



Designation: F2660 – 13

Standard Test Method for Qualifying Coatings for Use on A490 Structural Bolts Relative to Environmental Hydrogen Embrittlement¹

This standard is issued under the fixed designation F2660; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reappraisal. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reappraisal.

1. Scope

1.1 This test method defines the procedures and tests to evaluate the effect of a coating system on the susceptibility to environmental hydrogen embrittlement (EHE) of an ASTM A490 high strength structural bolt.

1.2 This test method shall qualify a coating system for use with any size of A490 bolts (that is, 1/2 to 1-1/2 in.) high strength structural bolts, relative to EHE.

1.3 The characteristic to be evaluated by this test method is the susceptibility to EHE caused by hydrogen generated from corrosion protection of the steel bolt by sacrificial galvanic corrosion of the coating. Testing shall be performed on coated, specimen ASTM A490 bolts manufactured to the maximum susceptible tensile strength values (see Table 1) of the bolt (see Section 5 Specimen Bolt Requirements). The internal hydrogen embrittlement (IHE) susceptibility will also be inherently evaluated when the EHE is tested through this test method. There is no need for a separate IHE susceptibility test.

1.4 The values stated in inch-pound units are to be regarded as standard. No other units of measurement are included in this standard.

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

2. Referenced Documents

2.1 *ASTM Standards:*²

A490 Specification for Structural Bolts, Alloy Steel, Heat Treated, 150 ksi Minimum Tensile Strength

E4 Practices for Force Verification of Testing Machines

E8/E8M Test Methods for Tension Testing of Metallic Materials

F519 Test Method for Mechanical Hydrogen Embrittlement Evaluation of Plating/Coating Processes and Service Environments

F606 Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, Direct Tension Indicators, and Rivets

F1624 Test Method for Measurement of Hydrogen Embrittlement Threshold in Steel by the Incremental Step Loading Technique

F1789 Terminology for F16 Mechanical Fasteners

F2078 Terminology Relating to Hydrogen Embrittlement Testing

G3 Practice for Conventions Applicable to Electrochemical Measurements in Corrosion Testing

G15 Terminology Relating to Corrosion and Corrosion Testing (Withdrawn 2010)³

G44 Practice for Exposure of Metals and Alloys by Alternate Immersion in Neutral 3.5 % Sodium Chloride Solution

G82 Guide for Development and Use of a Galvanic Series for Predicting Galvanic Corrosion Performance

2.2 *Research Council on Structural Connections:*³
Specification for Structural Joints Using High Strength Bolts (LRFD) Load and Resistance Factor Design

Specification for Structural Joints Using High Strength Bolts (ASD) Allowable Stress Design

2.3 *Other References:*

Townsend Jr., H. E., Met Trans, V6A, April, 1976

Raymond, L., The Susceptibility of Fasteners to Hydrogen Embrittlement and Stress Corrosion Cracking: Fastener System Design. In J. H. Bickford, & S. Nassar, Handbook of Bolts and Bolted Joints, New York, USA: Marcel Dekker, Inc., 1998, pp. 723-756

2.4 *International Standards Organization (ISO):*

ISO 17025 General Requirements for the Competence of Testing and Calibration Laboratories

3. Terminology

3.1 *Definitions:*

³ The last approved version of this historical standard is referenced on www.astm.org.

¹ This test method is under the jurisdiction of ASTM Committee F16 on Fasteners and is the direct responsibility of Subcommittee F16.01 on Test Methods. Current edition approved Nov. 1, 2013. Published December 2013. Originally approved in 2012 as F2660-12. DOI: 10.1520/F2660-13.

² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

TABLE 1 Specimen Bolt Sizes and Wedge Tensile Load Values

Nominal Size	Minimum Length	Tensile Stress Area	Wedge Tensile Load	
		As (in. ²)	Min. (lb)	Max. (lb)
(D)	(in.)			
1/2-13	1-1/2	0.1419	25,600	27,600
3/4-10	2-1/2	0.3345	59,000	63,000
1-8	5	0.6057	103,000	107,000

3.1.1 Terminology for this test method shall be used in accordance with Terminology **F1789**, Terminology **F2078**, and Terminology **G15** except as described below.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *specimen lot, n*—at least 100 ASTM **A490** specimen bolts manufactured in the same process from the same lot of a steel alloy.

3.2.2 *specimen bolt, n*—is a bolt with dimensions that conform to the requirements of A490 bolt dimensions but has mechanical properties, which exceed those of A490 requirements (see **5.1.1** and **Table 1**).

4. Significance and Use

4.1 This test method describes the testing procedure that shall be used to qualify a coating system that is under consideration for use on ASTM **A490** high strength structural bolts made of any steel composition permitted by the **A490** specification. The test method measures the susceptibility of coated specimen bolts to the influence of an externally applied potential (see **7.2.3.3**) by testing for the threshold of embrittlement in a salt solution environment.

