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Review and Upgrading of Military Fastener Test Standard MIL-STD-1312

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INTRODUCTION

The National Institute of Standards and Technology (NIST) has conducted a study of United States Military Standard MIL-STD-1312, Fastener Test Methods. Military Standard MIL-STD-1312 is a unified compilation of over 35 individual fastener test methods for determining the capability of fasteners to withstand various environmental and mechanical conditions encountered in service. Each of the individual fastener test methods is itself a fastener test standard, and is designated with its own document number. For this study, only selected test methods which prescribe certain mechanical tests for fasteners were reviewed. These test methods were evaluated and recommendations formulated for upgrading or replacing them to reflect the current state of the art. This work was done under contract MIPR 2-0117 from the Defense Industrial Supply Center (DISC).

The process that was used to develop these recommendations involved evaluating and comparing the procedures and requirements of other comparable national fastener test method standards to determine if the military standards could be replaced with non-government standards without jeopardizing military requirements. The test method standards which were compared are identified and include documents published by the following organizations.

AASHTO - American Association of State Highway and Transportation Officials
AIA - Aerospace Industries Association of America, Inc.
AREA - American Railway Engineering Association
ASTM - Previously, American Society for Testing and Materials
IFI - Industrial Fasteners Institute
ISO - International Organization for Standardization
SAE International (Automotive)
SAE International (Aerospace)
Federal Specifications and Standards
Military Specifications and Standards

These recommendations present suggested improvements to the military standards comprising MIL-STD-1312, inconsistencies with standards of other standards organizations, indications of deficiencies in the MIL-STD-1312 standards, and non-government standards which could potentially replace the present MIL-STD-1312 test procedures.

This study evaluated the latest published revisions of the following MIL-STD-1312 standards pertaining to mechanical test methods for fasteners. Note that standards designated DOD-STD-1312 are considered to be part of MIL-STD-1312.

MIL-STD-1312-5: Fastener Test Methods, Method 5, Stress

Durability

MIL-STD-1312-6: Fastener Test Methods, Method 6, Hardness

MIL-STD-1312-8: Fastener Test Methods, Method 8, Tensile Strength

MIL-STD-1312-10: Fastener Test Methods, Method 10, Stress Rupture

MIL-STD-1312-11: Fastener Test Methods, Method 11, Tension Fatigue

MIL-STD-1312-12: Fastener Test Methods, Method 12, Thickness of Metallic Coatings

MIL-STD-1312-13: Fastener Test Methods, Method 13, Double Shear Test

MIL-STD-1312-14: Fastener Test Methods, Method 14, Stress Durability - Internally Threaded Fasteners

MIL-STD-1312-15: Fastener Test Methods, Method 15, Torque - Tension

MIL-STD-1312-18: Fastener Test Methods, Method 18, Elevated Temperature Tensile Strength

MIL-STD-1312-20: Fastener Test Methods, Method 20, Single Shear

MIL-STD-1312-28: Fastener Test Methods, Method 28, Elevated Temperature Double Shear

DOD-STD-1312-105: Fastener Test Methods, Metric, Method 105, Stress Durability

DOD-STD-1312-108: Fastener Test Methods, Metric, Method 108, Tensile Strength

DOD-STD-1312-111: Fastener Test Methods, Metric, Method 111, Tension Fatigue

DOD-STD-1312-113: Fastener Test Methods, Metric, Method 113, Double Shear Test

In many instances two or three MIL-STD-1312 fastener test standards specify similar test requirements and procedures. This report is organized by grouping together these similar test method standards into one section under a common heading (i.e., MIL-STD-1312-8, MIL-STD-1312-18, and DOD-STD-1312-108 are grouped together under the heading Tensile Strength). This was done to facilitate the comparison of the test standards within a section, and to highlight any inconsistencies which presently exist between the documents. The standards grouped under the same general test method heading may only differ in the temperature range of testing or in the types of fasteners to which they apply to (metric/nonmetric or externally/internally threaded). When feasible, the standards within a section should be subjected to simultaneous review, replacement, or revision.

Each section covering a particular test method grouping is divided into two parts: Part A: RECOMMENDATIONS and PART B: REQUIREMENT SUMMARIES. Part A lists NIST recommendations and suggested actions to be taken for each of the test method standards. Included, where appropriate, are suggested non-government test standards which could be incorporated into the MIL-STD-1312 standards by reference, and suggested areas where revisions should be made to update the MIL-STD-1312 standards. Part B provides summaries of the more critical requirements of the primary United States and ISO test standards pertaining to each of the test methods.

Section 1 - STRESS DURABILITY

MIL-STD-1312-5A, 19 October 1984: Fastener Test Methods, Method 5, Stress Durability

MIL-STD-1312-14, 5 January 1987: Fastener Test Methods, Method 14, Stress Durability, Internally Threaded Fasteners

DOD-STD-1312-105, 26 March 1984: Fastener Test Methods, Metric, Method 105, Stress Durability

STRESS DURABILITY

MIL-STD-1312-5A
MIL-STD-1312-14
DOD-STD-1312-105

Part A: RECOMMENDATIONS

MIL-STD-1312-5A, 19 October 1984: Fastener Test Methods, Method 5, Stress Durability

On the basis of this study, there is presently no suitable non-government standard to replace MIL-STD-1312-5A. A test method having similar requirements and procedures can be found in ASTM F 606, "Standard Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers and Rivets." Section 7, "Test for Embrittlement of Metallic Coated Externally Threaded Fasteners", describes a test method for examining the presence of embrittlement in externally threaded fasteners which, in general, specifies test procedures similar to MIL-STD-1312-5A. There are, however, several major and minor differences which exist between MIL-STD-1312-5A and ASTM F 606 that would prevent ASTM F 606, as presently written, from replacing MIL-STD-1312-5A. The major differences include the following:

- The stated applicabilities of the two test methods are not identical. MIL-STD-1312-5A is used for evaluating the capability of externally threaded fasteners to withstand various stresses encountered in military hardware. The test is applicable to all types of externally threaded fasteners subject to embrittlement. The "Test for Embrittlement of Metallic Coated Externally Threaded Fasteners" specified in Section 7 of ASTM F 606 is used for determining the presence of embrittlement in metallic coated fasteners only.

- The "Test for Embrittlement of Metallic Coated Externally Threaded Fasteners" specified in Section 7 of ASTM F 606 requires using a wedge under the head of the fastener. MIL-STD-1312-5A specifies testing without a wedge.

- The "Test for Embrittlement of Metallic Coated Externally Threaded Fasteners" specified in Section 7 of ASTM F 606 requires a test for the loss of clamping strength to be conducted prior to disassembly of the fastener. MIL-STD-1312-5A does not require this measurement.

- The post-stress examination procedures are different for the two methods. MIL-STD-1312-5A requires inspection for the presence of cracks using either magnetic particle or liquid penetrant nondestructive inspection techniques. The "Test for Embrittlement of Metallic Coated Externally Threaded Fasteners" specified in Section 7 of ASTM F 606 only requires a visual inspection using 20 power magnification.

- Other details pertaining to test procedures such as test fixtures, installation procedures, load measuring methods, time under load, and use of lubrication also differ between MIL-STD-1312-5A and ASTM F 606.

It is recommended that fastener test method MIL-STD-1312-5A be reviewed simultaneously with test standards MIL-STD-1312-14 and DOD-STD-1312-105 to ensure consistency between the standards, and either be revalidated or appropriately updated. Specific recommendations for updating MIL-STD-1312-5A are the following: update referenced standards and specifications to current number designations (e.g. MIL-I-6866 & MIL-I-6868 are no longer current); and edit the methods of loading described in sections 4 and 5 and the test report requirements of section 6 of MIL-STD-1312-5A and DOD-STD-1312-105 to achieve consistency between the two test standards.

<u>MIL-STD-1312-14, 5 January 1987</u>: Fastener Test Methods, Method 14, Stress Durability, Internally Threaded Fasteners

On the basis of this study, there is presently no suitable non-government standard to replace MIL-STD-1312-14. Currently, MIL-STD-1312-14 is referenced as the required stress durability test method in many fastener specifications published by several organizations including the military and SAE International. The wide use of this standard indicates its acceptance as a national standard.

A test method having similar requirements and procedures can be found in ASTM F 606 - 90, "Standard Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers and Rivets." Section 7 of ASTM F 606, "Test for Embrittlement of Metallic Coated Externally Threaded Fasteners", describes a test method for examining the presence of embrittlement in <u>externally threaded</u> fasteners which, in general, specifies test procedures similar to MIL-STD-1312-14. There are, however, several major and minor differences which exist between MIL-STD-1312-14 and ASTM F 606 that would prevent ASTM F 606, as presently written, from replacing MIL-STD-1312-5A. The major differences include the following:

- The stated applicabilities of the two test methods are not identical. MIL-STD-1312-14 is used for evaluating the capability of <u>internally threaded</u> fasteners to withstand various stresses encountered in military hardware. The test is applicable to all types of internally threaded fasteners subject to embrittlement. The "Test for Embrittlement of Metallic Coated Externally Threaded Fasteners" specified in Section 7 of ASTM F 606 - 90 is used for determining the presence of embrittlement in externally threaded metallic coated fasteners only.

- The "Test for Embrittlement of Metallic Coated Externally Threaded Fasteners" specified in Section 7 of ASTM F 606 requires using a wedge under the head of the fastener. Use of a wedge would not apply to testing internally threaded fasteners.

- The "Test for Embrittlement of Metallic Coated Externally Threaded Fasteners" specified in Section 7 of ASTM F 606 requires a test for the loss of clamping strength to be conducted prior to disassembly of the fastener. MIL-STD-1312-14 does not require this measurement.

- The post-stress examination procedures are different for the two methods. MIL-STD-1312-14 requires inspection for the presence of cracks either by visual inspection using 10 power magnification, or by magnetic particle or fluorescent penetrant nondestructive inspection techniques. Parts suspected of having cracks must also be microscopically examined using 100X magnification. The "Test for Embrittlement of Metallic Coated Externally Threaded Fasteners" specified in Section 7 of ASTM F 606 only requires a visual inspection using 20 power magnification.

- Other details pertaining to test procedures such as test fixtures, installation procedures, load measuring methods, time under load, and use of lubrication also differ between MIL-STD-1312-14 and ASTM F 606.

It is recommended that fastener test method MIL-STD-1312-14 be reviewed simultaneously with MIL-STD-1312-5A and DOD-STD-1312-105 to ensure consistency between the standards, and either be revalidated or appropriately updated. Specific recommendations for updating MIL-STD-1312-14 are the following: appropriate test standards should be cited for the magnetic particle and fluorescent penetrant nondestructive inspection techniques called for in the Specimen Examination Section 5.2; and, in keeping with past MIL-STD-1312 practice, a new metric counterpart to MIL-STD-1312-14 should be written (e.g., DOD-STD-1312-114).

DOD-STD-1312-105, 26 March 1984: Fastener Test Methods, Metric, Method 105, Stress Durability

On the basis of this study, there is presently no suitable non-government standard to replace DOD-STD-1312-105. A test method having similar requirements and procedures can be found in ASTM F 606M - 91, "Standard Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers and Rivets [Metric]." Section 7 of ASTM F 606M, "Test for Embrittlement of Metallic Coated Externally Threaded Fasteners", describes a test method for examining the presence of embrittlement in externally threaded fasteners which in general specifies test procedures similar to DOD-STD-1312-105. There are however several major and minor differences which exist between DOD-STD-1312-105 and ASTM F 606M that would prevent ASTM F 606M, as presently written, from replacing DOD-STD-1312-105. The major differences include the following:

- The stated applicabilities of the two test methods are not identical. DOD-STD-1312-105 is used for evaluating the capability of externally threaded fasteners to withstand various stresses encountered in military hardware. The test is applicable to all types of externally threaded fasteners subject to embrittlement. The "Test for Embrittlement of Metallic Coated Externally Threaded Fasteners" specified in Section 7 of ASTM F 606M is used for determining the presence of embrittlement in <u>metallic coated</u> fasteners only.

- The "Test for Embrittlement of Metallic Coated Externally Threaded Fasteners" specified in Section 7 of ASTM F 606M requires using a wedge under the head of the fastener. DOD-STD-1312-105 specifies testing without a wedge.

- The "Test for Embrittlement of Metallic Coated Externally Threaded Fasteners" specified in Section 7 of ASTM F 606M requires a test for the loss of clamping strength to be conducted prior to disassembly of the fastener. DOD-STD-1312-105 does not require this measurement.

- The post-stress examination procedures are different for the two methods. DOD-STD-1312-105 requires inspection for the presence of cracks using either magnetic particle or liquid penetrant nondestructive inspection techniques. The "Test for Embrittlement of Metallic Coated Externally Threaded Fasteners" specified in Section 7 of ASTM F 606M only requires a visual inspection using 20 power magnification.

- Other details pertaining to test procedures such as test fixtures, installation procedures, load measuring methods, time under load, and use of lubrication also differ between DOD-STD-1312-105 and ASTM F 606M.

It is recommended that fastener test method DOD-STD-1312-105 be reviewed simultaneously with test standards MIL-STD-1312-5A and MIL-STD-1312-14 to ensure consistency between the standards, and either be revalidated or appropriately updated. Specific recommendations for updating DOD-STD-1312-105 are the following:

update referenced standards and specifications to current number designations (e.g. MIL-I-6866 & MIL-I-6868 are no longer current); and edit the methods of loading described in sections 4 and 5 and the test report requirements of section 6 of MIL-STD-1312-5A and DOD-STD-1312-105 to achieve consistency between the two test standards.

Part B: REQUIREMENT SUMMARIES

The following are requirement summaries of the primary United States and ISO test standards dealing with stress durability of externally and internally threaded fasteners. Specific requirements of test standards MIL-STD-1312-5A, MIL-STD-1312-14, and DOD-STD-1312-105 are listed where they differ from other standards.

TEST METHOD TITLE: Stress Durability of Externally Threaded Fasteners

TEST METHOD DESIGNATIONS:

DOD-STD-1312-105, 26 March 1984: Fastener Test Methods, Metric, Method 105, Stress Durability

MIL-STD-1312-5A, 19 October 1984: Fastener Test Methods, Method 5, Stress Durability

TEST DESCRIPTION: The Stress Durability of Externally Threaded Fasteners test is for determining the stress durability of externally threaded fasteners by testing for the existence of embrittlement. This is accomplished by the following procedures: installing the fastener in an appropriate fixture; loading the fastener to a specified load level; keeping the fastener in the tightened state for a specified period of time; disassembling the fastener from the test fixture; and examining it for the presence of transverse cracks by liquid penetrant or magnetic particle inspection. The presence of cracks or fracture of the fastener constitutes failure of the test.

TECHNICAL REQUIREMENTS / CRITICAL ELEMENTS:

1. Test fixture The fastener is axially loaded in a test fixture. Any method capable of applying and maintaining a load of 75-80 percent of the product minimum tensile strength in the specimen is acceptable. Test methods DOD-STD-1312-105 and MIL-STD-1312-5A list five suitable methods of conducting this test and describe their corresponding fixture configurations. These five methods of testing are: (1) torque method of loading; (2) elongation method of loading; (3) external loading method; (4) external loading method (flexure fixture); and (5) strain gage method.

2. Tensile load measuring method The axial load can be measured by any method capable of measuring the induced tensile load applied to the fastener. Acceptable methods of determining the axial load are described in DOD-STD-1312-105 and MIL-

STD-1312-5A for the five methods of testing included in these test methods.

3. Lubrication The threads of the fastener, the bearing surface of the fastener head and the bearing surface of the nut must be lubricated with a suitable lubricant conforming to Military Specification MIL-T-5544.

4. Assembly of fastener in test fixture A minimum of two full threads of the test specimen must extend above the face of the nut or tapped block (depending on fixture configuration) toward the head of the fastener.

5. Test temperature The test must be conducted at room temperature.

6. Method of loading These Critical Elements depend on the method of loading:

TORQUE METHOD OF LOADING

(a) Torque wrenches are required with adapters to fit the configuration of the test fastener nut. The torque wrenches must be calibrated for accuracy within the limits specified by Federal Specification GGG-W-686.

(b) A level of torque corresponding to an axial load equal to 75-80 percent of the specified minimum ultimate tensile strength must be determined prior to testing. The level of torque may be estimated from the equation below, or preferably from torque-tension curves developed from tests using fasteners from the lot being evaluated. A tensile test machine with appropriate test fixtures is a suitable arrangement for determining this value.

$$T = KDL$$

where T = torque, N·m (in-lbf),
K = 0.1 coefficient of friction,
D = nominal diameter of fastener, mm (in.), and
L = induced load, kN (lbf).

(c) Not more than three spacers may be used in the test fixture.

ELONGATION METHOD OF LOADING

(a) An amount of elongation corresponding to an axial load equal to 75-80 percent of the specified minimum ultimate tensile strength must be determined prior to testing.

The amount of elongation may be estimated by the equation below, or preferably from load-elongation curves developed from tests using fasteners from the lot being evaluated as described in the test method. A tensile test machine with appropriate test fixtures is a suitable arrangement for determining this value.

$$e = \frac{P}{E}\left(\frac{L}{A} + \frac{L_t}{A_t}\right)$$

where e = total bolt elongation, mm (in.),
P = clamping force, N (lbf),
A = cross sectional area of shank, mm^2 (in^2),
L = length of grip, mm (in.),
A_t = cross sectional thread stress area, mm^2 (in^2),
L_t = thread length between bearing faces, mm (in.), and
E = modulus of elasticity, MPa (lbf/in^2).

NOTE: Approximately two pitches should be added to the thread length portion when using a nut.

(b) A precision measuring instrument, such as a micrometer, is required to measure elongation of the test fastener over the ends of the fastener. If the condition of the end surfaces on which the measurement is taken is not suitable for precise measurements, the surfaces must be prepared by grinding or center-drilling prior to assembly in the test fixture. The fastener length measuring instrument must have an accuracy of 2.5 μm (0.0001 in) or better.

EXTERNAL LOADING METHOD

(a) Static-load type testing equipment is required which can apply sufficient force to develop an induced load of 75-80 percent of the minimum ultimate tensile strength of the fastener. If the load is applied with weights, the mass value of the weights must be traceable to NIST. If the load is measured and indicated by a load cell system, the system must be verified annually in accordance with ASTM E 4.

(b) The test fixtures must be designed to assure axial loading of the fastener.

EXTERNAL LOADING METHOD (Flexure Fixture)

(a) Suitable equipment such as a tensile test machine and fixtures must be used to develop the required axial load on the fastener.

STRAIN GAGE METHOD OF LOADING

(a) The support block with one or more strain gages attached becomes the load measuring device or "load cell" when used with an accurate strain indicator. The "load cell" and strain indicator must be calibrated as a system in accordance with the procedures described in ASTM E 74; however, the calibrating force may be applied by a universal-type testing machine which has had the load verified in accordance with ASTM E 4 within one year prior to using. The indicated load of the "load cell" and the strain indicator must be verified annually in accordance with ASTM E 4.

7. Load application The test fastener must be loaded to 75-80 percent of its specified minimum ultimate tensile strength.

8. Test period The fastener must remain in the tightened state for the time period specified by the procurement document.

9. Inspection After disassembling the fastener from the fixture, the fastener should be inspected for the presence of transverse cracks by either magnetic particle inspection for magnetic materials in accordance with MIL-STD-1949, or MIL-STD-6866 for other materials.

10. Acceptance and failure The presence of cracks or fracture of the fastener constitutes failure of the test.

REFERENCED DOCUMENTS:

ASTM E 4: Standard Practices for Load Verification of Testing Machines

ASTM E 74: Standard Practices for Calibration of Force-Measuring Instruments for Verifying the Load Indication of Testing Machines

ASTM F 606-86: Standard Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets

Federal Specification GGG-W-686: Wrench, Torque

MIL-STD-6866: Inspection, Liquid Penetrant [Supersedes MIL-I-6866]

MIL-STD-1949: Inspection, Magnetic Particle

[Supersedes MIL-I-6868]

MIL-T-5544: Thread Compound, Antiseize, Graphite-Petrolatum

TEST METHOD TITLE: Test for Embrittlement of Metallic Coated Externally Threaded Fasteners

TEST METHOD DESIGNATIONS:

ASTM F 606-90: Standard Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets
Section 7: Test for Embrittlement of Metallic Coated Externally Threaded Fasteners

ASTM F 606M-91: Standard Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets [Metric]
Section 7: Test for Embrittlement of Metallic Coated Externally Threaded Fasteners

TEST DESCRIPTION: The Test for Embrittlement of Metallic Coated Externally Threaded Fasteners test is for determining if embrittlement exists in metallic coated externally threaded fasteners. This is accomplished by the following procedures: installing the fastener with a wedge under the head in an appropriate fixture; assembling the fastener with a nut; tensioning the fastener to a specified load level by tightening the nut; maintaining the fastener in the tightened state for a specified period of time; testing for the loss of clamping strength; disassembling the fastener from the fixtures; and examining it for the presence of cracks. An excess loss of clamping strength, the presence of cracks, or fracture of the fastener are the primary criteria which constitute failure of the test.

TECHNICAL REQUIREMENTS / CRITICAL ELEMENTS:

1. Test fixture The test fixture consists of four components; (a) a hardened wedge, (b) steel support section, (c) a hardened washer and (d) a mating nut.

   (a) A wedge is installed under the head of the fastener as described in the test method. Wedges having the appropriate dimensions, wedge angle and hardness are required (see method).

   The hole diameter in the wedge and the radius or depth of chamfer at the hole top and bottom are dependent on the fastener diameter.

   The outside diameter of the wedge must be greater than the head size of the fastener.

The wedge thickness at the thin side of the hole is dependent on the test method, but is typically one half the fastener diameter.

The angle of the wedge is dependent on the fastener size and grade as follows:

<u>Wedge Angles, Degrees</u>

Nominal Fastener Diameter	Studs and Fasteners-Unthreaded Lengths Less Than 2 dia	Fasteners with Unthreaded Lengths 2 dia and Longer
¼ to ¾ in	4	6
Over ¾ to 1-½ in	0	4
5 to 20 mm	4	6
Over 20 mm	0	4

(b) Steel support plates, blocks or spacers which can be of varying thicknesses and configurations are used alone or in combination such that after installation and tightening of the fastener a minimum of three full threads will be in the grip (between the head and the nut). The hole in the support plate(s) shall be as close to the major diameter of the fastener as practical, but not greater than the hole in the hardened washer.

(c) The hardened washer must meet the requirements specified by ASTM F 436 or ASTM F 436M, as appropriate, and be of appropriate size for the type and size of fastener to be tested. The washer is installed between the support plates and the nut.

(d) An internally threaded nut of the appropriate type and size is required, with sufficient strength to develop full tensile strength of the fastener being tested.

2. <u>Load measuring method</u> The fastener must be axially tensioned in the test fixture by tightening the nut only. The axial load can be measured by any method capable of measuring the induced tensile load applied to the fastener. Test methods ASTM F 606 and ASTM F 606M describe a torque method for applying and determining the induced load. Another acceptable method of applying and measuring clamping load, strain gage method of loading, is described in test methods DOD-STD-1312-105 and MIL-STD-1312-5A. The other methods of loading described in these two methods, elongation method of loading, external loading method, and external loading method (flexure fixture) are not suitable for this method. [Note: For any method that is used, an appropriate wedge is

required under the head of the fastener.]

TORQUE METHOD OF LOADING

(a) Torque wrenches are required with adapters to fit the configuration of the test fastener nut. The torque wrenches must be calibrated for accuracy within the limits specified by Federal Specification GGG-W-686.

(b) A level of torque corresponding to a clamping load equal to 75 percent of the specified minimum ultimate tensile strength must be determined prior to testing. This determination must be made using fasteners from the lot being evaluated as described in the test method. A tensile test machine with appropriate fixtures is a suitable arrangement for this purpose.

STRAIN GAGE METHOD OF LOADING

(a) The support block with one or more strain gages attached becomes the load measuring device or "load cell" when used with an accurate strain indicator. The "load cell" and strain indicator must be calibrated as a system in accordance with the procedures described in ASTM E 74. The calibrating force may be applied by a universal-type testing machine. The indicated load of the "load cell" and the strain indicator must be verified at least annually in accordance with ASTM E 4.

3. Tension load The test fastener must be tensioned to 75 percent of its specified minimum ultimate tensile strength.

4. Time at load The fastener must remain in the tightened state for at least 48 hours.

5. Loss of clamping strength A test for the loss of clamping strength over the test period must be conducted prior to disassembly of the fastener. If the torque method of tightening is used, the retightening torque, with the nut in motion, must be not less than 90 percent of the initial tightening torque. If a direct tension method of tightening is used, then the loss of clamping strength must be no more than 10 percent of the initial clamping force.

6. Examination The test fastener should be visually examined prior to disassembly for evidence of embrittlement-induced failure, such as cracks or a missing head. An optical instrument with a minimum of 20 power magnification is required to examine the fastener for evidence of embrittlement failure.

