Designation: F3043 – 15

Standard Specification for "Twist Off" Type Tension Control Structural Bolt/Nut/Washer Assemblies, Alloy Steel, Heat Treated, 200 ksi Minimum Tensile Strength[1,2]

This standard is issued under the fixed designation F3043; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers one style of heat treated, alloy steel, tension control bolt-nut-washer assemblies, also referred to as "sets," having a tensile strength of 200 to 215 ksi. These assemblies are capable of developing a minimum predetermined tension when installed by applying torque to the nut, while at the same time applying a counter torque to separate the spline end from the body of the bolt using an appropriate spline drive installation tool.

1.2 An assembly consists of a tension control bolt with spline end, nut and washer covered by this specification.

1.3 The assemblies are available with round heads described in Section 10, in sizes 1 in. to 1¼ in. inclusive.

1.4 The fastener assemblies are intended for use in structural connections in the following environmental conditions:

1.4.1 Interiors, normally dry, including interiors where structural steel is embedded in concrete, encased in masonry or protected by membrane or noncorrosive contact type fireproofing.

1.4.2 Interiors and exteriors, normally dry, under roof, where the installed assemblies are soundly protected by a shop-applied or field-applied coating to the structural steel system.

1.5 The fastener assemblies are not intended for use in structural connections in the following environments, with or without protection by a shop-applied or field-applied coating to the structural steel system:

1.5.1 Exteriors not under roof.

1.5.2 Chemical environments in which strong concentrations of highly corrosive gases, fumes, or chemicals, either in solution or as concentrated liquids or solids, contact the fasteners or their protective coating.

1.5.3 Heavy industrial environments severe enough to be classified as a chemical environment as described in 1.5.2.

1.5.4 Condensation and high humidity environments maintaining almost continuous condensation, including submerged in water and soil.

1.5.5 Cathodically protected environments, in which current is applied to the structural steel system by the sacrificial anode method or the DC power method.

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

1.7 The following precautionary statement pertains only to the test method portions, Section 13, Section 14 and Annex A2 of this Specification*: 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:*[3]

A751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

E709 Guide for Magnetic Particle Testing

E1444/E1444M Practice for Magnetic Particle Testing

F606/F606M Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, Direct Tension Indicators, and Rivets

F788 Specification for Surface Discontinuities of Bolts, Screws, and Studs, Inch and Metric Series

F812 Specification for Surface Discontinuities of Nuts, Inch and Metric Series

[1] This specification is under the jurisdiction of ASTM Committee F16 on Fasteners and is the direct responsibility of Subcommittee F16.02 on Steel Bolts, Nuts, Rivets and Washers.

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[2] The "Twist Off" Type Tension Control Structural Bolt/Nut/Washer Assemblies, Alloy Steel, Heat Treated, 200 ksi Minimum Tensile Strength of Grade 2 is covered by US patent number 7 070 664, July 4, 2006. Interested parties are invited to submit information regarding the identification of an alternative(s) to this patented item to the ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend.

[3] 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.

F1470 Practice for Fastener Sampling for Specified Mechanical Properties and Performance Inspection
F1789 Terminology for F16 Mechanical Fasteners
F2328 Test Method for Determining Decarburization and Carburization in Hardened and Tempered Threaded Steel Bolts, Screws, Studs, and Nuts

2.2 *ASME Standards:*[4]
B1.3 Screw Thread Gaging Systems for Acceptability: Inch and Metric Screw Threads (UN, UNR, UNJ, M, and MJ)
B1.15 Unified Inch Screw Threads (UNJ Thread Form)
B18.2.6 Fasteners for Use in Structural Applications

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 The definition of terms used in this specification shall be as specified in Terminology F1789, unless otherwise defined herein.

3.1.2 *component lot, n*—component lot, for the purpose of assigning an identification number and from which test samples shall be selected, shall consist of all tension control bolts, all nuts or all washers processed essentially together through all operations to the shipping container, of which each component has the following common characteristics: heat number (mill heat); nominal dimensions (size), grade, and heat treatment lot.

3.1.3 *manufacturer, n*—entity that assembles, lubricates, tests, and certifies compliance with this specification.

4. Ordering Information

4.1 Orders for assemblies shall include the items of information below. Optional items not on the purchase order shall be considered as not being required (see Note 1):

4.1.1 Quantity of assemblies,

4.1.2 Size, including nominal tension control bolt diameter, bolt length (without the spline end), and thread pitch,

4.1.3 Grade, that is, Grade 1 or Grade 2,

4.1.4 Name of product, that is, twist off type tension control bolt/nut/washer assemblies[2],

4.1.5 ASTM designation and year of publication, and

4.1.6 Special requirements, if required.

NOTE 1—A typical order description follows: 1000 assemblies, 1¼ diameter by 4 in. long with 7 threads per in., Grade 2, Tension Control Bolt/Nut/Washer Assemblies, Round Heads, ASTM F3043.

5. Materials and Manufacture

5.1 *Tension Control Bolt/Nut/Washer Assemblies:*

5.1.1 The assemblies shall be of the round head style.

5.1.2 The assemblies shall consist of one tension control bolt, with one nut and one washer assembled on the bolt and the nut threaded on the bolt a minimum of one turn.

5.1.3 All nuts shall be heavy hex.

5.1.4 All washers used in the assembly shall be circular and through hardened.

5.1.5 *Protective Coatings*—The bolts, nuts and washers shall not be coated by hot dip zinc coating, mechanical deposition, electroplating, dip-spin, dip-drain, or spray methods with zinc or other metallic coatings.

NOTE 2—Protective coatings may be shop-applied or field-applied to installed assemblies.

5.1.6 *Lubrication:*

5.1.6.1 The assemblies shall be lubricated by the manufacturer to meet the Assembly Lot Tension requirements in Section 9.

5.1.6.2 Lubrication other than that applied by the manufacturer shall not be permitted, as the type and amount of lubrication is critical to meeting the minimum clamping forces specified.

5.1.7 *Secondary Processing*—Secondary processing shall not be permitted to an assembly lot.

5.2 *Tension Control Bolts:*

5.2.1 *Heat Treatment:*

5.2.1.1 If phosphate coating has been applied to the raw material, the residual phosphate shall be removed prior to heat treatment, and a record of the application of this processing step shall be maintained by the processor.

5.2.1.2 Tension control bolts shall be heat treated by quenching in oil from the austenitizing temperature and then tempering by reheating to a temperature not less than 1000°F.

5.2.2 *Thread*—The threads of tension control bolts shall be rolled.

5.3 *Nuts:*

5.3.1 Nuts shall be made by hot forming.

5.3.2 Nuts shall be heat treated by quenching in a liquid medium from a temperature above the transformation temperature and tempering at a temperature of at least 850°F.