5. Specimen Bolt Requirements

5.1 Coated Bolts:

5.1.1 Testing shall be carried out using specially processed ASTM **A490**, Type 1 specimen bolts specially heat treated to achieve maximum strength values per **Table 1** in order to qualify the Standard **A490** bolts. Specimen bolts are designed to simulate a worst case material condition with respect to susceptibility to environmental hydrogen embrittlement (EHE). For this reason, wedge tensile values for specimen bolts exceed the maximum limits for **A490** bolts; therefore, the specimen bolts shall not have standard **A490** markings so they will not be identified as standard **A490** bolts.

5.1.2 Specimen bolts shall be one of two nominal inch sizes: 3/4-10 UNC or 1-8 UNC. Alternatively, small specimen size bolts, 1/2-13 UNC may be used, but are subject to more severe strength requirements shown in **8.4**.

5.1.3 Specimen bolts shall for a lot that displays the maximum wedge tensile load condition permitted by Specification **A490**, when tested in accordance with Test Methods **F606**. **Table 1** gives the range of acceptable wedge tensile loads for each specimen bolt size.

5.1.4 Test results shall be provided by an ISO 17025 accredited laboratory. Wedge tensile strengths for the specimen bolts must be within the range specified in **Table 1** and dimensional and compositional conformance to Specification **A490** shall be provided by the supplier of each specimen lot.

5.2 Coatings:

5.2.1 The coating to be evaluated shall be applied to all specimen bolts under normal production conditions.

5.2.2 The process of coating specimen bolts shall include all post-coating processing under normal production conditions.

5.3 Uncoated Bolts:

5.3.1 Testing shall be carried out using ASTM A490 Type 1 bolts produced at the same time with the same processes and from the same lot of steel alloy as coated bolts.

6. Sample Quantities Required

6.1 A minimum of fifteen (15) bolts from any specimen lot shall be used for evaluation and qualification. Ten (10) bolts shall be coated and the remaining five (5) bolts shall remain uncoated. Additional samples may be required for repeat test and shall be held in contingency.

7. Test Procedures

7.1 Open Circuit Potential (OCP):

7.1.1 The freely corroding or Open Circuit Potential (OCP) shall be measured in 3.5% NaCl solution produced in accordance with Practice **G44** to characterize the galvanic corrosion behavior of the coating relative to the steel bolt. The OCP measurement shall be made on a coated specimen bolt in accordance with Practice **G3**. The OCP measurement shall be taken using a potentiostat capable of making measurements with a resolution no less than ± 5 mV.

NOTE 1—If the coating is a known material then the measured OCP can be compared to the values described in Guide **G82**.

7.1.2 A second OCP test shall be performed and the two tests shall be compared for consistency. If the OCP test is not ± 5 mV with a known value for a known coating or with the other OCP test for an unknown coating, then a known material other than the coating shall be used to test the accuracy of the reference electrode. If the electrode is accurate, then another bolt sample shall be tested to obtain consistency. Some reasons for inconsistency include dissimilar materials in the test setup or coating voids that can change the OCP value.

7.2 Environmental Hydrogen Embrittlement Testing:

7.2.1 Mechanical Test Set-up:

7.2.1.1 The test shall be conducted on bolts that have been truncated by removal of the bolt head. Cut off the bolt head using a water cooled cut off saw or other device that does not cause excessive heating of the bolt. The length of the specimen bolt for testing shall be a minimum length of 1.5 inches and a maximum length of 4.0 inches. The truncated bolt specimen shall be adjusted to achieve the placement of a minimum of two threads between the gripping devices. The exposed threads shall be equally spaced on each side of the minor diameter of the threads. This placement of the bolt specimen in the gripping device is shown in **Fig. 1**.

7.2.1.2 The loading method required for this test is four-point (4 pt) bend, which produces constant moment along the gage section so that the stress may be calculated anywhere along the length of the fastener. The test is conducted under displacement control. The loading method shall have a specified load accuracy of $\pm 0.5\%$, programmable to increase

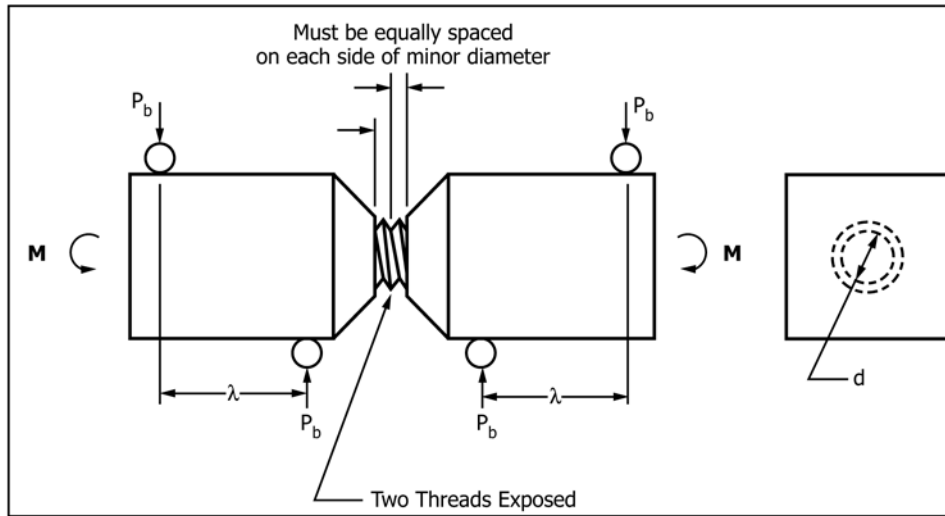


FIG. 1 Four-Point Bend Loading of Fasteners. Maximum Tensile Stress, $\sigma_t = 32P_b\lambda/\Pi d^3$

