Society of Automotive Engineers, Inc.
400 COMMONWEALTH DRIVE, WARRENDALE, PA. 15096

AEROSPACE MATERIAL SPECIFICATION

AMS 7469B
Superseding AMS 7469A

Issued 6-30-64
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UNS N07041

BOLTS AND SCREWS, NICKEL ALLOY, CORROSION AND HEAT RESISTANT
Upset Headed, Heat Treated, Roll Threaded
2050°F (1120°C) Solution and 1650°F (900°C) Precipitation Heat Treatment

1. SCOPE:

1.1 Type: This specification covers aircraft quality bolts and screws fabricated from a corrosion and heat resistant nickel alloy.

1.2 Application: Primarily for use where fasteners are required to have high strength and good resistance to relaxation up to 1600°F (870°C) and oxidation resistance up to 1800°F (980°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., 400 Commonwealth Drive, Warrendale, PA 15096.

2.1.1 Aerospace Material Specifications:

AMS 2350 - Standards and Test Methods
AMS 2373 - Quality Assurance Sampling of Bolts and Screws
AMS 5712 - Alloy Bars, Forgings, and Rings, Corrosion and Heat Resistant, 53Ni - 19Cr - 11Co - 9.8Mo - 3.2Ti - 1.6Al - 0.006B, Vacuum Melted, Solution Heat Treated

2.1.2 Aerospace Standards:

AS 1132 - Design Parameters for Bolts and Screws, External Wrenching, Unified Thread 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, Geometric Control Requirements

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

ASTM E8 - Tension Testing of Metallic Materials
ASTM E21 - Elevated Temperature Tension Tests of Metallic Materials
ASTM E112 - Estimating the Average Grain Size of Metals
ASTM E139 - Conducting Creep, Creep-Rupture, and Stress-Rupture Tests of Metallic Materials

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

2.3.1 Military Standards:

MIL-STD-794 - Parts and Equipment, Procedures for Packaging and Packing of
MIL-STD-1312 - Fasteners, Test Methods

3. TECHNICAL REQUIREMENTS:

3.1 Material: Shall be AMS 5712 alloy heading stock.

3.2 Fabrication:

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

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

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 no surface hardening by carburizing or nitriding. The total sulfur content of the atmosphere shall be maintained at less than 5 grains per 100 cu ft (114 mg/m^3).

3.2.2.2 Solution Heat Treatment: Blanks shall be solution heat treated by uniformly heating to 2050°F ± 25 (1120°C ± 15), holding at heat for 30 min., and quenching in oil or air.

3.2.2.3 Precipitation Heat Treatment: After cold working the fillet radius as in 3.2.4 and rolling the threads as in 3.2.5, parts shall be precipitation heat treated by heating to 1650°F ± 15 (900°C ± 8), holding at heat for 4 hr ± 0.25, and cooling in air. Parts should be heated rapidly through the temperature range 1200° - 1400°F (650° - 760°C).

3.2.3 Oxide Removal: Surface oxide and oxide penetration resulting from prior heat treatment shall be removed from the full body diameter and the bearing surface of the head of the solution heat treated blanks prior to cold working the fillet radius and rolling the threads. The oxide 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-head shank junction than shown in Fig. 1B.

3.2.4 Cold Working of Fillet Radius: After removal of oxide as in 3.2.3, the head-to-shank fillet radius of headed 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 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 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 finished, solution heat treated blanks by a single rolling process after removal of oxide as in 3.2.3.

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

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

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

3.2.6.3 One volume of nitric acid (sp gr 1.42) and 4 volumes of water for 10 - 15 min. at 140° - 160°F (60° - 70°C).

3.3 Properties: Parts shall conform to the requirements of 3.3.1, 3.3.2, and 3.3.3. Threaded members of gripping fixtures for tensile and stress-rupture tests shall be of sufficient size and strength to develop the full strength of the part without stripping the thread. The loaded portion of the shank shall have a minimum of two full thread turns from thread runout exposed between the loading fixtures during tensile and stress-rupture tests. Finished parts shall be tested in accordance with the following applicable test methods of MIL-STD-1312:

Requirement	Test Method
Hardness	No. 6
Room Temperature Tensile Strength	No. 8
Stress-Rupture	No. 10
Elevated Temperature Tensile Strength	No. 18

3.3.1 Tensile Properties:

3.3.1.1 At Room Temperature:

3.3.1.1.1 Finished Parts: Parts shall have breaking load not lower than the value 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 have tensile strength not lower than 155,000 psi (1069 MPa); 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-head-shank fillet radius except when this radius is associated with an undercut or with a shank diameter less than the minimum pitch diameter of the thread.

