



THE THEORY BEHIND BOLTS

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OUTLINE

- **Why?**
- **Behavior of Bolts in Torqued Tension**
- **Installation of Pretensioned Bolts**
- **Inspection of Pretensioned Bolts**
- **Bolting FAQs**

WHY?

- **How will this help my business?**
- **How will this help my projects?**
- **How will this make my job easier?**

WHY?

In business, we tend to obsess over the “how” – as in “Here’s *how* you do it.” Yet we rarely discuss the “*why*” – as in “Here’s *why* we’re doing it.” But it’s often difficult to do something exceptionally well if we don’t know the reasons that we’re doing it in the first place. People at work are thirsting for context, yearning to know what they do contributes to a larger whole. And a powerful way to provide that context is to spend a little less time telling how and a little more time showing why.

- *DRiVE* by Daniel Pink

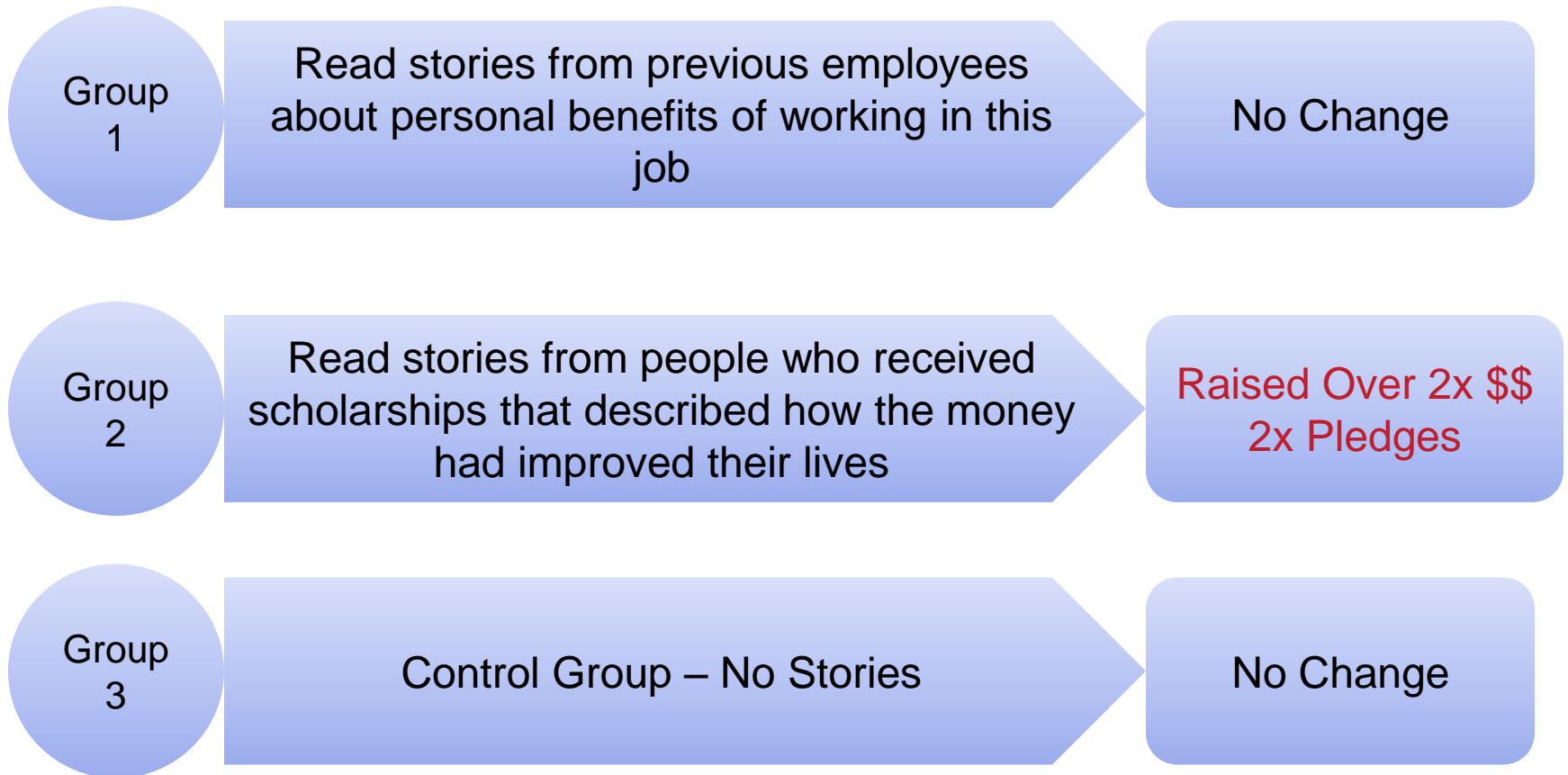
WHY?

