



Standard Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets¹

This standard is issued under the fixed designation F 606; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 These test methods establish procedures for conducting tests to determine the mechanical properties of externally and internally threaded fasteners, washers, and rivets.

1.2 Property requirements and the applicable tests for their determination are specified in individual product standards. In those instances where the testing requirements are unique or at variance with these standard procedures, the product standard shall specify the controlling testing requirements.

1.3 These test methods describe mechanical tests for determining the following properties:

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1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

NOTE 1—A complete metric companion to Test Methods F 606 has been developed—F 606M; therefore, no metric equivalents are shown in these test methods.

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2. Referenced Documents

2.1 ASTM Standards:

- A 394 Specification for Steel Transmission Tower Bolts, Zinc-Coated and Bare²
- E 8 Test Methods of Tension Testing of Metallic Materials³
- E 10 Test Method for Brinell Hardness of Metallic Materials³
- E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials³
- E 83 Practice for Verification and Classification of Extensometers³
- F 436 Specification for Hardened Steel Washers²
- F 606M Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets [Metric]²

2.2 Military Standard:

- MIL STD 1312, Test 13 and Test 20⁴

3. Test Methods for Externally Threaded Fasteners

3.1 *Product Hardness*—Tests shall be conducted after the removal of any surface oxide, decarburization, plating or other coating. All readings shall be within the hardness values listed in the product specification. The average of all readings on the same part shall be considered as the product hardness. Test results shall conform to the product specification for the lot represented by the test specimens to be considered conforming. Test specimen preparation and hardness tests shall be conducted in accordance with Test Method E 18 for Rockwell tests, Test Method E 10 for Brinell tests, Test Method E 92 for Vickers tests, or Test Method E 384 for Microhardness tests. The method used is at the option of the manufacturer, with regards to the size and grade of the products.

3.1.1 *Routine Test Locations*—For testing the hardness of the finished product, the following test locations can be used:

3.1.1.1 For hex and square head bolts; test shall be conducted on the wrench flats, top of head, unthreaded shank, end of bolt or at the arbitration location.

3.1.1.2 For studs, products without parallel wrench flats and

² *Annual Book of ASTM Standards*, Vol 01.08.

³ *Annual Book of ASTM Standards*, Vol 03.01.

⁴ Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

for head styles other than hex and square; tests shall be conducted on the unthreaded shank, end of the bolt or stud or at the arbitration location.

3.1.1.3 Stress relieved products (3.1.1.1 and 3.1.1.2) are measured anywhere on the surface or through the cross section. Refer to the product specification for particular test location or use the arbitration location.

3.1.1.4 The Rockwell Hardness Scale may be used for all product diameters; however, the Brinell hardness is limited to products over 1-1/2 in. nominal diameter.

3.1.2 *Laboratory Inspection*—After observing 3.1 and 3.1.1, a minimum of three readings shall be taken on each sample of finished product.

3.1.3 *Arbitration Test Location*—For purposes of arbitration between the purchaser and seller over reported test results, hardness tests shall be conducted at the mid-radius ($r/2$) of a transverse section through the threads taken at a distance of approximately one diameter from the point end of the bolt or one end of the stud. Four readings shall be taken from the point end of the bolt or one end of the stud. Four readings shall be taken approximately 90° to one another on the same plane, if product size permits. Smaller diameter products may also use the opposite parallel surface area of the bolt head end as sectioned above. (See Fig. 1). The use of Brinell hardness is limited to product sizes greater than 2-1/4 in. nominal diameter.

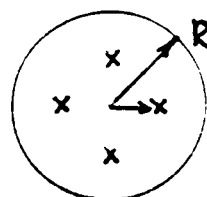
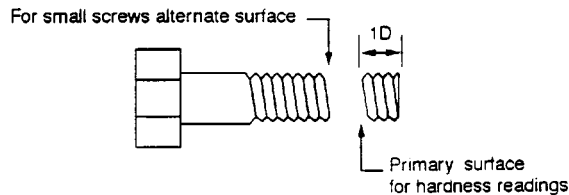
3.2 *Tension Tests*—It is preferred that bolts and studs be tested full size, and it is customary, when so testing, to specify a minimum ultimate load (or stress) in pounds-force (or pounds-force per square inch.) Paragraphs 3.2 through 3.5 apply when testing externally threaded fasteners full size. Paragraph 3.6 shall apply where the individual product specifications permit the use of machined specimens. (See Test Methods E 8.)

3.2.1 *Proof Load*—The proof-load test consists of stressing the product with a specified load that the product must withstand without measurable permanent set. Alternative tests for determining the ability of a fastener to pass the proof-load test are the yield strength test and the uniform hardness test. Either Method 1 (3.2.3), Method 2 (3.2.4), or Method 3 (3.2.5) may be used, but Method 1 shall be the arbitration method in

case of any dispute as to acceptance of the product. (See Test Methods E 8.)

3.2.2 In both Methods 1 and 2, assemble the product in the fixture of the tension testing machine so that six complete threads (except for heavy hex structural bolts, which shall be based on four threads) are exposed between the grips. This is obtained by freely running the nut or fixture to the thread runout of the specimen and then unscrewing the specimen six full turns. For continuous thread bolts, at least six full threads shall be exposed between the fixture ends; however, for referee purposes, six full threads shall be exposed.

3.2.3 *Method 1, Length Measurement*—To ensure consistent and repetitive length measurements of the fastener, the threaded end and top of the bolt head shall have conical depressions made at the approximate axis or center line of the fastener. If raised or depressed markings on the head interfere with the placement of the measuring depressions, the head shall be carefully ground. The measuring instrument shall have pointed anvils which mate with the center line depressions and be capable of measuring changes in length of 0.0001 in. with an accuracy of 0.0001 in. in any 0.001 in. range. Place the fastener between the measuring anvils and rotate it approximately 1/4 turn to the left center, right then center again to assure sound seating. Zero the instrument or record indicated measurement. If using a bolt extensometer, the bolt with attached extensometer may be assembled into the tension testing machine. If not, mark the fastener so it may be placed as close as possible to the same position for the second reading. Remove and assemble the fastener into the tension testing machine as outlined in 3.4. With a test speed which shall not exceed 0.12 in./min., as determined with a free-running cross head, axially load the fastener to the proof load value specified in the product specification. This load shall be maintained for a period of 10 s before releasing the load. Replace the fastener between the measuring anvils and rotate as before, stopping the mark at the same approximate position as the first reading. The measurement shall show no permanent elongation. A tolerance of ± 0.0005 in. shall be allowed (for measurement error only) between the measurement made before loading and that made after loading. Variables such as straightness, thread alignment,



R = Radius
X = R/2

FIG. 1 Hardness Arbitration Test Location

or measurement error could result in apparent elongation of the product when the specified proof load is initially applied. In such cases, the product may be retested using a 3 % greater load, and shall be considered acceptable if there is no difference in the length measurement after this loading within a 0.0005 in. measurement tolerance as outlined.

