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TWO PENNSYLVANIA PLAZA, NEW YORK, N.Y. 10001

AEROSPACE MATERIAL SPECIFICATION

AMS 7477B
Superseding AMS 7477A

Issued 1-31-64
Revised 11-1-70

BOLTS AND SCREWS, STEEL, CORROSION AND HEAT RESISTANT
Upset Headed, Heat Treated, Roll Threaded
1800 F (982.2 C) Solution and Precipitation Heat Treated

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

2. APPLICATION: Premium quality bolts and screws for use where a good combination of fatigue resistance, strength, and resistance to relaxation at temperatures up to 1200 F (649 C) is required.

3. MATERIAL: Shall be AMS 5731 steel heading stock.

3.1 Stock: Shall be reduced 15 - 25% in cross sectional area during the final drawing or rolling at a temperature not higher than 1600 F (871 C) unless stock is so reduced or is otherwise processed, during manufacture of parts, to prevent grain growth during heat treatment. Stock reduced as above shall have hardness of Brinell 201 - 285 or equivalent.

4. FABRICATION:

4.1 Blanks: Heads shall be formed by hot forging or cold forging; machined heads will not be permitted. Heading stock to be hot forged shall not be heated to a temperature higher than 2100 F (1149 C).

4.2 Heat Treatment: Headed blanks shall, before finishing the shank and the bearing surface of the head, Ø cold working the head-to-shank fillet radius, and rolling the threads, be solution and precipitation heat treated as follows:

4.2.1 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 no surface hardening by carburizing or nitriding.

4.2.2 Solution Heat Treatment: Blanks shall be solution heat treated by uniformly heating to 1800 F ± 25 (982.2 C ± 14), holding at heat for approximately 1 hr, and quenching in oil or water.

4.2.3 Precipitation Heat Treatment: After solution heat treatment as in 4.2.2, blanks shall be precipitation heat treated by heating to a temperature within the range 1300 - 1400 F (704.4 - 760 C), holding at the selected temperature within ±15 F (±8.3 C) for approximately 16 hr, and cooling in air.

4.3 Oxide Removal: The solution and precipitation heat treated blanks, before cold working the fillet radius and rolling the threads, shall have all surfaces free from surface oxide and oxide penetration caused by prior heat treatment. The removal process shall produce no intergranular attack or corrosion 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 than shown in Fig. 1B.

4.4 Cold Working of Fillet Radius: After removal of oxide in 4.3, the head-to-shank fillet radius of parts having the radius complete throughout the circumference of the part shall be cold worked sufficiently to remove all visual evidence of grinding or tool marks. Distortion due to cold working shall Ø not raise metal more than 0.002 in. above the contour at "A" or depress metal more than 0.002 in. 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 of fillet arc, starting at the point of tangency of the fillet radius and the bearing surface of the head.

4.5 Thread Rolling: Threads shall be formed on the heat treated and finished blanks by a single rolling process after removal of oxide as in 4.3.

4.6 Cleaning: Parts, after finishing, shall be degreased and then immersed in one of the following solutions for the time and at the temperature shown:

Ø (a) One volume of nitric acid (sp gr 1.42) and 9 volumes of water for not less than 20 min. at room temperature.

(b) One volume of nitric acid (sp gr 1.42) and 4 volumes of water for 30 - 40 min. at room temperature.

(c) One volume of nitric acid (sp gr 1.42) and 4 volumes of water for 10 - 15 min. at 140 - 160 F (60 - 71.1 C).

5. TECHNICAL REQUIREMENTS: Parts shall conform to the metallurgical and mechanical requirements specified below, determined in accordance with MIL-STD-1312 except as otherwise specified herein; Ø when ASTM methods are specified for determining conformance, tests shall be conducted in accordance with the issue of the ASTM method listed in the latest issue of AMS 2350. Parts shall also conform to the latest issue of the following:

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

5.1 Macroscopic Examination: Parts or sections of parts, as applicable, shall be etched in a solution of approximately 40% hydrochloric acid (sp gr 1.19), 10% of a 30% solution of hydrogen peroxide, and 50% Ø water, or other suitable etchant, for sufficient time to reveal flow lines but not longer than 30 min. and shall then be examined at approximately 20X magnification to determine conformance to the following requirements, except that examination for the thread imperfections of 5.1.3 may be made by microscopic examination of specimens polished and etched as in 5.2.

