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

AEROSPACE MATERIAL SPECIFICATION

AMS 7471D
Superseding AMS 7471C
Issued 7-15-63
Revised 10-15-79

BOLTS AND SCREWS, NICKEL ALLOY, CORROSION AND HEAT RESISTANT
Upset Headed, Heat Treated, Roll Threaded
1950°F (1065°C) Solution Heat Treatment

1. SCOPE:

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

1.2 Application: Primarily for joining parts where high strength up to 1500°F (815°C) and oxidation resistance up to 1750°F (955°C) are required.

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 5708 - Alloy Bars and Forgings, Corrosion and Heat Resistant, Nickel Base - 19.5Cr - 13.5Co - 4.3Mo - 3.0Ti - 1.4Al, Consumable Electrode or Vacuum Induction Melted, 1975°F (1079.4°C) 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 E112 - Estimating the Average Grain Size of Metals
ASTM E139 - Conducting Creep, Creep-Rupture, and Stress-Rupture Tests of Metallic Materials

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

Printed in U.S.A.

2.3.1 Federal Standards:

FED-STD-H28 - Screw-Thread Standards for Federal Services

2.3.2 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 5708 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 and stabilization 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.

3.2.2.2 Solution Heat Treatment: Blanks shall be solution heat treated by heating to a temperature Ø within the range 1900° - 1975°F (1040° - 1080°C), holding at the selected temperature within ±25°F (±15°C) for 1 to 4 hr, and cooling at a rate equivalent to air cool or faster.

3.2.2.2.1 A temperature lower than 1900°F (1040°C) may be used provided that the furnace control Ø is such that during the holding period no part is below 1875°F (1025°C).

3.2.2.3 Stabilization Heat Treatment: Solution heat treated blanks shall be stabilization heat treated by heating to 1550°F ± 15 (845°C ± 8), holding at heat for 4 hr ± 0.5 and cooling in air.

3.2.2.4 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 1400°F ± 15 (760°C ± 8), holding at heat for 16 hr ± 1, and cooling in air.

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 and stabilization 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-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 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 and stabilization 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 part 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
Tensile Strength	No. 8
Stress-Rupture	No. 10

3.3.1 Tensile Properties: Shall be as follows:

3.3.1.1 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 165,000 psi (1138 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.

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

Tensile Strength, min	175,000 psi (1207 MPa)
Yield Strength at 0.2% Offset, min	115,000 psi (793 MPa)
Elongation in 4D, min	15%
Reduction of Area, min	18%

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

3.3.2 Hardness: Shall be uniform and within the range 34 - 44 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): Shall be as follows:

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 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 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 75,000 psi (517 MPa) is applied continuously, shall not rupture in less than 23 hours. Tests shall be conducted in accordance with ASTM E139.

3.4 Quality: Parts, as received by purchaser, 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 usage of the parts. 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: 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 in a solution of approximately 40% hydrochloric acid (sp gr 1.19), 10% of a 30% solution of hydrogen peroxide, and 50% water, or other suitable etchant, for sufficient time to reveal flow lines but not longer than 30 min., shall be 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 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 thinner-than-standard heads 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 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, laps, or porosity except laps in threads as permitted by 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 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 not lower than 100X magnification to determine conformance to the following requirements:

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 predominantly 2 - 6 with no grains finer than 7 or coarser than 1, determined by comparison of the 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 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 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 ensure 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 Ø are classified as acceptance tests and shall be performed on each lot.

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 submitted 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.

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 and showing the results of tests to determine conformance to the 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, this specification number and its revision letter, 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 7471D
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 ø 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, ø 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 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: 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 of 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	(Millimetre)	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.