3.2.4 *Method 2, Yield Strength*—Assemble the product in the testing equipment as outlined in 3.4. As the load is applied, measure and record the total elongation of the product or any part of it that includes the exposed threads to produce a load-elongation diagram. Determine the load or stress at an offset equal to 0.2 % of the length of bolt occupied by six full threads as shown in Fig. 2 (except for heavy hex structural bolts, which shall be based on four threads) by the method described in 3.6.3.1.

3.2.4.1 *Method 2A, Yield Strength for Austenitic Stainless Steel and Non-ferrous Materials*—Assemble the product in the testing equipment as outlined in 3.4. As the load is applied, measure and record the total elongation of the product in order to produce a load elongation diagram. Determine the load or stress at an offset equal to 0.2 % strain based on the length of the bolt between the holders as shown in Fig. 2, which will be subject to elongation under load by using the method described in 3.6.3.1.

3.2.5 *Method 3, Uniform Hardness*—The fasteners shall be tested for hardness as described in 3.1, and in addition, the hardness shall also be determined in the core. The difference between the mid-radius and core hardness shall be not more than 3 points on a Rockwell C Scale; and both readings must be within product specification. This test is valid for fasteners up to and including 1 in. in diameter.

3.3 *Bolts or Studs Too Short for Tension Testing*—Product lengths less than those shown in Table 1 for product 1/4 through 3/4 in. in diameter and less than three diameters in length for product above 3/4 in. in diameter, or that do not have sufficient threads for proper engagement and still leave the specified number of complete threads exposed between the grips, shall

TABLE 1 Minimum Length of Product Requiring Tension Testing

Nominal Product Size, in.	Minimum Length, in.
1/4	5/8
5/16	3/4
3/8	7/8
7/16	1
1/2	1 1/8
9/16	1 1/4
5/8	1 1/2
3/4	1 3/4
7/8 and larger	3 dia

be deemed too short for tension testing, and acceptance shall be based on a hardness test performed in accordance with 3.1. If tests other than product hardness are required, their requirements should be referenced in the product specification.

3.4 *Axial Tension Testing of Full-Size Products:*

3.4.1 Test bolts in a holder with the load axially applied between the head and a nut or suitable fixture (Fig. 2), either of which shall have sufficient thread engagement to develop the full strength of the product. Assemble the nut or fixture on the product, leaving a minimum of six complete bolt threads exposed between the grips except for heavy hex structural bolts, which shall have four complete threads exposed between the grips.

3.4.2 Test studs by assembling one end in the threaded fixture to the thread runout. For studs having unlike threads, this shall be the end with the finer pitch thread, or with the larger minor diameter. Likewise, assemble the other end of the stud in a threaded fixture, leaving six complete threads exposed between the grips. For continuous thread studs, at least six complete threads shall be exposed between the fixture ends. The maximum speed of the free-running cross head shall not exceed 1 in./min. When reporting the tensile strength of product, in pounds-force per square inch, calculate the thread stress area as follows:

$$A_s = 0.7854 [D - (0.9743/n)]^2 \tag{1}$$

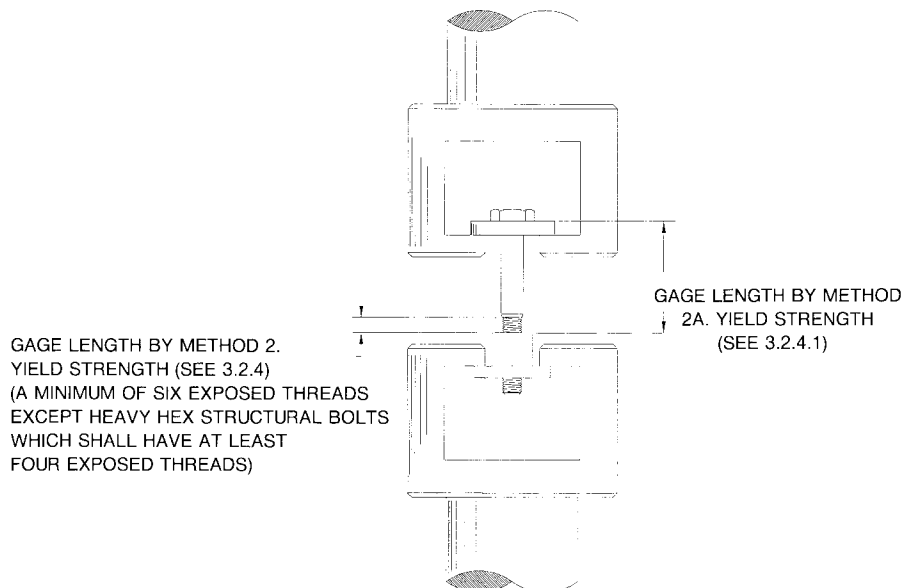


FIG. 2 Tension Testing of Full-Size Bolt (Typical Set-Up)

where:

A_s = thread stress area, in.²,

D = nominal diameter of bolt or stud, in., and

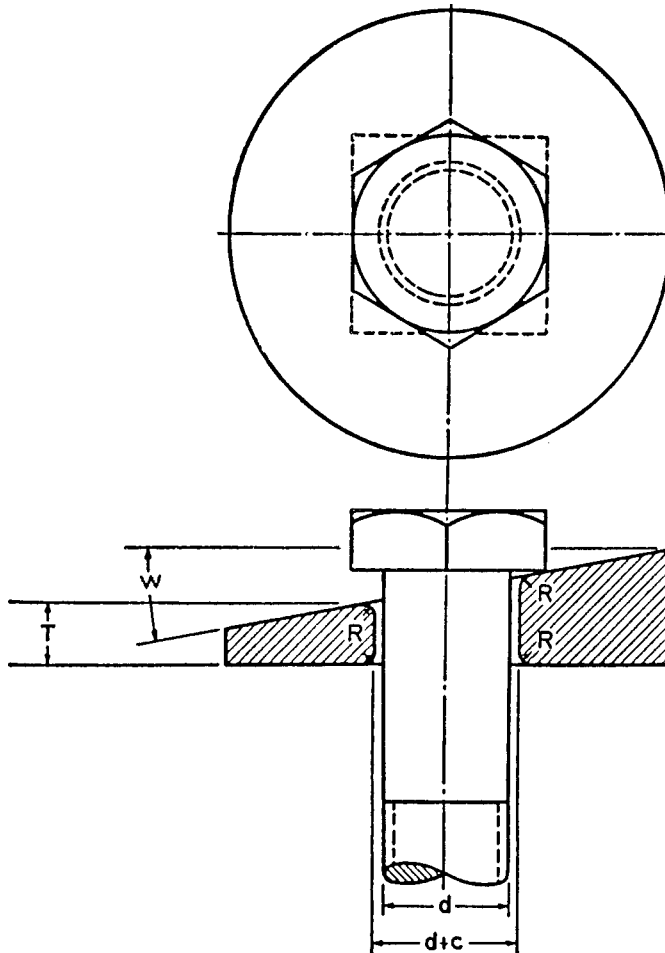
n = number of threads per inch.

3.4.3 To meet the requirements of the test described in 3.4.1 and 3.4.2, the product shall support a load prior to fracture not less than the minimum tensile strength specified in the product specification for its size, strength, and thread series. In addition, the tensile fracture shall occur in the body or threaded section with no fracture at the junction of head and shank.

