Night School 27: Fundamentals of Welding and Bolting

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Bolting Part 3 – Ordering, Storing, Installing, and Inspecting

November 30, 2021 | Chad Larson

Smarter. Stronger. Steel.

AISC Night School

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AISC Night School

Course Description

Fundamentals of Bolting and Welding

Session 7: - Bolting Pt. 3: Ordering, Storing, Installing, and Inspecting

November 30, 2021

This session will focus on structural fastener installation methods. Recommendations on the best practices to achieve proper fastener tension will be given. The differences between just tight and tightened right, including inspection requirements for common installation methods will be explained.

AISC Night School

Learning Objectives

- Learn about required ordering information.
- Learn about proper fastener storage and handling.
- Gain an understanding of pre-installation verification testing.
- Learn about common installation methods.
- Learn about inspection requirements for different installation and joint types.

Night School 27: Fundamentals of Welding and Bolting

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Bolting Pt. 3: Ordering, Storing, Installing, and Inspecting
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Ordering Information

See ASTM specifications F3125, F3148, A563, etc.

9

ASTM F3125

- **3. Ordering Information**
- 3.1 Orders for bolts under this specification shall include:
- 3.1.1 *ASTM designation.*
- 3.1.2 *Quantity:* Number of bolts or assemblies, including washers, if required.
- 3.1.3 *Size:* Including nominal bolt diameter and bolt length, and thread pitch if other than standard.
- 3.1.4 *Grade:* A325, A325M, A490, A490M, F1852 or F2280.
- 3.1.5 *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**.
- 3.1.6 *Style:* Heavy Hex or Twist-Off Style.
- 3.1.7 *Coatings or finishes:* If other than plain finish, specify the coating process or finish required, see Annex A1.

10

Ordering Continued…

- 3.2 *Test reports,* see Section 14.
- 3.3 Additional details of other assembly components such as nuts and washers, if required.
- 3.4 Rotational capacity testing of matched sets or assemblies in accordance with Annex A2, as required in 8.1.5 and when requested by the purchaser.
- 3.5 Heavy Hex bolts may be ordered individually, packaged with nuts, packaged with nuts and washers, or as assemblies.
- 3.6 Any special observation or inspection requirements shall be specified at the time of inquiry and at the time of order. See Section 13.2.
- 3.7 Any supplementary requirements. (A325T or A325S)
- 3.8 Country of origin requirements, if any.

11

Notes

- NOTE 1—A typical description follows:
  - 1000 pieces 3⁄4 ” × 3” ASTM F3125–19, Grade A325 heavy hex bolt, Type 1, each with one hardened ASTM F436 Type 1 washer, and one A563 Grade DH heavy hex nut.
- NOTE 2—Bolts are sometimes detailed with names such as A325 HS, A325 SC, A325 X or A490 N. These names relate to connection design and bolt installation, but do not change the manufacturing requirements and are preferably not shown on bolt orders.

12

RCSC Group and Grade Designations

Table 2.1
Group Designations for Bolts and Matched Bolting Assemblies

Group	Tensile Strength	Bolts	Matched Bolting Assemblies
Group 120	120 ksi	ASTM F3125 Grade A325	ASTM F3125 Grade F1852
Group 144	144 ksi	—	ASTM F3148 Grade 144
Group 150	150 ksi	ASTM F3125 Grade A490	ASTM F3125 Grade F2280

Table 2.2
Permitted Nut Grades

Group Designation	Bolt Type	Coating	ASTM A563 Nut Grade
120	1	Plain	C, C3, D, DH, and DH3
		Coated in compliance with 2.8	DH
	3	Plain	C3 and DH3
144 and 150	1	Plain	DH and DH3
		Coated in compliance with 2.8	DH
	3	Plain	DH3

13

F3125/F3125M – 19$^{\varepsilon 2}$

TABLE 5 Mechanical Property Requirements for Bolts Tested Full Size

		120 ksi - A325, F1852			150 ksi - A490, F2280			
	Stress Area[A]	Tensile min	Proof Load Length Measurement min	Alternative Proof Load Yield Strength Method min	Tensile min	Tensile max.	Proof Load Length Measurement min	Alternative Proof Load Yield Strength Method min
in.	in^2	lbf	lbf	lbf	lbf	lbf	lbf	lbf
½-13 UNC	0.142	17050	12050	13050	21300	24600	17050	18500
⅝-11 UNC	0.226	27100	19200	20800	33900	39100	27100	29400
¾-10 UNC	0.334	40100	28400	30700	50100	57800	40100	43400
⅞-9 UNC	0.462	55450	39250	42500	69300	79950	55450	60100
1-8 UNC	0.606	72700	51500	55750	90900	104850	72700	78800
1⅛-7 UNC	0.763	91600[B]	64900[B]	70250[B]	114450	132000	91550	99200
1¼-7 UNC	0.969	116300[B]	82400[B]	89200[B]	145350	167650	116300	126000
1⅜-6 UNC	1.155	138600[B]	98200[B]	106300[B]	173250	199850	138600	150200
1½-6 UNC	1.405	168600[B]	119500[B]	129300[B]	210750	243100	168600	182600
Above values based on		120 ksi	85 ksi	92 ksi	150 ksi	173 ksi	120 ksi	130 ksi
		830 MPa - A325M			1040 MPa - A490M			
	Stress Area[A]	Tensile min.	Proof Load Length Measurement min	Alternative Proof Load Yield Strength Method min	Tensile min.	Tensile max.	Proof Load Length Measurement min	Alternative Proof Load Yield Strength Method min
mm	mm^2	kN	kN	kN	kN	kN	kN	kN
M12 x 1.75 MC	84.3	70	50.6	55.6	87.7	103	70	79.2
M16 x 2.0 MC	157	130	94.2	104	163	190	130	148
M20 x 2.5 MC	245	203	147	162	255	296	203	230
M22 x 2.5 MC	303	251	182	200	315	366	251	285
M24 x 3.0 MC	353	293	212	233	367	427	293	332
M27 x 3.0 MC	459	381	275	303	477	555	381	431
M30 x 3.5 MC	561	466	337	370	583	679	466	527
M36 x 4.0 MC	817	678	490	539	850	989	678	768
Above values based on		830 MPa	600 MPa	660 MPa	1040 MPa	1210 MPa	830 MPa	940 MPa

14

Bolt Length Selection

Table C-2.2
Bolt Length Selection

Nominal Bolt Diameter, d_b, in.	To Determine the Required Bolt Length, Add to *Grip + Washer + Direct tension indicator*, in.
½	1 1/16
⅝	⅞
¾	1
⅞	1⅛
1	1¼
1⅛	1½
1¼	1⅝
1⅜	1¾
1½	1⅞

15

Washers
RCSC Section 6

Table 6.1
Washer Requirements for Pretensioned and Slip-Critical Bolted Joints with Oversized and Slotted Holes in the Outer Ply

Bolt Group	Nominal Bolt Diameter, d_b, in.	Hole Type in Outer Ply		
		Oversized	Short-Slotted	Long-Slotted
Group 120	½ – 1½	ASTM F436[a]		5/16-in.-thick plate washer or continuous bar[b,c]
Group 144 and 150	≤ 1			
	> 1	ASTM F436 extra thick[a,b,d]		ASTM F436 washer with either a ⅜-in.-thick plate washer or continuous bar[b,c]

[a] This requirement shall not apply at the head at round heads of ASTM F3125 Grades F1852 and F2280, or F3148 Grade 144 *bolting assemblies* with round heads that meet the requirements in Section 2.4 and provide a bearing circle diameter that meets the requirements of the relevant ASTM Standard.
[b] See ASTM F436 Section 1.2. Multiple washers with a combined thickness of 5/16 in. or larger do not satisfy this requirement.
[c] The plate washer or bar shall be of structural-grade steel material, but need not be hardened.
[d] Alternatively, a ⅜-in.-thick plate washer and an ordinary thickness F436 washer may be used. The plate washer need not be hardened.

16

Alternative-Designs Section 2.12 RCSC

- **2.12. Alternative-Design Bolting Components, Assemblies, and Methods**
- The Specification allows for **innovation** in *bolting components* and *assemblies* in *joints* that transmit forces through shear, tension, combined tension and shear, or friction on *faying surfaces* and that meet the requirements in this Section. Other mechanical fasteners are not covered in this Specification. The provisions in this Specification that are not explicitly covered by the relevant consensus standard of an alternative-design *bolting component* or *assembly* shall still apply.

