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Fastener Fundamentals and Important Changes in the 2020 RCSC *Specification for Structural Joints Using High-Strength Bolts*
January 28, 2021

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Course Description

Fastener Fundamentals and Important Changes in the 2020 RCSC *Specification for Structural Joints Using High-Strength Bolts*
January 28, 2021

This webinar will present an update on structural fasteners with a focus on changes introduced in the new 2020 RCSC *Specification for Structural Joints Using High-Strength Bolts*. This review will address a broad range of topics including fastener strength, nomenclature, callout criteria, hole sizes, available coatings, EOR responsibility, alternative design requirements, new installation methods, and changes to existing installation methods.

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Learning Objectives

- Explain how the updated RCSC *Specification for Structural Joints Using High-Strength Bolts* treats non-steel material, such as thermal breaks, within the grip of the bolt.
- List the responsibilities of the Engineer of Record, as required by the 2020 RCSC *Specification*.
- Identify issues involved with determining if a bolt should be considered as having threads excluded, or not, in design. Describe how the 2020 RCSC *Specification* has changed in the handling of the transition zone.
- Describe how the 2020 RCSC *Specification* treats galvanized faying surfaces for the limit state of slip. Compare this to the 2016 AISC *Specification for Structural Steel Buildings*.

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Hold smartphone camera over codes for more information

Landscape (horizontal) camera mode may help in some cases

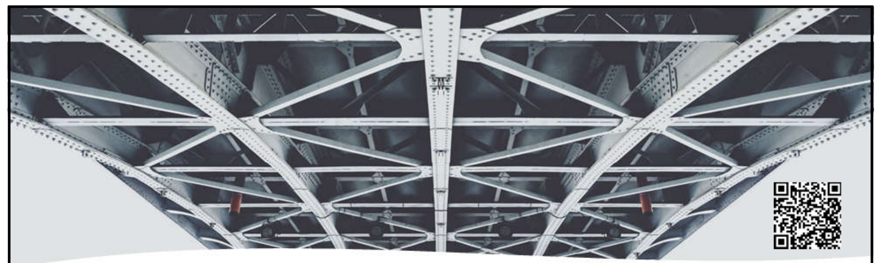
Links are also provided at the end of the presentation

Fastener Fundamentals

Important Changes in the 2020 RCSC Specification

January 28, 2021

- Chad Larson
- President - LeJeune Bolt Company
- Vice Chair - ASTM F16 Committee on Fasteners
- Chair - RCSC Task Group 4 on Installation
- https://www.linkedin.com/in/chad-larson-f3148/



Fastener Fundamentals

Important Changes in the 2020 RCSC Specification

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Chad Larson

- AISC - Task Committee 6 on Connection Design
- AISC - Task Committee 10 on Materials
- RCSC - Secretary and Treasurer
- RCSC - Executive Committee
- RCSC - Specification Committee
- RCSC - Task Group 1 on General Requirements
- RCSC – Chair, Task Group 4 on Installation
- RCSC/ASTM Liaison
- RCSC/AISC Liaison
- AIA - Accredited Speaker and Presenter
- JSS - Committee on the English Translation of JSSII 09-2015
- ASTM - Award of Merit Selection Committee
- Author of ASTM F3125 and ASTM F3148

9

Chad Larson

- ASTM - Chair, F16 Committee on Fasteners
- ASTM - Vice Chair, F16 Committee on Fasteners
- ASTM - Chair, F16.02 Subcommittee on Steel Bolts, Nuts and Washers
- ASTM - Chair, F16.02.02 Task Group on Structural Bolts
- ASTM - F16.01 Fastener Test Methods
- ASTM - F16.02 Subcommittee on Steel Bolts, Nuts and Washers
- ASTM - F16.03 Coatings on Fasteners
- ASTM - F16.90 Executive
- ASTM - F16.93 Quality Assurance Provisions for Fasteners
- ASTM - F16.97 Coordination with NA TAGs to ISO TC2 on Fasteners
- ASTM - A01.22.01 Bolting
- ASTM - Chair, F16 Award Committee
- ASTM F16 Fred F. Weingruber Award Recipient

10

Where is the specification?

- Part 16 of the 15th Edition *Steel Construction Manual*
  - 2016 *Specification for Structural Steel Buildings* (ANSI/AISC 360-16)
  - 2014 *Specification for Structural Joints Using High Strength Bolts*
- The new RCSC 2020 Specification is available for download now!
  - Will be published with ANSI/AISC 360-22 in the next edition of the *Manual*
- https://www.aisc.org/globalassets/aisc/publications/standards/a348-20w.pdf

11

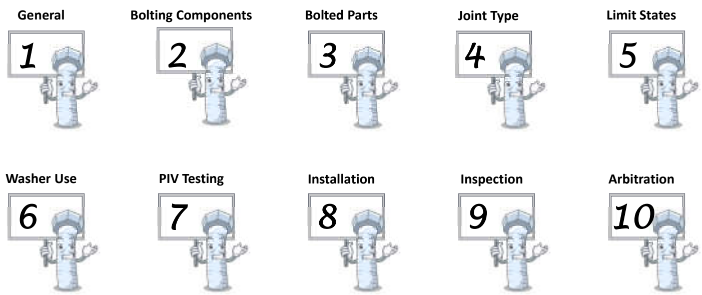
Original RCSC Specification – 3 Pages

Approved by
Research Council on Riveted and Bolted
Structural Joints of the Engineering Foundation
January, 1951

Endorsed by
American Institute of Steel Construction
Industrial Fasteners Institute

12

10 Sections (114 Pages) - Plus Slip Coefficient Appendix A



13

Bolt Council

RCSC 2020

- 937 total changes
- Significant effort by RCSC specification committee and all volunteer membership
- Specification Committee Chair
  - Larry Kruth - AISC

https://www.aisc.org/globalassets/aisc/publications/standards/a348-20w.pdf

14

RCSC 2020

- Draft and Ballot Coordinator
  - G.A. Rassati - University of Cincinnati
- Task Group Chairs
  - **Task Group 1** - General Requirements:
    G.A. Rassati - University of Cincinnati
  - **Task Group 2** - Products and Parts:
    Toby Anderson - Bay Bolt
  - **Task Group 3** - Design:
    James Swanson - University of Cincinnati
  - **Task Group 4** - Installation:
    Chad Larson - LeJeune Bolt Company
  - **Task Group 5** - Inspection:
    Dan Kaufman - Retired - AISC

15

RCSC 2020

- Editorial Committee
  Thomas Schlafly - AISC
  Robert Shaw – Steel Structures Technology Center
  Rachel Shanley – Simpson Gumpertz & Heger
- Executive Committee
  - **Chair**:
    Salim Brahimi – Industrial Fastener Institute
  - **Vice-Chair**:
    Robert Shaw – Steel Structures Technology Center
  - **Secretary-Treasurer**:
    Jonathan McGormley – Wiss, Janney, Elstner Associates
  - **Directors**:
    Toby Anderson – Bay Bolt
    Curtis Mayes – Stanley D Lindsey & Associates
    Carly McGee – KTA-Tator
    Tom Schlafly - AISC
    Gian Andrea Rassati – University of Cincinnati
    Todd Ude – Parsons
    James Swanson – University of Cincinnati

16

NEW EDITION

New RCSC Specification

Learning Objectives

- New glossary items
- New standards (F3125, F3148, F2833, F3019, A1059)
- New alternative design language and innovation clause
- New strength "Group" Designations (120, 144, 150)
- New bolt strength (144 ksi)
- New practices
  - Design for shear
  - Treatment of galvanized faying surfaces
  - Hole sizes
- New pretension requirements
- New installation method (Combined Method)
- Changes to current installation methods
  - Turn of Nut
  - Calibrated wrench
  - Direct Tension Indicators

17

The Basics

- Updated Membership Roster
- Updated Table of Contents
- Updated Symbols
- Updated Glossary
- Updated References
- Updated Index

18

The Glossary

- Bolt Tension Measurement Device
- Bolting Assembly
- Bolting Component
- Calibrated Gap
- Cure
- Degree of Cure
- Initial Tension
- Initial Torque

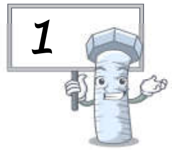
19

The Glossary

- Job Inspection Gap
- Matched Bolting Assembly
- Pretensioning Methods – definitions for all 5 methods
- Style
- Sufficient Thread Engagement
- Temporary Bolts

20

General



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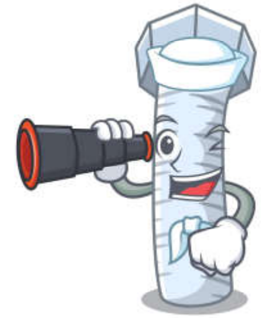
21

Scope

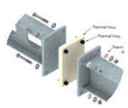
The RCSC Specification has historically only considered joints with steel in the grip. This is still the case, but commentary has been added to give designers guidance on the use of thermal breaks

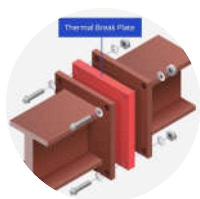


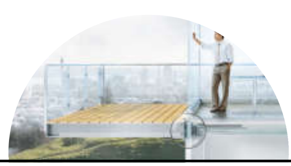
https://www.aisc.org/globalassets/modern-steel/archives/2018/09/breakingupisnthardtodo.pdf

Thermal Breaks

A thermal break is an element of low thermal conductivity and high compressive strength, placed in an assembly to reduce the flow of thermal energy between conductive materials







Thermal Break Commentary

Peterman et al. show that low-modulus materials are permissible in snug-tightened *joints* with bolts subject to shear when long-term loads are limited to 30% of the low-modulus materials' ultimate load. Low-modulus materials that showed acceptable behavior in that study had through-thickness modulus of elasticity between 400 ksi and 800 ksi and through-thickness compressive strength between 25 ksi and 65 ksi.

Additionally, with the presence of compressible materials in the *grip*, the snug-tightening operation will not generate a sufficient force in the bolt to deform the shank so that the head and/or the nut adapt to the slope of the surfaces under them. Therefore, only surfaces that are near-perpendicular to the bolt axis should be used in thermal break joints.

