



AEROSPACE MATERIAL

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

AMS 7460C

Superseding AMS 7460B

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BOLTS AND SCREWS, TITANIUM ALLOY

6Al - 4V

Heat Treated, Roll Threaded

1. SCOPE:

1.1 Type: This specification covers high quality bolts and screws made of 6Al - 4V titanium alloy.

1.2 Application: Primarily for joining parts where high-strength, light-weight fasteners are required for use up to 600° F (316° C).

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 10001.

2.1.1 Aerospace Material Specifications:

AMS 2350 - Standards and Test Methods

AMS 2373 - Quality Assurance Sampling of Bolts and Screws

AMS 4967 - Titanium Alloy Bars and Forgings, 6Al - 4V, Annealed,
Heat Treatable

2.1.2 Aerospace Standards:

AS 1132 - Design Parameters for Bolts and Screws, External Wrenching,
Unified Threaded Inch Series

AS 1177 - Nondestructive Inspection Standards for Bolts and Screws

AS 3062 - Bolts, Screws, and Studs, Screw Thread Requirements

AS 3063 - Bolts, Screws, and Studs, Straightness, Concentricity, and
Squareness Requirements

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

ASTM E8 - Tension Testing of Metallic Materials

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

2.3.1 Military Standards:

MIL-STD-1312 - Fasteners, Test Methods

3. TECHNICAL REQUIREMENTS:

3.1 Material: Shall be AMS 4967 titanium alloy.

3.2 Fabrication:

3.2.1 Blanks: Heads shall be formed by hot forging or by machining.

SAE Technical Board rules provide that: "All technical reports, including standards, approvals, and practices recommended, are advisory only. Their use by anyone engaged in industry or trade is entirely voluntary. There is no agreement to adhere to any SAE standard or recommended practice, and no commitment to conform to or be guided by any technical report. In formulating and approving technical reports, the Board and its Committees will not investigate or consider patents which may apply to the subject matter. Prospective users of the report are responsible for protecting themselves against infringement of patents."

- 3.2.2 Heat Treatment: Headed and machined blanks shall, before finishing the shank and the bearing surface of the head, cold working the head-to-shank fillet radius when specified, and rolling the threads, be heat treated as follows:
- 3.2.2.1 Heating Equipment: Furnaces may be any type ensuring uniform temperature throughout the parts being heated and shall be equipped with, and operated by, automatic temperature controllers. The heating medium or atmosphere shall cause neither surface hardening nor embrittlement unless blanks are machined, after heat treatment, to remove surface hardening.
- 3.2.2.2 Solution Heat Treatment: Blanks shall be uniformly heated to a temperature approximately 50 F (28 C) degrees below the beta transus as determined on the heat of material from which blanks are made, held at the selected temperature within $\pm 15^{\circ}\text{F}$ ($\pm 8.3^{\circ}\text{C}$) for 30 - 60 min., and quenched in water.
- 3.2.2.3 Precipitation Heat Treatment: Solution heat treated blanks shall be heated to a temperature within the range 900 - 1100° F (482.2 - 593.3° C), held at the selected temperature within $\pm 10^{\circ}\text{F}$ ($\pm 5.6^{\circ}\text{C}$) for 4 - 8 hr, and cooled in air.
- 3.2.3 Contamination Removal: The solution and precipitation heat treated blanks, before cold working the fillet radius when specified and rolling the threads, shall have all surfaces free from surface contamination and contamination penetration caused by prior heat treatment. The removal process shall produce no intergranular attack, corrosion, or changes of structure of the blanks. The metal removed from the bearing surface of the head and the full body diameter of the shank shall be as little as practicable to obtain a clean, smooth surface and in no case shall be so great as to produce more cutting of flow lines in the head-to-shank junction of upset headed parts than shown in Fig. 1B.
- 3.2.4 Cold Working of Fillet Radius: After removal of contamination as in 3.2.3, the head-to-shank fillet radius of parts having the radius complete throughout the circumference of the part shall, when specified, be cold worked sufficiently to remove all visual evidence of grinding or tool marks. Distortion due to cold working shall not raise metal more than 0.002 in. (0.05 mm) above the contour at "A" or depress metal more than 0.002 in. (0.05 mm) below the contour at "B" as shown in Fig. 2; distorted areas shall not extend beyond "C" as shown in Fig. 2. In configurations having an undercut associated with the fillet radius, the cold working will be required only for 90 deg (1.57 rad) of fillet arc, starting at the point of tangency of the fillet radius and the bearing surface of the head.
- 3.2.5 Thread Rolling: Threads shall be formed on the heat treated and finished blanks by a single rolling process.
- 3.3 Properties: Parts shall conform to the requirements of 3.3.1.1 or 3.3.1.2, as applicable. Threaded members of gripping fixtures for tensile tests shall be of sufficient size and strength to develop the full strength of the part without stripping the thread. For tensile tests on finished parts, the parts shall be tested in accordance with MIL-STD-1312, Test 8.
- 3.3.1 Tensile Properties:
- 3.3.1.1 Finished Parts: Parts shall have breaking load not lower than that specified in Table II. If the size or shape of the part is such that failure would occur outside the threaded section but the part can be tested satisfactorily, such as parts having a shank diameter equal to or less than the thread minor diameter or having an undercut, parts shall conform to only the tensile strength requirement of 3.3.1.2; for such parts, the diameter on which stress is based shall be the actual measured minimum diameter of the part. Tension fasteners with either standard double hexagon or hexagon type heads having a minimum metal condition in the head equal to the design parameters specified in AS 1132 shall not fracture in the head-to-shank fillet radius except when this radius is associated with an undercut.

