Designation: F3148 – 17a

Standard Specification for High Strength Structural Bolt Assemblies, Steel and Alloy Steel, Heat Treated, 144ksi Minimum Tensile Strength, Inch Dimensions[1]

This standard is issued under the fixed designation F3148; 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 chemical, dimensional, physical and mechanical requirements for quenched and tempered bolts manufactured from steel and alloy steel, in inch dimensions. The bolts are available as structural bolting assemblies which include a fixed spline bolt, a suitable nut and at least one washer covered by reference herein.

1.2 *Intended Use:*

1.2.1 Bolts manufactured under this specification, and structural bolting assemblies supplied under this specification, are intended for use in structural connections covered in the Specification for Structural Joints Using High-Strength Bolts and installed using the torque-and-angle or part turn/combined installation method.

1.2.2 Structural bolting assemblies in this specification are furnished in nominal diameters from ½ to 1-¼ in. inclusive.

1.3 *Classification:*

1.3.1 Structural bolting assemblies are designated as Grade 144.

1.3.2 Bolts are designated by type denoting raw material chemical composition.

Type 1 - 144ksi - carbon steel, carbon boron steel, alloy steel or alloy steel with boron addition
Type 3 - 144ksi - weathering steel

1.4 Terms used in the specification are defined in Terminology F1789.

1.4.1 *Torque-and-Angle Fixed-Spline Structural Bolt*—bolt that includes an integral fixed-spline end which extends beyond the threaded portion of the bolt and is used as a component of a torque-and-angle fixed-spline structural bolting assembly.

1.4.2 *Torque-and-Angle Fixed-Spline Structural Bolting Assembly*[2]— a fastener assembly comprised of a torque-and-angle fixed-spline bolt with a suitable nut and at least one washer, installed and tightened using a special electric wrench and socket system which has an inner socket that engages the fixed-spline end of the bolt and with an outer socket that engages and turns the nut, in two separate and distinct operations, the first is a controlled torque application and the second is a specified angle.

1.4.3 *Combined Method*—A tightening method comprised of two steps, the first tightening step using a torque regulating tool and the second tightening step in which a specified turn is applied to the turned part of the assembly. Also known as the 'part turn method'.

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.*

1.6 ASTM International takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

[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 torque-and-angle fixed-spline structural bolting system has a patent application pending. Interested parties are invited to submit information regarding the identification of an alternative(s) to this patent-pending item to the ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend.

2. Referenced Documents

2.1 *ASTM Standards:*[3]

A563 Specification for Carbon and Alloy Steel Nuts
A751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
B695 Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel
E709 Guide for Magnetic Particle Testing
E1444/E1444M Practice for Magnetic Particle Testing
F436/F436M Specification for Hardened Steel Washers Inch and Metric Dimensions
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
F1136/F1136M Specification for Zinc/Aluminum Corrosion Protective Coatings for Fasteners
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
F2833 Specification for Corrosion Protective Fastener Coatings with Zinc Rich Base Coat and Aluminum Organic/Inorganic Type
G101 Guide for Estimating the Atmospheric Corrosion Resistance of Low-Alloy Steels

2.2 *ASME Standards:*[4]

B 1.1 Unified Screw Threads
B 18.2.6 Fasteners for Use in Structural Applications
B 18.18 Quality Assurance for Fasteners

2.3 *RCSC:*[5]

Specification for Structural Joints Using High-Strength Bolts

3. Ordering Information

3.1 Orders for structural bolting assemblies under this specification shall include:

3.2 *Mandatory ordering information:*

3.2.1 ASTM F3148 designation and revision,
3.2.2 *Quantity*—Number of assemblies,
3.2.3 Grade 144,
3.2.4 *Size*—Including nominal diameter and bolt length,
3.2.5 *Type*—Type 1 or Type 3. When Type is not specified either Type 1 or Type 3 may be furnished at the supplier's option.
3.2.6 *Coatings or finishes*—If other than plain finish, specify the coating process or finish required, see Table 1.

3.3 Additional ordering information when specified by purchaser;

3.3.1 Test reports, see Section 15.
3.3.2 Additional details of other assembly components.
3.3.3 Rotational capacity testing of assemblies per Annex A1.
3.3.4 Observation or inspection requirements. See 14.2.

[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.

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

[5] Research Council on Structural Connections (RCSC) http://www.boltcouncil.org/

TABLE 1 Permitted Coatings[G]

	B695[A,F]		F1136/F1136M[D,F]		F2833[E,F]	
Bolt	Class 55		Grade 3		Grade 1	
Nut	Class 55		Grade 5		Grade 1	
Washer	Class 55		Grade 3		Grade 1	
	Nut Pitch Dia. Overtap in.	Bolt Pitch OS After Coating[C] in.	Nut Pitch Dia. Overtap[B] in.	Bolt Pitch OS After Coating[C] in.	Nut Pitch Dia. Overtap[B] in.	Bolt Pitch OS After Coating[C] in.
½-13 UNC	0.018	0.012	0.009	0.006	0.009	0.006
⅝-11 UNC	0.020	0.013	0.010	0.007	0.010	0.007
¾-10 UNC	0.020	0.013	0.010	0.007	0.010	0.007
⅞-9 UNC	0.022	0.015	0.011	0.008	0.011	0.008
1-8 UNC	0.024	0.016	0.012	0.008	0.012	0.008
1 ⅛-7 UNC	0.024	0.016	0.012	0.008	0.012	0.008
1 ¼-7 UNC	0.024	0.016	0.012	0.008	0.012	0.008

