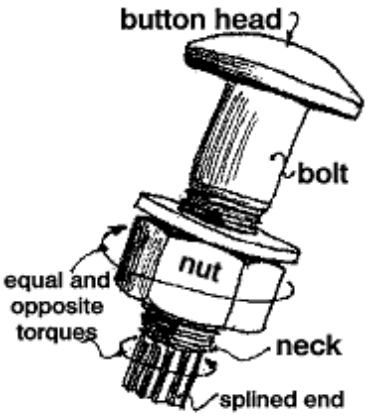
TWIST-OFF Bolts/TC Bolts



Twist-off Bolts

As every method, the RCSC/AISC specification requires Pre-Installation Verification testing that must be conducted onsite with hardware delivered to site. Test results, by the distributor or manufacturer, **DO NOT** satisfy the specification's requirements. However, test results appearing on supplier Material Test Reports (MTRs) MUST represent all details of bolts being tested. It is especially important that the MTRs represent a coating when bolts are coated.

This method usually defaults to "twist-off" bolts, sometimes called "tension-control" or TC bolts. These assemblies' function by calibrating the torque needed to twist off a splined extension manufactured into the bolt shank. Made correctly, the "twist-off" will occur at a bolt pretension above the minimum required.

The main advantage of "twist-off" bolts is that they can be tightened from one side by one person, although bolt installers now realize that regular hex bolts and DTI's can also be installed one-side, one-man, too.

There are several disadvantages to the "twist-off" system:

1. Special wrenches are needed.
2. TC bolts come in limited lengths and diameters.
3. If ASTM F3125/F1852/F2280 Rotational Capacity bolt testing is requested, TC bolts will most likely fail.
4. Special connection clearances must be detailed for wrench access.
5. Frequently more expensive than hex bolts and DTI's.
6. Galvanized twist-off assemblies are in VERY limited supply.
7. Field relubrication is prohibited by code.
8. Compacting plies must be accomplished prior to twist-off.
9. Deterioration of the thread condition for any reason will change the torque-tension relationship, and Kulak has shown in an ASCE paper that in as little as three days out of protected storage, one-third of all the twist-off bolts tested did not develop the required pretension at break-off.
10. Additional studies conducted by the University of Toronto show TC bolts performance is negatively affected by temperature and humidity changes.

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?

The installation tool 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 splined end breaking off before minimum pretension, or tensile load climbs and then falls, as indicated by the tension calibrator, without ever achieving minimum pretension. For TC bolts there is no permissible way to rework the fastener and retest. Non-compliant production lots must be rejected and replaced, or reworked, by the TC bolt manufacturer.

Tools:

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

If an installation tool applied to a fastener assembly, does not result in at least 105% of required minimum pretension, the cause must be determined before any bolts are final pretensioned in the steelwork. Also, manual, non-powered TC bolt tools, **WILL NOT** result in minimum pretension being achieved.

Installation crews:

Do the installers understand how to employ the selected method?

The installers must understand that a snugged tightened condition must be achieved, and the fastener's splined end remains intact, before a shear wrench is applied to any TC bolt. Any TC bolts whose ends have sheared off during snugging must be removed and replaced.

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. Aggressive snug-tightening may result in a pretension near or greater than the minimum required per AISC/RCSC Table 7.1 and break bolts. This is especially true of bolt diameters ¾" and below.

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 348-20) and the *American Institute of Steel Construction's* **Specification for Structural Steel Buildings** (AISC 360-16). 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[1].

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

[1]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."

installation and testing because these methods are negatively affected by weathering and lubrication degradation.

Tension Calibrator Steps:

1. To be performed with every installation tool and repeated after any changes to the TC bolts original lubricated condition.
2. Place each unique configuration of sample fastener assembly in a tension calibrator with washers positioned in accordance with table 6.1, if necessary, and section 6.2.
3. Snug the fastener in accordance with AISC/RCSC section 8.1 and inspect per section 9.1.
4. Apply the TC Shear tool to the fastener and operate until the splined end twists off the fastener.
5. Verify the resulting pretension meets or exceeds required bolt pretension as listed in AISC/RCSC, table 7.1.
6. If the resulting pretension does not meet the value in AISC/RCSC table 7.1, the fasteners must be returned to the manufacturer for rework and the non-compliant lot of TC fasteners must not be incorporated in the steel work. TC Bolts may not be altered or reworked by anyone but the manufacturer. It is not permissible to remedy noncompliant TC assemblies.[2]

Bolting Methodology

1. Collect only as many bolts to be snugged and tightened during a single shift, from protected storage to prevent lubrication degradation.
2. Minimize fastener exposure to the elements and do not disassemble fasteners into individual components. TC bolts are to remain assembled and in as-new condition up until the moment of installation.
3. 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 twisting the splined end from the fastener. If the end shears off during snugging, the bolt must be discarded and replaced.
4. Immediately, or as soon as possible after snugging, apply the shear wrench to each bolt until the tool twists the splined end off and releases the wrench.
5. If the joint remains snugged for more than a day or even one shift, additional tension calibrator testing may be required, to assure representative samples have been tested. If excessive time has elapsed, or environmental exposure has occurred, prior to final pretensioning, remove representative samples for re-testing in a tension calibrator (see Pre-Installation Verification).

