SAE Aerospace
An SAE International Group

AEROSPACE MATERIAL SPECIFICATION

SAE AMS-S-8949A

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Superseding AMS-S-8949

Steel Bars, Plates, Sheets, Billets, and Reforging Stock
Type D6AC

NONCURRENT NOTICE

This specification has been declared “NONCURRENT” by the Aerospace Materials Division, SAE, as of September 2002. It is recommended, therefore, that this specification not be used for new designs.

“NONCURRENT” refers to those materials or processes that have been widely used and may be required on some existing designs in the future. The Aerospace Materials Division, however, does not recommend these as standard materials or processes for future use in new designs. “NONCURRENT” specifications are available from SAE upon request.

For bars, forgings, and tubing, it is recommended that AMS 6431, Steel, Bars, Forgings, and Tubing, 1.05Cr – 0.55Ni – 1.0Mo – 0.11V – (0.45-0.50C), Vacuum Consumable Electrode Melted, be used.

For sheet, strip, and plate, it is recommended that AMS 6439, Steel, Sheet, Strip, and Plate, 1.05Cr – 0.55Ni – 1.0Mo – 0.12V – (0.42-0.48C), Consumable Electrode Vacuum Melted, Annealed, be used.

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This document has been taken directly from U.S. Military Specification MIL-S-8949 and contains only minor editorial and format changes required to bring it into conformance with the publishing requirements of SAE technical standards. The initial release of this document is intended to replace MIL-S-8949. Any part numbers established by the original specification remain unchanged.

The original Military Specification was adopted as an SAE standard under the provisions of the SAE Technical Standards Board (TSB) Rules and Regulations (TSB 001) pertaining to accelerated adoption of government specifications and standards. TSB rules provide for (a) the publication of portions of unrevised government specifications and standards without consensus voting at the SAE Committee level, and (b) the use of the existing government specification or standard format.

Under Department of Defense policies and procedures, any qualification requirements and associated qualified products lists are mandatory for DOD contracts. Any requirement relating to qualified products lists (QPL's) has not been adopted by SAE and is not part of this SAE technical document.

1. SCOPE:

1.1 Scope:

This specification establishes the requirements for procuring vacuum melted Cr-Mo-V-Ni, type D6AC steel forged billets, reforging stock, bars, rods, plate, sheet, and strip.

1.2 Classification:

1.2.1 Physical conditions: Products shall be furnished in one of the following physical conditions, as specified (see 6.2).

(a). As forged.
(b). As rolled.
(c). Annealed - hardness not to exceed 229 Brinell.
(d). Annealed and cold finished - hardness not to exceed Rockwell C30.
(e). Normalized.
(f). Normalized and tempered - hardness not to exceed 327 Brinell.

1.2.2 Surface finish: Material shall be supplied with a surface finish equivalent to one of the following commercial steel finishes, as specified on the purchase order:

(a). Forged billets, reforging stock, bars, and rods:

(1) As forged or rolled.
(2) Descaled and oiled.
(3) Rough turned.
(4) Cold drawn.
(5) Centerless ground.

(b). Plate and strip material: Hot rolled, descaled, and oiled.
(c). Sheet and strip material: Hot or cold rolled, annealed, descaled, and oiled.

2. APPLICABLE DOCUMENTS:

The following publications, of the issue in effect on date of invitation for bids or request for proposal, form a part of this specification to the extent specified herein.

2.1 SAE Publications:

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

AMS 2300	Magnetic Particle Inspection - Premium Aircraft Quality Steel Cleanliness
AMS 2301	Magnetic Particle Inspection - Aircraft Quality Steel Cleanliness
AMS 2630	Ultrasonic Inspection
AMS 2640	Magnetic Particle Inspection

2.2 ASTM Publications:

Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM E45-63 Recommended Practice for Determining the Inclusion Content of Steel

2.3 U.S. Government Publications:

Available from DODSSP, Subscription Services Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

FED-STD-48 Tolerances for Steel and Iron Wrought Products
FED-STD-151 Metals; Test Methods
FED-STD-183 Continuous Identification Marking of Iron and Steel Products

MIL-STD-163 Steel Mill Products, Preparation for Shipment and Storage

3. REQUIREMENTS:

3.1 Material:

The material shall be produced by the consumable electrode, vacuum melting process. When inspected in accordance with the procedures specified herein, material shall comply with the magnetic particle indication limits, inclusion limits, and ultrasonic indication limits as specified in 3.1.1, 3.1.2, 3.1.3, and table I.

