SOCIETY OF AUTOMOTIVE ENGINEERS, Inc. 485 Lexington Ave., New York, N.Y. 10017

AEROSPACE MATERIAL SPECIFICATIONS

AMS 7477A
Superseding AMS 7477
Issued 1-31-64
Revised 4-15-67

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

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

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

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

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

4. FABRICATION:

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

4.2 Heat Treatment:

4.2.1 Heating Equipment: Furnaces may be any type ensuring uniform temperature throughout the parts being heated and shall be equipped with, and operated by, automatic temperature controllers. The heating medium or atmosphere shall cause no surface hardening by carburizing or nitriding.

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

4.2.3 Precipitation Heat Treatment: After solution heat treatment as in 4.2.2, blanks shall be precipitation heat treated by heating to a temperature not lower than 1300 F (704 C) but not higher than 1400 F (760 C), holding at heat for 16 hr, and cooling in air.

4.3 Oxide Removal: The solution and precipitation heat treated blanks, before cold working the head to shank fillet radius and rolling the threads, shall have all surfaces free from surface oxide and oxide penetration caused by prior heat treatment. The oxide removal process shall produce no intergranular attack or corrosion of the blanks. The metal removed from the bearing surface of the head ø and the full body diameter of the blank shall be as little as practicable to obtain a clean, smooth surface and in no case shall be so great as to produce more cutting of flow lines in the head to shank junction than shown in Fig. 1B.

4.4 Cold Working of Fillet Radius: After removal of oxide as in 4.3, the head to shank fillet radius of parts shall be cold worked; the working operation shall be sufficient to remove all visual evidence of grinding or tool marks. Distortion due to cold working shall not raise metal more than 0.002 in. ø above the contour at "A" or depress metal more than 0.002 in. below the contour at "B" as shown in Fig. 2; distorted areas shall not extend beyond "C" as shown in Fig. 2. In configurations where an undercut is 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 washer face.

4.5 Thread Rolling: Threads shall be formed by a single rolling process after removal of oxide as in 4.3.

5. TECHNICAL REQUIREMENTS: When ASTM methods are specified for determining conformance to the following requirements, tests shall be conducted in accordance with the issue of the ASTM method listed in the latest issue of AMS 2350.

5.1 Flow Lines: Flow lines of heads on parts, when a longitudinal section through the part is electrolytically etched in a suitable solution and examined at approximately 10X magnification, should follow the contour of the shank, head to shank fillet, and bearing surface, as shown in Fig. 1A. Slight cutting of flow lines by the oxide removal process of 4.3 is permissible, as shown in Fig. 1B, but 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. In case of dispute, a 10% oxalic acid solution shall be used for etching. 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 parts having unsymmetrical heads shall be as agreed upon by purchaser and vendor.

5.1.1 Examination for Internal Defects: Visual examination of longitudinal sections of the head and shank and of the threads, after etching in 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 for 10 - 30 min. at room temperature, shall reveal no cracks, laps, or porosity. The head and shank section shall extend not less than D/2 in. from the washer face of the part and the threaded section shall extend not less than D/2 in. beyond the thread runout, where "D" is the nominal diameter of the shank after heading. If the two sections would overlap, the entire length of the bolt shall be sectioned and examined as a whole.

5.2 Threads:

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

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

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

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

5.2.5 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 crest crater or crest lap imperfections listed in Table I may be increased by 1/2 the difference between the minimum major diameter and the actual major diameter as measured on the part.

5.2.6 Slight deviations from thread contour are permissible at the crest of the thread within the major diameter limits as shown in Fig. 9 and at the incomplete thread at each end of the threaded section.

5.2.7 Parts having holes for locking devices are permitted to have slight ovalization of the hole and the countersink and slight flattening of the crest of the thread at the countersink, provided the diameter of the hole is within specified tolerances.

5.2.8 Thread runout is that portion of the threaded part between the end of the full thread and the beginning of the unthreaded shank or, if there is no unthreaded shank, the head to fillet radius (See Figs. 10A, 10B, 10C, and 10D). For full shank parts, thread runout shall comprise the incomplete threads and a portion Ø of the blank diameter from which the thread is rolled (See Fig. 11A or 11B). For relieved shank parts having shank diameter equivalent to the blank diameter from which the thread is rolled, thread runout shall comprise the incomplete threads only (See Fig. 11C). The end of the full thread is that point on the root of the thread nearest to the shank or head up to which the thread conforms to the thread specification.