3.5 *Wedge Tension Testing of Full-Size Product*—The wedge tensile strength of a hex or square-head fastener, socket-head cap screw (with the exception of socket button or flat countersunk head products) or stud is the tensile load that the product is capable of sustaining when stressed with a wedge under the head. The purpose of this test is to obtain the tensile strength and demonstrate the “head quality” and ductility of the product.

3.5.1 *Wedge Tension Testing of Bolts*—Determine the ultimate

load of the bolt as described in 3.4 except place a wedge under the bolt head. When both wedge tension and proof load testing are required by the product specification use the proof load-tested bolts for wedge testing. The wedge shall have a minimum hardness of 45 HRC. Additionally, the wedge shall have a minimum thickness of one half the nominal bolt diameter (measured at the thin side of the hole, see Fig. 3). The wedge shall have an included angle as shown in Table 2 for the product type being tested. The hole in the wedge shall have a clearance over the nominal size of the bolt, and its edges top and bottom shall be rounded as specified in Table 3. The minimum outside dimension of the wedge shall be such that during the test no corner loading of the product head (adjacent to the wedge) shall occur. (See head orientation in Fig. 3). The bolt shall be tension tested to fracture. To meet the requirements of this test, the bolt shall support a load prior to fracture not less than the minimum tensile strength specified in the product specification for the applicable size, grade, and thread series. In addition, the



c = clearance of hole

D = diameter of bolt or screw

R = radius or chamfer

T = reference thickness of wedge at thin side of hole equals one half diameter of bolt or screw

W = wedge angle (see Table 2)

FIG. 3 Wedge Test Details—Bolts

TABLE 2 Tension Test Wedge Angles

Nominal Product Size, in.	Degrees	
	Bolts ^A	Studs and Flange Bolts
¼ – 1	10	6
Over 1	6	4

^A Heat-treated bolts that are threaded one diameter or closer to the underside of the head, shall use a wedge angle of 6° for sizes ¼ through ¾ in. and 4° for sizes over ¾ in.

TABLE 3 Tensile Test Wedge Hole Clearance—Details

Nominal Product Size, in.	Nominal Clearance in Hole, in.	Nominal Radius on Corners of Hole, in.
¼ – ½	0.030	0.030
⅜ – ¾	0.050	0.060
⅞ – 1	0.060	0.060
1 ⅛ – 1 ¼	0.060	0.125
1 ⅜ – 1 ½	0.094	0.125
1 ¾ – 2	0.094	0.225
2 ¼ – 3	0.125	0.256

tensile fracture shall occur in the body or threaded section with no fracture at the junction of head and shank.

NOTE 2—Fracture at the junction of the head and shank is prohibited at any load, including those above the minimum requirements.

3.5.2 *Wedge Tension Testing of Studs*—When both wedge tension and proof load testing are required by the product specifications, assemble one end of the same stud previously used for proof load testing in a threaded fixture to the thread runout. For studs having unlike threads, this shall be the end with the finer pitch thread or with the larger minor diameter. Assemble the other end of the stud in a threaded wedge to the runout and then unscrew six full turns, thus leaving six complete threads exposed between the grips, as illustrated in Fig. 4. For continuous thread studs, at least six complete threads shall be exposed between the fixture ends. The angle of the wedge for the stud size and grade shall be as specified in Table 2. Assemble the stud in the testing machine and tension test to fracture, as described in 3.4. The minimum hardness of the threaded wedge shall be 45 HRC. The length of the

threaded section of the wedge shall be equal to at least the diameter of the stud. To facilitate removal of the broken stud, counterbore the wedge. The thickness of the wedge at the thin side of the hole shall equal the diameter of the stud plus the depth of counterbore. The thread in the wedge shall have Class 3B tolerances, except when testing studs having an interference fit thread, in which case the wedge shall be threaded to provide a finger-free fit. The supporting fixture, as shown in Fig. 4, shall have a hole clearance over the nominal size of the stud, and shall have its top and bottom edges rounded or chamfered to the same limits specified for the hardened wedge in Table 3. To meet the requirements of this test, the stud shall support a load prior to fracture not less than the minimum tensile strength specified in the product specification for its size, grade, and thread series.

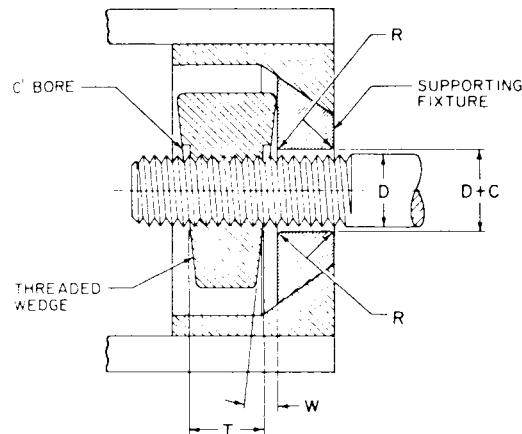
NOTE 3—Dimensional tolerances for all test fixtures used in this test method, unless otherwise noted, shall conform to standard machining practices.

3.6 *Tension Testing of Machined Test Specimens:*

3.6.1 Where bolts and studs cannot be tested full size, conduct tests using test specimens machined from the bolt or stud (see Test Methods E 8).

3.6.1.1 Bolts and studs ⅜ in. in diameter and smaller may be machined concentric with the axis of the bolt or stud. The specimen shall have a turned section as large as feasible and shall have a gage length four times the diameter of the specimen. See Fig. 5 and Fig. 6.

3.6.1.2 Bolts and studs ⅝ in. in diameter through 1 ¼ in. in diameter may have their shanks machined concentric with the axis of the bolt or stud, leaving the bolt head and threaded section intact as shown in Fig. 5. Alternatively, bolts and studs ⅝ in. in diameter through 1 ¼ in. in diameter may have their shanks machined to a test specimen with the axis of the specimen located midway between the axis and outside surface of the bolt or stud as shown in Fig. 7. Bolts of a small cross section that will not permit taking the 0.500-in. round, 2-in. gage length test specimen shall have a turned section as large as feasible and concentric with the axis of the bolt or stud. The gage length for measuring the elongation shall be four times the diameter of the specimen. Fig. 6 illustrates an example of



- C = clearance of hole (see Table 3)
- D = diameter of stud
- R = radius or chamfer (see Table 3)
- T = E plus depth of counterbore
- W = wedge angle (see Table 2)
- E = length of threaded section of wedge = D