REFERENCED DOCUMENTS:

ASTM E 4: Standard Practices for Load Verification of Testing Machines

ASTM E 74: Standard Practices for Calibration of Force-Measuring Instruments for Verifying the Load Indication of Testing Machines

ASTM F 436: Standard Specification for Hardened Steel Washers

ASTM F 436M: Standard Specification for Hardened Steel Washers [Metric]

DOD-STD-1312-105: Fastener Test Methods, Metric, Method 105, Stress Durability

Federal Specification GGG-W-686: Wrench, Torque

MIL-STD-1312-5A: Fastener Test Methods, Method 5, Stress Durability

TEST METHOD: Hydrogen Embrittlement (Stress Durability) of Internally Threaded Fasteners (Nuts)

TEST METHOD DESIGNATION:

ISO 7481, 1987-05-15: Aerospace - Fasteners - Self-locking nuts with maximum operating temperature less than or equal to 425°C - Test methods, Section 3.5: Stress embrittlement test

MIL-STD-1312-14, 5 January 1987: Fastener Test Methods, Method 14, Stress Durability - Internally Threaded Fasteners

TEST DESCRIPTION: The Hydrogen Embrittlement (Stress Durability) of Internally Threaded Fasteners (Nuts) test is for determining the stress durability of nuts by testing for the existence of embrittlement. This is accomplished by the following procedures: installing the nut onto a mating externally threaded member in an appropriate fixture; tensioning the externally threaded member to a specified load level with the load against the nut; maintaining the externally threaded member and nut in the tightened state for a specified period of time; disassembling the nut from the externally threaded member and test fixture; and examining the nut for the presence of transverse cracks by visual inspection, by liquid penetrant inspection, or by magnetic particle inspection. The presence of cracks or fracture of the fastener constitutes failure of the test.

TECHNICAL REQUIREMENTS / CRITICAL ELEMENTS:

1. Test fixture When the torque or extension methods of loading are used, the test fixture described in the test methods must be used. For other methods of loading (test method MIL-STD-1312-14 only), see the DOD-STD-1312-105 and MIL-STD-1312-5 test methods.

   Externally threaded member (bolt)

   MIL-STD-1312-14 An externally threaded member (bolt) with strength sufficient to develop a minimum of 110 percent of the minimum rated tensile strength of the nut being tested is required.

   ISO 7481 An externally threaded member (bolt) is required with threads per ISO 5855/1 and ISO 5855/2, and tensile strength greater than the nut under test.

2. Fastener assembly (Test method MIL-STD-1312-14 only) A minimum of two full threads of the test specimen must extend above the face of the nut toward the head of the fastener, and a minimum of two full form threads must be unengaged

below the bearing surface of the nut.

3. Lubrication Supplementary lubrication must only be used when specifically required by the product specification or test method.

4. Test temperature The test must be conducted at room temperature.

5. Method of loading

   MIL-STD-1312-14 When installation torques are specified, the torque method described in the test method must be used. When installation loads, stresses or elongations are specified, the extension method described in the test method is preferred although any of the methods described in DOD-STD-1312-105 and MIL-STD-1312-5 may be used.

   ISO 7481 The torque method of loading is specified.

These Critical Elements depend on the method of loading:

TORQUE METHOD OF LOADING

a. Torque wrenches are required with adapters to fit the configuration of the test fastener nut. The torque wrenches must be calibrated for accuracy as specified by a test method equivalent to Federal Specification GGG-W-686.

b. The assembly must be torqued to the value specified by the procurement document by holding the fixture and externally threaded member and rotating the nut.

EXTENSION METHOD OF LOADING (MIL-STD-1312-14 only)

a. An amount of extension corresponding to the specified axial load must be predetermined prior to testing. The amount of extension must be determined by following:

$$e = \frac{F}{E} \left[X + 0.75\ Z + \frac{YR^2}{S^2} - Y \right]$$

where e = desired extension, mm (in.),
E = modulus of elasticity of bolt material at room temperature MPa (lbf/in^2),
X = fixture length, mm (in.),
Y = bolt nominal grip length, mm (in.),

Z = internally threaded fastener thread length, mm (in),
S = bolt maximum grip diameter, mm (in.),
F = desired stress at bolt root area, MPa (psi)*, and
R = bolt basic thread minor diameter, mm (in.)*.

* If stress is specified at area other than thread minor diameter, use value for R relative to diameter at that area. If load is specified, divide load by thread minor diameter area of bolt to determine F.

b. The ends of the externally threaded member (bolt) must be prepared so that accurate repeatable length measurements are obtained. The bolt ends are to be ground parallel to each other and perpendicular to the bolt axis and marked to ensure that all measurements are made at the same point; or the bolt ends are to be spot drilled on centers at each end to provide an accurate contact with balls on the measuring instrument.

c. A precision measuring instrument, such as a micrometer, is required to measure extension of the test fastener over the ends of the fastener. The fastener length measuring instrument must have a precision of 2.5 μm (0.0001 in) or better.

<u>EXTERNAL LOADING METHOD</u> (MIL-STD-1312-14 only)
[see DOD-STD-1312-105 for test details]

a. Static-load type testing equipment is required which can apply sufficient force to develop an induced specified load. If the load is applied with weights, the mass value of the weights must be traceable to NIST. If the load is measured and indicated by a load cell system, the system must be verified annually in accordance with ASTM E 4.

b. The test fixtures must be designed to assure axial loading of the externally threaded member and nut.

<u>EXTERNAL LOADING METHOD (Flexure Fixture)</u>
(MIL-STD-1312-14 only)
[see MIL-STD-1312-5 for test details]

a. Suitable equipment such as a tensile test machine and fixtures must be used to develop the required axial load on the fastener.

b. The flexure fixture must be designed such that tightening of the test nut transfers the applied load from the flexure fixture to the externally threaded member and nut.

STRAIN GAGE METHOD OF LOADING (MIL-STD-1312-14 only) [see DOD-STD-1312-105 and MIL-STD-1312-5 for test details]

a. The support block with one or more strain gages attached becomes the load measuring device or "load cell" when used with an accurate strain indicator. The "load cell" and strain indicator must be calibrated as a system in accordance with the procedures described in ASTM E 74; however, the calibrating force may be applied by a universal-type testing machine which has had the load verified in accordance with ASTM E 4 within one year prior to using.

6. Load application The test assembly must be tightened to the torque, load or stress level specified.

7. Test period The fastener assembly must remain in the tightened state for the time period specified by the procurement document.

8. Inspection After disassembling the nut from the bolt and fixture, the nut must be inspected as specified in the test method.

MIL-STD-1312-14 The nut must be inspected for the presence of transverse cracks by either 10X magnification, magnetic particle or fluorescent penetrant inspection. Nuts suspected of having cracks must be sectioned and microscopically examined for the presence of cracks using 100X magnification.

ISO 7481 The nut must be inspected for the presence of cracks by visual examination, using low magnification if necessary, after sectioning.

10. Acceptance and failure The presence of cracks or fracture of the fastener constitutes failure of the test.

REFERENCED DOCUMENTS:

ASTM E 4: Standard Practices for Load Verification of Testing Machines

ASTM E 74: Standard Practices for Calibration of Force-Measuring Instruments for Verifying the Load Indication of Testing Machines

DOD-STD-1312-105: Fastener Test Methods, Metric, Method 105,

Stress Durability

Federal Specification GGG-W-686: Wrench, Torque

ISO 5855/1: Aerospace construction - MJ threads - Part 1: Basic profile

ISO 5855/2: Aerospace - MJ threads - Part 2: Dimensions of screws and nuts

MIL-STD-1312-5A: Fastener Test Methods, Method 5, Stress Durability

MIL-STD-6866: Inspection, Liquid Penetrant
[Supersedes MIL-I-6866]

MIL-STD-1949: Inspection, Magnetic Particle
[Supersedes MIL-I-6868]

Section 2 - HARDNESS

MIL-STD-1312-6, 19 October 1984: Fastener Test Methods, Method 6, Hardness

HARDNESS

MIL-STD-1312-6

Part A: RECOMMENDATIONS

MIL-STD-1312-6, 19 October 1984: Fastener Test Methods, Method 6, Hardness

On the basis of this study, there is presently no suitable non-government standard to completely replace MIL-STD-1312-6. There are, however, suitable ASTM standards to replace the general hardness testing requirements of Sections 4 and 5 of MIL-STD-1312-6. It is recommended that MIL-STD-1312-6 be revised by replacing the present text describing the general requirements and procedures for each of the hardness tests and scales with statements that cite the appropriate ASTM standard as the hardness test procedures to follow. The most recent revision of each ASTM hardness test method should always be referenced. The ASTM hardness test methods provide greater detail in the test and calibration/verification procedures than does MIL-STD-1312-6, and would bring hardness testing of military fasteners in line with other national and ISO hardness standards. MIL-STD-1312-6 has not kept pace with the national and international hardness communities.

Presently, MIL-STD-1312-6 includes the following hardness tests and scales:

- Rockwell Hardness [B and C Scales],
- Rockwell Superficial Hardness [30T and 30N Scales],
- Vickers Hardness [Test forces from 1 to 120 kgf], and
- Microhardness [Vickers hardness and Knoop hardness - test forces from 1 to 1000 gf].

The MIL-STD-1312-6 requirements for these hardness tests and procedures can be replaced with the following ASTM hardness test method standards:

For Rockwell Hardness [B and C scales] and Rockwell Superficial Hardness [30T and 30N scales] replace with ASTM test method standard:

ASTM E 18: Standard Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials.

For Vickers Hardness [test forces from 1 to 120 kgf] replace with ASTM test method standard:

ASTM E 92: Standard Test Method for Vickers Hardness of Metallic Materials.

For Microhardness [Vickers and Knoop - test forces from 1 to 1000

gf] replace with ASTM test method standard:
ASTM E 384: Standard Test Method for Microhardness of Materials.

The present text of MIL-STD-1312-6 which describes specific requirements and procedures for testing fasteners may be retained in the document with some revision. These sections include the following: 1. Scope; 2. Referenced Documents; 3. Definitions; 5. Detail Requirements [paragraphs 5.1.1, 5.1.2, and 5.1.3]; Table I; and 6. Notes.

It is recommended that the detail requirements of Section 5 be reviewed. Currently, there is little guidance on the locations for making the hardness measurements for each type of fastener. ASTM test method F-606 "Standard Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets" could be used as a guide in making these revisions. The nomenclature used for the hardness scales in Table 1 should also be updated to current usage (e.g., HRC for Rockwell C Scale). See the relevant ASTM standards for correct nomenclature.

It is also recommended that, in keeping with past practice, a new metric counterpart to MIL-STD-1312-6 should be written (e.g. DOD-STD-1312-106). Table I, which is a guide for selecting the appropriate hardness scale based on fastener size, currently includes only non-metric fasteners.

Part B: REQUIREMENT SUMMARIES

The following are requirement summaries of the primary United States and ISO test method standards dealing with hardness testing (in general and specific to fastener testing) using the following hardness scales: Microhardness (Knoop and Vickers); Rockwell (all scales); Superficial Rockwell (N and T scales); and Vickers. Specific requirements of test standard MIL-STD-1312-6 are listed where they differ from other standards.

TEST METHOD TITLE: Microhardness of Fasteners (Vickers hardness and Knoop hardness - test forces from 1 to 1000 gf)

TEST METHOD DESIGNATIONS:

ASTM E 384-89: Standard Test Method for Microhardness of Materials

ISO 4516, 1980-05-15: Metallic and related coatings - Vickers and Knoop microhardness tests

ISO 6507/2, 1983-09-15: Metallic materials - Hardness test - Vickers test - Part 2: HV 0.2 to less than HV 5

ISO 6507-3, 1989-11-01: Metallic materials - Hardness test - Vickers test - Part 3: Less than HV 0.2

MIL-STD-1312-6, 19 October 1984: Fastener Test Methods, Method 6, Hardness

Specific fastener specifications and test method standards may specify microhardness measurements as part of the testing requirements. These specifications and standards reference the above microhardness test methods as the applicable procedures to follow. These specifications include;

Those of Consensus standards organizations,
Federal specifications and standards,
Industry specifications and standards,
International specifications and standards,
Military specifications and standards, and
National Aerospace standards.

TEST DESCRIPTION: The Microhardness of Fasteners test is an indentation hardness test for determining whether the fasteners satisfy specified hardness requirements. Microhardness is often used when testing small sized fasteners where macrohardness tests using larger test forces (larger indentations) are not possible, and for evaluating microstructural properties such as decarburization and case depth of the fastener. This test includes both the Vickers and Knoop indentation hardness tests using test forces from 1 to 1000 gf. Microhardness testing is typically conducted using a commercial microhardness machine for which the test force, indenter, and the optical measuring device have been directly verified. Periodic checks of the test machine operation are performed by the test laboratory using commercially manufactured and calibrated standardized hardness test blocks.

The principle of the microhardness test involves forcing an indenter (square-pyramid diamond for Vickers hardness or rhombus-pyramid diamond for Knoop hardness) into the surface or sectioned surface of the fastener for a specified time period. The indenter is then removed leaving an indentation in the test surface. After removal of the indenter, the length of the diagonal(s) of the indentation are optically measured with a microscope. The Vickers hardness number is calculated from the mean of the measured lengths of the two diagonals and the level of test force used. The Knoop hardness number is calculated from the measured length of the longer diagonal and the level of test force used. For both tests, the hardness number may be derived from equations or from tables provided in certain test method standards.

Specific hardness test requirements are usually specified in the product specifications and test method standards. These requirements include the specimen preparation, locations for measurements, number of measurements, level of test force to be used, and the test acceptance/rejection criteria.

TECHNICAL REQUIREMENTS / CRITICAL ELEMENTS:

1. Testing machine An appropriate microhardness testing machine is required as described and specified in the test method standards. Test method standards ASTM E 384, ISO 146, ISO 4516, ISO 6507/2 and ISO 6507-3 provide detailed descriptions of the requirements and operation of a suitable microhardness tester. The test machine must be capable of forcing an indenter, under a force of 1 to 1000 gf, gradually and smoothly into the surface of a test piece, and holding it there for a specified time interval.

2. Specimen support area The testing machine must be equipped with a rigid specimen support. The support area must be clean and free of pits, heavy scratches, and all foreign matter.

3. Indenters Standard indenters are required which are of the appropriate type for the hardness test being used. The Vickers hardness test requires a highly polished, pointed, square-based pyramidal diamond indenter. The Knoop hardness

test requires a highly polished, pointed, rhombus-based pyramidal diamond indenter. The indenters must conform to the requirements prescribed in the test method standards. ASTM E 384, ISO 146 or ISO 4516 provide detailed descriptions of suitable indenters.

The indenters must be examined periodically. If the diamond is loose in the mounting material, chipped, cracked or otherwise damaged, it must be replaced. After each removal and replacement of the indenter, the new indenter must be inspected to ensure that it is correctly mounted in its housing.

4. <u>Measuring microscope</u> An appropriate measuring microscope with proper illumination is required for measuring the indentations. The measuring microscope must be graduated in 0.5 μm or smaller divisions (ISO 146 requires graduated divisions which allow an estimation of the measurement within at least 0.2 μm). Usually the microscope is an integral part of the hardness tester, and is designed to readily bring the last indentation into view for measurement. [Note: ASTM E 384 specifies additional requirements for the measuring equipment illumination. Either the Kohler or Abbé-Nelson illumination systems must be used. See the test method.]

5. <u>Verification of the testing machine</u> The test machine must be verified at least every 18 months (at least every 12 months is recommended) unless otherwise specified. Verification may either be by separate verification of test forces, indenter, and microscope (direct verification) or by using standardized test blocks (indirect verification) as specified in ASTM E 384 and ISO 146, as appropriate.

   <u>Direct verification</u> of the test machine requires independent verifications of each test force used within the working range of the testing machine, the indenter, and the measuring microscope. This method is used for new and rebuilt machines and is the responsibility of the manufacturer.

   <u>Indirect verification</u> of the test machine requires the use of standardized blocks calibrated in accordance with ASTM E 384 (Part C) or ISO 640, as appropriate. This method is used for verifying machines in service.

   <u>Periodic checks of the testing machine</u> A routine check of the operation and accuracy of the hardness machine using the <u>indirect verification method</u> must be made at least once each day that the testing machine is used. Standardized hardness test blocks, calibrated in accordance with ASTM E 384 (Part C) or ISO 640, as appropriate, must be used when performing

the routine check. Commercially manufactured hardness test blocks which have been appropriately calibrated are suitable for this purpose. The routine check should be conducted for each of the test forces at which the test machine will be used. (ISO 146 requires that if multiple test forces will be used, then at least two test forces must be chosen.) The routine check procedure is as follows:

(a) Two preliminary indentations should be made to ensure that the testing machine is working freely and that the test block, indenter, and anvil are seated correctly. The results of the preliminary indentations should be ignored.

(b) After the preliminary indentations, at least five hardness readings must be on a standardized hardness test block. ASTM E 384 requires that the hardness level of the standardized block be in the hardness range at which the machine is to be used. ISO 146 requires readings be made using multiple blocks at different hardness ranges (see method). The testing machine is satisfactory if the mean of the readings falls within the tolerances marked on the standardized hardness test block. If not, the testing machine must be verified by either direct or indirect verification.

6. <u>Test piece preparation</u> The hardness test must be carried out on a smooth, even surface having a roughness much less than the size of the impression. When specified, preparation of the test piece must be as stipulated in the test method or product specification.

Final surface preparation is generally performed by filing, sanding, grinding or polishing, or a combination of these methods. Extreme care must be taken not to overheat, cold work, or otherwise distort the surface. The degree of surface finish which is required is dependent on the test forces and microscope magnifications used. However, for all tests the perimeter of the indentation must be clearly visible when measuring the indentation. The small size of the microhardness indentation may require that the test surface be given a metallographic polish. Residual deformation from mechanical polishing must be removed, particularly for low-load testing.

<u>Sectioning the fastener</u> A metal-cutting saw or abrasive cut-off wheel is required for sectioning the fastener. Sawing, whether by hand or machine with lubrication, can be used on all metals with hardnesses below approximately 35 HRC. Saw cuts produce surfaces containing extensive plastic flow which must be removed by further preparation. For sectioning metals with hardnesses above about 35 HRC, an

abrasive cut-off wheel is recommended. The choice of the type of cut-off wheel and lubricant depend on the grade and hardness of the metal to be cut. Aluminum oxide wheels are preferred for ferrous metals, and silicon carbide wheels for nonferrous alloys. Other methods of sectioning fasteners are permitted as long as they do not affect the hardness of the metal at the surface to be examined. When the test section is not to be mounted, two parallel and flat surfaces must be prepared.

The thickness of the test piece or layer under test must exceed 1.5 times the diagonal of the indentation. After testing, there must be no deformation visible on the back of the test piece.

Mounting When the test piece is too small to adequately be held by hand when preparing the test surface, the piece must be embedded in a sample mount. Two common methods of mounting specimens are; (1) mounting in thermosetting plastic which requires equipment that can apply heat and pressure to the mounting mold, and (2) mounting in castable plastics.

[Note: ASTM E 3 describes suitable equipment for performing each required step in preparing a sample for microhardness examination.]

7. Test forces The depth, shape and size of the indentation produced by a microhardness test is very sensitive to the level of the test force used, particularly at the lower force levels. The maximum test force should be used which is compatible with the surface under test, unless otherwise specified.

Although virtually any level of test force may be used between 1 and 1000 gf (depending on the ability of the test machine), there are common force increments which are typically used. Commonly used test forces are as follows:

Test force		Hardness symbol	
(gf)	(N)	ASTM	ISO
1	0.0098	HV_1 or HK_1	HV 0.001 or HK 0.001
2	0.0196	HV_2 or HK_2	HV 0.002 or HK 0.002
5	0.0490	HV_5 or HK_5	HV 0.005 or HK 0.002
10	0.0981	HV_{10} or HK_{10}	HV 0.01 or HK 0.01
20	0.1961	HV_{20} or HK_{20}	HV 0.02 or HK 0.02
25	0.2452	HV_{25} or HK_{25}	HV 0.025 or HK 0.025

50	0.4903	HV_{50} or HK_{50}	HV 0.05 or HK 0.05
100	0.9807	HV_{100} or HK_{100}	HV 0.1 or HK 0.1
200	1.961	HV_{200} or HK_{200}	HV 0.2 or HK 0.2
300	2.942	HV_{300} or HK_{300}	HV 0.3 or HK 0.3
500	4.903	HV_{500} or HK_{500}	HV 0.5 or HK 0.5
1000	9.807	HV_{1000} or HK_{1000}	HV 1 or HK 1

8. Time periods for the application and dwell of the test force Unless otherwise specified, the dwell time of the full test force must be 10 to 15 seconds. If the dwell time is outside the allowed 10 to 15 second time period, the actual application time must be reported (see Microhardness number). Application and dwell times as required in the test standards are as follows:

Test method	Total Force Application	Dwell*
ASTM E 384	---	10s-15s
ISO 4516	---	10s-15s
ISO 6507/2	≤10s	10s-15s
ISO 6507-3	≤10s	10s-15s
MIL-STD-1312-6	---	≥15s

*The dwell time must be in this range unless otherwise specified.

9. Indentations The number and locations of the hardness indentations must be as specified in the test method standards and product specifications.

Indentation spacing The distance between the center of any indentation and the edge of the specimen must be as follows:

Test Method	Distance to the edge of the specimen
ASTM E 384	not specified.
ISO 4516	not specified.
ISO 6507/2 and ISO 6507-3	at least 2½ times the measured diagonal of the larger indentation for steel, copper, and copper alloys, and at least 3 times the measured diagonal of the larger indentation for light metals and their alloys.
MIL-STD-1312-6	at least 2½ times the measured diagonal

for a Vickers indenter, and at least 2 times the length of the minor axis for a Knoop indenter.

The distance between the center of two adjacent indentations must be as follows:

Test Method	Distance between Adjacent Indentations
ASTM E 384	at least 2 times the extent of any stress deformation (coldworking, "butterfly" fractures, etc).
ISO 4516	at least 2½ times the measured diagonal.
ISO 6507/2 and ISO 6507-3	at least 3 times the measured diagonal of the larger indentation for steel, copper, and copper alloys. at least 6 times the measured diagonal of the larger indentation for light metals and their alloys.
MIL-STD-1312-6	at least 2½ times the measured diagonal for a Vickers indenter, and at least 2 times the measured diagonal of the minor axis for a Knoop indenter.

10. Test environment Unless otherwise specified, the microhardness test must be conducted at an ambient temperature within the limits of 10 to 35°C (50 to 95°F).

    The hardness machine must be protected from shock and vibration throughout the test. For microhardness testing, vibration can be a serious source of error, particularly when testing at the smaller force levels.

11. Microhardness number The Knoop and Vickers microhardness values are computed from the applied force and the measurement of the diagonal(s) of the indentation. The microhardness number may be obtained by using equations, usually provided in the test standards, or from tables of hardness values. Test standards ASTM E 384 (Vickers and Knoop) and ISO 409/2 (Vickers only) provide appropriate hardness value tables.

    The following equations may be used for computation of the microhardness values.

    Vickers A convenient method of computing the Vickers microhardness number is from the following equation, where the unit of force is grams-force and the unit of the diagonal measurements is micrometers:

$$HV = 1854.4 \times F / d^2$$

where:
F = applied force (gf), and

$$d = \frac{d_1 + d_2}{2}$$

where:
d_1 and d_2 are the two separately measured diagonals (μm)

Knoop A convenient method of computing the Knoop microhardness number is from the following equation, where the unit of force is grams-force and the unit of the diagonal measurement is micrometers:

$$HK = 14229 \times F / d^2$$

where:
F = applied force (gf), and
d = length of the long diagonal (μm).

12. Reporting microhardness values When reporting microhardness values, the Vickers value must be denoted by the hardness value followed by the symbol HV, and the Knoop value must be denoted by the hardness value followed by the symbol HK. Additionally, the applied force must be reported as part of the hardness value as follows:

ASTM The force must be reported as grams-force by subscript notation following the HV or HK. For example, 400 HK_{100} denotes a Knoop microhardness of 400 measured with an applied force of 100 gf.

ISO The force must be reported as kilograms-force following the HV or HK. For example, 400 HK 0.1 denotes a Knoop microhardness of 400 measured with an applied force of 0.1 kgf or 100 gf.

If the time at full applied forced is other than 10 to 15 s, the actual time must be reported. ISO test standards require that the time duration at full applied force be included in the microhardness result by adding the time at the end. For example, 70 HK 0.025/20 signifies a Knoop microhardness of 70 measured with a test force of 0.025 kgf (0.245 N) applied for 20 seconds.

REFERENCED DOCUMENTS:

ASTM E 3: Standard Methods of Preparation of Metallographic Specimens

ISO 146: Metallic materials - Hardness test - Verification of Vickers hardness testing machines HV 0.2 to HV 100

ISO 409/2: Metallic materials - Hardness test - Tables of Vickers hardness values for use in tests made on flat surfaces - Part 2: HV 0.2 to less than HV 5

ISO 640: Metallic materials - Hardness test - Calibration of standardized blocks to be used for Vickers hardness testing machines HV 0.2 to HV 100

TEST METHOD TITLE: Rockwell Hardness of Fasteners

TEST METHOD DESIGNATIONS:

AASHTO T 80-85: Standard Methods of Test for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials
[Same as ASTM E 18-84]

AASHTO T 244-79 (1986): Standard Methods and Definitions for Mechanical Testing of Steel Products
Section 18: Rockwell Test
[Same as ASTM A 370-77]

ASTM A 370-90: Standard Test Methods and Definitions for Mechanical Testing of Steel Products
Section 18: Rockwell Test
[ASTM E 18 is referenced for detailed requirements]

ASTM E 18-89a: Standard Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials

FED. TEST METHOD STD. No. 151b, November 24,1967: Federal Test Method Standard, Metals: Test Methods
[ASTM E 18 is the accepted test method.]

ISO 3738/1, 1982-10-15: Hardmetals - Rockwell hardness test (scale A) - Part 1: Test method

ISO 6508, 1986-11-15: Metallic materials - Hardness test - Rockwell test (scales A - B - C - D - E - F - G - H - K)

MIL-STD-1312-6, 19 October 1984: Fastener Test Methods, Method 6, Hardness

SAE J417, December 1983: Hardness Tests and Hardness Number Conversions
[ASTM E 18 is referenced for detailed requirements]

Specific fastener specifications and test method standards may specify Rockwell hardness measurements as part of the testing requirements. These specifications and standards reference the above Rockwell hardness test methods as the applicable procedures to follow. These specifications include;

Those of Consensus standards organizations,
Federal specifications and standards,
Industry specifications and standards, such as ASTM F 606,
International specifications and standards,
Military specifications and standards, and
National Aerospace standards.