5.2.8.1 Full shank parts shall have a minimum thread runout of one thread and a maximum of two threads. The transition between the blank diameter and the full shank diameter shall consist of a radius "A" Ø and either a taper as in Fig. 11A or a shoulder as in Fig. 11B. The radius "A" shall be not less than the amount specified below; for parts having only a radius, with no chamfer, between the runout threads and the full shank diameter, as shown in Fig. 11B, the incomplete thread shall not encroach upon radius "A":

Threads per inch	Radius "A" Inch
Over 28	0.005
28 - 13	0.010
12 - 10	0.015
9 - 8	0.020

5.2.8.2 Relieved shank parts, having a shank diameter equivalent to the blank diameter from which the thread Ø is rolled, shall have a minimum thread runout of 0.625 x thread pitch and a maximum of two threads.

5.2.8.3 For parts threaded to the head, unless otherwise specified on the drawing, dimension "X" (See Figs. 12A and 12B) between the end of the full thread and the bearing surface shall be as follows:

Ø X min (rounded to three decimal places) = 1.5 x thread pitch + B maximum
X max = X min + 0.020 inch.

The runout shall be as defined in 5.2.8.1 for the full shank condition and in 5.2.8.2 for the relieved shank condition but shall not encroach upon the head to shank fillet radius "B".

5.2.8.4 The flanks and the flat at the root of the incomplete thread shall be joined by radii which blend with the flanks and the flat and are smooth and devoid of abrupt tool stop marks; these radii shall be not Ø smaller than the minimum root radius specified for the complete threads except that slight deviation from this requirement will be permitted at the junction of the radii with the flat at the root of the thread. The incomplete thread shall gradually decrease in depth within an axial length not less than 0.625 x thread pitch and shall blend smoothly with the blank diameter from which the thread is rolled.

5.2.9 All thread elements shall be within specified limits starting at a length 2 x the pitch from the end, including chamfer, and extending for the specified full thread length.

5.3 Straightness, Concentricity, and Squareness: For purposes of these inspections, shank and threads shall be included but shall be considered as separate elements of the part.

5.3.1 Straightness of Shank and Threads: Shank and threads shall be straight within the limits specified on the drawing for the total length (L) of the part under the head (See Fig. 13). Visibly abrupt changes in diameter or shape of the shank and threads which might cause stress concentrations are not permissible.

5.3.2 Concentricity of Thread Pitch Diameter: The concentricity of thread pitch diameter in relation to shank diameter shall be within the limits specified on the drawing for a distance of not less than 1.5 times the nominal part diameter away from the last full thread along the shank (See Fig. 14). For parts having a shank length less than 1.5 times the nominal part diameter, the concentricity of the shank diameter over its full length in relation to the thread pitch diameter shall be within the limits specified on the drawing.

5.3.3 Concentricity of Head: The concentricity of the head in relation to the shank diameter shall be within the limits specified on the drawing for a distance of not less than 1.5 times the nominal part diameter away from the washer face along the shank (See Fig. 15). For parts threaded to the head and for parts having a shank length less than 1.5 times the nominal part diameter, concentricity of head shall be measured in relation to thread pitch diameter in lieu of shank diameter.

5.3.4 Squareness of Washer Face: The squareness of the washer face with the shank diameter shall be within the limits specified on the drawing for a distance of not less than 1.5 times the nominal part diameter away from the washer face along the shank (See Fig. 15). For parts threaded to the head and for parts having a shank length less than 1.5 times the nominal part diameter, squareness of washer face shall be measured in relation to thread pitch diameter in lieu of shank diameter.

5.4 Structure: Parts shall have microstructure of completely recrystallized material except in the area of the threads and the head to shank fillet radius. Grain size shall be 5 or finer, by comparison of polished and etched specimens with the chart in ASTM E112. Up to 25%, by area, of abnormally large grains will be permitted in any specific area of 100 or more adjacent grains; abnormally large grains are defined as grains more than 3 ASTM numbers coarser than the average grain size of the part.

5.5 Properties: Parts shall conform to the requirements of 5.5.1.1 or 5.5.1.2, as applicable, and to the requirements of 5.5.2 and 5.5.3. Threaded members of gripping fixtures shall be of sufficient size and strength to develop the full strength of the part without stripping the thread. For tensile and stress-rupture tests on finished parts, the parts shall be aligned in fixtures so that there are 2.5 - 3 full threads exposed between the loading members.