5.3.3 Threads shall be formed by tapping.

5.4 *Washers:*

5.4.1 Washers shall be through hardened.

6. Chemical Composition

6.1 *Tension Control Bolts:*

6.1.1 Steel for tension control bolts shall be made by the basic oxygen process.

6.1.2 Bolts shall be alloy steel conforming to the chemical composition in Table 1.

TABLE 1 Chemical Requirements for Tension Control Bolts[A]

Element	Composition, %			
	Heat Analysis, %		Product Analysis, %	
	min	max	min	max
Carbon	0.38	0.42	0.36	0.44
Manganese	0.40	0.60	0.37	0.63
Phosphorus	. . .	0.01	. . .	0.015
Sulfur	. . .	0.01	. . .	0.015
Silicon	. . .	0.10	. . .	0.12
Chromium	1.20	1.40	1.15	1.45
Molybdenum	0.60	0.80	0.57	0.83
Vanadium	0.30	0.40	0.27	0.43

[A] Aluminum, cobalt, niobium / columbium, nickel, titanium, tungsten, zirconium, or any other alloying elements may be added to obtain the desired alloying effect.

[4] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Two Park Ave., New York, NY 10016-5990, http://www.asme.org.

6.1.3 Product analysis may be made by the purchaser on finished bolts representing each lot. The chemical composition shall conform to the requirements in Table 1, Product Analysis.

6.1.4 Heats of steel to which bismuth, selenium, tellurium, lead or boron has been intentionally added shall not be permitted.

6.1.5 Compliance with 6.1.4 shall be based on certification that heats of steel having any of the listed elements intentionally added were not used to produce the bolts.

6.1.6 Chemical analysis shall be performed in accordance with Test Methods, Practices, and Terminology A751.

6.2 *Nuts:*

6.2.1 Steel for nuts shall be made by the basic oxygen or electric-furnace process.

6.2.2 Nuts shall conform to the chemical composition in Table 2.

6.2.3 Product analysis may be made by the purchaser on finished nuts representing each lot. The chemical composition shall conform to the requirements in Table 2, Product Analysis.

6.2.4 Chemical analysis shall be performed in accordance with Test Methods, Practices, and Terminology A751.

6.3 *Washers:*

6.3.1 Steel used in the manufacture of washers shall be produced by the basic-oxygen or electric-furnace process.

6.3.2 Washers shall conform to the chemical composition specified in Table 3.

6.3.3 Product analysis may be made by the purchaser on finished washers representing each lot. The chemical composition shall conform to the requirements in Table 3, Product Analysis.

6.3.4 Chemical analysis shall be performed in accordance with Test Methods, Practices, and Terminology A751.

7. Mechanical Property Requirements for Tension Control Bolts, Nuts and Washers

7.1 *Tension Control Bolts:*

7.1.1 *Hardness*—Bolts shall conform to the hardness specified in Table 4.

7.1.2 *Tensile Properties:*

7.1.2.1 Bolts shall be wedge tested full size and shall conform to the minimum and maximum wedge tensile load, and proof load or alternative proof load specified in Table 5. The load achieved during proof load testing shall be equal to or greater than the specified proof load.

7.1.2.2 When the length of the bolt makes full size testing impractical, machined specimens shall be tested and shall conform to the requirements specified in Table 6. When bolts are tested by both full size and machined specimen methods, the full size test shall take precedence.

7.1.2.3 For bolts on which both hardness and tension tests are performed, acceptance based on tensile requirements shall take precedence in the event of low hardness readings.

7.1.2.4 Sample bolts shall be used to verify that the alloy steel material and heat treatment provides resistance to Environmental Hydrogen Embrittlement (EHE), in accordance with the requirements of Annex A2.

7.2 *Nuts:*

7.2.1 Nuts shall conform to the surface hardness specified in Table 7.

7.2.2 Nuts shall withstand the proof load stress specified in Table 8.

TABLE 2 Chemical Requirements for Nuts

Element	Composition, %			
	Heat Analysis, %		Product Analysis, %	
	min	max	min	max
Carbon	0.30	0.48	0.28	0.50
Manganese	0.60	0.90	0.57	0.93
Silicon	0.15	0.35	0.13	0.37
Phosphorus	. . .	0.050	. . .	0.055
Sulfur	. . .	0.050	. . .	0.055

TABLE 3 Chemical Requirements for Washers

Element	Composition, %			
	Heat Analysis, %		Product Analysis, %	
	min	max	min	max
Carbon	0.42	0.48	0.40	0.50
Manganese	0.60	0.90	0.57	0.93
Silicon	0.15	0.35	0.13	0.37
Phosphorus	. . .	0.030	. . .	0.035
Sulfur	. . .	0.030	. . .	0.035

TABLE 4 Hardness Requirements for Tension Control Bolts

Bolt Size, in.	Bolt Length, in.	Rockwell C	
		min	max
1 to 1¼, incl	all	38	45

TABLE 5 Tensile Requirements for Full Size Tension Control Bolts

Bolt Size, Threads per in.	Stress Area, in.^{2} [A,B]	Tensile Load, lbf[C]	
		min	max
Column 1	Column 2	Column 3	Column 4
Grade 1			
1 in. - 8	0.615	123 100	132 300
1⅛ in. - 7	0.776	155 200	166 800
1¼ in. - 7	0.983	196 700	211 400
Grade 2			
1 in. - 8	0.640	128 000	137 700
1⅛ in. - 7	0.808	161 600	173 600
1¼ in. - 7	1.019	203 800	219 100

[A] The stress area for Grade 1 is calculated as:

$$A_s = 0.7854\,[0.5\,(d_{3\ max} + d_{2\ max})]^2$$

[B] The stress area for Grade 2 is calculated in accordance with Annex A1.

[C] Loads tabulated are based on the following:

Bolt Size, in.	Column 3	Column 4
1 to 1¼	200 000 psi	215 000 psi

TABLE 6 Tensile Strength Requirements for Specimens Machined from Bolts

Nominal Bolt Diameter, in.	Tensile Strength, ksi		Yield Strength (0.2 % offset), min, ksi	Elongation in 2 in. or 50 mm, min, %	Reduction of Area, min, %
	min	max			
1 to 1¼, incl	200	215	180	14	40

TABLE 7 Hardness Requirements for Nuts

Bolt Size, in.	Surface Hardness, Rockwell C	
	min	max
1 to 1¼, incl	30	40

TABLE 8 Proof Load Requirements for Nuts

Nominal Size - Threads per in.	Stress Area, A_s, in.^{2} [A,B]	Proof Load Stress, ksi	Nut Proof Load, lbf[C]
Grade 1			
1 in. - 8	0.615	200	123 100
1⅛ in. - 7	0.776	200	155 200
1¼ in. - 7	0.983	200	196 700
Grade 2			
1 in. - 8	0.640	200	128 000
1⅛ in. - 7	0.808	200	161 600
1¼ in. - 7	1.019	200	203 800

[A] The stress area for Grade 1 is calculated as:

$$A_s = 0.7854\ [0.5\ (d_{3\ max} + d_{2\ max})]^2$$

[B] The stress area for Grade 2 is calculated in accordance with Annex A1.

[C] To determine nut proof load in pounds, multiply the appropriate nut proof load stress by the tensile stress area of the thread.

7.3 *Washers:*

7.3.1 Washers shall conform to the core hardness specified in Table 9.

8. Assembly Lot Tension Test

8.1 *Purpose*—The assembly lot tension test shall be performed on fastener assemblies to determine the ability of the assembly to provide the required minimum tension.

8.2 *Requirement*—Full size completed assemblies tested in accordance with 14.4 shall develop a bolt tension when the spline end is separated from the bolt conforming to the requirements in Table 10, Column 1.