17

Jobsite requirements

See RCSC specification for details

18

RCSC - Storage and Handling

- **2.10. Storage and Lubrication**
- 2.10.1. Once received at the installation site, *bolting components* and *bolting assemblies* shall be kept in ***protected storage***.
- 2.10.2. Only as many *bolting components* and *bolting assemblies* as are **anticipated to be installed** during the work shift shall be taken from *protected storage*.
- 2.10.3. *Bolting components* and *bolting assemblies* that are not incorporated into the work shall be **returned to *protected storage*** at the end of the work shift.
- 2.10.4. *Bolting components* (including some *bolting assemblies*) may be field lubricated to help with installation as deemed practical or necessary, except that the following *matched bolting assemblies* shall not be relubricated by anyone other than the *Manufacturer*:
  - (1) *Spline end twist-off matched bolting assemblies*;
  - (2) *Matched bolting assemblies* when using the *combined method* and ASTM F3148 Grade 144 *spline end fixed matched bolting assemblies*; and
  - (3) Alternative-design *bolting components* or *matched bolting assemblies* (see Section 2.12).

19

RCSC - Storage and Handling

- 2.10.5. Heavy hex head bolting components for *snug-tightened joints* that accumulate rust or dirt shall not be incorporated into the work unless they are cleaned and lubricated, if necessary.
- 2.10.6. *Bolting components* and *bolting assemblies* intended for *pretensioned* or *slip-critical joints* that accumulate rust or dirt shall not be incorporated into the work unless they are cleaned and lubricated, if necessary, and then retested as specified in Section 7. See Section 2.10.4 for prohibitions on relubrication.
- 2.10.7. *Temporary bolts* shall be exempt from this Section's storage requirements.

20

Storage and Handling

Properly Stored

Properly Stored

21

Storage and Handling

Not Properly Stored

Not Properly Handled

22

RCSC 3.1

- **3.1. Connected Plies**
- Unless otherwise approved by the *Engineer of Record,* all connected plies in a *joint* that are within the *grip* of the bolt and any materials that are used under the bolt head or nut **shall be steel** with *faying surfaces* that are *uncoated*, *coated*, or *galvanized* as defined in Section 3.2.
- The slope of the surfaces of parts in contact with the bolt head and nut shall be equal to or less than 1:20 with respect to a plane that is normal to the bolt axis.

23

RCSC 3.2

- **3.2. Faying Surfaces**
- *Faying surfaces* and surfaces adjacent to the bolt head and nut shall be free of dirt and other foreign material.
- 3.2.1. *Snug-Tightened Joints* and *Pretensioned Joints:* The *faying surfaces* of *snug tightened joints* and *pretensioned joints* as defined in Sections 4.1 and 4.2 are permitted to be *uncoated*, *coated* with coatings of any formulation, or *galvanized*.

24

Joint Types – as Defined by RCSC

Shear/Bearing Joint. A *snug-tightened joint* or *pretensioned joint* with bolts that transmit shear loads and for which the design criteria are based upon the shear strength of the bolts and the bearing strength of the connected materials.

Pretensioned Joint. A *joint* that transmits shear and/or tensile loads in which the bolts have been installed in accordance with Section 8.2 to provide a pretension in the installed bolt.

Slip-Critical Joint. A *joint* that transmits shear loads or shear loads in combination with tensile loads in which the bolts have been installed in accordance with Section 8.2 to provide a *pretension* in the installed bolt (clamping force on the *faying surfaces*), and with *faying surfaces* that have been prepared to provide a calculable resistance against slip.

25

EOR Requirements - RCSC Section 4

- For *joints* with bolts that are loaded in shear or combined shear and tension, the *Engineer of Record* shall specify the *joint* type in the contract documents as *snug-tightened*, *pretensioned*, or *slip-critical*.
- For *slip-critical joints*, the required class of slip resistance in accordance with Section 5.4 shall also be specified.
- For *joints* with bolts that are loaded in tension only, the *Engineer of Record* shall specify the *joint* type in the contract documents as *snug-tightened* or *pretensioned*.
- Table 4.1 summarizes the applications and requirements of the three *joint* types.

26

RCSC Table 4.1

Table 4.1
Summary of Applications and Requirements for Bolted Joints

Load Transfer	Application	Joint Type[a,b]	Faying Surface Prep.	Install per Section	Inspect per Section	Arbitrate per Section 10
Shear only	Resistance to shear load by shear/bearing.	ST	No	8.1	9.1	No
	Resistance to shear load by shear/bearing. Bolt *pretension* is required, but for reasons other than slip resistance.	PT	No	8.2	9.2	If req'd to resolve dispute
	Resistance to shear load by friction on *faying surfaces* is required.	SC	3.2.2	8.2	9.3	If req'd to resolve dispute
Combined shear and tension	Resistance to shear load by shear/bearing. Tension load is static only.[c]	ST	No	8.1	9.1	No
	Resistance to shear by shear/bearing. Bolt *pretension* is required, but for reasons other than slip resistance.	PT	No	8.2	9.2	If req'd to resolve dispute
	Resistance to shear load by friction on *faying surfaces* is required.	SC	3.2.2	8.2	9.3	If req'd to resolve dispute
Tension only	Static loading only.[c]	ST	No	8.1	9.1	No
	All other conditions of tension-only loading.	PT	No	8.2	9.2	If req'd to resolve dispute

[a] Under *Joint Type*: ST = *snug-tightened*, PT = *pretensioned*, and SC = *slip-critical*; see Section 4.
[b] See Sections 4 and 5 for the design requirements for each *joint* type.
[c] Per Section 4.2, the use of Group 144 and 150 bolts in *snug-tightened joints* with tensile loads is not permitted.

27

Snug-Tight – What is it?

- Shear/bearing connections and the high-strength bolts in them are required to be at least snug tight.
- Pretensioning methods all depend on achieving the snug-tight condition first.

2020 Rev. RCSC Specification

Snug-Tight Condition. The *joint* condition in which the plies have been brought into ***firm contact*** and each *bolting assembly* has at least the tightness attained with either a few impacts of an impact wrench, resistance to a suitable non-impacting wrench, or the full effort of an ironworker using an ordinary spud wrench.

Snug-Tightened Joint. A *joint* in which the *bolting assemblies* have been installed to the *snug-tight condition*.

28

RCSC – Snug-Tightened Joints

- **4.1. Snug-Tightened Joints**
- Except as required in Sections 4.2 and 4.3, *snug-tightened joints* are permitted.
- Bolts in *snug-tightened joints* shall be designed in accordance with the applicable provisions of Sections 5.1, 5.2 and 5.3, installed in accordance with Section 8.1 and inspected in accordance with Section 9.1. As indicated in Table 4.1, requirements for *faying surface* condition **shall not apply** to *snug-tightened joints*.

29

Snug-Tight Joint Commentary:

- The ultimate strength of a *connection* is **independent** of the bolt pretension and slip movement.
- There are numerous practical cases in the design of structures where, if slip occurs, it will **not be detrimental** to the serviceability of the structure.
- Additionally, there are cases where slip of the *joint* is desirable to permit rotation in a *joint* or to minimize the transfer of moment. To provide for these cases while at the same time making use of the shear strength of *high-strength bolts*, *snug-tightened joints* are permitted.

30

Snug-Tight Joint Commentary:

- The *snug-tightened condition* is **typically achieved** with a few impacts of an impact wrench, application of an electric torque wrench until the wrench begins to slow or the full effort of a worker on an ordinary spud wrench.
- **More than one cycle** through the bolt pattern may be required to achieve the *snug-tightened condition*. The splines on *spline end twist-off bolts* may be twisted off or left in place in *snug-tightened joints*.

31

Snug-Tight Joint Commentary:

- The actual tensions that result in individual bolts in *snug-tightened joints* will vary from *joint* to *joint* depending upon the thickness, flatness, and degree of parallelism of the connected plies, as well as the effort applied.
- In most *joints*, plies of *joints* involving material of ordinary thickness and flatness can be drawn into *firm contact* at relatively low levels of bolt tension. However, in some *joints* in thick material or in material with large burrs, it may not be possible to achieve *faying surface* contact at all bolt hole locations as is commonly achieved in *joints* of thinner plates. This is generally not detrimental to the performance of the *joint*.