[A] Supplementary nut lubrication to A563 S1, S2 or S3 is required for mechanically deposited zinc coatings.
[B] Nut overtap shall not exceed this amount unless agreed upon between the purchaser and user. If a larger overtap is used or required, coated structural bolt assembles shall pass the RC test requirements per F3148, Annex A1 as proof of assembly, ductility and thread strength.
[C] Bolt pitch oversize limit in case of dispute. Material within the plain gage limits which meets the coating thickness requirements and assembles freely need not be measured to this tolerance.
[D] Grade 5 of this coating meets the supplementary lubrication requirements of A563 S1.
[E] Grade 1 of this coating meets the supplementary lubrication requirements of A563 S1.
[F] Nuts overtapped for coating shall be proof load tested to a minimum of 175 000 psi.
[G] Other finishes – specify other protective finish, if required.
OS= Oversize

3.3.5 Country of origin.

3.3.6 Supplementary requirements.

NOTE 1—A typical description follows: 1000 pieces ¾-10 × 3 in. ASTM F3148-15, Grade 144, Type 1, each with one hardened ASTM F436/F436M Type 1 washer, and one A563 Grade DH heavy hex nut.

4. Dimensions

4.1 *Head and Body:*

4.1.1 Bolts shall be round head conforming to the dimensions specified in Table 2.

4.1.2 The thread length shall not be changed except as provided in Supplementary Requirement S1. Other dimensions shall not be changed.

4.2 *Threads:*

4.2.1 Uncoated bolt threads shall be as specified in Table 2.

4.2.2 Coated bolt threads shall be as specified in Table 2 before coating.

4.3 The gauging limit for coated bolts shall be verified during manufacture. In case of dispute, a calibrated thread ring gauge of the same size as the oversize limit in Table 1 (Class X tolerance, gauge tolerance plus) shall be used to verify conformance. The gauge shall assemble with hand effort following application of light machine oil to prevent galling and damage to the gauge. These inspections, when performed to resolve controversy, shall be conducted at the frequency specified in the quality assurance provisions of ASME B 18.18.

NOTE 2—It is the intent of this specification that coated nuts and bolts assemble freely when ordered together. It is recognized that the batch nature of coating processes and the cumulative effect of coating thickness may create intermittent assembly problems.

5. Product Marking

5.1 At a minimum all assemblies shall be marked as required in Table 2. Marking shall be on the bolt head and shall be raised or depressed, at the manufacturer's option. The marking shall be visible after coating.

5.2 Grade/Type marking, the manufacturer's mark, and the private label distributor's mark (if used), shall be in separate and distinct locations.

6. Chemical Composition

6.1 Type 1 bolts shall be carbon steel, carbon boron steel, alloy steel or alloy steel with Boron addition at the manufacturer's option, conforming to the chemical composition specified in Table 3.

TABLE 2 Dimensions, Threads, Marking, and Matching Components

	Type 1	Type 3
Round Head Dimensions, ASME[A]	B18.2.6	B18.2.6
Thread Fit, ASME	B1.1 UNC 2A	B1.1 UNC 2A
Grade Marking	144	144
Nut	A563 DH	A563 DH3
Flat Washer	F436/F436M – 1	F436/F436M – 3

[A] All dimensions except spline geometry

6.2 Type 3 bolts shall be weathering steel and shall conform to the chemical compositions A or B specified in Table 3. Optionally, the chemical composition may have a Corrosion Index of 6 or greater, as calculated from the Heat Analysis, and as described in Guide G101 Guide for Estimating the Atmospheric Corrosion Resistance of Low-Alloy Steels.

6.3 Product analysis made on finished bolts representing each lot shall conform to the product analysis requirements specified in Table 3, Footnote A.

6.4 Heats to which bismuth, selenium, tellurium, or lead has been intentionally added shall not be permitted.

6.5 Chemical analysis shall be performed in accordance with Test Methods, Practices, and TerminologyA751.

7. Materials and Manufacture

7.1 Structural bolting assemblies shall be certified, supplied and installed as matched sets. These assemblies shall be capable of developing a minimum predetermined initial and final tension when installed using an appropriate fixed spline-drive installation tool. See Appendix X1.

7.2 *Production Method:*

7.2.1 Bolts shall be cold formed, warm formed, hot formed, hot forged, machined, or any combination thereof.

7.3 *Heat Treatment:*

7.3.1 All Bolts shall be quenched in oil from the austenitizing temperature.

7.3.2 All Bolts shall be tempered by reheating to not less than 800°F/427°C.

7.4 Threads shall be rolled or cut.

7.5 *Coatings and Other Finishes:*

7.5.1 Coatings, including supplementary lubrication and nut oversize requirements are provided in Table 1.

7.5.2 When coated assemblies are required, the purchaser shall specify the coating process and any additional special requirements.

7.5.3 Threaded components of assemblies (bolts and nuts) shall be coated by the same process, limited to one process per item with no mixed processes in a component lot.

7.5.4 Nut and washer components of the assemblies shall be in accordance with Table 2.

7.6 *Secondary Processing:*

7.6.1 Lot control and full traceability shall be maintained throughout all outside or secondary processes.

7.6.2 Lots to which secondary processing has been performed by any party after sale from the manufacturer must be traceable using a lot number which differs from the manufacturer's original lot number.

7.6.3 If processing that can affect mechanical or performance properties is performed after initial testing, the bolts or assemblies, or both, shall be retested for all specified mechanical properties and performance requirements affected by the processing.

