SAE Aerospace
An SAE International Group

AEROSPACE STANDARD

AS7461 | REV. B

Issued 1992-05
Reaffirmed 2001-10
Revised 2006-06

Superseding AS7461A

Bolts and Screws, Titanium Alloy 6Al-4V, UNS R56400 Fatigue-Rated, Procurement Specification For

FSC 5306

RATIONALE

Revise specification to re-instate tensile test loads for bolts (Table 2A) based on a stress area which is the mean between the maximum pitch diameter and the maximum minor (root) diameter.

1. SCOPE

1.1 Type

This procurement specification covers aircraft-quality bolts and screws made from 6Al-4V titanium alloy of the type identified under the Unified Numbering System as UNS R56400. The following specification designation and its properties are covered:

AS7461 160 ksi minimum ultimate tensile strength at room temperature.

77 ksi tension to 19.2 ksi tension fatigue at room temperature.

1.2 Application

Primarily for aerospace propulsion system applications where high strength, light weight, fatigue rated fasteners are required for use up to approximately 600 °F.

1.3 Safety - Hazardous Materials

While the materials, methods, applications, and processes described or referenced in this specification may involve the use of hazardous materials, this specification does not address the hazards which may be involved in such use. It is the sole responsibility of the user to ensure familiarity with the safe and proper use of any hazardous materials and to take necessary precautionary measures to ensure the health and safety of all personnel involved.

TO PLACE A DOCUMENT ORDER: **Tel: 877-606-7323 (inside USA and Canada)**
Tel: 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: CustomerService@sae.org
SAE WEB ADDRESS: **http://www.sae.org**

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other documents shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this specification and references cited herein, the text of this specification takes precedence. Nothing in this specification, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

2.1.1.1 Aerospace Material Specifications

AMS 2750 Pyrometry

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

2.1.1.2 Aerospace Standards

AS1132 Design Parameters for Bolts and Screws, External Wrenching, Unified Thread Inch Series

AS1814 Terminology for Titanium Microstructure

AS3062 Bolts, Screws, and Studs, Screw Thread Requirements

AS3063 Bolts, Screws, and Studs, Geometric Control Requirements

AS8879 Screw Threads - UNJ Profile, Inch, Controlled Radius Root with Increased Minor Diameter

2.1.2 AIA/NAS Publications

Available from Aerospace Industries Association, 1000 Wilson Boulevard, Suite 1700, Arlington, VA 22209-3928, Tel: 703-358-1000, www.aia-aerospace.org.

NASM1312-6 Fastener Test Methods, Method 6, Hardness

NASM1312-8 Fastener Test Methods, Tensile Strength

NASM1312-11 Fastener Test Methods, Tension Fatigue

2.1.3 U.S. Government Publications

Available from the Document Automation and Production Service (DAPS), Building 4/D, 700 Robbins Avenue, Philadelphia, PA 19111-5094, Tel: 215-697-6257, http://assist.daps.dla.mil/quicksearch/

2.1.3.1 Military Standards

MIL-STD-2073-1 DoD Materiel, Procedures for Development and Application of Packaging Requirements

2.1.4 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM B 600 Descaling and Cleaning Titanium and Titanium Alloy Surfaces

ASTM E 8 Tension Testing of Metallic Materials

ASTM E 340 Standard Test Method for Macroetching Metals and Alloys

ASTM E 407 Standard Test Practice for Microetching Metals and Alloys

ASTM E 1417 Liquid Penetrant Examination

2.1.5 ASME Publication

Available from American Society of Mechanical Engineers, 22 Law Drive, P.O. Box 2900, Fairfield, NJ 07007-2900, Tel: 973-882-1170, www.asme.org.

ASME B46.1M Surface Texture (Surface Roughness, Waviness, and Lay)

2.2 Definitions

PRODUCTION INSPECTION LOT:

Shall be all finished parts of the same part number, made from a single heat of alloy, heat treated at the same time to the same specified condition, produced as one continuous run, and submitted for vendor's inspection at the same time.

Refer to AS1814 for titanium microstructure terms and definitions.

2.3 Unit Symbols

° - degree, angle

° Baume' - hydrometer scale unit for measuring specific gravity of liquids

°F - degree Fahrenheit

% - percent (1% = 1/100)

lbf - pound-force

ksi - kips (1000 pounds) per square inch

sp gr - specific gravity

3. TECHNICAL REQUIREMENTS

3.1 Material

Shall be AMS 4967 titanium alloy.