3.3.1.1.2 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 prepared as in 4.3.1. Such specimens shall meet the following requirements:

Tensile Strength, min	155,000 psi (1069 MPa)
Elongation in 4D, min	8%
Reduction of Area, min	10%

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

3.3.1.2 At 1400°F (760°C):

3.3.1.2.1 Finished Parts: Parts, heated to 1400°F ± 5 (760°C ± 3), held at heat for 30 min. before testing, and tested at 1400°F ± 5 (760°C ± 3), shall have breaking load not lower than the value 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 un undercut, parts shall have tensile strength not lower than 126,000 psi (869 MPa); 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 or with a shank diameter less than the minimum pitch diameter of the thread.

3.3.1.2.2 Machined Test Specimens: If the size or shape of the part is such that a tensile test cannot be made on the part, tensile test specimens prepared as in 4.3.1 shall meet the following requirements when heated to 1400°F ± 5 (760°C ± 3), held at heat for 30 min. before testing, and tested in accordance with ASTM E21 at 1400°F ± 5 (760°C ± 3):

Tensile Strength, min	126,000 psi (869 MPa)
Elongation in 4D, min	8%
Reduction of Area, min	10%

3.3.2 Hardness: Shall be uniform and not lower than 30 HRC or equivalent but hardness of the threaded section and of the head-to-shank fillet area may be higher than that of other areas as a result of the cold working operations.

3.3.3 Stress-Rupture Properties at 1350°F (732°C):

3.3.3.1 Finished Parts: Parts, maintained at 1350°F ± 3 (732°C ± 2) while the load specified in Table II is applied continuously, shall not rupture in less than 30 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 3.3.3.1.1.

3.3.3.1.1 Parts having a shank diameter less than the maximum minor (nominal minor) diameter of the part shall be tested as in 3.3.3.1 except that the load shall be as specified in 3.3.3.2. The diameter on which stress is based shall be the actual measured minimum diameter of the part.

3.3.3.2 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 prepared as in 4.3.1, maintained at 1350°F ± 3 (732°C ± 2) while a load sufficient to produce an initial axial stress of 85,000 psi (586 MPa) is applied continuously, shall not rupture in less than 30 hours. Tests shall be conducted in accordance with ASTM E139.

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, Ø determined in accordance with AS 3063.

Ø 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, etched at room temperature for 10 - 30 min. in a solution consisting of approximately 50% hydrochloric acid (sp gr 1.19), 20% hydrofluoric acid (sp gr 1.15), 4% nitric acid (sp gr 1.42), and 26% water or in other suitable etchant, shall be examined at a magnification of approximately 20X 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 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 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 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 heads thinner-than-standard as in AS 1132, 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 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, laps, or porosity except laps in threads as permitted in 3.4.2.3.3 and 3.4.2.3.4. 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 laps, seams, 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 nonpressure 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 that 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 one-half 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 Kalling's reagent (100 mL of absolute ethyl alcohol, 100 mL of hydrochloric acid (sp gr 1.19), and 5 g of cupric chloride), 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 examined at a magnification not lower than 100X to determine conformance to the requirements of 3.4.3.1, 3.4.3.2, and 3.4.3.3.

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

3.4.3.2 Grain Size: Shall be 1 or finer, determined by comparison of a polished and etched specimen with the chart in ASTM E112.

3.4.3.3 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. There shall be no evidence of carburization, recarburization, or nitriding. 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. (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 for vendor's tests 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 sample and to perform such confirmatory testing as he deems necessary to ensure that the parts conform to the requirements of this specification.