FIG. 4 Wedge Test Details—Studs

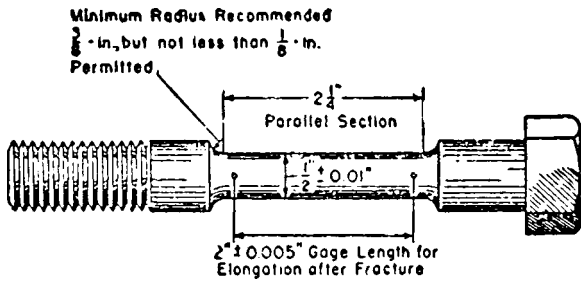


FIG. 5 Tension Test Specimen for Bolt with Turned-Down Shank

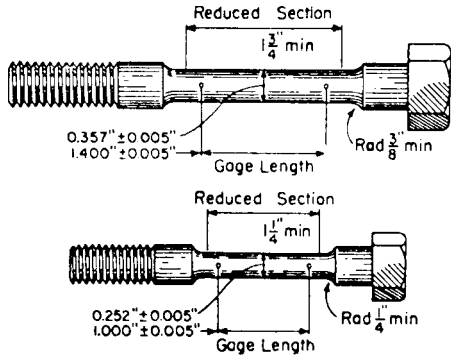


FIG. 6 Examples of Small-Size Specimens Proportional to Standard 2-in. Gage Length Specimen

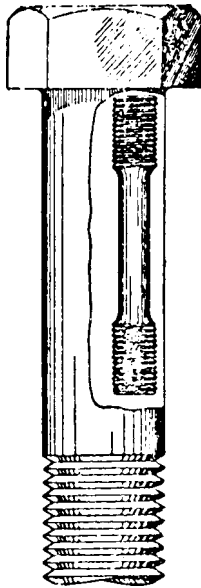


FIG. 7 Location of Standard Round 2-in. Gage Length Tension Test Specimen When Turned from Large Size Bolt

these small-size specimens. For arbitration purposes, machined test specimens for bolts and studs $\frac{5}{8}$ in. in diameter through $1\frac{1}{4}$ in. in diameter shall be machined with the axis of the specimen located midway between the center and outside surface.

3.6.1.3 Bolts and studs $1\frac{3}{8}$ in. in diameter and larger may have their shanks machined to the dimensions of a 0.500-in. round, 2-in. gage length test specimen with the axis of the specimen located midway between the center and outside surface of the bolt or stud as shown in Fig. 7.

3.6.1.4 Machined test specimens shall exhibit tensile

strength, yield strength (or yield point), elongation, and reduction of area equal to or greater than the values of these properties specified for the product size in the applicable product specification when tested in accordance with this section.

3.6.2 Determination of Tensile Properties:

3.6.2.1 Yield Point—Yield point is the first stress in a material, less than the maximum obtainable stress, at which an increase in strain occurs without an increase in stress. Yield point is intended for application only for materials that may exhibit the unique characteristic of showing an increase in strain without an increase in stress. The stress-strain diagram is characterized by a sharp knee or discontinuity. Determine yield point by one of the following methods:

3.6.2.2 Drop of the Beam or Halt of the Pointer Method—In this method apply an increasing load to the specimen at a uniform rate. When a lever and poise machine is used, keep the beam in balance by running out the poise at approximately a steady rate. When the yield point of the material is reached, the increase of the load will stop, but run the poise a trifle beyond the balance position, and the beam of the machine will drop for a brief but appreciable interval of time. When a machine equipped with a load-indicating dial is used, there is a halt or hesitation of the load-indicating pointer corresponding to the drop of the beam. Note the load at the “drop of the beam” or the “halt of the pointer” and record the corresponding stress as the yield point.

3.6.2.3 Autographic Diagram Method—When a sharp-kneed stress-strain diagram is obtained by an autographic recording device, take the stress corresponding to the top of the knee (Fig. 8), or the stress at which the curve drops as the yield point (Fig. 9).

3.6.2.4 Total Extension Under Load Method—When testing

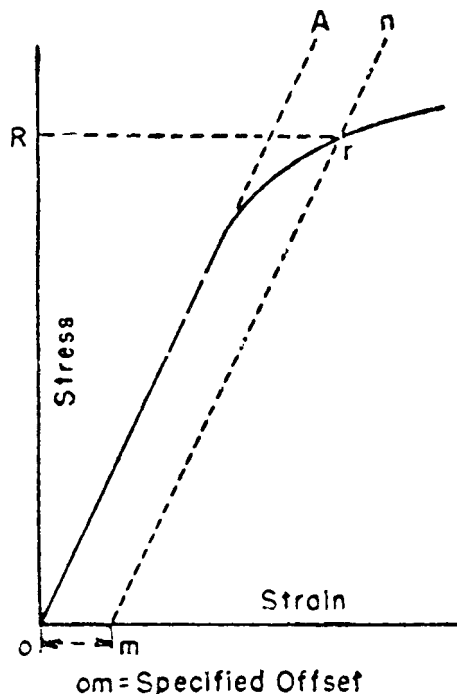


FIG. 8 Stress-Strain Diagram for Determination of Yield Strength by the Offset Method

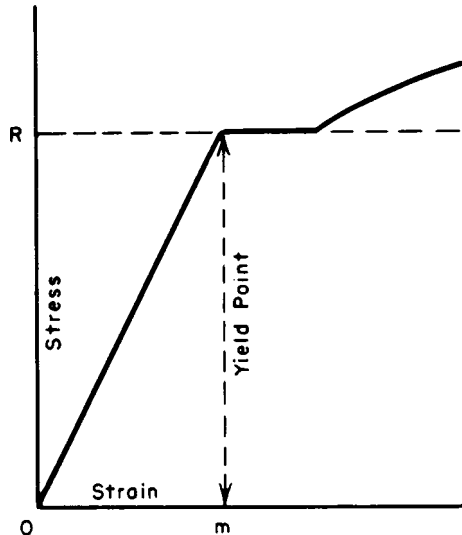


FIG. 9 Stress-Strain Diagram Showing Yield Point Corresponding with Top of Knee

material for yield point and the test specimens may not exhibit a well-defined disproportionate deformation that characterizes a yield point as measured by the drop of the beam, halt of the pointer, or autographic diagram methods described in 3.6.2.2 and 3.6.2.3, a value equivalent to the yield point in its practical significance may be determined by the following method and may be recorded as yield point: Attach a Class C or better extensometer (Note 4 and Note 5) to the specimen. When the load producing a specified extension (Note 6) is reached, record the stress corresponding to the load as the yield point, and remove the extensometer (Fig. 10).

NOTE 4—Automatic devices are available that determine the load at the specified total extension without plotting a stress-strain curve. Such devices may be used if their accuracy has been demonstrated. Multiplying calipers and other such devices are acceptable for use provided their accuracy has been demonstrated as equivalent to a Class C extensometer.

NOTE 5—Reference should be made to Practice E 83.

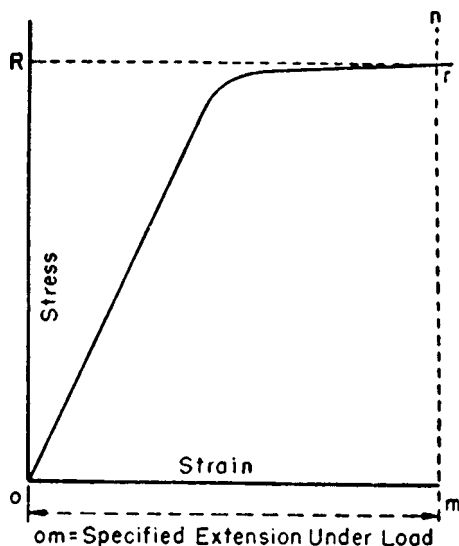


FIG. 10 Stress-Strain Diagram Showing Yield Point or Yield Strength by Extension Under Load Method

NOTE 6—For steel with a specified yield point not over 80 000 psi, an appropriate value is 0.005 in./in. of gage length. For values above 80 000 psi, this test method is not valid unless the limiting total extension is increased.