3.2 Design

Finished (completely manufactured) parts shall conform to the following requirements:

3.2.1 Dimensions

The dimensions of finished parts, after all processing, shall conform to the part drawing. Dimensions apply before any required coating with dry film lubricants.

3.2.2 Surface Texture

Surface texture of finished parts, prior to any required coating, shall conform to the requirements as specified on the part drawing, determined in accordance with ASME B46.1.

3.2.3 Threads

Screw thread UNJ profile and dimensions shall be in accordance with AS8879, unless otherwise specified on the part drawing.

3.2.3.1 Incomplete Threads

Incomplete threads are permissible at the chamfered end and the juncture of the unthreaded portion of the shank or adjacent to the head as specified in AS3062.

3.2.3.2 Chamfer

The entering end of the thread shall be chamfered as specified on the part drawing.

3.2.4 Geometric Tolerances

Part features shall be within the geometric tolerances specified on the part drawing and, where applicable, controlled in accordance with AS3063.

3.3 Fabrication

3.3.1 Blanks

Heads shall be formed by hot forging.

3.3.1.1 Cleaning

Blanks shall be cleaned prior to heat treatment in accordance with ASTM B 600, or other methods approved by the purchaser. Blank surfaces shall be free of halogen compounds, such as residue from halogenated solvents and coolants, and salt from sweaty hands. Surfaces of parts, fixtures, racks, etc. shall be clean and free of dirt, water, oil, grease, paint, ink, crayon markings, dye pickup, finger prints, and other foreign materials. After cleaning and prior to heat treatment, personnel handling blanks shall wear clean white cotton gloves or equivalent.

3.3.2 Heat Treatment

Headed blanks after cleaning as in 3.3.1.1 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 heat treated as follows:

3.3.2.1 Heating Equipment

Furnaces may be any type ensuring uniform temperature throughout the blanks being heated and shall be equipped with, and operated by, automatic temperature controllers and data recorders conforming to AMS 2750. The heating medium or atmosphere shall cause neither surface hardening nor embrittlement.

3.3.2.2 Solution Heat Treatment

Blanks shall be uniformly heated to a temperature within the range 1650 to 1750 °F, held at the selected temperature within ±25 °F for 30 to 60 minutes, and quenched in water.

3.3.2.3 Precipitation Heat Treatment

Solution heat treated blanks shall be heated to a temperature within the range 900 to 1100 °F, held at the selected temperature within ±10 °F for 4 to 8 hours, and cooled in air.

3.3.3 Contamination Removal

The solution and precipitation heat treated blanks, before cold working the fillet radius and rolling the threads, shall have the full body, head-to-shank fillet, and bearing surface of the head free from surface contamination and contamination penetration caused by prior heat treatment. The removal process shall produce no intergranular attack or 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 than shown in Figure 1B.

3.3.4 Cold Rolling of Fillet Radius

After removal of contamination as in 3.3.3, the head-to-shank fillet radius of parts having the radius complete throughout the circumference of the part shall be cold rolled sufficiently to remove all visual evidence of grinding or tool marks. Distortion due to cold rolling shall conform to Figure 2 unless otherwise specified on the part drawing. It shall not raise metal more than 0.002 inch above the contour at "A" or depress metal more than 0.002 inch below the contour at "B" as shown in Figure 2. In configurations having an undercut associated with the fillet radius, the cold rolling will be required only for 90° of fillet arc, starting at the point of tangency of the fillet radius and the bearing surface of the head. For shouldered bolts having an unthreaded shank diameter larger than the thread major diameter and having an undercut associated with a fillet between the threaded shank and the shoulder of the unthreaded shank, the cold rolling will be required only for 90° of fillet arc, starting at the point of tangency of the fillet radius and the shouldered surface of the unthreaded shank. For parts with compound fillet radii between head and shank, cold roll only the radius that blends with the head. The shank diameter on close tolerance full shank bolts shall not exceed its maximum diameter limit after cold rolling the head-to-hank fillet radius.

3.3.5 Thread Rolling

Threads shall be formed on the heat treated and finished blanks by a single rolling process after removal of contamination as in 3.3.3.

3.4 Product Marking

Each part shall be identification marked as specified on the part drawing. The markings may be formed by forging or stamping, raised or depressed 0.010 inch maximum, with rounded root form on depressed characters.