Based on the results in the literature, the *Engineer of Record* should consider, as a minimum, the following aspects of a thermal break joint:

- The stiffness and strength of the inserted layers and their influence on the intended performance of the joint;
- The maximum bolt tension that the layers in the *grip* can withstand without losing integrity or performance;
- The installation instructions to prevent overtightening of bolts;
- The effects of the thickness of the added plies on the stiffness and strength of the *bolting assembly* and of the *connection* as a whole;
- The resistance to exposure of the added plies, when applicable;
- The type of forces that the joint is intended to transfer (e.g., shear, shear and tension, compression, tension, without fatigue);
- The long-term behavior of the inserted layers; and
- The electro-chemical interactions of the inserted layers with coatings on steel, if applicable.

24

Thermal Break Language

Section 1 Commentary and Section 3.1 – Bolted Parts

3.1 Connected Plies - 2014

All connected plies that are within the *grip* of the bolt and any materials that are used under the head or nut shall be steel with faying surfaces that are uncoated, coated or galvanized as defined in Section 3.2. Compressible materials shall not be placed within the *grip* of the bolt. 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.

3.1 Connected Plies - 2020

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.

25

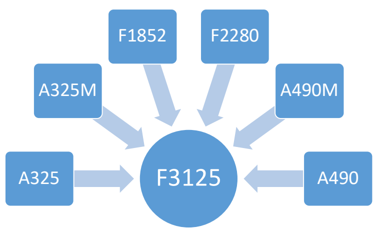
Referenced Standards and Specifications

New Standards

26

ASTM F3125

Standard Specification for High Strength Structural Bolts and Assemblies, Steel and Alloy Steel, Heat Treated, Inch Dimensions 120 ksi and 150 ksi Minimum Tensile Strength, and Metric Dimensions 830 MPa and 1040 MPa Minimum Tensile Strength



- Published in 2015, just after the 2014 edition of the RCSC Specification
- Already published in AISC 360-16
- There is a good chance you are already familiar with F3125

27

Referenced Standards and Specifications

- **Added ASTM F3125**
  - F3125 combined 6 previous structural bolt standards into a single document in 2015
  - Increase in A325 minimum tensile strength over 1" diameter bolts from 105 ksi to 120 ksi
    - Increase in pretension and slip resistance
  - 1-1/4" Twist-Off type bolts added
  - Old designations are now "Grades" within F3125
  - New rotational capacity test
  - 45 pages down to 13
  - 54 tables down to 7
  - Elimination of 32 cross references
  - https://www.astm.org/Standards/F3125.htm

28

ASTM F3125

Designation: F3125/F3125M – 19$^{\varepsilon 2}$

Standard Specification for
High Strength Structural Bolts and Assemblies, Steel and Alloy Steel, Heat Treated, Inch Dimensions 120 ksi and 150 ksi Minimum Tensile Strength, and Metric Dimensions 830 MPa and 1040 MPa Minimum Tensile Strength[1]

This standard is issued under the fixed designation F3125/F3125M; 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.

https://studylib.net/doc/18286153/six-into-one---modern-steel-construction
https://www.aisc.org/globalassets/modern-steel/archives/2015/11/six.pdf

Referenced Standards and Specifications

- **Added ASTM F3148**
  - New strength "Group 144"
  - Uses "Combined Method" for pretensioning
  - Fixed spline drive, looks like twist-off type, but it's not
  - Minimum pretension equal to Grade A490
  - Approved in ANSI/AISC 358 Prequalified Connections, Moment frames for seismic applications, SidePlate/SidePlate PLUS
  - Currently balloting for AISC 360-22
  - https://www.astm.org/Standards/F3148.htm

ASTM F3148

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.

Referenced Standards and Specifications

- **Added ASTM F2833**
  - Standard Specification for Corrosion Protective Fastener Coatings with Zinc Rich Base Coat and Aluminum Organic/Inorganic Type
  - https://www.astm.org/Standards/F2833.htm
- **Added ASTM F3019**
  - Standard Specification for Chromium Free Zinc-Flake Composite, with or without Integral Lubricant, Corrosion Protective Coatings for Fasteners
  - https://www.astm.org/Standards/F3019.htm
- **Added ASTM A1059**
  - Standard Specification for Zinc Alloy Thermo-Diffusion Coatings (TDC) on Steel Fasteners, Hardware, and Other Products
  - https://www.astm.org/Standards/A1059.htm

33

Section 1

EOR

1.6 Structural Design Drawings and Specifications

The *Engineer of Record* shall specify the following information in the contract documents:

(1) The Group designation (Section 2.1) of bolt or *bolting assembly* and steel type (Section 2 Commentary) to be used;

(2) The *joint* type (Section 4); and

(3) The required class of slip resistance if *slip-critical joints* are specified (Section 4).

34

1.6 - Structural Design Drawings and Specifications

EOR Responsibility

Engineer of Record commentary was spread throughout the document in previous editions of the *Specification*

EOR considerations have been summarized in one location to paint a better overall picture of EOR responsibility in 1.6

Guidance still exists within other sections, but 1.6 commentary is a good check list of items every EOR should be familiar with

35

Commentary:
A summary of additional information that the *Engineer of Record* may specify, may require the Engineer's attention, or may require the Engineer's approval is provided below. The parenthetical reference after each listed item indicates the location of the referenced item in this Specification.

(1) *Bolting assembly* grade, type (type 1 or type 3), *style* (heavy hex or twist-off), coating (hot-dip galvanized, mechanically galvanized, etc.), and any other considerations on special components or installation methods related to the *bolting assembly* (Section 2);

(2) Specifying when threads must be excluded from the shear plane, if applicable (Section 5);

(3) Use of *faying surface* coatings in *slip-critical joints* that provide a *mean slip coefficient* determined in accordance with Appendix A, but differing from Class A or Class B coatings (Section 3.2.2(2);

(4) Use of any materials other than steel within the *joint* (outside of the scope of the Specification, discussed in Commentary to Section 1.1);

(5) Use of alternative-design *bolting components*, *assemblies*, or installation methods, including the corresponding installation and inspection requirements that are provided by the *Manufacturer* (Section 2.12);

36

Commentary:
A summary of additional information that the *Engineer of Record* may specify, may require the Engineer's attention, or may require the Engineer's approval is provided below. The parenthetical reference after each listed item indicates the location of the referenced item in this Specification.

(6) *Reuse* of bolts (Section 2.11);

(7) If *re-pretensioning* of galvanized *bolting assemblies* is required by the *Engineer of Record*, this must be clearly specified in the contract documents (see Commentary to Section 8.2);

(8) Use of thermal cutting of bolt holes produced free hand or for use in cyclically loaded *joints* (Section 3.3);

(9) Use of oversized (Section 3.3.2), short-slotted (Section 3.3.3), or long slotted holes (Section 3.3.4) in lieu of standard holes;

(10) Use of a value of *Du* other than the value provided in Section 5.4;

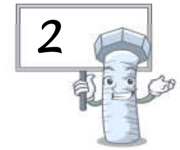
(11) Restrictions on the use of hole types (Section 3.3);

(12) Use of hole sizes larger than permitted in Section 3.3.

37

Specification for
Structural Joints Using High-Strength Bolts

Bolting Components



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38

Section 2

Bolting Components and Assemblies

- Significantly changed in terms of layout and presentation
- Added strength "Groups" in Table 2.1
- Added strength "Group 144"
- Updated Fig C-2.1
- New Table 2.5 – Fully Threaded Bolts
- New coatings Table 2.6

39

Strength "Group"

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

40

Strength "Group"

A similar approach was taken by AISC 360-16

- Group A - ASTM F3125 Grade A325, A325M, F1852
- Group B - ASTM F3125 Grade A490, A490M, F2280
- Group C - ASTM F3043 and F3111 Grade 1, 2

Will hopefully coordinate Groups with AISC 360-22

Grouping by ksi is more intuitive for users

May eventually coordinate with ASTM markings

41

Structural Bolt Grades and Groups

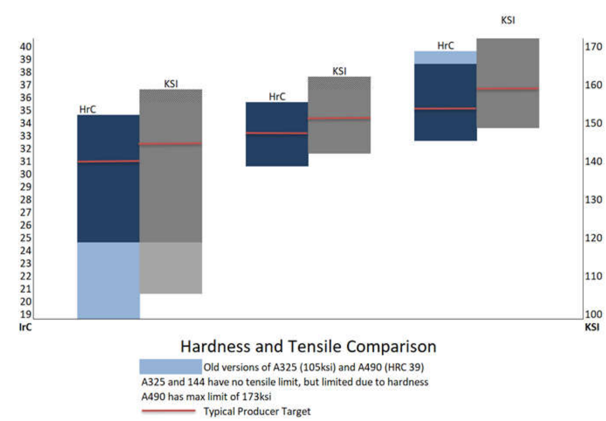
- 120 ksi Tensile "Group 120"
  - A325
  - A325M
  - F1852
- 144 ksi Tensile "Group 144"
  - F3148
- 150 ksi Tensile "Group 150"
  - A490
  - A490M
  - 2280

42

Why 144 ksi?

- Optimize strength without adding cost
- Same materials and processes - slightly tighter controls
- Japan JIS B1186 F10T/S10T very common strength in Asia 1000 N/mm2 = 145 ksi
- Permit numerous coatings, including HDG, below critical threshold for hydrogen embrittlement
- Probably would not write A325 today, but we are stuck with the legacy in design and inventory
- A325 has survived using "overstrength" and modification of resistance factors, but not all bolts are overstrength

43



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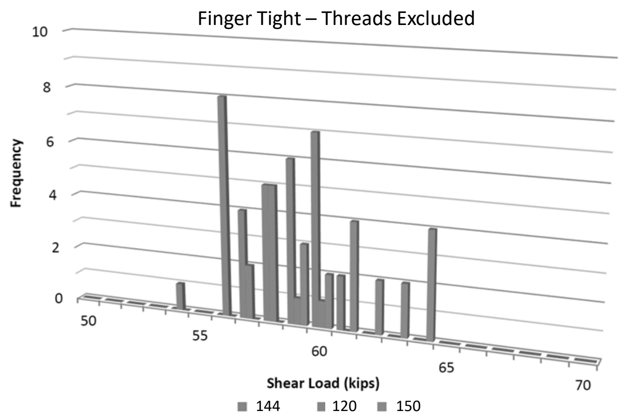


Figure 4.46: Frequency Distribution of Ultimate Shear Loads FT-X

45

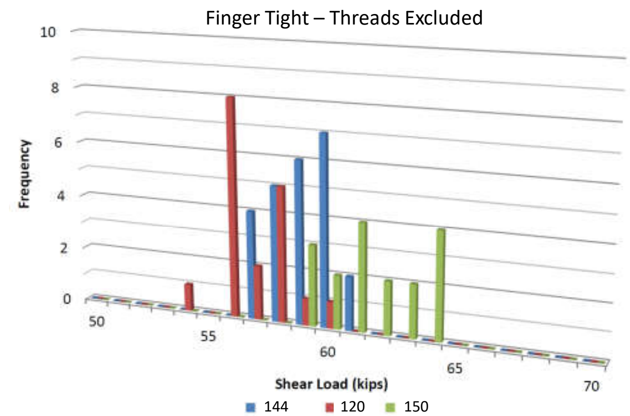


Figure 4.46: Frequency Distribution of Ultimate Shear Loads FT-X

46

Japanese Standards Association (JSA)

JIS B1186

F10T and S10T

1,000 N/mm^2
145 ksi min.