3.6.3 *Yield Strength*—Yield strength is the stress at which a material exhibits a specified limiting deviation from the proportionality of stress to strain. The deviation is expressed in terms of strain, percent offset, total extension under load, etc. Determine yield strength by one of the following methods:

3.6.3.1 *Offset Method*—To determine the yield strength by the “offset method,” it is necessary to secure data (autographic or numerical) from which a stress-strain diagram may be drawn. Then on the stress-strain diagram (Fig. 8) lay off Om equal to the specified value of the offset, draw mn parallel to OA , and thus locate r . The yield strength load R is the load corresponding to the highest point of the stress-strain curve before or at the intersection of mn with r . In reporting values of yield strength obtained by this method, the specified value of “offset” used should be stated in parentheses after the term yield strength, thus:

$$\text{Yield strength (0.2 \% offset)} = 52\ 000\ \text{psi} \quad (2)$$

In using this method, a minimum extensometer magnification of 250 to 1 is required. A Class B1 extensometer meets this requirement (see Note 5). See also Note 7 for automatic devices.

3.6.3.2 *Extension Under Load Method*—For tests to determine the acceptance or rejection of material whose stress-strain characteristics are well known from previous tests of similar material in which stress-strain diagrams were plotted, the total strain corresponding to the stress at which the specified offset (see Note 8) occurs will be known within satisfactory limits. The stress on the specimen, when this total strain is reached, is the value of the yield strength. The total strain can be obtained satisfactorily by use of a Class B1 extensometer (Note 4 and Note 5).

NOTE 7—Automatic devices are available that determine offset yield strength without plotting a stress strain curve. Such devices may be used if their accuracy has been demonstrated.

NOTE 8—The appropriate magnitude of the extension under load will obviously vary with the strength range of the particular material under test. In general, the value of extension under load applicable to any material strength level may be determined from the sum of the proportional strain and the plastic strain expected at the specified yield strength. The following equation is used:

$$\text{Extension under load, in./in. of gage length} = (YS/E) = r$$

where:

- YS = specified yield strength, psi,
- E = modulus of elasticity, psi, and
- r = limiting plastic strain, in./in.

3.6.4 *Tensile Strength*—Calculate the tensile strength by dividing the maximum load the specimen sustains during a tension test by the original cross-sectional area of the specimen.

3.6.5 *Elongation:*

3.6.5.1 Fit the ends of the fractured specimen together carefully and measure the distance between the gage marks to the nearest 0.01 in. for gage lengths of 2 in. and under, and to the nearest 0.5 % of the gage length for gage lengths over 2 in. A percentage scale reading to 0.5 % of the gage length may be

used. The elongation is the increase in length of the gage length, expressed as a percentage of the original gage length. In reporting elongation values, give both the percentage increase and the original gage length.

3.6.5.2 If any part of the fracture takes place outside of the middle half of the gage length or in a punched or scribed mark within the reduced section, the elongation value obtained may not be representative of the material. If the elongation so measured meets the minimum requirements specified, no further testing is indicated, but if the elongation is less than the minimum requirements, discard the test and retest.

3.6.6 *Reduction of Area*—Fit the ends of the fractured specimen together and measure the mean diameter or the width and thickness at the smallest cross section to the same accuracy as the original dimensions. The difference between the area thus found and the area of the original cross section expressed as a percentage of the original area, is the reduction of area.

3.7 *Total Extension at Fracture Test:*

3.7.1 The extension at fracture (A_L) test shall be carried out on stainless steel and nonferrous products (bolts, screws, and studs) in the finished condition, with lengths equal to or in excess of those minimums listed in Table 1.

3.7.2 The products to be tested shall be measured for total length (L_1) as described in 3.7.2.1 and shown in Fig. 11.

3.7.2.1 Mark both ends of the bolt, screw, or stud using a permanent marking substance such as bluing so that measuring reference points for determining total length L_1 and L_2 are established. Using an open-end caliper and steel rule or other device capable of measuring to within 0.010 in., determine the total length of the product as shown in Fig. 11.

3.7.3 The product under test shall be screwed into the threaded adapter to a depth of one diameter (see Fig. 2) and load applied axially until the product fractures. The maximum speed of the free-running cross head shall not exceed 1 in./min.

3.7.4 After the product has been fractured in accordance with 3.7.3, the two broken pieces shall be fitted closely together and the overall length (L_2) measured (see 3.7.2.1 and Fig. 11). The total extension at fracture shall then be calculated as follows:

$$A_L = L_2 - L_1$$

3.7.5 The value obtained shall equal or exceed the minimum values shown in the applicable specification for the product and material type.

3.8 *Single Shear Test*—(Note 9) This test is intended to

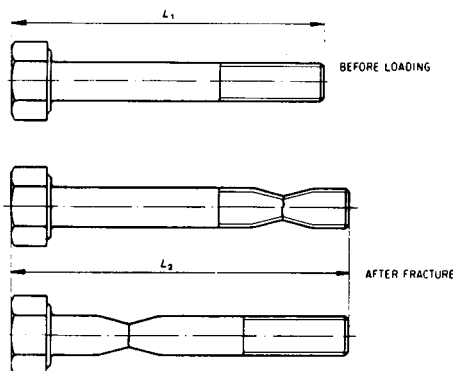


FIG. 11 Determination of Total Extension at Fracture (A_L) (only Screw Product Shown)

determine the ability of a fastener to withstand a predetermined load when applied transversely to the axis of the fastener. Shear is defined as an action or stress caused by applied forces that causes two adjacent parts of a body to slide on each other to cause separation. Shear tests may be conducted in either tension-type or compression-type single shear fixture.

3.8.1 The specimen shall be tested using hardened steel plates of sufficient thickness to preclude bearing failure. Holes in the shear plates shall be $\frac{1}{16}$ in. larger than the nominal thread diameter of the test bolt and the holes shall be chamfered 0.010 in. to relieve sharp edges. Shear plates shall be prevented from separating by means of a suitable jig or by using a nut on the test bolt tightened finger tight.

3.8.2 The test specimen, when assembled in the shear jig, shall be mounted in a tensile-testing machine capable of applying load at a controllable rate. The grips shall be self-aligning and care shall be taken when mounting the specimen to assure that the load will be transmitted in a straight line transversely through the test bolt. Load shall be applied and continued until fracture of the bolt. Speed of testing as determined with a free-running cross head shall not be less than $\frac{1}{4}$ in. nor greater than $\frac{1}{2}$ in. per min.

3.8.3 The maximum load applied to the specimen, coincident with or prior to bolt fracture shall be recorded as the shear strength of the bolt. At the discretion of the testing activity, tests need not be continued to destruction provided that the specimen supports, without evidence of bolt fracture, the minimum load specified.