3.5 Mechanical Properties

Parts shall conform to the requirements of 3.5.1 and 3.5.2. Threaded members of gripping fixtures for tensile and fatigue 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 three full thread turns from the thread runout exposed between the loading fixtures during the tensile and fatigue tests. Finished parts shall be tested in accordance with the following applicable test methods:

a. Room Temperature Ultimate Tensile Strength: NASM1312-8

b. Fatigue Strength: NASM1312-11

3.5.1 Ultimate Tensile Strength at Room Temperature

3.5.1.1 Finished Parts

Tension bolts, such as hexagon, double hexagon, and spline drive head, shall have an ultimate tensile load not lower than that specified in Table 2A and shall be tested to failure in order to observe fracture location, first measuring and recording the maximum tensile load achieved. Screws, such as 100° flush head, pan head, and fillister head, shall have an ultimate tensile load not lower than that specified in Table 2B, screws need not be tested to failure, however the maximum tensile load achieved shall be measured and recorded. 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 root diameter or having an undercut, parts shall conform to only the ultimate tensile strength requirements of 3.5.1.2; for such parts, the diameter of the area on which stress is based shall be the actual measured minimum diameter of the part. Tension fasteners with either standard double hexagon drive or hexagon-type heads having a minimum metal condition in the head equal to the design parameters specified in AS1132 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.

3.5.1.2 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 E 8 on specimens prepared as in 4.5.6. Tests on such specimens shall be conducted at a strain rate of 0.003 to 0.007 inch/inch/minute through the 0.2% offset after which the rate shall be increased so as to produce failure in approximately 1 minute. Specimens may be required by the purchaser to perform confirmatory tests. Specimens shall meet the following requirements:

a. Ultimate Tensile Strength, minimum: 160 ksi

b. Elongation in 2 inches or 4D, minimum: 8%

c. Reduction of Area, minimum: 20%

3.5.2 Fatigue Strength

Finished parts tested in tension-tension fatigue at room temperature with maximum load as specified in Table 2 and minimum load equal to 25% of maximum load shall have average life of not less than 30,000 cycles with no part having life less than 15,000 cycles. Tests need not be run beyond 60,000 cycles for purposes of computing average life. If the shank diameter of the part is less than the minimum pitch diameter of the thread, parts shall withstand fatigue testing as above using loads sufficient to produce a maximum stress of 77 ksi and a minimum stress of 19.2 ksi. The above requirements apply only to parts 0.138 inch and larger in nominal thread size with round, square, hexagonal, or double hexagonal heads designed for tension applications and not having an undercut and having a head-to-shank fillet radius equal to or larger than that specified in AS1132; for all parts to which the above requirements do not apply, fatigue test requirements shall be as specified on the part drawing.

3.6 Quality

Parts shall be uniform in quality and condition, clean, sound, smooth, and free from burrs and foreign materials, and from imperfections, detrimental to the usage of the parts.

3.6.1 Macroscopic Examination

Parts or sections of parts as applicable, shall be etched in a solution consisting of:

a. 15% ± 2% by volume, technical grade nitric acid, 42° Baume'

b. 10% ± 1.5% by volume, hydrofluoric acid (48%)

c. Balance water

(or other suitable etchant) for sufficient time to reveal flow lines but not longer than 5 minutes, and then be examined at a magnification of approximately 20X to determine conformance to the requirements of 3.6.1.1 and 3.6.1.2.

3.6.1.1 Flow Lines

3.6.1.1.1 Head-to-Shank

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 Figure 1A, except that slight cutting of flow lines by the contamination removal process of 3.3.3 is permissible, as shown in Figure 1B; excessive cutting of flow lines in the shank, head-to-shank fillet, and bearing surface, as shown in Figure 1C, is not permissible except when an undercut is associated with the fillet radius. The head style shown in Figures 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 thinner than AS1132 standard heads, shall be as agreed upon by purchaser and vendor.

3.6.1.1.2 Threads

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

3.6.1.2 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 3.6.2.3.3 and 3.6.2.3.4. 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.

3.6.2 Microscopic Examination

Specimens cut from parts shall be polished, etched in accordance with ASTM E 340 and ASTM E 407 and examined at a magnification not lower than 100X to determine conformance to the requirements of 3.6.2.1, 3.6.2.2, and 3.6.2.3.

3.6.2.1 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. Alpha case or evidence of slight overheating on nonbearing surfaces of the head is permissible if the depth of overheating or case in not greater than 0.003 inch. Measurements shall be made normal to the surface. A structure showing outlines of equiaxed beta grains and no primary alpha grains will be cause for rejection.

