 These composition limits do not preclude the presence of other elements. Limits may be established and analysis required for unnamed elements by agreement between the manufacturer or supplier and purchaser.

3.1.2 Copper may be reported as “remainder”, or as the difference between the sum of results for all elements and 100%, or as the result of direct analysis.

3.1.3 When all the elements in the table are analyzed, the sum shall be 99.5% minimum, but such determination is not required for routine acceptance of each lot.

3.2 Condition:

The product shall be supplied in the following condition:

3.2.1 Bars, Rods, and Shapes: Hot or cold worked to size, solution heat treated, and cold straightened if necessary.

3.2.1.1 The cross-sectional area of bars, rods, and shapes shall be less than one-half that of the ingots from which they are formed; i.e., bars, rods, and shapes shall have been subjected to over 50% reduction of area during formation.

3.2.2 Forgings: Solution heat treated.

3.2.3 Stock for Forging: As ordered by the forging manufacturer.

3.3 Heat Treatment:

Product shall be solution heat treated by heating within the range 1400 to 1475 °F (760 to 802 °C), holding at heat for 30 to 60 minutes, and quenching in water. Pyrometry shall be in accordance with AMS 2750.

3.4 Properties:

The product shall conform to the following requirements:

3.4.1 As Solution Heat Treated (TB00):

3.4.1.1 Bars, Rods, and Shapes:

3.4.1.1.1 Tensile Properties: Shall be as shown in Table 2, determined in accordance with ASTM E 8 or ASTM E 8M; elongation requirement applies only to product over 0.311 inch (7.90 mm) in nominal diameter or distance between parallel sides.

TABLE 2 - Tensile Properties

Property	Value
Tensile Strength, maximum	85.0 ksi (586 MPa)
Elongation in 2 Inches (50.8 mm), minimum	35%

3.4.1.1.2 Maximum Average Grain Size: Shall be not larger than shown in Table 3, determined in accordance with ASTM E 112. Product may be precipitation heat treated as in 3.4.2 before examination.

TABLE 3 - Maximum Average Grain Size

Nominal Diameter or Least Distance Between Parallel Sides Inches	Nominal Diameter or Least Distance Between Parallel Sides Millimeters	Maximum Grain Size Millimeter
Up to 1.000, excl	Up to 25.40, excl	0.050
Over 1.000 to 1.500, excl	Over 25.40 to 38.10, excl	0.075
Over 1.500 to 2.000, excl	Over 38.10 to 50.80, excl	0.100
Over 2.000 to 3.000 excl	Over 50.80 to 76.20 excl	0.125

3.4.1.2 Forgings:

3.4.1.2.1 Hardness: Shall be not higher than 85 HRB, or equivalent, determined in accordance with ASTM E 18.

3.4.1.2.2 Average Grain Size: Shall be as agreed upon by purchaser and vendor, determined in accordance with ASTM E 112.

3.4.1.2.3 Average Grain Flow: Grain flow of die forgings, except in areas which contain flash-line end grain, shall follow the general contour of the forgings showing no evidence of re-entrant grain flow.

3.4.1.3 Bar, Rod, Shapes, and Forgings:

3.4.1.3.1 Microstructure: Product shall contain not more than 6% beta phase constituent, determined at 100X magnification on specimens prepared in accordance with ASTM E 3.

3.4.2 After Precipitation Heat Treatment: Bars, rods, shapes, and forgings shall have the following properties after being precipitation heat treated by heating within the range 600 to 675 °F (316 to 358 °C), holding at heat for 3 hours ± 0.25, and cooling in air.

3.4.2.1 Bars, Rods, and Shapes:

3.4.2.1.1 Tensile Properties: Shall be as shown in Table 4, determined in accordance with ASTM E 8 or ASTM E 8M.

TABLE 4 - Minimum Tensile Properties

Property	Value
Tensile Strength	165 ksi (1138 MPa)
Yield Strength at 0.2% Offset	140 ksi (965 MPa)
Elongation in 2 Inches (50.8 mm)	3%

3.4.2.1.2 Hardness: Bars, rods, and shapes 0.188 inch (4.78 mm) and over in nominal diameter or least distance between parallel sides shall have hardness not lower than 36 HRC, or equivalent, determined in accordance with ASTM E 18. The product shall not be rejected on the basis of hardness if the tensile properties of 3.4.2.1.1 are acceptable, determined on product taken from the same sample as that with nonconforming hardness or from another sample with similar nonconforming hardness.

3.4.2.2 Forgings:

3.4.2.2.1 Hardness: Shall be not lower than 36 HRC, or equivalent, determined in accordance with ASTM E 18.

3.4.3 After Re-Solution and Precipitation Heat Treatment: Bars, rods, shapes, and forgings shall have hardness not lower than 36 HRC, or equivalent, determined in accordance with ASTM E 18, after being re-solution heat treated in accordance with 3.3 and precipitation heat treated in accordance with 3.4.2.

3.4.4 Forging Stock: As agreed upon by purchaser and vendor.

3.5 Quality:

Product, as received by purchaser, shall be uniform in quality and condition, sound, and free from foreign materials and from imperfections detrimental to usage of the product.

3.6 Tolerances:

Bars and rods shall conform to AMS 2221 as applicable to refractory alloys.

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for Inspection:

The vendor of the product shall supply all samples for vendor's tests and shall be responsible for the performance of all required tests. Purchaser reserves the right to sample and to perform any confirmatory testing deemed necessary to ensure that the product conforms to specified requirements.

4.2 Classification of Tests:

4.2.1 Acceptance Tests: Composition (3.1), tensile properties of bars, rods, and shapes in solution heat treated condition (3.4.1.1.1), grain size of bars, rods, and shapes (3.4.1.1.2), microstructure of bars, rods, shapes, and forgings (3.4.1.3.1), forging grain size as agreed upon (3.4.1.2.2), tensile properties of bars, rods, and shapes after precipitation heat treatment (3.4.2.1.2), and hardness of forgings after re-solution and precipitation heat treatment (3.4.3) are acceptance tests and shall be performed on each lot.

4.2.2 Periodic Tests: Properties of bars, rods, shapes, and forgings (except hardness, See 4.2.1) after re-solution and precipitation heat treatment (3.4.3), and properties of forging stock (3.4.4) are periodic tests and shall be performed at a frequency selected by the vendor unless frequency of testing is specified by purchaser.

4.3 Sampling and Testing:

Shall be in accordance with the following:

4.3.1 Bars, Rods, and Shapes: ASTM B 249 or ASTM B 249M and the following:

4.3.1.1 Specimens for tensile testing of bars, rods, and shapes over 1.500 inches (38.10 mm) in nominal diameter or least distance between parallel sides shall have their axes located at approximately mid-radius.

4.3.2 Forgings: Two samples from each lot; a lot shall be all forgings of one part number processed consecutively and presented for vendor's inspection at one time.

4.3.3 Forging Stock: As agreed upon by purchaser and vendor.

4.4 Reports:

The vendor of the product shall furnish with each shipment a report showing the results of tests for chemical composition of each lot and the results of tests on each lot to determine conformance to the other acceptance test requirements and, when performed, to the periodic test requirements. This report shall include the purchase order number, lot number, AMS 4650L, size, and quantity. If forgings are supplied, the part number and the size and melt source of stock used to make the forgings shall also be included.

4.5 Resampling and Retesting:

Failure of any specimen to meet specified requirements shall cause product represented by such specimens to be subject to rejection. A retest sample of at least two specimens shall be randomly selected to replace each failed specimen from the original sample. All retest samples shall conform to specified requirements. If any retest specimen fails to meet specified requirements, the product represented shall be rejected.