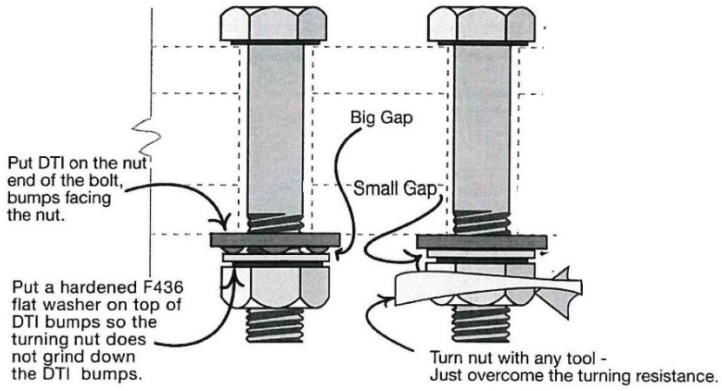
Direct Tension Indicators/DTIs



DTI's are individual bolt load cells, which measure pretension developed during tightening, regardless of torque resistance of the bolt. By far the simplest method, a DTI is put on one end of a bolt and tightened until the bumps are compressed enough so that a feeler gage cannot be inserted all around, or when the Squirter® DTI has deployed silicone properly. DTI's are completely independent of torque resistance of the bolt assembly, and because the compression of the DTI bumps can be visually observed, bolt installers tend NOT to leave the bolts with insufficiently compressed DTI's.

When Using Squirter® DTIs, Installers don't miss any bolts. Inspection by using a feeler gage (on a sample of the bolts only) can be done by anyone at any time. If the DTI is put on the nut end of the bolt, tightening can be done by one person because it is not necessary to hold the bolt roll.

Pre-Installation Verification

Per AISC/RCSC section 7 Pre-Installation Verification, fastener assembly testing must be conducted, onsite, by the installation crew, using actual installation tools. Contrary to popular opinion Pre-Installation Verification testing **DOES NOT** pass or fail fastener assemblies. Testing is intended to discover possible issues between fasteners, tools and installers, before field bolting operations commence.

The next few sections describe issues that may be highlighted by Pre-Installation testing results.

Fasteners:

Are the fastener assemblies capable of achieving 105%, or more, of minimum required bolt pretension at all?

Torque must be applied to the fastener assembly until the tension calibrator indicates adequate pretension or the bolt fails, whichever occurs first. Failure occurs by either the bolt breaking before minimum pretension, or tensile load climbs and then falls, as indicated by the tension calibrator, without ever achieving minimum pretension. Except for TC bolts[1], applying additional lubricant may

[1] *The Research Council on Structural Connections*, **Specification for Structural Joints Using High-Strength Bolts**: Section 2.10.4 “matched bolting assemblies [TC bolts] shall not be relubricated by anyone other than the Manufacturer”

alleviate failure. However, if additional lubricant solves bolt failure, all fasteners represented by lubricated test samples, must be similarly lubricated.

Tools:

Do the installation tools have enough output torque to tighten adequately lubricated fastener assemblies, to at least 105% of minimum required pretension?

If the full effort of an installation tool applied to a fastener assembly, does not result in at least 105% of required minimum pretension, the tool must be replaced for testing as well as for installation. While not always true, an adequate installation tool should have a drive chuck at least as large as the fasteners being tightened. For example, when tightening ¾" bolts, the installation tool should have a square drive chuck of ¾" or more. Also, a tool's manual may claim a higher output torque than the tool can produce. Such claims are usually stated vaguely, such as, claiming the tool's motor ***can produce*** some high amount of torque. This statement may describe no-load torque output but once load is applied, the high torque described will not be realized.

Installation crews:

Do the installers understand how to employ the selected method?

The installers must understand that a snugged tightened condition must be achieved before the pretensioning method is employed. Once a snug condition exists, the installers must fully understand the method they employ and not confuse, or combine, fundamentals of individual methods. Such as applying a torque value to compress a DTI or use a torque value as an inspection technique. Doing so combines elements of Calibrated Wrench and DTIs.

Snug-Tightened Joints:

Every bolted joint must be snug-tightened before a pretensioning method can be performed. Snug-tighten is defined as the effort applied to bring the steel plies into *firm contact*. AISC/RCSC describes the effort as the full effort of an ironworker or a few impacts of an impact wrench (section 8.1) until the nut cannot removed by hand. An attempt at manual nut removal is the only requirement for inspection (section 9.1). There is no pretension requirement for a "snugged" joint. Per AISC's **Specification for Structural Steel Buildings** (AISC 360) Section J3:

> "There are no specific minimum or maximum tension requirements for snug-tight bolts."