3.6.2.2 Grinding Damage

Altered microstructure consisting of continuous or intermittent disturbed material or heat affected zone is considered grinding damage and is rejectable. None is permitted on the shank or head-to-shank fillet. Grinding burns are allowed on the head of the fastener and head bearing surface to a maximum depth of .003 inch.

3.6.2.3 Surface Hardening

Parts shall have no change in hardness from core to surface except as produced during cold working of the head-to-shank fillet radius and during rolling of threads. In case of dispute over results of the microscopic examination, microhardness testing in accordance with NASM1312-6 shall be used as a referee method; a Vickers hardness reading within 0.003 inch of an unrolled surface which exceeds the reading in the core by more than 30 points shall be evidence of nonconformance to this requirement.

3.6.2.4 Threads

3.6.2.4.1 Root defects such as laps, seams, notches, slivers, folds, roughness, and oxide scale are not permissible (see Figure 4).

3.6.2.4.2 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 Figures 5 and 6).

3.6.2.4.3 There shall be no laps along the flank of the thread below the pitch diameter (see Figure 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 is generally parallel to the flank (see Figure 7).

3.6.2.4.4 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 1) as measured from the thread crest when the thread major diameter is at minimum size (see Figure 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 1 may be increased by one-half of the difference between the minimum major diameter and the actual major diameter as measured on the part.

3.6.3 Fluorescent Penetrant Inspection

Parts shall be subject to fluorescent penetrant inspection in accordance with ASTM E 1417; use of higher sensitivity penetrant is permissible. Any required coating shall be removed for this inspection.

3.6.3.1 The following conditions shall be cause for rejection of parts inspected.

3.6.3.1.1 Discontinuities transverse to grain flow (i.e., at an angle of more than 10° to the axis of the shank), such as grinding checks and quench cracks.

3.6.3.1.2 Longitudinal indications (i.e., at an angle of 10° or less to the axis of the shank) due to imperfections other than seams, forming laps, and nonmetallic inclusions.

3.6.3.2 The following conditions shall be considered acceptable on parts inspected.

3.6.3.2.1 Parts having longitudinal indications (i.e., at an angle of 10° or less to the axis of the shank) of seams and forming laps parallel to the grain flow that are within the limits specified in 3.6.3.2.2 through 3.6.3.2.5 provided the separation between indications is not less than 0.062 inch in all directions.

3.6.3.2.2 Sides of Head

There shall be not more than three indications per head. The length of each indication may be the full height of the surface but no indication shall break over either edge to a depth greater than 0.031 inch or the equivalent of the basic thread height (see Table 1), whichever is less.

3.6.3.2.3 Shank or Stem

There shall be not more than five indications. The length of any indication may be the full length of the surface but the total length of all indications shall not exceed twice the length of the surface. No indication shall break into a fillet or over an edge.

3.6.3.2.4 Threads

There shall be no indications, except as permitted in 3.6.2.3.

3.6.3.2.5 Top of Head and End of Stem

The number if indications is not restricted, but the depth of any individual indication shall not exceed 0.010 inch, as shown by sectioning representative samples. No indication, except those of 3.6.3.2.2, shall break over an edge.

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. Purchaser reserves the right to perform such confirmatory testing as deemed necessary to ensure that the parts conform to the requirements of this specification.

4.2 Responsibility for Compliance

The manufacturer's system for parts production shall be based on preventing product defects, rather than detecting the defects at final inspection and then requiring corrective action to be invoked. An effective manufacturing in-process control system shall be established, subject to the approval of the purchaser, and used during production of parts.

4.3 Production Acceptance Tests

The purpose of production acceptance tests is to check, as simply as possible, using a method which is inexpensive and representative of the part usage, with the uncertainty inherent in random sampling, that the parts comprising a production inspection lot satisfy the requirements of this specification.

4.4 Classification of Tests

The inspection of parts are classified as follows:

a. Acceptance tests that are to be performed on each production inspection lot. A summary of acceptance tests is specified in Table 3.

b. Periodic tests which are to be performed periodically on production lots at the discretion of the vendor or purchaser. Fatigue test as in 3.5.2 is classified as periodic test.

4.5 Acceptance Test Sampling

4.5.1 Material

In accordance with AMS 4967.

4.5.2 Nondestructive Test - Visual and Dimensional

A random sample of parts shall be taken from each production inspection lot; the size of the sample to be as specified in Table 4. The classification of dimensional characteristics shall be as specified in Table 5. All dimensional characteristics are considered defective when out of tolerance.

