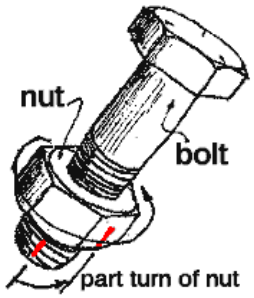
Turn-of-Nut/Part Turn Method



Turn-of-Nut

Note: As with every bolt pretensioning method, Turn-of-Nut may only be performed after all steel plies in a connection have been drawn into firm contact, i.e. snug-tightened. Failure to do so will result in inadequate bolt pretension and loose connections. Also, The Pre-installation Verification fastener testing must be conducted per applicable AISC/RCSC sections with the caveat that Turn-of-Nut verification may not verified by Direct Tension Indicator verification (AISC/RCSC 16.2-59).

Turn-of-Nut is performed by rotating the nut or bolt of a fastener assembly a specific turn angle based on the fastener's length, and diameter while restraining the unturned element from rotating.

Pre-installation Verification

Per AISC/RCSC section 7 preinstallation verification, fastener assembly testing must be conducted, onsite, by the installation crew, using actual installation tools. Contrary to popular opinion Preinstallation 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 instances that may be highlighted by preinstallation testing results.

Fasteners

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

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

[1] AISC/RCSC, *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"

If the full effort of an installation tool applied to a fastener assembly, does not result in at least 105% of required minimum tension, 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 tensioning 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 rotate the nut to turn angle listed for Turn of Nut or employing a torque wrench as an inspection technique after the turn is complete. Doing so combines elements of Calibrated Wrench and Turn of Nut.

Snug-tightened Joints

Every bolted joint must be snug-tightened before a pre-tensioning 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."

The snug-tight condition is critical for the Turn of Nut method since it relies on the snug position as its starting point. With only hand tight as the inspection criteria, Snug-tight may begin with a pretension that is negligible or zero. If so, the turn listed in AISC/RCSC table 8.1 may result in less than minimum required pretension to comply with AISC/RCSC table 5.2.

Conversely, snug-tightening may result in a pretension near or greater than the minimum required, and the required turn may strip or break the bolt when employed. This is especially true of bolt diameters ¾" and below.

Snug-tightening does not affect the success of other methods. Calibrated wrench, DTIs, and TC bolts do not use a snug position a starting point. If aggressive (high snugging) occurs, these methods will alert those involved aggressive snugging has occurred. A DTI will flatten, a TC bolt will shear, or a calibrated wrench will not advance the nut/bolt during the pretensioning operation. If low snugging occurs, the same three methods will work as designed. The DTI and

TC bolt will remain intact and a Calibrated Wrench will continue to tighten until the stall torque is reached.

Pre-installation 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 pre-tensioning method, and confirming at least 105% of minimum required tension has been achieved. While each method accomplishes this with different tools, fastener components, or tightening techniques, all 4 tensioning 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 7.2:

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

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

1. Place each unique configuration of sample fastener assembly in a tension calibrator with washers positioned in accordance with AISC/RCSC table 6.1, if necessary, and section 6. 2.
2. Snug the fastener in accordance with AISC/RCSC section 8.1 and inspect per section 9.1.
3. Apply the appropriate turn angle based on the ratio of the bolt diameter to its length (table 8.1).
4. Verify the resulting pre-tension meets or exceeds the value in table 7.1.
5. If the turn angle does not produce adequate tension, continue turning until the resulting pre-tension meets or exceeds the minimum required bolt pre-tension. Since table 8.1 permits an upper tolerance for each rotation angle/turn, it is allowable to rotate the nut beyond the value listed in the table. However, if more turn is necessary, the ACTUAL turn angle/rotation determined must be used for field bolting operations, and not the table's listed turn.

Bolting Methodology:

1. Determine the ratio between the fastener's length and diameter as well as the slope disposition of the outer steel plies.
2. 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.
3. Using a marker, or similar, draw a mark from the center of the end of the bolt, across the nut, and onto the steel. This will indicate the starting position of the nut.
4. Apply the specified turn from the appropriate table, or from tension calibrator testing, while the unturned element is restrained from rotation (usually requiring a second installer).
5. Rotation exceeding the table can be ignored and may not be corrected or reworked except by replacing the fastener assembly.

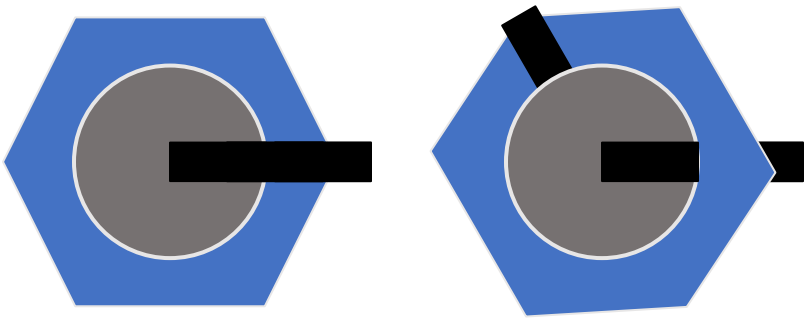


Figure 1: Marked nut, bolt & steel, before and after 2/3 turn.

