NSBA Steel Bridge Forum

Smarter. Stronger. Steel.

Bridge Bolting

October 28th, 2021

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Chad Larson

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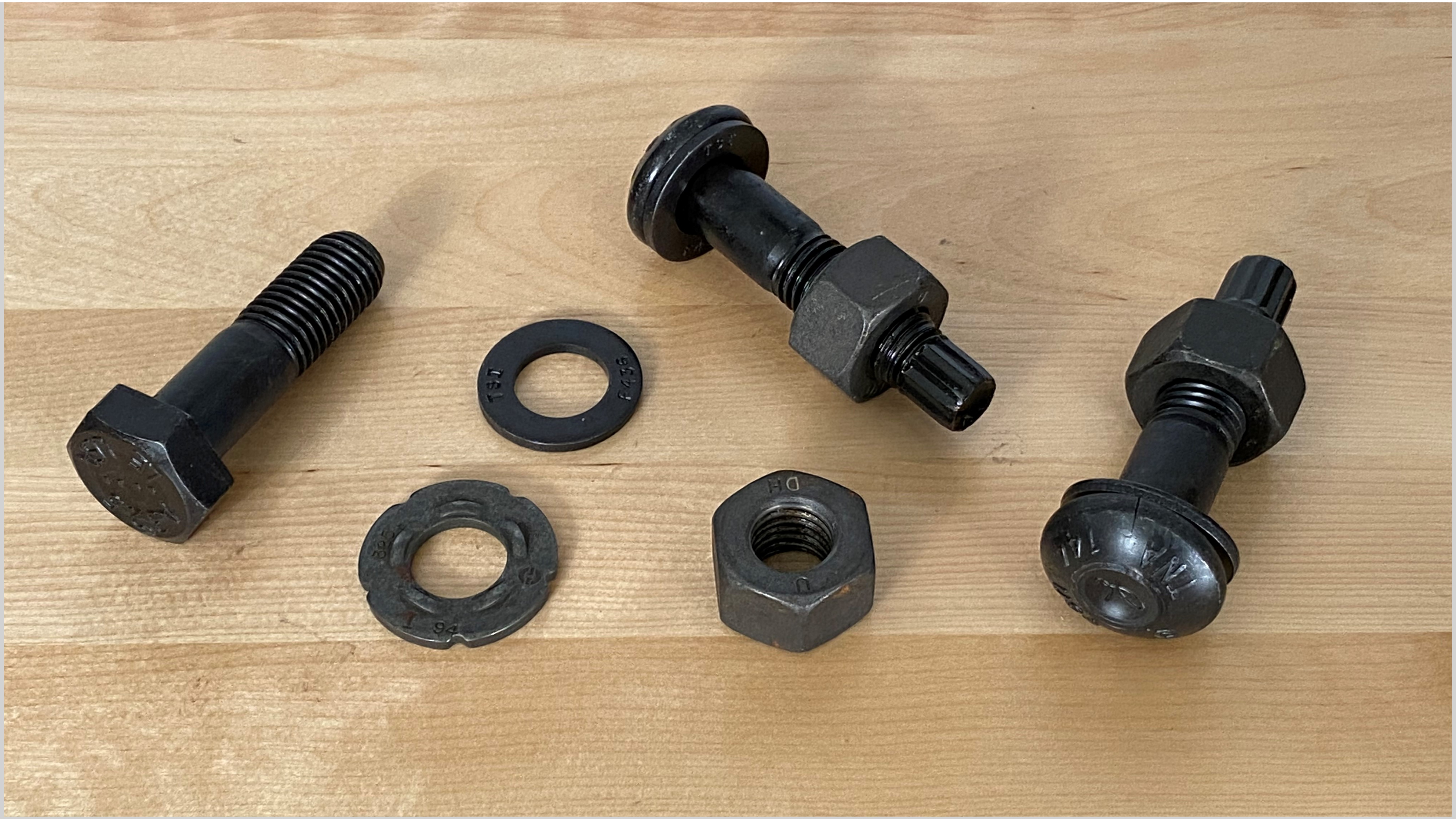
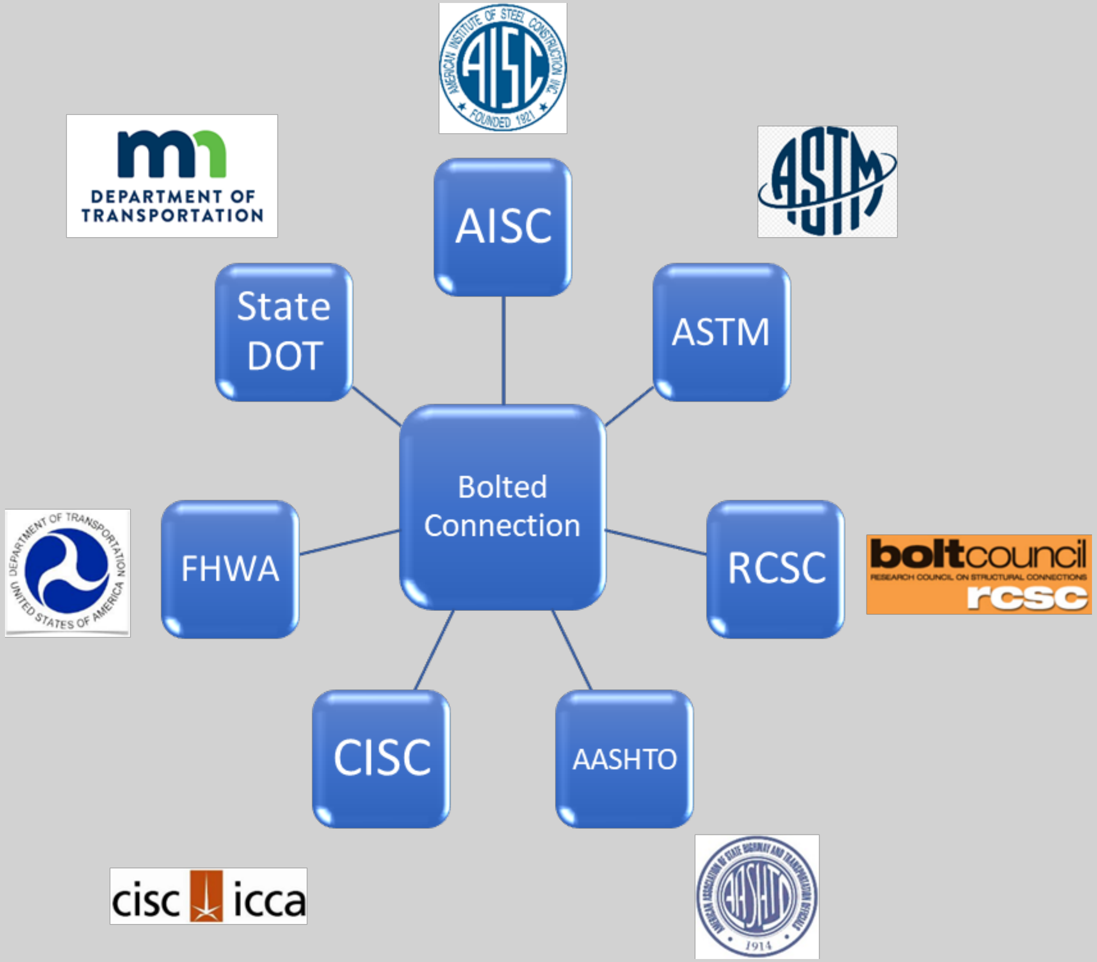
- Author of ASTM F3125
- Author of ASTM F3148
- Inventor of the Torque and Angle Structural Fastening System
- Vice Chair - ASTM F16 Committee on Fasteners
- Chair - RCSC Task Group 4 on Installation
- https://www.linkedin.com/in/chad-larson-f3148/