TABLE I. Inclusion limits

ASTM E45 63 inclusion type	Dimensional limitations, thickness or diameter (inch)	Worst field
Type A - thin	0.00016 (max)	1.5
Type A - heavy	.00040 (max)	1.0
Type B - thin	.0003 to .0005, excl.	1.5
Type B - heavy	.0005 to .0010, incl.	1.0
Type C - thin	.00020 (max)	1.5
Type C - heavy	.00035 (max)	1.0
Type D - thin	.0002 to .0004, excl.	2.0
Type D - heavy	.0004 to .0010, incl.	1.5

3.1.1 Magnetic particle: When inspected by magnetic particle methods in accordance with AMS 2640, the frequency and severity of indications rated in accordance with AMS 2301 shall not exceed 0.80 and 0.67, respectively.

3.1.2 Micro inclusion content: Material tested in accordance with 4.4.2 shall meet the requirements of table I.

3.1.2.1 For types A, B, and C thin combined, there shall be not more than three fields of No. 1.5A type or No. 1.5B and C types and not more than five other lower rateable A, B, and C type thin fields per specimen. For D type thin, there shall be not more than three No. 2.0 fields and no more than five other lower rateable D type thin fields per specimen. There shall be not more than one field each of No. 1.0A, B, and C type or No. 1.5D type heavy per specimen.

3.1.2.2 A rateable field is defined as one which has a type A, B, C, or D inclusion rating of at least No. 1.0 thin or heavy in accordance with the dimensional limitations of table I and the Jernkontoret chart, plate I, ASTM E45-63.

3.1.3 Ultrasonic inspection: Material 1/2 inch and greater in thickness shall meet the following requirements, when inspected in accordance with 4.4.3:

a. Discontinuity indications in excess of the response from a 5/64-inch flat-bottomed hole at the estimated discontinuity depth are not acceptable.
b. Resolved indications equal to, or greater than, 60 percent of the response from 3/64-inch flat-bottomed hole shall not have their indicated centers closer than 1 inch.
c. Plate materials under 3/4 inch in thickness: when tested using contact shear wave techniques, there shall be no indications exceeding those produced by a discontinuity 1/16 inch wide, 1 inch long, and 3 percent of the plate thickness in depth.
d. Plates over 3/4 inch in thickness shall exhibit no indications exceeding the indications from a 1/8 inch diameter flat-bottomed hole drilled into a block of the same material as that being tested.

3.2 Data:

Data shall be supplied as required herein (see 4.1.1 and 6.2).

3.3 Chemical composition:

The chemical composition shall conform to the limits specified in table II.

TABLE II. Chemical composition

Element	Percent composition (by weight)	Check analysis	
		Under (min)	Over (max)
Carbon	0.42 - 0.48	0.01	0.01
Manganese	.60 - .90	.03	.03
Silicon	.15 - .30	.05	.05
Phosphorus	.010 (max)	----	.005
Sulphur	.010 (max)	----	.005
Chromium	.90 - 1.20	.05	.05
Molybdenum	.90 - 1.10	.05	.05
Vanadium	.07 - .15	.01	.01
Nickel	.40 - .70	.03	.03
Other	.50 (max)		

3.4 Microstructure - grain size:

The average grain size of the material as supplied shall be No. 7 or finer, when tested as specified in 4.4.5.

3.5 Response to thermal treatment:

Specimens selected in accordance with 4.4.6.1 shall develop the mechanical properties specified in table III, when heat treated and tested in accordance with 4.4.6.2 and 4.4.6.3.