3.8.4 A typical test fixture for tension shear testing is shown in Fig. 12.

NOTE 9—This single-shear test is primarily used for testing Specification A 394 tower bolts which range in size from $\frac{1}{2}$ through 1 in. diameter. For general use, the shear test practices and fixturing found in MIL STD 1312 Test 13 is used for double shear and Test 20 may be used for single shear.

4. Test Methods for Internally Threaded Fasteners

4.1 *Product Hardness*—For routine inspection of both heat-treated and nonheat-treated nuts, hardness shall be determined

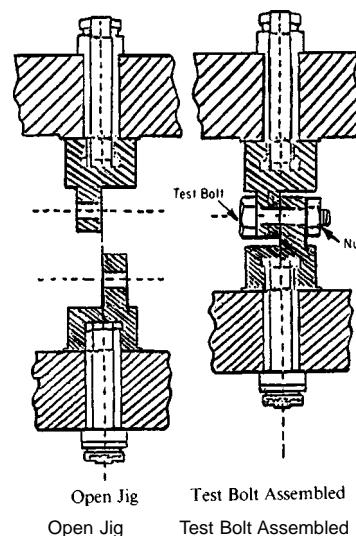


FIG. 12 Typical Single Shear Fixture (Tension Type)

on the bearing face or wrench flats after removal of any oxide, decarburization, plating, or other coating material. Rockwell or Brinell hardness shall be used at the option of the manufacturer, taking into account the size and grade of the product.

4.1.1 The preparation of test specimens and the performance of hardness tests for Rockwell and Brinell testing shall be in conformance with the requirements of Test Methods E 18 and E 10, respectively.

4.1.2 Readings when taken on the bearing face shall be halfway between the major diameter of the thread and one corner. The reported hardness shall be the average of two hardness readings located 180° apart. The readings when taken on the wrench flats shall be one third of the distance from a corner to the center of the wrench face. The reported hardness shall be the average of two readings located from opposite corners.

4.1.3 For the purpose of arbitration or for nuts too large for full size testing, where hardness alone shall determine acceptance (see 4.1.4), the following shall apply.

4.1.3.1 Sample nuts shall be sectioned laterally at approximately one half (1/2) of the nut height. Such samples need not be threaded, but shall be part of the manufacturing lot that was formed (in the case of heat-treated nuts, formed and heat-treated) with the product to be shipped. The preparation of the sample shall be in accordance with 4.1.1 above. All readings shall be conducted on a Rockwell Hardness testing machine. For standard hex, heavy hex and square nuts, the half of the nut not to be tested may be discarded. For special nut configurations both sections shall be identified and made available to the purchaser, if specified on the purchase order or inquiry.

4.1.3.2 *Nonheat-Treated Nuts (See Fig. 13)*—Two readings shall be taken 180° apart at the core (halfway between the major diameter if threaded, or blank hole if not threaded) and a corner of the nut. The reported hardness shall be the average of the two readings, and in addition both readings shall be within the hardness values listed in the product specification.

4.1.3.3 *Heat-Treated Nuts (See Fig. 14)*—Two sets of three readings 180° apart shall be taken. The three readings shall be taken across the section of the nut at the following positions:

Position 1—As close to the major diameter, as possible, if threaded, or hole side wall if the nut is blank, but no closer than 2 1/2 times the indent diameter.

Position 2—At the core (halfway between the major diameter, if threaded, or hole side wall, if blank) and a corner of the nut.

Position 3—As close to the corner of the nut as possible, but no closer than 2 1/2 times the indent diameter.

4.1.3.4 The reported hardness shall be the average of all six

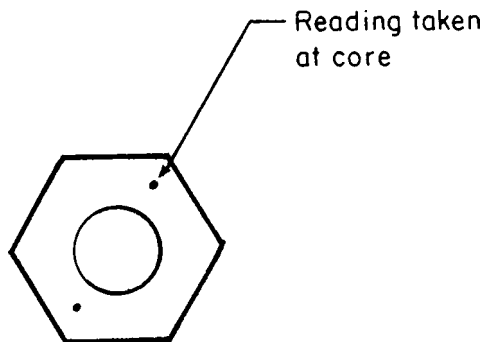


FIG. 13 Nonheat-Treated Nut

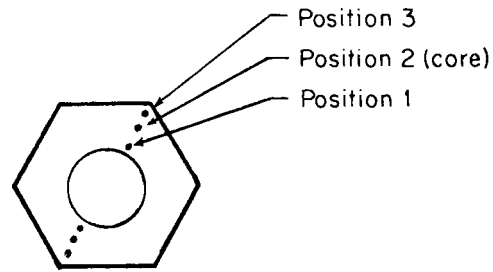


FIG. 14 Heat-Treated Nut

readings. In addition all readings shall be within hardness values listed in the product specification.

4.1.4 Nuts exhibiting a proofload in excess of 160 000 lb may be considered, at the option of the manufacturer, as too large for full-size testing. Full-size testing is recommended whenever possible.

4.1.5 For nuts on which hardness and proof load tests are performed, acceptance based on proof load requirements shall take precedence in the event of controversy with hardness tests.

4.2 *Proof Load Test*—Assemble the nut to be tested on a hardened threaded mandrel (4.2.2) or a test bolt (4.2.1) as illustrated in Fig. 15(a) Tension Method or Fig. 15(b) Compression Method. The hardened test mandrel and the tension method shown in Fig. 15(a) shall be mandatory as a referee if arbitration is necessary. Apply the specified proof load for the nut against the nut. The nut shall resist this load without stripping or rupture, and shall be removable from the test bolt or mandrel by the fingers after the load is released. Occasionally it may be necessary to use a manual wrench or other means to start the nut in motion. Use of such means is permissible, provided the nut is removable by the fingers following the initial loosening of not more than one-half turn of the nut. If the threads of the mandrel or test bolt are damaged during the test, discard the test.

4.2.1 The test bolt shall have threads appropriate to the standard specified for the nut being tested and shall have a yield strength in excess of the specified proof load of the nut being tested.

4.2.2 Mandrels shall have a hardness of 45 HRC minimum and shall have threads conforming to Class 3A except that the maximum major diameter shall be the minimum major diameter plus 0.002 in. or 0.25 times the major diameter tolerance (whichever is greater) of Class 3A threads.