5.5.1 Tensile Properties:

5.5.1.1 Finished Parts: Shall have breaking load not lower than 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 reduced shank diameter or an undercut, parts shall conform to only the tensile strength requirement of 5.5.1.2.

5.5.1.2 Tensile 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 machined from finished parts, or from coupons of the material heat treated with the parts, to the dimensions shown in ASTM A370 shall conform to the following requirements; the diameter on which stress is based shall be the actual measured minimum diameter of the specimen:

Tensile Strength, psi	130,000 min
Yield Strength at 0.2% Offset or at 0.0098 in. in 2 in. Extension Under Load (E = 29,100,000), psi	85,000 min
Elongation, % in 4D	15 min
Reduction of Area, %	20 min

5.5.2 Stress-Rupture Strength at 1200 F (648.9 C):

5.5.2.1 Finished Parts: A part, maintained at 1200 F ± 3 (648.9 C ± 1.7) while the axial load specified in Table II is applied continuously, shall not rupture in less than 23 hours. 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 reduced shank diameter or an undercut, parts shall conform to the requirements of 5.5.2.2.

5.5.2.2 Test Specimens: If the size or shape of the part is such that a stress-rupture test cannot be made on the part, tensile test specimens machined from the part, or from coupons of the material heat treated with the parts, and having unnotched gage sections, maintained at 1200 F ± 3 (648.9 C ± 1.7) while an axial stress of 70,000 psi is applied continuously, shall not rupture in less than 23 hours. The diameter of the area on which stress is based shall be the actual measured minimum diameter of the specimen.

5.5.3 Hardness: Shall be uniform and within the range of Brinell 248 - 341 or equivalent but hardness of the threaded portion may be higher as a result of the thread rolling.

6. QUALITY: Parts shall be uniform in quality and condition, clean, sound, smooth, and free from burrs and foreign materials and from internal and external imperfections detrimental to their performance.

6.1 Parts subject to fluorescent penetrant inspection shall conform to the following standards.

6.1.1 Discontinuities transverse to grainflow (i.e., at an angle of more than 10 deg to the axis of the shank), Ø such as grinding checks and quench cracks, shall be cause for rejection.

6.1.2 Longitudinal indications (i.e., at an angle of 10 deg or less to the axis of the shank) of seams and forming laps parallel to grainflow are acceptable within the following limits, provided the separation between in- Ø dications is not less than 1/16 in. in all directions. Longitudinal indications due to imperfections other than seams and forming laps shall be cause for rejection.

6.1.2.1 Sides of Head: A maximum of 3 indications per head is permitted and the length of each indication may be the full height of the surface. No indication shall break over either edge to a depth greater than 1/32 in. or the equivalent of the basic thread height (See Table I), whichever is less.

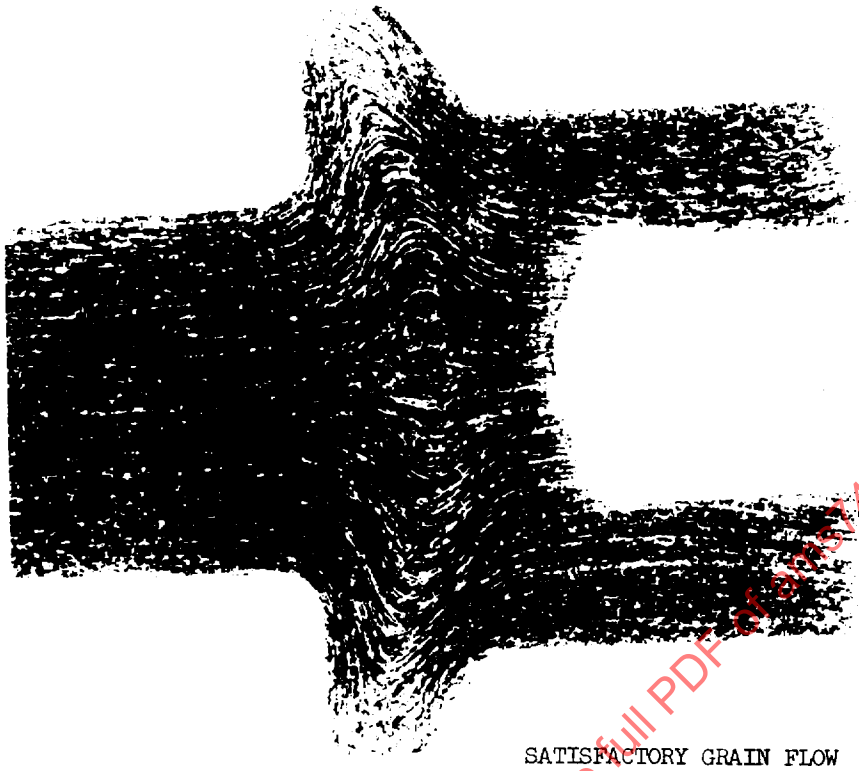
6.1.2.2 Shank or Stem: A maximum of 5 indications is permitted. The length of any indication may be the full length of the surface but the total length of all indications shall not exceed twice the length of the surface. No indication shall break into a fillet or over an edge.