Structural Bolts



Standards Organizations



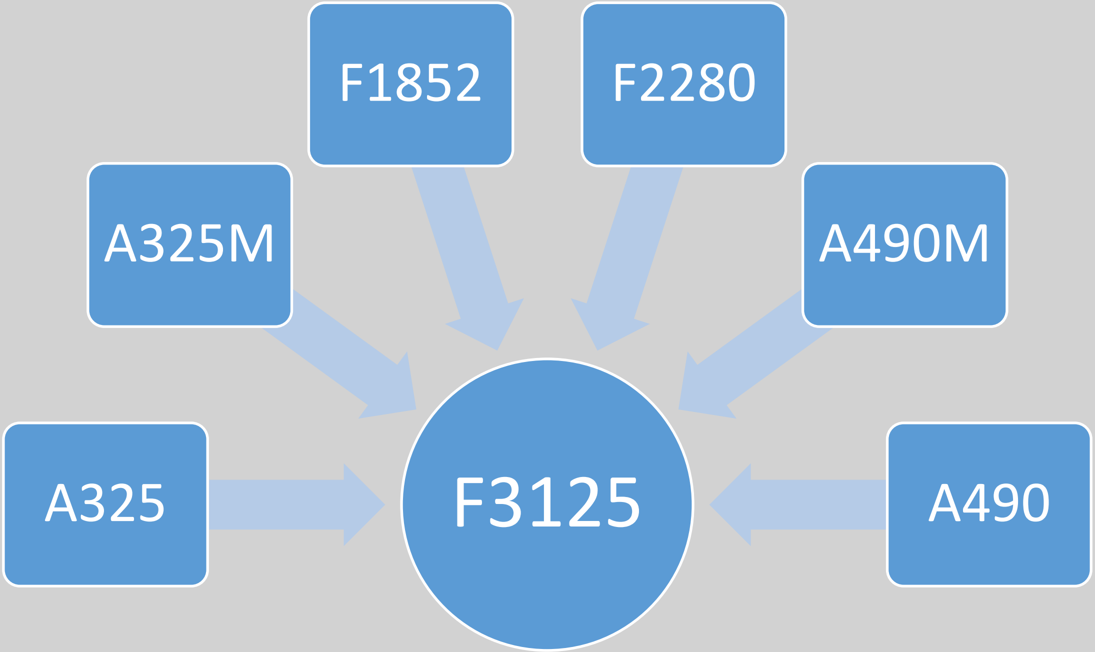
Changes

New RCSC Specification 2020 Edition

- 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

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

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

Six INTO One

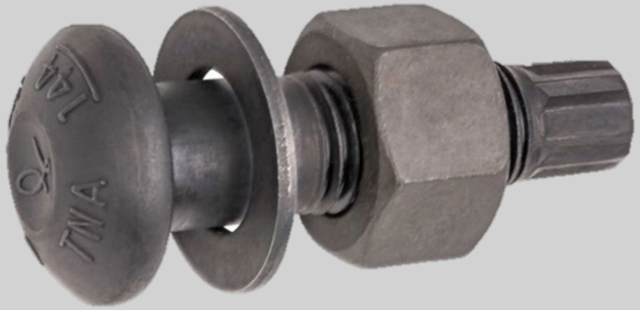
The consolidation of multiple ASTM structural bolt standards will help simplify bolt specification.

BY CHAD LARSON AND THOMAS J. SCHLAFLY

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

Added ASTM F3148

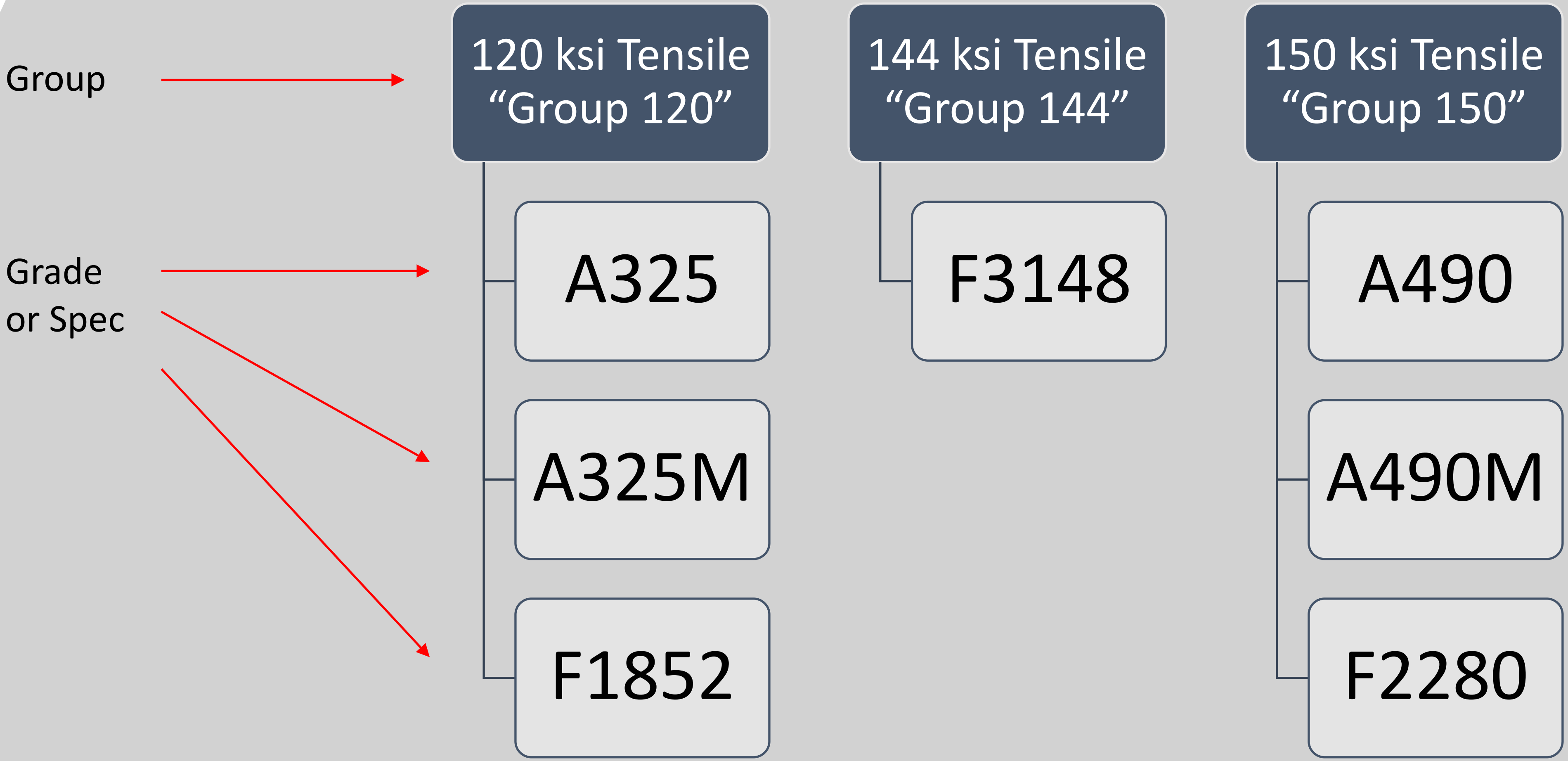
- **Added ASTM F3148**
  - New strength "Group 144"
  - Uses "Combined Method" for pretensioning
  - Fixed spline drive
  - Minimum pretension equal to Grade A490
  - Approved in ANSI/AISC 358 Prequalified Connections, Moment frames for seismic applications
  - Currently balloting in AISC 360-22
  - On Agenda at AASHTO T-14 and AREMA Committee 15
  - https://www.astm.org/Standards/F3148.htm



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

Structural Bolt Grades and Groups



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

Galvanized Faying Surfaces 3.2.2

- Previous testing demonstrated an improvement in slip resistance when hand wire brushing was performed. RCSC has required hand wire brush roughening of faying surfaces ever since.
- More recent 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 in fact now forbids roughening.
- AISC still requires –

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

Slip Critical Galvanized Faying Surfaces

Between 1 and 9 slip classes over the years

- 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 A 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???