9. Carburization/Decarburization of Bolts

9.1 This test is intended to evaluate the presence or absence of carburization and decarburization as determined by the difference in microhardness near the surface and core.

9.2 *Requirements:*

9.2.1 *Carburization*—The assemblies shall show no evidence of a carburized surface when evaluated in accordance with 14.1.4.

9.2.2 *Decarburization*—Hardness value differences shall not exceed the requirements set forth for decarburization in Test Method F2328 for class ¾ H materials when evaluated in accordance with 14.1.4.

10. Dimensions of Tension Control Bolts, Nuts, and Washers

10.1 *Tension Control Bolts:*

10.1.1 Tension control bolts shall be furnished with round heads.

TABLE 9 Core Hardness Requirements for Washers

Rockwell C	
Min 40	Max 45

TABLE 10 Assembly Lot Tension Test Requirements

Bolt Size, in.	Grade 1		Grade 2	
	Manufacturers Acceptance Test Tension, lbs, min[A]	Tension lbs, min (for information only)[B]	Manufacturers Acceptance Test Tension, lbs, min[A]	Tension lbs, min (for information only)[B]
	Column 1	Column 2	Column 1	Column 2
1	90 000	86 000	94 000	90 000
1⅛	114 000	109 000	119 000	113 000
1¼	145 000	138 000	150 000	143 000

[A] The manufacturer's acceptance test tension values are 5 % higher than the tension in Column 2 and are rounded to the nearest 1000 lbs (kip).

[B] The values in Column 2 are equal to 70 % of the specified minimum tensile strength for tests of full size F3043 bolts tested in axial tension and are rounded to the nearest 1000 lbs (kip).

10.1.2 The head, body and spline dimensions shall conform to the dimensional requirements in Table 11, and ASME B18.2.6 section 6.5 for straightness, 6.6 for true position of head, and 6.11 for incomplete thread diameter.

10.1.3 *Threads:*

10.1.3.1 The thread length shall be as specified in Table 11.

10.1.3.2 Threads for Grade 1 shall have the coarse series, class 2A UNJ thread as specified in ASME B1.15.

10.1.3.3 Threads for Grade 2 shall be as specified in Annex A1, and shall have Class 2A tolerances as calculated in section 4.3.3 of ASME B1.15.

10.1.3.4 The gauging limit for bolts shall be verified during manufacture. In case of purchaser/supplier controversy over thread compliance, System 21 of ASME B1.3 shall be used for referee purposes.

10.2 *Nuts:*

10.2.1 The dimensions for nuts shall conform to the dimensional requirements in Table 12, and ASME B18.2.6, sections 3.1.4, 3.1.5 and 3.1.6.

10.2.2 Threads for nuts for Grade 1 shall be coarse series, class 2B UNJ thread as specified in ASME B1.15.

10.2.3 Threads for nuts for Grade 2 shall be as specified in Annex A1, and shall have Class 2B tolerances as calculated in section 4.3.4 of ASME B1.15.

10.3 *Washers:*

10.3.1 All circular washers shall conform to the dimensions shown in Table 13.

10.3.2 The deviation from flatness shall not exceed 0.010 in. per inch as the maximum deviation from a straight edge placed on the cut side.

10.3.3 Circular runout of the outside diameter with respect to the hole shall not exceed 0.030 FIM.

10.3.4 Burrs shall not project above the immediately adjacent washer surface more than 0.010 in.

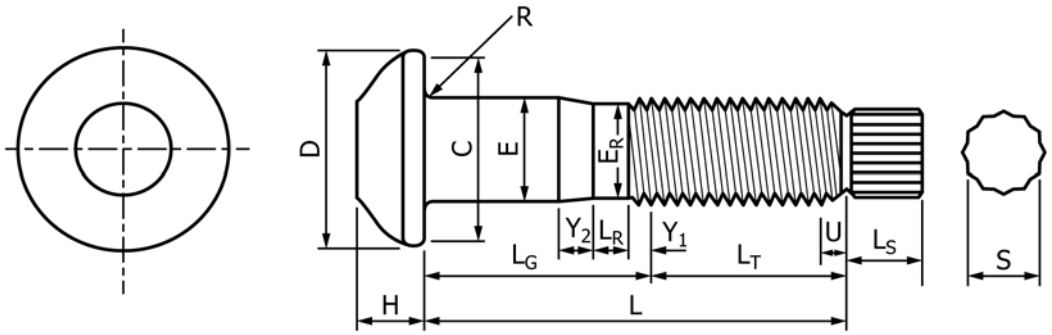
11. Workmanship, Finish, and Appearance

11.1 For tension control bolts, the allowable limits, inspection, and evaluation of the surface discontinuities, quench cracks, forging cracks, head bursts, shear bursts, seams, folds, thread laps, voids, tool marks, nicks, and gouges shall be in accordance with Specification F788except that threads shall

TABLE 11 Tension Control Bolts

NOTE 1—The bolt length L shall be the distance measured parallel to the axis of the bolt from the bearing surface of the head to the center point of the groove through which shear will occur. Bolts are normally supplied in ¼ in. length increments.

NOTE 2—For bolts 1 in. diameter with length up to 6 in., inclusive, length tolerance is 3⁄16 in. underlength. For longer 1 in. diameter bolts and other diameters, length tolerance is ¼ in. underlength.



Nominal Size		1	1⅛	1¼
Basic Diameter, E, in.[A]		1.000	1.125	1.250
Full-Size Body Diameter E, in.	max	1.022	1.149	1.277
	min	0.976	1.098	1.223
Head Height, H, in.[B]	nom	39/64	11/16	25/32
	max	0.643	0.738	0.824
	min	0.607	0.678	0.759
Head Diameter, D, in.[C]	nom	2⅛	2⅜	2½
	max	2.158	2.375	2.589
Bearing Diameter, C, in.[D]	nom	2	2¼	2½
	min	1.771	1.991	2.224
Radius of Fillet, R, in.	nom	3⁄32	3⁄32	7⁄64
	max	0.110	0.110	0.138
	min	0.087	0.087	0.098
Transition Body Diameter, E_R, in.	nom	59/64	1 1⁄32	1 5⁄32
	max	0.933	1.046	1.171
	min	0.917	1.030	1.155
Body Transition Length, Y_2, in.	nom	0.305	0.354	0.354
	max	0.394	0.450	0.450
	min	0.207	0.244	0.244
Reduced Body Length, L_R, in.	nom	½	9⁄16	9⁄16
	max	0.625	0.715	0.715
	min	0.375	0.429	0.429
Transition Thread Length Y_1, in.[E]	Ref	0.31	0.34	0.34
Thread Length, L_T, in.[F]	Ref	2.049	2.322	2.322
Maximum center of groove to First Fully Formed Thread, U, in.[G]	Max	0.455	0.500	0.500
Spline Length, L_s, in.[H]	Ref	0.80	0.90	0.984
Spline Width Across Flats, S, in.[H]	Ref	0.700	0.787	0.897

[A] Where specifying nominal size in decimals, zeros preceding the decimal shall be used and the fourth decimal place shall be omitted.
[B] The head height shall be that overall distance measured parallel to the axis of the product from the top of the head to the bearing surface and shall include the thickness of the washer face. Raised grade and manufacturer's identification are excluded from head height.
[C] The circumference may be irregular with a rounded or flat edge.
[D] The bearing surface shall be flat and perpendicular to the body within the FIM limits specified for total runout. Measurement of FIM shall extend as close to the periphery of the bearing surface as possible while the bolt is being held in a collet or other gripping device at a distance of one bolt diameter from the underside of the head. A die seam across the bearing surface is not permissible.
[E] Transition thread length, Y_1, is a reference dimension, intended for calculation purposes only, that represents the length of incomplete threads and tolerance on grip gaging length.
[F] See ASME B18.2.6, section 6.10.
[G] Unless otherwise specified, bolts need not be pointed. The distance, U, is from the center of the groove to the first fully formed thread crest. This shall be determined by measuring how far the point enters into a cylindrical NOT GO major diameter ring gage.
[H] The spline dimensions and groove dimensions are reference dimensions and shall be at the discretion of the manufacturer. Users should consult with the supplier to assure wrenchability.

have no laps at the root or on the flanks located below the pitch line, when inspected in accordance with Specification F788, S1.2.