Recommendations in *DRiVE* are based on research

Consider the following study:

- Adam Grant – University of Pennsylvania Psychologist
- Study of Call Center Representatives
- Making calls for a University Fund Raising Operation
- Had 3 groups with reading assignments each night
- They were not to share what they read

WHY?



WHY?

- **How will this make my job easier?**

More consistent work with less rework

- **How will this help my projects?**

Armed to educate the Inspector rather than argue or make unnecessary changes

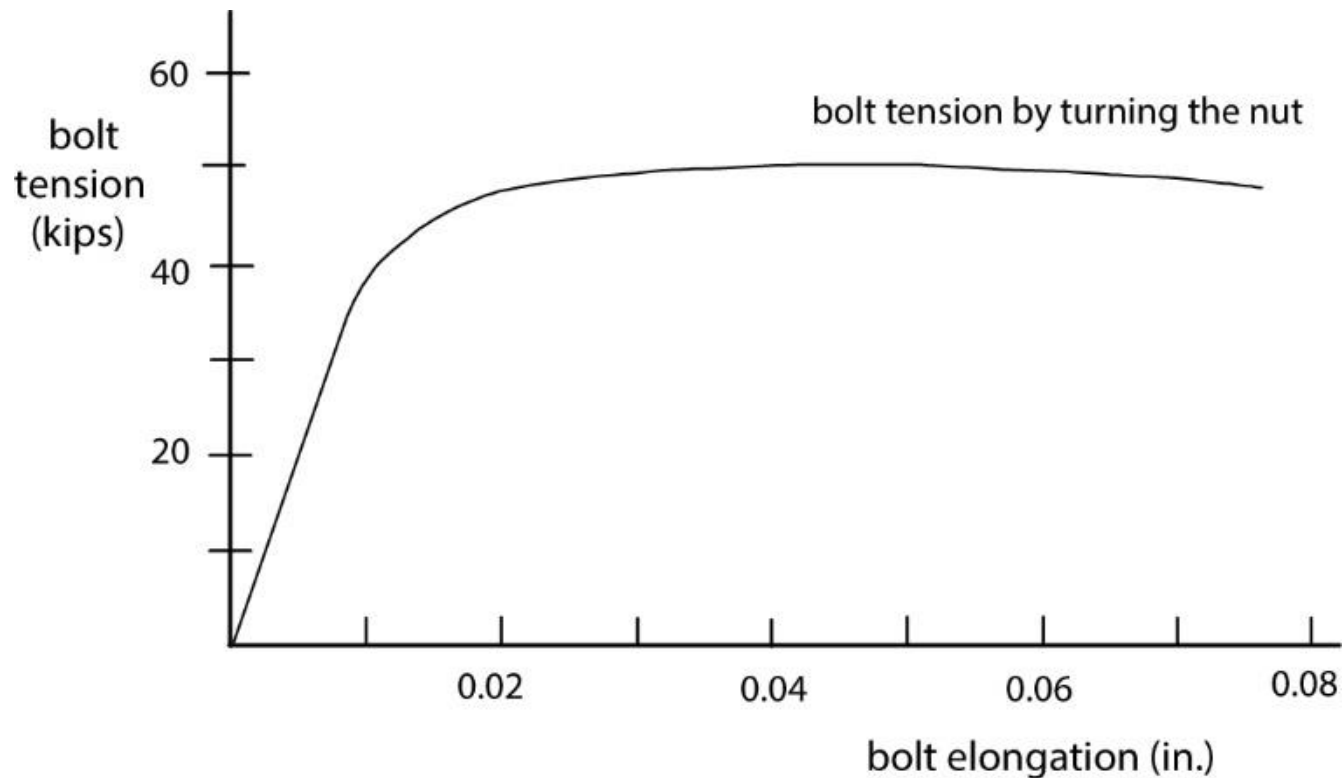
- **How will this help my business?**

It will save money

WHY ARE PRETENSIONED BOLTS NECESSARY?

- **In all structures carrying cranes of over 5 ton (50 kN) capacity: roof truss splices and connections of trusses to columns; column splices; column bracing; knee braces; and crane supports**
- **Connections for the support of machinery and other live loads that produce impact**
- **Joints with ASTM A490 bolts in tension**
- **Joints that utilize oversized holes or slotted holes (with load parallel to slot)**
- **Joints in which slip at the faying surfaces would be detrimental to the performance of the structure.**
- **Connections in the Seismic Force Resisting System**
- **Slip critical connections**

TORQUED-TENSION BEHAVIOR



From AISC Design Guide #17 for 7/8" A325 bolt

MINIMUM PRETENSION

Nominal Bolt Diameter, d_b , in.	Specified Minimum Bolt Pretension, T_m , kips ^a	
	ASTM A325 and F1852	ASTM A490 and F2280
$\frac{1}{2}$	12	15
$\frac{5}{8}$	19	24
$\frac{3}{4}$	28	35
$\frac{7}{8}$	39	49
1	51	64
$1\frac{1}{8}$	56	80
$1\frac{1}{4}$	71	102
$1\frac{3}{8}$	85	121
$1\frac{1}{2}$	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.