The Hole Truth

- Standard hole size was nominal + 1/16” for all diameters
- ASME B18.2.6 permits a fin or swell under the bolt head that could exceed the +1/16” hole size
- Increased 1” and larger holes to nominal + 1/8” to help erection tolerance, bolts fit better, but not considered oversized
- This change already done in AISC 360-16

Increase in Nominal Hole Size

Already Done in AISC 360-16

Table 3.1
Nominal Bolt Hole Dimensions

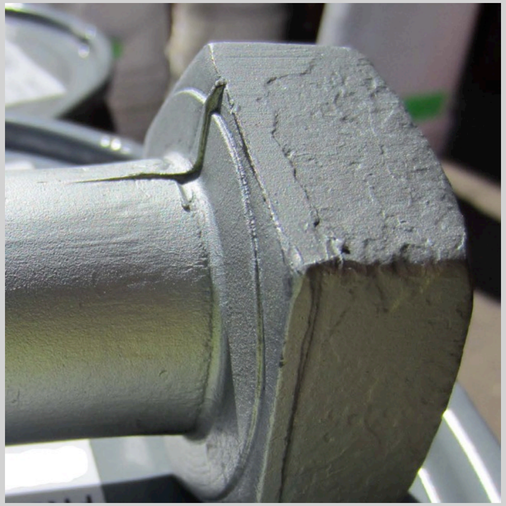
Nominal Bolt Diameter, d_b, in.	Nominal Bolt Hole Dimensions[a,b], in.			
	Standard (diameter)	Oversized (diameter)	Short-Slotted (width × length)	Long-Slotted (width × length)
½	9/16	5/8	9/16 × 11/16	9/16 × 1¼
5/8	11/16	13/16	11/16 × 7/8	11/16 × 1 9/16
¾	13/16	15/16	13/16 × 1	13/16 × 1 7/8
7/8	15/16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

Hole Sizes

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



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	$L_s \leq 38$ in.	54	65	68
		$L_s > 38$ in.	45	54	56
	Threads excluded from shear plane	$L_s \leq 38$ 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.

Pretension Requirement - 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

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

Pretension – New Location

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

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.

Structural Bolt Pretensioning Methods

North America

- Twist Off Type (TC bolt)
- Turn of Nut
  - Undefined Torque + Angle
- DTI Washer
- Calibrated Wrench
  - Torque without K control

Europe

- Combined Method
  - Defined Torque + Angle
- HRC (Twist-Off Type)
- DTI Washer
- Torque Method
  - Torque with K control

Structural Bolt Pretensioning Methods

Commercial Construction

($20 to $30 per hole)

- 55% - Twist Off Type (TC bolt)
- 30% - Turn of Nut
  - Undefined Torque + Angle
- 10% - DTI Washer
- <5% - Calibrated Wrench
  - Torque without K control

Bridge Construction

($40 to $50 per hole)

- 75% - Turn of Nut
  - Undefined Torque + Angle
- 20% - DTI Washer
- <5% - Twist Off Type (TC bolt)
- <1% - Calibrated Wrench
  - Torque without K control

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."

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*.

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.

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.

DTI Section 8 - 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.

DTI Section 9 - 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.

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.

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*.

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.

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.

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

Combined Method – Section 8

- 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*.

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 (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 8d_b, the required nut rotation shall be determined by actual testing in a suitable *bolt tension measurement device*; see *combined method* Commentary.

Combined Method - Section 9

- 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

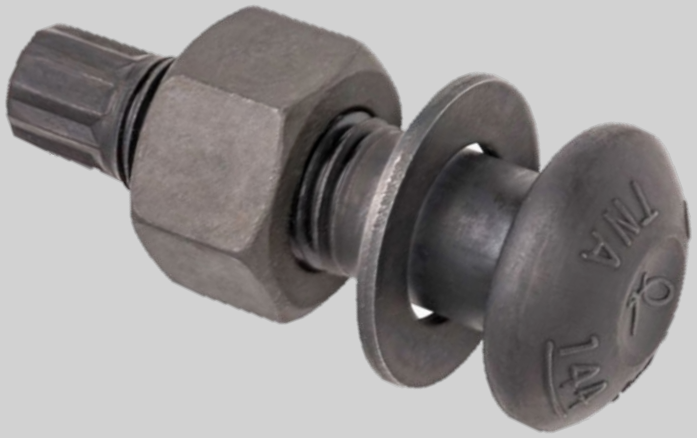
(3) Verify by *routine observation* that the bolting crew properly rotates the turned element relative to the unturned element by the amount specified in Table 8.2. Alternatively, when *bolting assemblies* are match-marked after the initial application of the torque, but prior to *pretensioning*, visual 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.

New Fastener System for Combined Method

- ASTM F3148 Spline Drive Assembly
- Fixed Spline
- 144 KSI

New Fastener System Goals

- Economize Strength
- Improve Reliability
- Single Side/Single Installer
- Solution for Pretensioned Joints
- Solution for Snug Only (bearing) Joints
- Bring Improved Tool Technology to Market
- Bring Single-side Installation to bridge Market