4.2 Classification of Tests:

4.2.1 Acceptance Tests: Tests to determine conformance to requirements for material (3.1), room-temperature tensile properties (3.3.1.1), hardness (3.3.2), stress-rupture properties (3.3.3), and quality (3.4) are classified as acceptance tests and shall be performed on each lot.

4.2.2 Periodic Tests: Tests to determine conformance to requirements for 1400°F (760°C) tensile properties (3.3.1.2) are classified as periodic tests and shall be performed at a frequency selected by the vendor unless frequency of testing is specified by purchaser.

4.3 Sampling: Shall be in accordance with AMS 2373 and the following; a lot shall be all parts of one size and configuration made from a single heat of alloy processed in one continuous run and presented for vendor's inspection at one time:

4.3.1 Specimens for tensile and stress-rupture testing of machined test specimens shall be of standard proportions in accordance with ASTM E8 with either 0.250 in. (6.25 mm) diameter at the reduced parallel gage section or smaller specimens proportional to the standard when required. Specimens shall be machined from finished parts or from coupons of the same heat of alloy processed with the parts they represent.

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 applicable material specification, showing results of tests to determine conformance to the room-temperature tensile property, hardness, and stress-rupture requirements, and stating that the parts conform to the other technical requirements of this specification. This report shall include the purchase order number, AMS 7469B, contractor or other direct supplier of material, part number, nominal size, 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 Packaging and Identification:

5.1.1 Parts having different part numbers shall be packed in separate containers.

5.1.2 Each container of parts shall be marked to show not less than the following information:

FASTENERS, NICKEL ALLOY, CORROSION AND HEAT RESISTANT
AMS 7469B
PART NUMBER _____
PURCHASE ORDER NUMBER _____
QUANTITY _____
MANUFACTURER'S IDENTIFICATION _____

5.1.3 Containers of parts shall be prepared for shipment in accordance with commercial practice and in compliance with applicable rules and regulations pertaining to the handling, packaging, and transportation of the parts to ensure carrier acceptance and safe delivery. Packaging shall conform to carrier rules and regulations applicable to the mode of transportation.

5.1.4 For direct U.S. Military procurement, packaging shall be in accordance with MIL-STD-794, Level A or Level C, as specified in the request for procurement. Commercial packaging as in 5.1.1 and 5.1.3 will be acceptable if it meets the requirements of Level C.

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

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

8. NOTES:

8.1 Marginal Indicia: The phi (Ø) symbol is used to indicate technical changes from the previous issue of this specification.

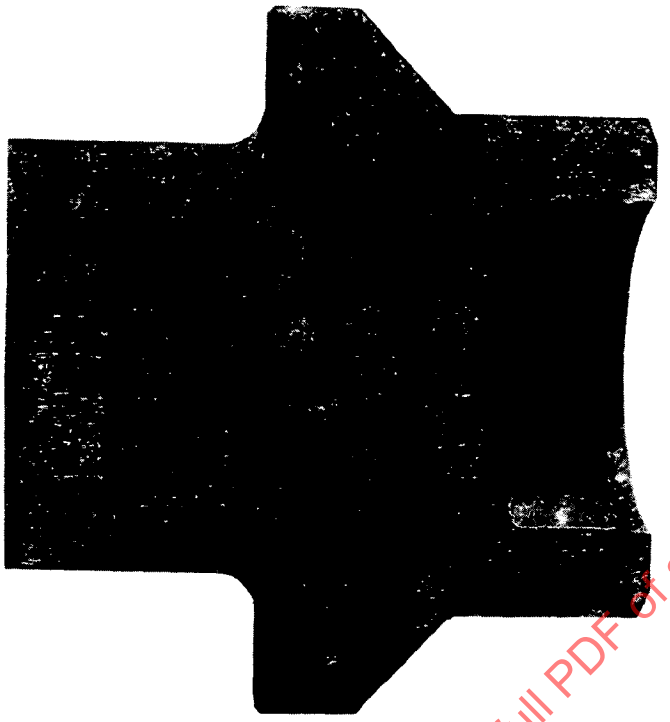
8.2 For direct U.S. Military procurement, purchase documents should specify not less than the following:

Title, number, and date of this specification
Part number or size or parts desired
Quantity of parts desired
Applicable level of packaging (See 5.1.4).