11.2 For the nut component, the allowable limits, inspection, and evaluation of surface discontinuities, quench cracks, forging cracks, inclusion cracks, bursts, shear bursts, seams, voids, tool marks, nicks and gouges shall be in accordance with Specification F812.

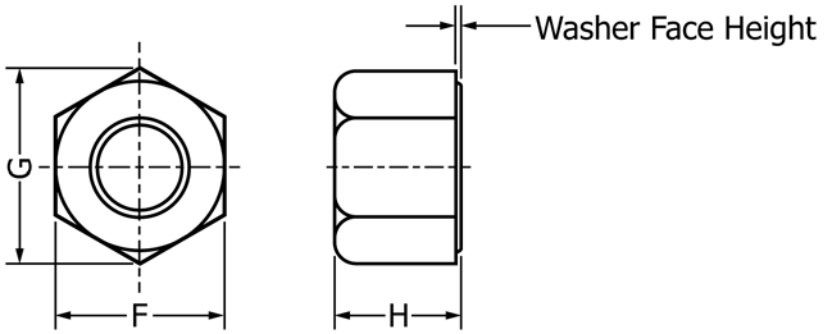
11.3 Washers shall be free of excess mill scale and foreign material on bearing surfaces.

TABLE 12 Nut Dimensions

NOTE 1—The tops of washer faced nuts shall be flat and the diameter of chamfer circle shall be equal to the maximum width across flats within a tolerance of -15%. The length of chamfer at hex comers shall be 5% to 15% of the basic thread diameter. The surface of chamfer may be slightly convex or rounded.

NOTE 2—Bearing surfaces shall be flat and perpendicular to the axis of the threaded hole within the total runout (FIM) tabulated for the respective nut size.

NOTE 3—FIM = Full Indicator Movement



Nominal Size[A]		1	1⅛	1¼
		1.000	1.125	1.250
Width Across Flats, F[B]	nom	1⅝	1 13/16	2
	max	1.625	1.812	2.000
	min	1.575	1.756	1.938
Width Across Corners, G[C]	max	1.876	2.093	2.309
	min	1.796	2.002	2.209
Thickness, H[D]	nom	1 3/16	1 11/32	1 15/32
	max	1.214	1.367	1.501
	min	1.147	1.295	1.424
Washer Face Height	nom	1/64	1/64	1/64
Total Runout of Bearing Face FIM[E]		0.024	0.027	0.030

[A] Where specifying nominal size in decimals, zeros preceding the decimal shall be used and the fourth decimal place shall be omitted.
[B] The width across flats of heavy hex nuts shall be the overall distance measured, perpendicular to the axis of the nut, between two opposite sides of the nut. No transverse section through the nut between 25% and 75% of the actual nut thickness, as measured from the bearing surface, shall be less than the minimum width across flats.
[C] A rounding or lack of fill at junction of hex comers with chamfer shall be permissible, provided the width across comers is within specified limits at and beyond a distance equal to 17.5% of the basic thread diameter from the chamfered faces.
[D] The nut thickness shall be the overall distance measured parallel to the axis of the nut, from the top of the nut to the bearing surface, and shall include the thickness of the washer face where provided.
[E] Nuts shall have a washer faced bearing surface and chamfered top. The diameter of washer face shall be within the limits of the maximum width across flats and 95% of the minimum width across flats.

12. Magnetic Particle Inspection for Tension Control Bolt Longitudinal Discontinuities and Transverse Cracks

12.1 *Requirements:*

12.1.1 Each sample representative of the bolt lot shall be magnetic particle inspected for longitudinal discontinuities and transverse cracks.

12.1.2 The lot, as represented by the sample, shall be free from nonconforming bolts, as defined in Specification F788, when inspected in accordance with Section 12.2.

12.2 *Inspection Procedure:*

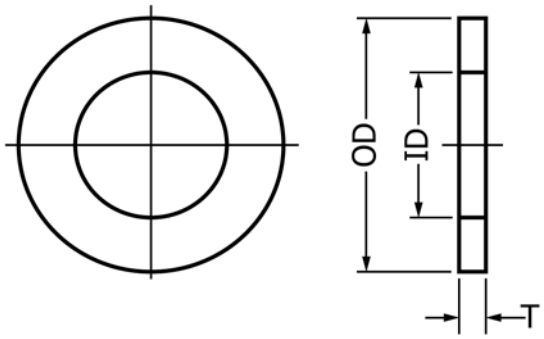
12.2.1 The inspection sample shall be selected at random from each bolt lot in accordance with 13.4.2.4 and examined for longitudinal discontinuities and transverse cracks in the threads, body, fillet, and underside of the head.

12.2.2 Magnetic particle inspection shall be conducted in accordance with Guide E709 or Practice E1444/E1444M. Guide E709 shall be used for referee purposes. If any nonconforming bolt is found during the manufacturers examination of the lot selected in 12.2.1, the lot shall be 100 % magnetic particle tested and all nonconforming bolts shall be removed and scrapped or destroyed.

12.2.3 Eddy current or liquid penetrant inspection may be substituted for the 100 % magnetic particle inspection when nonconforming bolts are found and 100 % inspection is required. On completion of the eddy current or liquid penetrant inspection, a random sample selected from each bolt lot in accordance with Guide F1470, shall be reexamined by the magnetic particle method. In case of controversy, the magnetic particle test shall take precedence.

12.2.4 Magnetic particle indications of themselves shall not be cause for rejection. If in the opinion of the quality assurance representative the indications may be cause for rejection, a sample taken in accordance with Guide F1470 shall be examined by microscopic examination or removal by surface grinding to determine if the indicated discontinuities are within Specification F788 limits.

TABLE 13 Hardened Circular Washers Dimensions



Nominal Size		1	1⅛	1¼
Inside Diameter (ID), in.	nom	1 1/16	1 3/16	1⅜
	max	1.085	1.251	1.438
	min	1.063	1.188	1.375
Outside Diameter (OD), in.	nom	2	2¼	2½
	max	2.063	2.313	2.563
	min	1.937	2.187	2.437
Thickness (T), in.	nom	¼	¼	5/16
	max	0.264	0.264	0.343
	min	0.209	0.209	0.287

13. Testing

13.1 *Testing Responsibility:*

13.1.1 Each component lot and assembly lot shall be tested by the manufacturer prior to shipment in accordance with the lot identification control quality assurance plan in 13.4.

