



AEROSPACE MATERIAL SPECIFICATION

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AMS 6411

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Revised

STEEL BARS, FORGINGS, AND TUBING
0.85Cr - 1.8Ni - 0.40Mo - 0.07V (0.28 - 0.33C)
Premium Quality, Consumable Electrode Melted

1. ACKNOWLEDGMENT: A vendor shall mention this specification number in all quotations and when acknowledging purchase orders.
2. FORM: Bars, forgings, mechanical tubing, and forging stock.
3. APPLICATION: Primarily for parts requiring high tensile strength and good ductility with relatively high impact strength, superior transverse properties, and hardness.
4. COMPOSITION:

	min	max
Carbon	0.28	0.33
Manganese	0.75	1.00
Silicon	0.20	0.35
Phosphorus	--	0.015
Sulfur	--	0.015
Chromium	0.75	1.00
Nickel	1.65	2.00
Molybdenum	0.35	0.50
Vanadium	0.05	0.10
Copper	--	0.35

- 4.1 Check Analysis: Composition variations shall meet the requirements of the latest issue of AMS 2259, paragraph titled "Low Alloy Steels."
5. CONDITION: Unless otherwise ordered, the product shall be supplied in the following condition:
 - 5.1 Bars: In a machinable condition and hot finished having hardness not higher than Brinell 241 or equivalent, except that bars ordered cold finished may have hardness as high as Brinell 248 or equivalent.
 - 5.2 Forgings: Normalized and tempered, having hardness not higher than Brinell 269 or equivalent.
 - 5.3 Mechanical Tubing: In a machinable condition and cold finished, having hardness not higher than Rockwell C 25 or equivalent, except that tubing ordered hot finished shall have hardness not higher than Rockwell B 99 or equivalent.
 - 5.4 Forging Stock: As ordered by the forging manufacturer.
6. TECHNICAL REQUIREMENTS: When ASTM methods are specified for determining conformance to the following requirements, tests shall be conducted in accordance with the issue of the ASTM method listed in the latest issue of AMS 2350.

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- 6.1 Hardenability: Shall be J49=14 min and J45=24 min when determined on the standard end-quench test specimen in accordance with the Method of Determining Hardenability published in the latest issue of the SAE Handbook, except that the steel shall be normalized at $1700\text{ F} \pm 10$ ($926.7\text{ C} \pm 5.6$) and the test specimen austenitized at $1550\text{ F} \pm 10$ ($843.3\text{ C} \pm 5.6$). The hardenability test is not required on a product which will not yield a suitable specimen but the steel from which the product is made shall conform to the hardenability specified.
- 6.2 Grain Size: Predominantly 5 or finer with occasional grains as large as 3 permissible, ASTM E112, McQuaid-Ehn test.
- 6.3 Decarburization:
- 6.3.1 Bars and tubing ordered ground, turned, or polished shall be free from decarburization on such ground, turned, or polished surfaces. Inside decarburization of such tubing shall not exceed the maximum depth specified in 6.3.4.
- 6.3.2 Allowable decarburization of bars, billets, or tubing ordered for redrawing or forging or to specified microstructural requirements shall be as agreed upon by purchaser and vendor.
- 6.3.3 Decarburization of bars to which 6.3.1 or 6.3.2 is not applicable shall be not greater than the following:

Nominal Diameter or Distance Between Parallel Sides Inches	Depth of Decarburization Inch
Up to 0.375, incl	0.015
Over 0.375 to 0.500, incl	0.017
Over 0.500 to 0.625, incl	0.019
Over 0.625 to 1.000, incl	0.022
Over 1.000 to 1.500, incl	0.025
Over 1.500 to 2.000, incl	0.030
Over 2.000 to 2.500, incl	0.035
Over 2.500 to 3.000, incl	0.040
Over 3.000 to 4.000, incl	0.045

