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

AEROSPACE MATERIAL SPECIFICATION

AMS 7461C
Superseding AMS 7461B
Issued 6-30-64
Revised 1-15-78

BOLTS AND SCREWS, TITANIUM ALLOY
6Al - 4V
Upset Headed, Heat Treated, Roll Threaded

1. SCOPE:

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

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

2. APPLICABLE DOCUMENTS: The following publications form a part of this specification to the extent specified herein. The latest issue of Aerospace Material Specifications (AMS) and Aerospace Standards (AS) shall apply. The applicable issue of other documents shall be as specified in AMS 2350.

2.1 SAE Publications: Available from Society of Automotive Engineers, Inc., 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 4967 - Titanium Alloy Bars and Forgings, 6Al - 4V, Annealed, Heat Treatable

2.1.2 Aerospace Standards:

AS 1132 - Design Parameters for Bolts and Screws, External Wrenching, Unified Threaded Inch Series
AS 1177 - Nondestructive Inspection Standards for Bolts and Screws
AS 3062 - Bolts, Screws, and Studs, Screw Thread Requirements
AS 3063 - Bolts, Screws, and Studs, 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

2.3 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 4967 titanium alloy.

3.2 Fabrication:

3.2.1 Blanks: Heads shall be formed by hot forging.

Printed in U.S.A.

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 heat treated as follows:

3.2.2.1 Heating Equipment: Furnaces may be any type ensuring uniform temperature control throughout the parts being heated and shall be equipped with, and operated by, automatic temperature controllers. The heating medium or atmosphere shall cause neither surface hardening nor embrittlement.

3.2.2.2 Solution Heat Treatment: Blanks shall be uniformly heated to a temperature approximately 50 F (28 C) deg below the beta transus as determined on the heat of material from which blanks are made, held at the selected temperature within ±15°F (±8°C) for 30 - 60 min., and quenched in water.

3.2.2.3 Precipitation Heat Treatment: Solution heat treated blanks shall be heated to a temperature within the range 900° - 1100°F (482° - 593°C), held at the selected temperature within ±10°F (±6°C) for 4 - 8 hr, and cooled in air.

3.2.3 Contamination Removal: The solution and precipitation heat treated blanks, before cold working the ø 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, 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 Fig. 1B.

3.2.4 Cold Working of Fillet Radius: After removal of contamination as in 3.2.3, the head-to-shank fillet radius of parts having the radius complete throughout the circumference of the part shall 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 heat treated and finished blanks by a single rolling process.

3.3 Properties: Parts shall conform to the requirements of 3.3.1.1 or 3.3.1.2, as applicable, and of 3.3.2. Threaded members of gripping fixtures for tensile tests shall be of sufficient size and strength to develop the full strength of the part without stripping the thread. Finished parts shall be tested in accordance with the following applicable test methods of MIL-STD-1312:

Requirement	Test Method
Tensile Properties	No. 8
Fatigue Strength	No. 11

3.3.1 Tensile Properties:

3.3.1.1 Finished Parts: Parts shall have breaking load not lower than the value specified in Table II. If ø 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 160,000 psi (1103 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 Machined Test Specimens: If the size or shape of the part is such that a tensile test cannot be made on the part, tensile tests shall be conducted in accordance with ASTM E8 on specimens machined from finished parts or from coupons of the same heat of material heat treated with the parts. Tests shall be conducted at a strain rate of 0.003 - 0.007 in. per in. per min. (0.003 - 0.007 mm/mm/min.) through the 0.2% offset after which the rate shall be increased so as to produce failure in approximately one additional minute. Specimens shall conform to the following requirements:

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

3.3.2 Fatigue Strength: Parts tested in tension-tension fatigue at room temperature with maximum load as specified in Table II 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 part, parts shall withstand fatigue testing as above using loads sufficient to produce a maximum stress of 77,000 psi (531 MPa) and a minimum stress of 19,200 psi (132 MPa). The above requirements apply only to parts 0.138 in. (3.51 mm) and larger in nominal thread size with round, square, hexagonal, or double hexagonal heads designed for tension applications and not having an undercut; for all parts to which the above requirements do not apply, fatigue test requirements shall be as specified on the drawing.