RCSC Table 8.1

MINIMUM PRETENSION

$$T_{min} = 0.70F_u A$$

From ASTM

Net Tensile Area, A_{st}

$$F_u = 120,000 \text{ psi} = 120 \text{ ksi (ASTM A325)}$$

$$A_{st} = 0.462 \text{ in.}^2 \text{ (14}^{\text{th}} \text{ Ed. AISC Manual Table 7-17)}$$



MINIMUM PRETENSION

$$T_{min} = 0.70F_uA$$

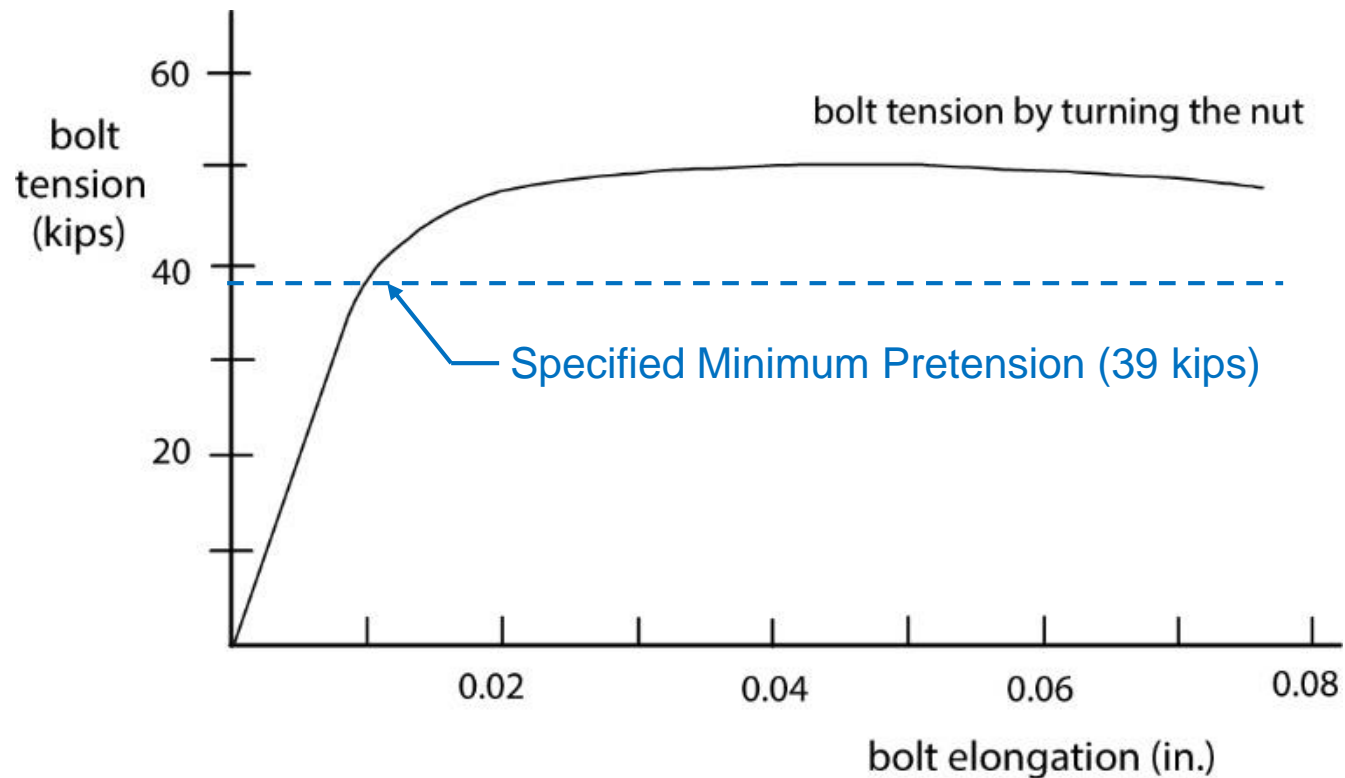
$$T_{min} = 0.70(120 \text{ ksi})(0.462 \text{ in}^2)$$

$$T_{min} = 38.8 \text{ kips}$$

Rounded to the nearest kip, the minimum installed pretension for a 7/8" A325 Bolt is