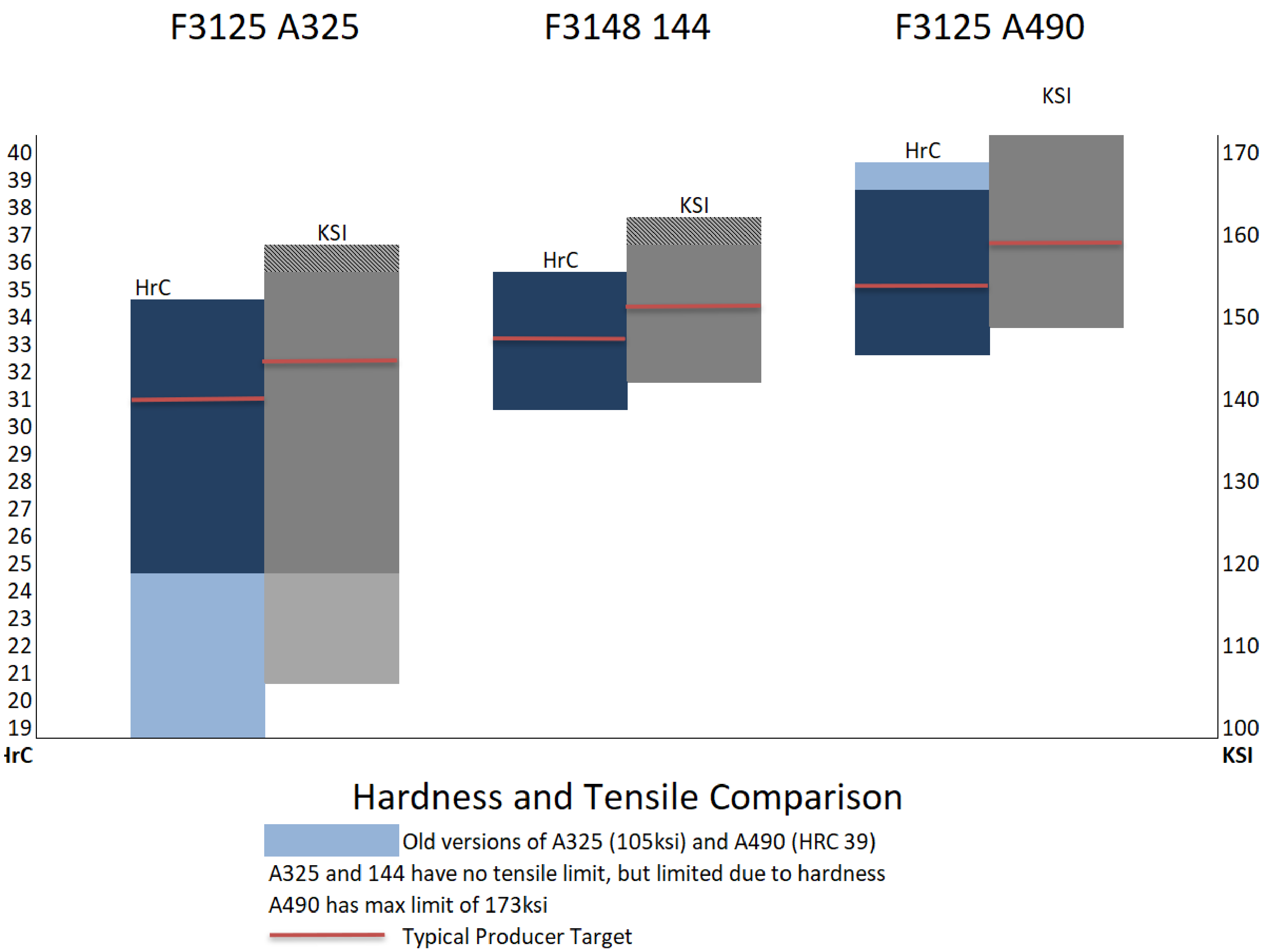


Why 144 ksi?

- Optimize strength without adding cost
- Same materials and processes - tighter control
- Japan JIS B1186 F10T/S10T = 145 ksi
- Numerous coatings, including galvanizing
- Probably would not write A325 today, but we are stuck with the legacy in design and inventory

Economize Strength

- Market uses both 120ksi and 150ksi fasteners
- Most 120ksi product is already well over 140ksi in strength
- Designers cannot use this available strength
- For no added cost we can tighten the spec requirements and use higher strength in design
- Possibility to consolidate market on one strength grade


F3125 A325
F3148 144
F3125 A490
KSI
HrC
KSI
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KSI
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20
19
HrC
170
160
150
140
130
120
110
100
KSI
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

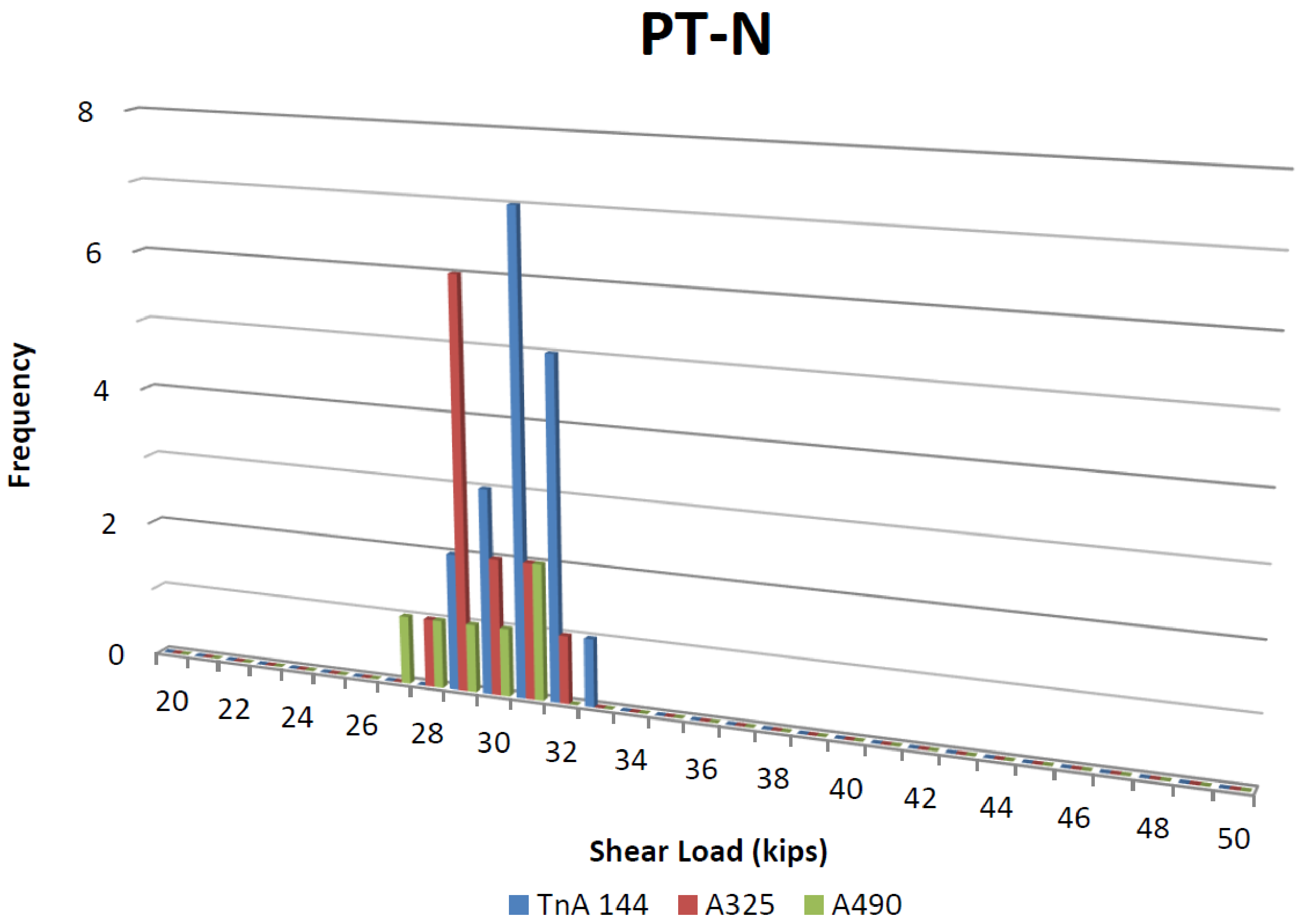
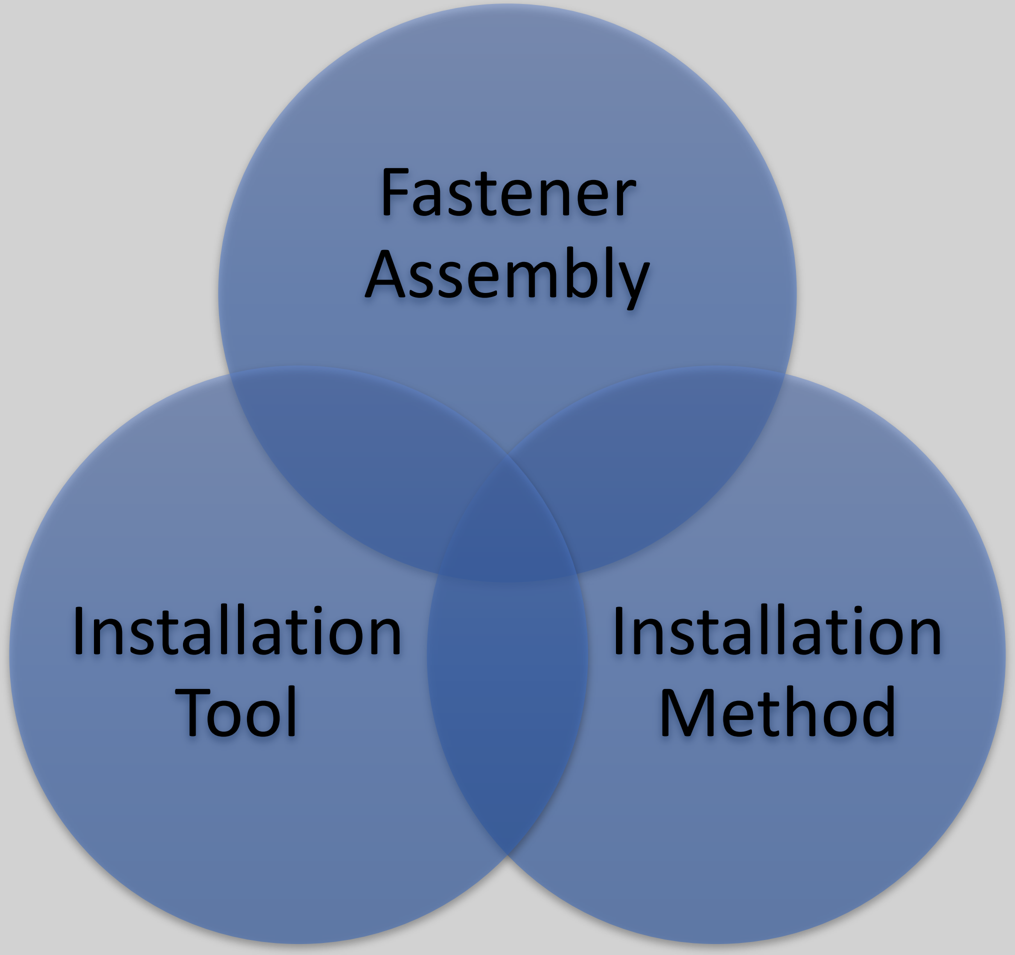