3.3.1.2 Machined Test Specimens: If the size or shape of the part is such that a tensile test cannot be made on the part, tensile tests shall be conducted in accordance with ASTM E8 on specimens machined from finished parts or from coupons of the same heat of material heat treated with the parts. Tests shall be conducted at a strain rate of 0.003 - 0.007 in. per in. per min. (0.003 - 0.007 mm/mm/min.) through the 0.2% offset after which the rate shall be increased so as to produce failure in approximately one additional minute. Specimens shall conform to the following requirements:

Tensile Strength, min	160,000 psi (1103 MPa)
Elongation in 2 in. (50.8 mm) or 4D, min	8%
Reduction of Area, min	20%

3.4 Quality: Parts shall be uniform in quality and condition, clean, sound, smooth, and free from burrs and foreign materials and from internal and external imperfections detrimental to their performance. Parts shall conform to AS 1177.

3.4.1 Dimensional Examination: Parts shall conform to the following:

3.4.1.1 Straightness, Concentricity, and Squareness: Parts shall be within the limits of the drawing, determined in accordance with AS 3063.

3.4.1.2 Threads: Shall be as specified on the drawing and shall conform to AS 3062.

3.4.2 Macroscopic Examination: Parts or sections of parts, as applicable, shall be etched in a solution of approximately 5% hydrofluoric acid (sp gr 1.15) and 95% water for sufficient time to reveal flow lines but not longer than 1 hr and examined at approximately 20X magnification to determine conformance to the following requirements, except that examination for the thread imperfections of 3.4.2.3 may be made by microscopic examination of specimens polished and etched as in 3.4.3.

3.4.2.1 Flow Lines:

3.4.2.1.1 If parts have upset heads, examination of a longitudinal section through the part shall show flow lines in the shank, head-to-shank fillet, and bearing surface which follow the contour of the part as shown in Fig. 1A, except that slight cutting of flow lines by the contamination removal process of 3.2.3 is permissible, as shown in Fig. 1B; excessive cutting of flow lines in the shank, head-to-shank fillet, and bearing surface, as shown in Fig. 1C, is not permissible except when an undercut is associated with the fillet radius. The head style shown in Fig. 1A through 1C is for illustrative purposes only but other symmetrical head styles shall conform to the above requirements. Flow lines in upset heads on parts having special heads, such as Dee- or Tee-shaped heads or particularly thin heads, shall be as agreed upon by purchaser and vendor.

3.4.2.1.2 Flow lines in threads shall be continuous, shall follow the general thread contour, and shall be of maximum density at root of thread (See Fig. 3).

3.4.2.2 Internal Defects: Examination of longitudinal sections of the head and shank and of the threads shall reveal no cracks or other injurious imperfections. The head and shank section shall extend not less than D/2 from the bearing surface of the head and the threaded section shall extend not less than D/2 beyond the thread runout where "D" is the nominal diameter of the shank after heading. If the two sections would overlap, the entire length of the part shall be sectioned and examined as a whole.