3.5.1 Notched specimens: Notched tensile specimens heat treated with the unnotched tensile specimens and tested in accordance with 4.4.6 and 4.4.6.3 shall exhibit breaking strengths of 220 ksi, minimum. The ratio or notched to unnotched breaking strength shall equal or exceed 1 to 1.

3.6 Hardness of forgings:

When specified (see 6.2), forgings shall be thermally treated to attain desired mechanical properties.

3.7 Decarburization:

When tested as specified in 4.4.7.2, decarburization of materials other than sheet and strip shall not exceed the limits specified in table IV. Sheet and strip shall be free from decarburization to the extent that the hardness increase from the surface to any point below the surface of an oil-hardened specimen shall not exceed 3 points on the Rockwell 30N scale.

TABLE III. Mechanical properties, unnotched

Property	Orientation of axis specimen relative to the major axis of grains in the microstructure	
	Longitudinal	Transverse
Ultimate Tensile strength-acceptable range, ksi	240 (max) 220 (min)	240 (max) 220 (min)
Yield strength at 0.2 percent offset, ksi	190 (min)	190 (min)
Elongation - percent in 4D		
Up to 50 sq. in.	12 (min)	10 (min)
Over 50 to 200 sq. in.	12 (min)	8 (min)
Over 200 sq. in.	10 (min)	7 (min)
Sheet and plate under 5/8 inch thick	10 (min)	8 (min)
Reduction of area - percent (Not applicable to sheet under 1/8 inch thick):		
Up to 200 sq. in.	35 (min)	25 (min)
Over 200 sq. in.	30 (min)	20 (min)
Charpy impact strength, room temperature, ft.-lbs.		15 (min)

TABLE IV. Decarburization limits

Nominal diameter or thickness (inches)	Maximum affected depth of decarburization (inches)
0.125 and under	0.002
Over .125 to 0.188	.003
Over .188 to .250	.006
Over .250 to .375	.010
Over .375 to .500	.015
Over .500 to .625	.020
Over .625 to 1.00	.025
Over 1.00 to 2.00	.035
Over 2.00 to 3.00	.048
Over 3.00 to 4.00	.062
Over 4.00 to 5.00	.094
Over 5.00	.125

3.8 Dimensional tolerances:

Permissible variations from required dimensions shall not exceed the tolerances specified in tables V and VI, as applicable.

TABLE V. Dimensional tolerances

Product and dimension	FED-STD-48 tolerance table number
Sheet	
Thickness, hot rolled	11b1
Thickness, cold rolled	12b1
Width, hot rolled	11b2
Width, cold rolled	12b2
Length, hot rolled (cut sheets)	11b3
Length, cold rolled (cut sheets)	12b3 (11a6)
Camber, hot rolled and cold rolled	11b7 and 12b7
Flatness, hot rolled and cold rolled	11b8 and 12b8
Strip	
Thickness, hot rolled	14b1
Thickness, cold rolled	15b1
Crown, hot rolled	14b2
Crown, cold rolled	15b2
Width, hot rolled	14b3
Width, cold rolled	15b3
Length, hot rolled	14b4
Length, cold rolled	15b4
Camber, hot rolled	14b5
Camber, cold rolled	15b5
Flatness, hot rolled and cold rolled strip: The variation from flatness shall not exceed 1/2 inch in any 8 feet of length.	

3.9 Identification of product:

Each piece shall be identified in accordance with FED-STD-183. The markings shall include the heat number of the metal and the designation of this specification, and identification of the producer.

3.10 Workmanship:

Material shall be sound and free from cracks, laps, seams foreign materials and other discontinuities detrimental to the fabrication or to the performance of parts.