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

3.4.1 Dimensional Examination: Parts shall conform to the following:

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

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

3.4.2 Macroscopic Examination: Parts or sections of parts, as applicable, shall be etched in a solution of approximately 5% hydrofluoric acid (sp gr 1.15) and 95% water for sufficient time to reveal flow lines but not longer than 1 hr and examined at approximately 20X magnification to determine conformance to the requirements of 3.4.2.1, 3.4.2.2, and 3.4.2.3, 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 contamination removal process of 3.2.3 is permissible, as shown in Fig. 1B; excessive cutting of flow lines in the shank, head-to-shank fillet, and bearing surface, as shown in Fig. 1C, is not permissible except when an undercut is associated with the fillet radius. The head style shown in Figs. 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-standard heads, shall be as agreed upon by purchaser and vendor.

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

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

3.4.2.3 Threads:

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

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

3.4.2.3.3 There shall be no laps along the flank of the thread below the pitch diameter (See Fig. 7). A single lap is permissible along the flank of the thread above the pitch diameter on either the pressure or non-pressure flank (one lap at any cross section through the thread) provided it extends toward the crest and generally parallel to the flank (See Fig. 7).

3.4.2.3.4 Crest craters, crest laps, or a crest lap in combination with a crest crater are permissible, provided the imperfections do not extend deeper than 20% of the basic thread height (See Table I) as measured from the thread crest when the thread major diameter is at minimum size (See Fig. 8). The major diameter of the thread shall be measured prior to sectioning. As the major diameter of the thread approaches maximum size, values for depth of crest crater and crest lap imperfections listed in Table I may be increased by 1/2 of the difference between the minimum major diameter and the actual major diameter as measured on the part.

3.4.3 Microscopic Examination: Specimens cut from parts shall be polished, etched in a solution of approximately 1% hydrofluoric acid (sp gr 1.15), 12% nitric acid (sp gr 1.42), and 87% water, and examined at not lower than 100X magnification to determine conformance to the requirements of 3.4.3.1 and 3.4.3.2.

3.4.3.1 Ø 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 non-bearing surfaces of the head is permissible if the depth of overheating or case is not greater than 0.003 in. (0.08 mm). 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.

3.4.3.2 Ø Surface Hardening: Parts shall have no surface hardening due to cold working 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 MIL-STD-1312, Test 6, shall be used as a referee method; a Vickers hardness reading within 0.003 in. (0.08 mm) of the surface more than 30 points higher than the reading in the core will be evidence of nonconformance to this requirement.

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for Inspection: The vendor of parts shall supply all samples and shall be responsible for performing all required tests. Results of such tests shall be reported to the purchaser as required by 4.4. Purchaser reserves the right to perform such confirmatory testing as he deems necessary to ensure that parts conform to the requirements of this specification.

4.2 Classification of Tests:

4.2.1 Acceptance Tests: Tests to determine conformance to tensile property (3.3.1), macroscopic examination (3.4.2), and microscopic examination (3.4.3) requirements are classified as acceptance tests.

4.2.2 Periodic Tests: Tests to determine conformance to fatigue strength (3.3.2) requirements are classified as periodic tests.

4.3 Sampling: Shall be in accordance with AMS 2373. Frequency of sampling for periodic tests shall be as agreed upon by purchaser and vendor.

4.4 Reports: The vendor of parts shall furnish with each shipment three copies of a report stating that the chemical composition of the parts conforms to the requirements of the applicable material specification, showing the results of tests to determine conformance to the tensile property requirements, and stating that the parts conform to 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, 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 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 shall be marked to show the following information:

FASTENERS, TITANIUM ALLOY, 6Al - 4V
AMS 7461C
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 these 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 5.1.3 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.