13.1.2 When components or assemblies are furnished by a source other than the manufacturer, the responsible party as defined in Section 18 shall be responsible for assuring all tests have been performed and the components and assemblies comply with the requirements of this specification.

13.2 *Purpose of Lot Inspection*—The purpose of a lot inspection program is to ensure that each lot conforms to the requirements of this specification. For such a plan to be fully effective, it is essential that distributors and purchasers maintain the identification and integrity of each lot until the assemblies are installed.

13.3 *Lot Control*—All components shall be manufactured, processed, and tested in accordance with a lot control plan that provides lot purity and lot identification. The manufacturer and distributors shall identify and maintain the integrity of each lot of components and finished assemblies from raw material selection through all processing operations and treatments to final packing and shipment. Each component lot shall be assigned its own component lot number and each assembly lot its own assembly lot number.

13.4 *Number of Tests:*

13.4.1 *Sampling of Assemblies:*

13.4.1.1 Assembly lot tension test sample size shall be in accordance with Guide F1470, Sample Level C, Table 3, with a minimum of two assemblies.

13.4.1.2 When tested in accordance with the required sampling plan, a component lot shall be rejected if any of the test specimens fail to meet the applicable requirements.

13.4.2 *Sampling of Tension Control Bolts:*

13.4.2.1 Tensile strength, proof load, product hardness and carburization/decarburization sampling shall be in accordance with Guide F1470.

13.4.2.2 Chemical composition sampling shall be one test per heat conducted by the steel producer.

13.4.2.3 Sampling for dimensional and thread fit compliance shall be in accordance with the quality assurance provisions of ASME B18.2.6.

13.4.2.4 Sampling for workmanship, surface discontinuities, including head bursts, and magnetic particle inspection shall be in accordance with Guide F1470.

13.4.2.5 Sampling for resistance to Environmental Hydrogen Embrittlement shall be in accordance with Annex A2.

13.4.3 *Sampling of Nuts:*

13.4.3.1 Proof load and product hardness sampling shall be in accordance with Guide F1470.

13.4.3.2 Chemical composition sampling shall be one test per heat conducted by the steel producer.

13.4.3.3 Sampling for dimensional and thread fit compliance shall be in accordance with the quality assurance provisions of ASME B18.2.6.

13.4.4 *Sampling of Washers:*

13.4.4.1 Product hardness sampling shall be in accordance with Guide F1470.

13.4.4.2 Chemical composition sampling shall be one test per heat conducted by the steel producer.

14. Test Methods

14.1 *Tension Control Bolts:*

14.1.1 Chemical analyses shall be conducted in accordance with Test Methods, Practices, and Terminology A751.

14.1.2 *Tensile and Hardness*—Tensile and hardness tests shall be conducted in accordance with Test Methods F606 using the wedge tension testing of full size product method to determine full size tensile strength.

14.1.3 *Proof Load*—Proof load tests shall be conducted in accordance with Test Methods F606/F606M Method 1, Length Measurement, or Method 2, Yield Strength, at the option of the manufacturer.

14.1.4 *Carburization/decarburization*—Carburization/decarburization tests shall be conducted in accordance with Test Method F2328 using the Microindentation Hardness Method.

14.1.5 *Environmental Hydrogen Embrittlement*—Testing for resistance to Environmental Hydrogen Embrittlement shall be in accordance with Annex A2.

14.2 *Nuts:*

14.2.1 Chemical analyses shall be conducted in accordance with Test Methods, Practices, and Terminology A751.

14.2.2 Hardness and proof load tests shall be conducted in accordance with Test Methods F606/F606M.

14.3 *Washers:*

14.3.1 Chemical analyses shall be conducted in accordance with Test Methods, Practices, and Terminology A751.

14.3.2 *Hardness:*

14.3.2.1 Hardness tests shall be conducted in accordance with the Rockwell test method specified in Test Methods F606/F606M.

14.3.2.2 A minimum of two core hardness readings shall be taken 180° apart on at least one face at a minimum depth of 0.015 in from the original surface.

14.4 *Assembly Installation Tension Test:*

14.4.1 *Test Conditions*—Tests shall be conducted at an ambient temperature between 50 and 90°F (10 and 32°C).

14.4.2 *Test Device:*

14.4.2.1 The tension measuring device shall be capable of measuring the assembly tension after torquing.

14.4.2.2 The tension measuring device shall be calibrated to within 1% of the required pretension.

14.4.2.3 The tension measuring device (and any other equipment) shall be calibrated based on the frequency of use and the equipment manufacturer's recommendation, but not less than one time per year.

14.4.3 *Installation and Tension Test:*

14.4.3.1 Install the tension control bolt, nut, washer, and appropriate spacer washer(s) in the tension measuring device. The device shall not restrain the head from turning.

14.4.3.2 Install the washer(s) under the nut such that three to five threads of the bolt are located between the bearing face of the nut and the underside of the bolt head using the washer furnished with the assembly in contact with the nut.

14.4.3.3 Initially tighten the assembly using a hand wrench by turning the nut to produce the setting tension specified below.

Setting Tension	
Bolt Diameter, in.	Tension, 1000 lb
1	8 to 10
1⅛	11 to 13
1¼	14 to 16

14.4.3.4 Complete tightening the assembly nut using a spline drive installation tool capable of engaging the nut and spline end simultaneously during this process. Tighten continuously until the spline shears from the bolt.

14.4.3.5 The bolt component shall not be restrained during the assembly tightening.

14.4.3.6 In order to pass, shearing of the spline end shall occur in the shear groove. Failure in the threaded region shall be considered nonconforming.

14.4.3.7 Record the tension after shearing of the spline end as the assembly installation tension.

15. Inspection

15.1 If the inspection described in 15.2 is required by the purchaser, it shall be specified in the inquiry and contract or order.

15.2 The purchaser's representative shall have free entry to all parts of the manufacturer's works or supplier's place of business that concern the manufacture or supply of the assemblies. The manufacturer or supplier shall afford the purchaser's representative all reasonable facilities to satisfy the representative that the assemblies are being furnished in accordance with this specification. All tests and inspections required by the specification that are requested by the purchaser's representative shall be made before shipment, and shall be conducted so as not to interfere unnecessarily with the operation of the manufacturers or suppliers operations.

16. Rejection and Rehearing

16.1 Disposition of nonconforming sets shall be in accordance with the section on Disposition of Nonconforming Lots of Guide F1470.

17. Certification

17.1 The manufacturer or supplier, whichever is the responsible party as defined in Section 18, shall furnish the purchaser a test report for each lot that includes the following:

17.1.1 Heat analysis and heat number of each component (bolt, nut, and washer), and a statement certifying that heats having the elements listed in 6.1.4 intentionally added were not used to produce the tension control bolts.

17.1.2 Results of hardness, tensile and proof load tests of each component (bolt, nut, and washer), when applicable.

17.1.3 Results of test for resistance for Environmental Hydrogen Embrittlement, with a copy of the test report as required by Section A2.9 of Annex A2.

17.1.4 *Results of Assembly Lot Installation Tension Tests*—At the manufacturer's option, the mean and standard deviations may be reported.