47

Threads Included and Threads Excluded

48

Thread Length

Table 2.4
Dimensional Requirements for Bolting Components and Assemblies

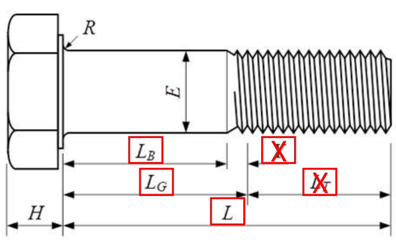
Bolting Component or Assembly	Dimensional Standard
Group 120 and 150 heavy hex bolt	ASME B18.2.6
Group 120 and 150 *spline end twist-off matched bolting assembly*	ASME B18.2.6
Group 144 heavy hex bolt Group 144 *spline end fixed matched bolting assembly*	ASTM F3125 ASME B18.2.6 except for spline dimensions
ASTM A563 heavy hex nut ASTM A194 heavy hex nut	ASME B18.2.6 ASME B18.2.2
ASTM F436 washer	ASTM F436
ASTM F959 *direct tension indicator*	ASME B18.2.6

49

X Marks the Spot

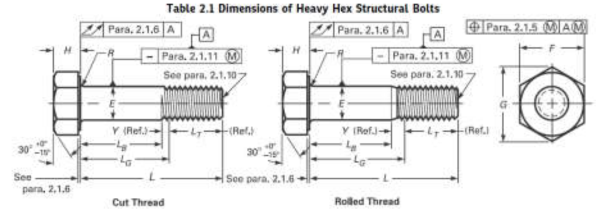
- Confusion in the industry for the past 30+ years regarding bolt thread lengths
- AISC, RCSC, and others have used a "reference" thread length by bolt diameter
- Producers do not measure "reference lengths"
- B18.2.6 calls out length of body, length of grip, and overall length
- Thread length is simply what remains when the other conditions are met
- Reference length does not consider the overall length tolerance and transition area

50



51

Table 2.1 Dimensions of Heavy Hex Structural Bolts



Nominal Size or Basic Product Diameter [Note (1)]		Body Diameter, E [Notes (2) and (3)]		Width Across Flats, F [Note (4)]			Width Across Corners, G		Head Height, H [Note (5)]			Radius of Fillet, R		Thread Length, L_T [Note (6)]	Transition Thread Length, Y [Note (6)]	Maximum Total Runout of Bearing Surface FIM [Note (7)]
		Max.	Min.	Nominal	Max.	Min.	Max.	Min.	Nominal	Max.	Min.	Max.	Min.	Ref.	Ref.	
1/2	0.500	0.515	0.482	7/8	0.875	0.850	1.010	0.969	5/16	0.323	0.302	0.031	0.009	1.00	0.19	0.016
5/8	0.625	0.642	0.605	1 1/16	1.062	1.031	1.227	1.175	25/64	0.403	0.378	0.062	0.021	1.25	0.22	0.019
3/4	0.750	0.768	0.729	1 1/4	1.250	1.212	1.443	1.383	15/32	0.483	0.455	0.062	0.021	1.38	0.25	0.022
7/8	0.875	0.895	0.852	1 7/16	1.438	1.394	1.660	1.589	35/64	0.563	0.531	0.062	0.031	1.50	0.28	0.025
1	1.000	1.022	0.976	1 5/8	1.625	1.575	1.876	1.796	39/64	0.627	0.591	0.093	0.062	1.75	0.31	0.028
1 1/8	1.125	1.149	1.098	1 13/16	1.812	1.756	2.093	2.002	11/16	0.718	0.658	0.093	0.062	2.00	0.34	0.032
1 1/4	1.250	1.277	1.223	2	2.000	1.938	2.309	2.209	25/32	0.813	0.749	0.093	0.062	2.00	0.38	0.035
1 3/8	1.375	1.404	1.345	2 3/16	2.188	2.119	2.526	2.416	27/32	0.878	0.810	0.093	0.062	2.25	0.44	0.038
1 1/2	1.500	1.531	1.470	2 3/8	2.375	2.300	2.742	2.622	15/16	0.974	0.902	0.093	0.062	2.25	0.44	0.041

52

X Marks the Spot

- There is a requirement in B18.2.6 that short bolts with a body length under a certain length be fully threaded
- *Bolts of nominal lengths that have a calculated L_B min. length equal to or shorter than 2.5 times the thread pitch for sizes 1 in. diameter and smaller, and 3.5 times the thread pitch for sizes larger than 1 in. diameter, shall be threaded for full length (see Table 2.1.9.2).*

53

ASME B18.2.6-2019

Table 2.1.9.2 Maximum Grip Gaging Lengths and Minimum Body Lengths for Structural Bolts

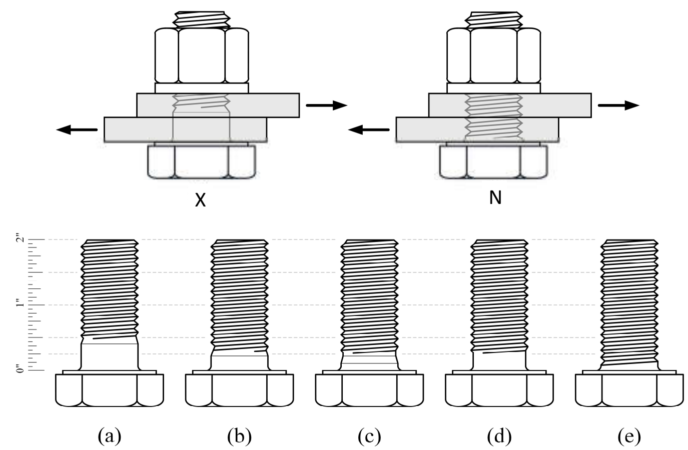
	Nominal Diameter and Thread Pitch																	
	½-13		⅝-11		¾-10		⅞-9		1-8		1⅛-7		1¼-7		1⅜-6		1½-6	
Nominal Length, *L*	L_G Max.	L_B Min.	L_G Max.	L_B Min.	L_G Max.	L_B Min.	L_G Max.	L_B Min.	L_G Max.	L_B Min.	L_G Max.	L_B Min.	L_G Max.	L_B Min.	L_G Max.	L_B Min.	L_G Max.	L_B Min.
1¼	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1½	0.50	0.31	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1¾	0.75	0.56	0.50	0.28	...	...	...	...	...	...	...	...	...	...	...	...	...	...
2	1.00	0.81	0.75	0.53	0.62	0.37	...	...	...	...	...	...	...	...	...	...	...	...
2¼	1.25	1.06	1.00	0.78	0.87	0.62	0.75	0.47	...	...	...	...	...	...	...	...	...	...
2½	1.50	1.31	1.25	1.03	1.12	0.87	1.00	0.72	0.75	0.44	...	...	...	...	...	...	...	...
2¾	1.75	1.56	1.50	1.28	1.37	1.12	1.25	0.97	1.00	0.69	...	...	...	...	...	...	...	...
3	2.00	1.81	1.75	1.53	1.62	1.37	1.50	1.22	1.25	0.94	1.00	0.66	1.00	0.62	...	...	...	...
3¼	2.25	2.06	2.00	1.78	1.87	1.62	1.75	1.47	1.50	1.19	1.25	0.91	1.25	0.87	...	...	...	...
3½	2.50	2.31	2.25	2.03	2.12	1.87	2.00	1.72	1.75	1.44	1.50	1.16	1.50	1.12	1.25	0.81	1.25	0.81
3¾	2.75	2.56	2.50	2.28	2.37	2.12	2.25	1.97	2.00	1.69	1.75	1.41	1.75	1.37	1.50	1.06	1.50	1.06
4	3.00	2.81	2.75	2.53	2.62	2.37	2.50	2.22	2.25	1.94	2.00	1.66	2.00	1.62	1.75	1.31	1.75	1.31
4¼	3.25	3.06	3.00	2.78	2.87	2.62	2.75	2.47	2.50	2.19	2.25	1.91	2.25	1.87	2.00	1.56	2.00	1.56
4½	3.50	3.31	3.25	3.03	3.12	2.87	3.00	2.72	2.75	2.44	2.50	2.16	2.50	2.12	2.25	1.81	2.25	1.81
4¾	3.75	3.56	3.50	3.28	3.37	3.12	3.25	2.97	3.00	2.69	2.75	2.41	2.75	2.37	2.50	2.06	2.50	2.06

54

Thread Lengths – Not All Equal

7/8" x 2" from 3 different producers

55



56

Table 1. Comparison of minimum ASME body length with assumed AISC body length.