3.4.2.3 Threads:

3.4.2.3.1 Root defects such as notches, slivers, folds, roughness, and oxide scale are not permissible (See Fig. 4).

3.4.2.3.2 Multiple laps on the flanks of threads are not permissible regardless of location. Single laps on the flanks of threads that extend toward the root are not permissible (See Figs. 5 and 6).

- 3.4.2.3.3 There shall be no laps along the flank of the thread below the pitch diameter (See Fig. 7). A single lap is permissible along the flank of the thread above the pitch diameter on either the pressure or non-pressure flank (one lap at any cross section through the thread) provided it extends toward the crest and generally parallel to the flank (See Fig. 7).
- 3.4.2.3.4 Crest craters, crest laps, or a crest lap in combination with a crest crater are permissible, provided the imperfections do not extend deeper than 20% of the basic thread height (See Table I) as measured from the thread crest when the thread major diameter is at minimum size (See Fig. 8). The major diameter of the thread shall be measured prior to sectioning. As the major diameter of the thread approaches maximum size, values for depth of crest crater and crest lap imperfections listed in Table I may be increased by 1/2 of the difference between the minimum major diameter and the actual major diameter as measured on the part.
- 3.4.3 Microscopic Examination: Specimens cut from parts shall be polished, etched in a solution of approximately 1% hydrofluoric acid (sp gr 1.15), 12% nitric acid (sp gr 1.42), and 87% water, and examined at not lower than 100X magnification to determine conformance to the following requirements:
- 3.4.3.1 Microstructure: Parts shall have microstructure free from indications of overheating resulting from heating above the beta transus without subsequent working in the alpha-beta temperature range. Slight overheating on and adjacent to the top of the head is permissible if the depth of overheating is not greater than 0.003 in. (0.08 mm). Measurements shall be made normal to the top of the head. A structure showing outlines of equiaxed beta grains and no primary alpha grains will be cause for rejection.
- 3.4.3.2 Surface Hardening: Parts shall have no surface hardening except as produced during cold working of the head-to-shank fillet radius when specified and during rolling of threads. Parts shall show no evidence of alpha case will not be permitted. In case of dispute over results of the microscopic examination, microhardness testing in accordance with MIL-STD-1312, Test 6, shall be used as a referee method; a Vickers hardness reading within 0.003 in. (0.08 mm) of the surface more than 30 points higher than the reading in the core will be evidence of nonconformance to this requirement.
4. QUALITY ASSURANCE PROVISIONS:
- 4.1 Responsibility for Inspection: The vendor of parts 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 parts conform 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 2373.
- 4.4 Reports: The vendor of parts shall furnish with each shipment three copies of a report stating that the chemical composition of the parts conforms to the requirements of the applicable material specification, showing the results of tests to determine conformance to the tensile property requirements, and stating that the parts conform to all other technical requirements of this specification. This report shall include the purchase order number, this specification number and its revision letter, contractor or other direct supplier of material, part number, and quantity.
- 4.5 Resampling and Retesting: If any part or specimen used in the above tests fails to meet the specified requirements, disposition of the parts may be based on the results of testing three additional parts or specimens for each original nonconforming specimen. Failure of any retest part or specimen to meet the specified requirements shall be cause for rejection of the parts represented and no additional testing shall be permitted. Results of all tests shall be reported.

5. PREPARATION FOR DELIVERY:

5.1 Identification: Each different part number shall be packed in a separate container. Each container shall be marked to show the following information:

FASTENERS, TITANIUM ALLOY, 6Al - 4V
AMS 7460C
PART NUMBER _____
PURCHASE ORDER NUMBER _____
QUANTITY _____
MANUFACTURER'S IDENTIFICATION _____

5.2 Packaging: Containers of parts shall be prepared for shipment in accordance with commercial practice to assure carrier acceptance and safe transportation to the point of delivery. Packaging shall conform to carrier rules and regulations applicable to the mode of transportation.