5.1.1 Flow Lines:

5.1.1.1 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 oxide removal process of 4.3 is permissible, as shown in Fig. 1B; excessive cutting of flow lines in the shank, head-to-shank fillet, and bearing surface, as Ø shown in Fig. 1C, is not permissible except when an undercut is associated with the fillet radius. The head style shown in Figs. 1A through 1C is for illustrative purposes only but other symmetrical head styles shall conform to the above requirements. Flow lines in heads on parts having special heads, such as Dee- or Tee-shaped heads or thinner-than-standard heads, shall be as agreed upon by purchaser and vendor.

5.1.1.2 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).

5.1.2 Internal Defects: Examination of longitudinal sections of the head and shank and of the threads shall reveal no cracks, laps, or porosity. The head and shank section shall extend not less than D/2 in. from the bearing surface of the head and the threaded section shall extend not less than D/2 in. 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.

5.1.3 Threads:

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

5.1.3.2 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).

5.1.3.3 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).

5.1.3.4 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.

5.2 Microscopic Examination: Specimens cut from parts shall be polished, etched in Kalling's reagent (100 ml of absolute ethyl alcohol, 100 ml of hydrochloric acid (sp gr 1.19), and 5 g of cupric chloride), Ø Marble's reagent (20 ml of hydrochloric acid (sp gr 1.19), 20 ml of water, and 4 g of cupric sulfate pentahydrate), or other suitable etchant, and then examined at not lower than 100 X magnification to determine conformance to the following requirements:

5.2.1 Microstructure: Parts shall have microstructure of completely recrystallized material except in the area of the threads and the head-to-shank fillet radius.

5.2.2 Grain Size: Shall be 5 or finer as determined by comparison of the specimen with the chart in ASTM E112. Up to 25%, by area, of abnormally large grains will be permitted in any specific area of 100 or more adjacent grains; abnormally large grains are defined as grains more than 3 ASTM numbers coarser than the average grain size of the part.

5.2.3 Surface Hardening: Parts shall have no surface hardening except as produced during cold working of the head-to-shank fillet radius and during rolling of threads. Evidence of carburization or nitriding Ø will not be permitted. In case of dispute over results of the microscopic examination, microhardness testing shall be used as a referee method; a Vickers hardness reading within 0.003 in. of the surface more than 30 points higher than the reading in the core will be evidence of nonconformance to this requirement.

5.3 Properties: Parts shall conform to the requirements of 5.3.1.1 or 5.3.1.2, as applicable, 5.3.2, and 5.3.3.1 or 5.3.3.2, as applicable. Threaded members of gripping fixtures for tensile and stress-rupture Ø tests shall be of sufficient size and strength to develop the full strength of the part without stripping the thread. For tensile and stress-rupture tests on finished parts, the parts shall be aligned in fixtures so that three full turns of thread are exposed in the gage section.

5.3.1 Tensile Properties:

5.3.1.1 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 Ø diameter or having an undercut, parts shall conform to only the tensile strength requirement of 5.3.1.2; for such parts, the diameter on which stress is based shall be the actual measured minimum diameter of the part and parts shall fracture only in the unthreaded shank section or the undercut, not in the area of the head-to-shank fillet radius except when this radius is associated with an undercut.

5.3.1.2 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 A370 on specimens machined Ø from finished parts or from coupons of the same heat of material heat treated with the parts. Specimens shall conform to the following requirements:

Tensile Strength, psi	130,000 min
Yield Strength at 0.2% Offset	85,000 min
Elongation, % in 2 in. or 4D	15 min
Reduction of Area, %	20 min

5.3.1.2.1 When permitted by purchaser, hardness tests on the end of parts may be substituted for tensile tests of machined specimens.

5.3.2 Hardness: Shall be uniform and within the range Rockwell C 24 - 35 or equivalent but hardness of the threaded section and of the head-to-shank fillet area may be higher as a result of the cold working operations.

5.3.3 Stress-Rupture Test at 1200 F (648.9 C):

5.3.3.1 Finished Parts: Parts, maintained at 1200 F ± 3 (648.9 C ± 1.7) while the load specified in Table II is applied continuously, shall not rupture in less than 23 hours. If the shank diameter of the part is less than the maximum minor (nominal minor) diameter of the thread but the part can be tested satisfactorily, parts shall conform to the requirements of 5.3.3.1.1.