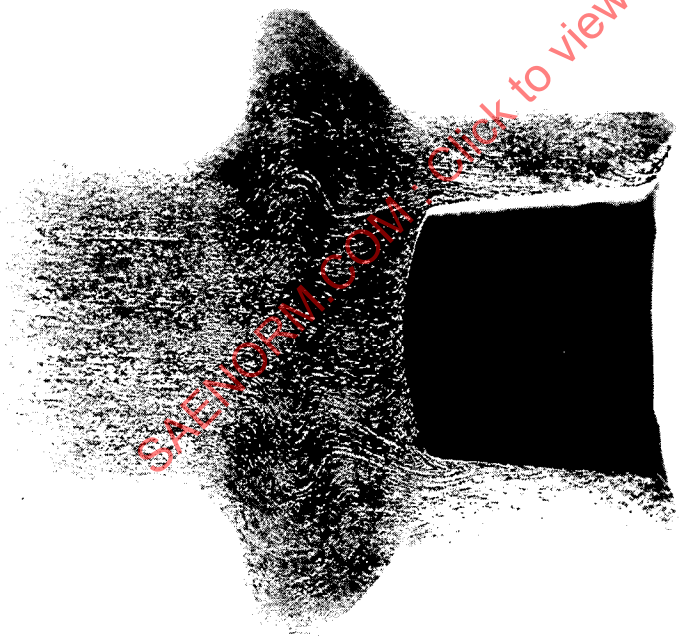
TABLE I

Threads Per Inch	Basic Thread Height Ref (See Note 1)		20% Basic Thread Height	
	Inch	(Millimetres)	Inch	(Millimetre)
80	0.0081	(0.206)	0.0016	(0.041)
72	0.0090	(0.229)	0.0018	(0.046)
64	0.0102	(0.259)	0.0020	(0.051)
56	0.0116	(0.295)	0.0023	(0.058)
48	0.0135	(0.343)	0.0027	(0.069)
44	0.0148	(0.376)	0.0030	(0.076)
40	0.0162	(0.411)	0.0032	(0.081)
36	0.0180	(0.457)	0.0036	(0.091)
32	0.0203	(0.516)	0.0041	(0.104)
28	0.0232	(0.589)	0.0046	(0.117)
24	0.0271	(0.688)	0.0054	(0.137)
20	0.0325	(0.826)	0.0065	(0.165)
18	0.0361	(0.917)	0.0072	(0.183)
16	0.0406	(1.031)	0.0081	(0.206)
14	0.0464	(1.179)	0.0093	(0.236)
13	0.0500	(1.270)	0.0100	(0.254)
12	0.0541	(1.374)	0.0108	(0.274)
11	0.0590	(1.499)	0.0118	(0.300)
10	0.0650	(1.651)	0.0130	(0.330)
9	0.0722	(1.834)	0.0144	(0.366)
8	0.0812	(2.062)	0.0163	(0.414)

Note 1. Basic thread height is defined as being equivalent to 0.650 times the pitch.