TEST DESCRIPTION: The Rockwell Hardness of Fasteners test is an indentation hardness test for determining whether the fasteners under test satisfy specified hardness requirements. This test is typically conducted using a commercial Rockwell hardness machine for which the test force, indenter, and the measuring device have been directly verified. Periodic checks of the test machine operation are performed by the test laboratory using commercially manufactured and calibrated standardized hardness test blocks.

The principle of operation of the testing machine involves forcing an indenter (spheroconical diamond or steel ball) into the surface of the fastener, or sectioned surface of the fastener, under two specified force levels: (1) a preliminary (minor) force of 10 kgf; and (2) a total (major) force of a level which is dependent on the hardness scale. The hardness value is based on the difference in depths of the indentation before and after application of the total force, measured in each case while the indentor is under the preliminary force. The measurement of the indentation depths and the calculation of the resultant hardness value are usually performed and displayed by the hardness test machine.

Specific hardness test requirements are usually specified in the product specifications and test method standards. These requirements include the specimen preparation, locations for measurements, number of measurements, hardness scale (test force and type of indentor) to be used, and the test acceptability/rejection criteria.

[Note: This test method does not include Rockwell Superficial hardness testing.

TECHNICAL REQUIREMENTS / CRITICAL ELEMENTS:

1. Testing machine An appropriate Rockwell hardness testing machine is required as described and specified in the test method standards. Test method standards ASTM E 18, ISO 716, ISO 3738/1 and ISO 6508 provide detailed descriptions of the requirements and operation of a suitable Rockwell hardness tester.

   Test forces The test machine must be capable of forcing a specified indenter (spheroconical diamond or steel ball) into the surface of a test piece in a specified manner under two distinct test forces. Initially, a preliminary (minor) force of 10 kgf (98 N) is applied regardless of the Rockwell hardness scale. Additional force is then applied to produce a total (major) test force. The level of the total test force is dependent on the hardness scale as described in the test method standards.

2. Verification of the testing machine The test machine must be verified for each hardness scale used at least every 18 months (at least every 12 months is recommended) unless otherwise specified. Verification may either be by direct verification or by indirect verification as specified in ASTM E 18 and ISO 716, as appropriate.

Direct verification of the test machine requires independent verifications of the test forces, the indenter, and the depth measuring device. This method is used for new and rebuilt machines.

Indirect verification of the test machine requires the use of standardized blocks calibrated in accordance with ASTM E 18 (Part C) or ISO 674, as appropriate. This method is used for referee, laboratory, or routine testing.

After each removal and replacement of the indenter or specimen support, the new indenter or specimen support must be inspected to ensure that it is correctly mounted in its housing. The first two hardness readings after such a change should be disregarded.

Periodic checks of the testing machine A routine check of the operation and accuracy of the hardness machine must be made at least once each day that the testing machine is used. Standardized hardness test blocks, calibrated in accordance with ASTM E 18 (Part C) or ISO 674, as appropriate, must be used when performing the routine check. Commercially manufactured hardness test blocks which have been appropriately calibrated are suitable for this purpose. The routine check must be conducted as follows:

(a) Two preliminary indentations must be made to ensure that the testing machine is working freely and that the test block, indenter, and anvil are seated correctly. The results of the preliminary indentations should be ignored.

(b) After the preliminary indentations, at least three hardness readings must be made on a standardized hardness test block on the scale and at the hardness level at which the machine is to be used. The testing machine is satisfactory if the mean of the readings falls within the tolerances marked on the standardized hardness test block. If not, the testing machine must be verified by either direct or indirect verification.

3. Specimen support area The testing machine must be equipped with a rigid specimen support which is suitable for the geometry of the fastener or specimen to be tested. The

specimen support or anvil must support the test piece in a plane normal to the axis of the indenter and the line of the indenting force. Cylindrical pieces must be tested using a V-grooved anvil, or an anvil having hard, parallel, twin cylinders. Flat pieces must be tested on a flat anvil having a smooth, flat bearing surface. The support area must be clean and free of pits, heavy scratches, and all foreign matter.

4. <u>Indenters</u> Standard indenters are required which are of the appropriate type for the hardness scales that are to be used. Acceptable standard indenters are a spheroconical diamond and steel balls with diameters of 1/16, 1/8, ¼, and ½ in. (1.588, 3.175, 6.350, and 12.70 mm) depending on the hardness scale to be used. The indenters must conform to the requirements prescribed in the test method standards. ASTM E 18 or ISO 716 provide detailed descriptions of suitable indenters.

   The indenters must be examined periodically. For diamond indenters, if the diamond is loose in the mounting material, chipped, cracked or otherwise damaged, it must be replaced. For steel ball indenters, if the ball has developed a flat spot or other surface defect it must be replaced.

5. <u>Hardness scales</u> The appropriate Rockwell hardness scale must be used as specified in the product specification or test method. The hardness scale is based on the type of indenter used and the level of the total force applied to the indenter. If a hardness scale is not specified, a suitable scale must be chosen which is appropriate for the type of fastener material which is to be tested. Typically, the B-scale or C-scale is used for metallic fasteners. Test methods ASTM E 18 and MIL-STD-1312-6 provide guidance for selecting the appropriate hardness scale. The required indenter type and total test force for the Rockwell A, B and C scales are as follows:

Hardness Scale	Indenter Type	Total Test Force (kgf)	(N)
A	spheroconical diamond	60	588.4
B	1/16 in. (1.588 mm) diameter steel ball	100	980.7
C	spheroconical diamond	150	1471

The required indenter type and total test force for other Rockwell hardness scales are designated in the test method standards.

6. Test piece preparation Preparation of the test piece must be as stipulated in the test method or product specification, when specified. The hardness test must be carried out on a smooth, even surface having a roughness much less than the size of the impression. The surface must be free from oxide scale, plating, paint, foreign matter, and lubricants.

Sectioning the fastener When the fastener must be sectioned, two parallel and flat surfaces must be prepared. The thickness of the test piece must exceed 10 times the depth of the indentation.

A metal-cutting saw or abrasive cut-off wheel is required for sectioning the fastener. Sawing, whether by hand or machine with lubrication, can be used on all metals with hardnesses below approximately 35 HRC. Saw cuts produce surfaces containing extensive plastic flow which must be removed by further preparation. For sectioning metals with hardnesses above about 35 HRC, an abrasive cut-off wheel is recommended. The choice of the type of cut-off wheel and lubricant depend on the grade and hardness of the metal to be cut. Aluminum oxide wheels are preferred for ferrous metals, and silicon carbide wheels for nonferrous alloys. Other methods of sectioning fasteners are permitted as long as they do not affect the hardness of the metal at the surface to be examined.

Final surface preparation is generally performed by filing, sanding, grinding or polishing, or a combination of these methods. Care must be taken to not overheat or work harden the surface.

Mounting When the test piece is too small to adequately be held by hand when preparing the test surface, the piece must be embedded in a sample mount. Two common methods of mounting specimens are; (1) mounting in thermosetting plastic which requires equipment that can apply heat and pressure to the mounting mold, and (2) mounting in castable plastics.

7. Time periods for the application and dwell time of forces The time required for the application and dwell times of the preliminary and total forces must be in accordance with the test method.

Specified application and dwell times are as follows:

	Preliminary Force		Total Force	
Test method	Application	Dwell	Application	Dwell*
ASTM E 18	---	≤3s	1s - 8s	≤3s

ISO 3738/1	---	---	6s - 8s	≤2s
ISO 6508	---	---	2s - 8s	1s - 3s
SAE J417	---	---	---	---
MIL-STD-1312-6	---	---	---	≤2s

* Total force dwell times are material dependent (see test method.)

8. Indentations The number and locations of the hardness indentations must be as specified in the test method standards and product specifications.

Indentation spacing The distance between the center of any indentation and the edge of the specimen must be as follows:

Test Method	Distance to the edge of the specimen
ASTM E 18	at least 2½ times the measured diameter of the indentation.
ISO 3738/1	at least 1.5 mm.
ISO 6508	at least 2½ times the diameter of the indentation, but at least 1 mm.
MIL-STD-1312-6	at least 2½ times the measured diameter of the indentation.
SAE J417	not specified.

The distance between the centers of two adjacent indentations must be as follows:

Test Method	Distance between Adjacent Indentations
ASTM E 18	at least 3 times the diameter of the indentation.
ISO 3738/1	at least 1.5 mm.
ISO 6508	at least four (4) times the diameter of the indentation (but at least 2 mm).
MIL-STD-1312-6	at least 2½ times the diameter of the indentation for a spheroconical diamond indenter, and at least five (5) times the diameter of the indentation for a ball indenter.
SAE J417	not specified.

9. <u>Test environment</u> Unless otherwise specified, the Rockwell hardness test must be conducted at an ambient temperature within the limits of 10 to 35°C (50 to 95°F). The hardness machine must be protected from shock or vibration throughout the test.

10. <u>Rockwell hardness number</u> The Rockwell hardness number is based on the difference in the penetration depths of the indenter before and after application of the total test force, measured in each case while the indentor is under the preliminary force level. The test machine usually provides a means of converting the measurements of penetration depths to a Rockwell hardness number and displaying the resultant Rockwell hardness value either digitally or on an analog dial.

    Unless otherwise specified, Rockwell hardness readings must be reported to the nearest whole number (ISO 3738/1 has stricter requirements). When reporting Rockwell hardness values, the Rockwell hardness must be denoted by the hardness value followed by the symbol HR with an additional letter indicating the scale. For example, 40 HRC denotes a Rockwell hardness of 40, measured on the C scale.

<u>REFERENCED DOCUMENTS:</u>

ISO 674: Metallic materials - Hardness test - Calibration of standardized blocks to be used for Rockwell hardness testing machines (scales A - B - C - D - E - F - G - H - K)

ISO 716: Metallic materials - Hardness test - Verification of Rockwell hardness testing machines (scales A - B - C - D - E - F - G - H - K)

ISO 3738-2: Hardmetals - Rockwell hardness test (scale A) - Part 2: Preparation and calibration of standard test blocks

TEST METHOD TITLE: Rockwell Superficial Hardness of Fasteners

TEST METHOD DESIGNATIONS:

AASHTO T 80-85: Standard Methods of Test for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials
[Identical to ASTM E 18-84]

AASHTO T 244-79 (1986): Standard Methods and Definitions for Mechanical Testing of Steel Products
Section 18: Rockwell Test
[Identical to ASTM A 370-77]

ASTM A 370-90: Standard Test Methods and Definitions for Mechanical Testing of Steel Products
Section 18: Rockwell Test
[ASTM E 18 is referenced for detailed requirements]

ASTM E 18-89a: Standard Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials

FED. TEST METHOD STD. No. 151b, November 24,1967: Federal Test Method Standard, Metals: Test Methods
[ASTM E 18 is the accepted test method.]

ISO 1024, 1989-11-01: Metallic materials - Hardness test - Rockwell superficial test (scales 15N, 30N, 45N, 15T, 30T and 45T)

MIL-STD-1312-6, 19 October 1984: Fastener Test Methods, Method 6, Hardness

SAE J417, December 1983: Hardness Tests and Hardness Number Conversions
[ASTM E 18 is referenced for detailed requirements]

Specific fastener specifications and test method standards may specify Rockwell superficial hardness measurements as part of the testing requirements. These specifications and standards reference the above Rockwell superficial hardness test methods as the applicable procedures to follow. These specifications include;

- Those of Consensus standards organizations,
- Federal specifications and standards,
- Industry specifications and standards,
- International specifications and standards,
- Military specifications and standards, and
- National Aerospace standards.

TEST DESCRIPTION: The Rockwell Superficial Hardness of Fasteners test is an indentation hardness test for determining whether the fasteners under test satisfy specified hardness requirements. This test is typically conducted using a commercial Rockwell superficial hardness machine for which the test force, indenter, and the measuring device have been directly verified. Periodic checks of the test machine operation are performed by the test laboratory using commercially manufactured and calibrated standardized hardness test blocks.

The principal of operation of the testing machine involves forcing an indentor (diamond spheroconical or steel ball) into the surface of the fastener, or sectioned surface of the fastener, under two specified force levels; (1) preliminary (minor) force, and (2) total (major) force. The hardness value is based on the difference in depths of the indentation before and after application of the total force, measured in each case while the indentor is under the preliminary force. The measurement of the indentation depths and the calculation of the resultant hardness value are usually performed and displayed by the hardness test machine. The Rockwell superficial hardness test is the same as the Rockwell hardness test except that smaller preliminary and total test forces are used.

Specific hardness test requirements are usually specified in the product specifications and test method standards. These requirements include the specimen preparation, locations for measurements, number of measurements, hardness scale (test force and type of indentor) to be used, and the test acceptability/rejection criteria.

TECHNICAL REQUIREMENTS / CRITICAL ELEMENTS:

1. Testing machine An appropriate Rockwell superficial hardness testing machine is required as described and specified in the test method standards. Test method standards ASTM E 18, ISO 1024 and ISO 1079 provide detailed descriptions of the requirements and operation of a suitable Rockwell superficial hardness tester.

   Test forces The test machine must be capable of forcing a specified indenter (spheroconical diamond or steel ball) into the surface of a test piece in a specified manner under two distinct test forces. Initially, a preliminary (minor) force of 3 kgf (29 N) is applied regardless of the Rockwell superficial hardness scale. Additional force is then applied to produce a total (major) test force. The level of the total test force is dependent on the hardness scale as described in the test method standards.

   The Rockwell superficial hardness value is based on the difference in the penetration depths of the indenter before and after application of the total test force, measured in each case while the indentor is under the preliminary force. The test machine usually provides a means of converting the measurements of penetration depths to a Rockwell superficial hardness number and displaying the resultant Rockwell superficial hardness value either digitally or on an analog dial.

Verification of the testing machine The test machine must be verified for each hardness scale used at least every 18 months (at least every 12 months is recommended) unless otherwise specified. Verification may either be by direct verification or by indirect verification as specified in ASTM E 18 and ISO 1079, as appropriate.

Direct verification of the test machine requires independent verifications of the test forces, the indenter, and the depth measuring device.

Indirect verification of the test machine requires the use of standardized blocks calibrated in accordance with ASTM E 18 (Part C) or ISO 1355, as appropriate.

After each removal and replacement of the indenter or specimen support, the new indenter or specimen support must be inspected to ensure that it is correctly mounted in its housing. The first two hardness readings after such a change should be disregarded.

Periodic checks of the testing machine A routine check of the operation and accuracy of the hardness machine must be made at least once each day that the testing machine is used. Standardized hardness test blocks, calibrated in accordance with ASTM E 18 (Part C) or ISO 1355, as appropriate, must be used when performing the routine check. Commercially manufactured hardness test blocks which have been appropriately calibrated are suitable for this purpose. The routine check must be conducted as follows:

(a) Two preliminary indentations must be made to ensure that the testing machine is working freely and that the test block, indenter, and anvil are seated correctly. The results of the preliminary indentations should be ignored.

(b) After the preliminary indentations, at least three hardness readings must be made on a standardized hardness test block on the scale and at the hardness level at which the machine is to be used. The testing machine is satisfactory if the mean of the readings falls within the tolerances marked on the standardized hardness test block. If not, the testing machine must be verified by either direct or indirect verification.

2. Specimen support area The testing machine must be equipped with a rigid specimen support which is suitable for the geometry of the fastener or specimen to be tested. The specimen support or anvil must support the test piece in a plane normal to the axis of the indenter and the line of the indenting force. Cylindrical pieces must be tested using a V-grooved anvil, or an anvil having hard, parallel, twin cylinders. Flat pieces must be tested on a flat anvil having a smooth, flat bearing surface. The support area must be clean and free of pits, heavy scratches, and all foreign matter.

3. Indenters Standard indenters are required which are of the appropriate type for the hardness scales that are to be used. Acceptable standard indenters are a spheroconical diamond indenter (N-scale), and a steel ball indenter (T-scale) with a diameter of $^1/_{16}$ in. (1.588 mm). The indenters must conform to the requirements prescribed in the test method standards. ASTM E 18 or ISO 1079 provide detailed descriptions of suitable indenters.

4. Hardness scales Rockwell superficial hardness includes the N-scale and T-scale each with a choice of a total test force of either 15, 30 or 45 kgf. The difference in the N-scale and T-scale is the type of indenter used. For the N-scale a spheroconical diamond is used, and for the T-scale a $^1/_{16}$ in. (1.588 mm) diameter steel ball is used. The appropriate scale and test force must be used as specified in the product specification or test method. If a hardness scale is not specified, a suitable scale must be chosen which is appropriate for the type of fastener material which is to be tested. Test method standard MIL-STD-1312-6 provides limited guidance for selecting the appropriate hardness scale. The required indenter type and total test force for the Rockwell superficial N and T scales are as follows:

Hardness Scale	Indenter Type	Total Test Force (kgf)	(N)
15N	spheroconical diamond	15	147
30N	spheroconical diamond	30	294
45N	spheroconical diamond	45	441
15T	$^1/_{16}$ in. (1.588 mm) diameter steel ball	15	147

30T	$^{1}/_{16}$ in. (1.588 mm) diameter steel ball	30	294
45T	$^{1}/_{16}$ in. (1.588 mm) diameter steel ball	45	441

5. Test piece preparation Preparation of the test piece must be as stipulated in the test method or product specification, when specified. The hardness test must be carried out on a smooth, even surface having a roughness much less than the size of the impression. The surface must be free from oxide scale, plating, paint, foreign matter, and lubricants.

   Sectioning the fastener When the fastener must be sectioned, two parallel and flat surfaces must be prepared. The thickness of the test piece must exceed 10 times the depth of the indentation.

   A metal-cutting saw or abrasive cut-off wheel is required for sectioning the fastener. Sawing, whether by hand or machine with lubrication, can be used on all metals with hardnesses below approximately 35 HRC. Saw cuts produce surfaces containing extensive plastic flow which must be removed by further preparation. For sectioning metals with hardnesses above about 35 HRC, an abrasive cut-off wheel is recommended. The choice of the type of cut-off wheel and lubricant depend on the grade and hardness of the metal to be cut. Aluminum oxide wheels are preferred for ferrous metals, and silicon carbide wheels for nonferrous alloys. Other methods of sectioning fasteners are permitted as long as they do not affect the hardness of the metal at the surface to be examined.

   Final surface preparation is generally performed by filing, sanding, grinding or polishing, or a combination of these methods. Care must be taken to not overheat or work harden the surface.

   Mounting When the test piece is too small to adequately be held by hand when preparing the test surface, the piece must be embedded in a sample mount. Two common methods of mounting specimens are; (1) mounting in thermosetting plastic which requires equipment that can apply heat and pressure to the mounting mold, and (2) mounting in castable plastics.

6. Time periods for the application and dwell time of forces The time required for the application and dwell times of the preliminary and total forces must be in accordance with the test method.

   Specified application and dwell times are as follows:

Test method	Preliminary Force Application	Dwell	Total Force Application	Dwell*
ASTM E 18	---	≤3s	1s - 8s	≤3s
ISO 1024	---	---	1s - 8s	1s - 3s
MIL-STD-1312-6	---	---	---	≤2s
SAE J417	---	---	---	---

* Total force dwell times are material dependent (see test method.)

7. Indentations The number and locations of the hardness indentations must be as specified in the test method standards and product specifications.

Indentation spacing The distance between the center of any indentation and the edge of the specimen must be as follows:

Test Method	Distance to the edge of the specimen
ASTM E 18	at least 2½ times the measured diameter of the indentation.
ISO 1024	at least 2½ times the measured diameter of the indentation.
MIL-STD-1312-6	at least 2½ times the measured diameter of the indentation.
SAE J417	not specified.

The distance between the centers of two adjacent indentations must be as follows:

Test Method	Distance between Adjacent Indentations
ASTM E 18	at least three (3) times the diameter of the indentation.
ISO 1024	at least three (3) times the measured diameter of the indentation.
MIL-STD-1312-6	at least 2½ times the diameter of the indentation for a spheroconical diamond indenter, and at least five (5) times the diameter of the indentation for a ball indenter.
SAE J417	not specified.

8. Test environment Unless otherwise specified, the Rockwell superficial hardness test must be conducted at an ambient temperature within the limits of 10 to 35°C (50 to 95°F). The hardness machine must be protected from shock or vibration throughout the test.

9. Rockwell superficial hardness number Unless otherwise specified, Rockwell superficial hardness readings must be reported to the nearest whole number. When reporting Rockwell superficial hardness values, the Rockwell superficial hardness must be denoted by the hardness value followed by the symbol HR, followed by a number representing the total test force, and an additional letter indicating the scale. For example, 55 HR30N denotes a Rockwell superficial hardness of 55, measured on the 30N scale.

REFERENCED DOCUMENTS:

ISO 1079: Metallic materials - Hardness test - Verification of Rockwell superficial hardness testing machines (scales 15N, 30N, 45N, 15T, 30T and 45T)

ISO 1355: Metallic materials - Hardness test - Calibration of standardized blocks to be used for Rockwell superficial hardness testing machines (scales 15N, 30N, 45N, 15T, 30T and 45T)

TEST METHOD TITLE: Vickers Hardness - Test forces from 9.807 to 1176 N (1 to 120 kgf)

TEST METHOD DESIGNATIONS:

ASTM E 92-82 (Reapproved 1987): Standard Test Method for Vickers Hardness of Metallic Materials

ISO 3878, 1983-08-15: Hardmetals - Vickers hardness test

ISO 6507/1, 1982-07-01: Metallic materials - Hardness test - Vickers test - Part 1: HV 5 to HV 100

ISO 6507/2, 1983-09-15: Metallic materials - Hardness test - Vickers test - Part 2: HV 0.2 to less than HV 5

MIL-STD-1312-6, 19 October 1984: Fastener Test Methods, Method 6, Hardness

SAE J417, December 1983: Hardness Tests and Hardness Number Conversions
[ASTM E 92 is referenced for detailed requirements]

Specific fastener specifications and test method standards may specify Vickers hardness measurements as part of the testing requirements. These specifications and standards reference the above Vickers hardness test methods as the applicable procedures to follow. These specifications include;

Those of Consensus standards organizations,
Federal specifications and standards,
Industry specifications and standards,
International specifications and standards,
Military specifications and standards, and
National Aerospace standards.

TEST DESCRIPTION: The Vickers hardness test is an indentation hardness test for determining whether fasteners or fastener materials satisfy specified hardness requirements. This test includes Vickers indentation hardness tests using test forces from 9.807 to 1176 N (1 to 120 kgf). Vickers hardness is typically conducted using a commercial hardness machine for which the test force, indenter, and the optical measuring device have been directly verified. Periodic checks of the test machine operation are performed by the test laboratory using commercially manufactured and calibrated standardized hardness test blocks.

The principle of the Vickers hardness test involves forcing a square-pyramid diamond indenter into the surface or sectioned surface of the fastener or fastener material for a specified time period. The indenter is then removed leaving an indentation in the test surface. After removal of the indenter, the length of the diagonals of the indentation are optically measured with a measuring device, typically a microscope. The Vickers hardness number is calculated from the mean of the measured length of the two diagonals and the level of test force used. The hardness number may be derived from equations or from tables provided in certain test method standards.

Specific hardness test requirements are usually specified in the product specifications and test method standards. These requirements include the specimen preparation, locations for measurements, number of measurements, level of test force to be used, and the test acceptability/rejection criteria.

TECHNICAL REQUIREMENTS / CRITICAL ELEMENTS:

1. Testing machine An appropriate Vickers hardness testing machine is required as described and specified in the test method standards. The test machine must be capable of forcing an indenter, under a predetermined test force, gradually and smoothly into the surface of a test piece, and maintaining the force for a specified time. Test forces for Vickers hardness testing are within the range of 9.807 to 1176.8 N (1 to 120 kgf). Test method standards ASTM E 92, ISO 146, ISO 6507/1 and ISO 6507/2 provide detailed descriptions of the requirements and operation of a suitable Vickers hardness tester. [Note: ISO test method standards limit the maximum test force for Vickers hardness testing to 980.7 N (100 kgf).]

2. Specimen support area The testing machine must be equipped with a rigid specimen support. The support area must be clean and free of pits, heavy scratches, and all foreign matter.

3. Indenters Standard indenters are required which must conform to the requirements prescribed in the test method standards. The Vickers hardness test requires the use of a highly polished, pointed, square-based pyramidal diamond indenter having specific geometrical dimensions. ASTM E 92 and ISO 146 provide detailed requirements and descriptions of suitable indenters.

   The indenters must be examined periodically. If the diamond is loose in the mounting material, chipped, cracked or otherwise damaged, it must be replaced. After each removal and replacement of the indenter, the new indenter must be inspected to ensure that it is correctly mounted in its housing.

4. Measuring device An appropriate measuring device such as a microscope with proper illumination is required for measuring the indentations. The measuring device must be capable of measuring the length of an impression diagonal, d, to the following accuracies:

ASTM E 92: ±0.0005 mm or ±0.5% of d, whichever is larger.

ISO 146: for $0.02 \le d < 0.1$, accuracy of ± 1% of d,
for $0.1 \le d < 0.2$, accuracy of ± 0.001 mm,
for $d \ge 0.2$, accuracy of ± 0.5% of d.