5.3.3.1.1 Parts having a shank diameter less than the maximum minor (nominal minor) diameter of the part shall be tested as in 5.3.3.1 except that the load shall be as specified in 5.3.3.2. The diameter on which stress is based shall be the actual measured minimum diameter of the part.

5.3.3.2 Machined Test Specimens: If the size or shape of the part is such that a stress-rupture test cannot be made on the part, a test specimen, maintained at 1200 F ± 3 (648.9 C ± 1.7) while a load sufficient to produce an initial axial stress of 70,000 psi is applied continuously, shall not rupture in less than 23 hours. Specimens shall be machined from finished parts, or from coupons of the same heat of material heat treated with the parts, to the dimensions shown in ASTM A370. Tests shall be conducted in accordance with ASTM E139.

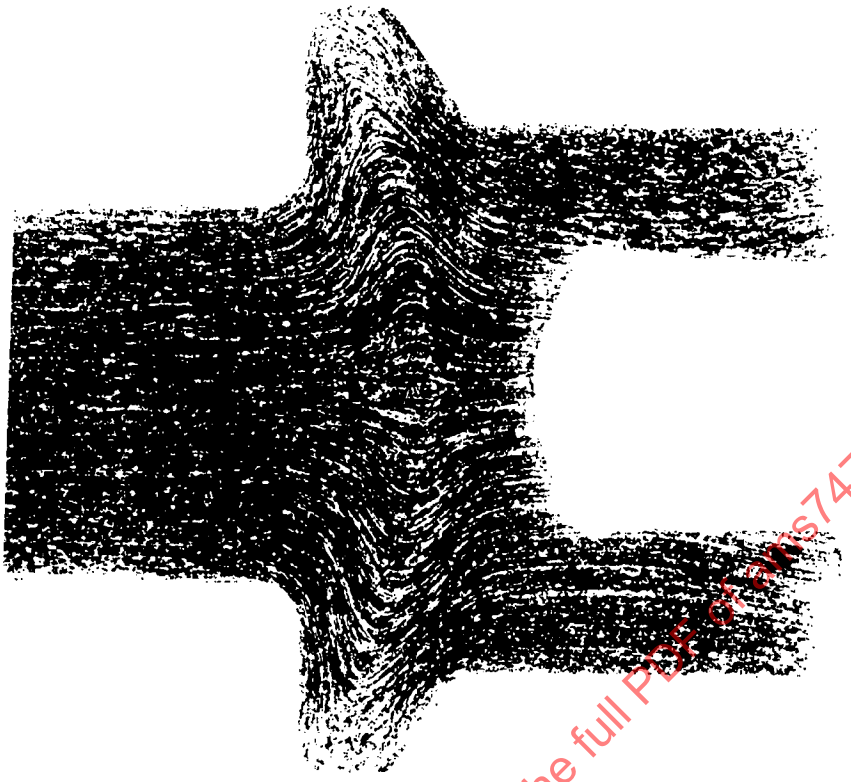
5.4 Resampling and Retesting: If any part or specimen used in the above tests fails to meet the specified requirements, acceptance of the parts may be based on the testing of three additional parts or specimens for each original nonconforming part or specimen, all of which additional parts or specimens shall conform to specified requirements. 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.

6. 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.

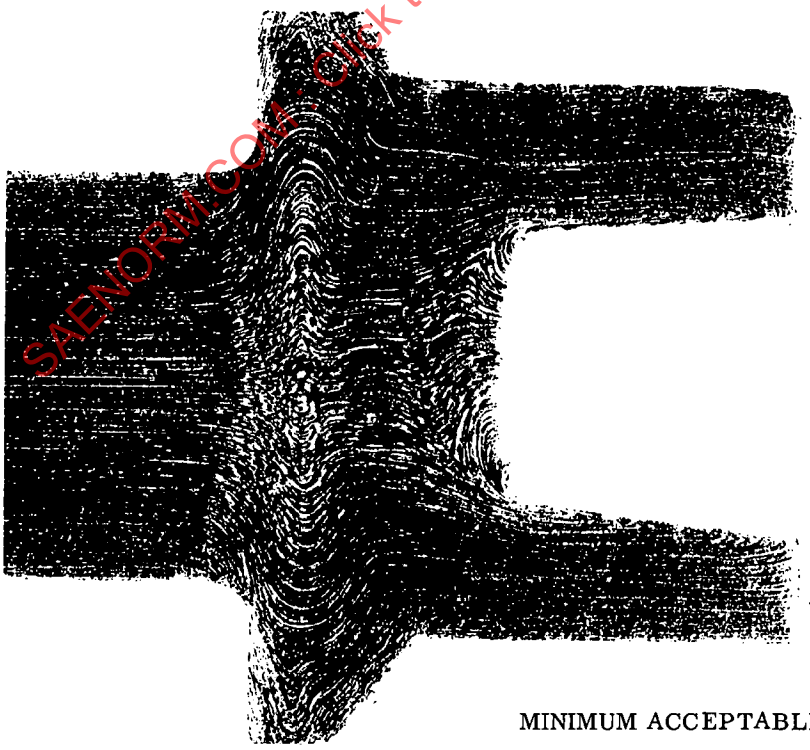
7. SAMPLING: Shall be in accordance with the latest issue of AMS 2373.