4.5.3 Fluorescent Penetrant Inspection

A random sample shall be selected from each production inspection lot: the size of the sample shall be as specified in Table 4 and classified as in Table 5. The sample units may be selected from those that have been subjected to and passed the visual and dimensional inspection, with additional units selected at random from the production inspection lot as necessary.

4.5.4 Macroscopic Examination

A random sample shall be selected from each production inspection lot, the size of the sample shall be as specified in Table 6. . The sample units may be selected from those that have been subjected to and passed the visual and dimensional inspection, with additional units selected at random from the production inspection lot as necessary.

4.5.4.1 Destructive Tests

A random sample shall be selected from each production inspection lot; the size of the sample shall be as specified in Table 6. The sample units may be selected from those that have been subjected to and passed the nondestructive tests and the fluorescent penetrant inspection, with additional units selected at random from the production inspection lot as necessary.

4.5.5 Acceptance Quality

Of random samples tested, acceptance quality shall be based on zero defectives.

4.5.6 Test Specimens

Specimens for tensile testing of machined test specimens shall be of standard proportions in accordance with ASTM E 8 with either 0.250 inch diameter at the reduced parallel gage section or smaller specimens proportional to the standard when required. Specimens shall be machined from finished parts or coupons of the same lot of alloy and be processed together with the parts they represent. Specimens shall be machined from the center of parts 0.750 inch and under in nominal diameter, from the center of coupons 0.800 inch and under in nominal diameter or distance between parallel sides, and from mid-radius of larger size parts or coupons.

4.6 Periodic Test Sampling

As agreed upon by purchaser and vendor.

4.7 Reports

The vendor of parts shall furnish with each shipment a report stating that the chemical composition of the parts conforms to the applicable material specification, showing the results of tests to determine conformance to the room temperature ultimate tensile strength requirements, and stating that the parts conform to the other technical requirements. This report shall include the purchase order number, AS7461A, lot number, contractor or other direct supplier of material, part number, nominal size, and quantity.

4.8 Rejected Lots

If a production inspection lot is rejected, the vendor of parts may perform corrective action to screen out or rework the defective parts, and resubmit for acceptance tests inspection as in Table 3. Resubmitted lots shall be clearly identified as reinspected lots.

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:

a. FASTENERS, TITANIUM ALLOY, 6Al-4V

b. AS7461(Current Revision Letter)

c. PART NUMBER

d. LOT NUMBER

e. PURCHASE ORDER NUMBER

f. QUANTITY

g. MANUFACTURER'S IDENTIFICATION

5.1.3 Threaded fasteners shall be suitably protected from abrasion and chafing during handling, transportation, and storage.

5.1.4 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 product to ensure carrier acceptance and safe delivery.

5.1.5 For direct U.S. Military procurement, packaging shall be in accordance with MIL-STD-2073-1, industrial packaging, unless Level A is specified in the request for procurement.

6. ACKNOWLEDGMENT

A vendor shall mention this specification number in all quotations 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 Direct U.S. Military Procurement:

Purchase documents should specify the following:

a. Title, number, and date of this specification

b. Part number of parts desired

c. Quantity of parts desired

d. Level A packaging, if required (see 5.1.5)

8.2 Equipment

8.2.1 The tank for the solution of 3.6.1 must be lined with polyvinyl chloride or comparable lining material.

8.2.2 Adequate ventilation is necessary because of the production of gaseous fumes due to vigorous reaction.

8.2.3 Fixtures, racks, and baskets shall be coated with acid resistant material that will not react with the nitric-hydrofluoric acid solution.