6.1.3 Threads: There shall be no indications of cracks, seams, or rolling laps in threads as shown by Ø Figs. 4, 5, and 6 except that indications of slight laps as shown by Figs. 7 and 8 will be permitted.

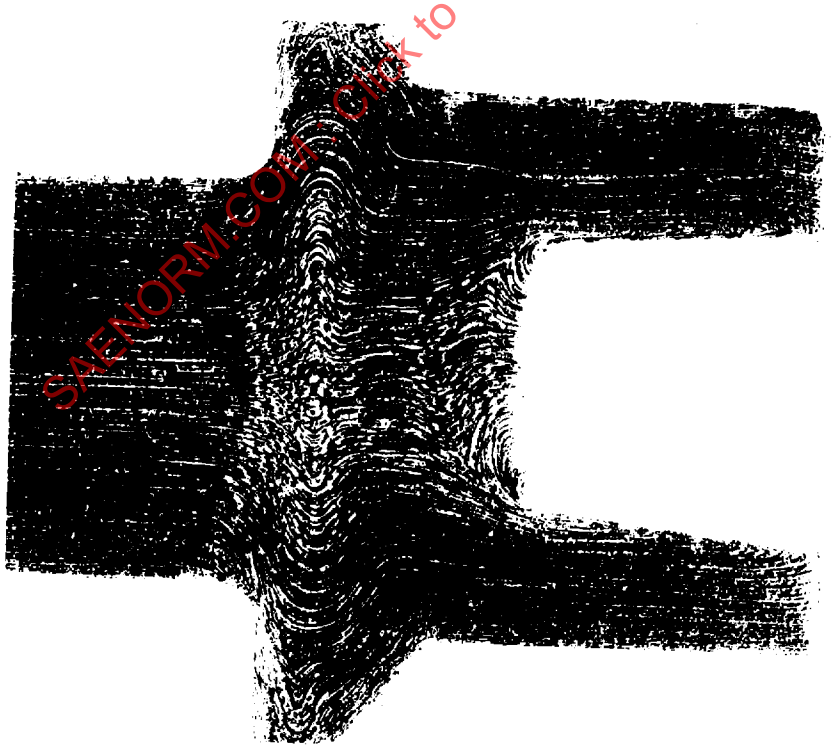
6.1.4 Top of Head and End of Stem: Indications are permitted provided that the depth of any individual indica- Ø tion does not exceed 0.010 in., as shown by sectioning representative samples, and does not break over an edge.

7. REPORTS: Unless otherwise specified, the vendor of parts shall furnish with each shipment three copies of a report stating that the chemical composition of the parts conforms to the requirements of the applicable material specification and showing the results of tests to determine conformance to the tensile and stress-rupture strength requirements of this specification. This report shall include the purchase order number, specification number, contractor or other direct supplier of material, part number, and quantity.