With only hand tight as the inspection criteria, Snug-tight may begin with a pretension that is negligible or zero.

Conversely, snug-tightening may result in a pretension near or greater than the minimum required and may strip or break the bolt. This is especially true of bolt diameters ¾" and below. Also, if the bolt survives, a DTI will prematurely flatten and must be replaced before pretensioning begins.

Verification Basics

The following content applies to AISC/RCSC Pre-installation testing only. Individual projects, State DOTs and Federal Highway specifications may differ substantially and will not be covered here. The following represents Applied Bolting Technology®'s interpretation of AISC/RCSC Pre-installation testing based on *The Research Council on Structural Connections'*, **Specification for Structural Joints Using High-Strength Bolts** (AISC 348) and the *American Institute of Steel Construction's* **Specification for Structural Steel Buildings** (AISC 360). Anyone interested in a different interpretation is welcome to read the documents themselves.

Verification testing can be summarized as snug-tightening, at least three sample fastener assemblies, in or with, a tension calibrator, applying the selected pretensioning method, and confirming at least 105% of minimum required pretension has been achieved. While each method accomplishes this with different tools, fastener components, or tightening techniques, all 4 pretensioning methods follow these basic principles of snug fastener, apply method, and verify conformity to specification. Lastly, all acceptable methods are expected to permanently deform the fastener into its inelastic region[2].

Sampling:

Pre-Installation Verification testing begins with sampling. Per AISC/RCSC section 7.1:

> "On a sample of not fewer than three complete bolting assemblies of each combination of diameter, length, grade, and lot to be used in the work & Using bolting assemblies that are representative of the condition of those that will be pretensioned in the work" (AISC/RCSC 16.2-52).

Regardless of method, it is critical that assembly samples be ***TRULY REPRESENTATIVE***, that is, in similar condition as fasteners being actively pretensioned. Testing a "new" fastener, removed directly from sealed shipping receptacles, does not constitute a representative sample, unless only new condition fasteners are actively being pretensioned.

Fasteners that have been snug-tightened & exposed to the weather, for any amount time, must be verified as is, if this condition accurately represents the fasteners' being tightened in the steelwork. ***TRULY REPRESENTATIVE*** samples are especially important for TC bolts and Calibrated Wrench installation and testing because these methods are negatively affected by weathering and lubrication degradation.

[2] AISC/RCSC 16.2-47 "In any of the foregoing installation methods, it can be expected that a portion of the bolt assembly (the threaded portion of the bolt within the grip length and/or the engaged threads of the nut and bolt) will reach the inelastic region of behavior. This permanent distortion has no undesirable effect on the subsequent performance of the bolt."

Tension Calibrator Steps

The following lists the steps for both Standard (non-squirting) and Squirter® type ASTM F959 DTIs

1. Place each unique configuration of sample fastener assembly, containing a DTI, in a tension calibrator with washers placed in accordance with section 6.1, if necessary, and a washer against the DTI bumps.
2. Snug the fastener in accordance with AISC/RCSC section 8.1 and inspect per section 9.1.
3. Tighten the fastener assembly until the tension calibrator indicates 105% of the minimum required bolt pretension as listed in AISC/RCSC Table 5.2 or AISC 360 table J3.1M, as appropriate.
4. Insert the appropriate feeler gauge into each available space between the DTI protrusions until the gauge physically touches the bolt shank. Each instance the feeler gauge fits between the DTI protrusions, and touches the bolt shank, shall be known as an entry. Each time the feeler gauge does not touch the bolt shank, shall be known as a refusal.
5. The number of entries may not be zero. Conversely, the number of refusals may not be 100%. In other words, a DTI must not be completely flattened at 105% of the minimum value listed in AISC/RCSC table 5.2 or AISC 360 table J3.1M.
6. The number of entries/refusals defines the unique assembly's test gap[3] and Job Inspection Gap.
7. Record the number of refusals as the baseline for field inspection. The number of refusals permitted in the steelwork must be more than assembly's test gap discovered during verification. For example, if the test gap is defined as 0 refusals, out of a potential of 5, the Job Inspection Gap shall be at least one additional refusal in the steelwork.
8. If the number of entries equal zero and refusal count is 100% at 105% of the value in in AISC/RCSC table 5.2 or AISC 360 table J3.1M, consult the advisory section[4] of Applied Bolting Technology®'s website and apply the recommendation described therein.