8.3 Key Words

Bolts, screws, procurement specification

8.4 The change bar (l) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the document.

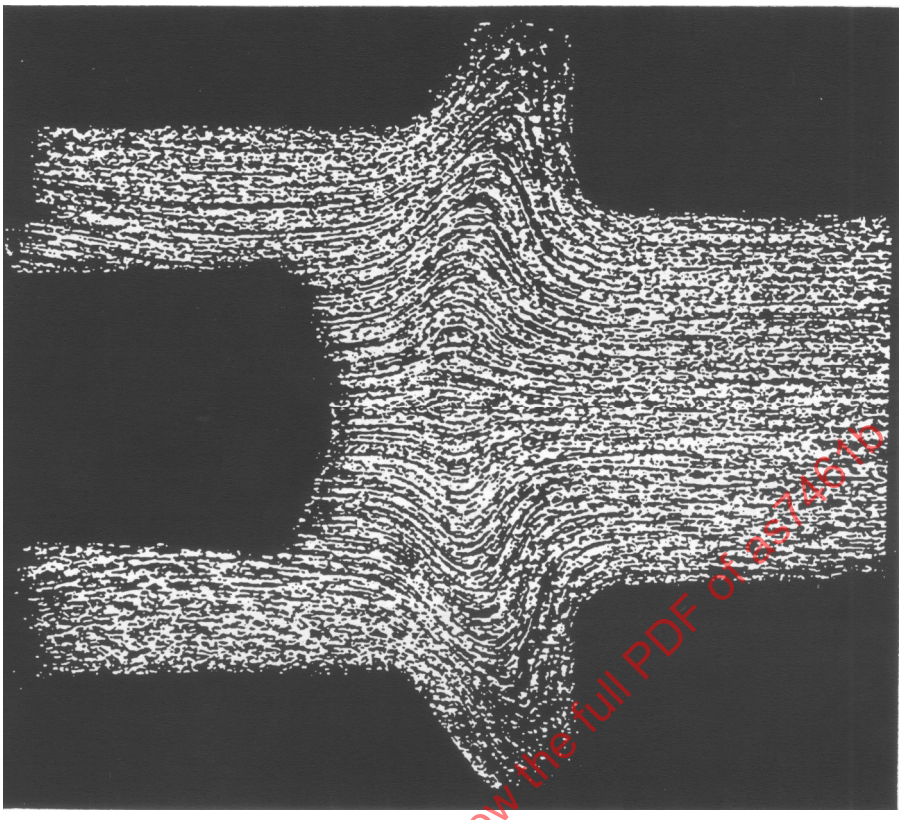


FIGURE 1A - SATISFACTORY GRAIN FLOW

SHOWING A SMOOTH, WELL FORMED GRAIN FLOW FOLLOWING THE CONTOUR OF THE HEAD-TO-SHANK FILLET RADIUS