17.1.5 Results of magnetic particle inspection tests.

17.1.6 Results of visual inspection for bursts.

17.1.7 Statement of compliance with dimensional and thread fit requirements.

17.1.8 Assembly lot number, individual component lot numbers for bolt-nut-washer, and purchase order number.

17.1.9 ASTM specification number, grade, and issue date.

17.1.10 Country of origin.

17.1.11 Complete mailing address of responsible party.

17.1.12 Title and signature of the individual assigned certification responsibility by the company officers.

17.2 Failure to include all the required information on the test report shall be cause for rejection.

18. Responsibility

18.1 The party responsible for the assemblies shall be the organization that supplies the assemblies to the purchaser and certifies that the assemblies have been manufactured, sampled, tested, and inspected in accordance with this specification and meets all of its requirements.

19. Product Marking of Tension Control Bolts, Nuts and Washers

19.1 *Manufacturers Identification*—All components of each assembly shall be marked by the manufacturer with a unique identifier to identify the manufacturer.

19.2 *Identification of Bolts:*

19.2.1 Bolts for Grade 1 assemblies shall be marked with the symbol "F3043-1". Bolts for Grade 2 assemblies shall be marked with the symbol "F3043-2".

19.2.2 *Marking Location and Methods*—All markings shall be located on the top of the bolt head and shall be raised or depressed at the manufacturer's option.

19.3 *Identification of Nuts:*

19.3.1 Nuts for Grade 1 assemblies shall be marked with the symbol "XT-1". Nuts for Grade 2 assemblies shall be marked with the symbol "XT-2".

19.3.2 Additional identification or distinguishing marks, or both, may be used by the manufacturer.

19.3.3 All marking symbols shall be raised or depressed on one face of the nut at the manufacturer's option.

19.3.4 Grade and manufacturer's identification shall be separate and distinct. The two identifications shall preferably be in different locations and, when on the same level, shall be separated by at least two spaces.

19.4 *Identification of Washers:*

19.4.1 Washers shall be marked with the symbol "XT".

19.4.2 Additional identification or distinguishing marks, or both, may be used by the manufacturer.

19.4.3 All marking symbols shall be depressed on one face of the washer.

19.4.4 Type and manufacturer's identification shall be separate and distinct. The two identifications shall preferably be in different locations and, when on the same level, shall be separated by at least two spaces.

19.5 *Acceptance Criteria*—Components that are not marked in accordance with these provisions shall be considered nonconforming and subject to rejection.

20. Packaging and Package Marking

20.1 *Packaging:*

20.1.1 Unless otherwise specified, the assemblies shall be properly packed to prevent loss and damage during shipment. Special packaging requirements shall be defined at the time of the inquiry and order, but shall not void the requirements in 20.1.2 and 5.1.2.

20.1.2 All products shall be assembled. (See 5.1.2.)

20.2 *Package Marking:*

20.2.1 Each shipping unit shall include or be plainly marked with the following information:

20.2.1.1 ASTM designation and grade,

20.2.1.2 Size, nominal diameter, and length,

20.2.1.3 Name of the manufacturer and the supplier, if furnished by an entity other than the manufacturer,

20.2.1.4 Number of assemblies,

20.2.1.5 Assembly lot number(s),

20.2.1.6 Purchase order number(s), when required by the customer, and

20.2.1.7 Country of origin.

21. Keywords

21.1 alloy steel; alternate design fasteners; bolts; fasteners; spline end; structural; tension control bolt; tension control bolt assembly; twist-off bolt

ANNEXES

(Mandatory Information)

A1. GRADE 2 ASSEMBLIES

A1.1 Thread Dimensions for Grade 2 Assemblies

A1.1.1 The basic thread dimensions for Grade 2 assemblies are as provided in Table A1.1.

A1.2 Stress Area for Grade 2 Assemblies

A1.2.1 The stress area A_s is calculated as follows:

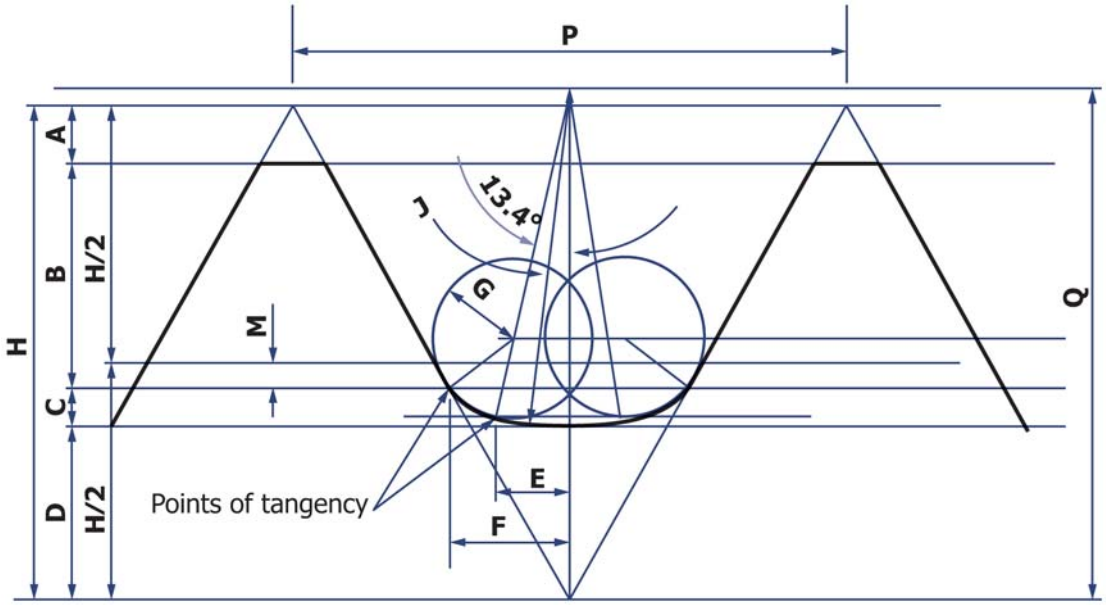
$$A_s = (\pi / 4)\,[(d_2 + d_3) / 2]^2$$

where:

A_s = tensile stress area, in.^{2}
d_{bsc} = basic major diameter, in.
n = threads per in.
H = $(\sqrt{3} / 2) * d_{bsc}/n$
d_2 = $d_{bsc} - (3/4\ H)$
d_1 = $d_2 - 2(H / 20)$
θ = $\sin^{-1}(2\sqrt{3} / 15)$
z = $(H / 6)(\cos \theta)$
x' = $(H / 6)(\sin 30°)$
y = $(H / 2)(\cos \theta)$
z' = $(2H / 3) - y - z$
d_3 = $d_1 - 2\,(z - x' + z')$

TABLE A1.1 Basic Thread Dimensions, Grade 2 Assemblies

NOTE 1—Values have been established based on a function of pitch, P. The thread values based on a function of height, H, are used for reference only.