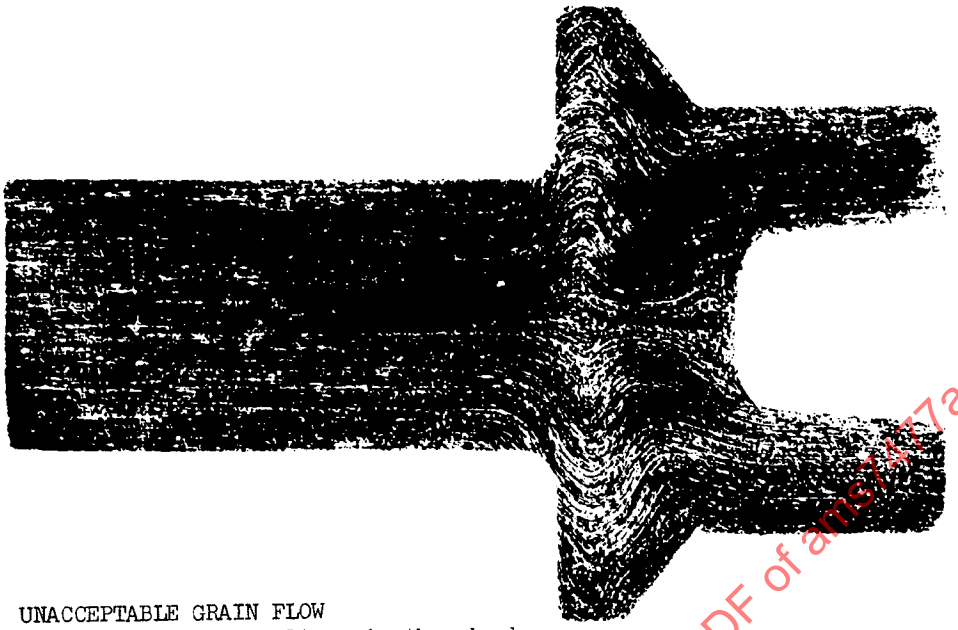
8. REJECTIONS: Parts not conforming to this specification or to authorized modifications will be subject to rejection.



SATISFACTORY GRAIN FLOW
FIGURE 1A

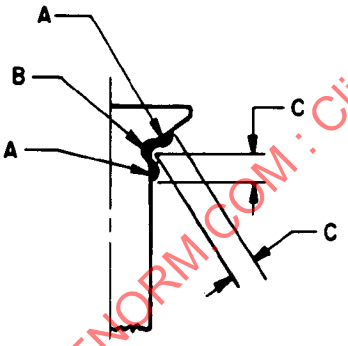


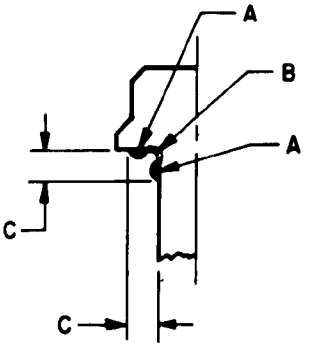
MINIMUM ACCEPTABLE STANDARD
Showing maximum permissible cutting of flow lines after machining to remove oxide and decarburization as in 4.3.
FIGURE 1B



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

FIGURE 1C



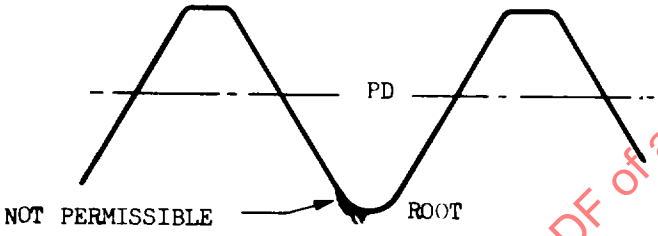


Nominal Bolt Diameter	C, max
Up to 0.3125, excl	0.062
0.3125 and 0.375	0.094
0.4375 - 0.625, incl	0.125
0.750 - 1.000, incl	0.156
Over 1.000	0.188