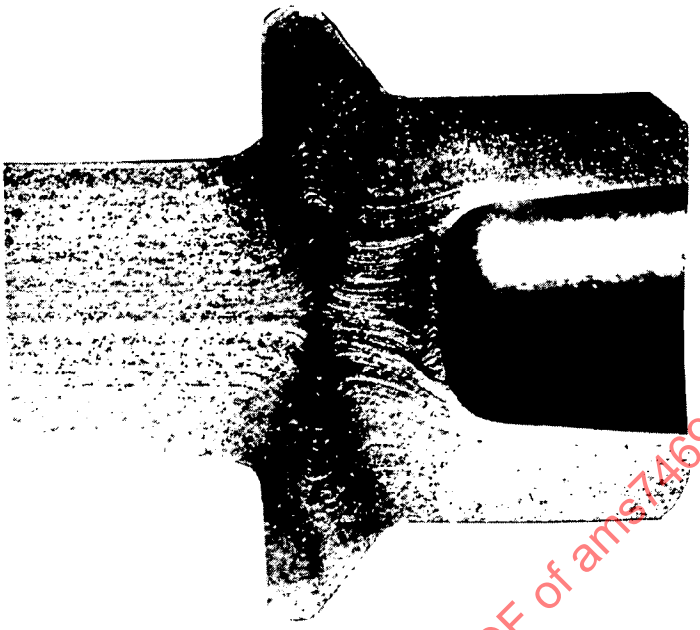
SATISFACTORY GRAIN FLOW
FIGURE 1A



MINIMUM ACCEPTABLE STANDARD

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

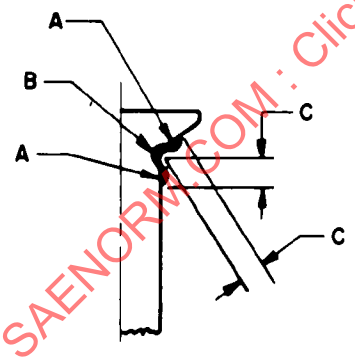
FIGURE 1B

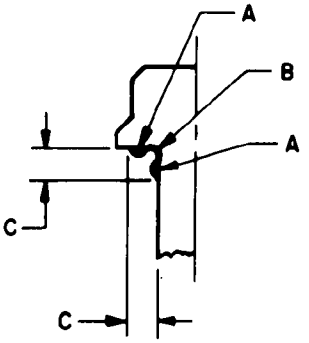


UNACCEPTABLE GRAIN FLOW

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

FIGURE 1C

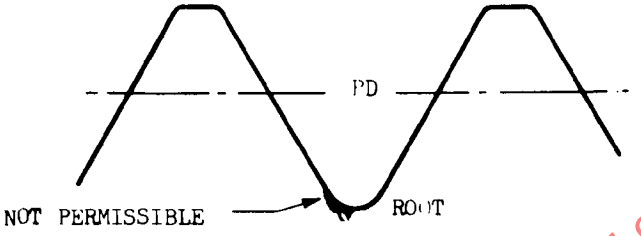




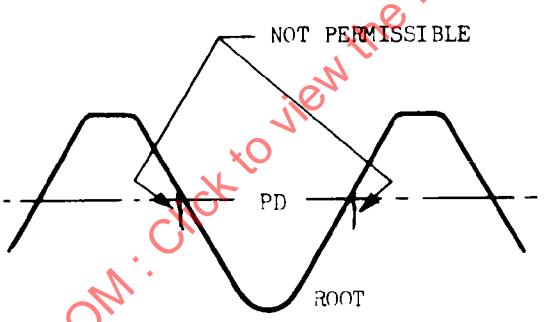
Nominal Bolt Diameter		C, max	
Inches	(Millimetres)	Inch	(Millimetres)
Up to 0.3125, excl	(Up to 7.94, excl)	0.062	(1.57)
0.3125 and 0.375	(7.94 and 9.52)	0.094	(2.39)
0.4375 - 0.625, incl	(11.11 - 15.88, incl)	0.125	(3.18)
0.750 - 1.000, incl	(19.05 - 25.40, incl)	0.156	(3.96)
Over 1.000	(Over 25.40)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

PERMISSIBLE DISTORTION FROM FILLET WORKING
FIGURE 2

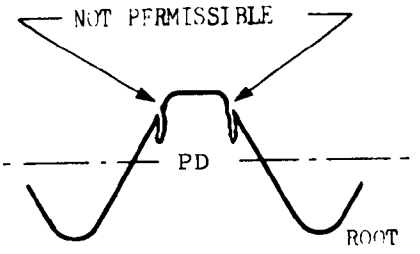
FLOW LINES, ROLLED THREAD
FIGURE 3



ROLLED THREAD
FIGURE 4



ROLLED THREAD
FIGURE 5



ROLLED THREAD
FIGURE 6