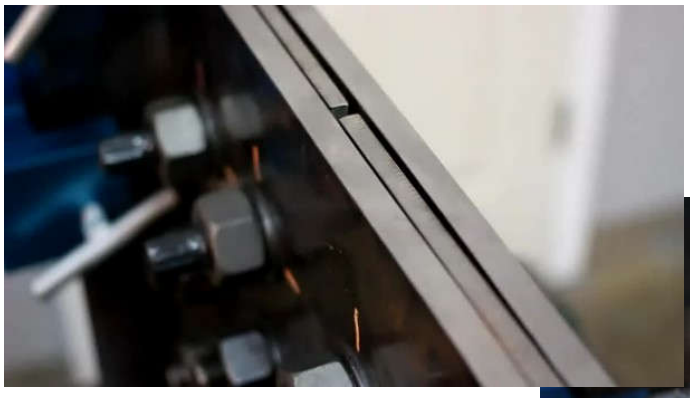
32

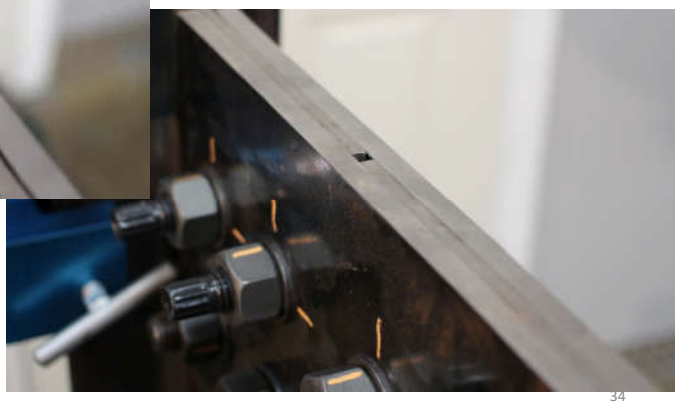
Snug-Tightened Joints

- **8.1. Snug-Tightened Joints**
- *Snug-tightened joints* shall comply with all of the following:
- (1) All bolt holes shall be aligned to permit insertion of the bolts without undue damage to the threads;
- (2) Bolts shall be placed in all holes with washers positioned as required in Section 6.1 and nuts threaded to complete the assembly;
- (3) Compacting the *joint* shall progress systematically from the most rigid part of the *joint*; and
- (4) The *joint* shall be installed to the *snug-tight condition* with *sufficient thread engagement*.

33

Snug-Tight Process





34

RCSC – Pretensioned Joints

4.2. Pretensioned Joints

- *Pretensioned joints* are required in the following applications:
- (1) *Joints* in which bolt *pretension* is required in the specification or code that invokes this Specification;
- (2) *Joints* that are subject to significant load reversal;
- (3) *Joints* that are subject to fatigue load with no reversal of the loading direction;
- (4) *Joints* with Group 120 *bolting assemblies* that are subject to tensile fatigue; and
- (5) *Joints* with Group 144 or Group 150 *bolting assemblies* that are subject to tension or combined shear and tension, with or without fatigue.

35

RCSC – Slip Critical Joints

- **4.3. Slip-Critical Joints**
- *Slip-critical joints* are required in the following applications involving shear or combined shear and tension:
- (1) *Joints* that are subject to fatigue load with reversal of the loading direction;
- (2) *Joints* that utilize oversized holes;
- (3) *Joints* that utilize slotted holes, except those with applied load approximately normal (within 80 to 100 degrees) to the direction of the long dimension of the slot; and
- (4) *Joints* in which slip at the *faying surfaces* would be detrimental to the performance of the structure.
- Bolts in *slip-critical joints* shall be designed in accordance with the applicable provisions of Sections 5.1, 5.2, 5.3, 5.4, and 5.5; installed in accordance with Section 8.2; and inspected in accordance with Section 9.3.

36

Preinstallation Verification

37

PIV Commentary

- **Commentary:**
- Pre-installation Verification Testing is essential for:
- (1) Evaluating the suitability of the *bolting assembly*, including the lubrication that is applied by the *Manufacturer* or specially applied, to develop the specified minimum *pretension*;
- (2) Verifying the adequacy and proper use of the specified *pretensioning* method to be used;
- (3) Determining the installation torque for the *calibrated wrench method of pretensioning*;
- (4) Verifying the *initial torque* applied achieves at least the required *initial tension* when using the *combined method* of *pretensioning*; and
- (5) Demonstrating the suitability of the bolt tightening equipment to be used during installation.

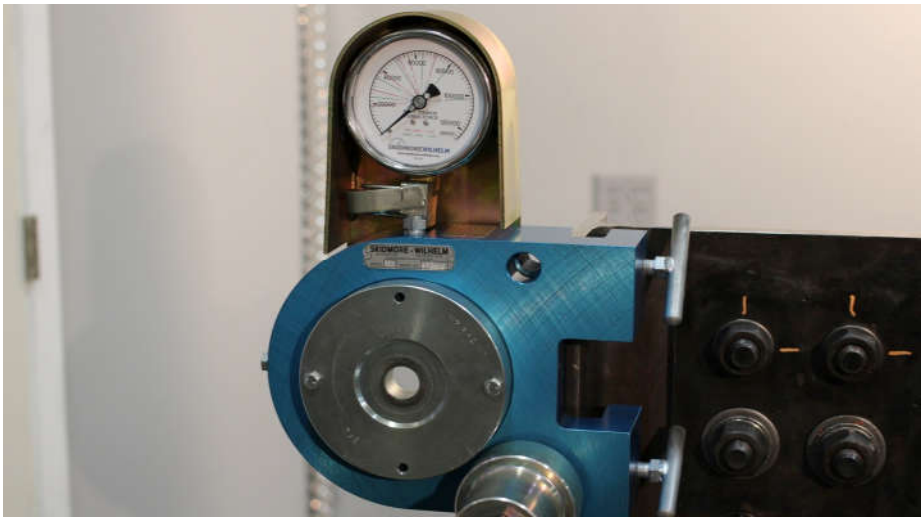
38

RCSC - Preinstallation Testing

- **7.1. Required Testing**
- Pre-installation verification testing shall be performed in compliance with all of the following:
- (1) At the site of installation;
- (2) Prior to the placement of *bolting assemblies* of verified lots in the work;
- (3) On a sample of not fewer than three complete *bolting assemblies* of each combination of diameter, length, grade, and *lot* to be used in the work;
- (4) Using *bolting assemblies* that are representative of the condition of those that will be *pretensioned* in the work;
- (5) Using ASTM F436 washers positioned in accordance with Section 6.2; and
- (6) In accordance with the test procedure in Section 7.2.

39

Tension Measuring Device



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41

Pre-installation Testing

42

Group 120 PIV – Increase from 105 ksi to 120 ksi

2014

Table 7.1 Minimum Bolt Pretension for Pre-Installation Verification

Nominal Bolt Diameter, d_b, in.	Minimum Bolt Pretension for Pre-Installation Verification, kips [a]	
	ASTM A325 and F1852	ASTM A490 and F2280
½	13	16
⅝	20	25
¾	29	37
⅞	41	51
1	54	67
1⅛	59	84
1¼	75	107
1⅜	89	127
1½	108	155

2020

Table 7.1
Minimum Bolt Pretension for Pre-Installation Verification

Nominal Bolt Diameter, d^b, in.	Minimum Bolt Pretension for Pre-Installation Verification, kips	
	Group 120	Group 144 and Group 150
½	13	16
⅝	20	25
¾	29	37
⅞	41	51
1	54	67
1⅛	67	84
1¼	85	107
1⅜	102	127
1½	124	155

43

RCSC - Required Testing

- A representative sample of **not fewer than three** *fastener assemblies* of each combination of diameter, length, grade and *lot* to be used in the work shall be checked at the site of installation in a *tension calibrator* to verify that the pretensioning method **develops a pretension that is equal to or greater** than that specified in Table 7.1.

- Washers shall be used in the pre-installation verification assemblies as required in the work in accordance with the requirements in Section 6.2.

44

Installation methods

See RCSC specification for more details…

45

SECTION 8. INSTALLATION

- The storage and lubrication of *bolting assemblies* and *bolting components* shall comply with the requirements of Section 2.10. For *joints* that are designated in the contract documents as *snug-tightened joints*, the *bolting assemblies* shall be installed in accordance with Section 8.1. For *joints* that are designated in the contract documents as *pretensioned joints* or *slip-critical joints*, the *bolting assemblies* shall be installed in accordance with Section 8.2.

46

8.2. Pretensioned and Slip-Critical Joints Commentary

- Five methods are provided without preference. Each method may provide satisfactory results **when conscientiously implemented** with the specified *fastener assembly* components in good condition. However, it must be recognized that **misuse or abuse is possible with any method**.
- With all methods, it is important to first install bolts in all holes of the *joint* and to **compact the *joint* until the connected plies are in *firm contact***. Only after completion of this operation can the *joint* be reliably *pretensioned*. Both the initial phase of compacting the *joint* and the subsequent phase of *pretensioning* should begin at the most rigidly fixed or stiffest point.