8. REPORTS: Unless otherwise specified, 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 and showing the results of tests to determine conformance to the tensile property, hardness, and stress-rupture strength requirements of this specification. This report shall include the purchase order number, AMS 7477B, contractor or other direct supplier of material, part number, and quantity.

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



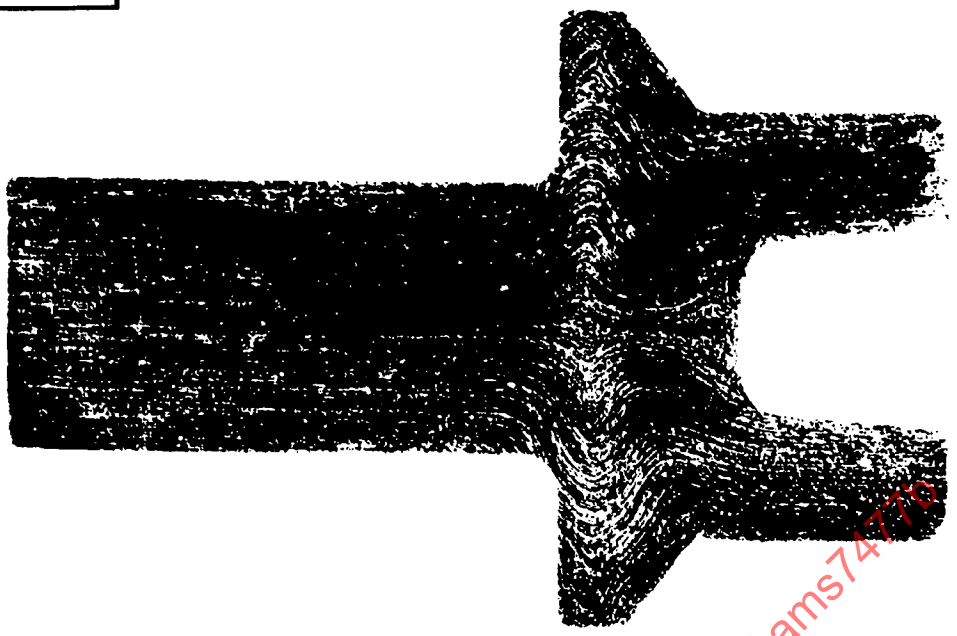
SATISFACTORY GRAIN FLOW
FIGURE 1A



MINIMUM ACCEPTABLE STANDARD

Showing maximum permissible cutting of flow lines after machining to remove oxide and decarburization as in 4.3.