7.6.4 When the secondary process is heat treatment, the bolts shall be tested for all specified mechanical properties.

TABLE 3 Chemical Requirements[A]

Heat Analysis	Type 1		Type 3		
	Carbon Steel with or without Boron	Alloy Steel with or without Boron	Composition A	Composition B	Based on Corrosion Index[B]
Carbon	0.30 – 0.52	0.30 – 0.48	0.33 – 0.40	0.38 – 0.48	0.30 – 0.52
Manganese	0.60 min	0.60 min	0.90 – 1.20	0.70 – 0.90	0.60 min
Phosphorus, max	0.035	0.035	0.035	0.035	0.035
Sulfur, max	0.040	0.040	0.040	0.040	0.040
Silicon	0.15 – 0.30	...	0.15 – 0.30	0.30 – 0.50	...
Boron, max	0.003	0.003	...	...	...
Copper	...	...	0.25 – 0.45	0.20 – 0.40	0.20 – 0.60[B]
Nickel	...	...	0.25 – 0.45	0.50 – 0.80	0.20[B,C] min
Chromium	...	...	0.45 – 0.65	0.50 – 0.75	0.45[B] min
Molybdenum	...	...	...	0.06 max	0.15[B,C] min

[A] Individual product analysis that is outside the specified range is permitted provided it is within 10% of the value required of the heat analysis.
[B] Type 3 bolts conforming to composition A or B, or type 3 bolts which have a copper minimum Heat Analysis of 0.20% and a Corrosion Index of 6 or higher as calculated from the Heat Analysis as described in Guide G101 Predictive method shall be accepted
[C] Either Nickel or Molybdenum must be present in the amount specified.

7.6.5 Secondary processing, including lubrication, by any party other than that which certified the assembly lot shall not be permitted unless under the direction of the manufacturer or responsible party.

7.7 *Lubrication:*

7.7.1 Assemblies shall have at least one component lubricated by the responsible party to meet the assembly lot tension requirements.

8. Testing and Lot Control

8.1 *Testing Responsibility:*

8.1.1 Each lot shall be tested by the responsible party prior to shipment in accordance with the lot control and identification quality assurance plan in 8.2 through 8.5.

8.2 Bolts shall be processed in accordance with a lot control and identification quality assurance plan. The manufacturer, secondary processors, and distributors shall identify and maintain the integrity of each production lot from raw material through all processing operations to final packing and shipment. Each lot shall be assigned a unique lot identification number, each lot shall be tested, and the lot inspection test reports retained.

8.3 Secondary processing shall be in accordance with a lot control and identification plan.

8.4 A lot shall be a quantity of uniquely identified bolts of the same nominal size and length produced consecutively at the initial operation from a single mill heat of material and processed at one time, by the same process, in the same manner so that statistical sampling is valid.

8.5 Fastener tension testing and rotational capacity testing require that the responsible party maintain assembly lot traceability. A unique assembly lot number shall be created for each change in assembly component lot number, such as nuts or washers.

8.6 *Number of Tests:*

8.6.1 The minimum number of tests required from each lot or each assembly lot shall be in accordance with F1470 and ASME B18.18. These tests and sample numbers are for final inspection only and shall be in addition to the manufacturer's established internal quality control system and in-process inspection procedures.

NOTE 3—The purpose of a lot inspection and control program is to ensure that each lot conforms to this specification and that lot integrity is maintained to the point of use. It is essential that secondary processors, distributors, and users maintain lot identification and integrity until installation.

NOTE 4—8.6.1 is intended to identify a statistically large number of non-conformances but does not assure 100% freedom from non-conforming product.

9. Test Methods

9.1 Tensile strength, proof load, surface discontinuities, hardness, micro-hardness, carburization/decarburization, coating thickness, magnetic particle, rotational capacity, and assembly tension testing, as applicable, shall be in accordance with Table 4.

9.2 Tensile strength shall be determined using the F606/F606M Wedge or Axial Tension Testing of Full Size Product Method or the Machined Test Specimens Method depending on size and nominal length as specified in 10.1.

9.3 Proof load shall be determined using F606/F606M Method 1, Length Measurement, or Method 2, Yield Strength, at the option of the manufacturer.

9.4 Magnetic Particle Inspection shall be conducted in accordance with Table 4 and Section 11.

9.5 Carburization/Decarburization Inspection shall be conducted in accordance with Table 4 and Section 12.

9.6 Assembly torque and angle tension tests shall be performed in accordance with Table 5 and Section 13.

10. Mechanical Properties

10.1 *Tensile Properties:*

TABLE 4 Number of Tests and Test Method or Criteria

	Sample Size	Test Method	Notes
Tensile Strength	F1470	F606/F606M	Wedge or axial full size. Machined. See 8.1.1.
Proof Load	F1470	F606/F606M	Method 1 or 2 optional. See 8.2.
Hardness	F1470	F606/F606M	
Dimensions and Thread Fit	ASME B18.18	ASME B18.2.6 and B1.1 2A	
Surface Discontinuities	F1470	F788	
Coating Weight/Thickness	F1470[B]	Product Specification	
Magnetic Particle	F1470	F788	Guide E709 or Practice E1444/E1444M. Sample based on quantity per heat number, per heat treatment process. At least one sampling per heat number, per heat treatment process
Carburization/Decarburization	At least 1	F2328	
Fastener Tension	F1470	Section 11	
Rotational Capacity[A]	F1470	Annex A1	Minimum of 2 sample size

[A] Fasteners assemblies shall be rotational capacity tested when specified on the inquiry and order.
[B] Use F1470 for sampling if sample requirements are not in the coating specification.