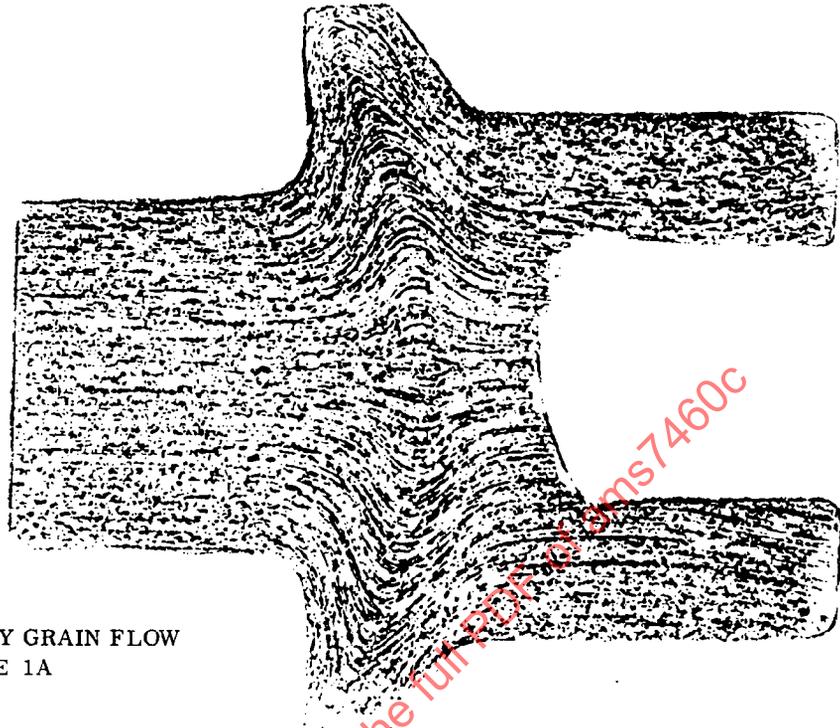
6. ACKNOWLEDGMENT: A vendor shall mention this specification number and its revision letter in all quotations and when acknowledging purchase orders.

7. REJECTIONS: Parts not conforming to this specification or to authorized modifications will be subject to rejection.

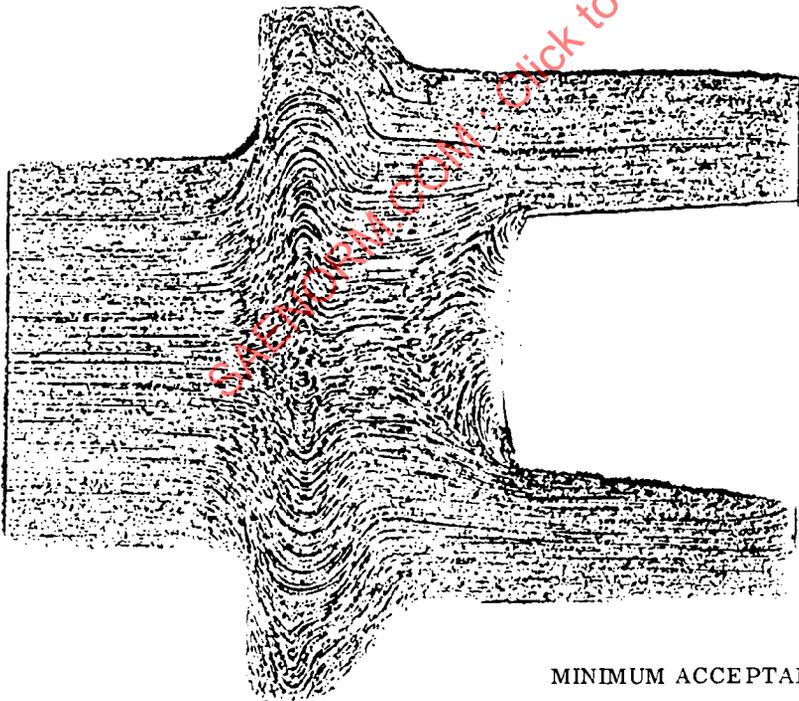
8. NOTES:

8.1 Marginal Indicia: No phi (\emptyset) symbol is used to indicate where technical changes have been made in this specification because of the extensive nature of all changes.