Potential Minimum ASME Body Length vs. Assumed AISC Body Length (L_B) in Inches														
	⅝"-11		¾"-10		⅞"-9		1"-8		1⅛"-7		1¼"-7		1½"-6	
Nominal Length, *L*	ASME L_B Min[1]	AISC Table 7-14[2]	ASME L_B Min[1]	AISC Table 7-14[2]	ASME L_B Min[1]	AISC Table 7-14[2]	ASME L_B Min[1]	AISC Table 7-14[2]	ASME L_B Min[1]	AISC Table 7-14[2]	ASME L_B Min[1]	AISC Table 7-14[2]	ASME L_B Min[1]	AISC Table 7-14[2]
1½	...	0.25	...	0.125	...	...	...	...	...	...	...	...	...	...
1¾	0.28	0.50	...	0.375	...	0.25	...	...	...	...	...	...	...	...
2	0.53	0.75	0.37	0.625	...	0.50	...	0.25	...	...	...	...	...	...
2¼	0.78	1.00	0.62	0.875	0.47	0.75	...	0.50	...	0.25	...	0.25	...	...
2½	1.03	1.25	0.87	1.125	0.72	1.00	0.44	0.75	...	0.50	...	0.50	...	0.25
2¾	1.28	1.50	1.12	1.375	0.97	1.25	0.69	1.00	...	0.75	...	0.75	...	0.50
3	1.53	1.75	1.37	1.625	1.22	1.50	0.94	1.25	0.66	1.00	0.62	1.00	...	0.75
3¼	1.78	2.00	1.62	1.875	1.47	1.75	1.19	1.50	0.91	1.25	0.87	1.25	...	1.00
3½	2.03	2.25	1.87	2.125	1.72	2.00	1.44	1.75	1.16	1.50	1.12	1.50	0.81	1.25
3¾	2.28	2.50	2.12	2.375	1.97	2.25	1.69	2.00	1.41	1.75	1.37	1.75	1.06	1.50
4	2.53	2.75	2.37	2.625	2.22	2.50	1.94	2.25	1.66	2.00	1.62	2.00	1.31	1.75
4¼	2.78	3.00	2.62	2.875	2.47	2.75	2.19	2.50	1.91	2.25	1.87	2.25	1.56	2.00
4½	3.03	3.25	2.87	3.125	2.72	3.00	2.44	2.75	2.16	2.50	2.12	2.50	1.81	2.25

[1] Potential minimum length of body (LB) per ASME 18.2.6 -19

[2] Calculated length of body (LB) using AISC Table 7-14—Nominal bolt length minus reference thread length

... Fully threaded (although some unthreaded portion under the head, in any configuration, may remain)

57

Now N Only

Treat as threads included and understand geometry

Table 2.5 Bolt Lengths Required to Be Fully Threaded in Accordance with ASME B18.2.6	
Nominal Bolt Diameter, in.	Bolt Length, L, in.
½	1¼
⅝	L ≤ 1½
¾	L ≤ 1¾
⅞	L ≤ 2
1	L ≤ 2¼
1⅛ & 1¼	L ≤ 2¾
1⅜ & 1½	L ≤ 3¼

58

ASME B18.2.6-2019

Table 2.1.9.2 Maximum Grip Gaging Lengths and Minimum Body Lengths for Structural Bolts

	Nominal Diameter and Thread Pitch																	
	½-13		⅝-11		¾-10		⅞-9		1-8		1⅛-7		1¼-7		1⅜-6		1½-6	
Nominal Length, *L*	L_G Max.	L_B Min.	L_G Max.	L_B Min.	L_G Max.	L_B Min.	L_G Max.	L_B Min.	L_G Max.	L_B Min.	L_G Max.	L_B Min.	L_G Max.	L_B Min.	L_G Max.	L_B Min.	L_G Max.	L_B Min.
1¼	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1½	0.50	0.31	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1¾	0.75	0.56	0.50	0.28	...	...	...	...	...	...	...	...	...	...	...	...	...	...
2	1.00	0.81	0.75	0.53	0.62	0.37	...	...	...	...	...	...	...	...	...	...	...	...
2¼	1.25	1.06	1.00	0.78	0.87	0.62	0.75	0.47	...	...	...	...	...	...	...	...	...	...
2½	1.50	1.31	1.25	1.03	1.12	0.87	1.00	0.72	0.75	0.44	...	...	...	...	...	...	...	...
2¾	1.75	1.56	1.50	1.28	1.37	1.12	1.25	0.97	1.00	0.69	...	...	...	...	...	...	...	...
3	2.00	1.81	1.75	1.53	1.62	1.37	1.50	1.22	1.25	0.94	1.00	0.66	1.00	0.62	...	...	...	...
3¼	2.25	2.06	2.00	1.78	1.87	1.62	1.75	1.47	1.50	1.19	1.25	0.91	1.25	0.87	...	...	...	...
3½	2.50	2.31	2.25	2.03	2.12	1.87	2.00	1.72	1.75	1.44	1.50	1.16	1.50	1.12	1.25	0.81	1.25	0.81
3¾	2.75	2.56	2.50	2.28	2.37	2.12	2.25	1.97	2.00	1.69	1.75	1.41	1.75	1.37	1.50	1.06	1.50	1.06
4	3.00	2.81	2.75	2.53	2.62	2.37	2.50	2.22	2.25	1.94	2.00	1.66	2.00	1.62	1.75	1.31	1.75	1.31
4¼	3.25	3.06	3.00	2.78	2.87	2.62	2.75	2.47	2.50	2.19	2.25	1.91	2.25	1.87	2.00	1.56	2.00	1.56
4½	3.50	3.31	3.25	3.03	3.12	2.87	3.00	2.72	2.75	2.44	2.50	2.16	2.50	2.12	2.25	1.81	2.25	1.81
4¾	3.75	3.56	3.50	3.28	3.37	3.12	3.25	2.97	3.00	2.69	2.75	2.41	2.75	2.37	2.50	2.06	2.50	2.06

59

Light Reading if Interested

steelwise

THE SHORT SHANK REDEMPTION

BY GIAN A. RASSATI, PHD, JAMES A. SWANSON, PHD, AND CHAD M. LARSON

Expert advice on bolt design for structural joints.

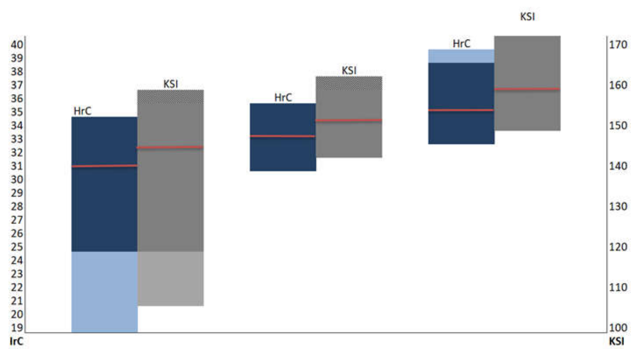


Gian Andrea Rassati (gian.rassati@uc.edu) and **James A. Swanson** (james.swanson@uc.edu) are both associate professors in the College of Engineering and Applied Science at the University of Cincinnati. **Chad M. Larson** (clarson@lejeunebolt.com) is president of LeJeune Bolt Company.

https://www.aisc.org/globalassets/modern-steel/archives/2020/december2020.pdf

60

F3125 A325 F3148 144 F3125 A490



Hardness and Tensile Comparison

- Old versions of A325 (105ksi) and A490 (HRC 39)
- A325 and 144 have no tensile limit, but limited due to hardness
- A490 has max limit of 173ksi
- Typical Producer Target

61

AISC LRFD Prior to 2010

TABLE J3.2
Nominal Stress of Fasteners and Threaded Parts, ksi (MPa)

Description of Fasteners	Nominal Tensile Stress, F_{nt}, ksi (MPa)	Nominal Shear Stress in Bearing-Type Connections, F_{nv}, ksi (MPa)
A307 bolts	45 (310) [a][b]	24 (165) [b][c][f]
A325 or A325M bolts, when threads are not excluded from shear planes	90 (620) [e]	48 (330) [f]
A325 or A325M bolts, when threads are excluded from shear planes	90 (620) [e]	60 (414) [f]
A490 or A490M bolts, when threads are not excluded from shear planes	113 (780) [e]	60 (414) [f]
A490 or A490M bolts, when threads are excluded from shear planes	113 (780) [e]	75 (520) [f]
Threaded parts meeting the requirements of Section A3.4, when threads are not excluded from shear planes	0.75 F_u [a][d]	$0.40F_u$
Threaded parts meeting the requirements of Section A3.4, when threads are excluded from shear planes	0.75 F_u [a][d]	$0.50F_u$

[a] Subject to the requirements of Appendix 3.
[b] For A307 bolts the tabulated values shall be reduced by 1 percent for each 1/16 in. (2 mm) over 5 diameters of length in the grip.
[c] Threads permitted in shear planes.
[d] The nominal tensile strength of the threaded portion of an upset rod, based upon the cross-sectional area at its major thread diameter, A_D, which shall be larger than the nominal body area of the rod before upsetting times F_y.
[e] For A325 or A325M and A490 or A490M bolts subject to tensile fatigue loading, see Appendix 3.
[f] When bearing-type connections used to splice tension members have a fastener pattern whose length,

AISC LRFD 2010 and 2016

TABLE J3.2
Nominal Strength of Fasteners and Threaded Parts, ksi (MPa)

Description of Fasteners	Nominal Tensile Strength, F_{nt}, ksi (MPa)[a]	Nominal Shear Strength in Bearing-Type Connections, F_{nv}, ksi (MPa)[b]
A307 bolts	45 (310)	27 (188)[c] [d]
Group A (e.g., A325) bolts, when threads are not excluded from shear planes	90 (620)	54 (372)
Group A (e.g., A325) bolts, when threads are excluded from shear planes	90 (620)	68 (457)
Group B (e.g., A490) bolts, when threads are not excluded from shear planes	113 (780)	68 (457)
Group B (e.g., A490) bolts, when threads are excluded from shear planes	113 (780)	84 (579)
Threaded parts meeting the requirements of Section A3.4, when threads are not excluded from shear planes	$0.75F_u$	$0.450F_u$
Threaded parts meeting the requirements of Section A3.4, when threads are excluded from shear planes	$0.75F_u$	$0.563F_u$

[a] For high-strength bolts subject to tensile fatigue loading, see Appendix 3.

More Reading on Short Bolts

Dimensional Tolerances and Length Determination of High-Strength Bolts
https://www.aisc.org/Dimensional-Tolerances-and-Length-Determination-of-High-Strength-Bolts

A Reliability Study of Joints with Bolts Designed with Threads X but Installed with Threads N
https://www.aisc.org/A-Reliability-Study-of-Joints-with-Bolts-Designed-with-Threads-Excluded-but-Installed-with-Threads-N

63

New Bolt Coatings

2.8.2. Coated Bolting Components and Assemblies not including Direct Tension Indicators

Zinc aluminum inorganic coatings complying with ASTM F1136, ASTM F2833 and ASTM F3019 are permitted to be applied prior to installation, in accordance with Table 2.6.