TABLE 5 Assembly Tension Test Minimum Tension, lbf

Bolt Diameter (in.)	½	⅝	¾	⅞	1	1⅛	1¼
Initial Minimum	7000	11000	16000	22000	29000	36000	46000
Final Minimum	16000	25000	37000	51000	67000	84000	107000

10.1.1 Except as permitted in 10.1.2 and 10.1.3, diameters 1 in. and smaller having a nominal length of 2¼ D and longer, and sizes over 1 in. having a nominal length of 3D and longer, shall be wedge tested full size to F606/F606M and shall conform to the minimum wedge tensile load and proof load or alternative proof load specified in Table 6.

10.1.2 Sizes 1 in. and smaller having a nominal length shorter than 2¼ D down to 2D, inclusive, that cannot be wedge tensile tested, shall be axially tension tested full size to F606/F606M and shall conform to the minimum tensile load and proof load specified in Table 6.

10.1.3 Sizes 1 in. and smaller having a nominal length shorter than 2D and sizes larger than 1 in. with nominal lengths shorter than 3D that cannot be axially tensile tested shall be qualified on hardness.

10.1.4 Fracture on full-size tests shall be in the threads of the bolt without fracture in the body or at the junction of the head and body.

TABLE 6 Tensile Strength Requirements for Bolts Tested Full Size

Nominal Size,	Stress Area[A]	Tensile min	Proof Load[B] min	Proof Load[C] min
in.	$in.^2$	lbf	lbf	lbf
½-13 UNC	0.142	20450	15350	16350
⅝-11 UNC	0.226	32550	24400	26000
¾-10 UNC	0.334	48100	36100	38400
⅞-9 UNC	0.462	66550	49900	53150
1-8 UNC	0.606	87250	65450	69700
1⅛-7 UNC	0.763	109900	82400	87750
1¼-7 UNC	0.969	139550	104650	111450
Above values based on		**144000psi**	**108000psi**	**115000psi**

[A] The stress area is calculated as follows:
$A_S = 0.7854\ [D-(0.9743/P)]^2$
Where A_S = Stress Area, D = Nominal Bolt Size, and P = thread pitch
[B] Proof load length measurement
[C] Alternative Proof load Yield Strength Method

10.1.5 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 7. When bolts are tested by both full-size and machined specimen methods, the full-size test shall take precedence.

10.2 *Hardness:*

10.2.1 Bolts shall conform to the hardness in Table 8. For lots on which both hardness and tension tests are performed, acceptance based on tensile requirements shall take precedence in the event of low hardness readings

11. Magnetic Particle Inspection

11.1 Magnetic particle testing shall be performed in accordance with Guide E709 or Practice E1444/E1444M. Guide E709 shall be used for referee purposes.

11.2 The lot, as represented by the samples, shall be free from nonconforming bolts, as defined in Specification F788. See Note 5.

11.3 If any nonconforming bolt is found during the manufacturer's sample examination the lot shall be 100% magnetic particle inspected and all nonconforming bolts shall be removed and scrapped or destroyed.

11.4 Eddy current or liquid penetrant inspection shall be an acceptable substitute for 100% magnetic particle inspection. On completion of the eddy current or liquid penetrant inspection the lot shall be reexamined by the magnetic particle

TABLE 7 Tensile Strength Requirements for Specimens Machined from Bolts

Tensile min.	Tensile max.	Yield min.	Elongation in 4D, min. %	Reduction of Area, min. %
144000 psi	...	115000 psi	14	35

TABLE 8 Hardness Requirements for Bolts

Brinell HB		Rockwell HRC	
Min	Max	Min	Max
293	326	31	35

method in the original sample quantity. In case of controversy, the magnetic particle test shall take precedence.

NOTE 5—Magnetic particle indications themselves shall not be cause for rejection. If in the opinion of the quality assurance representative the indications may be cause for rejection the samples shall be examined by microscopic examination or removal by surface grinding to determine if the indicated discontinuities are within the specified limits.

12. Carburization/Decarburazation

12.1 This test is intended to evaluate the presence or absence of carburization and decarburization as determined by the difference in micro-hardness near the surface and core.

12.2 *Carburization*—Bolts shall show no evidence of a carburized surface when evaluated to Test Method F2328.

12.3 *Decarburization*—Hardness value differences shall not exceed the requirements set forth for decarburization in Test Method F2328 for Class 2.

13. Assembly Quality Assurance

13.1 *General Requirements:*

13.1.1 The manufacturer or responsible party, or both shall develop a manufacturing, testing, and quality control plan that assures assemblies meet the initial and final tension requirements of this standard when used with the intended installation tool(s).

13.1.2 The manufacturer or responsible party, or both shall develop a manufacturing, testing, and quality control plan that assures installation tool(s) will meet the initial and final tension requirements of this standard when used with assemblies produced to this standard.

13.1.3 The test plan shall include an initial and final tension test, and shall use torque, tension and angle signature analysis to measure fastener assembly performance.

13.2 *Initial and Final Tension Test:*

13.2.1 The tension test shall demonstrate that the initial installation torque will achieve at least the minimum initial tension in Table 5, and from that initial tension, with the additional required degrees of turn, the assemblies will achieve at least the minimum final tension required in Table 5.

13.2.2 Test assemblies shall consist of one bolt, one nut and at least one washer.

13.2.3 Test shall be conducted at an ambient temperature between 50° and 90° F (10 and 32°C).

13.2.4 The measuring equipment shall be calibrated per the measuring equipment manufacturer's recommendation or the control plan if more restrictive, but not less than once per year.