For reference, values from AISC/RCSC table 8.1 of the *Research Council on Structural Connection's* (RCSC) **Specification for Structural Joints Using High Strength Bolts**, on the next page.

Nut Rotation from Snug-Tight Condition Table

Bolt Length	Flat Surfaces under Bolt Head and Nut	One face normal to bolt axis, other sloped not more than 1:20	Both faces sloped not more than 1:20 from normal to bolt axis
≤ 4D	**1/3 turn**	**1/2 turn**	**2/3 turn**
4D ≤ 8D	**1/2 turn**	**2/3 turn**	**5/6 turn**
8D ≤ 12D	**2/3 turn**	**5/6 turn**	**1 turn**

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 (1/6 turn) and minus 0 degrees.
Applicable only to *joints* in which all material within the *grip* is steel.
When the bolt length exceeds 12*db*, the required nut rotation shall be determined by actual testing in a suitable *tension calibrator* that simulates the conditions of solidly fitting steel.
Beveled washer not used.

Inspection

The inspector **MUST:**

1. Verify pre-installation verification has been performed.
2. Verify the joint has been snug-tightened.
3. Verify the original position of all elements.
4. Routinely witness the installation crew turning the nuts/bolts.
5. Verify the final rotated position of all elements.
6. Prohibit excessive rotation discovered or witnessed from being adjusted to reflect turn values from AISC/RCSC table 8.1.

The inspector **MUST NOT:**

1. Use a torque wrench as an inspection tool. Inspection is only as described above, verifying initial position at snug and final position after nut is turned.
2. Assume marking was applied prior to turning. Tightening and THEN marking the nut, after the turn is a very popular way to perform Turn-of-Nut and is an undetectable deception, if initial position marks are not observed by the inspector.
3. Instruct bolting crews to back off any turn that is greater than what appears in the table. Over rotation is not a cause for rejection or rework. Compensating for over rotation, by backing the nut off, will result in less than the required pretension.

While it is recommended that the bolt, nut, and steel be marked and inspected prior to Turn-of-Nut implementation, this step is not mandatory. In any case, failure to inspect nuts in their original (snug), un-turned position will result in unverifiable Turn-of-Nut execution. Nut marking does not relieve an inspector's responsibility to inspect the connection twice, before and after the turn.

Minimum Bolt Tension 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.

Advisories:

Ineffective for some bolts, The Guide:
Users of large diameter high-strength bolts, especially A490 bolts, should be aware that the RCSC specification requirement for installation of short grip bolts may not produce the required preload [pretension]. If such bolts are to be used in a slip-resistant joint [i.e., slip critical and pre-tensioned], calibration tests in a load-indicating device are advisable. (Kulak 59)

Hot Dipped Galvanizing, RCSC:
Some problems with the turn-of-nut pretensioning method have been encountered with hot-dip galvanized bolts. (AISC/RCSC 16.2-60).

Bolt Lubrication too effective or absent, RCSC:
Specification requirements for minimum turns testing of galvanized fasteners. Job-site testing in the tension calibrator demonstrated that the lubricant reduced the coefficient of friction between the bolt and nut to the degree that "the full effort of an ironworker using an ordinary spud wrench" to snug-tighten the joint actually induced the full required pretension. Also, because the nuts could be removed with an ordinary spud wrench, they were erroneously judged by the inspector to be improperly pretensioned. Excessively lubricated high-strength bolts may require significantly less torque to induce the specified pretension. The required pre-installation verification will reveal this potential problem.

Conversely, the absence of lubrication or lack of proper over-tapping can cause seizing of the nut and bolt threads, which will result in a twist failure of the bolt at less than the specified pretension. (AISC/RCSC 16.2-61).

AISC/RCSC section 9.1 snug-tightened inspection criteria flawed:
AISC/RCSC section 9.2.1 requires the inspector to witness one element being rotated relative to the other. If not, improper tension may result if an installation crew only applies the minimum amount of snug-tightening per section 9.1, **Snug Tightened Joints:**

> 9.1 ...It shall be determined that all of the bolts in the joint have been tightened sufficiently to prevent the turning of the nuts without the use of a wrench. No further evidence of conformity is required for snug-tightened joints.

If only hand tightening is used as a snug inspection criterion, it is possible for Turn-of-Nut's initial starting point, (i.e. adequate snug) will not be achieved and the method will fail. Such failures will not depend on whether fasteners were marked or not.