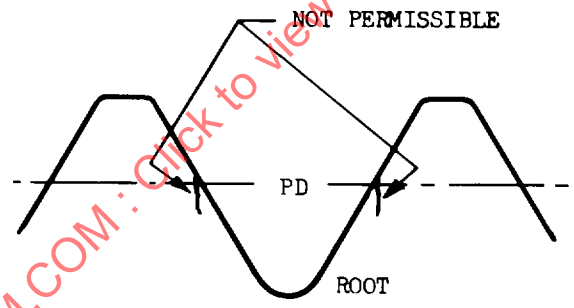
PERMISSIBLE DISTORTION FROM FILLET WORKING

FIGURE 2

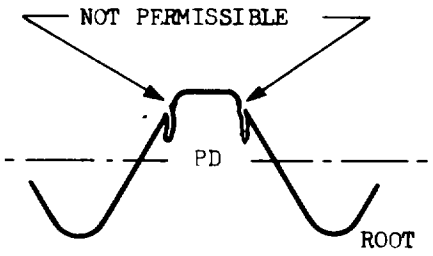
FLOW LINES - ROLLED THREAD
FIGURE 3



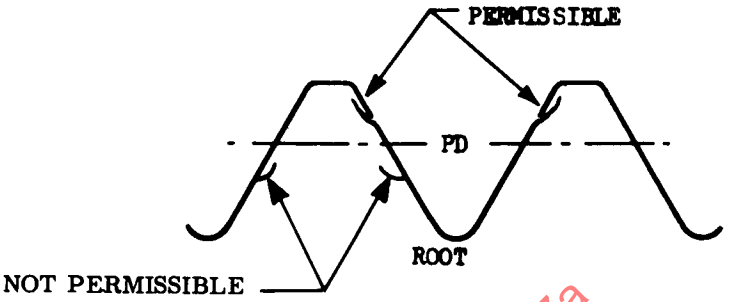
ROLLED THREAD
FIGURE 4



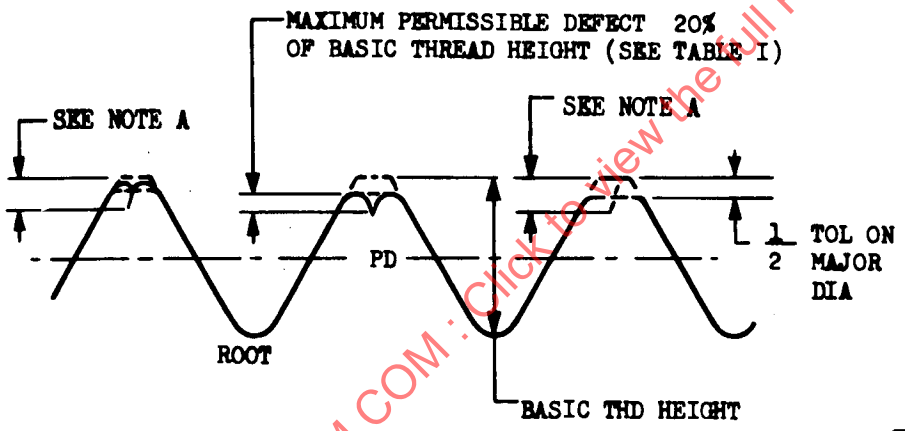
ROLLED THREAD
FIGURE 5



ROLLED THREAD
FIGURE 6

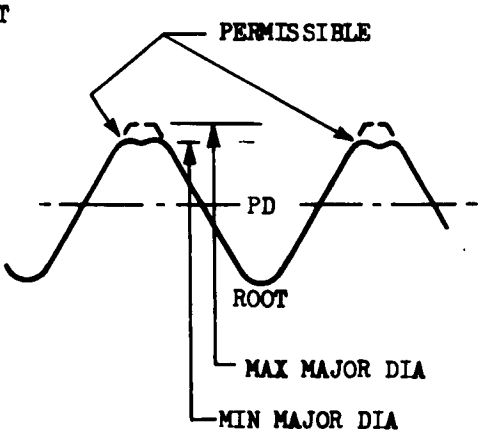


ROLLED THREAD
FIGURE 7

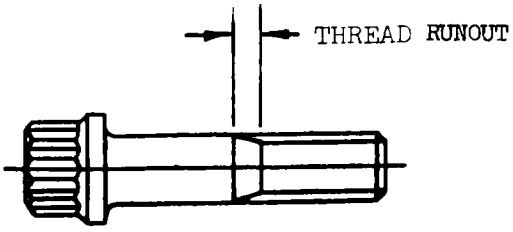


NOTE A. DEPTH OF DEFECT EQUALS 20% OF BASIC THREAD HEIGHT PLUS 1/2 THE DIFFERENCE OF THE ACTUAL MAJOR DIAMETER AND MINIMUM MAJOR DIAMETER.