13.2.5 The Assembly lot sample size shall be in accordance with F1470, "Assembly tension test", or greater if required by the test plan.

13.2.6 The assembly lot shall have a test report from the manufacturer or responsible party, or both to verify conformance to the initial tension and final tension requirements. The test report shall record the torque required at minimum initial tension in Table 5, and the additional rotation angle required from initial tension to exceed the final tension requirement in Table 5.

NOTE 6—Detailed installation instructions are routinely prepared by the manufacturer or responsible party, or both, supplying assemblies to this standard.

14. Other Quality Assurance Requirements

14.1 *Workmanship:*

14.1.1 The allowable limits, inspection, and evaluation of surface discontinuities shall be in accordance with Specification F788.

14.2 *Special Inspection:*

14.2.1 If observation or inspection is required by the purchaser, it shall be specified in the inquiry and order. Such observation or inspection requirements shall be specific and agreed upon by all parties.

14.2.2 The purchaser's representative shall have free entry to all parts of the manufacturer's or subcontractor's works, or supplier's place of business that concern the manufacture or supply of the material ordered.

14.2.3 The manufacturer or supplier shall afford the purchaser's representative all reasonable facilities to satisfy them that the material is being furnished in accordance with this specification.

14.2.4 All tests and inspections required by the purchaser's representative shall be made before shipment, and conducted so as not to interfere unnecessarily with the operation.

14.3 *Rejection and Rehearing:*

14.3.1 Disposition of nonconforming bolts shall be in accordance with the Practice F1470 section titled "Disposition of Nonconforming Lots."

15. Test Reports

15.1 When specified by the purchaser, the responsible party shall furnish a test report that includes the following, as applicable:

15.2 *General Information:*

15.2.1 Lot number,

15.2.2 Purchase order number, job number, sequence number or other special identifiers, if specified,

15.2.3 Mailing address of responsible party,

15.2.4 Title and signature of the individual assigned test report responsibility,

15.2.5 Date and standard, including revision number,

15.3 *Results*—Report results of all required tests,

15.3.1 Heat analysis, heat number, and calculated Corrosion Index for Type 3 material if not from composition A or B,

15.3.2 Results of hardness, tensile, and proof load tests,

15.3.3 Results of magnetic particle inspection,

15.3.4 Results of carburization and decarburization tests,

15.3.5 Results of rotational capacity tests; if required,

15.3.6 Results of fastener assembly testing,

15.3.7 Results of tests and inspections performed on matching nut and washer components used in assemblies,

15.3.8 Results of coating thickness; if required, and

15.3.9 Results of inspection for surface discontinuities and visual inspection for head bursts.

15.4 *Statements:*

15.4.1 Statement of conformance with dimensional and thread fit requirements;

15.4.2 Statement certifying that steel heats having the elements listed in 6.4 intentionally added was not used.

16. Packaging and Package Marking

16.1 *Packaging:*

16.1.1 Packaging shall be to the manufacturer's standard packaging practice or as agreed between the purchaser and supplier.

16.1.2 When special packaging or labeling is required, the requirements shall be defined at the time of the inquiry and again at the time of order.

16.1.3 Bolts shall be packaged as assemblies or as matched sets.

16.2 *Package Marking:*

16.2.1 Each shipping unit shall include and be plainly marked with the following information:

16.2.1.1 ASTM designation, Grade and Type.

16.2.1.2 Size,

16.2.1.3 Name of the manufacturer or responsible party,

16.2.1.4 Number of pieces,

16.2.1.5 Lot number,

16.2.1.6 Coating type and class or grade, as applicable,

16.2.1.7 Purchase order number or other distinguishing information, when required by the customer, and

16.2.1.8 Country of origin, when required by the customer.

17. Keywords

17.1 144 ksi; alloy steel; alternate design fasteners; angle; bolts; carbon steel; combined method; fasteners; fixed spline; inch; part turn; spline end; steel; structural; structural bolts; torque; torque angle; torque and angle; weathering steel

SUPPLEMENTARY REQUIREMENTS

The following requirements shall be applied when specified by the purchaser on the inquiry and order. Details of these requirements shall be agreed upon in writing between the manufacturer and purchaser.

S1 Bolts Threaded Full Length:

See Note S1.1.

S1.1 Bolts with nominal lengths equal to or shorter than four times the nominal bolt diameter may be threaded full length. These bolts need not have a shoulder.

S1.2 Bolts shall be marked in accordance with Table 2, except that the symbol shall include a "T", for example "144T".

S1.3 The distance from the under-head bearing surface to the first complete (full form) thread, as measured with a GO thread ring gauge, assembled by hand as far as the thread will permit, shall not exceed the length of 2-½ threads for bolt sizes 1 in. and smaller, and 3-½ threads for bolt sizes larger than 1 in.

NOTE S1.1— Many structural connection designs require the shear strength of a full body fastener. Increased thread lengths may place reduced diameters in shear planes reducing connection strength.

S2 Lubricant:

S2.1 Additional lubrication requirements shall be as agreed in writing between the user and responsible party.

S2.2 Lubrication requirements may include lubricated sealers used with coating systems, colored lubricants, or specified K factors. It may also include lubricants applied to the internal threads and a single nut bearing surface.

S2.3 Supplemental lubricants are not permitted on assemblies except when applied by the responsible party, see 7.6.5.

S2.4 Lubricant specified by the purchaser or required by the responsible party shall be applied to all of the same components within the lot.