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for inspection:

Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified, the supplier may utilize his own facilities or any commercial laboratory acceptable to the Government. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

TABLE VI. Tolerances applicable to rectangular sheared plates and universal mill plates

Nominal thickness (T) inch(es)	Thickness tolerances factor 1/, 2/				
	Width ranges (inches)				
	48 and under	48 to 60, excl.	60 to 72,, excl.	72 to 84, excl.	84 to 96
Under 0.250	0.094	0.107	0.120	0.133	0.160
0.250 to 0.3125, excl.	.080	.094	.107	.120	.133
0.3125 to 0.375, excl.	.067	.080	.094	.107	.120
0.375 to 0.4375, excl.	.060	.067	.080	.094	.107
0.4375 to 0.500, excl.	.054	.060	.067	.080	.094
0.500 to 0.625, excl.	.054	.054	.060	.067	.080
0.675 to 0.750, excl.	.054	.054	.054	.060	.067
0.750 to 1.000, excl.	.047	.054	.054	.054	.060
1.000 to 2.000, excl.	.047	.047	.054	.054	.054

1/ Minus tolerance shall be 0.010 for all thicknesses and widths.
2/ Plus tolerance, in inches, is the product of the specified factor and the nominal thickness in inches.

Width, inches	Tolerances for width and length (inch)			
	Under 0.375	0.375 to 0.625, incl.	0.625 to 1.000, incl.	1.000 and over
Under 20	1/8	1/8	3/16	1/4
20 to 36, excl.	3/16	1/4	3/16	3/8
36 and over	6/16	3/8	7/16	1/2

4.1.1 Data requirements: Reports of the results of quality assurance inspections shall accompany each shipment and shall be available to the purchaser on request at any time within 2 years from date of shipment (see 3.2 and 6.2).

4.2 Classification of inspections:

All examinations and tests specified herein for the testing of the product are classified as quality conformance inspections.

4.3 Examinations:

4.3.1 Examination of product: Each unit of product shall be examined to determine conformance to this specification with respect to surface finish (1.2.2), identification of product (3.9), and workmanship (3.10). Sample units, of a number not less than indicated in table VII, shall be randomly selected to represent each respective thickness. Inspection for thickness and crown of sheet and strip shall consist of measurements distributed along, and 1/2 inch from a longitudinal (with respect to rolling) edge, plus measurements near the center (as rolled).

4.3.2 Packaging, packing, and marking: Preparation for delivery shall be examined for conformance to section 5.

TABLE VII. Sampling

Lot size	Sample size	Acceptance number
1 - 65	4	0
66 - 110	5	0
111 - 300	7	0
301 - 500	10	0
501 - 800	15	0
Over 800	25	0

4.4 Tests:

4.4.1 Magnetic inspection: Heats from which sheet, strip, or plate are to rolled shall be subjected to magnetic particle inspection tests of semi-finished mill products prior to rolling to finished size. Samples shall be taken from the product at locations representing the top and bottom of the first, middle, and last usable ingot from each heat. Specimens shall be prepared for inspection by cutting longitudinal sections through the thickness of samples at off-center locations and finish machining the sections to a roughness height rating not to exceed 40 micro-inches. Magnetic particle tests shall be conducted in accordance with AMS 2640 and the frequency and severity rated in accordance with AMS 2301 (see 3.1.1).

4.4.1.1 Sampling: Slugs of sufficient size and weight for testing shall be cut from intermediate ground billet stock representing the top and bottom of the first and last consumable electrode ingot of the master heat represented. Where an order represents a portion of an ingot previously tested, recorded data taken from the original ingot approval test may apply.

4.4.1.2 Testing: The slugs shall be step-machined and tested in accordance with AMS 2300.

4.4.2 Inclusion rating:

4.4.2.1 Sampling: A slice shall be cut from the top and bottom of the first and last usable consumable vacuum melted ingot from each master heat. From a mid-radius position, radial specimens approximately 0.28 square inch in area shall be prepared.

4.4.2.2 Method: Specimens shall be polished on a face parallel to the longitudinal axis, and micro inclusion rating determined in accordance with ASTM E45-63, Method A.