47

8.2. Pretensioned and Slip-Critical Joints Commentary

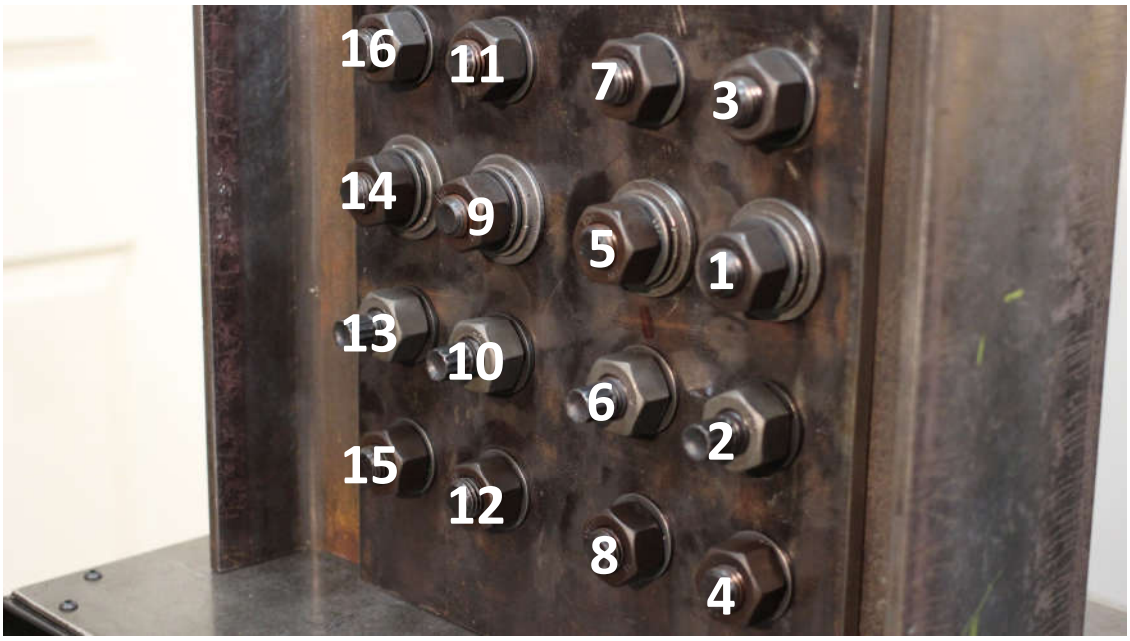
- In some *joints* in thick material, it **may not be possible** to reach continuous contact throughout the *faying surface* area, as is commonly achieved in *joints* of thinner plates. This is not detrimental to the performance of the *joint*. If the specified *pretension* is present in all *bolting assemblies* of the completed *joint*, the clamping force, which is equal to the total of the *pretensions* in all *bolting assemblies*, will be transferred at the locations that are in contact and the *joint* will be fully effective in resisting slip through friction.
- If individual bolts are *pretensioned* in a single continuous operation in a *joint* that has not first been properly compacted or fitted up, the pretension in the bolts that are *pretensioned* first **may be relaxed or removed** by the *pretensioning* of adjacent bolts. The resulting reduction in total clamping force will reduce the slip resistance.

48

Structural Bolt Pretensioning Methods

- 8.2.1 Turn of Nut
  - Undefined Torque + Angle
- 8.2.2 Calibrated Wrench
  - Torque without K control
- 8.2.3 Twist-Off Type (TC bolt)
  - Torque with K control
- 8.2.4 DTI Washer
- **8.2.5 Combined Method**
  - Defined Torque + Angle

49



50

Methods Worldwide

Japan
- Torque + Torque
- Twist-Off Type
- Torque Only
- DTI

Europe
- Combined Method
- Twist-Off Type
- DTI
- Torque Only

51

8.2. Pretensioned and Slip-Critical Joints

- The pre-installation verification procedures specified in Section 7 shall be performed using *bolting assemblies* that are representative of the condition of those that will be *pretensioned* in the work.

52

Increase and Relocation

2014

Table 8.1. Minimum Bolt Pretension, *Pretensioned* and *Slip-Critical Joints*

Nominal Bolt Diameter, d_b, in.	Specified Minimum Bolt Pretension, T_m, kips [a]	
	ASTM A325 and F1852	ASTM A490 and F2280
½	12	15
⅝	19	24
¾	28	35
⅞	39	49
1	51	64
1⅛	56	80
1¼	71	102
1⅜	85	121
1½	103	148

[a] Equal to 70 percent of the specified minimum tensile strength of bolts as specified in ASTM Specifications for tests of full-size ASTM A325 and A490 bolts with UNC threads loaded in axial tension, rounded to the nearest kip.

2020

Table 5.2
Minimum Bolt Pretension, Pretensioned and Slip-Critical Joints

Nominal Bolt Diameter, d_b, in.	Specified Minimum Bolt *Pretension*, T_m, kips	
	Group 120	Group 144 and Group 150
½	12	15
⅝	19	24
¾	28	35
⅞	39	49
1	51	64
1⅛	64	80
1¼	81	102
1⅜	97	121
1½	118	148

53

Turn of Nut Section 7 – PIV Section

- **7.2.1. *Turn-of-Nut Method***
- Step 1: Snug-Tightening
  The *bolting assembly* shall be installed to the *snug-tight condition* in the *bolt tension measurement device* using the tools, *bolting components*, assembly configuration, and installation methods to be used in the work.
- Step 2: Matchmarking
  If matchmarking is to be used in the work, the *bolting assembly* shall be matchmarked.
- Step 3: Pretensioning
  The rotation specified in Table 8.1 shall be applied to the *bolting assembly*.
- Step 4: Final Verification
  If the actual *pretension* developed in the *bolting assembly* is less than that specified in Table 7.1, the cause(s) shall be determined and resolved before the *bolting assemblies* are used in the work. Cleaning, lubrication, and retesting of these *bolting assemblies* is permitted provided that all assemblies are treated in the same manner.

54

Turn-of-Nut – Elimination of the Minus Tolerance

Table 8.1
Nut Rotation from Snug-Tight Condition for Turn-of-Nut Method Pretensioning[a,b]

Bolt Length[c]	Disposition of Outer Faces of Bolted Parts		
	Both Faces Normal to Bolt Axis	One Face Normal to Bolt Axis, Other Sloped not More Than 1:20[d]	Both Faces Sloped not More Than 1:20 from Normal to Bolt Axis[d]
Not more than $4d_b$	⅓ turn	½ turn	⅔ turn
More than $4d_b$ but not more than $8d_b$	½ turn	⅔ turn	⅚ turn
More than $8d_b$ but not more than $12d_b$	⅔ turn	⅚ turn	1 turn

a Nut rotation is relative to bolt regardless of the element (nut or bolt) being turned. For all required nut rotations, the tolerance is plus 60 degrees (⅙ turn) and minus 0 degrees.
b Applicable only to joints in which all material within the *grip* is steel.
c When the bolt length exceeds $12d_b$, the required nut rotation shall be determined by actual testing in a suitable *bolt tension measurement device*; see *turn-of-nut* Commentary.
d Beveled washer not used.

55

Turn of Nut - Installation

56

Turn of Nut - Section 8

- **8.2.1. *Turn-of-Nut Method* Pretensioning**

  After the snug-tightening operation has been performed, the nut or head rotation specified in Table 8.1 shall be applied to all *bolting assemblies* in the *joint*, progressing systematically from the most rigid part of the *joint* in a manner that will minimize relaxation of previously *pretensioned bolting assemblies*.

57

Turn of Nut - Section 9

- **9.2.1. *Turn-of-Nut Method* Pretensioning**
- The *Inspector* shall:

(1) Observe the pre-installation verification testing required in Section 7;

(2) Verify by *routine observation* that the *snug-tight condition* has been achieved in accordance with Section 8.1; and

(3) Verify by *routine observation* that the bolting crew subsequently rotates the turned element relative to the unturned element by the amount specified in Table 8.1. Alternatively, when *bolting assemblies* are match-marked after snug-tightening of the *joint* but prior to *pretensioning*, visual inspection after *pretensioning* is permitted in lieu of *routine observation*. No further evidence of conformity is required.

A *pretension* that is greater than the value specified in Table 5.2 shall not be cause for rejection. A rotation that exceeds the required values, including tolerance, specified in Table 8.1 shall not be cause for rejection.