39 kips

MINIMUM PRETENSION



From AISC Design Guide #17 for 7/8" A325 bolt

PREINSTALLATION VERIFICATION TENSION

Nominal Bolt Diameter, d_b , in.	Minimum Bolt Pretension for Pre-Installation Verification, kips ^a	
	ASTM A325 and F1852	ASTM A490 and F2280
$\frac{1}{2}$	13	16
$\frac{5}{8}$	20	25
$\frac{3}{4}$	29	37
$\frac{7}{8}$	41	51
1	54	67
$1\frac{1}{8}$	59	84
$1\frac{1}{4}$	75	107
$1\frac{3}{8}$	89	127
$1\frac{1}{2}$	108	155
^a Equal to 1.05 times the specified minimum bolt pretension required in Table 8.1, rounded to the nearest kip.		

RCSC Table 7.1

PREINSTALLATION VERIFICATION TENSION

$$T_{PIV} = 1.05T_{min}$$

$$T_{PIV} = 1.05(39 \text{ kips})$$

$$T_{PIV} = 40.95 \text{ kips}$$

Rounded to the nearest kip, the preinstallation verification tension for a 7/8" A325 Bolt is:

41 kips

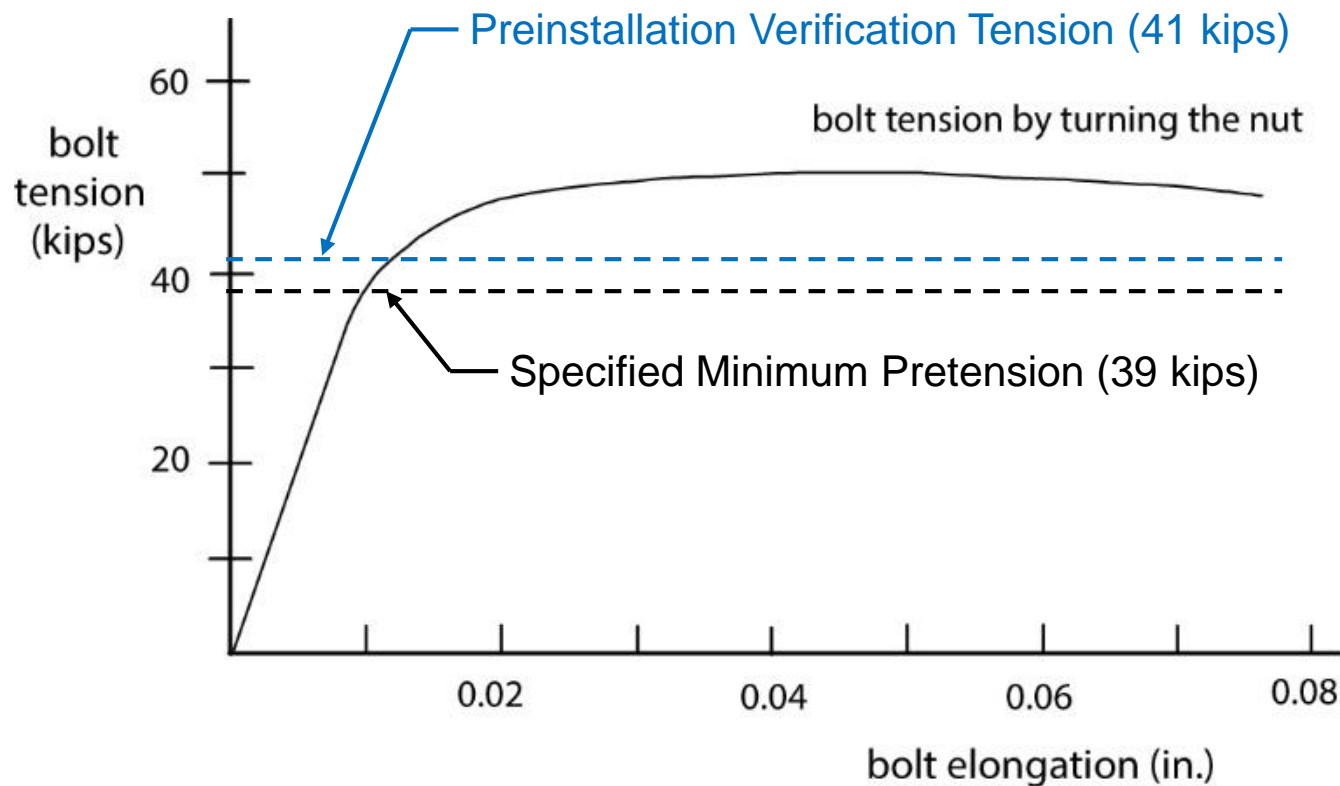
PREINSTALLATION VERIFICATION TENSION

Why does the minimum bolt pretension for preinstallation verification (PIV) testing differ from that required for installation and design?