Figure 4.29: Frequency Distribution of Ultimate Shear Loads PT-N

TnA144 Takes a Complete Approach



What did we need to consider?

Single Side Installation

No Reaction Arm

Angle Based Final Tension

Emphasis on Consistent

Snug Tight Level

Matched Bolt Assemblies

Combined Method

Combined Method

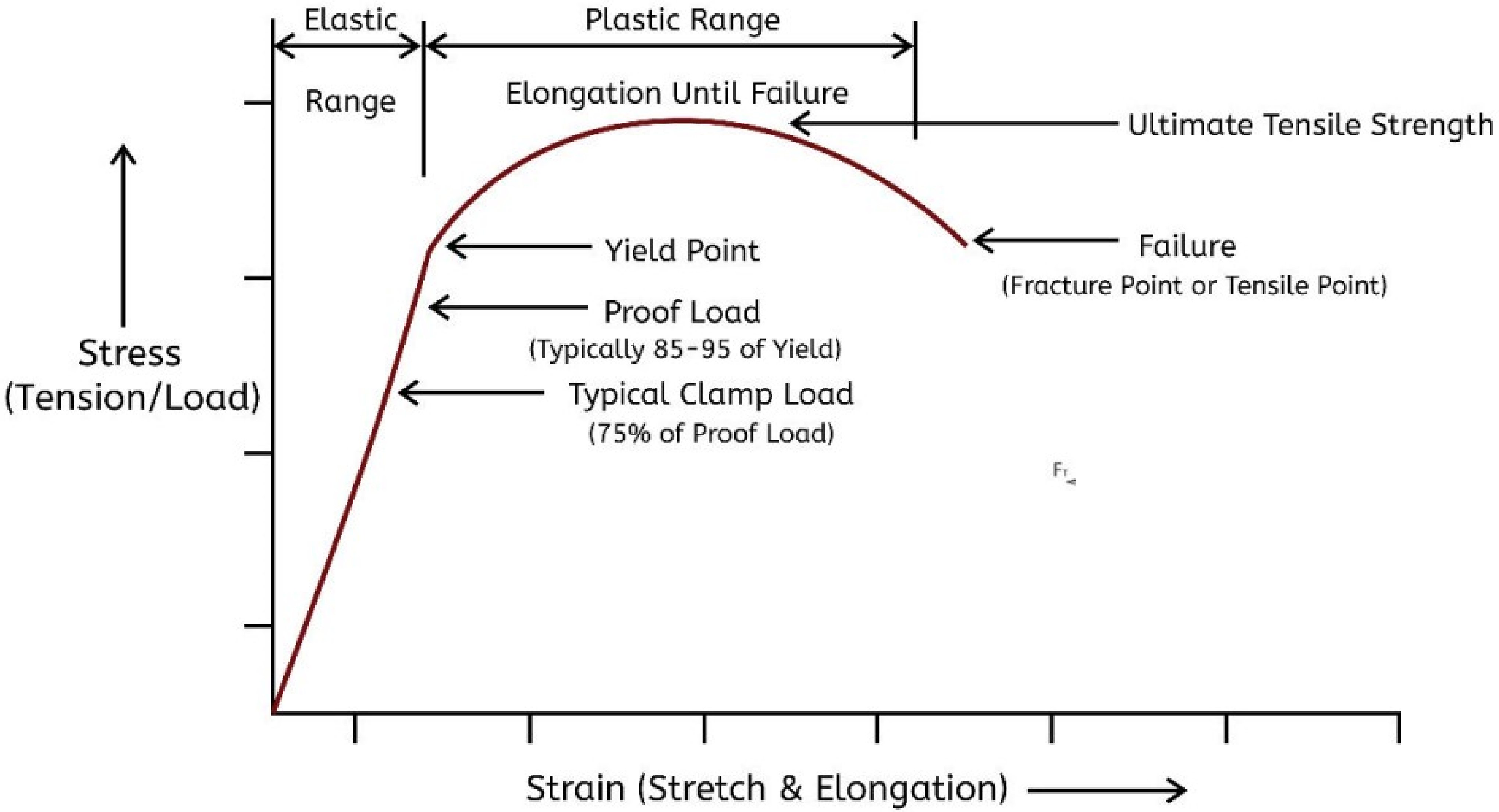
- Snug tightened to a high level of tension using torque
- Final pretension using angle/elongation