Table 2.6
Permitted Coatings for Bolts, Nuts and Washers

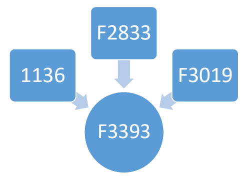
Specification	Bolt	Nut	Washer
ASTM F1136	Grade 3	Grade 5	Grade 3
ASTM F2833	Grade 1		
ASTM F3019	Grade 4		

- Coating of *spline-end bolting assemblies* shall be performed only under the direction of the *Manufacturer* and as permitted by the assemblies' respective standards.
- The *Engineer of Record* is permitted to approve other coatings that have been approved by ASTM between published editions of this Specification.

64

New Coatings

- **ASTM F1136**
- **ASTM F2833**
- **ASTM F3019**



Combined into F3393-20

Zinc-Flake Coating Systems for Fasteners

https://www.astm.org/Standards/F3393.htm

65

Alternative design

- Previous language was mostly carryover wording for twist-off type bolts before twist-off type bolts had their own installation method
- Previously considered pretensioned bolts that met A325 or A490 physical and mechanical properties, did not contemplate other strengths, non-pretensioned applications, other nuts, other washers, other coatings or other methods
- Innovation clause and language was added to provide guidance for use of alternative designs extending beyond the original language

66

Alternative design 2.12

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.

67

Alternative design 2.12

Commentary:

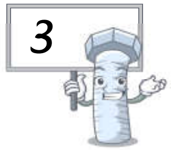
RCSC's policy has been to recognize only *bolting components* and *matched bolting assemblies* that meet approved ASTM standards. Other consensus standards that could be considered by the *Engineer of Record* include EN, JIS, and ISO standards. However, alternate products, standards, and installation methods (known collectively as "alternative-designs") may be used when approved by the *Engineer of Record*. Alternative-designs fall into two categories:

(1) Product made as an alternative-design to an ASTM standard referenced in this document and installed using RCSC installation methods or an alternate installation method. See Section 2.12.1. (lock pin and collar, new coating without ASTM std.)

(2) Product made to an ASTM standard that is *not* referenced in this document or made to another consensus standard and installed using RCSC installation methods or an alternate installation method. See Section 2.12.2. (A354 BD sub for A490, A193 B7 sub for A325)

68

Bolted Parts



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69

Galvanized Faying Surfaces 3.2.2

- Testing long ago demonstrated an improvement in slip resistance when hand wire brushing was performed. RCSC has required hand wire brush roughening and prohibited power wire brushing.
- University of Texas Study (2014) showed no advantage to hand wire brushing. In fact, showed a decrease in performance.
- As a result, RCSC no longer requires and instead forbids roughening.
- AISC still requires – balloting to remove requirement, but not prohibit.

- https://www.aisc.org/globalassets/aisc/research-library/university-of-texas-report-on-galvanized-slip-coefficients-draft-final-4915.pdf

70

71

Slip Critical Galvanized Faying Surfaces

Between 1 and 9 slip classes over the years
3.2.2 (3)

2014

(3) *Galvanized Faying Surfaces*: *Galvanized faying surfaces* shall first be hot dip galvanized in accordance with the requirements of ASTM A123 and subsequently roughened by means of hand wire brushing. Power wire brushing is not permitted. When prepared by roughening, the *galvanized faying surface* is designated as Class C for design.

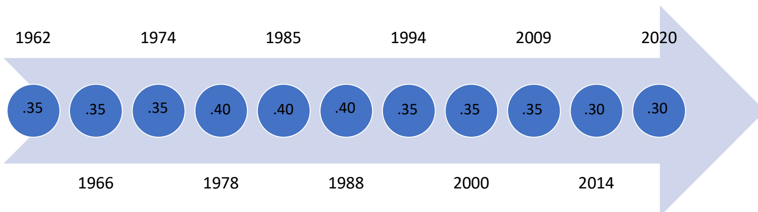
2020

(3) *Galvanized Faying Surfaces: Galvanized faying surfaces* shall be hot dip galvanized in accordance with the requirements of ASTM A123. Power or hand wire brushing is not permitted. *Galvanized faying surfaces* are designated as Class A for design.

2014 RCSC – Roughened by means of hand wire brushing required
2016 AISC – Roughened by means of hand wire brushing required
2017 AASHTO – Roughened by means of hand wire brushing no longer required, but not prohibited
2020 RCSC – Roughened by means of hand wire brushing prohibited
2022 AISC – Roughened by means of hand wire brush no longer required, but not prohibited???

72

Slip Coefficient for Galvanized Faying Surfaces - Timeline

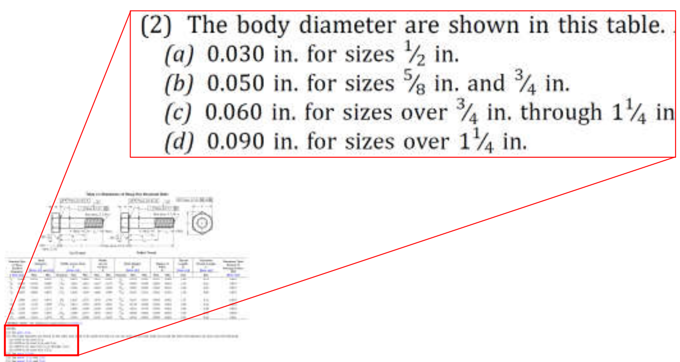


73

The Hole Truth

- Hole size change in Table 3.1 and addressed in 3.3.1 Commentary
- Standard hole size was nominal + 1/16” for all diameters
- This conflicted with ASME B18.2.6 which permits a fin or swell under the bolt head that could exceed the +1/16” hole size
- Many fabricators were oversizing holes to solve this and other fit problems. Pretensioning is required when oversizing holes
- Increased 1” and larger holes to nominal + 1/8” – helps erection tolerance, bolts fit better, but not considered oversized
- This change already done in AISC 360-16

74



(2) The body diameter are shown in this table.
(a) 0.030 in. for sizes $\frac{1}{2}$ in.
(b) 0.050 in. for sizes $\frac{5}{8}$ in. and $\frac{3}{4}$ in.
(c) 0.060 in. for sizes over $\frac{3}{4}$ in. through $1\frac{1}{4}$ in
(d) 0.090 in. for sizes over $1\frac{1}{4}$ in.

75

Hole Sizes

- BOLT HOLES AND TOLERANCE
- Rick Drake, SE, Member AISC, Fluor Enterprises, Inc.
- Tom Hunt, SE, Member AISC, Fluor Enterprises, Inc.

76

Increase in Nominal Hole Size – Already Done in AISC 360-16

Table 3.1
Nominal Bolt Hole Dimensions

Nominal Bolt Diameter, d_b, in.	Nominal Bolt Hole Dimensions[a,b], in.			
	Standard (diameter)	Oversized (diameter)	Short-Slotted (width × length)	Long-Slotted (width × length)
½	9/16	5/8	9/16 × 11/16	9/16 × 1¼
5/8	11/16	13/16	11/16 × 7/8	11/16 × 1 9/16
¾	13/16	15/16	13/16 × 1	13/16 × 1 7/8
7/8	15/16	1 1/16	15/16 × 1 1/8	15/16 × 2 3/16
1	1 1/8	1¼	1 1/8 × 1 5/16	1 1/8 × 2½
≥ 1 1/8	d_b + 1/8	d_b + 5/16	(d_b + 1/8) × (d_b + 3/8)	(d_b + 1/8) × (2.5d_b)

[a] The detailed hole dimension shall not exceed the nominal. The fabricated hole dimension shall not exceed the nominal +1/32 in. Exception: In the width of slotted holes, gouges not more than 1/16 in. deep are permitted.
[b] The slightly conical hole that naturally results from punching operations with properly matched punches and dies is acceptable.

77

Joint Type

Specification for
Structural Joints
Using High-
Strength Bolts

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78

Limit States

Specification for
Structural Joints
Using High-
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79

Nominal Shear and Tensile Stress 5.1

Table 5.1
Nominal Strengths per Unit Area of Bolts

Applied Load Condition			*Nominal Strength* per Unit Area, F_n, ksi		
			Group 120	Group 144	Group 150
Tension[a]	Static		90	108	113
	Fatigue			See Section 5.5	
Shear[a,b]	Threads included in shear plane	$L_s \le 38$ in.	54	65	68
		$L_s > 38$ in.	45	54	56
	Threads excluded from shear plane	$L_s \le 38$ in.	68	81	84
		$L_s > 38$ in.	56	68	70

[a] Except as required in Section 5.2.
[b] Reduction for values for $L_s > 38$ in. applies only when the *joint* is axially end loaded, such as splice plates on a beam or column flange, but it does not apply for web connections in shear.

80

Nominal Shear and Tensile Stress 5.1

2.7 Commentary
Previous editions of this Specification treated shear planes in the thread transition length (see dimension Y in Figure C-2.2) as if the threads were excluded. Recent evaluation of this transition area and the variations permitted by ASME B18.2.6 (Swanson et al., 2020a,b) have caused the more conservative approach taken in this edition.

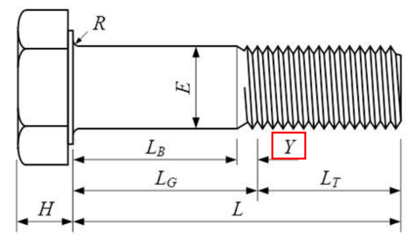
Section 5.1 - Bolts with lengths indicated in Table 2.5 are considered to be fully threaded in accordance with ASME B18.2.6. The shear strength of these bolts shall be determined based on the assumption that the threads are included in the shear plane.