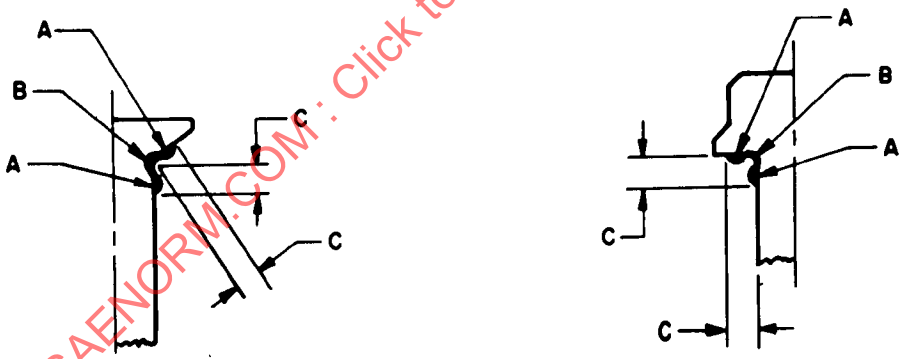
FIGURE 1B



UNACCEPTABLE GRAIN FLOW

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

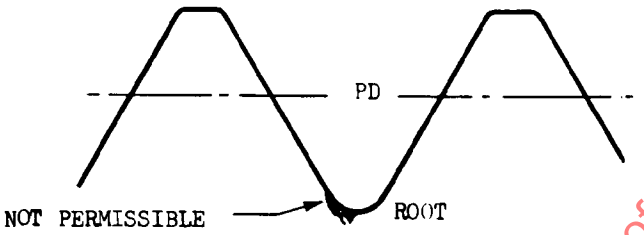
FIGURE 1C



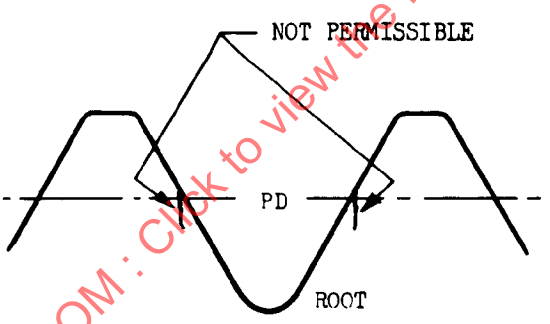
Nominal Bolt Diameter	C, max
Up to 0.3125, excl	0.062
0.3125 and 0.375	0.094
0.4375 - 0.625, incl	0.125
0.750 - 1.000, incl	0.156
Over 1.000	0.188

PERMISSIBLE DISTORTION FROM FILLET WORKING
FIGURE 2

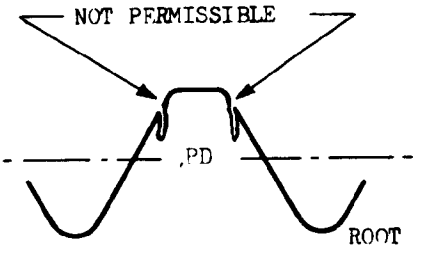
FLOW LINES, ROLLED THREAD
FIGURE 3



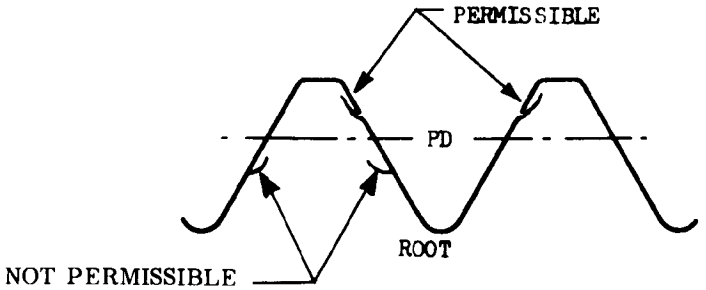
ROLLED THREAD
FIGURE 4



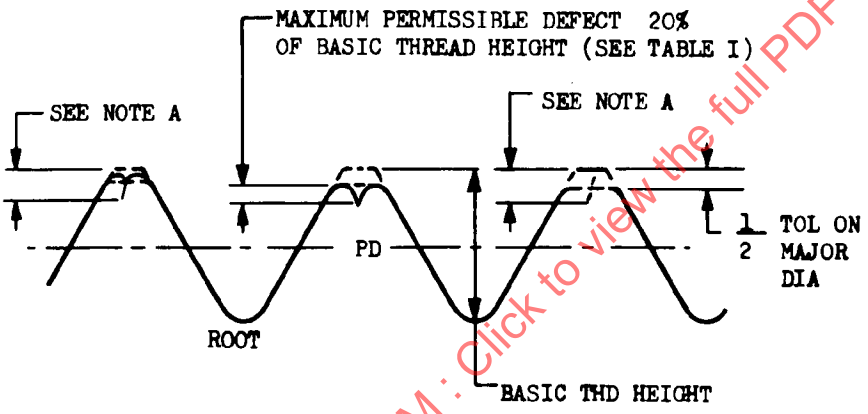
ROLLED THREAD
FIGURE 5



ROLLED THREAD
FIGURE 6



ROLLED THREAD
FIGURE 7



NOTE A. DEPTH OF DEFECT EQUALS 20% OF BASIC THREAD HEIGHT PLUS 1/2 THE DIFFERENCE OF THE ACTUAL MAJOR DIAMETER AND MINIMUM MAJOR DIAMETER.

ROLLED THREAD
FIGURE 8