- Uses torque, tension and angle signature curves for development

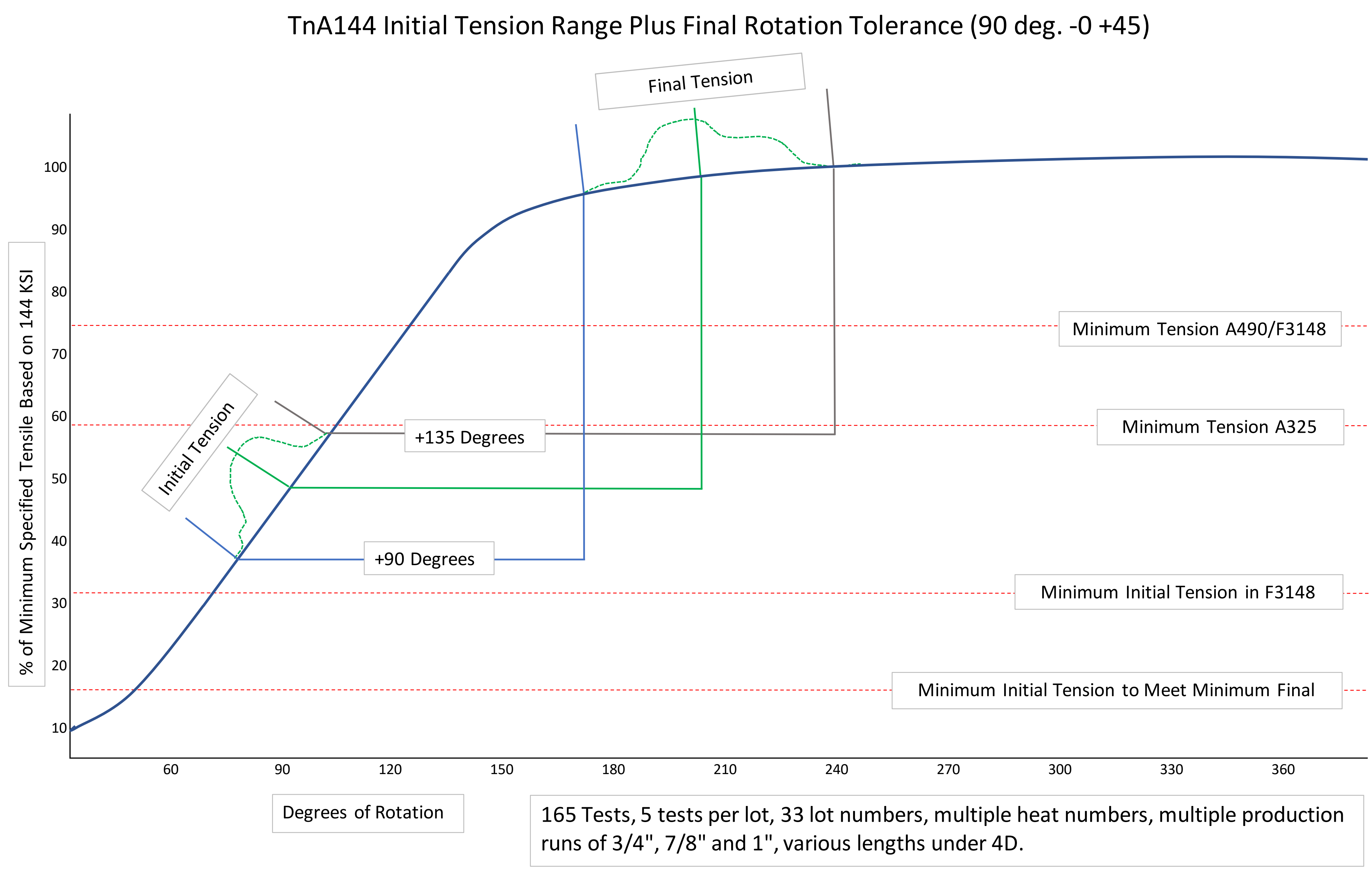
Two Steps to Tensioning (pretension)

- Snug tight – firm and continuous contact
  - No other installation method that makes this critical step this easy

- 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



Tensile Stress-Strain Diagram


TnA144 Initial Tension Range Plus Final Rotation Tolerance (90 deg. -0 +45)
Final Tension
100
90
80
70
60
50
40
30
20
10
% of Minimum Specified Tensile Based on 144 KSI
Minimum Tension A490/F3148
Minimum Tension A325
Initial Tension
+135 Degrees
+90 Degrees
Minimum Initial Tension in F3148
Minimum Initial Tension to Meet Minimum Final
60
90
120
150
180
210
240
270
300
330
360
Degrees of Rotation
165 Tests, 5 tests per lot, 33 lot numbers, multiple heat numbers, multiple production runs of 3/4", 7/8" and 1", various lengths under 4D.

Delft University of Technology

Evaluation tightening
preloaded bolt assemblies according to
EN 1090-2
"Technical requirements for steel structures"
for 95% reliability EN 1990 *