AISC TC6 has not yet decided on this topic for AISC 360-22 TBD

Table 2.5
Bolt Lengths Required to Be Fully Threaded in Accordance with ASME B18.2.6

Nominal Bolt Diameter, in.	Bolt Length, L, in.
½	1¼
⅝	L ≤ 1½
¾	L ≤ 1¾
⅞	L ≤ 2
1	L ≤ 2¼
1⅛ & 1¼	L ≤ 2¾
1⅜ & 1½	L ≤ 3¼

81



82

The Table Formerly Known as 8.1

- Table 5.2 Minimum Bolt Pretension moved from Table 8.1 to the more appropriate design section
- Increase in pretension for F3125 large diameter from 105 to 120 ksi
- Added strength Group 144 here and Table 5.3

83

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*	
	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

* 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

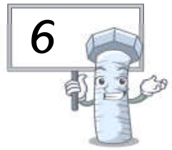
Table 5.2
Minimum Bolt Pretension, Pretensioned and Slip-Critical Joints

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

84

Specification for
Structural Joints Using High-Strength Bolts

Washer Use



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85

Washers

- Added requirement for washer under nut for Calibrated Wrench method, was formerly the turned element
- Added washer requirements for the combined installation method.
- Added requirements for Group 144

86

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	Hole Type in Outer Ply: Short-Slotted	Hole Type in Outer Ply: 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 5/16-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 5/16-in.-thick plate washer and an ordinary thickness F436 washer may be used. The plate washer need not be hardened.

87

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PIV

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PIV – Preinstallation Verification Testing

- Preinstallation verification testing organized into steps by method
- For 1-1/8” and larger Group 120 there is a higher pretension requirement to coincide with changes in F3125 tensile strength and the new Table 5.2

89

Step based PIV by Method - Example

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 match-marked.

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.

90

And Similar Steps to Inspection

9.2.1. *Turn-of-Nut Method*

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.

91

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

92

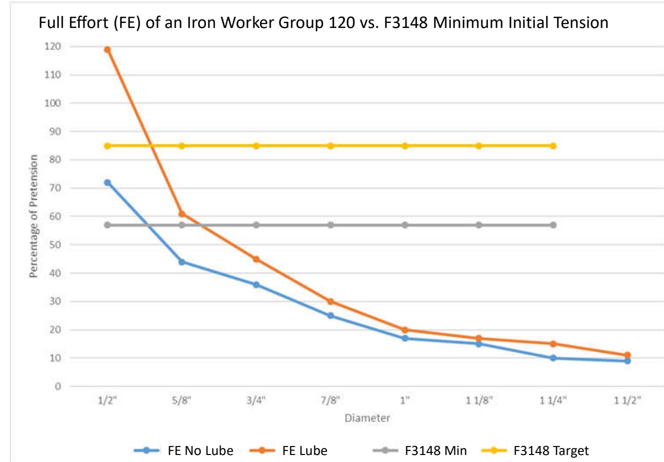
New Table Minimum Initial Tension

- 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

93



94

Table 7.3 Default Initial Torque Range

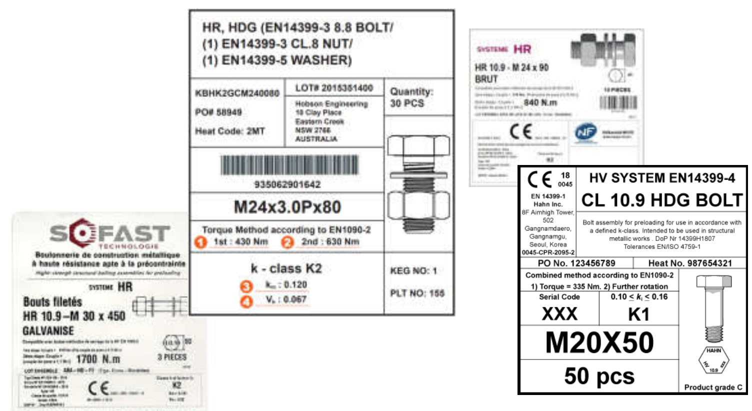
- It is expected that most producers or suppliers will provide torque values when using the Combined Method. If they do not, then this is the value to use

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 1½-in. diameter.

95



96

"K" Factor or Nut Factor

The friction relationship or K-factor between applied torque and the resulting fastener tension. The following formula can be used to get the K factor if the torque, tension and size are known.

K= T/N * 12/D

Where: K = K or nut factor
T = Torque
N = Clamp Force
D = Nominal bolt diameter

Example: ¾" x 2" TC Bolt. 300 ft. lbs. torque at 35,000 lbs. clamp load.

K= (300/35000) * (12/.750) = .137

Solving for Torque the equation becomes T= K*D*N (sometimes P, Sometimes F)

97

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Installation

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98

Section 8.1 Snug Tightened Joint Language

- Revised for improved readability and uniform terminology
- Section 8.2 consolidated language for each subsection that was repeated.

99

Snug Tight – What is it?

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

2000 – 2004 Rev. RCSC Specification

"The snug-tightened condition is the tightness that is attained with a few impacts of an impact wrench or the full effort of an ironworker using an ordinary spud wrench to bring the plies into firm contact."

2009 Rev. RCSC Specification

"Snug tight is the condition that exists when all of the plies in a connection have been pulled into firm contact by the bolts in the joint and all of the bolts in the joint have been tightened sufficiently to prevent the removal of the nuts without the use of a wrench."

100

Snug Tight – What is it?

2014 Rev. RCSC Specification

Snug-Tightened Joint. A *joint* in which the bolts have been installed in accordance with Section 8.1. The snug tightened condition is the tightness that is attained with a few impacts of an impact wrench or the full effort of an ironworker using an ordinary spud wrench to bring the plies into *firm contact.*

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*.

101

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.

102

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

103

Bolt Binding

104

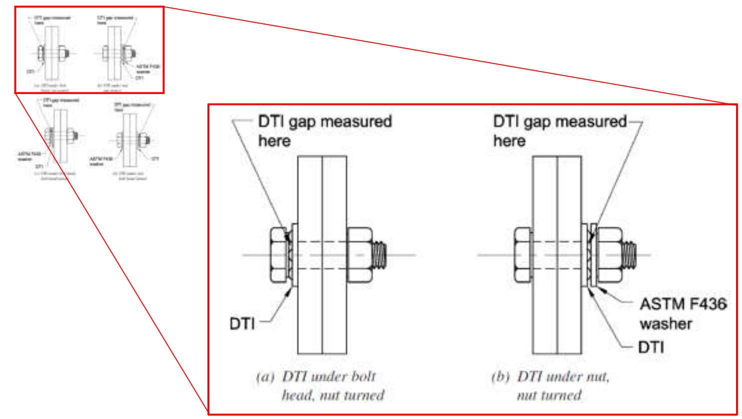
DTI language

- 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.

Why?

Eliminated some backward references to Section 7 and clarified acceptance language

105



106

Added "Combined Method" Pretensioning 8.2.5

Methods Examples Worldwide

- Turn of Nut
- Twist Off Type (HRC)
- Torque Plus Torque
- Direct Tension Indicator
- Calibrated Wrench
- Part Turn Method
- Combined Method
- Elongation
- Ultrasonic

107

Added "Combined Method" Pretensioning 8.2.5

- Application of *initial torque* to attain the required *initial tension*, followed by the application of relative rotation between a bolt and nut.
- Also known as Torque and Angle
- New for North American construction, but common in EN standards and OEM products
- Usually involves "signature analysis" of matched assemblies
- ASTM F3148 is the first commercial implementation of the combined method, but the combined method was written in a generic manner to permit use with A325 and A490
- RCSC Turn of Nut method is a combined method, initial torque requirement (full effort or a few impacts of a gun) plus relative rotation requirement (120 deg.)
- Acceptance based on testing performed at University of Cincinnati
- Over 6,000 signatures for development of F3148 to consider the hardness, tensile strength, lubrication, initial torque and final rotation

108

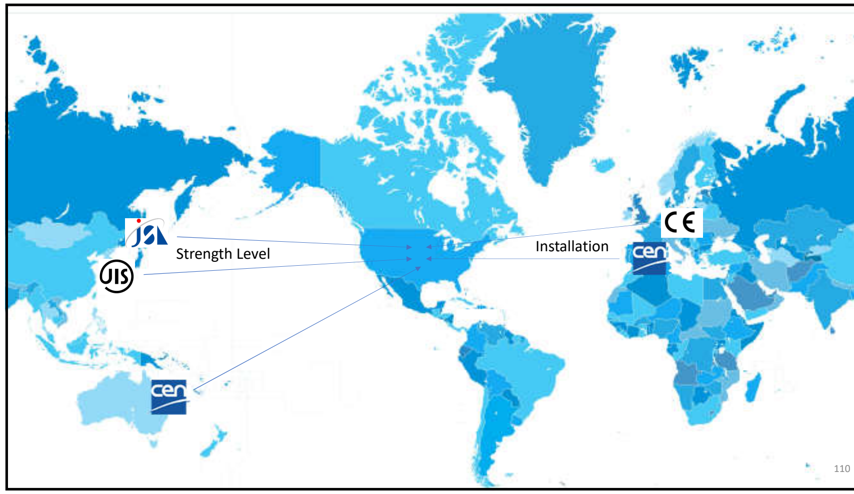
EN Combined Method 14399-3, 14399-4, 1090-2

Combined method								
Dimensions	M12	M16	M20	M22	M24	M27	M30	M36
Preload force $F_{p,C} = 0.7 \cdot f_{ub} \cdot A_s$ [kN]	59	110	172	212	247	321	393	572
Pretightening torque M_A [Nm][1]	75	190	340	490	600	940	1240	2100

	Further angle of rotation or revolution dimension for screw grip length Σt		
	Total nominal thickness "t" of the parts to be joined (including all lining plates and washers) d = screw diameter	Further angle of rotation	Further revolution dimension
1	t < 2d	60	1/6
2	2d ≤ t ≤ 6d	90	1/4
3	6d ≤ t ≤ 10d	120	1/3

Note: If the surface under the screw head or the nut (taking account of any square taper washers that are used as well) is not vertical to the screw axis, the necessary further angle of rotation should be determined in experiments.
[1] Example of manufacturer's recommendation

109



110

Combined Method Table 7.3 (if needed) and Table 8.2

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

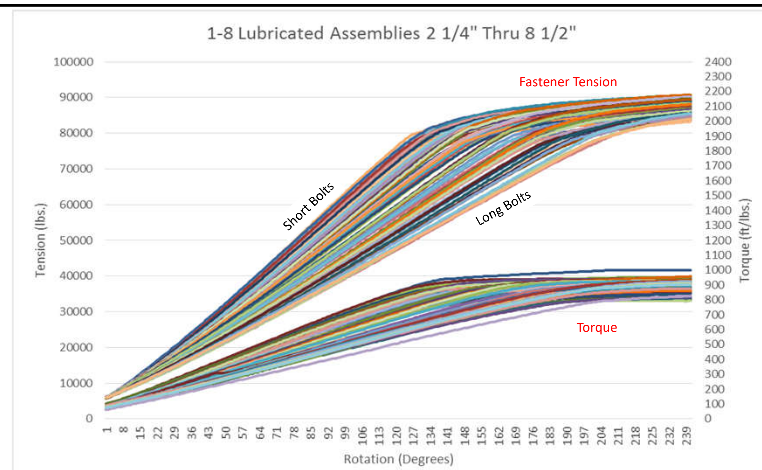
[a] This table shall not be used in lieu of Supplier provided torque values and shall only be used when torque has not been provided for a bolting assembly by the bolt Supplier.
[b] F3148 Group 144 bolting assemblies are only available up to 1⅛ in. diameter.