ISO 3878: for $d < 100$ µm, accuracy of ± 0.2 µm,
for $100 \mu m \le d < 200$ µm, accuracy of ± 1.0 µm,
for $d \ge 200$ µm, accuracy of ± 0.5% of d.

MIL-STD-1312-6: ±0.0005 mm or ±0.5% of d, whichever is larger.

Usually a microscope is an integral part of the hardness tester, and is designed to readily bring the last indentation into view for measurement.

5. Verification of the testing machine The test machine must be verified at least every 18 months (at least every 12 months is recommended) unless otherwise specified. Verification may either be by separate verification (direct verification) of test forces, indenter, and microscope or by using standardized test blocks (indirect verification) as specified in ASTM E 92 and ISO 146, as appropriate.

Direct verification of the test machine requires independent verifications of each test force used within the working range of the testing machine, the indenter, and the measuring microscope. This method is mandatory for new and rebuilt machines.

Indirect verification of the test machine requires the use of standardized blocks calibrated in accordance with ASTM E 92 (Part C) or ISO 640, as appropriate. This method is used for verifying machines in service.

Periodic checks of the testing machine A routine check of the operation and accuracy of the hardness machine using standardized hardness test blocks must be made at least once each day that the testing machine is used. Standardized hardness test blocks, calibrated in accordance with ASTM E 92 (Part C) or ISO 640, as appropriate, must be used when performing the routine check. Commercially manufactured hardness test blocks which have been appropriately calibrated are suitable for this purpose. The routine check should be conducted for each of the test forces at which the test machine will be used. (ISO 146 recommends that the indirect verification method be used for the periodic check which requires that if multiple test forces will be used, then at least two test forces must be chosen.)

The recommended routine check procedure is as follows:

(a) Two preliminary indentations should be made to ensure that the testing machine is working freely and that the test block, indenter, and anvil are seated correctly. The results of the preliminary indentations should be ignored.

(b) After the preliminary indentations, at least five hardness readings must be on a standardized hardness test block. ASTM E 92 requires that the hardness level of the standardized block be in the hardness range at which the machine is to be used. ISO 146 requires readings be made using multiple blocks at different hardness ranges (see method). The testing machine is satisfactory if the mean of the readings falls within the tolerances marked on the standardized hardness test block. If not, the testing machine must be verified by either direct or indirect verification.

6. Test piece preparation When specified, preparation of the test piece must be as stipulated in the test method or product specification. The test specimen should be flat and normal to the axis of the indenter.

Surface preparation is generally performed by filing, sanding, grinding or polishing, or a combination of these methods. Extreme care must be taken to not overheat, cold work, or otherwise distort the surface. The degree of surface finish which is required is dependent on the test forces and microscope magnifications used. However, for all tests the perimeter of the indentation must be clearly visible when measuring the indentation. The small size of lower load Vickers hardness indentations may require that the test surface be given a metallographic polish. Residual deformation from mechanical polishing must be removed, particularly for low-load testing.

Sectioning the fastener When sectioning of the fastener or material is required, a metal-cutting saw or abrasive cut-off wheel is required for sectioning the fastener. Sawing, whether by hand or machine with lubrication, can be used on all metals with hardnesses below approximately 35 HRC. Saw cuts produce surfaces containing extensive plastic flow which must be removed by further preparation. For sectioning metals with hardnesses above about 35 HRC, an abrasive cut-off wheel is recommended. The choice of the type of cut-off wheel and lubricant depend on the grade and hardness of the metal to be cut. Aluminum oxide wheels are preferred for ferrous metals, and silicon carbide wheels for nonferrous alloys. Other methods of sectioning fasteners are permitted as long as they do not affect the hardness of the metal at the surface to be examined. When the test section is not to be mounted, two parallel and flat surfaces must be prepared.

The thickness of the test piece or layer under test must exceed 1.5 times the diagonal of the indentation. After testing, there must be no deformation visible on the back of the test piece.

Mounting When the test piece is too small to be adequately held by hand when preparing the test surface, the piece must be embedded in a sample mount. Two common methods of mounting specimens are; (1) mounting in thermosetting plastic which requires equipment that can apply heat and pressure to the mounting mold, and (2) mounting in castable plastics.

[Note: ASTM E 3 describes suitable equipment for performing each required step in preparing a sample for hardness examination.]

7. Test forces The test force used must be as stipulated in the test method or product specification. Care should be taken when using test forces below 49.03 N (5 kgf). At these low force levels, the Vickers hardness number may be force-dependent.

Although virtually any level of test force may be used between 9.807 and 1176 N (1 and 120 kgf), depending on the ability of the test machine, there are common force increments which are typically used. Commonly used test forces are as follows.

Test forces (kgf)	(N)
1	9.807
2	19.61
2.5	24.52
3	29.42
5	49.03
10	98.07
20	196.1
30	294.2
50	490.3
100	980.7
120	1176

8. Time periods for the application and dwell of the test force

Unless otherwise specified, the dwell time of the full test force must be 10 to 15 seconds. If the dwell time is outside the allowed 10 to 15 second time period, the actual application time must be reported (see 11. Vickers hardness number). Application and dwell times as required in the test standards are as follows:

Test method	Total Force Application	Total Force Dwell*
ASTM E 92	---	10s-15s
ISO 3878	2s to 8s	10s-15s
ISO 6507/1	2s to 8s	10s-15s
ISO 6507/2	≤10s	10s-15s
MIL-STD-1312-6	---	≥15s

*The dwell time must be in this range unless otherwise specified.

9. Indentations The number and locations of the hardness indentations must be as specified in the test method standards and product specifications.

Indentation spacing The distance between the center of any indentation and the edge of the specimen must be as follows:

Test Method	Distance to the edge of the specimen
ASTM E 92	at least 2½ times the mean diagonal of the indentation.
ISO 3878	at least 2½ times the mean diagonal of the indentation.
ISO 6507/1 and ISO 6507/2	at least 2½ times the mean diagonal of the indentation for steel, copper, and copper alloys, and at least 3 times the measured diagonal of the larger indentation for lightmetals and their alloys.
MIL-STD-1312-6	at least 2½ times the mean diagonal of the indentation.

The distance between the center of two adjacent indentations must be as follows:

Test Method	Distance between Adjacent Indentations
ASTM E 92	at least 2½ times the mean diagonal of the indentation.

ISO 3878	at least 3 times the mean diagonal of the indentation.
ISO 6507/1 and ISO 6507/2	at least 3 times the mean diagonal of the indentation for steel, copper, and copper alloys. at least 6 times the measured diagonal of the larger indentation for lightmetals and their alloys.
MIL-STD-1312-6	at least 2½ times the mean diagonal of the indentation.

10. Test environment The Vickers hardness test must be conducted at a temperature as specified in the test method standard or product specification, or otherwise should be conducted at an ambient temperature within the limits of 10 to 35°C (50 to 95°F). Test temperatures as required in the test standards are as follows:

Test method	Test Temperature
ASTM E 92	---
ISO 3878	---
ISO 6507/1*	10 to 35°C
ISO 6507/2*	10 to 35°C
MIL-STD-1312-6	---

*Test standards ISO 6507/1 and ISO 6507/2 require that tests carried out under controlled conditions must be made at a temperature of 23 ± 5°C.

The hardness machine must be protected from shock and vibration throughout the test. Vibration can be a serious source of error, particularly when testing at the lower force levels.

11. Vickers hardness number The Vickers hardness values are computed from the applied force and the measurement of the mean diagonal of the indentation. The hardness number may be obtained by using equations, usually provided in the test standards, or from tables of hardness values. Test standards ASTM E 92, ISO 409/1 and ISO 409/2 provide appropriate hardness value tables.

The following equations may be used for computation of the Vickers hardness number, where the unit of force is kilograms-force or Newtons and the unit of the diagonal measurements is millimeters:

ASTM E 92, MIL-STD-1312-6 and SAE J417:

$$HV = 1.8544 \times F / d^2$$

where:
F = applied force (kgf), and

$$d = \frac{d_1 + d_2}{2}$$

where:
d_1 and d_2 are the two separately measured diagonals (mm).

<u>ISO</u>:

$$HV = 0.1891 \times F / d^2$$

where:
F = applied force (N), and

$$d = \frac{d_1 + d_2}{2}$$

where:
d_1 and d_2 are the two separately measured diagonals (mm).

12. <u>Reporting microhardness values</u> The Vickers value must be denoted by the measured hardness value followed by the symbol HV with a suffix number denoting the test force (in kgf) and a second suffix number indicating the duration of loading (in seconds) when it is other than 10 to 15 seconds.

    Examples:

    <u>640 HV 1</u> denotes a Vickers hardness of 640 measured with a test force of 9.807 N (1 kgf) applied for 10 to 15 s.

    <u>440 HV 30/20</u> denotes a Vickers hardness of 440 measured with a test force of 294.2 N (30 kgf) applied for 20 s.

<u>REFERENCED DOCUMENTS:</u>

ASTM E 3: Standard Methods of Preparation of Metallographic Specimens

ISO 146: Metallic materials - Hardness test - Verification of Vickers hardness testing machines HV 0.2 to HV 100

ISO 409/1: Metallic materials - Hardness test - Tables of Vickers hardness values for use in tests made on flat surfaces

- Part 1: HV 5 to HV 100

ISO 409/2: Metallic materials - Hardness test - Tables of Vickers hardness values for use in tests made on flat surfaces - Part 2: HV 0.2 to less than HV 5

ISO 640: Metallic materials - Hardness test - Calibration of standardized blocks to be used for Vickers hardness testing machines HV 0.2 to HV 100

Section 3 - TENSILE STRENGTH

MIL-STD-1312-8A, 19 October 1984: Fastener Test Methods, Method 8, Tensile Strength

MIL-STD-1312-18, 26 July 1985: Fastener Test Methods, Method 18, Elevated Temperature, Tensile Strength

DOD-STD-1312-108, 26 March 1984: Fastener Test Methods, Metric, Method 108, Tensile Strength

TENSILE STRENGTH

MIL-STD-1312-8A
MIL-STD-1312-18
DOD-STD-1312-108

Part A: RECOMMENDATIONS

MIL-STD-1312-8A, 19 October 1984: Fastener Test Methods, Method 8, Tensile Strength

On the basis of this study, there is presently no suitable non-government standard to completely replace MIL-STD-1312-8A. A test method having similar requirements and procedures can be found in ASTM F 606, "Standard Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers and Rivets". There are, however, several major and minor differences which exist between MIL-STD-1312-8A and ASTM F 606 that would prevent ASTM F 606, as presently written, from replacing MIL-STD-1312-8A. The major differences include the following:

- ASTM does not specify in their document the types of test fixtures specified in MIL-STD-1312-8A. Although ASTM F 606 does not prohibit these fixtures, their use may be unfamiliar to test laboratories.

- MIL-STD-1312-8A includes axial tensile testing of internally threaded fasteners which ASTM F 606 does not address.

- MIL-STD-1312-8A requires that yield load (yield strength) be determined by the Johnson's two-thirds approximate method. ASTM F 606 requires using the 0.2% offset method for the determination of yield strength.

- Other detail differences pertaining to test procedures, such as installation procedures, number of exposed threads, allowing specimen preload, use of washers, and loading rate, also differ between MIL-STD-1312-8A and ASTM F 606.

It is recommended that MIL-STD-1312-8A be reviewed and revised in conjunction with test standard DOD-STD-1312-108 to ensure consistency between the standards. The following are suggested recommendations for revising MIL-STD-1312-8A.

Eliminate the use of the Johnson's two-thirds approximate method for yield load determination, and add the requirement for using the 0.2% offset method for determining yield strength as described in ASTM F 606. The determination of yield strength of a fastener is in itself a questionable test method and the Johnson's two-thirds approximate method only adds to the uncertainty. ASTM recently voted not to include the Johnson's two-third method in ASTM F 606 because of its approximate nature and the difficulty in calibrating the fastener deflection measuring system.

The text fixture description given in paragraph 4.1.3.1 of MIL-STD-1312-8A should be revised to adopt the text of the analogous paragraph 4.1.3.1 of DOD-STD-1312-108 as well as the referenced figures. DOD-STD-1312-108 provides the fixture requirements within the document, whereas MIL-STD-1312-8A references a separate document.

The calibration/verification frequency requirement of paragraph 4.1.1 of either MIL-STD-1312-8A or DOD-STD-1312-108 should be revised to provide consistency between the standards. MIL-STD-1312-8A requires verification every 12 months, and DOD-STD-1312-108 requires verification every 6 months. ASTM typically recommends calibration/verification at least every 12 months although only requiring 18 month intervals.

The test report requirements of Section 6 of MIL-STD-1312-5A and DOD-STD-1312-105 should be revised to provide consistency between the standards.

<u>MIL-STD-1312-18, 26 July 1985</u>: Fastener Test Methods, Method 18, Elevated Temperature, Tensile Strength

On the basis of this study, there is presently no suitable non-government standard to completely replace MIL-STD-1312-18. Presently, MIL-STD-1312-18 specifies essentially the same tensile test requirements as test standards MIL-STD-1312-8A and DOD-STD-1312-108 with the addition of elevated temperature requirements. It is recommended that the elevated temperature requirements and procedures be extracted from MIL-STD-1312-18, and be incorporated into both test standards MIL-STD-1312-8A and DOD-STD-1312-108 as new sections or appendices which would describe the requirements for testing at elevated temperature. MIL-STD-1312-18 should then be discontinued.

<u>DOD-STD-1312-108, 26 March 1984</u>: Fastener Test Methods, Metric, Method 108, Tensile Strength

On the basis of this study, there is presently no suitable non-government standard to completely replace DOD-STD-1312-108. A test method having similar requirements and procedures can be found in ASTM F 606M, "Standard Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers and Rivets [Metric]." There are, however, several major and minor differences which exist between DOD-STD-1312-108 and ASTM F 606M that would prevent ASTM F 606M, as presently written, from replacing DOD-STD-1312-108. The major differences include the following:

- ASTM F 606M does not specify the types of test fixtures specified in DOD-STD-1312-108. Although ASTM F 606M does not prohibit these fixtures, their use may be unfamiliar to test laboratories.

- DOD-STD-1312-108 includes axial tensile testing of internally threaded fasteners which ASTM F 606M does not address.

- DOD-STD-1312-108 requires that yield load (yield strength) be determined by the Johnson's two-thirds approximate method. ASTM F 606M requires using the 0.2% offset method for the determination of yield strength.

- Other detail differences pertaining to test procedures, such as installation procedures, number of exposed threads, allowing specimen preload, use of washers, and loading rate, also differ between DOD-STD-1312-108 and ASTM F 606M.

It is recommended that DOD-STD-1312-108 be reviewed and revised in conjunction with test standard MIL-STD-1312-8A to ensure consistency between the standards. The following are suggested recommendations for revising DOD-STD-1312-108.

Eliminate the use of the Johnson's two-thirds approximate method for yield load determination, and add the requirement for using the 0.2% offset method for determining yield strength as described in ASTM F 606M. The determination of yield strength of a fastener is in itself a questionable test method and the Johnson's two-thirds approximate method only adds to the uncertainty. ASTM recently voted not to include the Johnson's two-third method in ASTM F 606M because of its approximate nature and the difficulty in calibrating the fastener deflection measuring system.

The calibration/verification frequency requirement of paragraph 4.1.1 of either MIL-STD-1312-8A or DOD-STD-1312-108 should be revised to provide consistency between the standards. MIL-STD-1312-8A requires verification every 12 months, and DOD-STD-1312-108 requires verification every 6 months. ASTM typically recommends calibration/verification at least every 12 months although requiring only 18 month intervals.

The test report requirements of section 6 of MIL-STD-1312-5A and DOD-STD-1312-105 should be revised to provide consistency between the standards

Part B: REQUIREMENT SUMMARIES

The following are requirement summaries of the primary United States and ISO test standards dealing with tensile testing of fasteners to determine the following product characteristics: Axial tensile strength or Failure load; Wedge tensile strength or Angularity evaluation; and Yield strength or Yield load. Specific requirements of test standards MIL-STD-1312-8A, MIL-STD-1312-18 and DOD-STD-1312-108 are often listed where they differ from other standards.

TEST METHOD TITLE: Axial Tensile Strength of Full-Size Threaded Fasteners

TEST METHOD DESIGNATIONS:

AASHTO T 244-79 (1986): Standard Methods and Definitions for Mechanical Testing of Steel Products
Supplement 3 - Steel Fasteners, Section S11.1.4: Axial Tension Testing of Full Size Bolts [Identical to ASTM A 370-77]

AREA Manual for Railway Engineering, 1969: AREA Specifications for Special Trackwork, [ASTM F 606 is the accepted test method.]

ASTM A 370-90: Standard Test Methods and Definitions for Mechanical Testing of Steel Products
Annex A3 - Steel Fasteners, Section A3.2.1.4: Axial Tension Testing of Full Size Bolts

ASTM F 606-90: Standard Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets
Sections 3.4.1 through 3.4.3: Axial Tension Testing of Full Size Products

ASTM F 606M-91: Standard Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets (Metric)
Sections 3.4.1 through 3.4.3: Axial Tension Testing of Full Size Products

DOD-STD-1312-108, 26 March 1984: Fastener Test Methods, Metric, Method 108, Tensile Strength

FED. TEST METHOD STD. No. 151b, November 24,1967: Federal Test Method Standard, Metals: Test Methods, [ASTM A 370 is the accepted test method.]

ISO 898-1, 1988: Mechanical properties of fasteners - Part 1: Bolts, screws and studs

Section 8.2: Tensile test for full-size bolts, screws and studs

MIL-STD-1312-8A, 19 October 1984: Fastener Test Methods, Method 8, Tensile Strength

MIL-STD-1312-18, 26 July 1985: Fastener Test Methods, Method 18, Elevated Temperature Tensile Strength

SAE J429, August 1983: Mechanical and Material Requirements for Externally Threaded Fasteners
Section 5.4: Axial Tensile Strength

SAE J1216, March 1978: Test Methods for Metric Threaded Fasteners
Section 3.5: Axial Tensile Strength

TEST DESCRIPTION: The Axial Tensile Strength of Full-Size Threaded Fasteners test is for determining the maximum or ultimate tensile load or stress which the fastener is capable of sustaining when axially loaded. This is accomplished by axially loading the fastener in tension until it fails. Tensile strength is based on the maximum load sustained by the fastener during the tensile test.

TECHNICAL REQUIREMENTS / CRITICAL ELEMENTS:

1. Testing machine A test machine is required which is capable of applying the specified axial tensile load to the fastener and test fixture. A mechanism is required for determining the maximum load sustained by the fastener during the test.

   Crosshead speed: Specific test method requirements are as follows:
   ASTM A 370 ------- as prescribed in the individual product specifications,
   ASTM F 606 ------- 1 in/min or slower,
   ASTM F 606M ------ 25 mm/min or slower,
   DOD-STD-1312-108 - load rate dependent, see method,
   ISO 898-1 -------- 25 mm/min or slower,
   MIL-STD-1312-8A -- load rate dependent, see method,
   SAE J429 --------- 1 in/min or slower,
   SAE J1216 -------- 25 mm/min or slower.

   Note: Average crosshead speed can be experimentally determined by using suitable length measuring and timing devices - see ASTM E 8.

   Load measuring device: each load measuring device must be verified by a method complying with ASTM E 4 at the specified intervals, or when the test machine is repaired or relocated. If proficiency tests indicate a load discrepancy, a new verification is required. Each load measuring device must be verified in conjunction with the associated load-display system.

Specific test method requirements are as follows:

ASTM A 370 -------	verification required every 18 months, recommended every 12 months (ASTM E 4),
ASTM F 606 -------	verification required every 18 months, recommended every 12 months (ASTM E 4),
ASTM F 606M ------	verification required every 18 months, recommended every 12 months (ASTM E 4),
DOD-STD-1312-108 -	verification required every 6 months (ASTM E 4 and MIL-STD-45662),
ISO 898-1 --------	not specified,
MIL-STD-1312-8A --	verification required every 12 months (ASTM E 4 and MIL-STD-45662),
SAE J429 ---------	verification required every 18 months, recommended every 12 months (ASTM E 4),
SAE J1216 --------	verification required every 18 months, recommended every 12 months (ASTM E 4).

2. Gripping fixtures Appropriate fastener gripping fixtures (see test method) are required with the capacities and dimensions for the sizes and types of fasteners to be tested. Fastener gripping fixtures should be self-aligning and positioned such that the axis of the fastener coincides with the load axis of the testing machine. The fixtures must show no indications of overload, such as deformation or specimen indents.

3. Companion fasteners For test methods which allow companion or mating fasteners as part of the test fixture, the companion fastener (bolt or nut) used for testing must be of sufficient strength to ensure failure of the fastener under test.

4. Assembly in fixtures The fastener must be installed in the gripping fixtures leaving the appropriate number of free threads subject to the load (typically, six threads are exposed between the fixtures, see method).

5. Load application Load is applied until failure of the test fastener occurs.

6. Tensile strength When reporting tensile strength as a stress use the following relationships:

ASTM F 606 and ASTM A 370

$$S_u = P_{max} / A_s$$

where: S_u = Tensile strength, lbf/in^2,
P_{max} = Maximum load, lb force,
A_s = thread stress area, in^2, defined as

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

where: D = nominal diameter of the fastener, in,
n = number of threads per inch.

ASTM F 606M

$$S_u = P_{max} / A_s$$

where: S_u = Tensile strength, MPa,
P_{max} = Maximum load, N,
A_s = thread stress area, mm^2, defined as

$$A_s = 0.7854\ (D-0.9382\ P)^2$$

where: D = nominal diameter of the fastener, mm,
P = thread pitch, mm.

ISO 898-1

$$R_m = P_{max} / A_s$$

where: R_m = Tensile strength, N/mm^2,
P_{max} = Maximum load, N,
A_s = thread stress area, mm^2, defined as

$$A_s = \frac{\pi}{4}\left(\frac{d_2+d_3}{2}\right)^2$$

where: d_2 = basic pitch diameter of the thread, mm, and
d_3 = minor diameter of the thread, mm

in which $d_3 = d_1 - H/6$

where: d_1 = basic minor diameter, mm, and
H = height of fundamental triangle of the thread, mm.

7. Fastener acceptability Acceptability or rejection of the fastener is based on the maximum load sustained by the fastener. In addition, for acceptance failure must occur in the body or threaded section of the fastener and not at the junction of the head and shank.

REFERENCED DOCUMENTS:

ASTM E 4: Standard Practices for Load Verification of Testing Machines

ASTM E 8: Standard Test Methods of Tension Testing of Metallic Materials

MIL-STD-45662: Calibration Systems Requirements

TEST METHOD TITLE: Wedge Tensile Strength of Full-Size Threaded Fasteners

TEST METHOD DESIGNATIONS:

AASHTO T 244-79 (1986): Standard Methods and Definitions for Mechanical Testing of Steel Products
Supplement 3 - Steel Fasteners, Section S11.1.5: Tension Testing of Full Size Bolts with a Wedge, and Section S11.1.6: Wedge Testing of HT Bolts Threaded to Head [Identical to ASTM A 370-77]

ASTM A 370-90: Standard Test Methods and Definitions for Mechanical Testing of Steel Products
Annex A3 - Steel Fasteners, Section A3.2.1.5: Tension Testing of Full Size Bolts with a Wedge, and Section A3.2.1.6: Wedge Testing of HT Bolts Threaded to Head

ASTM F 606-90: Standard Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets
Sections 3.5: Wedge Tension Testing of Full Size Product

ASTM F 606M-91: Standard Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets (Metric)
Sections 3.5: Wedge Tension Testing of Full Size Products

DOD-STD-1312-108, 26 March 1984: Fastener Test Methods, Metric, Method 108, Tensile Strength

FED. TEST METHOD STD. No. 151b, November 24,1967: Federal Test Method Standard, Metals: Test Methods, [ASTM A 370 is the accepted test method.]

ISO 898-1, 1988: Mechanical properties of fasteners - Part 1: Bolts, screws and studs
Section 8.5: Test for strength under wedge loading of full-size bolts and screws (not studs)

MIL-STD-1312-8A, 19 October 1984: Fastener Test Methods, Method 8, Tensile Strength

MIL-STD-1312-18, 26 July 1985: Fastener Test Methods, Method 18, Elevated Temperature Tensile Strength

SAE J429, August 1983: Mechanical and Material Requirements for Externally Threaded Fasteners
Section 5.5: Wedge Tensile Strength

SAE J1216, March 1978: Test Methods for Metric Threaded Fasteners
Section 3.6: Wedge Tensile Strength

TEST DESCRIPTION: The Wedge Tensile Strength of Full-Size Threaded Fasteners test is for determining the maximum tensile load or stress that a fastener is capable of sustaining when subjected to eccentric loading. This is accomplished by loading the fastener in tension with a wedge under the head when testing a bolt or screw, or with a threaded wedge when testing a stud. The fastener is tested in tension until failure. Tensile strength is based on the maximum load sustained by the fastener during the test.

TECHNICAL REQUIREMENTS / CRITICAL ELEMENTS:

1. Testing machine A test machine is required which is capable of applying the specified axial tensile load to the fastener and test fixture. A mechanism is required for determining maximum load sustained by the fastener during the test.

   Crosshead speed: Specific test method requirements are as follows:

   ASTM A 370 ------- as prescribed in the individual product specifications
   ASTM F 606 ------- 1 in/min or slower
   ASTM F 606M ------ 25 mm/min or slower
   DOD-STD-1312-108 - load rate dependent, see method
   ISO 898-1 -------- 25 mm/min or slower
   MIL-STD-1312-8A -- load rate dependent, see method
   SAE J429 --------- 1 in/min or slower
   SAE J1216 -------- 25 mm/min or slower

   Note: Average crosshead speed can be experimentally determined by using suitable length measuring and timing devices - see ASTM E 8.