58

Heavy Hex Assembly

59

Numerous Options

Pneumatic

Hydraulic

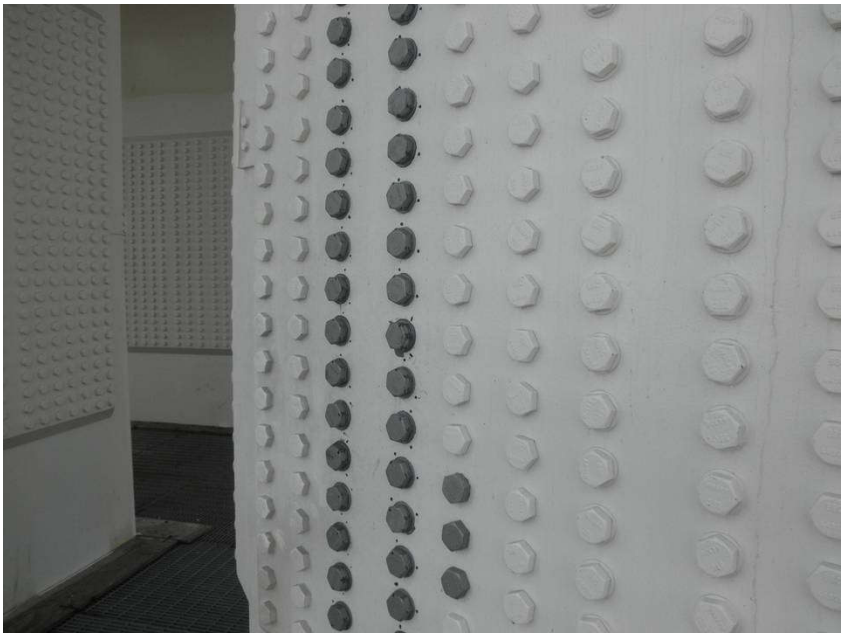
60

Non-impacting, Non-reacting Tools

Reaction arm to neighboring bolt

Reaction arm to steel or other

61



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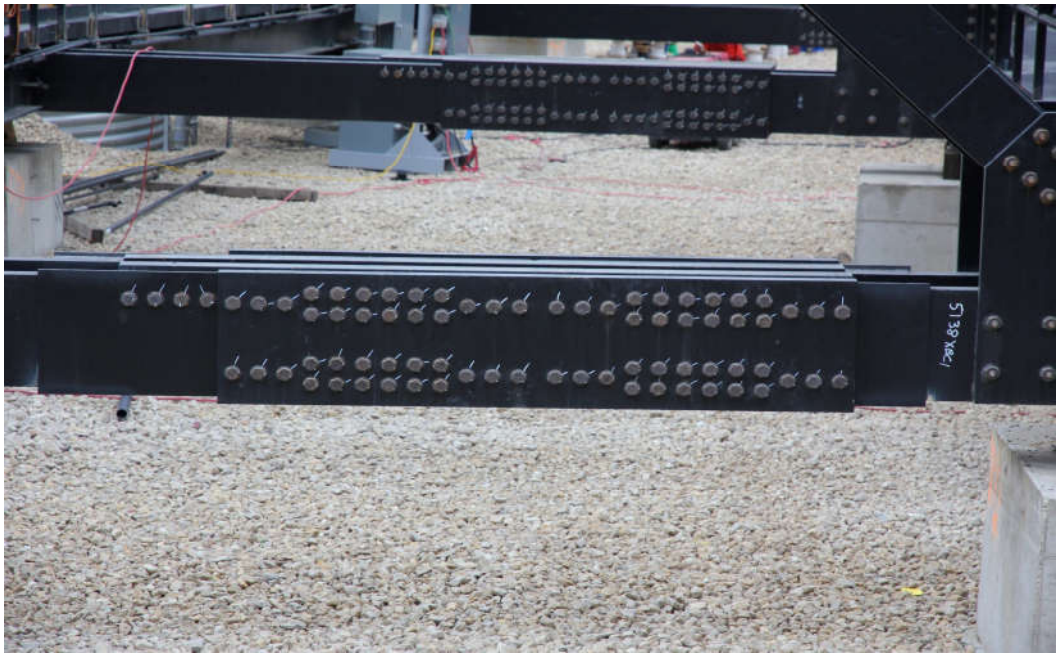


63

Calibrated Wrench

- **7.2.2. *Calibrated Wrench Method***
- Step 1: Snug-Tightening
- The *bolting assembly* shall be installed to the *snug-tight condition* in the *bolt tension measurement device* using the tools, *bolting components*, assembly configuration, and installation methods to be used in the work.
- Step 2: Pretensioning
- The torque required for the installation tool to develop a *pretension* in the *bolting assembly* equal to or greater than that specified in Table 7.1 shall be determined. The installation torque shall be applied to the nut. The highest torque measured from the three assemblies tested shall be the minimum installation torque to be used in the work.

64

6.2.2. *Calibrated Wrench Method:* When the *calibrated wrench method* for *pretensioning* is used, an ASTM F436 washer shall be used under the nut.

Table 6.1
Washer Requirements for Pretensioned and Slip-Critical Bolted Joints with Oversized and Slotted Holes in the Outer Ply

Bolt Group	Nominal Bolt Diameter, d_b, in.	Hole Type in Outer Ply		
		Oversized	Short-Slotted	Long-Slotted
Group 120	½ – 1½	ASTM F436[a]		5/16 in. thick plate washer or continuous bar[b,c]
Group 144 and 150	≤ 1			
	> 1	ASTM F436 extra thick[a,b,d]		ASTM F436 washer with either a 3/8-in.-thick plate washer or continuous bar[b,c]

[a] This requirement shall not apply at the head at round heads of ASTM F3125 Grades F1852 and F2280, or F3148 Grade 144 *bolting assemblies* with round heads that meet the requirements in Section 2.4 and provide a bearing circle diameter that meets the requirements of the relevant ASTM Standard.
[b] See ASTM F436 Section 1.2. Multiple washers with a combined thickness of 5/16 in. or larger do not satisfy this requirement.
[c] The plate washer or bar shall be of structural-grade steel material, but need not be hardened.
[d] Alternatively, a 3/8-in.-thick plate washer and an ordinary thickness F436 washer may be used. The plate washer need not be hardened.

65

Calibrated Wrench

- **8.2.2. *Calibrated Wrench Method* Pretensioning**
- After the snug-tightening operation has been performed, the installation torque determined in the pre-installation verification of the *bolting assembly* (Section 7.2.2) shall be applied by turning the nuts (not the bolt heads) in the *joint*, progressing systematically from the most rigid part of the *joint* in a manner that will minimize relaxation of previously *pretensioned bolting assemblies*. It is **prohibited** to use this method by turning the bolt head.
- Torque values determined from tables or from equations that claim to relate torque to *pretension* without verification shall not be used.
- Application of the installation torque need not produce a relative rotation between the bolt and nut that is equal to or greater than the rotation specified in Table 8.1.

Why?

- Different K Factor is possible/likely when turning the head
- Binding on the bolt body can require significant torque to overcome

66

Calibrated Wrench

- **9.2.2. *Calibrated Wrench Method* Pretensioning**
- The *Inspector* shall:
- (1) Observe the pre-installation verification testing required in Section 7;
- (2) Verify by *routine observation* that the *snug-tight condition* has been achieved in accordance with Section 8.1; and
- (3) Verify by *routine observation* that the bolting crew subsequently applies the calibrated wrench to the nut. No further evidence of conformity is required.
- A *pretension* that is greater than the value specified in Table 5.2 shall not be cause for rejection. The use of a torque greater than the minimum installation torque shall not be cause for rejection.

67

Calibrated Wrench Commentary

Calibrated wrench pretensioning was once removed from RCSC, but then later reinstated with more emphasis on detailed requirements that must be carefully followed. For calibrated wrench pretensioning, wrenches must be calibrated:

- (1) Daily;
- (2) When the *lot* of any component of the *bolting assembly* is changed;
- (3) When the *lot* of any component of the *bolting assembly* is relubricated;
- (4) When significant differences are noted in the surface condition of the bolt threads, nuts or washers; or,
- (5) When any major component of the wrench—including lubrication, hose, and air supply—are altered.

68

Calibrated Wrench Commentary

- It is also important that:
- (1) *Bolting components* are protected from dirt and moisture at the shop or job site as required in Section 2.10;
- (2) Washers are used as specified in Section 6;
- (3) The time between removal from *protected storage*, wrench calibration, and final *pretensioning* is minimal; and
- (4) Only the nut is to be turned during calibration and installation.

69

Calibrated Wrench

70

7.2.3. Twist-Off Tension Control Bolt Method

- **7.2.3. *Twist-Off Tension Control Bolt Method***
- Step 1: Snug-Tightening - The *bolting assembly* shall be installed to the *snug-tight condition* using the tools, *bolting components*, assembly configuration, and installation methods to be used in the work.
- Step 2: Intermediate Verification - It shall be verified that the splined end is not severed.
- Step 3: Pretensioning - The *twist-off tension control bolt* installation wrench shall be used to sever the splined end
- Step 4: Final Verification - It shall be verified that the splined end is severed. If the actual *pretension* developed in the *bolting assembly* is less than that specified in Table 7.1, the cause(s) shall be determined and resolved before the *bolting assemblies* are used in the work. Cleaning, lubrication, and retesting of these *bolting assemblies* is not permitted, except as allowed in Section 2.10, provided that all assemblies are treated in the same manner.

71

Twist-Off Type - Installation

72

TC Section 8.2.3 - Installation

- **8.2.3. Twist-Off Tension Control Bolt Method Pretensioning**
- After the snug-tightening operation is performed, the installer shall verify that the splined end has not been severed, and if this has occurred, the *bolting assembly* shall be removed and replaced.
- All bolts in the *joint* shall be *pretensioned* with the *spline end twist-off bolt* installation wrench, progressing systematically from the most rigid part of the *joint* in a manner that will minimize relaxation of previously *pretensioned* bolts.