- 6.3.3.1 Limits for depth of decarburization of bars over 4.000 in. in diameter or distance between parallel sides shall be as agreed upon by purchaser and vendor.
- 6.3.4 Decarburization of all tubing to which 6.3.1 or 6.3.2 is not applicable shall be not greater than the following:

Nominal Wall Thickness Inches	Depth of Decarburization, Inch	
	ID	OD
Up to 0.109, incl	0.008	0.015
Over 0.109 to 0.203, incl	0.010	0.020
Over 0.203 to 0.400, incl	0.012	0.025
Over 0.400 to 0.600, incl	0.015	0.030
Over 0.600 to 1.000, incl	0.017	0.035
Over 1.000	0.020	0.040

- 6.3.5 Unless otherwise agreed upon by purchaser and vendor, decarburization shall be measured by the microscopic method or by Rockwell Superficial 30-N scale hardness method, 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 nondecarburized depth under that 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.

6.3.5.1 When determining the depth of decarburization, it is permissible to disregard local areas provided the decarburization of such areas does not exceed the limits above by more than 0.005 in. and the width is 0.065 in. or less.

6.4 Macrostructure: Shall show freedom from pipe, internal cracks, and abnormal segregation. The appearance of specimens from ingots not sampled for testing in accordance with AMS 2300 shall be equivalent to that of specimens from those ingots tested and accepted to the requirements of AMS 2300.

6.5 Properties After Heat Treatment: Specimens normalized by heating to $1700\text{ F} \pm 10$ ($926.7\text{ C} \pm 5.6$), holding at heat for 1 hr, and cooling in air; hardened by heating to $1550\text{ F} \pm 10$ ($843.3\text{ C} \pm 5.6$), holding at heat for 1 hr, and quenching in oil; and then held at the required tempering temperature for not less than 1 hr, and cooled in air shall conform to the following requirements.

6.5.1 Longitudinal Tensile Properties:

Tensile Strength, psi	220,000 min
Yield Strength at 0.2% Offset or at 0.0172 in. in 2 in. Extension Under Load ($E = 28,000,000$), psi	185,000 min
Elongation, % in 2 in. or 4D	10 min
Reduction of Area (round specimens), %	35 min

6.5.2 Transverse Tensile Properties: When section size permits, specimens shall be tested in accordance with the latest issue of AMS 2310 and shall have the following properties:

Cross Section Area Sq Inches	Tensile Strength psi, min	Yield Strength psi, min	Reduction of Area, %	
			Average	Minimum
Up to 144, incl	220,000	185,000	35	30
Over 144 to 225, incl	220,000	185,000	30	25
Over 225	220,000	185,000	25	20

6.5.3 Impact Strength (Notch Sensitivity): The Izod impact value of transverse specimens heat treated in the same manner as tensile test specimens shall be not less than 15 ft-lb when tested at room temperature in accordance with ASTM E23, using a V-notched specimen. Before heat treatment, specimens shall be to size or approximately to size, except for the notch.

7. QUALITY: Steel shall be premium quality and shall conform to the requirements of the latest issue of AMS 2300. Unless otherwise permitted, material shall be multiple melted using consumable electrode process in the remelt cycle. The product 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.

8. QUALITY ASSURANCE SAMPLING AND TESTING: Shall be in accordance with the latest issue of AMS 2370 and the following:

8.1 Composition, Grain Size, and Macrostructure: The carbon and manganese contents, grain size, and macrostructure shall be determined on specimens representing the top and bottom of each consumable electrode remelted ingot.

8.2 Response of Forging Stock to Heat Treatment: Shall be determined on specimens taken from the top and bottom of the consumable electrode remelted ingots representing the first and last ingots from the original air melt heat.

9. TOLERANCES: Unless otherwise specified, tolerances shall conform to all applicable requirements of the following:

9.1 Bars: The latest issue of AMS 2251; for all hexagons, tolerances for cold finished shall apply.