S3 Rotational Capacity Testing:

S3.1 When specified on the inquiry and order, rotational capacity testing in accordance with Annex A1 shall be performed by the responsible party.

S3.2 Rotational capacity tests may be specified on plain or coated assemblies.

S3.3 Rotational capacity tests shall include sets of at least one bolt, one nut and one washer. Sampling shall be to Practice F1470 except the minimum sample size in all cases shall be two assemblies.

S3.4 Assembly lot rotational capacity test reports and product labeling to maintain assembly lot traceability is required.

S3.5 Components shall be packed together to prevent commingling with other lots.

ANNEX

A1. ROTATIONAL CAPACITY (RC) TESTS

(Mandatory Information)

A1.1 Scope

A1.1.1 This annex details rotational capacity (RC) tests intended to evaluate the presence of lubricant, the efficiency of lubricant and the compatibility of assemblies. The test serves as a quality control measure against excessively overtapped nuts or material with insufficient strength or ductility, and generally assures the assembly of elements (bolt, nut, and washer) will function together as a unit to achieve required preloads. When tested to meet the requirements of this annex, assemblies shall be purchased and installed as matched sets.

A1.1.2 This test is intended primarily for galvanized assemblies, but may be specified for other coatings and plain assemblies.

A1.1.3 When specified in contract documents this test may also be used for field-testing.

NOTE A1.1—The RC test applies to matched assembly lots that contain one bolt, one nut and one or more washers. It is the intent of this annex that assemblies be packaged together in the same shipping container to maintain lot integrity. These test methods are intended for use with 144 ksi bolts mated to the recommended nuts and washers. Research has not been done on all diameters and coatings, therefore some of the requirements in this test are extrapolated. The purchaser and supplier should consider any additional investigation necessary to establish appropriate RC testing guidelines

A1.2. Referenced Documents

A1.2.1 *ASTM Standards:*[3]

F1789 Terminology for F16 Mechanical Fasteners

F1470 Practice for Fastener Sampling for Specified Mechanical Properties and Performance Inspection

A1.3. Terminology

A1.3.1 Terms used in this specification are defined in Terminology F1789, unless otherwise defined herein.

A1.4 Testing

A1.4.1 *Testing Requirement:*

A1.4.1.1 Assemblies shall be tested in an assembled joint or tension measuring device in accordance with Test Method 1 or Test Method 2, and shall not show signs of failure when subjected to the nut rotation in Table A1.3 for Test Method 1 or Table A1.6 and Table A1.7 for Test Method 2. The test shall be performed by the responsible party as noted in A1.4.2 prior to shipment, but after zinc coating, lubrication or any secondary processing of components.

A1.4.2 *Testing Responsibility:*

A1.4.2.1 Each lot shall be tested by the manufacturer or responsible party prior to shipment.

A1.4.2.2 When bolts are furnished by a source other than the manufacturer, the responsible party shall assure RC tests have been performed and the bolts meet the requirements of this annex.

A1.4.2.3 Sampling shall be to F1470 unless otherwise agreed upon between the supplier and purchaser, except that the minimum sample size in all cases shall be two (2).

A1.5 Test Method 1 – Long Bolt Test Procedure

A1.5.1 *Equipment Required:*

A1.5.1.1 Calibrated tension measuring device appropriate for the bolts to be tested.

A1.5.1.2 Calibrated torque wrench and spud wrenches.

A1.5.1.3 Appropriate bushings and spacers.

A1.5.2 *Procedure-Bolts that fit in a tension measuring device:*

A1.5.2.1 Install the bolt and any spacers needed in the tension measuring device so that the bolt stick-out thread is flush with the nut to a maximum of three threads stick-out. This will typically provide three to five threads within the grip.

A1.5.2.2 Tighten the fastener assembly to the tensions listed in Table A1.1 (-0/+2 KIPS).

A1.5.2.3 Match-mark the bolt, nut and face plate of the tension measuring device.

A1.5.2.4 Tighten the fastener assembly to at least the minimum tension in Table A1.2 and record both the tension and torque. The torque shall be read with the nut in motion. The maximum torque is listed in Table A1.2.

A1.5.2.5 The torque value from A1.5.2.4 shall not exceed 0.25 PD,
where:

D = Dia. (in.)/12 = bolt diameter in ft
P = tension in pounds

A1.5.2.6 Further tighten the nut to the rotation listed in Table A1.3. The rotation is measured from the initial marking in step A1.5.2.3.

A1.5.2.7 Record the tension at the completion of the rotation in Table A1.3. The tension shall equal or exceed 1.15 × the minimum tension in Table A1.2. The minimum required values are listed in Table A1.4.

A1.5.2.8 Loosen and remove the nut. There shall be no signs of thread shear failure, stripping, or torsional failure. The nut shall turn on the bolt threads to the position it was in during the test. The nut does not need to run the full length of the threads. Inability to turn the nut by hand is considered thread failure. Broken bolts fail the test.

TABLE A1.1 Tension Requirement by Diameter

Bolt Dia. (in.)	½ in.	⅝ in.	¾ in.	⅞ in.	1 in.	1⅛ in.	1¼ in.
Initial Tension (kips)	2	3	4	5	6	8	10

TABLE A1.2 Maximum Permitted Torque at Minimum Design Tension

Bolt Dia. (in.)	½ in.	⅝ in.	¾ in.	⅞ in.	1 in.	1⅛ in.	1¼ in.
Tension (kips)[A]	15	24	35	49	64	80	102
Maximum Torque (ft. lbs.)	156	312	546	893	1333	1875	2656

[A]Minimum A490 design tension in the RCSC Specification for Structural Joints Using High-Strength Bolts. 75% of minimum specified tensile strength.