73

TC Section 9.2.3 - Inspection

- **9.2.3. *Twist-Off Tension Control Bolt Method* Pretensioning**
- The *Inspector* shall:
- (1) Observe the pre-installation verification testing required in Section 7;
- (2) Verify by *routine observation* that the *snug-tight condition* has been achieved in accordance with Section 8.1 and that splined ends are intact after snug-tightening; and
- (3) Verify by *routine observation* that the splined ends are subsequently twisted off during *pretensioning* by the bolting crew. No further evidence of conformity is required. A *pretension* that is greater than the value specified in Table 5.2 shall not be cause for rejection.

74

Twist-Off Type

- Single side installation
- Visual indicator
- Calibrated torque

- Snug only
  - Shear/bearing connection

- Tensioned
  - By Shear Wrench (TC Wrench)

75

Twist-Off Type

Electric

Electric

76

DTI Section 7 – PIV Testing

- **7.2.4. *Direct Tension Indicator Method***
- Step 1: Snug-Tightening

  The *bolting assembly* shall be installed to the *snug-tight condition* using the tools, *bolting components*, assembly configuration, and installation methods to be used in the work. *Snug-tightening* shall not exceed the *pretension* specified in Table 7.1.
- Step 2: Intermediate Verification

  The *bolting assembly* shall be further tightened to a *pretension* that is equal to that required in Table 7.1. It shall then be verified that the *job inspection gap* has not closed prematurely. To prove acceptability, the feeler gage used to verify the *job inspection gap* **shall be able to be inserted in half or more** of the spaces between the protrusions of the *direct tension indicator*. Verification with the feeler gage in this step satisfies verification for both Step 1 and Step 2.

77

DTI Section 7 – PIV Testing

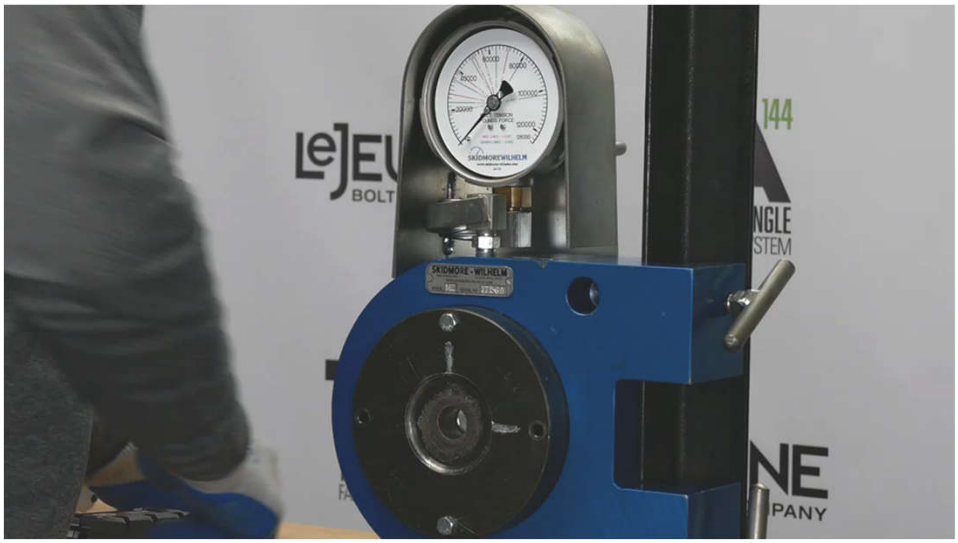
- Step 3: Pretensioning

  The *bolting assembly* shall be further tightened, as needed, until the feeler gage is **refused** (i.e., cannot be inserted) **in more than half** of the spaces between the protrusions of the *direct tension indicator.*
- Step 4: Final Verification

  It shall be verified that the pretension achieved is at least that specified in Table 7.1. If the actual *pretension* developed in the *bolting assembly* is less than that specified in Table 7.1, the cause(s) shall be determined and resolved before the *bolting assemblies* are used in the work. Cleaning, lubrication, and retesting of these *bolting assemblies* is permitted provided that all assemblies are treated in the same manner.

78

DTI - Installation



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DTI Section 8.2.4 - Installation

- **8.2.4. *Direct Tension Indicator Method* Pretensioning**
- After the snug-tightening operation is performed, the installer shall verify that the *direct tension indicator* protrusions have not been compressed to a gap that is less than the *job inspection gap* in half or more of the locations, and if this has occurred, the *direct tension indicator* shall be removed and replaced.
- All bolts in the *joint* shall be *pretensioned*, progressing systematically from the most rigid part of the *joint* in a manner that will minimize relaxation of previously *pretensioned* bolts. The installer shall verify that the *direct tension indicator* protrusions have been compressed to a gap that is less than the *job inspection gap* in more than half of the locations.

80

DTI Section 9.2.4 - Inspection

- **9.2.4. *Direct Tension Indicator Method* Pretensioning**
- The *Inspector* shall:

(1) Observe the pre-installation verification testing required in Section 7.

(2) Verify by *routine observation* that the *snug-tight condition* has been achieved in accordance with Section 8.1, that the appropriate feeler gage is **accepted in half or more** of the spaces between the protrusions of the *direct tension indicator*, and that the protrusions are properly oriented away from the work. If the appropriate feeler gage is accepted in fewer than half of the spaces, the *direct tension indicator* shall be removed and replaced.

(3) After *pretensioning*, verify by *routine observation* that the appropriate feeler gage is **refused entry into more than half** of the spaces between the protrusions. No further evidence of conformity is required.

A *pretension* that is greater than that specified in Table 5.2 or feeler gage refusal in all locations shall not be cause for rejection.

81

DTI Washer

82

Combined Method - Section 7

- **7.2.5. *Combined Method***
- Step 1: Initial Tensioning

  The *bolting assembly* shall be installed in the *bolt tension measurement device* using the tools, *bolting components*, assembly configuration, and installation methods to be used in the work. The ***initial torque* shall be applied to the nut**. If the *initial torque* has not been provided by the *Supplier*, then the torque in Table 7.3 shall be used. Tools used shall demonstrate or have certified output that does not vary by more than ±10 percent during use.
- Step 2: Intermediate Verification

  If the actual tension developed in the *bolting assembly* is less than the *initial tension* specified in Table 7.2, the cause(s) shall be determined and resolved before the *bolting assemblies* are used in the work. Cleaning, lubrication, and retesting of these *bolting assemblies* is not permitted, except as allowed in Section 2.10, provided that all assemblies are treated in the same manner.
- Step 3: Pretensioning

  If match-marking is to be used in the work, the *bolting assembly* shall be matchmarked. The **rotation specified in Table 8.2** shall be applied to the *bolting assembly*.
- Step 4: Final Verification

  If the actual *pretension* developed in the *bolting assembly* is less than that specified in Table 7.1, the cause(s) shall be determined and resolved before the *bolting assemblies* are used in the work.

83

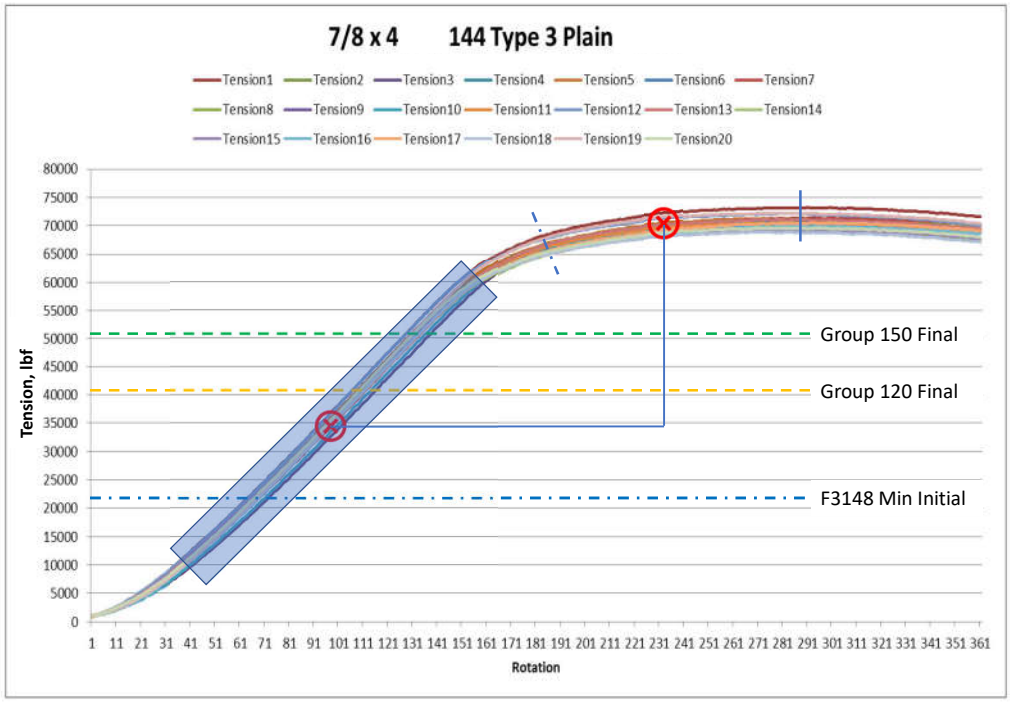
Combine Method - Installation

84

Two Steps to Tensioning (pretension)

- Snug tight – firm and continuous contact
  - Other installation methods do not control this.
- Final tensioning
  - By using angle or elongation for final pretensioning we can dramatically improve over torque-based installation methods like twist-off bolts.
  - By starting from a known initial condition we can improve performance over other angle-based installation methods like turn of nut.