   Load measuring device: each load measuring device must be verified by a method complying with ASTM E 4 at the specified intervals, or when the test machine is repaired or relocated. If proficiency tests indicate a load discrepancy, a new verification is required. Each load measuring device must be verified in conjunction with the associated load-display system.

   Specific test method requirements are as follows:

   ASTM A 370 ------- verification required every 18 months, recommended every 12 months (ASTM E 4),
   ASTM F 606 ------- verification required every 18 months, recommended every 12 months (ASTM E 4),
   ASTM F 606M ------ verification required every 18 months, recommended every 12 months (ASTM E 4),
   DOD-STD-1312-108 - verification required every 6 months (ASTM E 4 and MIL-STD-45662),

ISO 898-1 -------- not specified,
MIL-STD-1312-8A -- verification required every 12 months (ASTM E 4 and MIL-STD-45662),
SAE J429 --------- verification required every 18 months, recommended every 12 months (ASTM E 4),
SAE J1216 -------- verification required every 18 months, recommended every 12 months (ASTM E 4).

2. Gripping fixtures Appropriate fastener gripping fixtures (see test method) are required with the capacities and dimensions for the sizes and types of fasteners to be tested. Fastener gripping fixtures should be self-aligning and positioned such that the axis of the fastener coincides with the load axis of the testing machine. The fixtures must show no indications of overload, such as deformation or specimen indents.

3. Wedges Wedges are required having the appropriate dimensions, wedge angle and hardness (see methods). The angle of the wedge is dependent on the fastener size and grade and on the test method. The wedges are to be used as described in the appropriate test method.

   The hole diameter in the wedge and the radius or depth of chamfer at the hole top and bottom are dependent on the fastener diameter and the test method.

   The outside diameter of the wedge must be greater than the head size of the fastener.

   The wedge thickness at the thin side of the hole is dependent on the test method, but is typically one half the fastener diameter.

4. Companion fasteners For test methods which allow companion or mating fasteners as part of the test fixture, the companion fastener (bolt or nut) used for testing must be of sufficient strength to ensure failure of the fastener under test.

5. Assembly in fixtures The fastener must be installed in the gripping fixtures leaving the appropriate number of free threads subject to the load (typically, six threads are exposed between the fixtures, see method).

6. Testing bolts and screws When testing bolts or screws having a head configuration containing a flat on the edge (i.e., square head or hexagon head), the flat of the head must be aligned with the direction of uniform thickness of the wedge.

   Failure must occur in the body or threaded section of the fastener and not at the junction of the head and shank.

7. Testing studs [ASTM and SAE test methods only] A threaded wedge is required. The length of the threaded section of the wedge must be equal to at least the diameter of the stud.

   The support fixture under the wedge requires a hole diameter clearance and hole edge chamfers dependent on the stud size and test method.

   The wedge may be counterbored to facilitate removal of the broken stud (required by SAE test methods).

   The wedge thickness at the thin side of the hole must be equal to the stud diameter plus the depth of the counterbore.

   The end of the stud which will not have the threaded washer must be assembled into a threaded fixture to the thread run-out.

   When testing studs having unlike threads, the threaded wedge should be placed on the end having the coarser pitch thread or with the smaller minor diameter.

8. Load application Load is applied until failure of the test fastener occurs.

9. Tensile strength When reporting tensile strength as a stress use the following relationships:

   ASTM F 606 and ASTM A 370

$$S_u = P_{max} / A_s$$

   where: S_u = Tensile strength, psi,
   P_{max} = Maximum load, lb force,
   A_s = thread stress area, in^2, defined as

$$A_s = 0.7854 \, [D-(0.9743)/n]^2$$

   where: D = nominal diameter of the fastener, in,
   n = number of threads per inch.

   ASTM F 606M

$$S_u = P_{max} / A_s$$

   where: S_u = Tensile strength, MPa,
   P_{max} = Maximum load, N,

A_s = thread stress area, mm^2, and

$A_s = 0.7854\ (D-0.9382\ P)^2$

where: D = nominal diameter of the fastener, mm,
P = thread pitch, mm.

ISO 898-1

$R_m = P_{max} / A_s$

where: R_m = Tensile strength, N/mm^2,
P_{max} = Maximum load, N,
A_s = thread stress area, mm^2, defined as

$$A_s = \frac{\pi}{4}\left(\frac{d_2+d_3}{2}\right)^2$$

where: d_2 = basic pitch diameter of the thread, mm, and
d_3 = minor diameter of the thread, mm

in which $d_3 = d_1 - H/6$

where: d_1 = basic minor diameter, mm, and
H = height of fundamental triangle of the thread, mm.

10. Fastener acceptability Acceptability or rejection of the fastener is based on the maximum load sustained by the fastener. In addition, when testing bolts or screws, the failure must occur in the body or threaded section of the fastener and not at the junction of the head and shank.

REFERENCED DOCUMENTS:

ASTM E 4: Standard Practices for Load Verification of Testing Machines

ASTM E 8: Standard Test Methods of Tension Testing of Metallic Materials

MIL-STD-45662: Calibration Systems Requirements

TEST METHOD TITLE: Yield Strength of Full-Size Externally Threaded Fasteners

TEST METHOD DESIGNATIONS:

AASHTO T 244-79 (1986): Standard Methods and Definitions for Mechanical Testing of Steel Products
Supplement 3 - Steel Fasteners, Section S11.1.3.1: (Proof Load) Method 2, Yield Strength [Identical to ASTM A 370-77]

ASTM A 370-90: Standard Test Methods and Definitions for Mechanical Testing of Steel Products
Annex A3 - Steel Fasteners, Section A3.2.1.3(a): (Proof Load) Method 2, Yield Strength

ASTM F 606-90: Standard Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets
Section 3.2.4: (Proof Load) Method 2, Yield Strength

ASTM F 606M-91: Standard Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets (Metric)
Section 3.2.4: (Proof Load) Method 2, Yield Strength

DOD-STD-1312-108, 26 March 1984: Fastener Test Methods, Metric, Method 108, Tensile Strength

FED. TEST METHOD STD. No. 151b, November 24,1967: Federal Test Method Standard, Metals: Test Methods, [ASTM A 370 is the accepted test method.]

MIL-STD-1312-8A, 19 October 1984: Fastener Test Methods, Method 8, Tensile Strength

MIL-STD-1312-18, 26 July 1985: Fastener Test Methods, Method 18, Elevated Temperature Tensile Strength

TEST DESCRIPTION: The Yield Strength of Full-Size Externally Threaded Fasteners test is for determining the load or stress at which a fastener exhibits a specified deviation from the proportionality of load to elongation, or stress to strain. This is accomplished by axially loading the fastener in tension, and simultaneously measuring and recording the applied load and the fastener elongation. Yield strength is determined from the resulting load-elongation (or stress-strain) curve by a method described in the test method.

The Yield Strength of Full-Size Externally Threaded Fasteners test is included in the ASTM test methods as an alternate to the

Length Measurement method for determining Proof Load. Yield strength is determined by these test methods using the 0.2% offset method (see test methods).

For test methods DOD-STD-1312-108 and MIL-STD-1312-8A, yield strength is reported as yield load, and is determined using the Johnson two-thirds approximate method (see test methods).

TECHNICAL REQUIREMENTS / CRITICAL ELEMENTS:

1. Testing machine A test machine is required which is capable of applying the specified yield load to the fastener and test fixture.

   Crosshead speed: Specific test method requirements are as follows:
   ASTM A 370 ------- as prescribed in the individual product specifications
   ASTM F 606 ------- 1 in/min or slower
   ASTM F 606M ------ 25 mm/min or slower
   DOD-STD-1312-108 - load rate dependent, see method
   MIL-STD-1312-8A -- load rate dependent, see method
   MIL-STD-1312-18 -- load rate dependent, see method

   Note: Average crosshead speed can be experimentally determined by using suitable length measuring and timing devices - see ASTM E 8.

   Load measuring device: each load measuring device must be verified by a method complying with ASTM E 4 at the specified intervals, or when the test machine is repaired or relocated. If proficiency tests indicate a load discrepancy, a new verification is required. Each load measuring device must be verified in conjunction with the associated load-display system.

   Specific test method requirements are as follows:
   ASTM A 370 ------- verification required every 18 months, recommended every 12 months (ASTM E 4),
   ASTM F 606 ------- verification required every 18 months, recommended every 12 months (ASTM E 4),
   ASTM F 606M ------ verification required every 18 months, recommended every 12 months (ASTM E 4),
   DOD-STD-1312-108 - verification required every 6 months (ASTM E 4 and MIL-STD-45662),
   MIL-STD-1312-8A -- verification required every 12 months (ASTM E 4 and MIL-STD-45662),
   MIL-STD-1312-18 -- verification required every 12 months (ASTM E 4 and MIL-STD-45662),

2. Gripping fixtures Appropriate fastener gripping fixtures

(see test method) are required with the capacities and dimensions for the sizes and types of fasteners to be tested. Fastener gripping fixtures should be self-aligning and positioned such that the axis of the fastener coincides with the load axis of the testing machine. The fixtures must show no indications of overload, such as deformation or specimen indents.

3. Fastener-extension measuring system To measure fastener extension, the preferable method is to place the extension measuring device over the ends of the fastener. Alternately, when using the type of fastener gripping fixtures described in the ASTM test methods and NAS 1069, which transmit the tensile load to the fastener by loading the fixtures in tension, the extension measuring device can be placed adjacent to the fastener between the facing surfaces of the fixtures. When using the type of fastener gripping fixtures described in the DOD and MIL Standard test methods, which transmit the tensile load to the fastener by loading the fixtures in compression, the extension measuring device can be placed adjacent to the fastener on the external opposed surfaces of the tension plates. In all cases, the fixtures must be non-yielding over the entire fastener test load range.

   The extension measuring device, used in conjunction with an data recording system, must meet ASTM E 83, Class B1 requirements. The minimum extensometer magnification must be 250 to 1. Each extension measuring device must be verified by a method complying with ASTM E 83 as specified, or when the extension measuring device is adjusted or repaired. If proficiency tests indicate a discrepancy, a new verification is required. The extension measuring device must be capable of installation so as to measure the extension of the fastener only.

4. Data recording system A data recording system, such as an autographic recording device, is required to be used in conjunction with the load measuring and extension measuring devices. The system must record load and elongation, and provide an appropriate load-elongation (stress-strain) curve for determining yield strength. [Note: The ASTM test methods allow the use of an automatic device which determines offset yield strength without plotting a stress-strain curve as long as the device accuracy has been demonstrated.]

5. Assembly in fixtures The fastener must be installed in the gripping fixtures leaving the appropriate number of free threads subject to the load (typically, six threads are exposed between the fixtures, see method).

6. Load application As load is applied, elongation of the total

fastener or any part which includes the exposed threads must be measured and recorded to produce a load-elongation (or stress-strain) diagram.

7. Yield strength When testing to the ASTM test methods, yield strength is determined by the 0.2% offset method (see test methods). When following the 0.2% offset method for determining yield strength, the offset is 0.2% of the length of the exposed threads bearing the load (typically six full threads, except for heavy hex structural bolts which is four threads).

   For test methods DOD-STD-1312-108, MIL-STD-1312-8A and MIL-STD-1312-18, yield strength is reported as yield load, and is determined using the Johnson two-thirds approximate method (see test methods).

   When reporting yield strength as a stress use the following relationships:

   ASTM F 606 and ASTM A 370

$$S_u = P_{max} / A_s$$

   where: S_u = Yield strength, psi,
   P_{max} = Yield load, lb force,
   A_s = thread stress area, in^2, and

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

   where: D = nominal diameter of the fastener, in,
   n = number of threads per inch.

   ASTM F 606M

$$S_u = P_{max} / A_s$$

   where: S_u = Yield strength, MPa,
   P_{max} = Yield load, N,
   A_s = thread stress area, mm^2, and

$$A_s = 0.7854\ (D-0.9382\ P)^2$$

   where: D = nominal diameter of the fastener, mm,
   P = thread pitch, mm.

8. Fastener acceptability Acceptability or rejection of the fastener is based on the yield load or yield stress exhibited by the fastener.

REFERENCED DOCUMENTS:

ASTM E 4: Standard Practices for Load Verification of Testing Machines

ASTM E 8: Standard Test Methods of Tension Testing of Metallic Materials

ASTM E 83: Standard Practice for Verification and Classification of Extensometers

MIL-STD-45662: Calibration Systems Requirements

NAS 1069: Tension Fatigue Test Procedure for Aeronautical Fasteners

Section 4 - STRESS RUPTURE

MIL-STD-1312-10, 19 October 1984: Fastener Test Methods, Method 10, Stress Rupture

STRESS RUPTURE

MIL-STD-1312-10

Part A: RECOMMENDATIONS

MIL-STD-1312-10, 19 October 1984: Fastener Test Methods, Method 10, Stress Rupture

On the basis of this study, there is presently no suitable non-government standard to replace MIL-STD-1312-10. Two Standard Practices published by ASTM describe stress rupture testing:

> ASTM E 139: Standard Practice for Conducting Creep, Creep-Rupture, and Stress-Rupture Tests of Metallic Materials
>
> ASTM E 292: Standard Practice for Conducting Time-for-Rupture Notch Tension Tests of Materials.

These standards, however, do not directly address the testing of fasteners, and could not adequately replace MIL-STD-1312-10.

Currently, MIL-STD-1312-10 is cited as the required stress rupture test method in many fastener specifications published by several organizations including the military, the Aerospace Industries Association of America (AIA), and SAE International (Aerospace). The wide use of this standard indicates its acceptance as a national standard. It is recommended that MIL-STD-1312-10 be reviewed, and either be revalidated or, if required, be revised. Also, in keeping with past practice, a new metric counterpart to MIL-STD-1312-10 should be written (e.g., DOD-STD-1312-110).

Part B: REQUIREMENT SUMMARIES

The following are requirement summaries of the primary United States test standards dealing with stress rupture of fasteners and fastener materials. Specific requirements of test standard MIL-STD-1312-10 are often listed where they differ from other standards.

TEST METHOD TITLE: Stress Rupture of Fasteners

TEST METHOD DESIGNATIONS:

ASTM E 139-83 (Reapproved 1990): Standard Practice for Conducting Creep, Creep-Rupture, and Stress-Rupture Tests of Metallic Materials

ASTM E 292-83 (Reapproved 1990): Standard Practice for Conducting Time-for Rupture Notch Tension Tests of Materials

MIL-STD-1312-10, 19 October 1984: Fastener Test Methods, Method 10, Stress Rupture

TEST DESCRIPTION: The Stress Rupture of Fasteners test is for determining the time to rupture or fracture for a fastener subjected to a constant axial tensile load and constant temperature. The Stress Rupture of Fasteners test can also be used for determining whether a fastener is capable of sustaining a specified constant load and constant temperature for a minimum time period. In either case, the test is conducted by subjecting a fastener, or a test specimen machined from the fastener, to a specified temperature, and then loading the fastener or specimen in tension to a specified load level. The fastener is maintained at this load and temperature until the fastener fails or until a specified test time has elapsed.

TECHNICAL REQUIREMENTS / CRITICAL ELEMENTS:

1. Testing machine A test machine is required which can axially load the fastener or test specimen in tension, and maintain the applied load within specified limits until rupture of the specimen occurs or a specified time period elapses. The test machine must have a means to adjust for extension of the test fastener while maintaining the load level. A suitable type of testing machine includes a lever-arm creep testing machine.

   Axiality of loading Each test machine must ensure that the maximum bending strain does not exceed 10 percent of the axial strain. The axiality of loading must be periodically verified at room temperature on the assembled machine, pull rods, and grips by a suitable method such as described in ASTM E 602.

Load measuring system Each test machine must ensure the application of the load to an accuracy of 1 percent over the working range. The load measuring system must be verified by a method complying with ASTM E 4 and ASTM E 74 at least every 12 months or when the test machine is repaired or relocated. If proficiency tests indicate a load discrepancy, a new verification is required.

The test machine must be erected in a manner and in a location such that it is free of vibration and shock due to external causes.

2. Gripping Fixtures Appropriate specimen gripping fixtures are required with the capacities and dimensions for the sizes and types of fasteners or machined specimens to be tested. The specimen gripping fixtures should be attached to the testing machine, through a load train, such that they are self-aligning and the axis of the specimen coincides with the load axis of the testing machine.

3. Heating apparatus and temperature control An apparatus is required for heating the test fastener or machined specimen. The heating apparatus must be of a design and construction that ensures that it will not apply any force to the test specimen or loading mechanisms. A suitable heating apparatus for stress-rupture testing is a tubular electric resistance or radiation furnace.

   The heating apparatus must have a controller capable of attaining and controlling a temperature along the reduced section, notches, or other critical areas of the test fastener or test specimen. Temperature variations in the critical areas must not exceed the following limits:

   ASTM E 139
   Up to and including ---- 1800 ± 3°F (1000 ± 2°C)
   Above ------------------ 1800 ± 5°F (1000 ± 3°C)

   ASTM E 292
   Up to and including ---- 1800 ± 3°F (980 ± 1.7°C)
   Above ------------------ 1800 ± 5°F (980 ± 2.8°C)

   MIL-STD-1312-10
   Up to and including ---- 1200 ± 5°F
   Above ------------------ 1200 ± 3°F.

4. Temperature measurement Thermocouples are required having welded beads with no electrical shorts between the leads,

such as would be caused by twisting the wires. The thermocouples must be attached to the test fastener or test specimen in the manner and at the locations as specified in test methods. The thermocouple wire must have a calibration traceable to NIST.

A temperature recording system is required which can record the thermocouple readings for the duration of the test. A multipoint strip-chart recorder is a satisfactory method for recording the temperature readings. ASTM E 292 allows temperature readings to be recorded manually at least once a day.

The temperature measuring, controlling, and recording instruments must be calibrated at least every 12 months or when the test machine is repaired or relocated by a suitable method such as described in ASTM E 220.

5. Elapsed-time indicator An elapsed-time indicator is required which must have an accuracy of 1 percent of the total test time.

6. Test specimen preparation Fasteners may be tested full size or as round machined specimens as specified in the specification or test method.

   The test fastener or test specimen must be cleaned as specified in the specification or test method. The specific requirements of the test methods are as follows:

   ASTM E 139 and ASTM E 292 require that the specimen be washed in a suitable clean solvent that will not affect the metal being tested.

   MIL-STD-1312-10 requires that the test specimen be cleaned with detergent and rinsed with deionized water, followed by rinsing with isopropyl alcohol and air or blow drying. Specimen cleaning must be within one hour of testing. Following cleaning, the test specimen must be handled only with clean, lintless cotton gloves.

7. Test procedures For product specifications which specify percent elongation measurements, the original and final gage lengths must be measured with an instrument capable of resolving the gage length within 0.01 in. (0.2 mm), such as a micrometer or open-end caliper.

   When a bolt or bolt/nut combination is to be tested, MIL-STD-1312-10 requires that the test fastener must be installed in the gripping fixtures such that two to three free threads are exposed between the fixtures.

The load must be applied in a manner which avoids shock loading, overloading, or application of torque. The time for applying the load must be held to a minimum (MIL-STD-1312-10 requires that the time for loading must not exceed one minute).

During the test period, if the specimen temperature rises above or falls below the specified limits, the test must be rejected and retesting is required.

REFERENCED DOCUMENTS:

ASTM E 4: Standard Practices for Load Verification of Testing Machines

ASTM E 8: Standard Test Methods of Tension Testing of Metallic Materials

ASTM E 74: Standard Practice of Calibration of Force-Measuring Instruments for Verifying the Load Indication of Testing Machines

ASTM E 220: Standard Method for Calibration of Thermocouples by Comparison Techniques

ASTM E 602: Standard Method for Sharp-Notch Tension Testing with Cylindrical Specimens

MIL-STD-45662: Calibration Systems Requirements

Section 5 - TENSION FATIGUE

MIL-STD-1312-11A, 19 October 1984: Fastener Test Methods, Method 11, Tension Fatigue

DOD-STD-1312-111, 26 March 1984: Fastener Test Methods, Metric, Method 111, Tension Fatigue

TENSION FATIGUE

MIL-STD-1312-11A
DOD-STD-1312-111

Part A: RECOMMENDATIONS

MIL-STD-1312-11A, 19 October 1984: Fastener Test Methods, Method 11, Tension Fatigue

On the basis of this study, there is presently no suitable non-government standard to replace MIL-STD-1312-11A. Currently, MIL-STD-1312-11A is cited as the required tension fatigue test method in many fastener specifications published by several organizations including the military, the Aerospace Industries Association of America (AIA), and SAE International. The wide use of this standard indicates its acceptance as a national standard.

It is recommended that fastener test method MIL-STD-1312-11A be reviewed and revised in conjunction with DOD-STD-1312-111 to ensure consistency between the standards. The following are suggested recommendations for revising MIL-STD-1312-11A.

The referenced specifications and standards of Section 2 should be updated (e.g. MIL-I-6868 was replaced by MIL-STD-1949A which was replaced by ASTM E 1444).

The text of sections 4 and 5 of MIL-STD-1312-11A should be edited to be consistent with the present text of DOD-STD-1312-111 which is the better document, however, both test standards MIL-STD-1312-11A and DOD-STD-1312-111 should be updated to reflect current fatigue testing equipment and practices.

MIL-STD-1312-11A should be expanded to incorporate a reviewed and modified (if required) version of Appendix C of MIL-STD-1312B, "Alignment and Load Verification of Axial-Load Fatigue Testing Machines" as a section or appendix within MIL-STD-1312-11A. This would bring the alignment and load verification requirements into the test method standard where they belong.

DOD-STD-1312-111, 26 March 1984: Fastener Test Methods, Metric, Method 111, Tension Fatigue

On the basis of this study, there is presently no suitable non-government standard to replace DOD-STD-1312-111. Currently, MIL-STD-1312-11A (the non-metric counterpart to DOD-STD-1312-111) is cited as the required tension fatigue test method in many fastener specifications published by several organizations including the military, the Aerospace Industries Association of

America (AIA), and SAE International. The wide use of this standard indicates its acceptance as a national standard.

It is recommended that fastener test method DOD-STD-1312-111 be reviewed and revised in conjunction with MIL-STD-1312-11A to ensure consistency between the standards. The following are suggested recommendations for revising DOD-STD-1312-111.

The referenced specifications and standards of section 2 should be updated (e.g. MIL-I-6868 was replaced by MIL-STD-1949A which was replaced by ASTM E 1444).

Both test standards MIL-STD-1312-11A and DOD-STD-1312-111 should be updated to reflect current fatigue testing equipment and practices.

DOD-STD-1312-111 should be expanded to incorporate a reviewed and modified (if required) version of Appendix C of MIL-STD-1312B, "Alignment and Load Verification of Axial-Load Fatigue Testing Machines" as a section or appendix within DOD-STD-1312-111. This would bring the alignment and load verification requirements into the test method standard where they belong.

Part B: REQUIREMENT SUMMARIES

The following are requirement summaries of the primary United States test standards dealing with fatigue of fasteners and fastener materials. Specific requirements of test standards MIL-STD-1312-11A and DOD-STD-1312-111 are often listed where they differ from other standards.

TEST METHOD TITLE: Fatigue of Full-size Threaded Fasteners

TEST METHOD DESIGNATIONS:

DOD-STD-1312-111, 26 March 1984: Fastener Test Methods, Metric, Method 111, Tension Fatigue

ISO 3800/1, 1977-05-01: Threaded Fasteners - Axial load fatigue testing - Part 1: Test Methods

MIL-STD-1312-11A, 19 October 1984: Fastener Test Methods, Method 11, Tension Fatigue

NAS 1069, 1959: Tension Fatigue Test Procedure for Aeronautical Fasteners

TEST DESCRIPTION: The Fatigue of Full-size Threaded Fasteners test is for determining the axial tension-tension fatigue capability of full-size threaded fasteners. This is accomplished by axially loading the fastener through high/low tensile load cycles until the fastener fails, or until a predetermined number of cycles has been exceeded.

TECHNICAL REQUIREMENTS / CRITICAL ELEMENTS:

1. Testing Machine A fatigue testing machine is required which is capable of applying a cyclic axial load to the test fastener. The testing machine must be capable of maintaining the loads within 2 percent of the entire range of load levels.

2. Load Measuring Device: Each load measuring device must be verified statically and dynamically using suitable methods at least every 6 months or after 1000 hours of operating time whichever comes first, or when the test machine is repaired or relocated. If proficiency tests indicate a load discrepancy, a new verification is required. Each load measuring device must be verified in conjunction with the associated load-display system.

   Suitable load verification procedures are specified as follows:
   DOD-STD-1312-111 -- Appendix C of MIL-STD-1312,

ISO 3800/1 -------- not specified,
MIL-STD-1312-11 --- Appendix C of MIL-STD-1312,
NAS 1069 ---------- Appendix A of the test method.

3. Cycle counter The testing machine must be equipped with a device for counting the number of load cycles.

4. Gripping Fixtures Appropriate fastener gripping fixtures (see test methods) are required with the capacities and dimensions for the sizes and types of fasteners to be tested.

   Test nuts and bolts
   When testing externally threaded fasteners, an appropriate test nut or threaded adapter must be used. Each test method requires specific material, dimensional, hardness, and strength requirements for the test nuts (see test methods). The reusability of the test nuts is limited as follows:

   DOD-STD-1312-111 -- may be reused a maximum of five times if not damaged and on the same lot of bolts only,
   ISO 3800/1 -------- may be reused a maximum of six times if not damaged,
   MIL-STD-1312-11 --- may be reused a maximum of five times if not damaged and on the same lot of bolts only,
   NAS 1069 ---------- may not be reused.

