



# AEROSPACE MATERIAL SPECIFICATION

Society of Automotive Engineers, Inc.  
TWO PENNSYLVANIA PLAZA, NEW YORK, N. Y. 10001

## AMS 6441E

Superseding AMS 6441D

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STEEL TUBING, MECHANICAL  
1.45Cr (0.98 - 1.10C) (SAE 52100)  
Bearing Quality

### 1. SCOPE:

- 1.1 Form: This specification covers a bearing-quality, low-alloy steel in the form of mechanical tubing.
- 1.2 Application: Primarily for parts requiring a through-hardening steel usually with hardness of approximately 60 HRC and section thickness less than 0.50 in. (12.7 mm)

### 2. APPLICABLE DOCUMENTS: The following publications form a part of this specification to the extent specified herein. The latest issue of Aerospace Material Specifications (AMS) and Aerospace Standards (AS) shall apply. The applicable issue of other documents shall be as specified in AMS 2350.

- 2.1 SAE Publications: Available from Society of Automotive Engineers, Inc., Two Pennsylvania Plaza, New York, New York 10001.

#### 2.1.1 Aerospace Material Specifications:

AMS 2253 - Tolerances, Carbon and Alloy Steel Tubing  
AMS 2259 - Chemical Check Analysis Limits, Wrought Low Alloy and Carbon Steels  
AMS 2350 - Standards and Test Methods  
AMS 2370 - Quality Assurance Sampling of Carbon and Low Alloy Steels, Wrought Products Except Forgings

#### 2.1.2 Aerospace Standards:

AS 1182 - Standard Machining Allowance, Aircraft Quality and Premium Quality Steel Products

- 2.2 ASTM Publications: Available from American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103.

ASTM A370 - Mechanical Testing of Steel Products  
ASTM E45 - Determining the Inclusion Content of Steels  
ASTM E350 - Chemical Analysis of Carbon Steel, Low-Alloy Steel, Silicon Electrical Steel, Ingot Iron, and Wrought Iron  
ASTM E381 - Rating Macroetched Steel

- 2.3 Government Publications: Available from Commanding Officer, Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, Pennsylvania 19120.

#### 2.3.1 Federal Standards:

Federal Test Method Standard No. 151 - Metals; Test Methods

### 3. TECHNICAL REQUIREMENTS:

- 3.1 Composition: Shall conform to the following percentages by weight, determined by wet chemical methods in accordance with ASTM E350, by spectrographic methods in accordance with Federal Test Method Standard No. 151, Method 112, or by other approved analytical methods:

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	min	max
Carbon	0.98	1.10
Manganese	0.25	0.45
Silicon	0.20	0.35
Phosphorus	--	0.025
Sulfur	--	0.025
Chromium	1.30	1.60
Nickel	--	0.25
Molybdenum	--	0.08
Copper	--	0.35

3.1.1 **Check Analysis:** Composition variations shall meet the requirements of AMS 2259, paragraph titled "Low Alloy Steels".

3.2 **Condition:** Cold finished with microstructure of spheroidized cementite in ferrite matrix. Tubing ordered hot finished shall have hardness not higher than 95 HRB or equivalent, determined in accordance with ASTM A370.

3.3 **Properties:** Tubing shall conform to the following requirements; hardness testing shall be performed in accordance with ASTM A370:

3.3.1 **Inclusion Rating:** Steel from which tubing is produced shall be subjected to the macrostructure test and to either the fracture or microscopic test as agreed upon by purchaser and vendor. If agreement is not reached by purchaser and vendor, the microscopic test shall be performed.

3.3.1.1 **Macrostructure:** Visual examination of transverse sections from blooms and tube rounds, etched in accordance with ASTM E381 in hot hydrochloric acid (1:1) at 160 - 180 F (71.1 - 82.2 C) for sufficient time to develop a well-defined macrostructure shall show no injurious imperfections such as pipe, cracks, porosity, segregation, and inclusions detrimental to fabrication or to performance of parts. Macrostructure standards shall be as agreed upon by purchaser and vendor.

3.3.1.2 **Fracture:** Specimens, approximately 0.375 in. (9.52 mm) in thickness, shall be normalized, annealed, hardened, and fractured through the approximate center of the cross section. Such specimens shall show no injurious imperfections such as pipe, porosity, and segregation. The fractured surfaces shall show no nonmetallic streaks over 1/8 in. (3.2 mm) in length and not more than one non-metallic inclusion 1/16 - 1/8 in. (1.6 - 3.2 mm) in length shall be evident on the fractured surfaces of two or fewer specimens.

3.3.1.3 **Microscopic Test:** Radial specimens, approximately 0.28 sq in. (1.8 cm<sup>2</sup>) in surface area taken midway between center and surface of hardened fracture samples, shall be polished on a face longitudinal to the direction of rolling, for micro-inclusion rating in accordance with the Jernkontoret chart, Method A, Plate I of ASTM E45. Two-thirds of all specimens and at least one from each ingot tested, as well as the average of all specimens, shall not exceed the following limits:

Inclusion Rating, Worst Field

Type	A	B	C	D
Thin	2.5	2.0	2.0	1.5
Heavy	1.5	1.5	1.5	1.5

3.3.2 **Response to Heat Treatment:** Specimens shall be protected by suitable means or treated in a neutral atmosphere to minimize scaling and prevent either carburization or decarburization during heat treatment. The specimens shall be placed in a furnace which is at 1525 F ± 10 (829.4 C ± 5.6), allowed to heat to 1525 F ± 10 (829.4 C ± 5.6), held at heat for 20 min., and quenched in commercial paraffin oil (100 SUS at 100 F (37.8 C)) at room temperature. The hardened specimens shall have substantially uniform hardness not lower than 63 HRC at any point below any permissible decarburization.