1.05x that required for installation/design

- Recognizes natural scatter in PIV testing
- Provides confidence that a majority of the bolts in the work will achieve the minimum required for installation/design

PREINSTALLATION VERIFICATION TENSION



From AISC Design Guide #17 for 7/8" A325 bolt

SNUG TIGHT

1962 – “The tightness that is attained by a few impacts of an impact wrench or the full effort of a man using an ordinary spud wrench.”

1985 – “The tightness that exists when all plies in a joint are in firm contact. This may be attained by a few impacts of an impact wrench or the full effort of a man using an ordinary spud wrench.”

2009 – “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

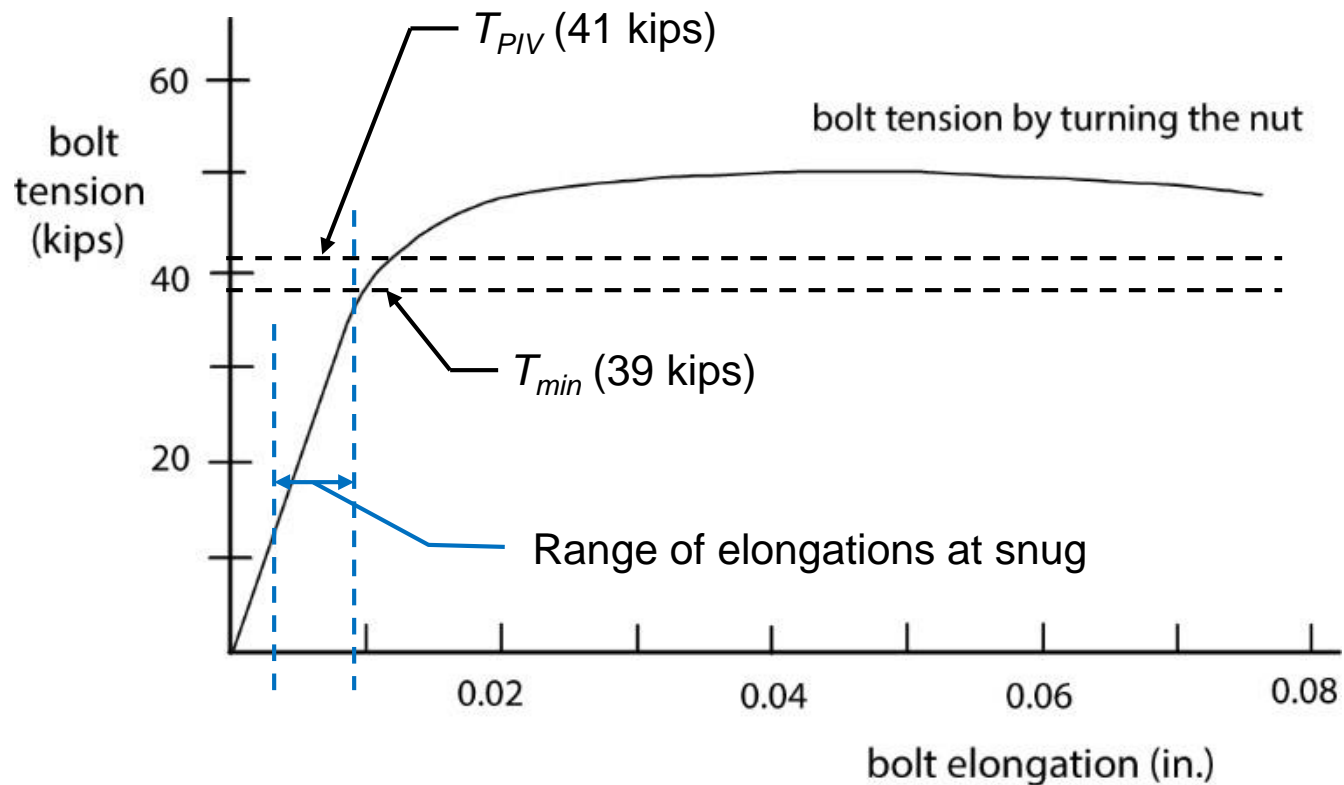
2014 – “The snug tightened condition is the tightness that is obtained with a few impacts of an impact wrench or the full effort of an ironworker using an ordinary spud wrench to bring the plies into firm contact.

Compare with the 1985 definition:

1985 – “The tightness that exists when all plies in a joint are in firm contact. This may be attained by a few impacts of an impact wrench or the full effort of a man using an ordinary spud wrench.”

There is NO Minimum or Maximum Tension at Snug!