   When evaluating nuts, an appropriate test bolt must be used (see test methods). Test methods DOD-STD-1312-111 and MIL-STD-1312-11 require that the test bolts be as specified in the product specification, and that prior to evaluating the nuts, a sample of the test bolts be tested using test nuts to determine their reliability. The reusability of the test bolts is limited as follows:

   DOD-STD-1312-111 -- may not be reused,
   ISO 3800/1 -------- not specified,
   MIL-STD-1312-11---- may not be reused,
   NAS 1069 ---------- may not be reused.

   Fixture alignment The alignment of the test setup must be verified statically and dynamically as specified in the test method each time the fixtures are changed or at least every 6 months whichever comes first, or when the test machine is repaired or relocated. Suitable alignment verification procedures are specified as follows:

   DOD-STD-1312-111 -- Appendix C of MIL-STD-1312,
   ISO 3800/1 -------- Section 5.3 of the test method,
   MIL-STD-1312-11 --- Appendix C of MIL-STD-1312,

NAS 1069 ---------- Appendix A of the test method.

5. Test procedures

Installation into gripping fixtures The fasteners must be assembled into the gripping fixtures as follows:

DOD-STD-1312-111: Tension bolts must be assembled with a minimum of two and a maximum of three threads exposed between the nut bearing face and bolt thread run out. Shear bolts must be assembled with a minimum of one half and a maximum of one thread exposed between the nut bearing face and bolt thread run out.

ISO 3800/1: Assembled with four to six pitches exposed between the nut bearing face and bolt thread run out. The nut threads must be fully engaged with a bolt length of at least one pitch protruding beyond the test nut.

MIL-STD-1312-11: Tension bolts must be assembled with a minimum of two and a maximum of three threads exposed between the nut bearing face and bolt thread run out. Shear bolts must be assembled with a minimum of one half and a maximum of one thread exposed between the nut bearing face and bolt thread run out.

NAS 1069: Tension fasteners must be assembled with approximately two pitches exposed between the nut bearing face and bolt thread run out. Short thread shear fasteners must be assembled with approximately one pitch exposed between the nut bearing face and bolt thread run out. If the bolt/nut combination does not provide sufficient threads to meet this requirement, the number of pitches must be reduced so that the nut threads are fully engaged on the bolt.

Load application The load levels (maximum and minimum loads) must be as specified in the product specification. There must be no torsional load applied to the fasteners.

Load ratio The load ratio must be as specified in the product specification or test method. The test methods specify the load ratio as follows:

DOD-STD-1312-111, MIL-STD-1312-11, and NAS 1069: the ratio of low load to high load must be one tenth (0.1),

ISO 3800/1: not specified.

Test speed The test speed (cycle frequency) must as follows:

DOD-STD-1312-111: The test speed must not exceed 210 Hz. The fastener temperature must not exceed 66°C as a result of test speed.

ISO 3800/1: The test speed must be between 4.2 and 250 Hz. The fastener temperature at the first engaged thread must not rise more than 50°C as a result of test speed.

MIL-STD-1312-11: The test speed must not exceed 12,500 cycles per minute. The fastener temperature must not exceed 150°F as a result of test speed.

NAS 1069: The test speed must not exceed 3600 cycles per minute.

Cycling Duration The duration of testing must be as specified in the product specification.

6. Fastener failure Fracture in the threads of the nut or bolt, or breakdown of the nut or bolt threads such that they fail to support the test loads constitutes failure and a valid test conclusion. Fracture of the bolt in any location other than the threads is not a valid test and the test must be repeated with a new nut and bolt.

7. Lubrication ISO 3800/1 requires that the test fasteners be thoroughly cleaned and coated with SAE 20 or equivalent oil prior to testing.

REFERENCED DOCUMENTS:

MIL-STD-1312: Fastener Test Methods

Section 6 - THICKNESS OF METALLIC COATINGS

MIL-STD-1312-12, 26 July 1985: Fastener Test Methods, Method 12, Thickness of Metallic Coatings

THICKNESS OF METALLIC COATINGS

MIL-STD-1312-12

MIL-STD-1312-12, 26 July 1985: Fastener Test Methods, Method 12, Thickness of Metallic Coatings

On the basis of this study, there is presently no suitable non-government standard to completely replace MIL-STD-1312-12. The ASTM, however, does publish test standards which are suitable for replacing many of the thickness of metallic coatings tests covered by MIL-STD-1312-12. It is recommended that the present requirements and procedures specified in MIL-STD-1312-12 for these individual test methods be replaced with statements specifying the use of an appropriate ASTM standard. Test methods which are unique to MIL-STD-1312-12 should be retained. The present text of MIL-STD-1312-12 which describes general requirements and procedures for testing fasteners should also be retained in the document. These sections include the following: 1. Scope; 2. Referenced Documents; 3. Definitions; 4.2. Test Specimens; and 6.1 Test report (which should be renumbered as 6.).

Currently, MIL-STD-1312-12 addresses the measurement of fastener coating thickness without regard to the fastener size or thread dimensions. As a result, a metric counterpart to MIL-STD-1312-12 is not required.

It is recommended that revisions be made to MIL-STD-1312-12 as follows:

1. Drop test method Although the drop test continues to be used in some laboratories, this method should be considered for removal from MIL-STD-1312-12 because of its poor over-all accuracy compared to other coating thickness measurement methods. This method now references Method 523 of FED-STD-151 for requirements. Method 523 of FED-STD-151 was discontinued and replaced by ASTM A 219. ASTM A 219 was discontinued and replaced by individual coating thickness measurement test standards (ASTM B 244, ASTM B 487, ASTM B 499, ASTM B 504, ASTM B 530), none of which covers the Drop test method. ASTM currently does have a Standard Guide describing this method, ASTM B 555: Standard Guide for Measurement of Electrodeposited Metallic Coating Thicknesses by the Dropping Test, which could be specified for use, if it is desired to retain this method within MIL-STD-1312-12.

2. Magnetic test method The following ASTM standards should replace the magnetic test method depending on the coating

and substrate materials:

ASTM B 499: Standard Test Method for Measurement of Coating Thicknesses by the Magnetic Method: Nonmagnetic Coatings on Magnetic Basis Metals

ASTM B 530: Standard Test Method for Measurement of Coating Thicknesses by the Magnetic Method: Electrodeposited Nickel Coatings on Magnetic and Nonmagnetic Substrates.

3. Eddy-current method The following ASTM standard should replace the eddy-current method:

   ASTM B 244: Standard Method for Measurement of Thickness of Anodic Coatings on Aluminum and of Other Nonconductive Coatings on Nonmagnetic Basis Metals with Eddy-Current Instruments.

4. Microscopic method The following ASTM standard should replace the microscopic method:

   ASTM B 487: Standard Test Method for Measurement of Metal and Oxide Coating Thickness by Microscopical Examination of a Cross Section.

5. Dimensional change method This method is unique to MIL-STD-1312-12 and, if desired, may be retained. It is recommended that ASTM B 767 be referenced for examples of suitable chemical stripping solutions.

6. Anodic dissolution method The following ASTM standard should replace the anodic dissolution method:

   ASTM B 504: Standard Test Method for Measurement of Thickness of Metallic Coatings by the Coulometric Method.

7. Strip and weigh method The following ASTM standard should replace the strip and weigh method:

   ASTM B 767: Standard Guided for Determining Mass Per Unit Area of Electrodeposited and Related Coatings by Gravimetric and Other Chemical Analysis Procedures.

Also, other methods for measuring coating thickness should be considered for addition to MIL-STD-1312-12. These include the following:

X-Ray spectrometric method Covered by the following ASTM standard:

ASTM B 568: Standard Test Method for Measurement of Coating

Thickness by X-Ray Spectrometry.

Beta backscatter method Covered by the following ASTM standard:

ASTM B 567: Standard Test Method for Measurement of Coating Thickness by the Beta Backscatter Method.

Part B: REQUIREMENT SUMMARIES

The following are examples of requirement summaries of the primary United States and ISO test standards dealing with the measurement of coating thickness (in general and specific to fastener testing). Specific requirements of test standard MIL-STD-1312-12 are often listed where they differ from other standards.

TEST METHOD TITLE: Measurement of Fastener Coating Thickness - Magnetic Methods
[Nonmagnetic Coatings on Magnetic Substrate Metals]
[Electrodeposited Nickel Coatings on Magnetic and Nonmagnetic Substrates]

TEST METHOD DESIGNATIONS:

ASTM B 499 - 88: Standard Test Method for Measurement of Coating Thicknesses by the Magnetic Method: Nonmagnetic Coatings on Magnetic Basis Metals

ASTM B 530 - 88: Standard Test Method for Measurement of Coating Thicknesses by the Magnetic Method: Electrodeposited Nickel Coatings on Magnetic and Nonmagnetic Substrates

ASTM E 376 - 89: Standard Practice for Measuring Coating Thickness by Magnetic-Field or Eddy-Current (Electromagnetic) Test Methods

FED. TEST METHOD STD. No. 151b, November 24,1967: Federal Test Method Standard, Metals: Test Methods [ASTM B 499 and ASTM B 530 are the accepted test methods which replaced ASTM A 219 which replaced FED. TEST METHOD STD. No. 151a, Method 522.1.]

ISO 2178, 1982-08-01: Nonmagnetic coatings on magnetic substrates - Measurement of coating thickness - Magnetic method

ISO 2361, 1982-08-15: Electrodeposited Nickel Coatings on Magnetic and Nonmagnetic Substrates - Measurement of Coating Thickness - Magnetic Method

MIL-STD-1312-12, 26 July 1985: Fastener Test Methods, Method 12, Thickness of Metallic Coatings

TEST DESCRIPTION: The Measurement of Fastener Coating Thickness - Magnetic Methods are nondestructive methods for measuring the thickness of; (a) nonmagnetic coatings on magnetic base metal fasteners, or (b) electrodeposited nickel coatings on magnetic and nonmagnetic substrates. The measurements are typically made using commercially available instruments and appropriate calibration standards. Thickness measuring instruments of the magnetic type operate on one of two principles: (1) by measuring the influence of the coating on the magnetic attraction between a magnet and the basis metal or coating-substrate combination; or (2) by measuring the reluctance of a magnetic flux path passing through the coating and the basis metal. The thickness of the coating is determined by comparing the test measurement to a predetermined calibration relating coating thickness to the magnetic attraction or reluctance of the magnetic flux. Usually, the measuring instruments automatically calculate and display the measured coating thickness. Each of these methods requires calibration of the measuring instruments with suitable thickness standards.

TECHNICAL REQUIREMENTS / CRITICAL ELEMENTS:

1. Facilities and equipment

   a. Instrument for measuring coating thickness A magnetic type instrument is required which can determine, after calibrating with appropriate thickness standards, the coating thickness within ±10 percent of its true thickness or ±1.5 μm whichever is greater. The instrument must be of a design which allows accurate measurements to be made at the appropriate locations on the test fastener.

   b. Thickness standards Calibration standards having uniform coating thicknesses are required for calibrating the test instrument. The thickness standards may be in the form of shims or foils, or coated specimens. The surface roughness and magnetic properties of the basis metal for all types of calibration standards must be similar to that of the test fastener. The basis metal suitability must be confirmed by comparing measurement readings of an uncoated standard and an uncoated test fastener.

      Test specimen curvature can greatly influence coating thickness measurements depending on the make and type of instrument which is used. In fastener testing, where coating thickness measurements are often made on curved surfaces such as the shank or threads, the influence of curvature must be considered. When measuring curved locations, the test instrument must be calibrated using coated standards or substrates on which foils will be placed which have the same curvature as the test fastener, unless calibration on flat surfaces can be shown to result in accurate measurements.

2. Instrument calibration The test instrument must be

calibrated in accordance with the manufacturer's instructions using suitable thickness standards. Calibration must be performed with the instrument or instrument probe in the same orientation as the fastener will be measured. The test instrument must be calibrated each time the instrument is put into service and at frequent intervals during use (at least once a day).

3. Measurements Prior to testing, the fastener surface and the instrument's probe or magnet must be cleaned of all foreign material without removing any coating material.

   The location of the plate thickness measurements must be as specified in the product specification or test method.

   MIL-STD-1312-12 specifies the following locations for measurement.
   - For externally threaded fasteners having a body, measure the thickness at a point adjacent to the thread runout area.
   - For externally threaded fasteners threaded to the head, measure the thickness on the head peripheral surface when the head configuration permits accurate measurement, or on the thread pitch diameter approximately 2 diameters from the point end or one-half the fastener length when the length is less than four diameters.
   - For nuts, measure the thickness on the bearing surface at the mid-radius.

   ISO test methods specify that the fastener test surfaces on which coating thicknesses are measured must be in accordance with ISO 4042 unless otherwise specified.

   The test instrument must be operated in accordance with the manufacturer's instructions. For each measurement, take at least 3 readings at the same location, and average the results. If any of the readings vary significantly from the norm (ASTM B 499 specifies readings differing more than 5 percent of the average or 2μm, whichever is greater), then that reading is to be discarded and repeated.

REFERENCED DOCUMENTS:

ASTM B 659: Standard Guide for Measuring Thickness of Metallic and Inorganic Coatings

ISO 3882: Metallic and other non-organic coatings - Review of methods of measurement of thickness

ISO 4042: Threaded components - Electroplated coatings

TEST METHOD TITLE: Measurement of Fastener Coating Thickness - Eddy-Current Method

TEST METHOD DESIGNATIONS:

ASTM B 244 - 79: Standard Method for Measurement of Thickness of Anodic Coatings on Aluminum and of Other Nonconductive Coatings on Nonmagnetic Basis Metals with Eddy-Current Instruments (This standard replaced ASTM B 529)

ASTM E 376 - 89: Standard Practice for Measuring Coating Thickness by Magnetic-Field or Eddy-Current (Electromagnetic) Test Methods

FED. TEST METHOD STD. No. 151b, November 24,1967: Federal Test Method Standard, Metals: Test Methods, Method 520.1, Electronic Test for Local Coating Thickness

ISO 2360, 1982-08-01: Non-conductive coatings on non-magnetic basis metals - Measurement of coating thickness - Eddy-current method

MIL-STD-1312-12, 26 July 1985: Fastener Test Methods, Method 12, Thickness of Metallic Coatings

TEST DESCRIPTION: The Measurement of Fastener Coating Thickness - Eddy-Current Method is a nondestructive method generally used for measuring the thickness of nonconductive coatings on nonmagnetic base metal fasteners. Thickness measurements using the eddy current method are usually made with commercially available instruments and appropriate calibration standards. These thickness measuring instruments operate on the principle that the magnitude of eddy-currents induced in the surface of the fastener by the measuring instrument is a function of the thickness of the nonconductive coating present between the instrument probe and fastener base metal. The thickness of the coating is determined by comparing the test measurement to a predetermined calibration relating coating thickness to the magnitude of the eddy-currents. Usually, the measuring instrument automatically calculates and displays the measured coating thickness.

TECHNICAL REQUIREMENTS / CRITICAL ELEMENTS:

1. Facilities and equipment

   a. Instrument for measuring coating thickness An eddy-current type instrument is required which can determine, after calibrating with appropriate thickness standards, the coating thickness within ±10 percent of its true thickness or ±1 μm (±0.5 μm for ISO 3882) whichever is greater. The instrument must be of a design which allows accurate measurements to be made at the appropriate locations on the test fastener.

b. Thickness standards Calibration standards having uniform coating thicknesses are required for calibrating the test instrument. The thickness standards may be in the form of shims or foils, or coated specimens. The electrical and magnetic properties of the basis metal for all types of calibration standards must be similar to that of the test fastener. The basis metal suitability must be confirmed by comparing measurement readings of an uncoated standard and an uncoated test fastener.

   Test specimen curvature can greatly influence coating thickness measurements depending on the make and type of instrument which is used. In fastener testing, where coating thickness measurements are often made on curved surfaces such as the shank or threads, the influence of curvature must be considered. When measuring curved locations, the test instrument must be calibrated using coated standards or substrates on which foils will be placed which have the same curvature as the test fastener, unless calibration on flat surfaces can be shown to result in accurate measurements.

2. Instrument calibration The test instrument must be calibrated in accordance with the manufacturer's instructions using suitable thickness standards. The test instrument must be calibrated each time the instrument is put into service and at frequent intervals during use (ISO 2360 requires at least once a hour).

3. Measurements Prior to testing, the fastener surface and the instrument's probe or magnet must be cleaned of all foreign material without removing any coating material.

   The location of the plating thickness measurements must be as specified in the product specification or test method.

   MIL-STD-1312-12 specifies the following locations for measurement.
   - For externally threaded fasteners having a body, measure the thickness at a point adjacent to the thread runout area.

   - For externally threaded fasteners threaded to the head, measure the thickness on the head peripheral surface when the head configuration permits accurate measurement, or on the thread pitch diameter approximately 2 diameters from the point end or one-half the fastener length when the length is less than four diameters.

- For nuts, measure the thickness on the bearing surface at the mid-radius.

ISO test methods specify that the fastener test surfaces on which coating thicknesses are measured must be in accordance with ISO 4042 unless otherwise specified.

The test instrument must be operated in accordance with the manufacturer's instructions. For each measurement, take several readings at the same location, and average the results.

REFERENCED DOCUMENTS:

ASTM B 659: Standard Guide for Measuring Thickness of Metallic and Inorganic Coatings

ISO 3882: Metallic and other non-organic coatings - Review of methods of measurement of thickness

ISO 4042: Threaded components - Electroplated coatings

TEST METHOD TITLE: Measurement of Fastener Coating Thickness - Microscopical Method

TEST METHOD DESIGNATIONS:

ASTM B 487 - 85 (Reapproved 1990): Standard Test Method for Measurement of Metal and Oxide Coating Thickness by Microscopical Examination of a Cross Section

FED. TEST METHOD STD. No. 151b, November 24, 1967: Federal Test Method Standard, Metals: Test Methods [ASTM B 487 is the accepted test method.]

ISO 1463, 1982-07-01: Metallic and oxide coatings - Measurement of coating thickness - Microscopical method

MIL-STD-1312-12, 26 July 1985: Fastener Test Methods, Method 12, Thickness of Metallic Coatings

TEST DESCRIPTION: The Measurement of Fastener Coating Thickness - Microscopical Method test is a destructive method for measuring the thickness of metallic and oxide coatings on fasteners by microscopically examining cross-sectional samples using an optical microscope. This is accomplished by cutting a cross-sectional sample from the fastener, and preparing it for microscopical examination. The sample preparation consists of mounting, grinding, polishing, and etching the sample. The coating thickness is typically measured using an optical microscope equipped with a measuring device such as a filar micrometer or a micrometer eyepiece.

TECHNICAL REQUIREMENTS / CRITICAL ELEMENTS:

1. Specimen preparation A cross-sectional sample must be cut from the test fastener, and prepared for microscopical examination using appropriate metallographic techniques as specified in the test methods. ASTM E 3 describes suitable equipment for performing each required step in preparing a sample for microetching and examination.

   (a) Measurement locations The location of the plate thickness measurements (location for sectioning fastener) must be as specified in the product specification or test method.

   MIL-STD-1312-12 specifies the following locations for measurement.
   - For externally threaded fasteners having a body, measure the thickness at a point adjacent to the thread runout area.

- For externally threaded fasteners threaded to the head, measure the thickness on the head peripheral surface when the head configuration permits accurate measurement, or on the thread pitch diameter approximately 2 diameters from the point end or one-half the fastener length when the length is less than four diameters.

- For nuts, measure the thickness on the bearing surface at the mid-radius.

ISO 1463 specifies that the fastener test surfaces on which coating thicknesses are measured must be in accordance with ISO 4042 unless otherwise specified.

(b) Sectioning A metal-cutting saw or abrasive cut-off wheel is required for sectioning the fastener. When sectioning the fastener, care must be exercised to avoid affecting the structure of the metal.

Sawing, whether by hand or machine with lubrication, can be used on all metals with hardnesses below approximately 35 HRC. Saw cuts produce surfaces containing extensive plastic flow which must be removed by further preparation.

For sectioning metals with hardnesses above about 35 HRC, an abrasive cut-off wheel is recommended. The choice of the type of cut-off wheel and lubricant depend on the grade and hardness of the metal to be cut. Aluminum oxide wheels are preferred for ferrous metals, and silicon carbide wheels for nonferrous alloys.

Other methods of sectioning fasteners are permitted as long as they do not alter the microstructure of the metal at the surface to be examined.

(c) Mounting If the sample is too small to adequately be held by hand when grinding and polishing, the sample must be mounted in a sample mount or held in a suitable fixture. This is particularly important when polishing. Two common methods of mounting specimens are; (1) mounting in thermosetting plastic which requires equipment that can apply heat and pressure to the mounting mold, and (2) mounting in castable plastics.

Overplating To prevent rounding of the specimen edge during polishing, an additional coating may be applied to the sample prior to mounting to support the metal coating and to assure accurate readings of thickness measurements. The overplating coating should have a hardness similar to the original coating. To produce the overplating, suitable electroplating equipment or an electroless specimen coating system is required. [Overplating is required by MIL-STD-1312-12.]

(d) Grinding The initial sample-surface preparation is generally performed by grinding on successively finer grinding paper until the desired surface smoothness is obtained. Grinding can be performed in a number of ways, from rubbing the sample on stationary abrasive paper to the use of automatic grinding devices.

(e) Polishing Final sample preparation for microscopic examination is generally performed by polishing with abrasive on an appropriately lubricated surface until the desired surface smoothness is obtained. Polishing can be performed using several choices of abrasive, lubricant, and surfaces depending on the metal.

Polishing can be accomplished by hand or by automatic methods. Usually, hand methods require holding the sample by hand against an abrasive-charged rotating wheel. Automatic polishing devices include mechanical and vibrating devices.

Care must be taken to ensure that the surface is completely flat up to its edges. Rounding of the edges can result from improper mounting, grinding, polishing, or etching.

Care must be taken to ensure that the surface is perpendicular to the surface of the fastener. Any taper will result in a measured thickness greater than the true thickness.

(f) Etching Etching of the sample surface is recommended to promote contrast between the metal layers, to remove traces of smeared metal, and to develop a fine line at the boundary of the coating.

Etchant solutions must be mixed and placed in a corrosion resistant tray or container. When etching, the sample must be placed in a stainless steel, glass or other non-reactant tray and on non-reactant supports such as glass rods. Rinse tanks or trays may be made of the same non-reactant materials.

A method of heating the etchant solutions is required, such as a gas or electric hotplate or steam jacket which is controlled manually. An instrument is required for measuring the temperature of the solutions, such as a glass thermometer.

Etching solution The solutions to be used for etching must be in accordance with the fastener specification or as described in the test methods. The solution must be suitable for the coating and substrate that is to be measured. Suitable etchant solutions for various coatings and substrates are listed in ASTM B 487 and ISO 1463.

2. Inspection and measurement An optical microscope equipped with an appropriate measuring instrument is required to view and measure the coating cross section. The magnification must permit adequate resolution of the coating thickness. ASTM B 487 and ISO 1463 require that the field of view be between 1.5 and 3 times the coating thickness. MIL-STD-1312-12 requires a magnification of 400X or greater.

   For measuring the thickness, an appropriate measuring instrument must be used in conjunction with the optical microscope. These include an ocular micrometer reticle, or a filar micrometer ocular. All measurement devices must be calibrated for accuracy using a calibrated stage micrometer. The stage micrometer must be calibrated at least once every year.

   Measurements may be made on the microscope image or on photographs.The image of the coating cross section must be measured at multiple points along the length of the cross section as specified in the fastener specification or test method. The reported thickness is the arithmetic mean of the multiple measurements.

REFERENCED DOCUMENTS:

ASTM E 3: Standard Methods of Preparation of Metallographic Specimens

ISO 4042: Threaded components - Electroplated coatings

TEST METHOD TITLE: Measurement of Fastener Coating Thickness - Dimensional Change Method

TEST METHOD DESIGNATIONS:

MIL-STD-1312-12, 26 July 1985: Fastener Test Methods, Method 12, Thickness of Metallic Coatings

TEST DESCRIPTION: The Measurement of Fastener Coating Thickness - Dimensional Change Method is a destructive method for measuring the coating thickness on the external thread of a 60-degree triangular thread form, or the coating thickness on cylindrical or parallel sections. The thickness of the coating is determined by measuring the coated dimensions, chemically removing the coating, and measuring the uncoated dimensions. Coating thickness is calculated from the difference between the coated and uncoated measurements.

TECHNICAL REQUIREMENTS / CRITICAL ELEMENTS:

1. Facilities and equipment

   a. Instruments for measuring coating thickness

      For measuring the coating thickness on the external thread of a 60-degree triangular thread form, functional diameter-indicating type thread gages are required as described in MIL-STD-1312-12. These gages must have been checked or set with master thread-setting plug gages conforming to FED-STD-H28/6.

      For measuring the coating thickness on cylindrical or parallel sections, suitable length measuring instruments are required, such as micrometers, calipers, dial gages, and measuring microscope.

   b. Stripping solution Coating stripping solutions are required which are capable of dissolving the coating without attacking the substrate. Suitable stripping solutions for a variety of coating/substrate combinations are provided in ASTM B 767.

3. Measurements Prior to measurement, the fastener surface must be cleaned of all foreign material without removing any coating material.

   The locations of the plating thickness measurements must be as specified in the product specification or test method.

   MIL-STD-1312-12 specifies the following locations for measurement.

When determining the coating thickness on the external thread of a 60-degree triangular thread form:

- The functional diameters must be measured at three approximately equidistant points around the outside diameter approximately 2 diameters from the point end or one-half the fastener length when the length is less than four diameters.

When measuring the coating thickness on cylindrical or parallel sections:

- For externally threaded fasteners having a body, measure the thickness at a point adjacent to the thread runout area.