Inspection:

The inspector **MUST:**

1. Verify Pre-Installation Verification has been performed.

[2] AISC/RCSC 348-14, 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”

2. Verify the joint has been snug-tightened.
3. Verify the splined ends have not twisted off during snugging operations.
4. Verify assemblies in the steel work match the condition of bolts tested during Pre-Installation verification or remove non-similar bolts for additional tension calibrator testing.
5. Verify the splined ends have properly severed during installation by the installation tool.

The inspector **MUST NOT:**

1. Accept Pre-Installation test results on new fasteners to represent assemblies that are not in
2. similar condition, due to exposure to the elements.
3. Accept TC bolts unassembled or permit individual component replacement.
4. Allow relubrication by anyone except the manufacturer.
5. Accept TC manufacturer MTR test results in lieu of actual on-site Pre-Installation verification testing.

A pretension that is greater than the [required] value shall not be cause for rejection.[3]

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.

TC Bolt Advisories:

Non-powered manual TC tools DO NOT result in minimum pretension. The tool's manual will state this fact and there is no known way to correct the flaw. Manual tools are only useful for joints that are snug tight only.

[3] RCSC 9.2.3 "A pretension that is greater than the value specified in Table 5.2 shall not be cause for rejection."

Studies conducted by the University of Toronto in 2004[4] and 2007[5] proved:

1. TC bolts behave differently in a Hydraulic Tension Calibrators (Skidmore) than they do when installed in steelwork. Therefore, TC bolt testing, with hydraulic load cells, will show results 10% higher than what will be realized in the steelwork.
2. Wetting a TC bolt, by rain or otherwise, reduces effective pretension by 10%.
3. Changes in temperature negatively affect pretension by 10%.
4. These issues are cumulative, i.e., a production lot of ¾" A325 TC bolts tested in a skidmore whose dial shows 29 kips will only provide ~ 26 kips when installed in steelwork. If rain wets installed TC bolts, of the same lot, effective installed pretension will be ~23.5 kips. Falling temperature ambient air will result in an additional reduction of effective pretension of 21 kips.

Since the 2005 study was funded by the RCSC, the information described above was presented at the 2007 RCSC Annual Meeting, in Cleveland Ohio by Professor Emeritus of U of T, Peter Birkemoe. Professor Birkemoe made the following recommendations that were not adopted into the RCSC Specification:

- Revise the Specification to have bolts removed from the steelwork for verification.
- Revise the Specification for TC bolts to be required to reach 1.1? times the minimum required pretension in the as-received condition and modify the current Pre-Installation verification requirements.
- Add cautionary notes in the commentary about the requirements for cold weather verification and installation.
- Include the "wet" condition as part of the verification requirements.

The above bullet points have been copied from Professor Birkemoe's RCSC presentation, verbatim. To read the complete 2007 report and meeting minutes, proceed to the RCSC website. The report can be found at: **http://boltcouncil.org/files/FinalReportonTCBoltsPhase1.pdf**

The Professor Birkemoe's presentation to the RCSC committee in 2007 can be found by following the link below and reading pages 36 to 50 of the PDF file:
http://boltcouncil.org/files/2009RCSCMainMinutesPackage.pdf

Additionally, ASTM 3125, the standard that governs manufacturing and testing of TC bolts (formerly standards F1852 and F2280), requires assembly testing in a "tension measuring device". For most manufacturers, a hydraulic load cell, such as a Skidmore Wilhelm, is used. Therefore, the pretension values listed on a Material Test Report (MTR) for a TC bolt manufactured lot, should be viewed through the lens of the U of T findings described in number 1, above. Achieved results in steelwork may be 10% less than what is listed on the MTR.

[4] Installation behaviour of ASTM F1852 twist-off type tension control bolts. W. Tan, University of Toronto, 2005.
[5] INSTALLATION CHARACTERISTICS OF F1852 TWIST-OFF TYPE TENSION CONTROL STRUCTURAL BOLT/NUT/WASHER ASSEMBLIES. V. Maleev, University of Toronto, 2007.

DTIs and TC/Twist Off bolts

While it is uncommon for DTIs to be used with TC bolts, it is permissible to do so. The DTI is added to the assembly, the TC shear wrench is applied to the fastener, and the DTI will confirm if the TC bolt was tightened adequately. Also, Squirter® DTIs combined with TC bolts satisfies AISC/RCSC PIV testing requirements so long as the first three assemblies include the Squirter DTI on the head side of the assembly, and the DTI protrusions are flattened below the calibrated gap. After the first three bolts are tightened, subsequent assemblies can have the Squirter DTIs on either the nut or head side.