TABLE II

Bolt Size		Tensile Breaking Load lb, min		Stress-Rupture Test Load lb	
		Standard Pitch Diam. UN and UNJ Threads	Reduced Pitch Diam. UN Threads Only	Standard Pitch Diam. UN and UNJ Threads	Reduced Pitch Diam. UN Threads Only
0.112	-40	997	928	407	361
0.112	-48	1,090	1,020	440	410
0.138	-32	1,500	1,420	612	551
0.138	-40	1,670	1,590	678	641
0.164	-32	2,310	2,210	964	887
0.164	-36	2,430	2,320	994	949
0.190	-32	3,300	3,180	1,360	1,300
0.250	-28	6,010	5,840	2,500	2,430
0.3125	-24	9,570	9,370	4,020	3,930
0.375	-24	14,500	14,200	6,180	6,070
0.4375	-20	19,600	19,300	8,340	8,200
0.500	-20	26,400	26,000	11,300	11,200
0.5625	-18	33,500	33,100	14,400	14,200
0.625	-18	42,200	41,900	18,300	18,100
0.750	-16	61,500	61,000	26,700	26,500
0.875	-14	84,000	83,400	36,400	36,200
1.000	-12	109,000	109,000	47,500	47,200

TABLE II (SI)

Bolt Size		Tensile Breaking Load N, min		Stress-Rupture Test Load N	
		Standard Pitch Diam. UN and UNJ Threads	Reduced Pitch Diam. UN Threads Only	Standard Pitch Diam. UN and UNJ Threads	Reduced Pitch Diam. UN Threads Only
0.112	-40	4,430	4,130	1,810	1,610
0.112	-48	4,850	4,540	1,960	1,820
0.138	-32	6,670	6,320	2,720	2,450
0.138	-40	7,430	7,070	3,020	2,850
0.164	-32	10,300	9,830	4,290	3,950
0.164	-36	10,800	10,300	4,420	4,220
0.190	-32	14,700	14,100	6,050	5,780
0.250	-28	26,700	26,000	11,100	10,800
0.3125	-24	42,600	41,700	17,900	17,500
0.375	-24	64,500	63,200	27,500	27,000
0.4375	-20	87,200	85,800	37,100	36,500
0.500	-20	117,000	116,000	50,300	49,800
0.5625	-18	149,000	147,000	64,100	63,100
0.625	-18	188,000	186,000	81,400	80,500
0.750	-16	274,000	271,000	119,000	118,000
0.875	-14	374,000	371,000	162,000	161,000
1.000	-12	485,000	485,000	211,000	210,000

Note 1. Requirements above apply to parts with UNC, UNF, UNJC, or UNJF threads, as applicable to the sizes shown, to Class 3A tolerances; requirements for reduced pitch diameter parts are based on 0.003 in. (0.08 mm) reduction below standard. Area upon which stress for tensile breaking load requirements is based is the tensile stress area as defined in FED-STD-H28, 1957 edition, and calculated from the equation:

$$A = 0.7854\ (D - 0.9743/n)^2$$

where, A = Tensile stress area
D = Maximum major (nominal major) diameter
n = Number of threads per inch (25.4 mm)

Area upon which stress for stress-rupture test load requirements is based is the area at the maximum minor (nominal minor) diameter for UN threads, calculated from the equation:

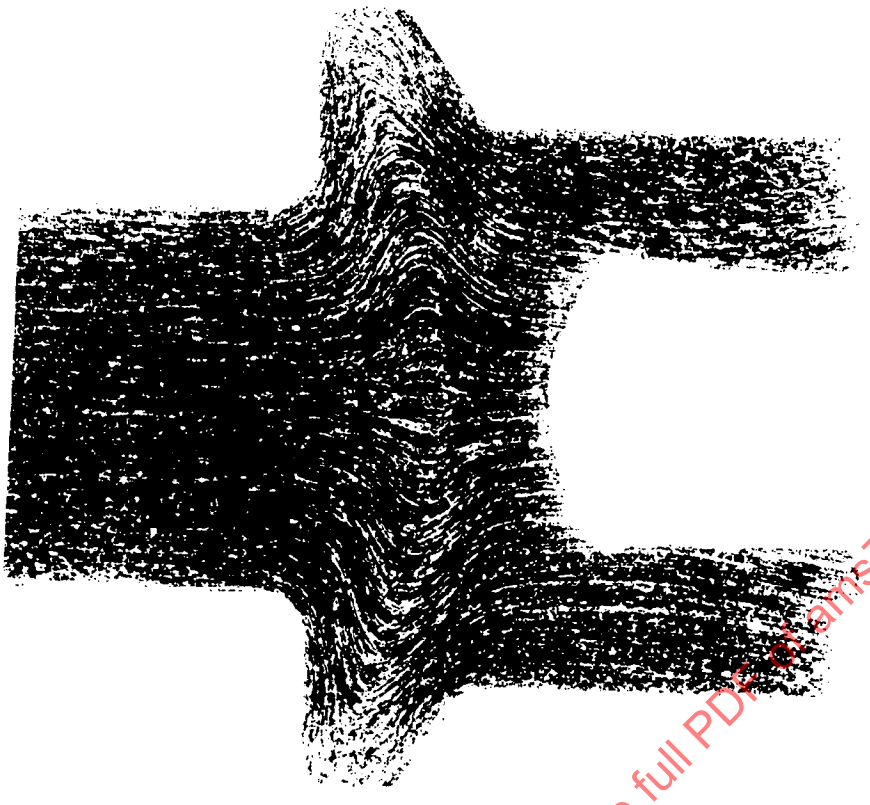
$$A = 0.7854\ (D - 3H/2)^2$$

where, A = Area at maximum minor (nominal minor) diameter
D = Maximum major (nominal major) diameter
H = Height of sharp-Vee thread

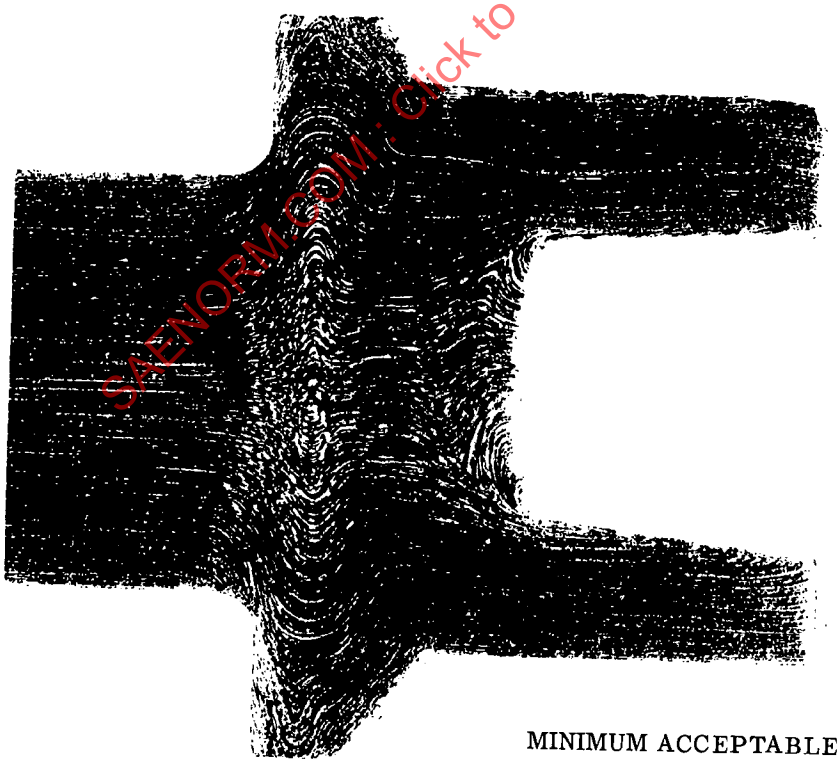
Load requirements are based on:

165,000 psi (1138 MPa) for tensile breaking loads
75,000 psi (517 MPa) for stress-rupture tests

Note 2. For sizes not shown, tensile breaking loads and stress-rupture test loads for parts tested as parts, not as specimens machined from parts or from coupons of the stock, shall be based upon the respective areas and stresses given above.



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