4.2.3 The proof load shall be determined at a free running cross head speed not exceeding 1.0 in/minute and shall be held at load for 10_s minimum

4.3 *Cone Proof Load Test*—Perform this test using a conical washer and threaded mandrel (as illustrated in Fig. 16) to determine the influence of surface discontinuities (that is, forging cracks and seams) on the load-carrying ability of hardened steel nuts through 1 1/2 in. in diameter by introducing a simultaneous dilation and stripping action of the nut. The mandrel shall conform to the requirements of 4.2.2. The conical washer shall have a hardness of 57 HRC minimum and a hole diameter equivalent to the nominal diameter of the mandrel +0.002, -0.000 in. The contact point of the cone shall be sharp for nut sizes 1/2 in. and less. For sizes over 1/2 in., the point shall be flat and 0.015 ± 0.001 in. in width. Assemble the

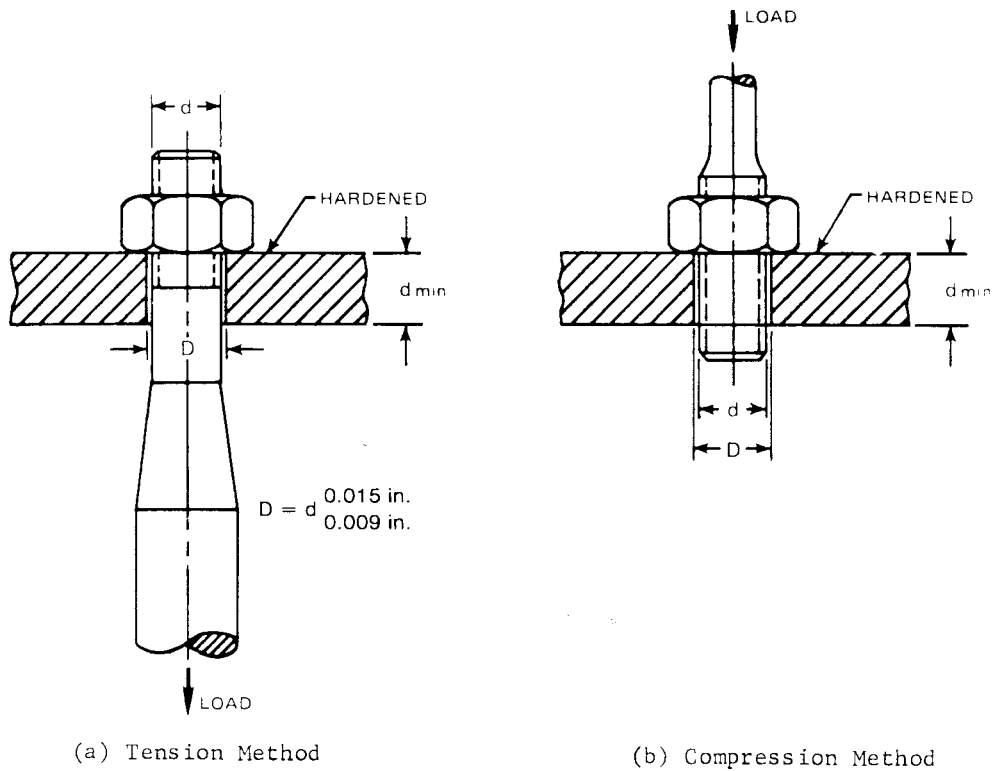


FIG. 15 Proof Load Testing—Nuts

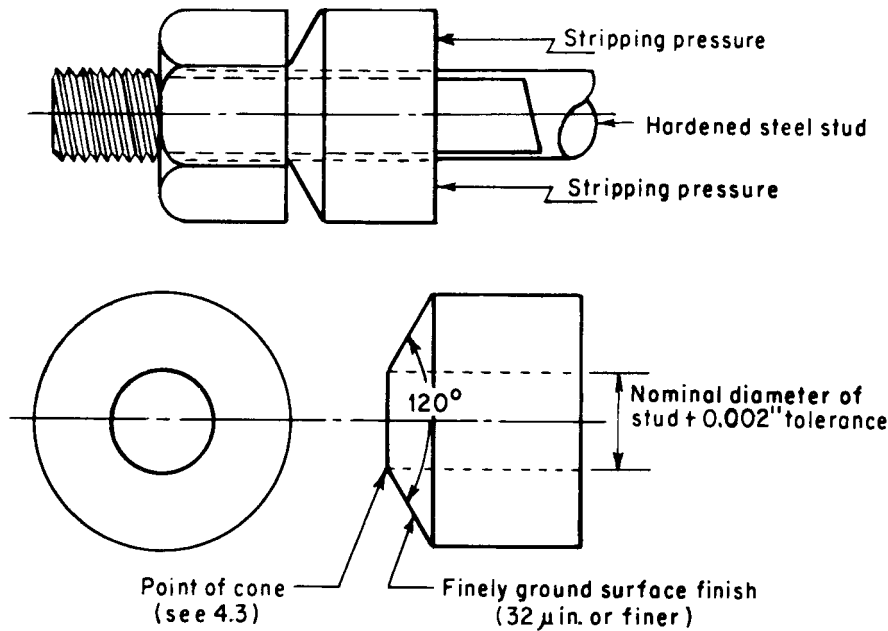


FIG. 16 Cone-Proof Test

nut and the conical washer on the mandrel, and apply the cone proof load for the nut against the nut. The speed of testing as determined with a free-running cross head shall be a maximum of 0.12 in./min. Apply the proof load for 10 s. Compute the cone proof load of a nut as follows:

$$CPL = (1 - 0.30D) \times f \times A_s$$

where:

CPL = cone proof load, lb,

- D = nominal diameter of nut, in.,
- f = specified proof stress of nut, psi,
- A_s = tensile stress area of nut, in.²,
= $0.7854 [D - (0.9743/n)]^2$, and
- n = threads per inch.

To meet the requirements of the cone proof load test, the nut shall support its specified cone proof load without stripping or rupture.

5. Test Methods for Washers and Direct Tension Indicators

5.1 General Requirements:

5.1.1 All tests shall be conducted on a Rockwell hardness tester.

5.1.2 Use of a 1/4in. (6 mm) or smaller spot anvil shall be used for hardness testing of washers and direct tension indicators

5.1.3 Readings are not to be taken on or near product markings.

5.1.4 Preparation of test specimens and the performance of hardness tests shall be performed in accordance with Test Methods E 18.

5.1.5 For arbitration purposes, a minimum of two readings 180° apart on at least one face shall be taken. (See Fig. 17.)

5.1.6 All readings shall be within the hardness values listed in the product specification, and the average of all readings shall be considered as the hardness of the product.

5.1.7 An initial reading may be used to establish that the hardness testing equipment is properly set up and that the correct scale is being used. Such readings are not used to determine conformance.

5.2 Through Hardened Washers:

5.2.1 *Surface Hardness*—Take hardness readings on a smooth flat portion of the washer, prepared by light grinding or polishing as necessary.

5.2.2 *Core Hardness*—Take hardness readings on a smooth flat portion of the washer, prepared by light grinding or polishing such that readings are taken at a minimum depth of 0.015 in. (0.38 mm) from the original surface.

5.3 Carburized Washers:

5.3.1 *Surface Hardness*—Take hardness readings on a smooth flat portion of the washer, using a method which prevents penetration into the core material.

5.3.2 *Core Hardness*—Take hardness readings on a smooth flat portion of the washer, prepared by light grinding or polishing such that readings are taken at a depth greater than the depth of case.

5.3.3 *Depth of Case*—Measurements of case depth shall be taken at a cross section through the rim of the washer, having

been ground and etched to define the case area.

5.4 Stainless Steel and Nonferrous Washers:

5.4.1 *Surface Hardness*—Take hardness readings on a smooth flat portion of the washer.

5.4.2 *Core Hardness*—Take hardness readings on a smooth flat portion of the washer, prepared by light grinding or polishing such that readings are taken at a minimum depth of 0.015 in. (0.38 mm) from the original surface.