ROLLED THREAD
FIGURE 8

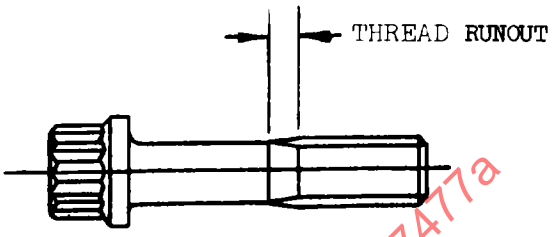


ROLLED THREAD
FIGURE 9



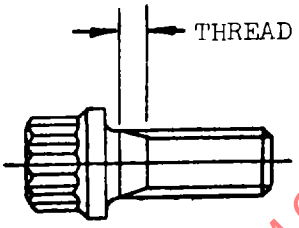
FULL SHANK

FIGURE 10A



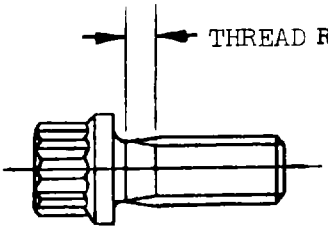
RELIEVED SHANK

FIGURE 10B



FULL SHANK
THREADED TO HEAD

FIGURE 10C



RELIEVED SHANK
THREADED TO HEAD

FIGURE 10D

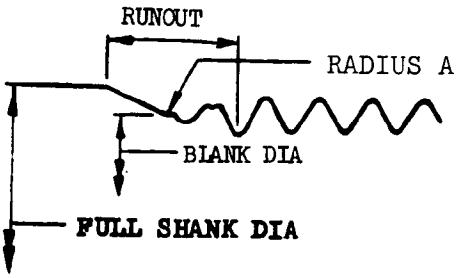


FIGURE 11A

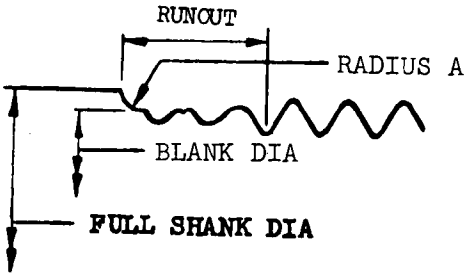


FIGURE 11B

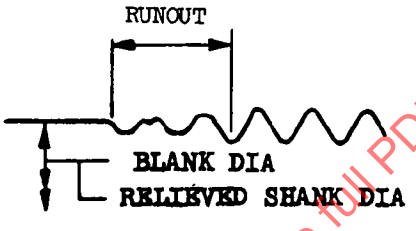
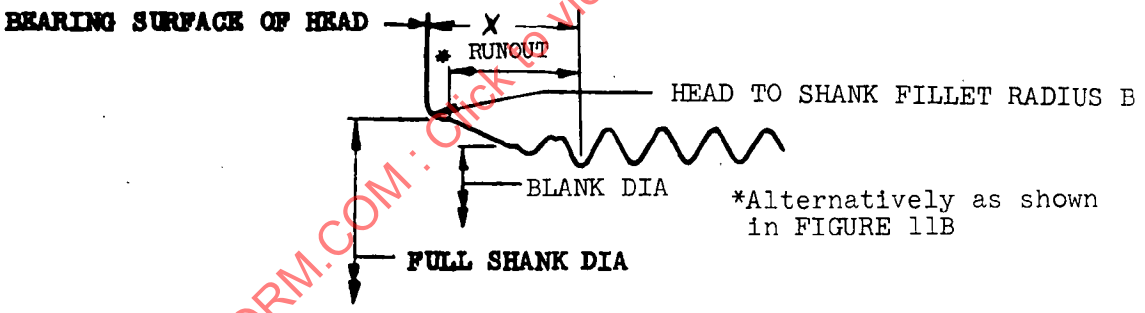
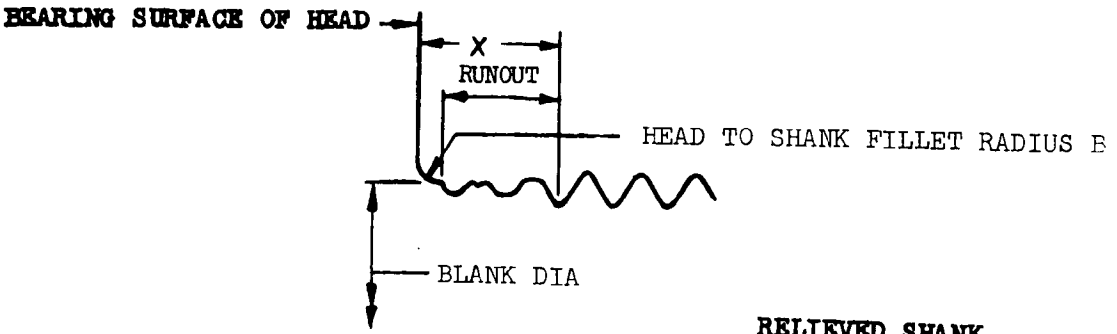


FIGURE 11C



FULL SHANK THREADED TO HEAD

FIGURE 12A



RELIEVED SHANK THREADED TO HEAD

FIGURE 12B