Delft university of technology

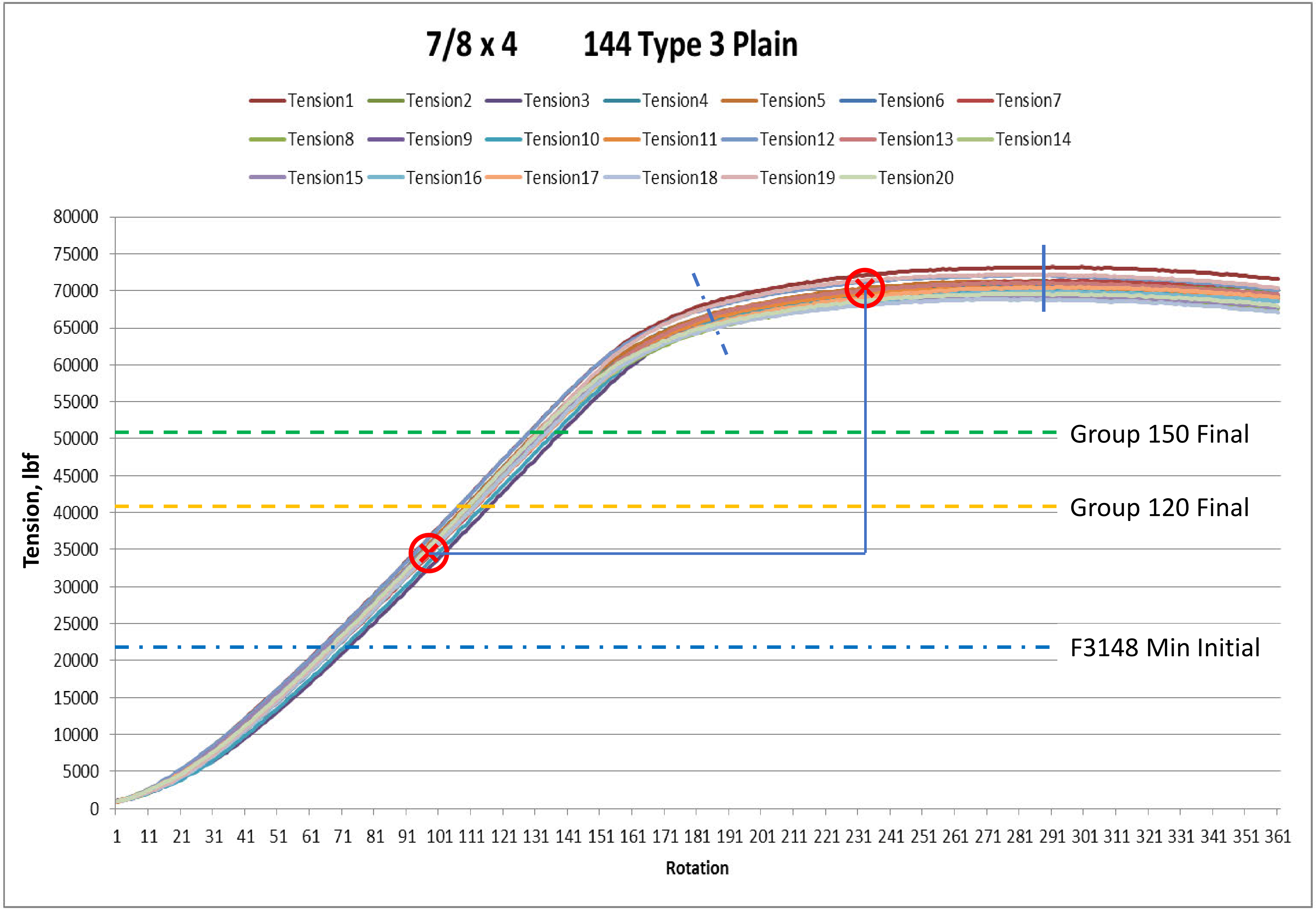
2 Conclusions

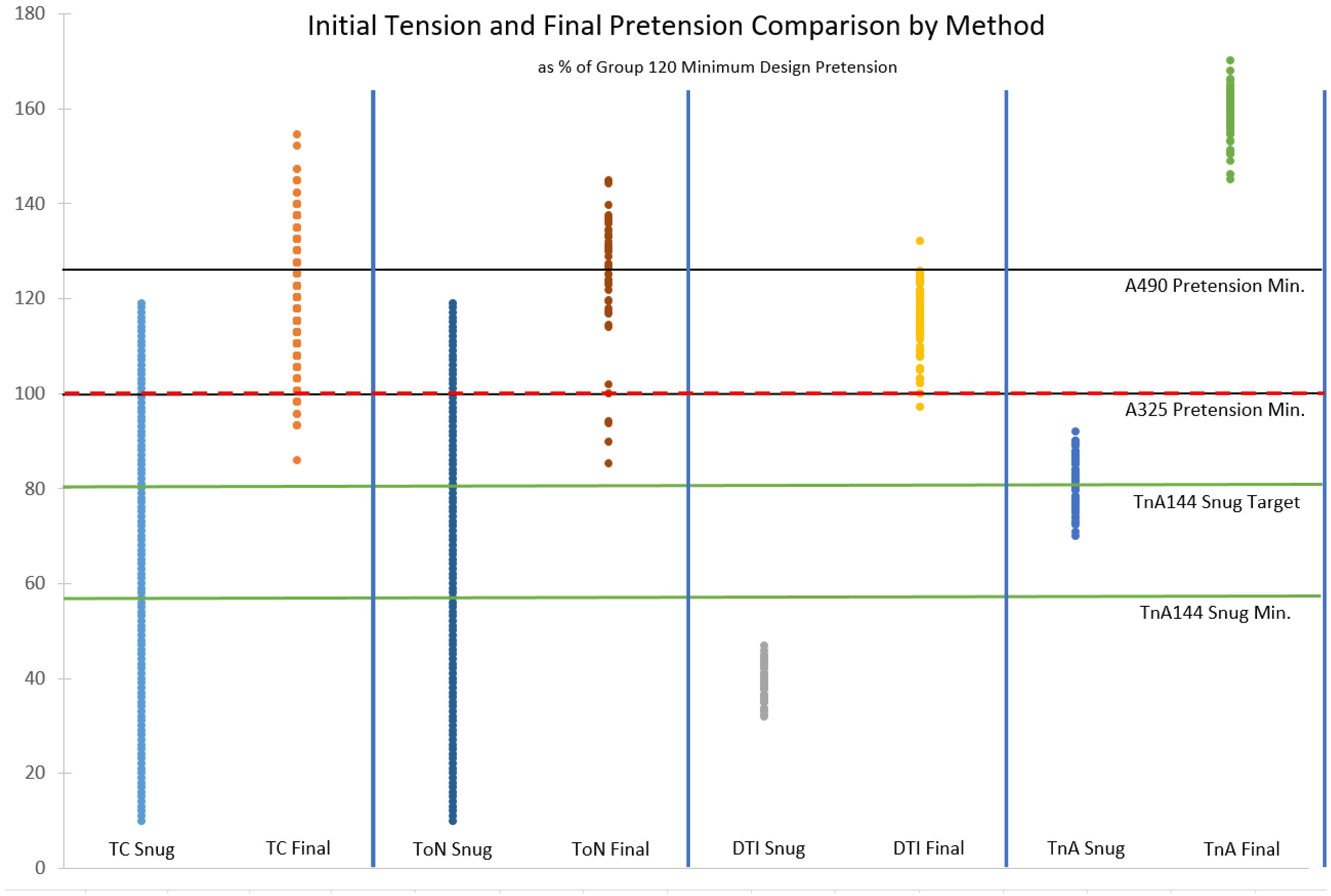
2.1 Clause 8.5.1 of EN 1090-2 determines that “unless otherwise specified the nominal minimum preloading force $F_{p,c}$ shall be taken as 0,7 $f_{ub}A_s$”.

EN 1990 determines in clause 4.2 that this nominal minimum preload $F_{p,c} = 0{,}7\, f_{ub}A_s$, shall be reached with a reliability of 95% according to a Normal distribution.

The values for the reliability according to the present methods mentioned in EN 1090-2 are determined as:

1. The torque method:	reliability	79,4	%
2. The combined method:	reliability	100	%
3. The HRC method:	reliability	81	%
4. The direct tension indicator (DTI) method:	reliability	> 95	%


7/8 x 4 144 Type 3 Plain
Tension1 Tension2 Tension3 Tension4 Tension5 Tension6 Tension7
Tension8 Tension9 Tension10 Tension11 Tension12 Tension13 Tension14
Tension15 Tension16 Tension17 Tension18 Tension19 Tension20
Tension, lbf
Rotation
Group 150 Final
Group 120 Final
F3148 Min Initial
0 5000 10000 15000 20000 25000 30000 35000 40000 45000 50000 55000 60000 65000 70000 75000 80000
1 11 21 31 41 51 61 71 81 91 101 111 121 131 141 151 161 171 181 191 201 211 221 231 241 251 261 271 281 291 301 311 321 331 341 351 361



Initial Tension and Final Pretension Comparison by Method
as % of Group 120 Minimum Design Pretension
180
160
140
120
100
80
60
40
20
0
A490 Pretension Min.
A325 Pretension Min.
TnA144 Snug Target
TnA144 Snug Min.
TC Snug
TC Final
ToN Snug
ToN Final
DTI Snug
DTI Final
TnA Snug
TnA Final

Improve Reliability of Single Side Installation

- Twist-off type tension control bolts are used in numerous commercial construction projects requiring pretension
- Rising labor costs and labor shortages will continue to drive the use of single side/single installer fasteners
- Twist-off type tension control bolts use torque to achieve pretension
- The industry has spent decades trying to improve torque-based reliability with out any significant breakthroughs

Improve Economy of Installation

- Fewer holes, fewer bolts, faster installation
- No torque reaction, no reaction arm, quiet electric tools
- Will eliminate 2nd snugging pass on many connections

- Improved shear capacity over A325
- Improved slip resistance over A325

Design and Cost Savings

			A325				A490				Group 144			
	Bolt Dia. In.	Slip Coeff.	Top Flange	Web	Bottom Flange	Total Bolts	Top Flange	Web	Bottom Flange	Total Bolts	Top Flange	Web	Bottom Flange	Total Bolts
Example 1	7/8	B	12	26	24	62	12	26	20	58	12	26	20	58
Example 2	7/8	B	20	70	28	118	16	56	24	96	20	58	24	102
Example 3	1	B	12	34	40	86	12	34	32	78	12	34	36	82

Total Bolts in Connection			
	Ex. 1	Ex. 2	Ex. 3
A325	62	118	86
Group 144	58	102	82
A490	58	96	78

ASTM F3148

- LeJeune Bolt Co. fastener system TnA144
- Matched and tested assemblies
- Mating tool that provides reaction free, single-side installation
- Each lot number has signature analysis for torque, tension and angle to verify it will work with tool output parameters
- Very reliable and efficient means of tightening bolts on shear/bearing connections or fully pretensioned connections