- For externally threaded fasteners threaded to the head, measure the thickness on the head peripheral surface when the head configuration permits accurate measurement.

- For nuts, measure the thickness on the bearing surface at the mid-radius.

After measuring the dimensions of the coated specimens, the specimen must be immersed in the stripping solution until the coating is dissolved. After dissolving the coating, the specimen must be rinsed and dried, and then remeasured in the same locations.

4. Coating thickness The average coating thickness is calculated from the dimensional measurements as follows:

   Coating on a 60-degree triangular thread form - The approximate coating thickness equals one-quarter of the difference between the average coated and uncoated functional diameter measurements.

   Coating on cylindrical or parallel sections - The coating thickness equals one-half the difference between the coated and uncoated measurements.

REFERENCED DOCUMENTS:

ASTM B 767: Standard Guide for Determining Mass Per Unit Area of Electrodeposited and Related Coatings by Gravimetric and Other Chemical Analysis Procedures

FED-STD-H28/6: Federal Standard, Screw-Thread Standards for Federal Services, Section 6, Gages and Gaging for Unified Screw Threads - UN and UNR Thread Forms

TEST METHOD TITLE: Measurement of Fastener Coating Thickness - Coulometric Method

TEST METHOD DESIGNATIONS:

ASTM B 504-90: Standard Test Method for Measurement of Thickness of Metallic Coatings by the Coulometric Method

ISO 2177, 1985-05-15: Metallic Coatings - Measurement of coating thickness - Coulometric method by anodic dissolution

MIL-STD-1312-12, 26 July 1985: Fastener Test Methods, Method 12, Thickness of Metallic Coatings

TEST DESCRIPTION: The Measurement of Fastener Coating Thickness - Coulometric Method is a method used for measuring the thickness of metallic coatings on fasteners which is destructive to the coating. The test method is also known as the anodic solution, anodic dissolution, or electrochemical stripping method. Thickness measurements are usually made with commercially available instruments and appropriate calibration standards. The method involves placing an electrolytic cell against the surface of the sample which exposes a well defined area of the sample to an appropriate electrolyte. An electrolyte is chosen which will completely dissolve the coating without affecting the sample substrate. A direct current, usually constant current, is passed through the cell until the coating is anodically dissolved, as indicated by a rapid change in voltage. The coating thickness measurement is based on the quantity of electricity required to dissolve the coating. Often, the coulometric instrument automatically calculates and displays the measured coating thickness.

TECHNICAL REQUIREMENTS / CRITICAL ELEMENTS:

1. Facilities and equipment

   a. Instrument for measuring coating thickness A coulometric test instrument is required which can determine, after calibrating with appropriate thickness standards, the coating thickness within ±10 percent of the true thickness. The instrument must be of a design which allows accurate measurements to be made at the appropriate locations on the test sample.

   Coulometric instruments are generally either: (1) direct reading instruments which electronically calculate coating thickness from current density; or (2) instruments which record the quantity of electricity used in dissolving the coating, from which coating thickness is calculated using calibration constants or tables.

Suitable instruments of both types are commercially available for use with electrolytes recommended by the manufacturer.

b. Coating thickness standards Calibration standards having known uniform coating thicknesses are required for calibrating the test instrument. The standards must have the same type of coating and substrate as the sample to be tested, and have an accuracy of ±5 percent or better.

c. Electrolyte A suitable electrolyte with the following characteristics is required for each coating/substrate combination to be tested.
   - The electrolyte must permit the coating metal to dissolve at a constant efficiency as close to 100 percent as possible.
   - The electrolyte must have a negligible spontaneous effect on the coating in the absence of electrical current flow.
   - The electrolyte must electrochemically differentiate between the coating and substrate such that a substantial voltage change occurs as the coating is penetrated and the substrate is exposed.

   Suitable electrolytes for selected coating/substrate combinations are provided in ASTM B 504, Appendix X1 and ISO 2177, Annex B. Electrolytes for use with commercial instruments must be chosen on the recommendations of the manufacturer.

2. Instrument calibration The test instrument must be calibrated using standards having known uniform coating thicknesses and the same type of coating and substrate as the sample to be tested. Commercial instruments should be calibrated in accordance with the manufacturer's instructions using suitable coating thickness standards.

   Direct-Reading Instruments must be calibrated against known coating thickness standards, and adjusted to produce correct readings corresponding to the standards.

   Nondirect-Reading Instruments must be calibrated against known coating thickness standards to determine a calibration constant, C, calculated as:

   C = coating thickness of standards / instrument reading

   The coating thickness is determined by multiplying the instrument reading by the calibration constant, C.

3. Measurements Prior to testing, the sample surface must be cleaned of all foreign material without removing any coating material. After positioning the electrolytic cell against the sample surface and introducing the electrolyte, make sure no air bubbles occur on the sample surface. Continue electrolysis until dissolution of the coating is complete, as indicated by a rapid change in voltage or automatic cut-off of the instrument. If a commercial instrument is used, the manufacturer's instructions and procedures must be followed with respect to measurement, electrolytes, and calibration.

   The location of the plating thickness measurements must be as specified in the product specification or test method.

   MIL-STD-1312-12 specifies the following locations for measurement of fasteners.

   - For externally threaded fasteners having a body, measure the coating thickness at a point adjacent to the thread runout area.

   - For externally threaded fasteners threaded to the head, measure the coating thickness on the head peripheral surface when the head configuration permits accurate measurement, or on the thread pitch diameter approximately 2 diameters from the point end or one-half the fastener length when the length is less than four diameters.

   - For nuts, measure the thickness on the bearing surface at the mid-radius.

   ISO test methods specify that the fastener test surfaces on which coating thicknesses are measured must be in accordance with ISO 4042 unless otherwise specified.

   After coating dissolution is complete, the test surface must be examined visually to ensure that removal of the coating is complete within the defined test area on the sample. If dissolution is not virtually complete, the test must be discarded and repeated.

4. Thickness results Coating thickness is determined as follows:

   Direct-Reading Instruments A calibrated direct-reading instrument will automatically calculate and display the measured coating thickness.

   Nondirect-Reading Instruments A calibrated nondirect-reading instrument will display a result, typically the quantity of electricity passed in dissolving the coating, in coulombs. The coating thickness is determined by multiplying the instrument reading by the calibration constant, C (see <u>Instrument calibration</u> above).

Alternatively, the coating thickness may be calculated as follows:

$$\text{Coating thickness, } \mu m = 100\ k\ (QE\ /\ AD)$$

where:

k = anodic-current efficiency (usually 100 for 100% efficiency),

E = electrochemical equivalent of the coating metal, in grams per coulomb,

A = area of coating dissolved, in cm^2,

D = density of the coating, in $grams/cm^3$, and

Q = I x t = quantity of electricity passed in dissolving the coating, in coulombs, where:

I = current, in amperes, and

t = time of test, in seconds.

<u>REFERENCED DOCUMENTS:</u>

ASTM B 659: Standard Guide for Measuring Thickness of Metallic and Inorganic Coatings

ISO 3882: Metallic and other non-organic coatings - Review of methods of measurement of thickness

ISO 4042: Threaded components - Electroplated coatings

TEST METHOD TITLE: Measurement of Fastener Coating Thickness - Weight of Coating (Strip and Weigh) Method

TEST METHOD DESIGNATIONS:

ASTM A 90 - 81 (Reapproved 1991): Standard Test Method for Weight of Coating Thickness on Zinc-Coated (Galvanized) Iron or Steel

ASTM B 767 - 88: Standard Guide for Determining Mass Per Unit Area of Electrodeposited and Related Coatings by Gravimetric and Other Chemical Analysis Procedures

MIL-STD-1312-12, 26 July 1985: Fastener Test Methods, Method 12, Thickness of Metallic Coatings

TEST DESCRIPTION: The Measurement of Fastener Coating Thickness - Weight of Coating Method is a destructive method for measuring the average thickness of metallic coatings on fasteners. This is accomplished by weighing the coated fastener, stripping the coating from the fastener without attacking the substrate, and weighing the uncoated fastener. Procedures for converting the weight of coating to coating thickness are provided in the test methods.

TECHNICAL REQUIREMENTS / CRITICAL ELEMENTS:

1. Weighing instrument A balance is required for weighing the test specimens. The sensitivity of the balance depends on the size of the test specimen, the coating thickness, and the required accuracy of the measurement. The balance must be capable of meeting the test method requirements as follows:

   ASTM A 90 --------- Weigh to the nearest 0.01 g or, for specimen weights over 125 g, weigh to the nearest 0.1 g.

   MIL-STD-1312-12 --- A laboratory balance is required capable of reading to an accuracy of ±0.0001 g.

2. Measuring surface area Measuring instruments are required which are capable of accurately measuring the area of the fastener surface that is covered by coating. Suitable measuring instruments include a planimeter, micrometer, vernier caliper, and measuring microscope. The surface area must be calculated as follows:

   ASTM A 90 --------- Determine the total coated area of the to the nearest 0.01 $in.^2$, or 5 mm^2.

MIL-STD-1312-12 --- The external and internal areas of the fastener must be measured separately. Internal areas are those that can not contact each other on two adjacent parts such as holes, recesses and internal threads.

3. Specimen preparation ASTM A 90 requires that the determination of coating thickness be made on a portion of the fastener that does not include any thread.

   Cleaning The coated test specimens must be cleaned and dried prior to weighing. ASTM A 90 requires washing with solvent naphtha or other suitable solvent, then rinsing with alcohol and drying thoroughly.

4. Stripping solution The coating stripping solution must be capable of dissolving the coating without attacking the substrate. Suitable stripping solutions for a variety of coating/substrate combinations are provided in ASTM B 767.

   ASTM A 90 recommends the following solutions for stripping a zinc coating from iron or steel:
   [standard method] hydrochloric acid - antimony trichloride
   [alternative standard method] dilute hydrochloric acid (1 to 1).

5. Stripping method After weighing the coated specimens, a single specimen must be immersed in the stripping solution until the coating is dissolved. ASTM A 90 suggests that a zinc-coated steel fastener should remain in the solution until the violent evolution of hydrogen has ceased, and only a few bubbles are being evolved (about 15 to 30 s).

   After dissolving the coating, the specimen must be rinsed and dried. ASTM A 90 requires scrubbing the specimen under running water, dipping in hot water, and drying by wiping or blow drying.

6. Weight of coating ASTM A 90 and ASTM 767 calculate weight of coating as weight (mass) per unit area of surface. MIL-STD-1312-12 calculates weight of coating in grams as a step for calculating coating thickness. The weight of coating must be calculated as follows:

   ASTM A 90

   Results in Inch-Pound Units

   $$\text{Weight of Coating} = C = [(W_1 - W_2) / A] \times N$$

   where:

C = weight of coating, oz/ft^2 of surface
W_1 = original weight of specimen, g,
W_2 = weight of stripped specimen, g,
A = coated area of original specimen, in.^{2} or mm^2, and
N = a constant = 5.08 if A is in inch^2, = 3.28×10^3 if A is in mm^2.

Report the weight of zinc coating to the nearest 0.01 oz/ft^2 when reporting in inch-pound units.

Results in SI Units

$$\text{Weight of Coating} = C = [(W_1 - W_2) / A] \times N$$

where:
C = weight of coating, g/m^2 of surface
W_1 = original weight of specimen, g,
W_2 = weight of stripped specimen, g,
A = coated area of original specimen, in.^{2} or mm^2, and
N = a constant = 1.55×10^3 if A is in inch^2, = 1×10^6 if A is in mm^2.

Report the weight of zinc coating to the nearest 1 g/m^2 when reporting in SI units.

ASTM B 767

$$\text{Mass per unit area (mg/cm}^2) = m / A$$

where:
m = mass of coating = the difference between the original mass of the specimen and the mass of the stripped specimen (mg), and
A = area covered by coating (cm^2)

MIL-STD-1312-12

$$\text{Weight of Coating} = W = (W_1 - W_2)$$

where:
W = weight of coating, g,
W_1 = original weight of specimen, g, and
W_2 = weight of stripped specimen, g.

7. Coating thickness When coating thickness is required, the coating thickness must be calculated from the weight of coating as follows:

ASTM A 90 provides a table in the Appendix of the test method for conversion of zinc coating weight (oz/ft^2 or g/m^2)

to coating thickness (mils or µm). One g/m^2 of zinc coating (galvanized) corresponds to 0.141 µm of coating thickness. One oz/ft^2 of zinc coating (galvanized) corresponds to 0.0017 in. of coating thickness.

ASTM B 767

$$\text{Thickness } (\mu m) = 10 \times M / D$$

where:
M = mass per unit area (mg/cm^2), and
D = Density of coating (g/cm^3)

MIL-STD-1312-12

$$\text{Coating Thickness} = T = W / (K_E A_E + K_I A_I)$$

where:
W = weight of coating, g
T = thickness of coating, in.,
A_E = external area, $in.^2$,
A_I = internal area, $in.^2$, and
K_E & K_I = constants for external and internal areas for each metallic coating.

Values of K_E and K_I for some commonly deposited metals are as follows:

Metal	K_E	K_I
Zinc	117.0	87.8
Cadmium	141.7	106.3
Copper	147.5	110.6
Nickel	146.0	48.2
Silver	172.5	129.4

8. Multiple coatings When multiple coatings are applied, MIL-STD-1312-12 requires repeating the weigh-strip-weigh process for each coating.

TEST METHOD TITLE: Measurement of Fastener Coating Thickness - X-Ray Methods

TEST METHOD DESIGNATIONS:

ASTM A 754 - 79 (reapproved 1990): Standard Test Method for Coating Thickness by X-Ray Fluorescence

ASTM B 568 - 91: Standard Test Method for Measurement of Coating Thickness by X-Ray Spectrometry

ISO 3497, 1976-02-01: Measurement of coating thickness - X-Ray spectrometric methods

TEST DESCRIPTION: The Measurement of Fastener Coating Thickness - X-Ray Methods are noncontact, nondestructive methods used for measuring the thickness of metallic and some non-metallic coatings. These X-ray methods include measuring coating thickness by X-ray fluorescence and X-ray spectrometry. Thickness measurements by X-ray methods are typically made with commercially available instruments and appropriate calibration standards. The methods involve hitting a fixed area of the coated sample with incident X-ray radiation [generated by an X-ray tube or by certain radioisotopes] causing the emission of secondary radiations characteristic of the elements composing the coating and substrate. The measuring instruments operate on the principle that a correlation exists between the coating thickness and the intensity of the secondary radiation which is either: (1) emitted from the coating (X-ray emission); or (2) emitted from the substrate but attenuated by the coating (X-ray absorption). The thickness of the coating is determined by comparing the test measurement to a predetermined calibration relating coating thickness to the secondary radiation intensity. Often the measuring instrument automatically calculates and displays the measured coating thickness.

TECHNICAL REQUIREMENTS / CRITICAL ELEMENTS:

1. Facilities and equipment

   a. Instrument for measuring coating thickness An X-ray type instrument for measuring coating thickness is required which can determine, after calibrating with appropriate thickness standards, the coating thickness within ±10 percent of its true thickness (±3 percent for ASTM A 754). Coating thickness may be measured by either X-ray emission or X-ray absorption techniques. The instrument must be of a design which allows accurate measurements to be made at the appropriate locations on the test sample.

   b. Coating thickness standards Calibration standards are required for calibrating the test instrument. The standards can be certified for thickness or mass per unit area. Those that are certified for thickness are reliable for coatings of the same density and composition. Those that are certified for mass per unit area are reliable for coatings of the same composition. The same density is not required for mass per unit area measurement.

The calibration standards must have the same type of coating and substrate as the sample to be tested. The coating of calibration standards must have the same X-ray emission or absorption properties as the coating to be measured. If thickness is to be measured by the X-ray absorption technique, the substrate of the calibration standard must have the same X-ray emission properties as the test specimen. The test methods provide criteria for determining the suitability of the calibration standards.

When thickness measurements are to be made on curved surfaces, a collimator on the excitation beam or a mask must be used to minimize the effects of curvature. If the curvature of the sample coating is too extreme for an instrument calibration made using flat standards to be valid, the instrument must be calibrated using standards having the same curvature as that of the test sample.

2. Instrument calibration The test instrument must be calibrated in accordance with the manufacturer's instructions using suitable thickness standards. The test instrument must be calibrated each time the instrument is put into service (ASTM A 754 requires using three standard samples covering the range of coatings to be measured). A control sample must be checked frequently (approximately every ½ hour) during operation.

   Exactly the same instrumental conditions must be used during calibration as will be used for testing samples. These conditions include collimator size, voltage, and tube current. ISO 3497 also requires that measuring time be the same.

3. Measurements The manufacturer's instructions and procedures must be followed with respect to calibration and measurement. The locations of the plating thickness measurements must be as specified in the product specification or test method. ISO test methods specify that the fastener test surfaces on which coating thicknesses are measured must be in accordance with ISO 4042 unless otherwise specified.

   When performing the thickness measurements, the following precautions must be observed:

- If the X-ray absorption technique is to be used, the thickness of the substrate must exceed the critical thickness at which there is no significant change in X-ray count rate for increasing thickness of substrate material. If the critical thickness is not exceeded, the substrate thicknesses of the specimen and the calibration standards must be the same.

- The size of the measurement area must not be larger than the coated area on the specimen. The specimen must be securely seated over the measuring opening and aligned relative to the excitation beam.

- Prior to testing, the sample surface must be cleaned of all foreign material without removing any coating material. Avoid testing specimen areas in locations having visible defects.

- Use a sufficient measuring time to obtain a repeatability that will yield the desired precision.

- Extrapolation beyond the range covered by the calibration standards can result in serious measurement errors. The use of additional thickness standards near the sample thickness will improve the accuracy of the measurement. ASTM B 568 requires that when making measurements between the highest thickness standard and the saturation (infinite thickness) standard, additional thickness standards must be used with values slightly above and below the presumed thickness of the sample.

4. Thickness results For instruments which do not display measurement results directly as thickness of coating or mass per unit area, the intensity readings must be converted to thickness units by using suitable calibration equations or curves. Guidance for making this conversion is provided in the Appendixes of ASTM A 754 and ASTM B 568 and an Annex of ISO 3497.

REFERENCED DOCUMENTS:

ISO 4042: Threaded components - Electroplated coatings

TEST METHOD TITLE: Measurement of Fastener Coating Thickness - Beta Backscatter Method

TEST METHOD DESIGNATIONS:

ASTM B 567 - 89: Standard Test Method for Measurement of Coating Thickness by the Beta Backscatter Method

ISO 3543, 1981-07-15: Metallic and non-metallic coatings - Beta backscatter method

TEST DESCRIPTION: The Measurement of Fastener Coating Thickness - Beta Backscatter Method is a nondestructive method for measuring the thickness of metallic and non-metallic coatings on both metallic and non-metallic substrates. The applicability of this method to specific combinations of coating and substrate is restricted to the requirement that the atomic numbers (or equivalent atomic numbers) of the coating and substrate must differ by an appropriate amount. Thickness measurements by beta backscatter methods are typically made with commercially available instruments and appropriate calibration standards. The method involves hitting a fixed area of the coated specimen with incident beta particles [generated by certain isotopes] causing a certain portion of the beta particles to be backscattered. The amount of backscatter measured by the instrument detector is a function of the atomic number of the elements composing the coating and substrate. Beta backscatter thickness measuring instruments operate on the principle that a correlation exists between the coating thickness and the intensity of the backscatter. The intensity of the backscatter will be between two limits: the backscatter intensity of the coating and that of the substrate. The thickness of the coating is determined by comparing the test measurement to a predetermined calibration relating coating thickness (or mass per unit area of the coating) to the backscatter intensity. Often the measuring instrument automatically calculates and displays the measured coating thickness.

TECHNICAL REQUIREMENTS / CRITICAL ELEMENTS:

1. Facilities and equipment

   a. Instrument for measuring coating thickness A beta backscatter type instrument for measuring coating thickness is required which can determine the coating thickness with an accuracy within ±10 percent of its true thickness. In general, a beta backscatter instrument is comprised of: a radiation source emitting mainly beta particles; a measuring system consisting of apertures and a detector capable of counting the number of backscattered particles; and a readout system displaying the backscatter intensity as counts or thickness units. The instrument must be of a design which allows accurate measurements to be made at the appropriate locations on the test fastener or specimen.

b. Coating thickness standards Calibration standards are required for calibrating the test instrument. These standards must have the following properties.

- The calibration standards must have a uniform coating thickness, and whenever possible have an accuracy of ±5 percent or better.

- The substrate of the calibration standards must be verified as having the same backscatter properties as that of the test specimen by comparing the backscatter intensities of uncoated substrates of both materials.

- The coating and substrate of the calibration standards should have the same (or equivalent) atomic numbers as the coating and substrate of the test specimen to be measured. If calibration standards are used which have "equivalent" atomic numbers as the test specimens, that is, standards made of different materials but having the same beta backscatter characteristics, their suitability must be verified prior to the measurements. The test methods and, often, the manufacturers instructions provide criteria for determining the suitability of the calibration standards.

- If the coating material of the calibration standards has the same or equivalent atomic number as the test specimen, but a different density, the coating thickness must be corrected for the difference in densities. This is done by multiplying the measured thickness by the coating density of the calibration standard and then dividing the product by the coating density of the test specimen.

Foils of the coating material may be used as calibration standards by placing them on the substrate. The foils must be clean, smooth, uniform in thickness, and in intimate contact with the substrate.

2. Instrument calibration The test instrument must be calibrated using suitable thickness standards in accordance with the manufacturer’s instructions. The test instrument must be calibrated each time the instrument is put into service and each time the measurement conditions change. The calibration curve must be defined by at least the zero point and by either two measurements in the logarithmic range (requiring two calibration standards), or by a single measurement if the slope of the logarithmic range is known

(requiring one calibration standard). [See test methods].

The test instrument calibration must be checked before use and at least every four hours during operation. ISO 3543 also requires that one calibration point, generally the bare substrate material, must be checked at least once an hour depending on instrument stability.

ASTM B 567 requires that before use the calibration be checked by taking five measurements on each calibration standard, removing and replacing the standard after each reading. The measurements must all be taken using the same test conditions as will be used for the specimen to be tested. For the calibration to be valid, the average of the five readings must be within ±3 percent of the stated thickness of the corresponding standard.

The condition of calibration standards must be checked prior to use. Standards which are visibly scratched, worn or pitted must not be used for calibration.

When thickness measurements are to be made on curved surfaces, the instrument must be calibrated using standards having the same curvature as that of the test specimen, unless it can be shown that readings from both flat and curved surfaces are essentially identical. The choice of appropriate aperture platens or masks will sometimes aid in producing nearly identical measurements on flat and curved specimens; however the choice of aperture is dependent on the particular instrument design. The manufacturer's instructions, guidelines and recommendations should be followed. ISO 3543 provides a procedure for comparing measurements on flat and curved specimens. If calibration using flat standards or standards having the same curvature is not possible, the readings must be corrected.

The substrate thicknesses of the calibration standards and the test specimen must be the same unless the thicknesses of the substrates exceed the saturation thickness at which there is no significant change in backscatter intensity for increasing thickness of substrate material. If the thicknesses are different, the readings must be corrected.

3. <u>Measurements</u> The manufacturer's instructions and procedures must be followed with respect to calibration and measurement. The locations of the plating thickness measurements must be as specified in the product specification or test method. ISO test methods specify that the fastener test surfaces on which coating thicknesses are measured must be in accordance with ISO 4042 unless otherwise specified.

When performing the thickness measurements, the following precautions must be observed:

- The thickness of the substrate must exceed the saturation thickness at which there is no significant change in backscatter intensity for increasing thickness of substrate material. If the saturation thickness is not exceeded, the substrate thicknesses of the specimen and the calibration standards must be the same.

- If measuring curved surfaces, the choice of the measuring aperture must be verified as being correct for the radius of curvature of the test specimen. If the instrument calibration is not made using standards having the same curvature as that of the test specimen, the calibration must be verified as being applicable to the measurement.

- The choice of the measuring aperture must be in accordance with the manufacturer’s recommendations. The size of the measuring aperture must not be larger than the coated area on the specimen. The specimen must be securely seated over the measuring opening.

- The substrate of the calibration standards must be verified as having the same backscatter properties as that of the test specimen by comparing the backscatter intensities of uncoated substrates of both materials. If they differ, the manufacturer’s recommendations for making corrections must be followed, or appropriate new standards must be used.

- Prior to testing, the fastener surface must be cleaned of all foreign material without removing any coating material. Avoid testing specimen areas in locations having visible defects.

- A sufficient measuring time must be used to obtain a repeatability that will yield the desired precision.

- The instrument manufacturer’s instructions must be followed concerning the coating thickness limit beyond which the particular instrument will give substantial errors.

4. <u>Thickness results</u> For instruments which do not display measurement results directly as thickness of coating or mass per unit area, the intensity of the backscatter must be converted to thickness units by using suitable calibration equations or graphs.

   If the instrument readout is in units of mass per unit area, the linear thickness may be obtained by:

$$T = \frac{M \times 10}{D}$$

where:

T = linear thickness of test specimen, μm,

M = mass per unit area of coating of test specimen, mg/cm^2, and

D = density of coating of test specimen, g/cm^3.