85



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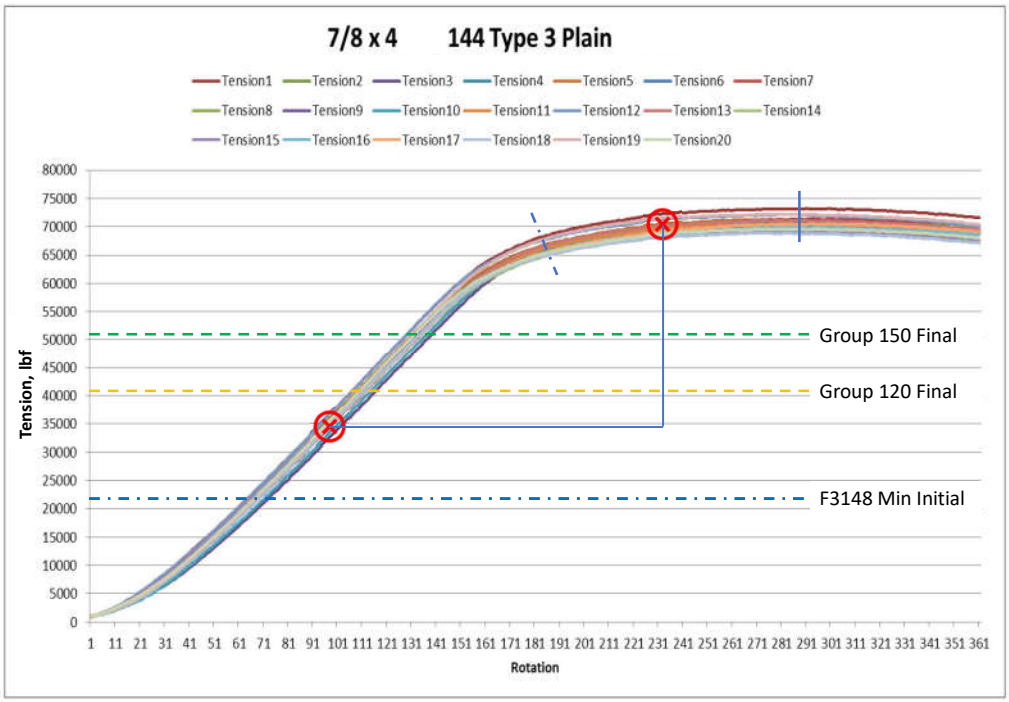

87

New Table Minimum Initial Tension

- Think of it as replacement for full effort of an iron worker.
- Linear vs. non-linear.

Table 7.2
Minimum Initial Tension for Pre-Installation Verification of Installation in Accordance with Section 8.2.5 (Combined Method)

Nominal Bolt Diameter, d^b, in.	Minimum Initial Tension for Pre-Installation Verification, kips	
	Group 120	Group 144 and Group 150
½	5	7
⅝	9	11
¾	13	16
⅞	17	22
1	23	29
1⅛	29	36
1¼	37	46
1⅜	44	55
1½	53	66

88

Table 7.3 - Default Initial Torque Range

- It is expected that most producers or suppliers will provide torque values when using the Combined Method. If they do not, Table 7.3 provides the value to use.

Table 7.3
Default Initial Torque Range for Pre-Installation Verification of Initial Tension in Accordance with Section 8.2.5 (Combined Method)

Nominal Bolt Diameter, d^b, in.	Torque Range for Pre-Installation Verification, lb-ft[a]			
	Group 120		Group 144[b] and Group 150	
	Min	Max	Min	Max
½	45	50	60	75
⅝	100	120	120	145
¾	170	205	210	250
⅞	260	310	335	400
1	405	480	510	605
1⅛	570	680	710	845
1¼	810	965	1010	1200
1⅜	1060	1260	1325	1575
1½	1390	1655	1735	2065

[a] This table shall not be used in lieu of *Supplier*-provided torque values and shall only be used when torque has not been provided for a *bolting assembly* by the bolt *Supplier*.
[b] F3148 Group 144 *bolting assemblies* are only available up to 1¼-in. diameter.

89

Combined Method – Section 8.2.5

- **8.2.5. *Combined Method* Pretensioning**
  After the application of the *initial torque* and when the plies have been brought into *firm contact*, the rotation specified in Table 8.2 shall be applied to all *bolting assemblies* in the *joint*, progressing systematically from the most rigid part of the *joint* in a manner that will minimize relaxation of previously *pretensioned bolting assemblies*.

90

Combined Method – Section 8

Table 8.2
Nut Rotation from Initial Torque for Combined Method Pretensioning[a,b]

Bolt Length[c]	Rotation
Not more than $4d_b$	90° (¼ turn)
More than $4d_b$ but not more than $8d_b$	120° (⅓ turn)

[a] Nut rotation is relative to bolt regardless of the element (nut or bolt) being turned. For all required nut rotations, the tolerance is plus 45 degrees (⅛ turn) and minus 0 degrees.
[b] Applicable only to *joints* in which all material within the *grip* is steel.
[c] When the bolt length exceeds $8d_b$, the required nut rotation shall be determined by actual testing in a suitable *bolt tension measurement device*; see *combined method* Commentary.

91

Combined Method - Section 9.2.5

- **9.2.5 *Combined Method* Pretensioning**

The *Inspector* shall:

(1) Observe the pre-installation verification testing required in Section 7;

(2) Verify by *routine observation* that the bolting crew applies to the nut the *initial torque* used in pre-installation verification testing, that the plies have been brought into *firm contact*, and that the requirements of Section 8.1 have been met; and

(3) Verify by *routine observation* that the bolting crew properly rotates the turned element relative to the unturned element by the amount specified in Table 8.2. Alternatively, when *bolting assemblies* are match-marked after the initial application of the torque, but prior to *pretensioning*, visual inspection after *pretensioning* is permitted in lieu of *routine observation*. No further evidence of conformity is required.

A *pretension* that is greater than the value specified in Table 5.2 shall not be cause for rejection. A rotation that exceeds the required values, including tolerance, in Table 8.2, shall not be cause for rejection.

92

Combined Method PIV Test

93

Inspection - 9.1. Snug-Tightened Joints

- **Prior to the *start of work***, it shall be verified that all *bolting components* to be used in the work meet the requirements in Section 2. Subsequently, it shall be verified that all **connected plies meet the requirements in Section 3.1** and all **bolt holes meet the requirements in Sections 3.3 and 3.4.** After the *connections* have been assembled to the requirements of Section 8.1, it shall be **visually verified** that the plies of the connected elements have been brought into *firm contact* and washers have been used as required in Section 6. No further evidence of conformity is required for *snug-tightened joints*.

94

9.2. Pretensioned Joints

- For *pretensioned joints*, the following inspection shall be performed in addition to that required in Section 9.1:
- (1) When the *turn-of-nut method* is used for *pretensioning*, the inspection shall be in accordance with Section 9.2.1;
- (2) When the *calibrated wrench method* is used for *pretensioning*, the inspection shall be in accordance with Section 9.2.2;
- (3) When the *twist-off tension control bolt method* is used for *pretensioning*, the inspection shall be in accordance with Section 9.2.3;

95

9.2. Pretensioned Joints

- (4) When the *direct tension indicator method* is used for *pretensioning*, the inspection shall be in accordance with Section 9.2.4;
- (5) When the *combined method* is used for *pretensioning*, the inspection shall be in accordance with Section 9.2.5; and
- (6) When alternative-design *bolting components*, *assemblies*, or installation methods that meet the requirements of Section 2.12 are used, the inspection shall be in accordance with inspection instructions provided by the consensus standard or *Manufacturer* and approved by the *Engineer of Record*.

96

9.3. Slip-Critical Joints

- **Slip-Critical Joints**
- Prior to assembly, it shall be visually verified that the *faying surfaces* of *slip-critical joints* meet the requirements in Section 3.2.2. Subsequently, the inspection required in Section 9.2 shall be performed.