TABLE A1.3 Required Rotation

Bolt Length	Up to 4D	> 4D to 8D	> 8D to 12D
Required Rotation	240	360	420

TABLE A1.4 Minimum Tension at Full Rotation

Bolt Dia. (in.)	½ in.	⅝ in.	¾ in.	⅞ in.	1 in.	1⅛ in.	1¼ in.
Tension (kips)	17	28	40	56	74	92	117

A1.6 Long Bolt Acceptance Criteria

A1.6.1 The assembly lot passes the RC test if all samples meet the requirements of A1.5.2.5, A1.5.2.7, and A1.5.2.8 after full rotation.

A1.6.2 The lot shall be considered nonconforming if the assembly fails to pass any one of the following requirements:

A1.6.2.1 Over the maximum allowable torque in Table A1.2.

A1.6.2.2 Inability of the assembly to reach the rotation required in Table A1.3.

A1.6.2.3 Inability to remove the nut after installing to the rotation specified in Table A1.3.

A1.6.2.4 Failure to provide the tension required in Table A1.4 after full rotation.

A1.6.2.5 Shear failure of the threads as determined by visual examination of bolt and nut threads following removal.

A1.6.2.6 Torsional or torsional/tension failure of the bolt. Elongation of the bolt, in the threads between the nut and bolt head, is to be expected at the required rotation and is not to be classified as a failure.

A1.7 Test Method 2 – Short Bolt Test Procedure

A1.7.1 *Equipment Required:*

A1.7.1.1 Steel plate.

A1.7.1.2 Calibrated torque wrench and spud wrenches.

A1.7.1.3 Bushings and Spacers.

A1.7.2 *Procedure-Bolts too Short to Fit in a Tension Measuring Device:*

A1.7.2.1 Install the bolt and any spacers needed in the steel plate so that the bolt thread is flush with the nut to a maximum of three threads stick-out. This will typically provide three to five threads within the grip.

A1.7.2.2 Using a torque not to exceed 20% of that permitted in Table A1.5, tighten the assembly in the steel plate.

TABLE A1.5 Maximum Torque Values

Bolt Dia. (in.)	½ in.	⅝ in.	¾ in.	⅞ in.	1 in.	1⅛ in.	1¼ in.
Torque (ft. lbs.)	180	370	630	1020	1540	2160	3050

A1.7.2.3 Match-mark the nut, bolt and plate

A1.7.2.4 Tighten the bolt by rotating the nut as required in Table A1.6. Prevent the bolt from rotating. Take a torque reading at the required rotation with the nut in motion.

A1.7.2.5 The torque measurement taken in A1.7.2.4 should not exceed the values listed in Table A1.5. Assemblies that exceed the listed torque have failed the test. These torque values are based on the assumed tension of 1.15 × minimum installation tension

A1.7.2.6 Further tighten the bolt by rotating the nut as required in Table A1.7. Prevent the bolt from rotating. Assemblies that strip or fracture prior to this rotation fail the test.

A1.7.2.7 Loosen and remove the nut. There shall be no signs of thread shear failure, stripping, or torsional failure. The nut shall turn on the bolt threads to the position it was in during the test. The nut does not need to run the full length of the threads. Inability to turn the nut by hand is considered thread failure. Broken bolts fail the test.

A1.8 Short Bolt Acceptance

A1.8.1 The assembly lot passes the RC test if all samples meet the requirements of A1.7.2.5, A1.7.2.6, and A1.7.2.7 after full rotation.

A1.8.2 The assembly lot shall be considered as nonconforming if the assembly fails to pass any one of the following specified requirements:

A1.8.2.1 Over the maximum allowable torque in Table A1.5.

A1.8.2.2 Failure to achieve the required rotation in Table A1.7.

A1.8.2.3 Inability to remove the nut after installing to the rotation in Table A1.7.

A1.8.2.4 Shear failure of the threads as determined by visual examination of bolt and nut threads following removal.

A1.8.2.5 Torsional or torsional/tension failure of the bolt. Elongation of the bolt, in the threads between the nut and bolt head, is to be expected at the required rotation and is not to be classified as a failure.

A1.9 Test Reports

A1.9.1 The responsible party shall furnish the purchaser a test report that includes the following:

A1.9.1.1 Results of rotational capacity tests. This shall include the test method used Method 1 (Tension Measuring Device) or Method 2 (Solid Plate).

A1.9.1.2 Assembly and assembly component lot numbers.

TABLE A1.6 Required Rotation

Bolt Length	Up to 4D	> 4D to 8D
Required Rotation	120	180

TABLE A1.7 Required Rotation from Initial Tension

Bolt Length	Up to 4D	> 4D to 8D
Required Rotation	90	120

A1.9.1.3 Mail address of responsible party.

A1.9.1.4 Title and signature of the individual assigned test report responsibility.

APPENDIXES

X1. TEST AND INSTALLATION PROCEDURES FOR TORQUE-AND-ANGLE TENSIONING OF FIXED-SPLINE F3148 ASSEMBLIES

(Nonmandatory Information)

X1.1 Scope

X1.1.1 This appendix details one possible installation procedure for torque-and-angle tensioning of fixed-spline F3148 assemblies. Manufacturers or responsible parties, or both, may provide alternative procedures for tensioning these assemblies.

X1.1.2 Test and installation tools shall be capable of tensioning fixed-spline bolts from a single side, and shall be capable of installing bolts to initial tension using torque, and final tension using angle.