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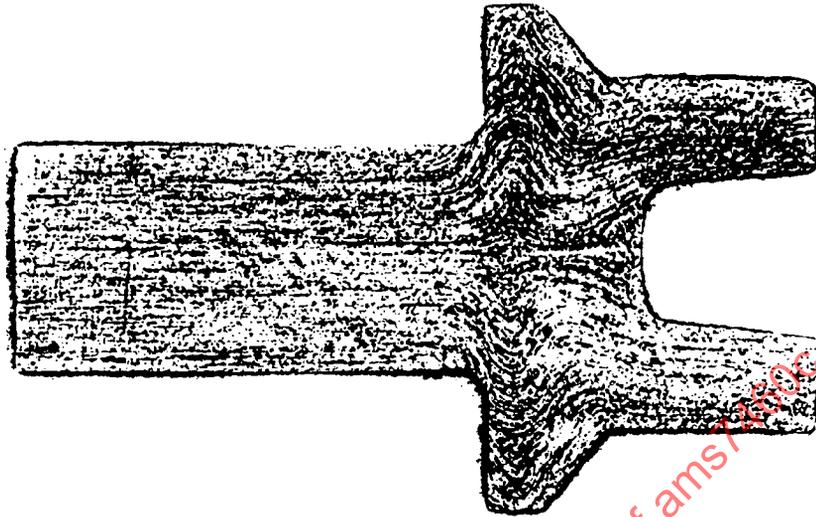
SATISFACTORY GRAIN FLOW
FIGURE 1A



MINIMUM ACCEPTABLE STANDARD

Showing maximum permissible cutting of flow lines after machining to remove oxide and decarburization as in 3.2.3.

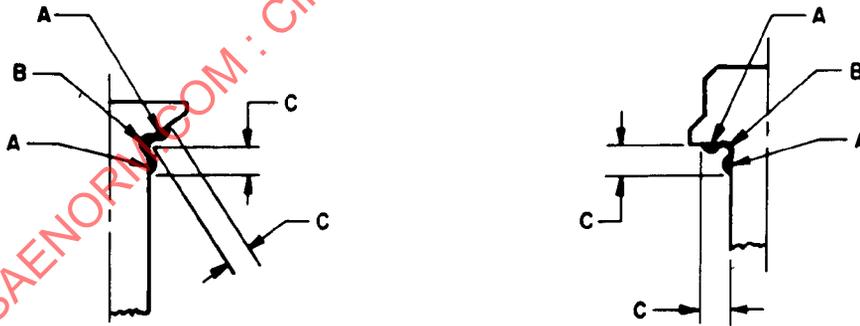
FIGURE 1B



UNACCEPTABLE GRAIN FLOW

Excessive cutting of flow lines in the shank, head to shank fillet, and bearing surface is not permissible.

FIGURE 1C

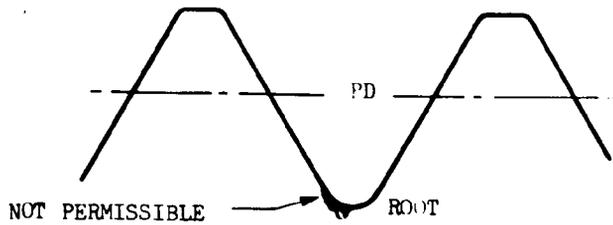


Nominal Bolt Diameter		C, max	
Inches	(Millimeters)	Inch	(Millimeters)
Up to 0.3125, excl	(Up to 7.94, excl)	0.062	1.57
0.3125 and 0.375	(7.94 and 9.52)	0.094	2.39
0.4375 - 0.625, incl	(11.11 - 15.88, incl)	0.125	3.18
0.750 - 1.000, incl	(19.05 - 25.40, incl)	0.156	3.96
Over 1.000	(Over 25.40)	0.188	4.78

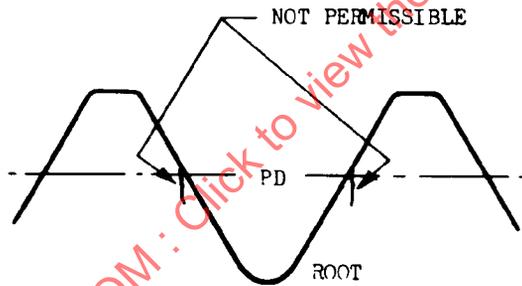
PERMISSIBLE DISTORTION FROM FILLET WORKING
FIGURE 2



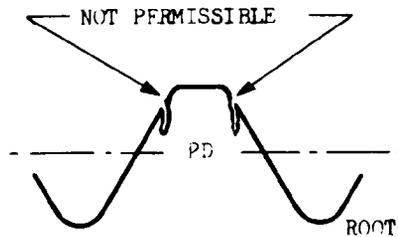
FLOW LINES, ROLLED THREAD
FIGURE 3



ROLLED THREAD
FIGURE 4



ROLLED THREAD
FIGURE 5



ROLLED THREAD
FIGURE 6

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