**3.3.3 Decarburization:**

- 3.3.3.1 Tubing ordered ground, turned, or polished shall be free from decarburization on the ground, turned, or polished surfaces. Decarburization on tubing ID shall not exceed the maximum depth specified in Table I.
- 3.3.3.2 Allowable decarburization of pierced billets, of tubing ordered for redrawing, or of tubing ordered to specified microstructural requirements other than spheroidized cementite in ferrite matrix shall be as agreed upon by purchaser and vendor.
- 3.3.3.3 Decarburization of tubing to which 3.3.3.1 or 3.3.3.2 is not applicable shall be not greater than shown in Table I:

**TABLE I**

Nominal Outside Diameter Inches	Depth of Decarburization Inch per Side	
	Hot	Cold
	Finished	Finished
Up to 1.000, incl	0.012	0.010
Over 1.000 to 2.000, incl	0.020	0.014
Over 2.000 to 3.000, incl	0.030	0.019
Over 3.000 to 4.000, incl	0.035	0.024
Over 4.000 to 5.000, incl	0.040	0.028

**TABLE I (SI)**

Nominal Outside Diameter Millimeters	Depth of Decarburization Millimeter per Side	
	Hot	Cold
	Finished	Finished
Up to 25.40, incl	0.30	0.25
Over 25.40 to 50.80, incl	0.51	0.36
Over 50.80 to 76.20, incl	0.76	0.48
Over 76.20 to 101.60, incl	0.89	0.61
Over 101.60 to 127.00, incl	1.02	0.71

- 3.3.3.4 Limits for depth of decarburization of tubing over 5.000 in. (127.00 mm) in nominal OD shall be as agreed upon by purchaser and vendor.
- 3.3.3.5 Decarburization shall be measured by the microscopic method or by Rockwell Superficial 30-N scale or equivalent hardness testing method on hardened but untempered specimens protected during heat treatment to prevent changes in surface carbon content. Depth of decarburization, when measured by a hardness method, is defined as the perpendicular distance from the surface to the depth under the surface below which there is no further increase in hardness. Such measurements shall be far enough away from any adjacent surface to be uninfluenced by any decarburization or lack of decarburization thereon.
- 3.3.3.5.1 When determining the depth of decarburization, it is permissible to disregard local areas provided the decarburization of such areas does not exceed the above limits by more than 0.005 in. (0.13 mm) and the width is 0.065 in. (1.65 mm) or less.
- 3.4 **Quality:** Steel shall be bearing quality. Tubing shall be uniform in quality and condition, clean, sound, and free from foreign materials and from internal and external imperfections detrimental to fabrication or to performance of parts.

- 3.4.1 Tubing ordered ground, turned, or polished shall be free from seams, laps, tears, and cracks open to the ground, turned, or polished surfaces.
- 3.4.2 Tubing ordered to surface conditions other than ground, turned, or polished shall, after removal of the standard machining allowance, be free from seams, laps, tears, cracks, and other defects exposed to the machined surfaces. Standard machining allowance shall be in accordance with AS 1182.
- 3.5 Sizes: Except when exact lengths or multiples of exact lengths are ordered, tubing will be acceptable in mill lengths of 6 - 20 ft (1.8 - 6.1 m) but not more than 10% of any shipment shall be supplied in lengths shorter than 10 ft (3 m).
- 3.6 Tolerances: Unless otherwise specified, tolerances shall conform to all applicable requirements of AMS 2253.

#### 4. QUALITY ASSURANCE PROVISIONS:

- 4.1 Responsibility for Inspection: The vendor of tubing shall supply all samples and shall be responsible for performing all required tests. Results of such tests shall be reported to the purchaser as required by 4.4. Purchaser reserves the right to perform such confirmatory testing as he deems necessary to assure that the tubing conforms to the requirements of this specification.
- 4.2 Classification of Tests: Tests to determine conformance to all technical requirements of this specification are classified as acceptance or routine control tests.
- 4.3 Sampling: Shall be in accordance with AMS 2370 and the following:
- 4.3.1 Specimens for inclusion rating (3.3.1) shall represent the full cross section of billet stock taken from the top and bottom of at least the first, middle, and last usable ingots of each heat. Samples for macro-structure testing (3.3.1.1) shall be full cross-sectional specimens obtained from the finished billet or a suitable rerolled product.
- 4.3.2 Specimens for response to heat treatment (3.3.2) shall be the full cross section of the tubing ground on both faces normal to the axis of the product so that the length is 0.625 in. (15.88 mm).
- 4.4 Reports:
- 4.4.1 The vendor of tubing shall furnish with each shipment three copies of a report of the results of tests for chemical composition, inclusion rating, and response to heat treatment of each heat in the shipment. This report shall include the purchase order number, heat number, material specification number and its revision letter, size, and quantity from each heat.
- 4.4.2 The vendor of finished or semi-finished parts shall furnish with each shipment three copies of a report showing the purchase order number, material specification number and its revision letter, contractor or other direct supplier of material, part number, and quantity. When material for making parts is produced or purchased by the parts vendor, that vendor shall inspect each lot of material to determine conformance to the requirements of this specification and shall include in the report a statement that the material conforms, or shall include copies of laboratory reports showing the results of tests to determine conformance.
- 4.5 Resampling and Retesting: If any specimen used in the above tests fails to meet the specified requirements, disposition of the tubing may be based on the results of testing three additional specimens for each original nonconforming specimen. Except as permitted in 4.6.1, failure of any retest specimen to meet the specified requirements shall be cause for rejection of the tubing represented and no additional testing shall be permitted. Results of all tests shall be reported.