97

AISC – Inspection

- Chapter N of the AISC Specification for Structural Steel Buildings contains Quality Control and Quality Assurance requirements for quality control. These include documentation of materials, personnel, specific production and QC procedures, and bolting inspection tasks.
- ***Quality Control Inspector (QCI)***. Individual designated to perform *quality control* inspection tasks for the work being performed*. (contractor)*
- ***Quality Assurance Inspector (QAI)***. *Authority having jurisdiction, building code, owner, engineer of record. (oversight)*

98

AISC – Inspection

- As a minimum, bolting inspection tasks shall be in accordance with Tables N5.6-1, N5.6-2 and N5.6-3. In these tables, the inspection tasks are as follows:
- Observe (O): The inspector shall observe these items on a random basis. Operations need not be delayed pending these inspections.
- Perform (P): These tasks shall be performed for each bolted connection.

99

Other Requirements

- In addition to the erector's quality control program, tests and inspection are specified by the Engineer of Record and/or the local building authority.
- Snug-tightened joints require visual inspection for firm contact.
- Pretensioned joints require pre-installation verification and routine observation of proper application.
- Slip-critical joints require inspection of the faying surfaces in addition to the above inspections.

100

Thank you!

AISC | Questions

Smarter. Stronger. Steel.

Individual Session Registrants

PDH Certificates

- All WFH individuals associated with a group registration will be issued a certificate.
- All individuals attending at your connection: you will receive an email on how to report their attendance from: registration@aisc.org.
    - Be on the lookout: Check your spam filter! Check your junk folder!
    - Completely fill out online form. Don't forget to check the boxes next to each attendee's name!

8-Session Registrants

PDH Certificates

One certificate will be issued at the conclusion of all 8 sessions.

8-Session Registrants

Access to the quiz

Information for accessing the quiz will be emailed to you by Wednesday. It will contain a link to access the quiz. EMAIL COMES FROM NIGHTSCHOOL@AISC.ORG.

Quiz and attendance records

Posted Friday mornings. www.aisc.org/nightschool -- Click on Current Course Details.

Reasons for quiz

- EEU – You must take all quizzes and the final exam to receive EEU.
- PDHs – If you watch a recorded session, you must pass quiz for PDHs.
- REINFORCEMENT – Reinforce what you learn tonight. Get more out of the course.

Note: If you attend the live presentation, you do not have to take the quizzes to receive PDHs

8-Session Registrants

Access to the recording

Information for accessing the recording will be emailed to you by Wednesday. The recording will be available for four weeks. (For 8-session registrants only.) EMAIL COMES FROM NIGHTSCHOOL@AISC.ORG.

PDHs via recording

If you watch a recorded session, you must take *and pass* the quiz for PDHs.

8-Session Registrants

Night School Resources

Find all your handouts, quizzes and quiz scores, recording access, and attendance information all in one place!

8-Session Registrants

Night School Resources

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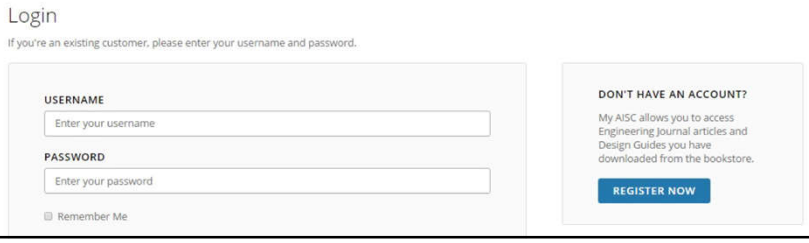

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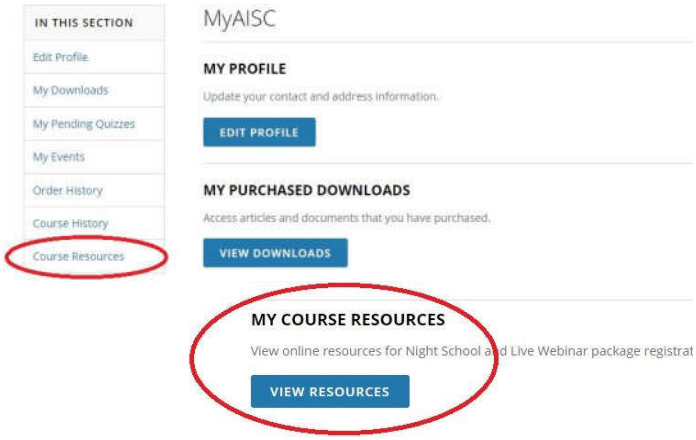


8-Session Registrants

Night School Resources

Course Resources

Event	Start Date
NS 13 8-Session Package-Night School 13 - Design of Industrial Buildings	1/30/2017 7:00:00 PM
NS 14 8-Session Package-Night School 14 - Fundamentals of Stability	6/5/2017 7:00:00 PM

8-Session Registrants

Night School Resources

Night School 13: Design of Industrial Buildings

8-SESSION PACKAGE RESOURCES

Event	Date	Handouts	Video	Quiz	Attendance
NS13 - Design Criteria	1/30/2017 7:00:00 PM	Handouts	View Passcode: NS13DSN	Pass Score: 80	Pending
NS13 - Economic Considerations	2/6/2017 7:00:00 PM	Handouts	Available 02/08/2017 5pm EST	Available 02/08/2017 5pm EST	Pending
NS13 - Lateral Load Systems and Details	2/13/2017 7:00:00 PM	Handouts	Available 02/15/2017 5pm EST	Available 02/15/2017 5pm EST	Pending
NS13 - Preliminary Design Procedures	2/27/2017 7:00:00 PM	Handouts	Available 03/01/2017 5pm EST	Available 03/01/2017 5pm EST	Pending
NS13 - Crane Girder Design and Frame Analysis	3/6/2017 7:00:00 PM	Handouts	Available 03/08/2017 5pm EST	Available 03/08/2017 5pm EST	Pending
NS13 - Frame Member and Connection Design	3/13/2017 7:00:00 PM	Handouts	Available 03/15/2017 5pm EST	Available 03/15/2017 5pm EST	Pending
NS13 - Transfer Crane Girder & Longitudinal Bldg Bracing Dsn	3/27/2017 7:00:00 PM	Handouts	Available 03/29/2017 5pm EST	Available 03/29/2017 5pm EST	Pending
NS13 - Building Envelope and Bracing Design	4/3/2017 7:00:00 PM	Handouts	Available 04/05/2017 5pm EST	Available 04/05/2017 5pm EST	Pending

8-Session Registrants

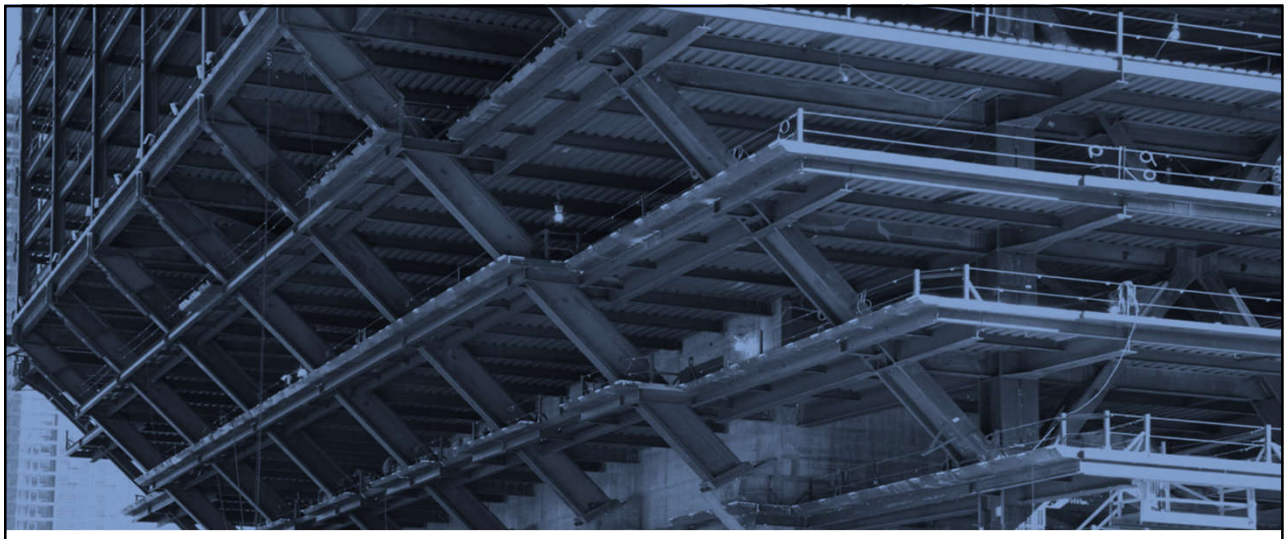
Night School Resources

- Weekly “quiz and recording” email.
- Weekly updates of the master quiz and attendance record, found at www.aisc.org/nightschool27. Scroll down to Quiz and Attendance records.
    - Updated on Friday mornings.

8-Session Registrants

Night School Resources

- Webinar connection information
    - Reminder email sent out Monday mornings
- Links to handouts also found here



AISC | Thank you

Smarter.
Stronger.
Steel.