REFERENCED DOCUMENTS:

ISO 4042: Threaded components - Electroplated coatings

Section 7 - DOUBLE SHEAR TEST

MIL-STD-1312-13A, 23 August 1991: Fastener Test Methods, Method 13, Double Shear Test

MIL-STD-1312-28, 26 July 1985: Fastener Test Methods, Method 28, Elevated Temperature Double Shear

DOD-STD-1312-113, 26 March 1984: Fastener Test Methods, Metric, Method 113, Double Shear Test

DOUBLE SHEAR

MIL-STD-1312-13A
MIL-STD-1312-28
DOD-STD-1312-113

Part A: RECOMMENDATIONS

MIL-STD-1312-13A, 23 August 1991: Fastener Test Methods, Method 13, Double Shear Test

On the basis of this study, there is presently no suitable non-government standard to replace MIL-STD-1312-13A. Currently, MIL-STD-1312-13A is cited as the required double shear test method in many fastener specifications published by several organizations including the military and the Aerospace Industries Association of America (AIA). The wide use of this standard indicates its acceptance as a national standard.

It is recommended that MIL-STD-1312-13A be reviewed and revised in conjunction with test standards MIL-STD-1312-28 and DOD-STD-1312-113 to ensure consistency between the standards. The following are suggested recommendations for revising MIL-STD-1312-13A.

An appropriate frequency of calibration/verification should be determined such that the requirement is consistent for all double shear test standards. The requirement is stated in paragraph 4.1.1 of each of the test standards MIL-STD-1312-13A, MIL-STD-1312-28 and DOD-STD-1312-113. MIL-STD-1312-13A requires verification every 12 months, and MIL-STD-1312-28 and DOD-STD-1312-108 require verification every 6 months. ASTM typically recommends calibration/verification at least every 12 months although requiring only 18 month intervals.

MIL-STD-1312-28 allows the testing of certain fasteners (protruding head) having a grip length of at least two times the fastener shank diameter. MIL-STD-1312-13A and DOD-STD-1312-113 restrict testing to fasteners having a grip length of at least three times the fastener shank diameter, unless specified otherwise. A common requirement should be stipulated.

MIL-STD-1312-28, 26 July 1985: Fastener Test Methods, Method 28, Elevated Temperature Double Shear

On the basis of this study, there is presently no suitable non-government standard to completely replace MIL-STD-1312-28. Presently, MIL-STD-1312-28 specifies essentially the same double shear test requirements as test standards MIL-STD-1312-13A and

DOD-STD-1312-113 with the addition of elevated temperature requirements. It is recommended that the elevated temperature requirements and procedures be extracted from MIL-STD-1312-28, and be incorporated into both test standards MIL-STD-1312-13A and DOD-STD-1312-113 as new sections or appendices which would describe the requirements for testing at elevated temperature. MIL-STD-1312-28 should then be discontinued.

MIL-STD-1312-28 allows the testing of certain fasteners (protruding head) having a grip length of at least two times the fastener shank diameter. MIL-STD-1312-13A and DOD-STD-1312-113 restrict testing to fasteners having a grip length of at least three times the fastener shank diameter, unless specified otherwise. A common requirement should be stipulated.

<u>DOD-STD-1312-113, 26 March 1984</u>: Fastener Test Methods, Metric, Method 113, Double Shear Test

On the basis of this study, there is presently no suitable non-government standard to replace DOD-STD-1312-113. Currently, DOD-STD-1312-113 is cited as the required double shear test method in many fastener specifications published by several organizations including the military, and the Aerospace Industries Association of America (AIA). The wide use of this standard indicates its acceptance as a national standard.

It is recommended that DOD-STD-1312-113 be reviewed and revised in conjunction with test standards MIL-STD-1312-13A and MIL-STD-1312-28 to ensure consistency between the standards. The following are suggested recommendations for revising DOD-STD-1312-113.

An appropriate frequency of calibration/verification should be determined such that the requirement is consistent for all double shear standards. The requirement is stated in paragraph 4.1.1 of each of the test standards MIL-STD-1312-13A, MIL-STD-1312-28 and DOD-STD-1312-113. MIL-STD-1312-13A requires verification every 12 months, and MIL-STD-1312-28 and DOD-STD-1312-108 require verification every 6 months. ASTM typically recommends calibration/verification at least every 12 months although requiring only 18 month intervals.

MIL-STD-1312-28 allows the testing of certain fasteners (protruding head) having a grip length of at least two times the fastener shank diameter. MIL-STD-1312-13A and DOD-STD-1312-113 restrict testing to fasteners having a grip length of at least three times the fastener shank diameter, unless specified otherwise. A common requirement should be determined.

Part B: REQUIREMENT SUMMARIES

The following are requirement summaries of the primary United States and ISO test standards dealing with double shear of externally threaded fasteners. Specific requirements of test standards MIL-STD-1312-13A, MIL-STD-1312-28 and DOD-STD-1312-113 are often listed where they differ from other standards.

TEST METHOD TITLE: Double Shear of Externally Threaded Fasteners

TEST METHOD DESIGNATIONS:

MIL-STD-1312-13A, 23 August 1991: Fastener Test Methods, Method 13, Double Shear Test

MIL-STD-1312-28, 26 July 1985: Fastener Test Methods, Method 28, Elevated Temperature Double Shear

DOD-STD-1312-113, 26, March 1984: Fastener Test Methods, Metric, Method 113, Double Shear Test

TEST DESCRIPTION: The Double Shear of Externally Threaded Fasteners test is for determining the ability of a fastener to withstand a predetermined load when applied transversely in double shear to the axis of the fastener. This is accomplished by assembling the test fastener in a double-shear jig designed to transmit the load transversely through the fastener. Load is applied until increased deformation of the test fastener occurs without increased load, or until failure. Acceptability or rejection of the fastener is based on the ultimate load.

TECHNICAL REQUIREMENTS / CRITICAL ELEMENTS:

1. Testing machine A testing machine is required which is capable of applying a compressive load at a controllable rate. A mechanism is required for determining the maximum load sustained by the fastener during the test.

   Load measuring device: Each load measuring device must be verified by a method complying with ASTM E 4 and MIL-STD-45662 as specified or when the test machine is repaired or relocated. If proficiency tests indicate a load discrepancy, a new verification is required. Each load measuring device must be verified in conjunction with the associated load-display system.

   Specific test method requirements are as follows:
   MIL-STD-1312-13A - verification required every 12 months

   MIL-STD-1312-28 -- verification required every 6 months

MIL-STD-1312-113 - verification required every 6 months

2. Test fixtures A half-hole, double-shear fixture is required as described in the test methods. The fixture must be self-aligning and positioned such that the axis of the total shear-load on the fastener coincides with the axial load axis of the testing machine.

   The shear plates must be constructed of hardened steel. The specific dimensional requirements for the shear plates are dependent on fastener dimensions and must be in accordance with the test methods. The shear plates must be reworked when wear results in a chamfer or radius of 0.250 mm (0.010 in.).

3. Load rate The load rate must be uniform, and is dependent on the double shear area. The test methods give calculated load rate values for selected fastener sizes based on nominal shank diameter. For other fastener sizes the initial load rate can be calculated as 100,000 pounds per minute per square inch of nominal double shear area (700 Newtons per minute per square millimeter of nominal double shear area). For this calculation, the double shear area is considered to be two times the nominal fastener shank area. The tolerance of the initial load rate must be within ±10 percent.

   The testing laboratory may apply the compressive load using a constant strain rate rather than load rate control. The constant strain rate used must produce the specified load rate (±10 percent) in the elastic range (see test methods).

4. Grip length Unless otherwise specified, the minimum grip length of the test fastener must be 3D (three times the nominal shank diameter). Test method standard MIL-STD-1312-28 allows a minimum grip length of 2D for protruding head fasteners.

5. Test procedures The test must be performed on the shank portion of the fastener such that the shear plates do not bear on the fastener threads or fillet.

   Load is applied until ultimate load has been reached (increased deformation of the test fastener occurs without increased load), or until failure.

6. Fastener acceptability Acceptability or rejection of the fastener is based on the ultimate load. Ultimate load is the maximum load recorded.

REFERENCED DOCUMENTS:

ASTM E 4: Standard Practices for Load Verification of Testing

Machines

MIL-STD-45662: Calibration Systems Requirements

Section 8 - TORQUE - TENSION

MIL-STD-1312-15, 26 July 1985: Fastener Test Methods, Method 15, Torque - Tension

TORQUE - TENSION

MIL-STD-1312-15

Part A: RECOMMENDATIONS

MIL-STD-1312-15, 26 July 1985: Fastener Test Methods, Method 15, Torque - Tension

On the basis of this study, there is presently no suitable non-government standard to adequately replace MIL-STD-1312-15. Several other standards writing organizations currently publish test method standards which specify torque-tension testing requirements. These include the following:

> ANSI B18.16.2M, 1979: Torque-Tension Requirements for Prevailing-Torque Type Steel Hex and Hex Flange Nuts,

> IFI-101, 1987: Torque-Tension Requirements for Prevailing-Torque Type Steel Hex and Hex Flange Nuts,

and

> SAE J174, April 1971: Torque-Tension Test Procedure for Steel Threaded Fasteners.

The requirements of these standards, however, would not adequately replace MIL-STD-1312-15.

Although MIL-STD-1312-15 is not often referenced as a required test method in military fastener specifications, the standard provides good guidance for developing torque-tension relationships in threaded fasteners, such as is required for the torque method of loading specified by Stress Durability test methods MIL-STD-1312-5A and DOD-STD-1312-105. As a result, it is recommended that MIL-STD-1312-15 be reviewed, and either be revalidated or revised if required. Specific recommendations for updating MIL-STD-1312-15 are the following: statements should be added to allow the use of other torque-tension calibrators to reflect current testing equipment and practices; in light of current testing machine technology, the hand-torque/tensile-machine method should be reevaluated as to whether it is the most suitable referee method; the word "bolt" in line 1 of paragraph 4.1.4.1 should be "hole"; and in keeping with past practice, a new metric counterpart to MIL-STD-1312-15 should be written (e.g. DOD-STD-1312-115).

Part B: REQUIREMENT SUMMARIES

The following are requirement summaries of the primary United States test standards dealing with torque-tension of fasteners and fastener materials. Specific requirements of test standard MIL-STD-1312-15 are often listed where they differ from other standards.

TEST METHOD TITLE: Torque-Tension of Full-Size Threaded Fasteners

TEST METHOD DESIGNATIONS:

ANSI B18.16.2M, 1979: Torque-Tension Requirements for Prevailing-Torque Type Steel Hex and Hex Flange Nuts

IFI-101, 1987: Torque-Tension Requirements for Prevailing-Torque Type Steel Hex and Hex Flange Nuts

MIL-STD-1312-15, 26 July 1985: Fastener Test Methods, Method 15, Torque - Tension

SAE J174, April 1971: Torque-Tension Test Procedure for Steel Threaded Fasteners

TEST DESCRIPTION: The Torque-Tension of Full-Size Threaded Fasteners test is for determining: (a) the tightening torque required to develop a specified tensile load in a threaded fastener; or (b) the tensile load developed in a threaded fastener by tightening to a specified torque; or (c) the room temperature torque-tension relationship over a range of torque and tensile loads. This is accomplished by assembling the test fastener in a test fixture with a companion fastener (a nut for evaluating a bolt or stud, or a bolt for evaluating a nut), and then tightening the fasteners by rotating either the test or companion fastener while holding all other parts stationary. The tensile load induced in the externally threaded fastener is measured while simultaneously measuring the torque required to tighten the fasteners.

TECHNICAL REQUIREMENTS / CRITICAL ELEMENTS:

1. Test fixtures for measuring the tensile load The test fastener is assembled in a steel test fixture capable of measuring the axial tensile load induced in the externally threaded fastener as it is tightened. The test methods describe specific dimensional, hardness and surface finish requirements for fixtures, which must be followed.

   MIL-STD-1312-15 specifies four suitable instruments for measuring the induced tensile load, and describes corresponding fixture configurations. These four instruments and fixturing systems are: (1) load cell system, (2) tensile machine, (3) bolt tension calibrator, and (4) precision strain gaged bolt or stud. Each of these load measuring systems must be verified for accuracy in accordance with ASTM E 4 within three months prior to being used, and each has specific accuracy requirements as follows.

Method	Accuracy Requirement
Load cell system	Within 2 percent of test load
Tensile machine	Within 1 percent of test load
Bolt tension calibrator	Within 4 percent of test load
Strain gaged bolt or stud	Within 2 percent of test load

ANSI B18.16.2M, IFI-101 and SAE J174 allow the use of any tension load measuring device which is capable of measuring the axial tension load induced in the bolt as it is tightened. Although these test methods do not describe specific instruments and fixturing systems for measuring the tensile load, any load measuring system used for these test methods must have the following accuracy.

Method	Accuracy Requirement
ANSI B18.16.2M	Within 5 percent of test load as specified in ANSI B18.16.1M
IFI-101	Within 5 percent of test load
SAE J174	Within 5 percent of test load

The following requirements depend on the method used for measuring the tensile load induced in the externally threaded fastener. Only the four methods described in MIL-STD-1312-15 are included. They also apply when testing to ANSI B18.16.2M, IFI-101 and SAE J174 when one of these methods is used to measure the induced tensile load.

(a) Load cell system The load measuring device or "load cell" consists of a support block with strain gages attached, and an accurate strain indicator as described in the test method. The "load cell" and strain indicator must be calibrated as a system in accordance with the procedures described in ASTM E 74; however, the calibrating force may be applied by a universal-type testing machine which has had the load verified in accordance with ASTM E 4 within one year prior to using.

(b) Tensile machine A tension or universal testing machine is required with appropriate fixtures of a design which adequately supports the fasteners and allows rotation of the fastener with a torque wrench or torque power-device. The tension machine must be capable of maintaining the induced load upon cessation of the torque process. The load measuring system must be verified in accordance with ASTM E 4.

(c) Bolt tension calibrator A bolt tension calibrator is required with appropriate fixtures for the size and type of fasteners to be evaluated. The machine must have a suitable system for indicating the induced load, and must be capable of maintaining the induced load upon cessation of the torque process. The load measuring system must be verified in accordance with ASTM E 4.

(d) Strain-gaged bolt or stud The load measuring device or "load cell" consists of a bolt or stud which has been strain gaged, and an accurate strain indicator as described in the test method. The system must be calibrated in accordance with the procedures described in ASTM E 74; however, the calibrating force may be applied by a universal or tensile-type testing machine which has had the load verified in accordance with ASTM E 4 within one year prior to using.

2. Method of applying and measuring torque Two methods may be used for applying and measuring torque: (1) hand torque method; or (2) machine or power-device torque method. For each method, the necessary adapters to fit the configuration of the fastener under test must be available. The required accuracies for the torque measuring systems used for these test methods are as follows.

Method	Accuracy Requirement
ANSI B18.16.2M	Within 2 percent of maximum range of device as specified in ANSI B18.16.1M
IFI-101	Within 2 percent of maximum range of device
MIL-STD-1312-15	
(Hand torque method)	As specified by Military Specification GGG-W-686
(Machine method)	Within 2 percent of the scale employed
SAE J174	Within 1 percent of a given torque reading

The following requirements depend on the method used for applying torque to the test fastener.

(a) Hand torque method Torque wrenches are required with adapters to fit the configuration of the test fastener. The torque wrenches must be calibrated for accuracy within the limits given above.

(b) Machine torque method A torque machine or power-device having a torque sensing device is required with adapters to fit the configuration of the test fastener. The torque sensing device must be calibrated for accuracy within the limits given above.

3. Companion fasteners Each test method states requirements for any companion fasteners (nuts when evaluating a bolt or stud, or bolts when evaluating a nut) which may be used as an integral part of the test. These requirements must be adhered to and include the following.

ANSI B18.16.2M The torque-tension test method described in ANSI B18.16.2M is for testing prevailing-torque type steel hex and hex flange nuts only. The companion bolt for the test nuts must meet the requirements of a "Test Bolt for Prevailing-torque Test" as described in ANSI B18.16.1M. A new bolt must be used for each test unit.

Test washers must conform with the dimensional, metallurgical, mechanical, and finish requirements as described in the test method. Clipped washers or multi-hole plates or strips may be used when they conform to the specified requirements.

IFI-101 The torque-tension test method described in IFI-101 is for testing prevailing-torque type steel hex and hex flange nuts only. The companion bolt for the test nuts must meet the requirements of a "Test Bolt" as described in IFI 100/107. When washers are required, they must be hardened with the dimensions, finish, and plating as described in the test method.

MIL-STD-1312-15 The companion fasteners used when testing to MIL-STD-1312-15 must be in accordance with the product specification. When washers are required, they must be hardened with the dimensions and finish as described in the test methods.

SAE J174 When evaluating nuts, companion bolts must conform to SAE J429, Grade B requirements, and the threads must be produced by rolling. When evaluating bolts, companion nuts must conform to SAE J995, Grade B requirements. The companion fastener threads must be of the same class as the test fastener. The finish must be zinc phosphate and oil (dry to touch), meeting a 72 hour salt spray life when tested in accordance with ASTM B 117. When washers are required, they must be hardened with the dimensions, finish, and plating as described in the test method.

4. <u>Assembly</u> Each test method specifies requirements for assembly of the fasteners in the test fixture or load-measuring instrument. These requirements must be adhered to and include the following.

   <u>ANSI B18.16.2M</u> The torque-tension test method described in ANSI B18.16.2M is for testing prevailing-torque type steel hex and hex flange nuts only. A washer, meeting the requirements of a "Test Washer" as specified in the test method, must be assembled between the load-measuring device and the test nut such that the "punch entry" side of the washer will be the surface against which the nut will seat. The length of the companion bolt must be such that when the nut is seated on the washer, a length equivalent to four to seven thread pitches of the companion bolt protrude through the top of the nut.

   <u>IFI-101</u> The torque-tension test method described in IFI-101 is for testing prevailing-torque type steel hex and hex flange nuts only. A hardened washer, meeting the requirements of a "Test Washer" as described in IFI 100/107, must be assembled between the load-measuring device and the test nut.

   <u>MIL-STD-1312-15</u> Unless otherwise specified, the fasteners must be assembled with two or three full form threads disengaged between the nut (or internal thread bearing face when evaluating a bolt or stud using a fixture which does not require a companion nut) and the external thread run-out. When nuts are used, a minimum of one complete thread must extend beyond the top of the nut. When using the "load cell system" for measuring the induced tensile load in the externally threaded fastener, washers are required beneath the bolt head, and adjacent to the load bearing surface of the nut.

   <u>SAE J174</u> When evaluating a bolt, a hardened steel washer, as described in the test method, is required under the bolt head. When evaluating a nut, a hardened steel washer is required under the nut. In either case, a minimum of two complete threads must extend beyond the top of the nut.

5. <u>Tightening</u> All fixtures and washers must not be permitted to rotate while tightening the test fastener. Each test method

states requirements for tightening the fasteners. These requirements must be adhered to and include the following.

ANSI B18.16.2M The torque must be applied by tightening the nut until the specified tightening torque is achieved. A recommended technique for tightening the nut using a torque wrench is described in Appendix A of ANSI B18.16.1M. A recommended technique for tightening the nut using a torque-sensing power device is described in Appendix B of ANSI B18.16.1M.

IFI-101 The torque must be applied by tightening the nut until the specified tensile load is achieved.

MIL-STD-1312-15 Unless otherwise specified, the torque must be applied by tightening the nut at a rate which allows the torque measurements to be read while the nut is in motion.

SAE J174 When evaluating a bolt, the bolt must be continuously and uniformly tightened at a speed not to exceed 30 rpm. When evaluating a nut, the nut must be tightened in a similar manner.

6. Lubrication Unless otherwise specified, lubricant must not be added to or removed from the test fasteners or fixtures.

7. Environment The test must be conducted at room temperature.

REFERENCED DOCUMENTS:

ANSI B18.16.1M: Mechanical and Performance Requirements for Prevailing-Torque Type Steel Metric Hex Nuts and Hex Flange Nuts

ASTM B 117: Method of Salt Spray (Fog) Testing

ASTM E 4: Standard Practices for Load Verification of Testing Machines

ASTM E 74: Standard Practice of Calibration of Force-Measuring Instruments for Verifying the Load Indication of Testing Machines

Federal Specification GGG-W-686: Wrench, Torque

IFI-100/107: Prevailing-Torque Type Steel Hex and Hex Flange Nuts

SAE J429: Mechanical and Material Requirements for Externally Threaded Fasteners

SAE J995: Mechanical and Material Requirements for Steel Nuts

SAE J1199: Mechanical and Material Requirements for Metric Externally Threaded Steel Fasteners

Section 9 - SINGLE SHEAR

MIL-STD-1312-20, 26 July 1985: Fastener Test Methods, Method 20, Single Shear

SINGLE SHEAR

MIL-STD-1312-20

Part A: RECOMMENDATIONS

MIL-STD-1312-20, 26 July 1985: Fastener Test Methods, Method 20, Single Shear

On the basis of this study, there is presently no suitable non-government standard to replace MIL-STD-1312-20. A test method having similar requirements and procedures can be found in ASTM F 606, "Standard Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers and Rivets." Section 3.8, "Single Shear Test", describes a test method which, in general, specifies similar test procedures to MIL-STD-1312-20. There are, however, several major and minor differences which exist between MIL-STD-1312-20 and ASTM F 606 that would prevent ASTM F 606, as presently written, from replacing MIL-STD-1312-20. The major differences include the following:

- Section 3.8 of ASTM F 606 is primarily intended for testing ASTM A 394 tower bolts. ASTM F 606 recommends following MIL-STD-1312-20 for the general single shear testing of fasteners.

- ASTM does not reference the types of test fixtures specified in MIL-STD-1312-20.

- Other details pertaining to test procedures, such as test fixture shear plates, calibration/verification frequency, and testing rate, also differ between MIL-STD-1312-20 and ASTM F 606.

It is recommended that MIL-STD-1312-20 be reviewed, and either be revalidated or revised. Also, in keeping with past practice, a new metric counterpart to MIL-STD-1312-20 should be written (e.g., DOD-STD-1312-120).

Part B: REQUIREMENT SUMMARIES

The following are requirement summaries of the primary United States and ISO test standards dealing with single shear of externally threaded fasteners. Specific requirements of test standard MIL-STD-1312-20 are often listed where they differ from other standards.

TEST METHOD TITLE: Single Shear of Externally Threaded Fasteners

TEST METHOD DESIGNATIONS:

ASTM F 606-90: Standard Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets
Section 3.8: Single Shear Test
(Note: Primarily used for testing ASTM Specification A 394 tower bolts.)

MIL-STD-1312-20: Fastener Test Methods, Method 20, Single Shear

TEST DESCRIPTION: The Single Shear of Externally Threaded Fasteners test is for determining the ability of a fastener to withstand a predetermined load when applied transversely to the axis of the fastener. This is accomplished by assembling the test fastener with a mating nut in a single-shear jig designed to transmit the load in a straight line transversely through the fastener. Load is applied until increased deformation of the test fastener occurs without increased load, or until failure. Shear strength is determined as the ultimate or maximum load.

TECHNICAL REQUIREMENTS / CRITICAL ELEMENTS:

1. Testing Machine A testing machine is required which is capable of applying a compressive load at a controllable rate. A mechanism is required for determining maximum load sustained by the fastener during the test.

   Crosshead Speed: The test machine must be capable of a free-running speed of ½ in/min or slower.

   Specific test method requirements are as follows:
   ASTM F 606-86 ---- between ¼ in/min and ½ in/min
   MIL-STD-1312-20 -- constant load rate or strain rate dependent, (see method)

   Note: Average crosshead speed can be experimentally determined by using suitable length measuring and timing devices - see ASTM E 8.

   Load Measuring Device: Each load measuring device must be verified as specified by the test method. Each load measuring device must be verified in conjunction with the associated load-display system.

Specific test method requirements are as follows:

ASTM F 606 ------- verification required every 18 months, recommended every 12 months (ASTM E 4),

MIL-STD-1312-20 -- verification required every 6 months (ASTM E 4 and MIL-STD-45662),

2. Gripping Fixtures A single-shear fixture is required which ensures that the load is transmitted in a straight line through the fastener, while preventing rotation of the fastener. Either tension-type or compression-type single-shear fixtures may be used. The fixture must be self-aligning and positioned such that the axis of the shear-load on the fastener coincides with the axial load axis of the testing machine. The fixtures must show no indications of overload, such as deformation or specimen indents.

   The requirements of the shear plates are as follows:

   ASTM F 606: describes one design for a single-shear fixture.

   Shear Plates: Hardened steel shear plates with holes being 1/16 in. larger than the nominal thread diameter of the fastener. The holes must be chamfered 0.010 in. to relieve sharp edges.

   MIL-STD-1312-20: describes three designs for a single-shear fixture.

   Shear Plates: Hardened steel shear plates with holes as specified in the product specification or,

$$D_h = (D_f + 0.001 \text{ in.}),\ +0.002 \text{ in. } -0.000 \text{ in.}$$

   where D_h = diameter of the hole, and
   D_f = maximum fastener shank diameter.

   The hole must be perpendicular to the test plate within 15 min. of arc. The hole must be radiused at one end to provide clearance between fastener head and shank fillet. The hole must be chamfered or broken 0.005/0.010 in. in the shear plane. Unless specified otherwise, the width of the shear plates at the fastener contact area shall be ½ D_f, +0.010 in. -0.000 in.

3. Test fastener assembly The test fastener must be assembled with a mating nut using appropriate installation equipment, and in accordance with the recommendations of the manufacturer.

4. Load application Load is applied until increased deformation of the test fastener occurs without increased load, or until failure.

5. Fastener acceptability Acceptability or rejection of the fastener is based on the ultimate load. Ultimate load is the maximum load recorded.

REFERENCED DOCUMENTS:

ASTM A 394: Standard Specification for Zinc-Coated Steel Transmission Tower Bolts

ASTM E 4: Standard Practices for Load Verification of Testing Machines

ASTM E 8: Standard Test Methods of Tension Testing of Metallic Materials

MIL-STD-45662: Calibration Systems Requirements