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

Bolt Length[c]	Rotation
Not more than $4d_b$	90°
More than $4d_b$ but not more than $8d_b$	120°

[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.

111



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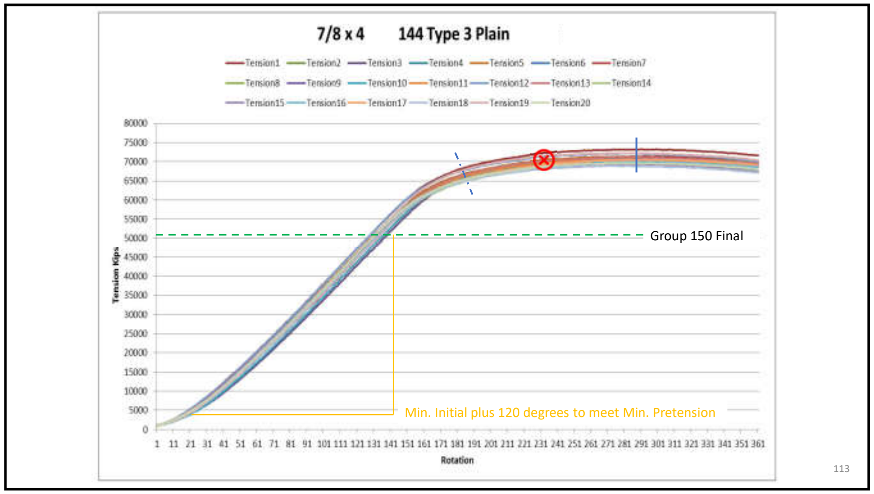
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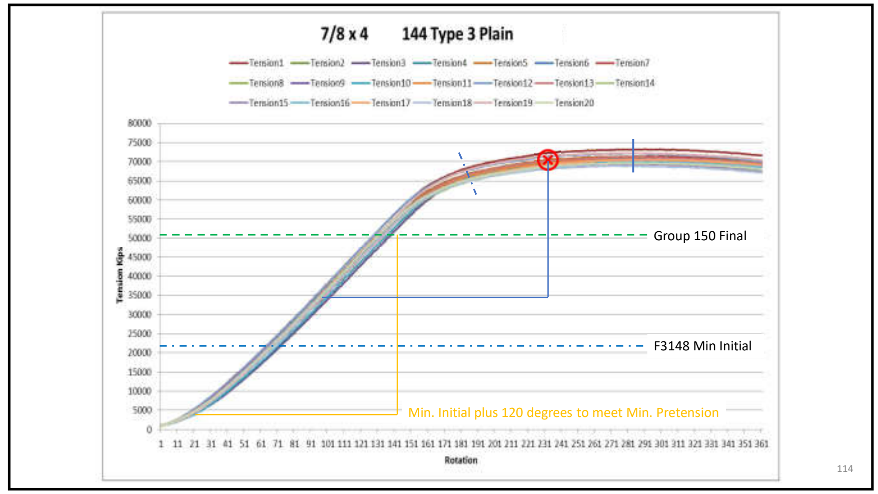
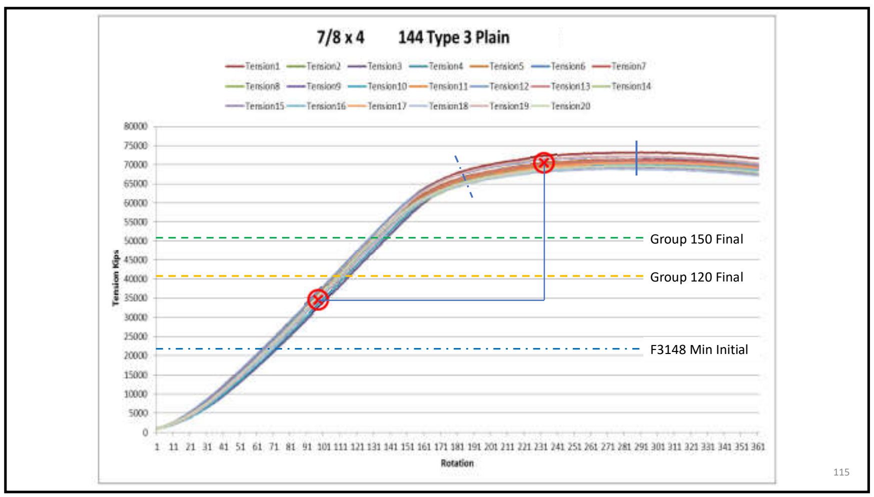
Group 150 Final
Min. Initial plus 120 degrees to meet Min. Pretension
Tension Kips
Rotation
113


7/8 x 4 144 Type 3 Plain
Group 150 Final
F3148 Min Initial
Min. Initial plus 120 degrees to meet Min. Pretension
Tension Kips
Rotation
114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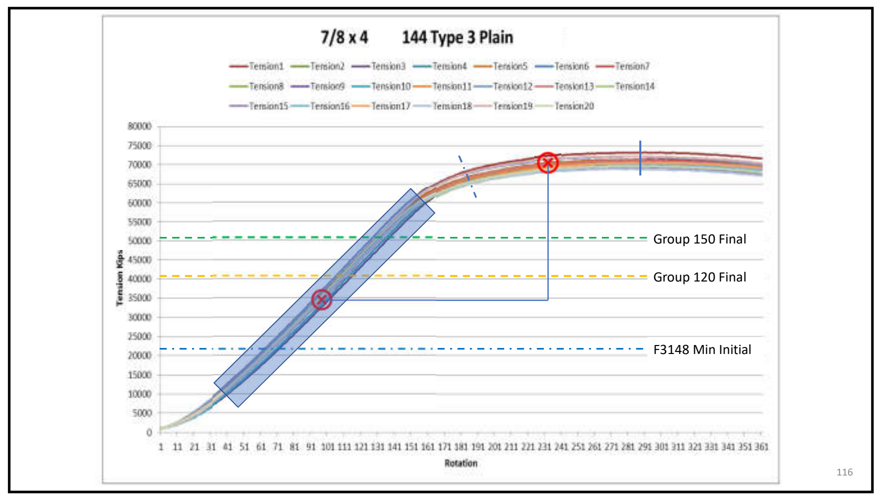
Group 150 Final
Group 120 Final
F3148 Min Initial
Tension Kips
Rotation
115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Group 150 Final
Group 120 Final
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Tension Kips
Rotation
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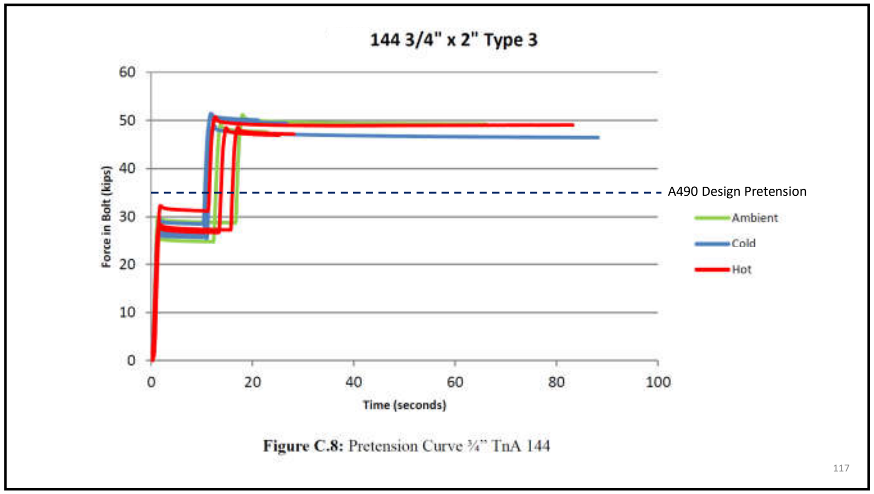
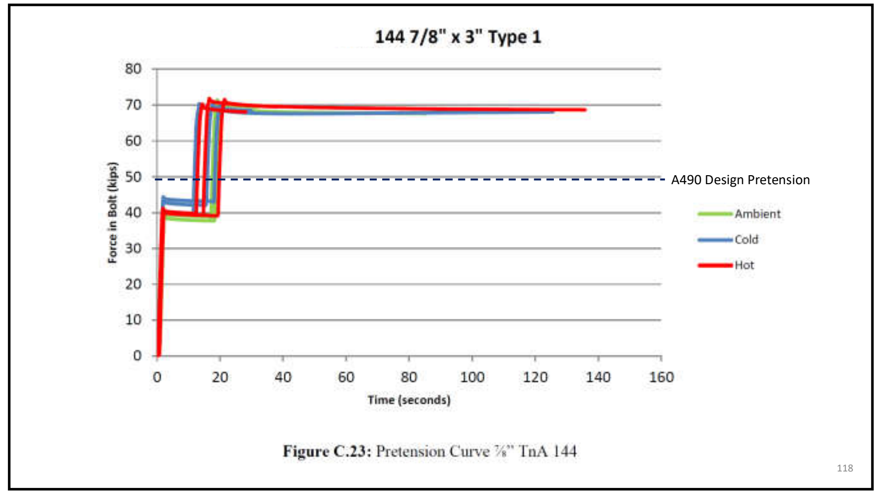
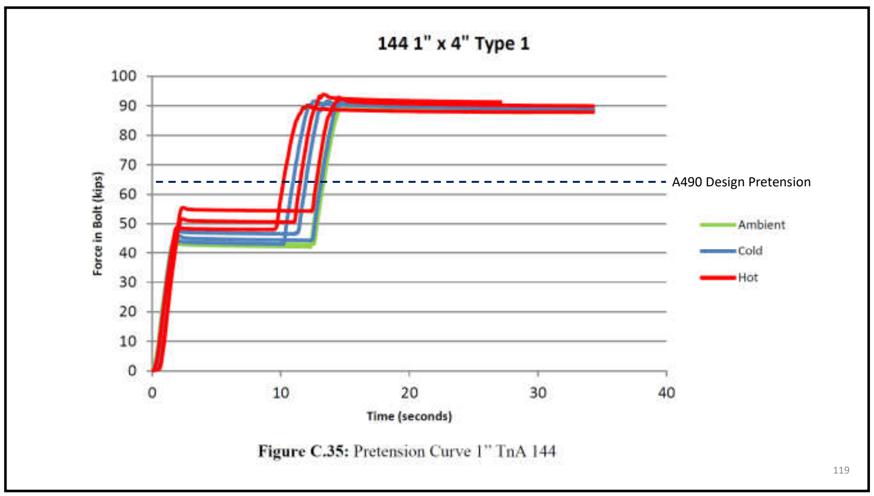
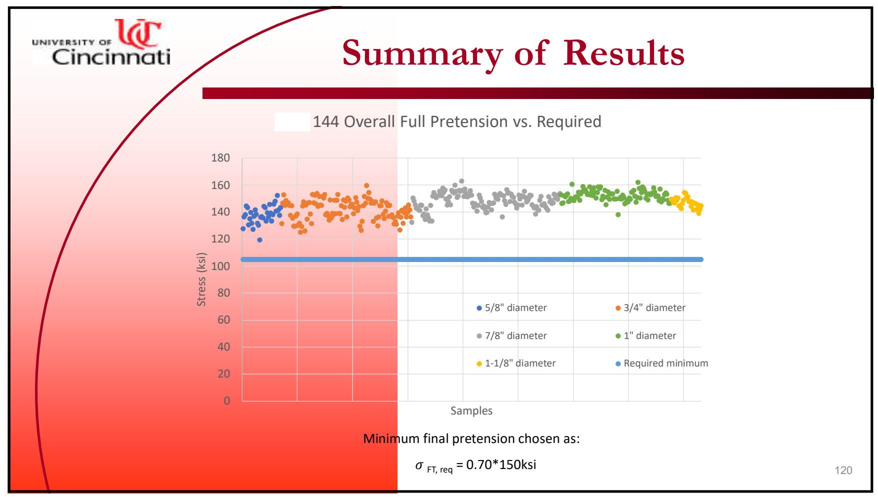
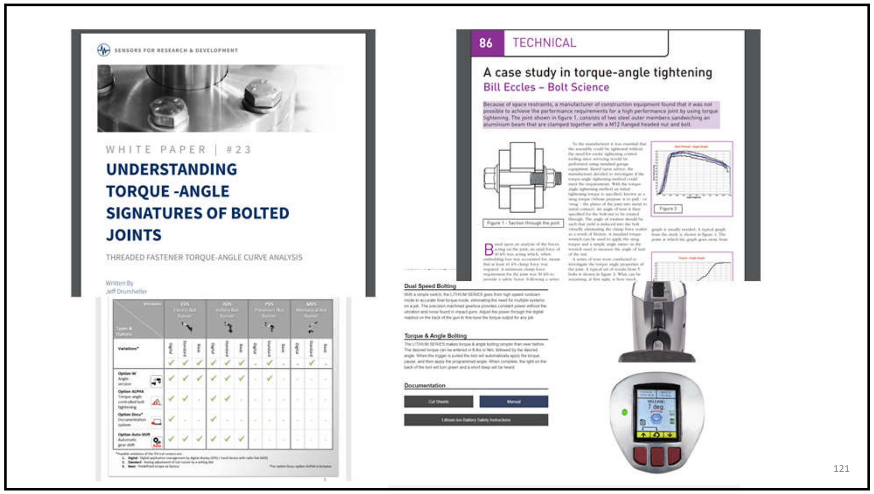