5.5 Direct Tension Indicators:

5.5.1 *Surface Hardness*—Take hardness readings on a smooth flat portion of the DTI, at a point approximately midway between the protrusion (top side) or pocket (bottom side) and the outside diameter. Prepare the DTI by light grinding or polishing as necessary.

5.5.2 *Core Hardness*—Take hardness readings on a smooth flat portion of the DTI, at a point approximately midway between the protrusion (top side) or pocket (bottom side) and the outside diameter. Prepare the DTI by light grinding or polishing such that readings are taken at a minimum depth of 0.015 in. (0.38 mm) from the original surface.

6. Rivets

6.1 *Product Hardness*—Determine hardness at the mid-radius of a transverse section of the product taken at a distance of one diameter from the point end of the rivet. Use either Brinell or Rockwell hardness tests, and measure as described in 3.1.

7. Test for Embrittlement of Metallic Coated Externally Threaded Fasteners

7.1 This is one test method for determining if embrittlement exists in a metallic coated externally threaded fastener covered by the product specifications of ASTM Committee F-16.

7.2 The test fastener shall be installed in a test fixture (see Note 1 in Fig. 18) with the head positioned against the wedge, assembled with a nut, and tensioned (by means of the nut only) by any means capable of measuring tensile load. The torque method described in 7.3 is one such method. The test samples shall be tensioned to 75 % of their specified minimum ultimate tensile strength. For studs with different thread pitches on either end, the finer thread pitch end shall be assembled with a nut and tested as the head end of the fastener.

7.2.1 The assembly shall remain in this tightened state for not less than 48 h, after which the test fastener shall be visually examined for embrittlement-induced failure, such as missing head.

7.2.2 The joint shall then be disassembled and the test fastener visually examined using a minimum of 20 power magnification for evidence of embrittlement failure, such as transverse cracks in the shank, threads or at the junction of head to shank.

7.2.3 For disassembly, if the torque method of tightening is used, torque shall be applied in the ON direction until the nut rotates a noticeable amount. The retightening torque with the nut in motion shall be measured and shall be no less than 90 % of the initial tightening torque.

7.2.4 If a direct tension method of tightening is used, then the loss of clamping strength (in pounds) over the test period shall be no more than 10 % of the initial clamping load.

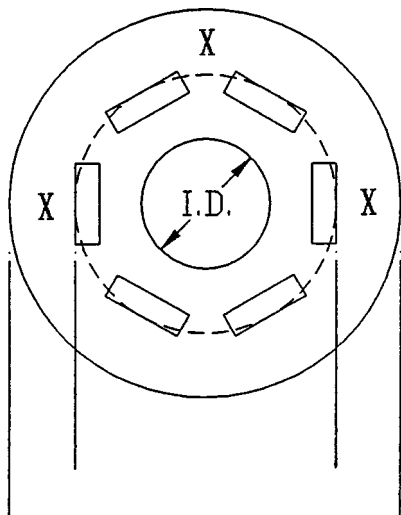
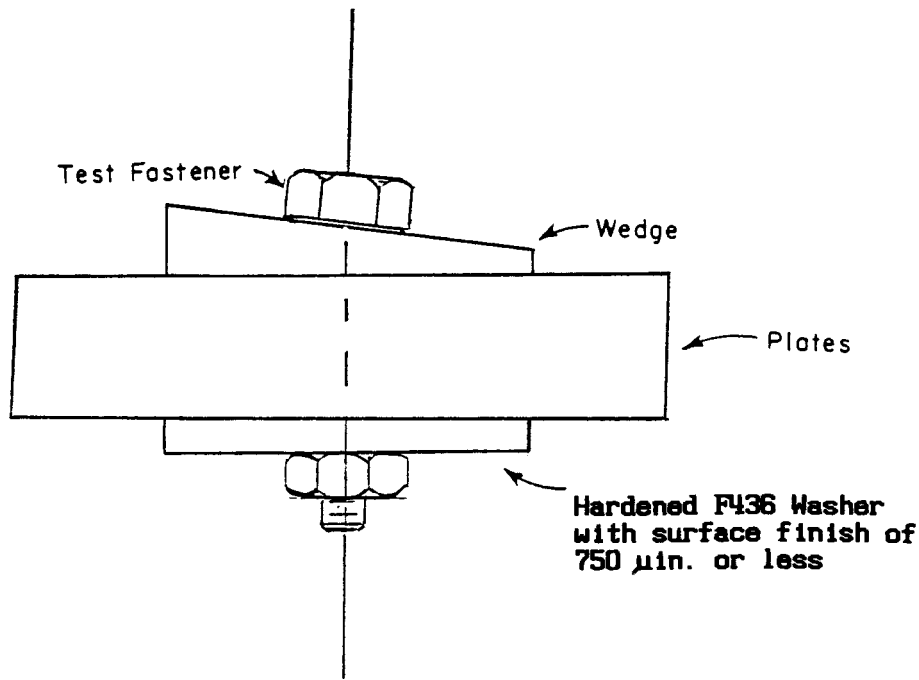


FIG. 17 Typical Hardness Reading Locations



NOTE 1—For expedience sake the test fixture shown above reflects a single bolt under load. It should be noted, however, that test fixtures with multiple test locations are acceptable

NOTE 2—Work is continuing on this test method and revisions are anticipated. Additionally caution should be taken when applying this test procedure. The heads of embrittled fasteners may suddenly break off and become flying projectiles capable of causing serious injury or blinding.

FIG. 18 Test Fixture

7.3 The test fixture shall comprise a hardened wedge (7.3.1), a plate(s) (7.3.2), and a hardened washer (7.3.3). (See Fig. 18.)

7.3.1 The wedge shall have an angle as specified in Table 4. Other dimensions and properties shall be in conformance with hardened wedges described in 3.5.1.

7.3.2 The plate(s) shall be steel and have a thickness such that, after installation and tightening, a minimum of three full threads of the test fastener will be in the grip. The hole in the plate(s) shall be as close to the major diameter of the fastener being tested as practical but not greater than the hole in the hardened washer (7.2.3).

7.3.3 The hardened washer shall be in conformance with Specification F 436.

7.4 If the torque method of tightening is used, the tightening torque shall be determined using a load-measuring device capable of measuring the actual tension induced in a fastener as the fastener is tightened. Three fasteners from the test lot shall be selected at random. Each shall be assembled into the load-measuring device, mated with a nut, and the nut tightened until a load equal to 75 % of the specified minimum ultimate tensile strength of the fastener is induced. The torque required to induce this load shall be measured and the arithmetic average of the three measured torques shall be the tightening torque. The surface against which the nut is torqued should be similar in hardness and finish to that of the test fixture (Fig. 18) and use of a hardened washer (7.3.3) is recommended.

7.5 To meet the requirements of this test the fastener shall show no evidence of embrittlement failure when visually examined and the retightening torque shall not be less than 90 % of the initial tightening torque.

TABLE 4 Test for Embrittlement Wedge Angles, Degrees

Nominal Size of Fastener, dia	Studs and Fasteners with Unthreaded Lengths, Less Than 2 dia	Fasteners with Unthreaded Lengths, 2 dia and Longer
1/4 to 3/4 in.	4	6
Over 3/4 to 1-1/2 in.	0	4

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