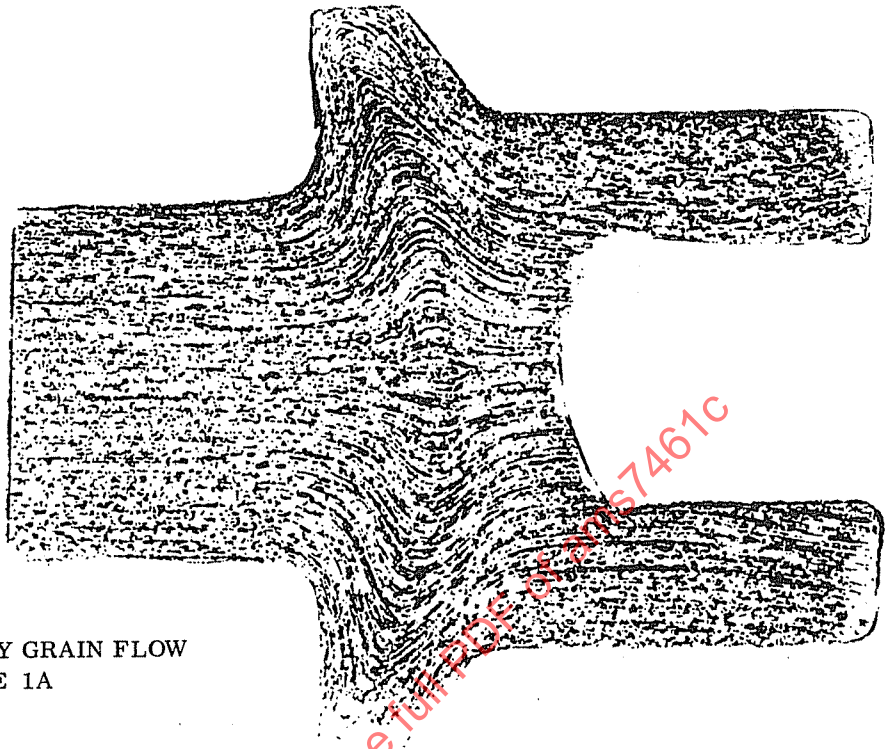
7. REJECTIONS: Parts not conforming to this specification or to authorized modifications will be subject to rejection.

8. NOTES:

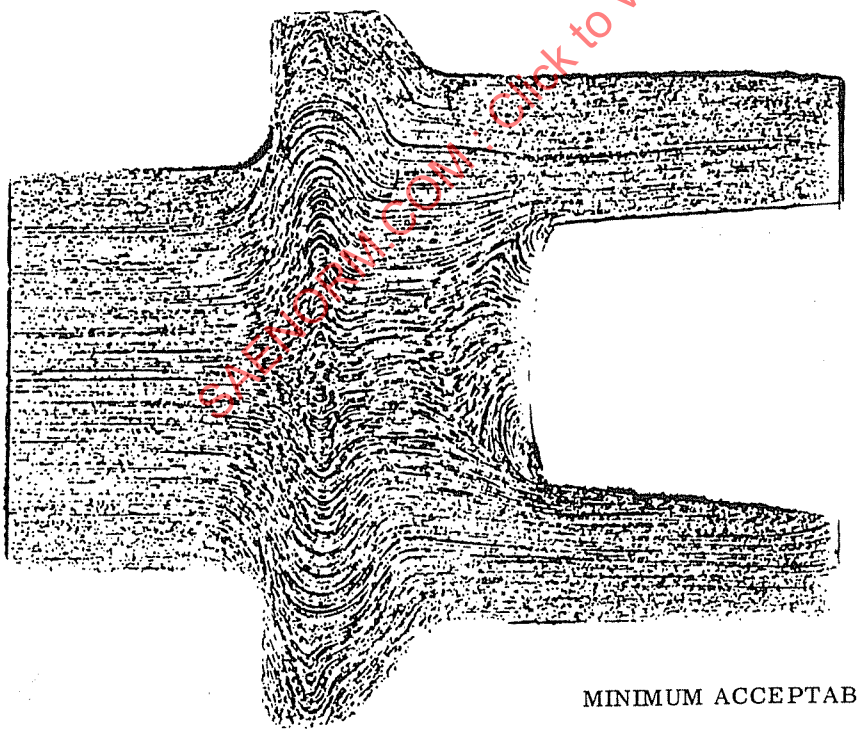
8.1 Marginal Indicia: The phi (Ø) symbol is used to indicate technical changes from the previous issue of this specification.