Nominal Size, in.	1	1⅛	1¼
Major Diameter, in.	0.9980	1.1228	1.2478
Threads per inch	8	7	7
Pitch, in.	0.1250	0.1429	0.1429
A, in.	0.0135	0.0155	0.0155
B, in.	0.0460	0.0526	0.0526
C, in.	0.0106	0.0121	0.0121
D, in.	0.0381	0.0435	0.0435
E, in.	0.0167	0.0190	0.0190
F, in.	0.0281	0.0321	0.0321
G, in.	0.0180	0.0206	0.0206
H, in.	0.1083	0.1237	0.1237
J, in.	0.0722	0.0825	0.0825
M, in.	0.0054	0.0062	0.0062
Q, in.	0.1104	0.1261	0.1261

A2. TEST METHOD

A2.1. Scope

A2.1.1 This test method defines the procedures and tests to evaluate the susceptibility to Environmental Hydrogen Embrittlement (EHE) of an ASTM F3043 bolt.

A2.1.2 This test method shall qualify the bolt for use relative to EHE.

A2.1.3 The characteristic to be evaluated by this test method is the susceptibility to EHE caused by hydrogen generated from corrosion. Testing shall be performed on specimen ASTM F3043 bolts manufactured to the tensile strength of the bolt (see Section A2.5 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.

A2.2. Referenced Documents

A2.2.1 *ASTM Standards:*[5]

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,

[5] 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.

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
F2660 Test Method for Qualifying Coatings for Use on A490 Structural Bolts Relative to Environmental Hydrogen Embrittlement
G3 Practice for Conventions Applicable to Electrochemical Measurements in Corrosion Testing
G15 Terminology Relating to Corrosion and Corrosion Testing (Withdrawn 2010)[6]
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

A2.2.2 *Other Reference:*

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

A2.3. Terminology

A2.3.1 *Definitions:*

A2.3.1.1 Terminology for this test method shall be used in accordance with Terminology F1789, Terminology F2078, and Terminology G15 except as described below.

A2.3.2 *Definitions of Terms Specific to This Standard:*

A2.3.2.1 *specimen lot, n*—at least 15 ASTM F3043 specimen bolts manufactured in the same process from the same lot of a steel alloy.

A2.4. Significance and Use

A2.4.1 This test method describes the testing procedure that shall be used to qualify material for use in ASTM F3043 bolts made of any steel composition permitted by this specification. The test method measures the susceptibility of the material to the influence of an externally applied potential (see A2.7.2.3.2) by testing for the threshold of embrittlement in a salt solution environment.

A2.5 Specimen Bolt Requirements

A2.5.1 Testing shall be carried out using ASTM F3043 specimen bolts heat treated to achieve strength values near the maximum permitted by this standard. Specimen bolts are designed to simulate a worst case material condition with respect to susceptibility to environmental hydrogen embrittlement (EHE). For this reason, tensile values for specimen bolts approach the maximum limits for F3043 bolts.

A2.5.2 Specimen bolts shall be the nominal inch size to be produced: 1, 1⅛ or 1¼ in.

A2.5.3 Specimen bolts shall be for a lot that displays between 210 and 215 ksi, when tested in accordance with Test Methods F606/F606M.

A2.5.4 Specimen bolts shall be from homogeneous lots traceable to given mill heats of steel alloy.

A2.5.5 Tensile strengths for the specimen bolts must be within the range of 210 and 215 ksi, and dimensional and compositional conformance to this Specification shall be provided by the supplier of each specimen lot.

A2.6. Sample Quantities Required

A2.6.1 A minimum of twelve (12) bolts from any specimen lot shall be used for evaluation and qualification. Additional samples may be required for repeat test and shall be held in contingency.

A2.7. Test Procedures

A2.7.1 *Open Circuit Potential (OCP):*

A2.7.1.1 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 corrosion behavior of the bolt. The OCP measurement shall be made on the 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.

A2.7.1.2 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 the other OCP test, then a known material 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. One reason for inconsistency is dissimilar metals in the test setup.

A2.7.2 *Environmental Hydrogen Embrittlement Testing:*

A2.7.2.1 *Mechanical Test Set-up:*

A2.7.2.1.1 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 of ASTM F2660 with the grade to be used for the bolts.

A2.7.2.1.2 The loading method required for this test is a 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 ± 0.5%, programmable to increase 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.

A2.7.2.2 *Fast Fracture Testing:*

A2.7.2.2.1 The first step in the testing sequence shall be a measurement of the fast fracture load of the specimen bolts in

[6] The last approved version of this historical standard is referenced on www.astm.org.

bending, FFS(B). 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 specimen bolts.

A2.7.2.2.2 The average of these five test results shall determine the fast fracture strength of each condition.

A2.7.2.3 *EHE Sample Testing:*

A2.7.2.3.1 To measure the EHE susceptibility of the fastener, bolts are tested in the environment/setup described in section A2.7.1.1 and A2.7.2.3.2 using the step load methodology described in Test Method F1624, Section 8, to measure P_{th}.

A2.7.2.3.2 To test at the OCP of the bolt, the environmental chamber shall be partially filled with 3.5% NaCl solution produced in accordance with Practice G44 with the level of the solution being maintained below the threshold section of the bolt specimen. The reference electrode shall be placed in close vicinity to the bolt threads. An electrochemical potential equal to the measured OCP from section A2.7.1 shall be imposed on the specimen during the test to negate the influence of any dissimilar metals in the environmental chamber, such as the loading pins and gripping devices. When the potential reading is stable, the remaining salt solution is added to the chamber to fully immerse the bolt sample.

(1) As an alternative to imposing an electrochemical potential, the test can be performed under freely corroding conditions, provided the specimen is isolated from all metal contacts. It should be verified that there is no conductivity between the specimen and the adapters. The freely corroding potential, or OCP (section A2.7.1), shall be measured and recorded.

A2.7.2.3.3 The loading profile of the first sample bolt shall be (10/5/2,4), or ten (10) steps tested with a hold time of 2-hours followed by ten (10) steps at a hold time of 4-hours in 5% increments of FFS(B), taken as the initial value of P_{max}. Loading is not released during the transition from the 2-hour to 4-hour hold requirement. The test proceeds until the sample experiences a load drop of more than 5% during any single step in the load rate. An example of the step loading profile is shown in Fig. 2B of ASTM F2660.

A2.7.2.3.4 Subsequent tests shall be at progressively decreasing loading rates by using the same (10/5/2,4) profile and lowering P_{max} to the value of the previous threshold load thereby lowering the ΔP for each loading step. As P_{max} is decreased, the resolution is increased and the loading rate is decreased. The test proceeds until the sample experiences a load drop of more than 5% during any single step in the load rate.

A2.7.2.3.5 The threshold load for the bolts, P_{th}, is obtained when the threshold load for the subsequent test is within a value of 5% of P_{max} of the threshold load measured on the previous test at the higher loading rate. The minimum value of the threshold load obtained through these measurements shall be used in the calculation described in A2.8. The lowest threshold value established by consecutive tests shall be considered the threshold load for the bolts, P_{th}. The minimum number of samples to accomplish the establishment of the threshold load shall be five (5) specimen bolts.

A2.8 EHE Acceptance Criterion

A2.8.1 Perform tests on fasteners to the same hydrogen embrittlement acceptance criterion as Test Method F519, Type 1a specimens that require a threshold stress equal in value to that of 75% of the notch tensile strength (NTS = 1.6 UTS) of the Type 1a specimen, which is equal to or greater than 1.2 UTS.