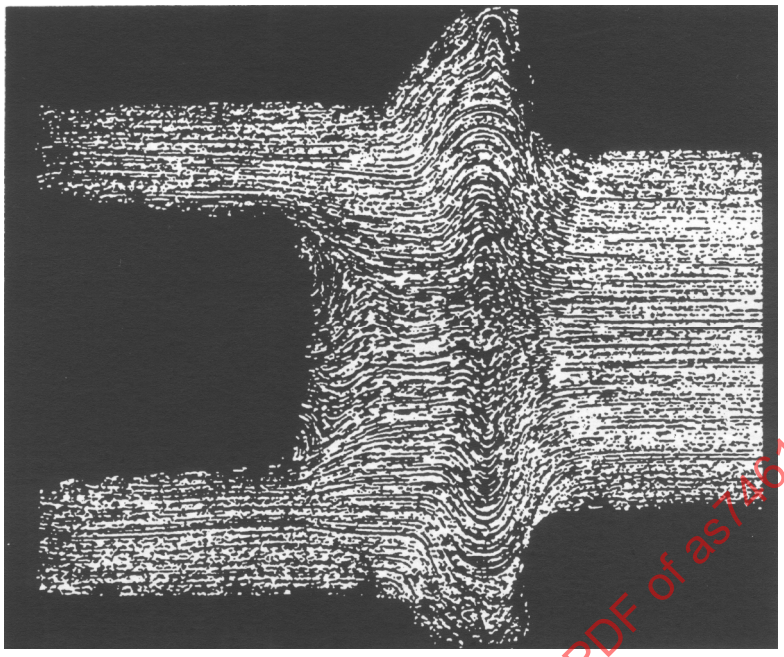


FIGURE 1B - MINIMUM ACCEPTABLE STANDARD

SHOWING MAXIMUM PERMISSIBLE CUTTING OF GRAIN FLOW
AFTER MACHINING TO REMOVE CONTAMINATION OXIDE

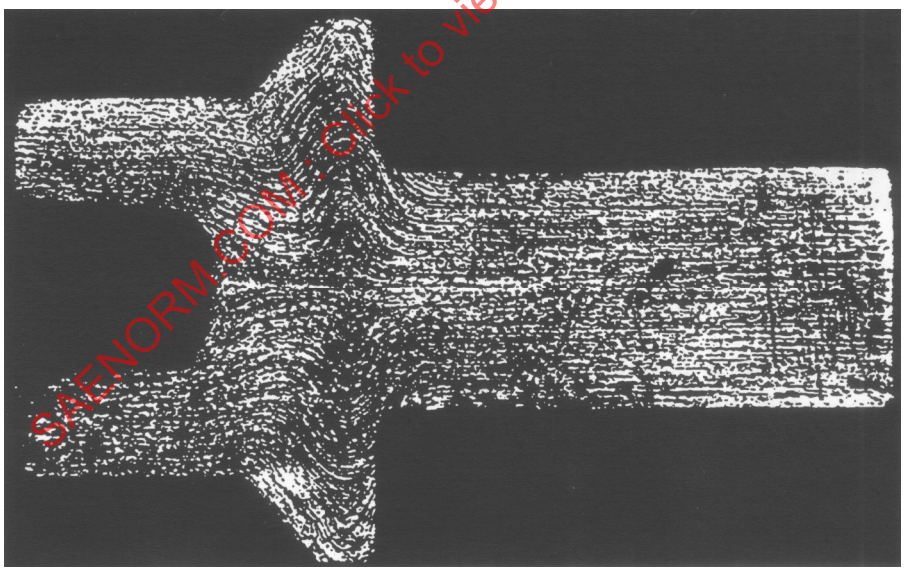
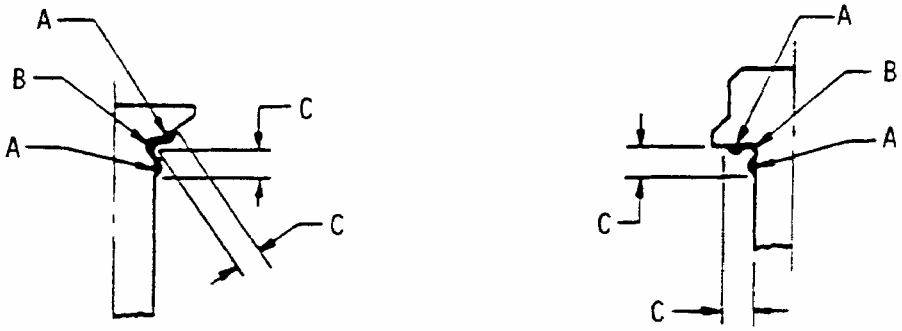