Bolting Methodology, non-squirting DTI

1. Snug the steel plies, in as many steps as necessary, to bring the steel into firm contact as required by AISC/RCSC section 8.1, without compressing the DTI below the Job Inspection Gap. If the DTI is compressed below the Job inspection Gap, during the snugging operation, remove and replace the DTI.
2. After snugging, apply enough torque to compress the DTI until the residual gap is less than the Job Inspection Gap.

[3] ASTM F959 Appendix X1. "The job inspection gap shall be a gap less than the measured DTI test gap at 1.05× the minimum required bolt tension."

AISC/RCSC 16.2-xi: Job Inspection Gap. A gap between a direct tension indicator and the hardened surface on which it bears that is less than the gap measured in a bolt tension measurement device when a tension equal to 1.05 times the minimum required pretension is applied to the bolting assembly.

[4] Additional assistance is available by directly contacting Applied Bolting Technology via email at info@appliedbolting.com or calling 800 552-1999 or 802 460-3100.

Bolting Methodology, Squirter® DTI

1. Snug the steel plies, in as many steps as necessary, to bring the steel into firm contact as required by AISC/RCSC section 8.1, without compressing the DTI below the Job Inspection Gap. If the DTI is compressed below the Job inspection Gap, during the snugging operation, remove and replace the DTI.
2. After snugging, apply enough torque to compress the DTI until the orange Squirt™ indication media is expelled from every available location and the residual gap is less than the Job Inspection Gap.

When inspecting non-squirting & Squirter® DTIs the inspector **MUST:**

1. Verify Pre-Installation Verification has been performed.
2. Verify the joint has been snug-tightened.
3. Verify the DTI bumps have not been compressed beyond the job inspection gap during the snugging operation.
4. Verify DTI bumps have been compressed below the job inspection gap after pretensioning.
5. Accept any fastener with a pretension greater than the minimum required.[5]

When inspecting non-squirting & Squirter® DTIs the inspector **MUST NOT:**

1. Inspect DTI assemblies with a torque wrench.
2. Compare the amount of turn between the nut and bolt with Turn-Of-Nut table 8.1.
3. Reject DTIs that have been completely flattened during pretensioning.

Minimum Bolt Pretension Per AISC/RCSC Table 5.2

Bolt diameter, in.	A325 bolts	A490 bolts
$1/2$	12	15
$5/8$	19	24
$3/4$	28	35
$7/8$	39	49
1	51	64
$1\ 1/8$	64	80
$1\ 1/4$	81	102
$1\ 3/8$	97	121
$1\ 1/2$	118	148

Equal to 0.70 times the minimum tensile strength of bolts as specified in ASTM F3125/F3125M for grades A325 and A490 bolts, with UNC threads, rounded to the nearest kip.

[5] AISC/RCSC 9.2.4 "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."

Minimum Bolt Pretension Per AISC 360, Table J3.1M

Bolt diameter, mm	A325M bolts	A490M bolts
M16	91	114
M20	142	179
M22	176	221
M24	205	257
M27	267	334
M30	326	408
M36	475	595

Equal to 0.70 times the minimum tensile strength of bolts, as specified in ASTM F3125/F3125M for grades A325M and A490M bolts, with MC threads, rounded to the nearest kN.

Pre-Installation Verification Test Teport
using Direct Tension Indicators

Date: _____

Wrench Model: _____

Skidmore No.: _____ **Skidmore Calibration Date:** _____

Bolt Grade: ☐ ASTM A325 ☐ ASTM A490

Bolt Size: _____ ☐ BLACK ☐ GALVANIZED ☐ DACROMET

Lot No.: _____

DTI Lot & config.: _____ ☐ DTI ON NUT SIDE ☐ DTI ON HEAD SIDE

Nut lot number: _____

F436 FW: _____

F436 Wide FW: _____

Required Tension: _____
(5% over minimum tension)
(7/8" Minimum = 39 kips, 5% over = 41 kips)

Sample #1
Bolt Tension _____

☐ .005"
☐ .015"

	ASSEMBLY ACCEPTABLE	
Refusals	**Yes**	**No**

Sample #2
Bolt Tension _____

	ASSEMBLY ACCEPTABLE	
Refusals	**Yes**	**No**

Sample #3
Bolt Tension _____

	ASSEMBLY ACCEPTABLE	
Refusals	**Yes**	**No**

Inspector: _____ **Date:** _____