SNUG TENSION



From AISC Design Guide #17 for 7/8" A325 bolt

INSTALLED TENSION

AISC & RCSC allow 4 standard installation methods:

- Turn of Nut
- Calibrated Wrench
- TC Bolt
- DTI

INSTALLED TENSION

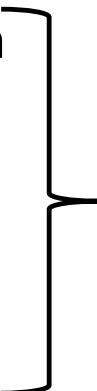
AISC & RCSC allow 4 standard installation methods:

- Turn of Nut

- Calibrated Wrench

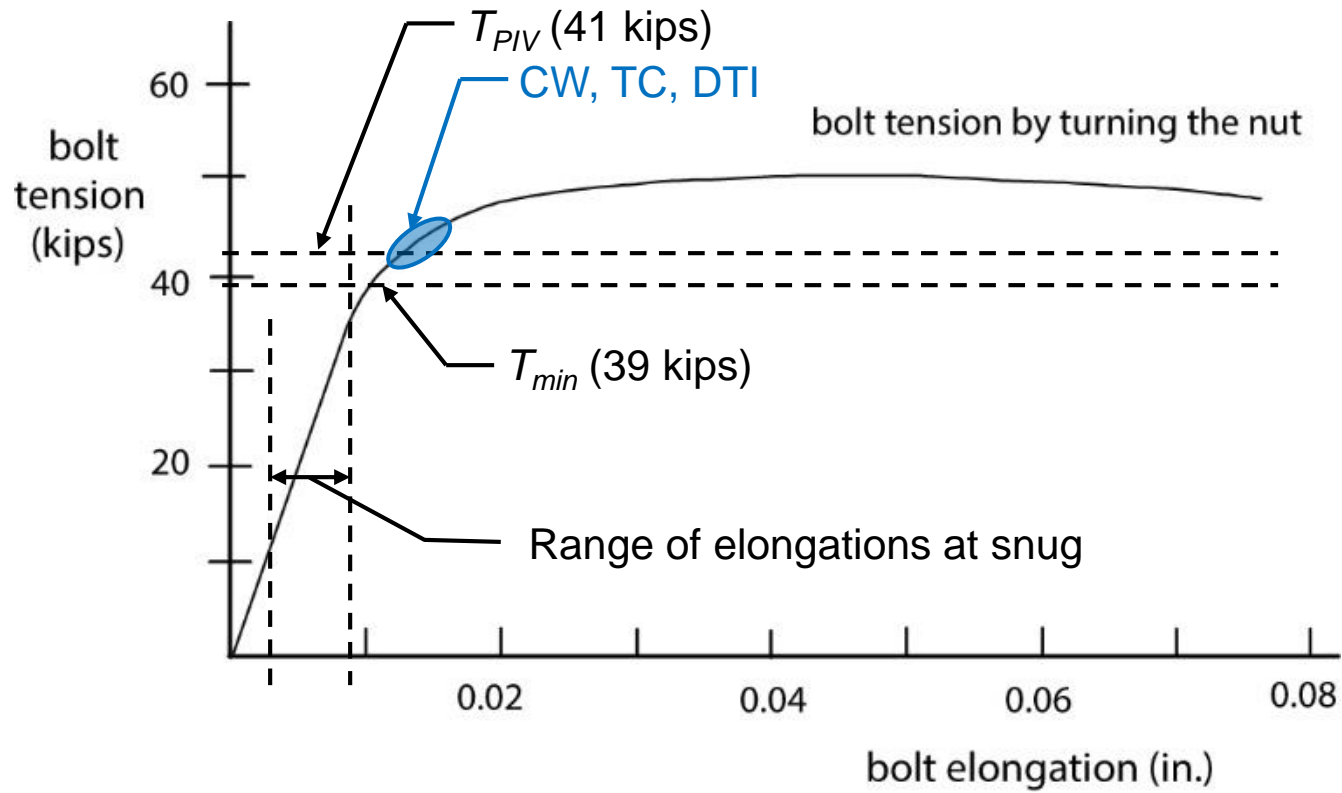
- TC Bolt

- DTI



Manufactured or Calibrated
to be at or near T_{PIV}

INSTALLED TENSION



From AISC Design Guide #17 for 7/8" A325 bolt

TURN OF NUT

History

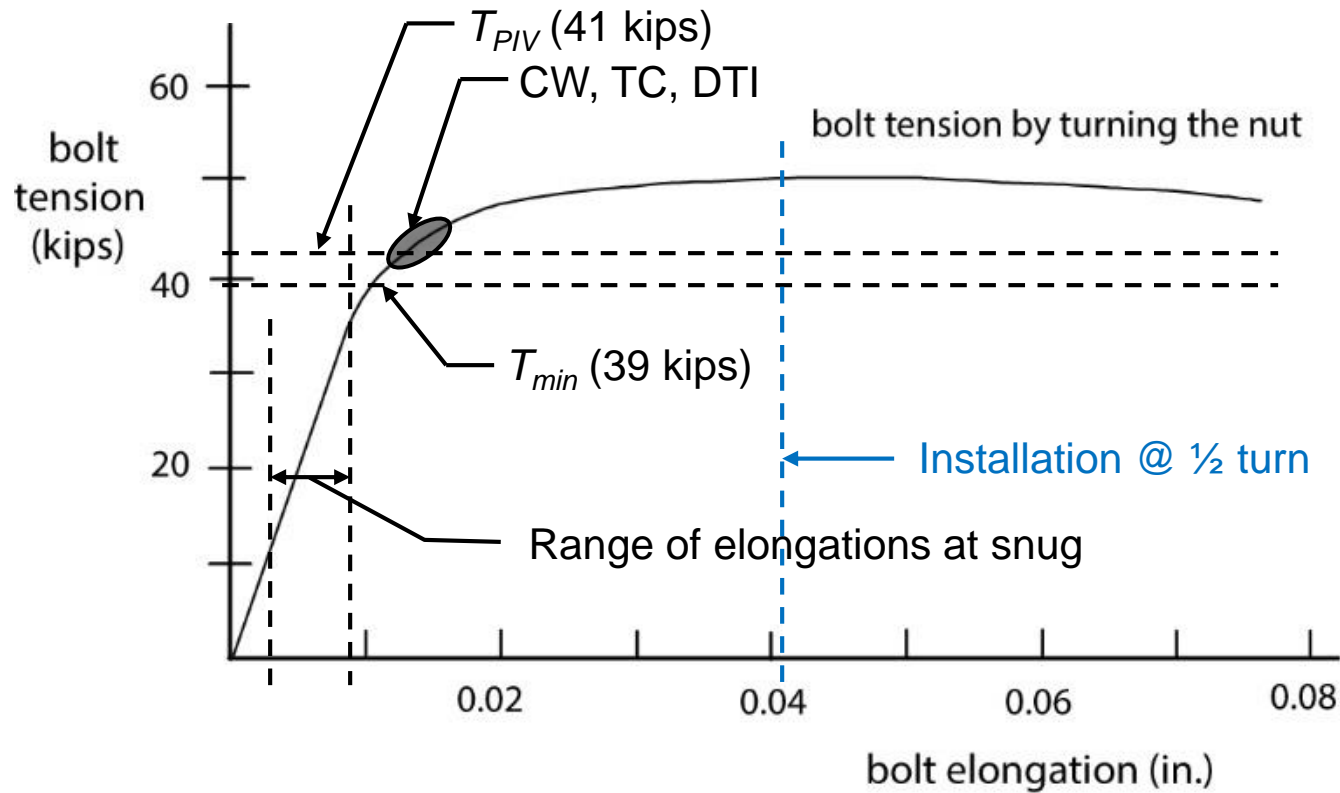
- American Association of Railways published research in 1955
- Allowed by RCSC in 1955 as an alternative
- Introduced to RCSC Specification in 1962
- Extensive research by Bethlehem Steel and others to arrive at current requirements

TURN OF NUT

- Tests show installed tensions 25% - 35% over the minimum required
- Relies on a known thread pitch (9 threads per inch for a 7/8" structural bolt) and known bolt stiffness



INSTALLED TENSION



From AISC Design Guide #17 for 7/8" A325 bolt

INSPECTION

RCSC & AISC Chapter N:

- **It shall be ensured 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 fastener assemblies are match-marked after the initial fit-up 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 8.1 shall not be cause for rejection.**

INSPECTION

No further evidence of conformity is required.

- **Torque alone is not a valid measure for fully tensioned installation.**
- **Standard torque-tension relationships are not allowed by the RCSC Specification.**
- **The torque used in the calibrated wrench method must be calibrated...**
 - Daily
 - For every installation tool
 - For every combination of bolt, nut and washer lot

WHY DO WE NOT INSPECT USING TORQUE?