144 3/4" x 2" Type 3
Force in Bolt (kips)
Time (seconds)
A490 Design Pretension
Ambient
Cold
Hot
Figure C.8: Pretension Curve ¾" TnA 144
117


144 7/8" x 3" Type 1
Force in Bolt (kips)
Time (seconds)
A490 Design Pretension
Ambient
Cold
Hot
Figure C.23: Pretension Curve ⅞" TnA 144
118


144 1" x 4" Type 1
Force in Bolt (kips)
Time (seconds)
A490 Design Pretension
Ambient
Cold
Hot
Figure C.35: Pretension Curve 1" TnA 144
119


University of Cincinnati
Summary of Results
144 Overall Full Pretension vs. Required
Stress (ksi)
Samples
5/8" diameter
3/4" diameter
7/8" diameter
1" diameter
1-1/8" diameter
Required minimum
Minimum final pretension chosen as:
$\sigma_{FT, req} = 0.70*150ksi$
120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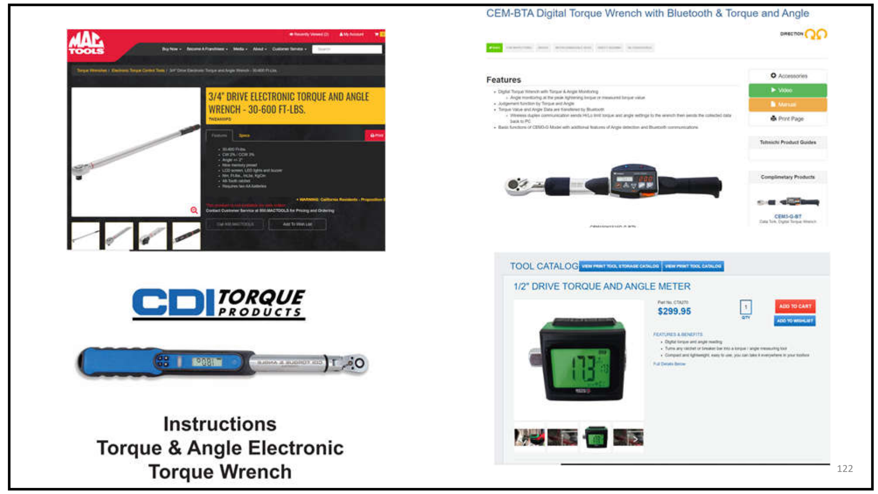
A case study in torque-angle tightening
Bill Eccles – Bolt Science
121


CEM-BTA Digital Torque Wrench with Bluetooth & Torque and Angle
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124

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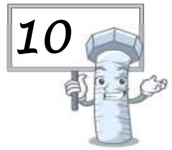
Arbitration



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125

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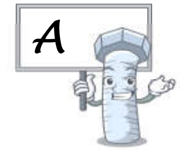
Appendix



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126

Appendix A

- **A1.1. Purpose and Scope**
- The purpose of this testing procedure is to determine the *mean slip coefficient* of a coating for use in the design of *slip-critical joints*. The *mean slip coefficient* is determined upon successful completion of both short-term compression tests and long-term tension creep tests.

- *Cure* (noun). A condition of an applied coating in which physical properties such as hardness and slip resistance are achieved.
- *Cure* (verb). The action of changing a coating from the physical properties it had when it was applied to the physical properties it is expected to have in service.
- *Degree of Cure*. Quantitative measurement or qualitative rating of a physical property, such as hardness, to determine the development of acceptable intended in-service properties of an applied coating.

127

Appendix A

A1.2.1. *Degree of Cure: Degree of cure* is an essential variable. *Cure* shall be performed according to published coating manufacturer's recommendations. The *degree of cure* of the coating shall be evaluated using one or more of the following: (a) Sclerometer Hardness, (b) Pencil Hardness, (c) MEK Double Rub Test, or (d) by other means as recommended by the coating manufacturer. Each evaluation method recommended by the coating manufacturer shall be performed at the time of test and shall be recorded on the certification.

A1.4. Duration of Coating Slip Certificate

Any coating slip certificate issued under this Appendix for a coating is valid for a term of 84 months after the certificate has been issued. After 84 months, the coating shall be fully retested according to this Appendix and reissued a new certificate.

128

Thank you!

129

Where is the specification?

- Part 16 of the 15th Edition *Steel Construction Manual*
  - 2016 *Specification for Structural Steel Buildings* (ANSI/AISC 360-16)
  - 2014 *Specification for Structural Joints Using High Strength Bolts*
- The new RCSC 2020 Specification is available for download now!
  - Will be published with ANSI/AISC 360-22 in the next edition of the *Manual*
- https://www.aisc.org/globalassets/aisc/publications/standards/a348-20w.pdf
- Thank you for your time!

130

Links

https://www.linkedin.com/in/chad-larson-f3148/
https://www.aisc.org/globalassets/aisc/publications/standards/a348-20w.pdf
https://www.aisc.org/globalassets/modern-steel/archives/2018/09/breakingupisnthardtodo.pdf
https://studylib.net/doc/18286153/six-into-one---modern-steel-construction
https://www.aisc.org/globalassets/modern-steel/archives/2015/11/six.pdf
https://www.astm.org/Standards/F3125.htm
https://www.astm.org/Standards/F3148.htm
https://www.astm.org/Standards/F2833.htm
https://www.astm.org/Standards/F3019.htm
https://www.astm.org/Standards/A1059.htm
https://www.astm.org/Standards/F3393.htm
https://www.asme.org/codes-standards/find-codes-standards/b18-2-6-fasteners-use-structural-applications-supplement
https://www.aisc.org/globalassets/modern-steel/archives/2020/december2020.pdf
https://www.aisc.org/Dimensional-Tolerances-and-Length-Determination-of-High-Strength-Bolts
https://www.aisc.org/A-Reliability-Study-of-Joints-with-Bolts-Designed-with-Threads-Excluded-but-Installed-with-Threads-N
https://www.aisc.org/globalassets/aisc/research-library/university-of-texas-report-on-galvanized-slip-coefficients-draft-final-4915.pdf
https://www.aisc.org/Specification-for-Structural-Steel-Buildings-ANSIAISC-360-16-1

131

AISC | Questions?

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PDH Certificates

- You will receive an email on how to report 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!

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PDH Certificates

- Reporting site (URL will be provided in the forthcoming email).
- Username: Same as AISC website username.
- Password: Same as AISC website password.

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AISC | Thank you

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