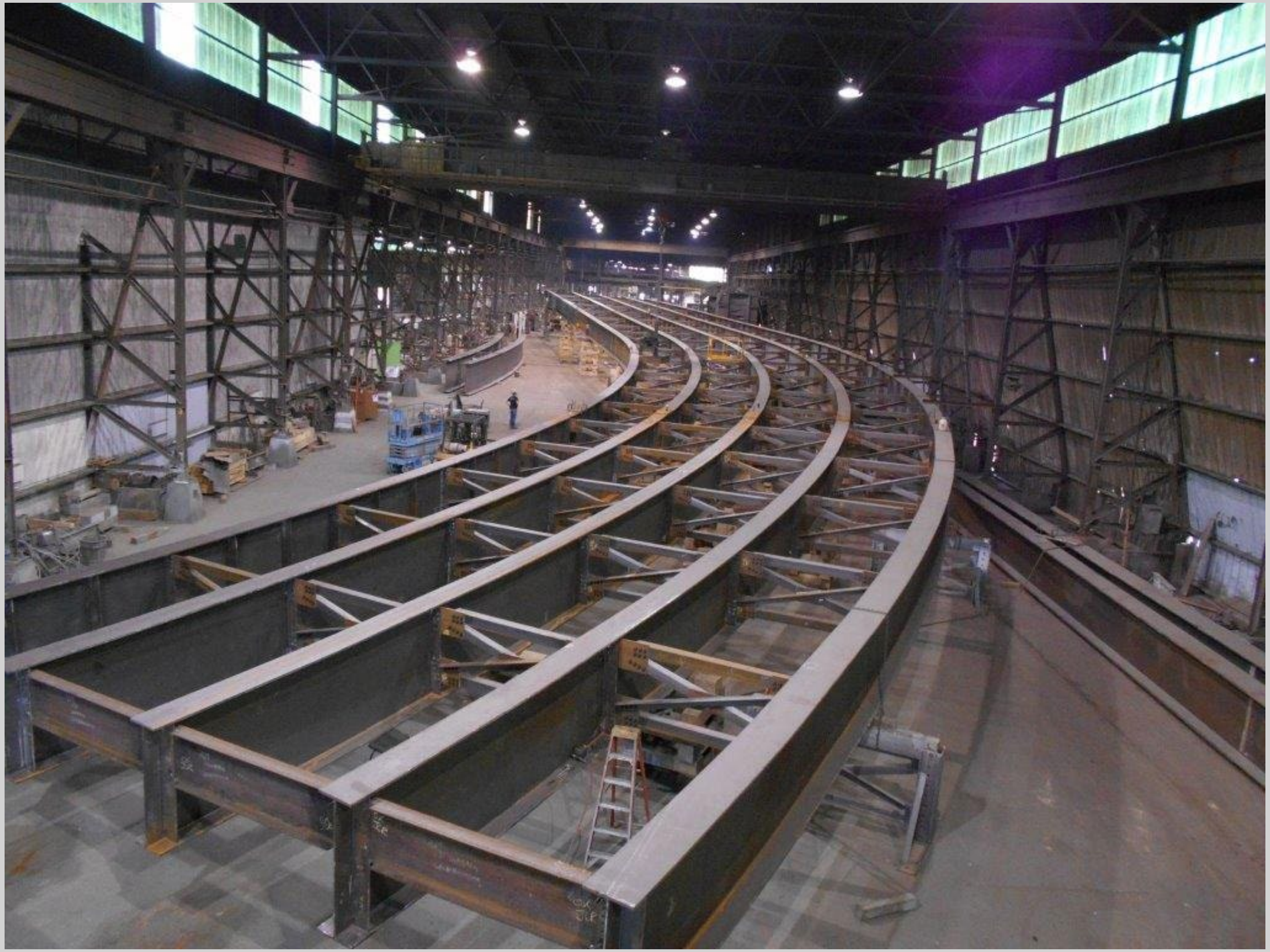
Features

- Single tool/Single side
- Correct cycle indicator LED
- Cordless Tool in Development
- Relative rotation (nut to bolt) guaranteed
- No removed end touch up when galvanized
- Snug verification automatically prior to angle measurement
- Tool is reversible – temporary works and easier PIV testing
- Available with single-side lubrication – paint prep much less costly
- Future app capability for data recording, QA controls – keg to connection
- Calibration reminders, worker productivity, status monitoring, BIM integration

Bring Single Side Installation to Bridge Market

- The bridge market has traditionally been the largest market for heavy hex bolts and the smallest market for twist-off type bolts
- The labor savings of single-sided installation has not been realized by the bridge market
- 144 strength level brings additional design and construction savings and a higher strength option for galvanized fasteners
- Take advantage of higher strength or simply use as a super conservative replacement for A325 to recognize significant labor savings

Bring Single Side Installation to Bridge Market



Bring Single Side Installation to Bridge Market

Status of ASTM F3148 – TnA144 Fastening System

- 2013-2016- Awarded fastener system Utility Patent in Mexico, Canada, UK, Germany, France, Italy and Spain
- 2013- Awarded "Hot Product" at the North American Steel Construction Conference
- 2015- ASTM Standard F3148 approved by ASTM Committee F16 on Fasteners and Subcommittee F16.02 on Bolts, Nuts and Washers. Title: *Standard Specification for High Strength Structural Bolt Assemblies, Steel and Alloy Steel, Heat Treated, 144ksi Minimum Tensile Strength, Inch Dimensions*
- 2018- Full size test program and acceptance into seismic specification for SidePlate
- 2019- Full size test program and acceptance into BRB seismic specification for CoreBrace

Status of ASTM F3148 – TnA144 Fastening System

- 2020- ASTM F3148 approved and published in the 2020 edition of the Research Council on Structural Connections *Specification for Structural Joints Using High Strength Bolts*
  - RCSC added ASTM F3148
  - RCSC added 144 strength level for all design considerations
  - RCSC added the combined tightening method, Section 8.2.5
- 2020- AISC Technical Committee 6 on Connection Design approved ASTM F3148 for inclusion in ballot drafts for the 2022 AISC 360-22 Specification for Structural Steel Buildings
- 2020- AISC Connection Prequalification Review Panel approved ASTM F3148 in ANSI/AISC 358 Prequalified Connections for Special Moment Frames for Seismic Applications
- 2021- Inventor of ASTM F3148 fastening system awarded Industrial Fastener Institute *Soaring Eagle Award* for development of the torque and angle system and methodology for the North American construction market

Status of ASTM F3148 – TnA144 Fastening System

- 2021 Awarded fastener system Utility Patent in US
- 2021- AISC 360-22 has completed 3 of 4 scheduled ballots and public review. Anticipate F3148 publication in AISC 360-22 in 2023.
- 2021- ASTM F3148 included in draft ballot for ISO/WD 17607-6 *Steel Structures – Execution of Structural Steelwork – Part 6: Bolting*
- 2021- ASTM F3148 added to AASHTO T14 Committee on Structural Steel agenda for inclusion in upcoming edition of the AASHTO *Bridge Design Specification*
- 2021- ASTM F3148 added to Committee 15 agenda for inclusion in the upcoming edition of the AREMA Manual for Railway Engineering

MERCYHEALTH HOSPITAL - ROCKFORD, IL

MITER GATES – CORPS OF ENGINEERS

INDUSTRIAL STRUCTURES AND MANUFACTURING PLANTS

COMMERCIAL STRUCTURES

OATI OFFICE BUILDING – BLOOMINGTON, MN

5,000 FT. OF CRANE RAIL – PARMA, OH

JOHNSON STREET BRIDGE – VICTORIA, BC

TEMPORARY STRUCTURES

KANSAS CITY SOUTHERN RAILWAY REHAB
REDLANDS BRIDGE – SPIRO, OK

FULL SIZE SEISMIC TESTING

SIDEPLATE SYSTEMS AND COREBRACE TESTING

UMAUMA BRIDGE - HAWAII

UPCOMING - NASA LAUNCH COMPLEX - MOON AND MARS

MN Bridge Office Special Provisions

- **B. Precision Bolting Systems**
- ***1 – DESIGNER NOTE: Insert either [may] or [will] per recommendation by Regional Bridge Construction Engineer. Default is [may].***
- To enable more accurate bolt tensioning, the Contractor **[may/will]** propose a precision bolting system. A precision bolting system is defined as the use of tools that have been calibrated to produce repeatable results in conjunction with an installation plan that addresses snugging and tensioning of a connection.
- ***2 – DESIGNER NOTE: Include the remaining portion related to field training unless the Regional Bridge Construction Engineer recommends this being removed.***
- At least one week prior to the start of steel erection, but not prior to submittal of the job-specific fastener installation plan, provide on-site training to all personnel that will be operating the precision bolting system and the Engineer. The training will address the following:
- (1) Procedures established in the job-specific fastener installation plan
- (2) Instructions for operating the precision bolting system
- (3) Acceptance criteria for the Direct Tension Indicator (DTI) washer based on the results of the Pre-Installation Verification (PIV) testing
- Maintain a record of training of all personnel and make available to the Engineer upon request. Any person found operating the precision bolting system that has not completed the job-specific training will be removed from the project site until training requirements have been satisfied.