incrementally in steps of load and time. The loading method shall be within the guidelines of calibration, force range, resolution, and verification of Practices E4.

7.2.2 Fast Fracture Testing:

7.2.2.1 The first step in the testing sequence shall be a measurement of the fast fracture load of the specimen bolts in bending. Determine this value by performing a test in accordance with Test Method F1624, Section 8, as shown in Fig. 2A,

using a fast fracture protocol. Test a minimum of five uncoated specimen bolts and a minimum of five coated specimen bolts. The average of these five test results shall determine the fast fracture strength of each condition.

7.2.2.2 The average fast fracture strength in bending of coated bolts, FFS(B)_{coated} must be within $\pm 5\%$ of the average fast fracture strength for uncoated bolts, FFS(B)_{uncoated}. If the coated bolts exhibit a fast fracture strength that is below 95%

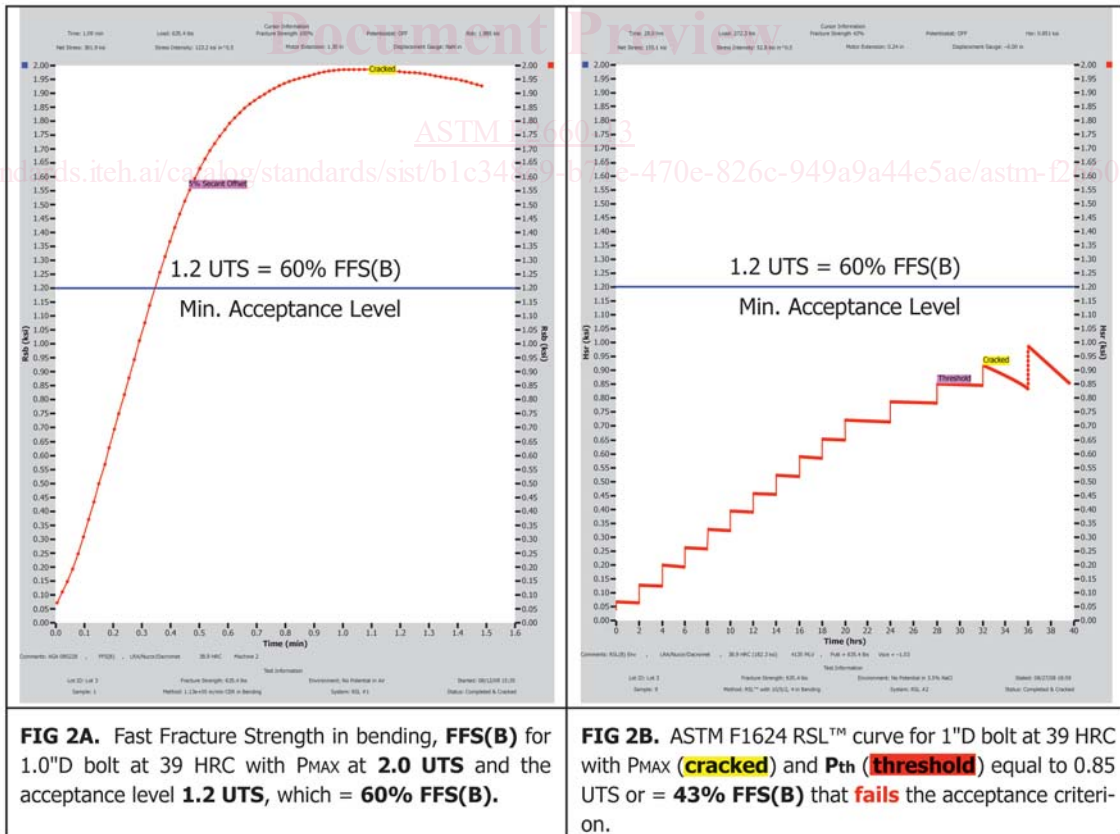


FIG 2A. Fast Fracture Strength in bending, FFS(B) for 1.0”D bolt at 39 HRC with P_{MAX} at 2.0 UTS and the acceptance level 1.2 UTS, which = 60% FFS(B).

FIG 2B. ASTM F1624 RSL™ curve for 1”D bolt at 39 HRC with P_{MAX} (cracked) and P_{th} (threshold) equal to 0.85 UTS or = 43% FFS(B) that fails the acceptance criterion.

FIG. 2