8.2 For direct U.S. Military procurement, purchase documents should specify 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).



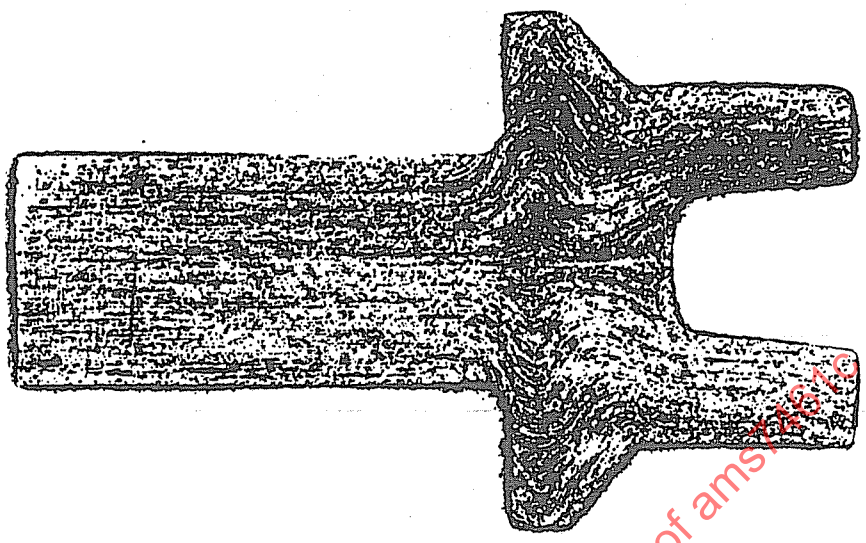
SATISFACTORY GRAIN FLOW
FIGURE 1A



MINIMUM ACCEPTABLE STANDARD

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

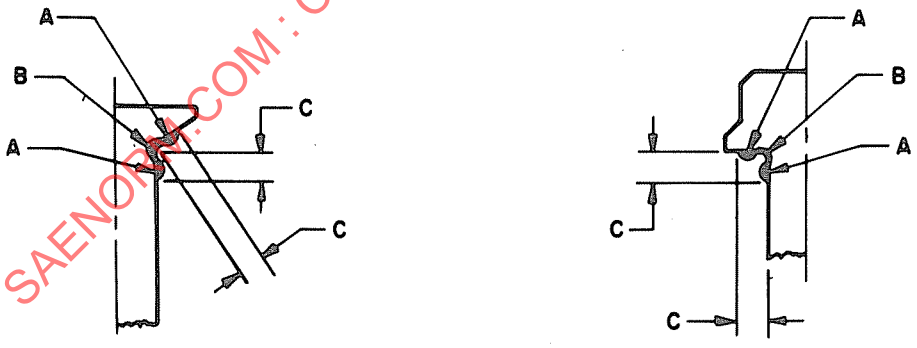
FIGURE 1B



UNACCEPTABLE GRAIN FLOW

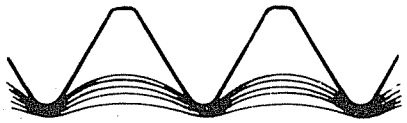
Excessive cutting of flow lines in the shank, head to shank fillet, and bearing surface is not permissible.