4.4.3 Ultrasonic inspection:

4.4.3.1 Sampling: Samples shall be selected as follows:

No. of pieces	Sample size
1 to 15	11 (or all units of a sample size less than 12)
15 to 180	15
181 to 300	35
301 to 500	50
Over 500	75

4.4.3.2 Method: Unless otherwise specified (see 6.2), samples shall be inspected in accordance with AMS 2630, except that hash or sonic noise level shall not exceed 20 percent of the height of an indication received from a 3/64-inch flat-bottomed hole. (Hash or sonic noise level shall be defined as the large number of unresolved indications resulting from nonhomogeneous structure and numerous minute indications). Loss of back reflection pattern due to multiple unresolved indications shall not exceed 20 percent of the normal back reflection received from the material under inspection.

NOTE: Care should be exercised to assure that loss of back reflection is not attributable to nonparallel or rough surfaces or to transducer misalignment.

4.4.4 Chemical analysis:

4.4.4.1 Sampling: One sample for check chemical analysis shall be selected to represent the first, middle, and last ingot from each master heat of steel, in accordance with FED-STD-151.

4.4.4.2 Test method: Samples shall be prepared and tested in accordance with Methods 111 or 112 of FED-STD-151.

4.4.5 Grain size:

4.4.5.1 Sampling: One sample shall be selected to represent the first, middle, and last ingots from each master heat of steel from which material is submitted for acceptance.

4.4.5.2 Test method: Specimens shall be sectioned and polished to appropriate fineness by metallographic methods and suitably etched to reveal the grain structure. The austenitic grain size shall be determined in accordance with Procedure B, C, or D, Method 311, of FED-STD-151.

4.4.6 Heat treatment and notched tensile strength:

4.4.6.1 Sampling: One bar, plate, sheet, or billet, as applicable, of each thickness and heat in a shipment shall be sampled to determine conformance to the tensile and notched tensile property requirements of 3.5 and 3.5.1. The test sample shall be of sufficient size to permit the fabrication of two unnotched tensile specimens and two notched tensile specimens. Two tensile specimens conforming to type R1, R2,or F2 of Method 211 of FED-STD-151 and two corresponding notched tensile specimens conforming to figure 1 or 2 of this specification shall be required from each test sample. Where possible specimen type R1 and R2 shall be used with type R1 being preferred. Tensile specimen direction and location shall be:

a. Billet material: The test specimens shall be taken from the mid-radius location of the billet. The longitudinal axis of the test specimens shall be transverse to the grain direction. Rectangular billets, 3-1/2 inches and greater in thickness, shall be tested so that the longitudinal axis of the specimen will be parallel to the thickness of the material.

b. Bar and rod material: Bars and rods, 3-1/2 inches and greater in thickness or width (4 inches in diameter for rounds), shall be tested so that the longitudinal axis of the test specimens will be transverse to the grain direction. For material less than 3-1/2 inches in both thickness and width (4 inches in diameter for rounds), the longitudinal axis of the test specimen shall be parallel to the grain direction. All specimens from bar and rod will be taken from mid-radius locations when size permits.

c. Plate and sheet material: The longitudinal axis of the test specimen shall be transverse to the direction of rolling when width permits. Specimen type R1 and R2 shall be used when thickness permits.

4.4.6.2 Heat treatment: Test specimens shall be heat treated as follows to obtain the property requirements of table III.

a. Austenitize at 1,600 F to 1,650 F for 1 hour.
b. Quench in circulating molten salt at 400 F to 425 F for 15 minutes.
c. Air cool to room temperature.
d. Temper at 400 F 10 F for 1 hour.
e. Air cool to room temperature.
f. Double temper at 1,000 F to 1,040 F.
g. Air cool to room temperature.

4.4.6.3 Test methods: Tensile and notch tensile tests shall be conducted in accordance with the tensile test requirements of Method 211 of FED-STD-151. The specimens shall meet the requirements specified in table III and 3.5.1, as applicable.

4.4.7 Decarburization:

4.4.7.1 Sampling: One sample from each configuration and size of mill product submitted for acceptance at one time shall be selected for determination of the depth of decarburization.