X1.1.3 This appendix is intended for field pre-installation verification testing of assemblies and installation tools for use in pretensioned or slip-critical connections. For other connection or installation requirements please contact the supplier for a detailed procedure.

X2. PRE-INSTALLATION VERIFICATION TESTING

X2.1 Number of Tests

X2.1.1 The number of tests from each assembly lot shall be no fewer than three (3).

X2.2 Tension Measuring Device

X2.2.1 A tension measuring device shall be used to measure tension. Calibration of the device shall be at least annually by the device manufacturer or a NIST accredited agency. The calibration date shall be clearly identifiable and a calibration certificate shall be made available if requested. The device shall have bushings that accept round heads, and plates and solid spacers specific to the bolt diameter and length being tested.

X2.3 Required Testing

X2.3.1 Each assembly lot to be used in the work shall be tested in a tension measuring device to verify the torque-and-angle installation method can develop tensions that equal or exceed those specified in Table X2.1.

X2.4 Test Procedure

X2.4.1 Install the assembly (bolt, nut, and washer) in a tension measuring device using the appropriate plate, bushing and spacer(s) for the diameter and length of bolt. The bolt head shall not be captured during testing. The washer shall be installed against the plate or spacer(s). The nut shall be installed against the washer, at least flush with the first thread of the bolt. Additional washers shall not be used in lieu of suitable spacers.

X2.4.2 Following the manufacturer's recommended practice, install the assembly using torque with a tool capable of engaging the nut and bolt spline. The assembly shall meet the minimum initial tension in Table X2.1.

X2.4.3 Following the manufacturer's recommended practice, from the initial tension condition, install the assembly to final tension, using the degree of angle specified in Table X2.2, with a tool capable of engaging the nut and bolt spline. The assembly shall meet the minimum final tension in Table X2.1.

X2.4.4 Repeat the test in section X2.4.1 through X2.4.3 for each additional test assembly. Each assembly test must meet the minimum tension requirement for initial and final tension.

NOTE X2.1—Acceptable tolerance on Table X2.2 angle of rotation is -0 /+ 45 degrees.

NOTE X2.2—Where the surface of the bolt head or nut is not perpendicular to the bolt axis, the required final installation angle should be determined by testing.

NOTE X2.3—Rotations beyond the tightening angle tolerance may be an indication that the assembly was not properly initial tightened. Please consult with supplier.

NOTE X2.4—Lengths over 8D may require additional rotation. Please consult with supplier.

TABLE X2.1 Assembly Tension Test Minimum Tension, lbf

Bolt Diameter (in.)	½	⅝	¾	⅞	1	1⅛	1¼
Initial Minimum	7000	11000	16000	22000	29000	36000	46000
Final Minimum	16000	25000	37000	51000	67000	84000	107000

TABLE X2.2 Angle Tightening Rotation

Bolt Length	Required Rotation[A]	Diameter in.						
		½	⅝	¾	⅞	1	1⅛	1¼
Up to 4D	90°	Up to 2	Up to 2½	Up to 3	Up to 3½	Up to 4	Up to 4½	Up to 5
>4D to 8D	120°	2¼ to 4	2¾ to 5	3¼ to 6	3¾ to 7	4¼ to 8	4¾ to 9	5¼ to 10

[A] See X3.3.

X3. INSTALLATION PROCEDURE

X3.1 Torque and Angle Installation Procedure

X3.1.1 Align bolt holes to permit insertion of the bolts without undue damage to the threads.

X3.1.2 Install a bolt in each hole. Install a washer against the steel over the threaded end of the bolt. Install the nut against the washer to a finger tight condition.

X3.2 Initial Tightening

X3.2.1 Start with the most rigid point of the connection. Perform initial tightening using torque with a tool capable of engaging the nut and bolt spline. The tool shall rotate the nut and hold the bolt spline from a single side. The tool shall shut off when a calibrated torque value is reached that is sufficient to achieve the minimum initial tension in Table X2.1.

X3.2.2 Repeat the initial tightening process for each additional bolt in the connection as described in X3.2.1. If gaps in the steel remain, systematically perform initial tightening of each bolt in the same pattern until the plies are in firm contact. Initial tightening shall be controlled by the installation tool so that over-tightening does not occur.

X3.3 Angle Tightening

X3.3.1 With bolts in the initial tight condition from X3.2, install the assembly to final tension using angle with a tool capable of engaging the nut and bolt spline. The tool shall rotate the nut and hold the bolt spline from a single side. The tool shall shut off when the minimum degree of nut rotation in Table X2.2 is achieved, within a tolerance of -0 /+ 45 degrees.

X3.3.2 Repeat the angle tightening process for each bolt in the connection, using the same systematic tightening pattern used for the initial tightening process.

X3.4 Inspection

X3.4.1 Inspection after initial tightening

X3.4.1.1 Perform routine observation of the initial tightening process to verify proper techniques are followed as described in X3.2.

X3.4.1.2 Verify that the plies in the connection have been pulled into firm contact.

X3.4.1.3 Verify that the proper length of bolt was used. The face of the nut shall be at least flush with the first thread of the bolt and the stick-out should be checked to ensure the nut does not hit the thread run-out.

X3.4.2 Inspection after angle tightening.

X3.4.2.1 Perform routine observation of the final angle tightening process to verify proper techniques are followed as described in X3.3.

NOTE X3.1—If routine observation is not possible, match marking for final installation may be required during the angle tightening process. This step of visual inspection should be included in the scope of work or contract documents to avoid disputes.