1"x2-1/2" A325 Bolts

300 ft-lb Installation Torque

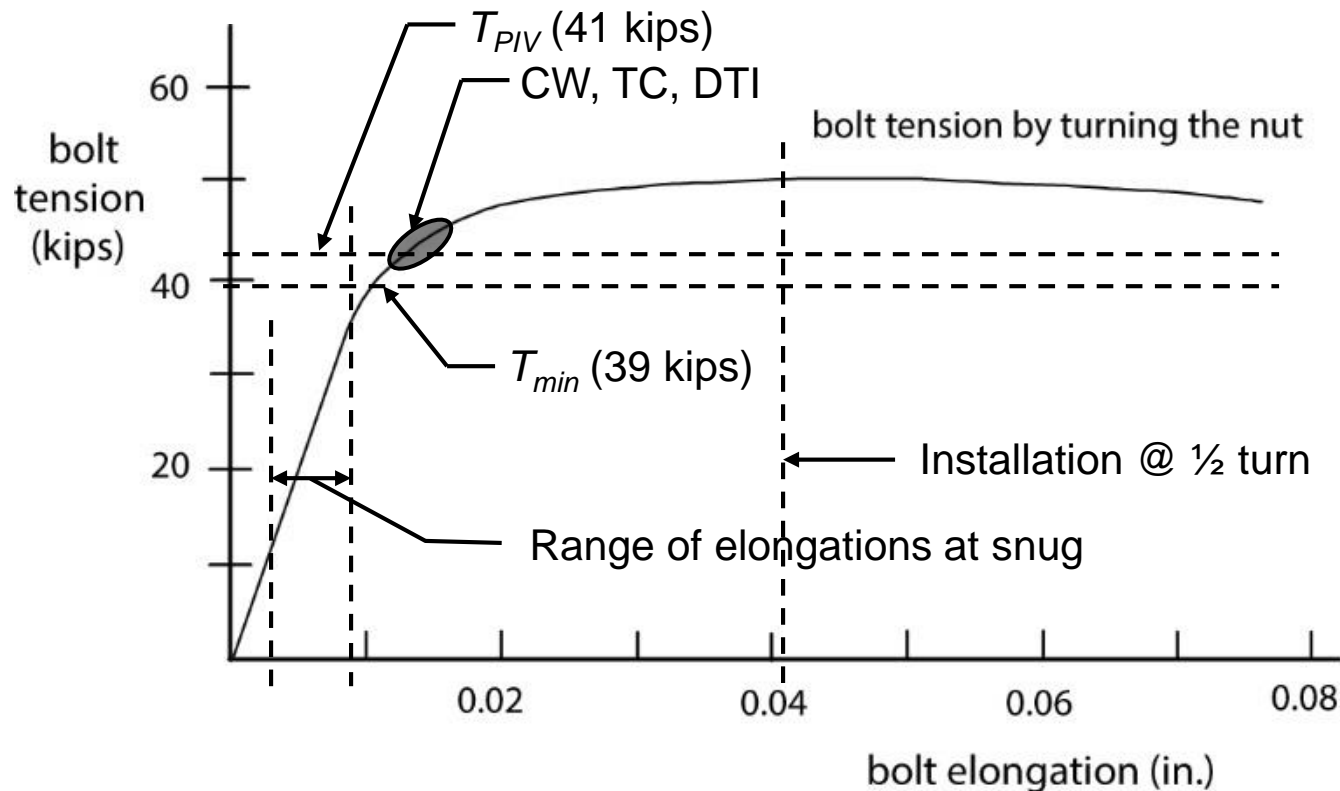
Installed Tension, kips			
	Dry	As-Received	Lubricated
1	14	24	36
2	15	24.5	38
3	17.5	24	37

Low – 14,000 lbs
K = 0.257

High – 38,000 lbs
K = 0.097

24,000 lb Variance in Tension!!

CAN BOLTS BE OVERTENSIONED OR OVER-ROTATED?



Over-rotation is not a cause for rejection. This is stated for each of the pretensioning methods presented in Section 9.2 of the RCSC Specification. If the bolts are over-rotated, they will break during installation and the problem will be immediately apparent.

IF BOLTS BREAK DOES THIS MEAN WE HAVE BAD BOLTS?

Sometimes it is not a big deal to break a few bolts. Bolts will sometimes be broken while trying to pull thick plies together to obtain a snug tight condition. If the problem begins occurs frequently, the cause for the breaking should be ascertained.

WHAT IS THE REQUIRED STICK THROUGH BEYOND THE NUT?

None. As defined in the Section 2.3.2 of the RCSC Specification, "The bolt length used shall be such that the end of the bolt extends beyond or is at least flush with the outer face of the nut when properly installed." Requiring a minimum stick-through increases the risk of jamming the nut on the thread run-out.

WHAT IS AN “N” BOLT AND AN “X” BOLT?

The terms X-bolts and N-bolts do not refer to different types of bolts, but rather different design assumptions and behaviors.

- “X” bolts have threads eXcluded from the shear plane and are allowed higher design loads.
- “N” bolts have threads iNcluded in the shear plane and have lower design loads.

It is important that “X” bolts are installed correctly – the connection is depending on these higher design values!

WHAT IS AN “N” BOLT AND AN “X” BOLT?

The rule of thumb is to insert the bolt through the thinner ply, NOT as shown in the figure