Canadian Institute of Steel Construction (CISC) Turn-of-Nut Installation:

The CISC Turn-of-Nut installation method is similar to AISC/RCSC Turn-of-Nut with a few exceptions.

1. Required turn values are the same when both faces normal as well as when one face is sloped 1:20.
2. 3/4 turn to be applied to all instances, when both faces sloped 1:20.
3. The acceptable rotation tolerance is ±30°.
4. Beveled washers are required when either steel ply is sloped 1:20 Max when using ASTM A490 and A490M bolts.
5. CISC Turn Table 8 does not limit itself to 12" maximum bolt length, as the RCSC does.
6. When both surfaces sloped 1:20 max, all bolts rotated 3/4 turn (RCSC requires length dependent turn values).

For a complete turn details, please refer to the *Nut Rotation from Snug-Tight Condition* table within the latest CISC **Handbook of Steel Construction.**

Inspection:

The inspector **MUST:**

1. Verify pre-installation verification of all assemblies has been performed.
2. Verify the joint has been snug-tightened.
3. Verify the original position of all elements.
4. Verify the final rotated position of all elements.
5. Routinely witness the installation crew actually turning the nuts/bolts.
6. Prohibit excessive rotation discovered or witnessed from being adjusted to reflect turn values from the applicable table within the CISC handbook.

While it is recommended that the bolt, nut, and steel be marked and inspected prior to Turn-of-Nut implementation, this step is not mandatory. In any case, failure to inspect nuts in their original (snug), un-turned position will result in unverifiable Turn-of-Nut execution. Nut marking

does not relieve an inspector's responsibility to inspect the connection twice, before and after the turn.

Figure 1: Ideal marking technique clearly indicating 1/3rd turn, However, the three bolts on the left are ready for initial inspection; the three on the right appear turned but it is impossible to know if they were turned or marked to appear turned.

CISC Advisories:

See advisories for AISC & RCSC.

Additional Advisories:

While the CISC does not specifically require Pre-installation Verification testing of all fasteners when using Turn-of-Nut per se, testing is recommended to assure hardware compliance with the appropriate ASTM Specification. Thread failure (stripping) will not be discernible otherwise.

Figure 3: These four nuts appear to have been turned although the exact angle is not obvious since the lines extend completely through the bolts' diameters. Nevertheless, without inspection of their initial position, turn or whether the joint was properly snug-tightened, induced pretension cannot be verified.

Figure 2: Obvious deception attempt. While markings suggest each nut or bolt has been rotated, the nut appears to be in its initial position suggesting bolt rotation. It is unlikely the bolts were rotated relative to the nuts since the washers are under the nuts, meaning the hex heads of the bolts would need to be rotated directly against the painted steel surface. A difficult endeavor, that would be exaggerated by the additional effort required to perform proper Turn-of-Nut in the first place. The gap along the upper flange also implies

DTIs and Turn of Nut

While DTIs may not be used when the chosen bolting method is **Turn of Nut**, adding a DTI to a structural bolting assembly changes the bolting method to a DTI installation. This does not mean **Turn of Nut** methodology cannot be applied to a DTI installation.

Tools designed to perform Turn of Nut independently will complement DTI installations by providing a means to limit overzealous or lackadaisical tool operators. The only requirement is the turn angle will need to be increased to account for the DTI gap closure absorbing some of the turn angle. This is especially useful when bolting per federal highway or state DOT standards because such standards often require DTIs to have at least a visual gap, after tightening. With a **"Turn of Nut"** tool, a turn angle that results in at least one visible gap, can easily be dialed in. Lastly, using a tool specifically designed for **Turn of Nut**, will not require match-marking the bolt prior to the turn since compression of the DTI, verified the appearance of orange media, will denote tool application, i.e., adequate tension.

It is also possible to use a tool that does not have an angular setting by marking the tool's socket at two places @ 180° degrees apart. The tool is placed on the fastener with one of the markings facing up and the other facing the ground. Next, tighten the bolt in 90° increments[1] until orange media appears at all available bump locations of the DTI, erring on the side of more flat bumps is better.

For installations following the AISC/RCSC specification, it is permitted to leave the DTI completely flat, with all feeler gage entry points closed. However, when following some highway and DOT specifications, at least one feeler gage entry point or a visible gap may be required. If so, determine the angle, in 90° increments, that satisfies all gap constraints.

[1] Increments of 90° are preferable to other angles because perpendicularity is universally recognizable.

Installation results using DuraSquirt® DTIs vs. Turn-of-Nut

Edmonton, AB Modularization Yard
September 2015
19 connections tightened & inspected

tightening method used	men working		hours worked		total man-hours
DuraSquirt® DTIs	1	x	1	=	1
Turn-of-Nut	2	x	4	=	8

Get DuraSquirt® DTIs

*Results from Kiewit Mod Yard trial