A2.8.2 To obtain the equivalent acceptance criterion for the bolt, the net tensile stress at the root of the thread should also be equal to or greater than 1.2 UTS. Since d/D for fasteners is always greater than 0.8, that is greater than 0.7 used with Test Method F519 notched tensile specimen, the fastener must be tested in bending to attain the same stress level.

A2.8.3 The acceptance criterion for EHE shall be a threshold load in bending, σ_b, to produce the same stress or greater than the load in tension that produces a stress of 1.2 UTS or $\sigma_b \geq 1.2$ UTS. Since the limit load of a bolt in bending equals 2.3 YS $\approx$ 2.0 UTS; the acceptance criterion for EHE is equivalent to $\geq$ 60% of the fast fracture load in bending, FFS(B).

A2.8.3.1 Therefore for acceptance, the following condition must be met:

$$P_{th} \geq 0.6 \text{ FFS (B)}$$

A2.9. Test Report

A2.9.1 *Report Content:*

A2.9.1.1 Heat analysis and heat number for the steel from which the bolts are made;

A2.9.1.2 Bolt diameter;

A2.9.1.3 Bolt tensile strength;

A2.9.1.4 Fast fracture load of the specimen bolts in bending, FFS(B);

A2.9.1.5 Data for step load testing;

A2.9.1.6 Determination of bend load threshold, P_{th}; and

A2.9.1.7 Statement that the material lot satisfies the requirements of Annex A2.

APPENDIX

(Nonmandatory Information)

X1. PRE-INSTALLATION VERIFICATION TESTING, PRETENSIONING AND INSPECTION

X1.1 Pre-Installation Verification Testing Using Bolt Tension Calibration Device

X1.1.1 Take three twist-off-type tension control bolt assemblies (bolt, nut and washer) of each production lot, as provided as a complete set by the manufacturer or supplier. Each set is called a "fastener assembly."

X1.1.2 Use a flat bushing, free of lubricant and preferably roughened rather than smooth, on the back of the bolt tension calibration device.

X1.1.3 Place the bolt in the bolt tension calibration device.

X1.1.4 Add spacers, spacer bushings, flat plate shims and/or washers as necessary to have approximately two to three threads of stickout beyond the face of the nut when the nut is finger tight. Any shims, spacers, or washers should be flat prior to use. Final stickout may range between five threads and a flush end condition (no stickout). Place the washer from the fastener assembly under the nut so that it will be adjacent to the nut.

X1.1.5 Snug the bolt using the technique (spud wrench, impact wrench, or installation wrench) to be used on the structure. Use approximately the same manual effort or wrench effort as will be used in the structure.

X1.1.6 Further tighten the bolt by turning the nut with the installation wrench until the bolt spline shears off.

X1.1.7 Verify that the achieved bolt pretension, as read on the bolt tension calibration device dial gage, reaches or exceeds the pretension given in the table below:

	Pretension, pounds, min	
Bolt Size, in.	Grade 1	Grade 2
1	90 000	94 000
1⅛	114 000	119 000
1¼	145 000	150 000

X1.1.8 Remove the fastener assembly and repeat steps X1.1.2 through X1.1.7 above so that a total of three consecutive fastener assemblies have been tested, and that all satisfy the requirements for bolt tension.

X1.1.9 Identifying the rotational-capacity test lot, record the achieved bolt pretensions for each tested fastener assembly in a record-keeping system.

X1.2 Twist-Off-Type Tension-Control Bolt Pretensioning

X1.2.1 Align all bolt holes to permit insertion of the bolts without undue damage to the threads.

X1.2.2 Place bolts in all holes, place the washer over the threaded end, and thread the nuts onto the bolts.

X1.2.3 Using a systematic approach, compact the joint from the most rigid part of the joint toward the free edges, achieving the snug tight condition. Snug tight is the condition that exists when all of the plies in a connection have been pulled into firm contact by the bolts in the joint and all of the bolts in the joint have been tightened sufficiently to prevent the removal of the nuts without the use of a wrench. Firm contact is defined as the condition that exists on a faying surface when the plies are solidly seated against each other, but not necessarily in continuous contact.

X1.2.4 Multiple passes with the wrench may be necessary to achieve firm contact when connection materials do not align in-plane, or the connecting elements do not fit flatly at the faying surface.

X1.2.5 Using a systematic approach, pretension each assembly using the installation wrench until the bolt spline shears off. In a joint bolt pattern with several rows, such as a large connection plate in a connection, or a bolted girder web or flange splice, the bolts in the center of the joint should be pretensioned first, then proceed toward the free edges of the plate. In a joint with a single or double row of bolts, pretensioning begins where the steel is already in contact, then proceed toward the end where the steel may not be in contact. If there is solid contact between the steel at all locations, the direction of pretensioning does not matter.

X1.2.6 Eject each spline from the wrench in a safe manner.

X1.3 Inspection of Twist-Off-Type Tension-Control Bolt Pretensioning

X1.3.1 *Inspection Prior to Installation:*

X1.3.1.1 Inspect the materials to verify that they are readily identifiable, have proper markings, and have proper documentation in accordance with the project specifications.

X1.3.1.2 Inspect the storage methods to ensure that fastener lots are kept separate and identifiable until time for assembly. Fastener assemblies (bolt, nut and washer) must be kept together as shipped by the supplier.

X1.3.1.3 Verify that adequate lubrication is present for the fasteners to be used. Modification or additional lubrication of any component of a twist-off-type tension-control bolt fastener assembly is not permitted, except when performed by the manufacturer.

X1.3.1.4 Observe the pre-installation verification for the fastener assemblies representative of those to be installed. Three fastener assemblies of each assembly lot must be tested at the start of the work, prior to installation on the structure. The pre-installation verification test is to be performed by the bolting crew(s).

X1.3.2 *Inspection After the Joint has been brought to the Snug Tight Condition:*

X1.3.2.1 Visually verify that firm contact has been achieved in the joint, using the proper fastener assemblies. Firm contact is defined as the condition that exists on a faying surface when the plies are solidly seated against each other, but not necessarily in continuous contact.

X1.3.2.2 Visually verify that the length of bolt used is proper for the grip. The end of the bolt threads must be at least flush with the face of the nut (not recessed). The maximum stickout is usually in the range of four to six threads, but varies by bolt diameter and production tolerances. If needed, use a sample bolt and nut from the same lot as a comparator, running the nut up the threads but allowing one full turn at the end for pretensioning. For joints where the threads must be excluded from the shear plane, additional verification of bolt length and the direction in which the bolt is oriented may be necessary.

X1.3.2.3 Visually verify that all twist-off bolts have the spline fully intact.

X1.3.2.4 Visually verify that all of the bolts in the joint have been tightened sufficiently to prevent the turning of the nuts without the use of a wrench. Where visual inspection indicates that the fastener may not have been sufficiently tightened to prevent the removal of the nut by hand, physically check that the nut cannot be removed by hand.

X1.3.3 *Inspection During and After Pretensioning:*

X1.3.3.1 Perform routine observation of the pretensioning of the bolts to verify the use of the proper techniques as described in X1.2. One need not observe all pretensioning operations and may rely upon the visual inspection to verify that the spline has been properly twisted off the end of the bolt.