FIGURE 1C - UNACCEPTABLE GRAIN FLOW

SHOWING EXCESSIVE CUTTING OF GRAIN FLOW IN THE SHANK,
FILLET, AND BEARING SURFACE WHICH IS NOT PERMISSIBLE



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

FIGURE 2 - PERMISSIBLE DISTORTION FROM FILLET WORKING

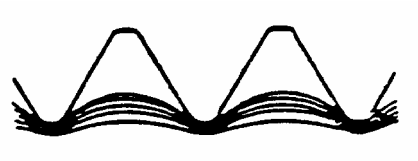


FIGURE 3 - FLOW LINES, ROLLED THREAD

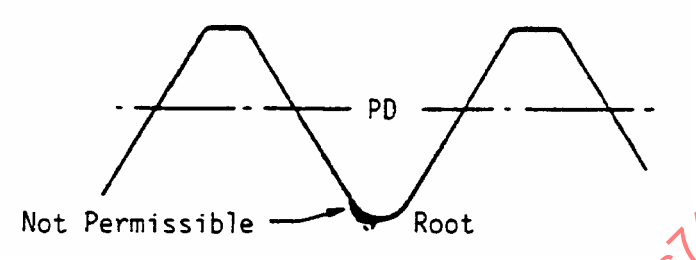


FIGURE 4 - ROOT DEFECTS, ROLLED THREAD

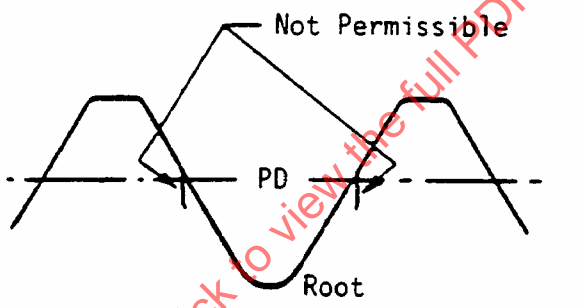


FIGURE 5 - LAPS BELOW PD EXTENDING TOWARD ROOT, ROLLED THREAD

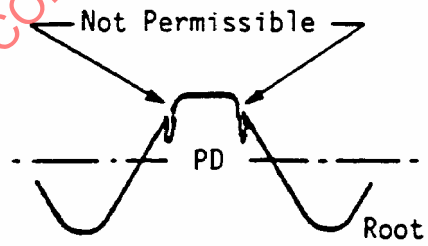


FIGURE 6 - LAPS ABOVE PD EXTENDING TOWARD ROOT, ROLLED THREAD

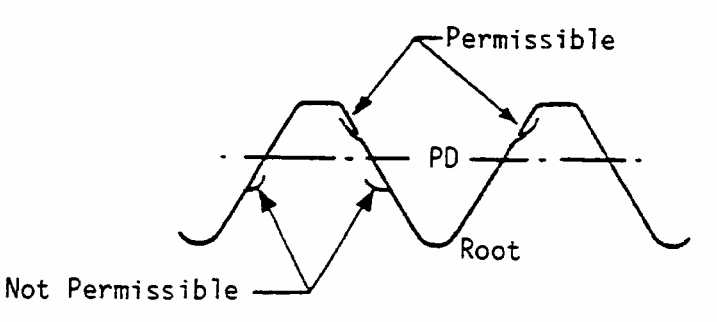
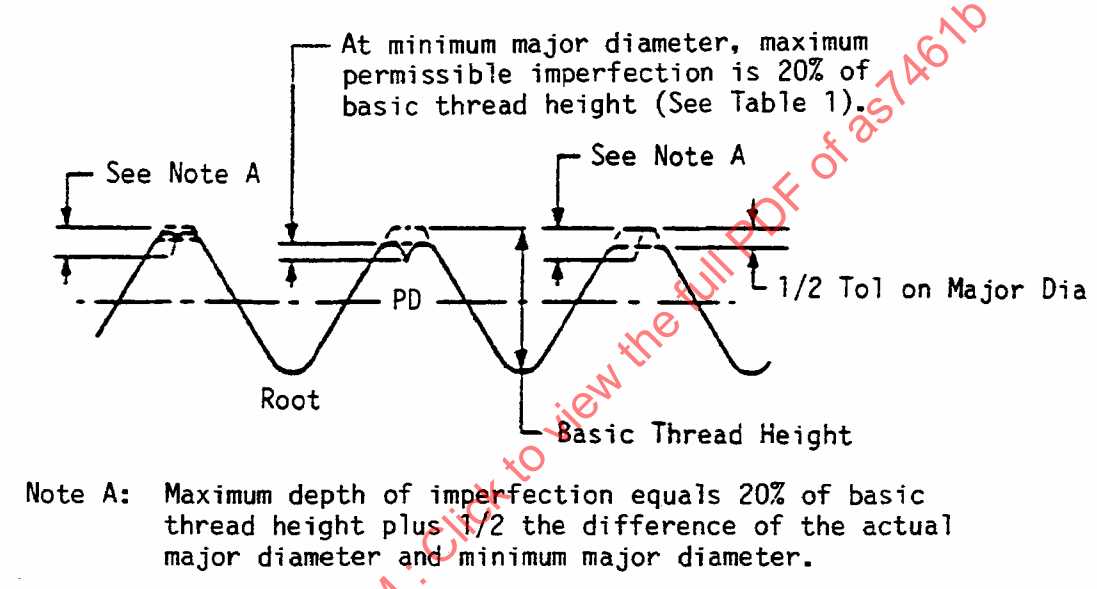


FIGURE 7 - LAPS EXTENDING TOWARDS CREST, ROLLED THREAD



Note A: Maximum depth of imperfection equals 20% of basic thread height plus 1/2 the difference of the actual major diameter and minimum major diameter.

FIGURE 8 - CREST CRATERS AND CREST LAPS, ROLLED THREAD

TABLE 1 - THREAD HEIGHT

Thread Pitches Per Inch n	Basic Thread Height Ref (see Note 1) inch	20% Basic Thread Height inch
80	0.0081	0.0016
72	0.0090	0.0018
64	0.0102	0.0020
56	0.0116	0.0023
48	0.0135	0.0027
44	0.0148	0.0030
40	0.0163	0.0033
36	0.0181	0.0036
32	0.0203	0.0041
28	0.0232	0.0046
24	0.0271	0.0054
20	0.0325	0.0065
18	0.0361	0.0072
16	0.0406	0.0081
14	0.0464	0.0093
13	0.0500	0.0100
12	0.0542	0.0108
11	0.0591	0.0118
10	0.0650	0.0130
9	0.0722	0.0144
8	0.0813	0.0163

Note 1 - Basic thread height is defined as being equivalent to 0.650 times the pitch, where pitch equals 1/n.