FIGURE 1C

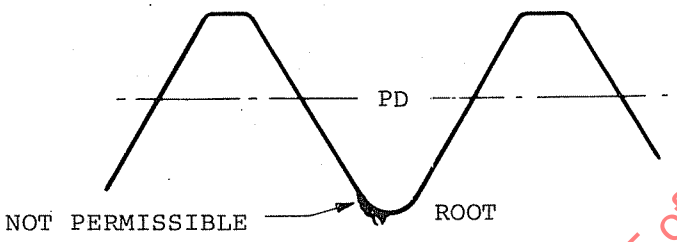


Nominal Bolt Diameter		C, max	
Inches	(Millimetres)	Inch	(Millimetres)
Up to 0.3125, excl	(Up to 7.938, excl)	0.062	1.57
0.3125 and 0.375	(7.938 and 9.52)	0.094	2.39
0.4375 - 0.625, incl	(11.112 - 15.88, incl)	0.125	3.18
0.750 - 1.000, incl	(19.05 - 25.40, incl)	0.156	3.96
Over 1.000	(Over 25.40)	0.188	4.78

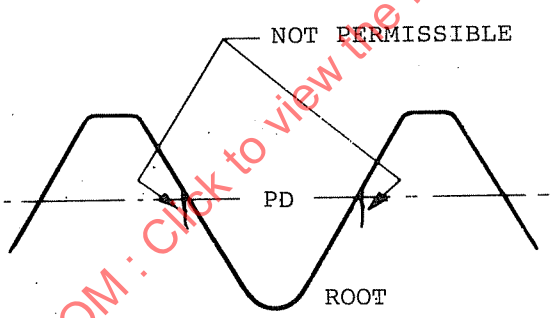
PERMISSIBLE DISTORTION FROM FILLET WORKING
FIGURE 2



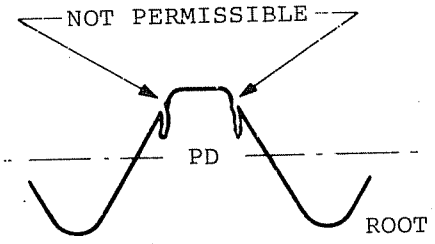
FLOW LINES, ROLLED THREAD
FIGURE 3



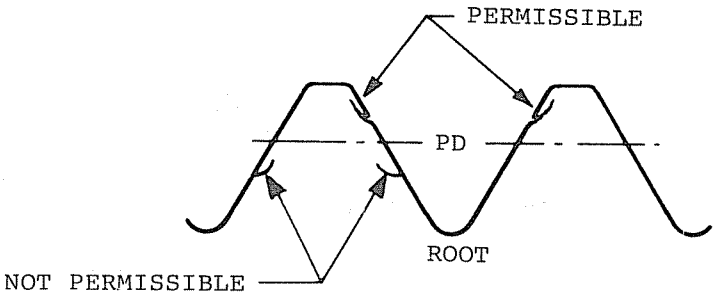
ROLLED THREAD
FIGURE 4



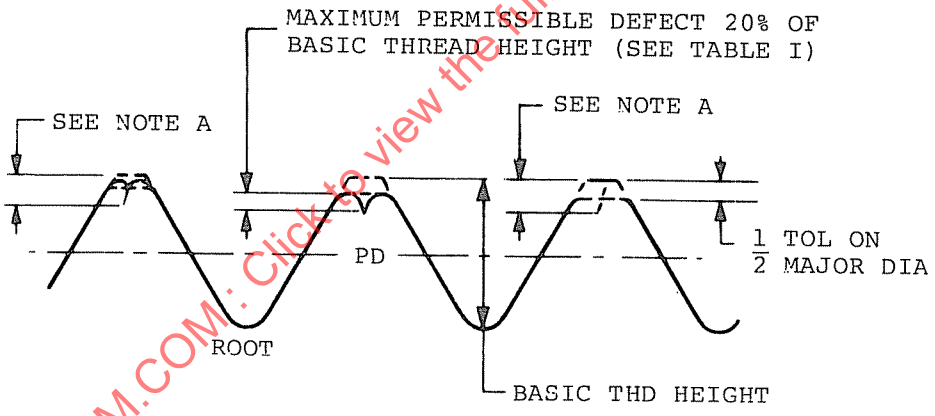
ROLLED THREAD
FIGURE 5



ROLLED THREAD
FIGURE 6



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