Instruction Manual

For Installing

HIGH-STRENGTH STRUCTURAL BOLTING ASSEMBLIES

with

DIRECT TENSION INDICATORS (ASTM F959/ASTM F959M) COMBINED INCH/METRIC EDITION

TurnaSure LLC 23rd Ed. August 2016

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INTRODUCTION

High-strength structural bolts are well established as economical and efficient devices for connecting structural steel. When AISC design and construction practices are followed, the *Specification for Structural Joints Using High-Strength Structural Bolts*, Approved by the Research Council on Structural Connections, sets the basic rules for their use. Designers, inspectors, and ironworkers should be thoroughly familiar with this specification. A copy of the current RCSC Specification (August 1st, 2014 Edition) may be downloaded free-of-charge at www.boltcouncil.org

Direct Tension Indicators (DTIs) are recognized by many engineers as the most reliable method for ensuring correct installation and tensioning of high-strength structural bolting assemblies. This manual is written for engineers, construction superintendents, inspectors, and ironworkers to assist in the proper installation of high-strength structural bolting assemblies using DTIs. Following the procedures in this manual will ensure that assemblies have been tensioned to the values required whether used in slip-critical connections, pretensioned connections subjected to direct tension, or shear/bearing connections requiring fully pretensioned bolts.

This manual discusses the theory of slip-critical connections or connections subjected to direct tension, proper installation of DTIs, general rules for bolt installation, problems typically encountered when installing high-strength bolts and other subjects relative to high-strength structural bolting. TurnaSure LLC has years of high-strength structural bolting experience and provides a range of consultation activities including ironworker training, lunch-and-learn seminars, site visits, tool recommendations, specification reviews, and training programs.

TurnaSure LLC also prepares instructional DVDs, and publishes technical reports and articles for publication in trade journals. Should you wish to receive any of this information or be placed on our mailing list, please contact us at the address shown on the inside cover or visit our website www.turnasure.com

INTRODUCTION (Cont.)

Previous editions of this Installation Manual were published in inch series or metric series separately. Since the merger of ASTM F959 and F959M into a combined standard, this manual now covers both inch and metric applications.

THEORY OF HIGH STRENGTH BOLTING

The principle of slip-critical connections relies upon tensioning each bolt in the connection to a specified minimum tension so that desired clamping force will be induced in the connection interface. Service loads are then transferred by frictional resistance in the joint interface rather than through bearing of the bolt shank or threads on the bolt hole edges in shear. In this type of connection there will be no movement of the connected materials when the connection is subjected to applied loads. Movement in many joints is highly undesirable, hence the development of the slip-critical or friction-grip connection. (Figure 1)

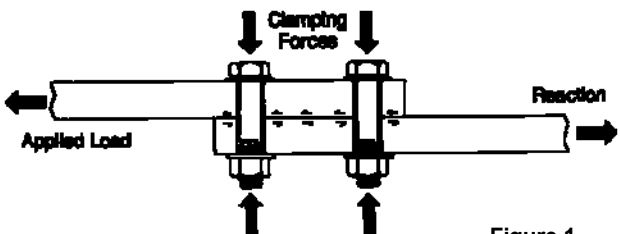


Figure 1

When applied loads are transmitted parallel to the bolt axis, tightening to a specified minimum tension is also important, particularly if the loads are cyclical and could induce loosening or fatigue failure of the bolts. The clamping force at the specified minimum tension should be significantly greater than the applied loads. This will prevent the plies from separating or the bolts from developing an increase in tension stress over the installed pretension stress.

Figure 2 below depicts a pretensioned connection of the type where fully tightened bolts are specified.

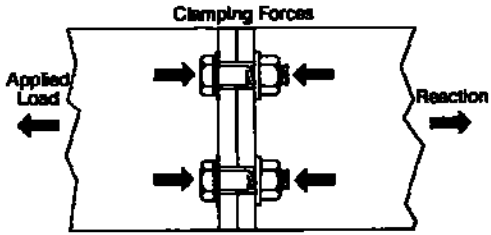


Figure 2

DIRECT TENSION INDICATORS (DTIs)

Direct Tension Indicators (DTIs) are simple and accurate devices for ensuring that bolts have been installed above the specified minimum tension. Used properly they positively ensure adequate clamping force.

Readers who have installed high-strength bolts using "torque/tension" values will notice that this manual does not relate torque to tension. Torque, or twisting force, is not a reliable measure or accurate predictor of bolt tension. DTIs measure tension without regard to how much effort (torque) must be applied to achieve a satisfactory result (clamp force).

A DTI is a steel, washer-shaped device with protrusions, "bumps," pressed out on one face, manufactured according to the provisions of ASTM F959/ASTM F959M. The fact that it resembles a washer is incidental. It is, in fact, a precision made mechanical load cell, a device for measuring tension.

When a DTI is installed on a bolt with the "bumps" placed against a hardened surface like the underside of the bolt head there are noticeable gaps between the "bumps." As the bolt assembly is tensioned, the "bumps" flatten. When the "bumps" are flattened to a gap less than the specified value the bolt has been properly tensioned and required clamping force is present.

A DTI does not make it more difficult to tension a bolt, it merely shows that the bolt has been properly tensioned when the gap has been reduced sufficiently. (Figure 3)

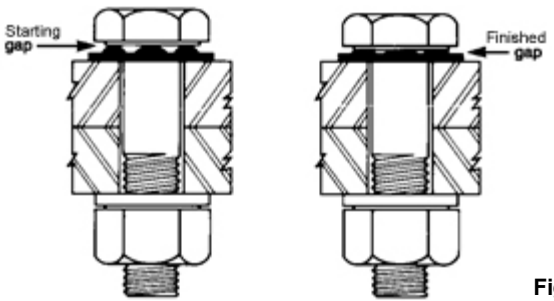


Figure 3

Direct Tension Indicators are supplied either "plain finish," that is without a coating, mechanically galvanized to ASTM B695 Class 55, or produced from Type 3 "weathering steel" for use with Type 3 high-strength bolts. Other coatings and finishes are available upon request.

DTIs are often installed under the bolt head and the nut turned, although numerous alternate configurations are equally valid. For plain finish (uncoated) DTIs, when the bolt is suitably tensioned the gap will be less than 0.015in/0.400mm in *more than half* of the spaces. Coated DTIs are installed similarly, although the criteria for coated DTIs requires that the gap be less than 0.005in/0.125mm in *more than half* of the spaces. (See Page 9 for detailed instructions)

INSPECTION

To assure that bolting assemblies on which DTIs are used are tightened sufficiently, feeler gauges are provided with DTI shipments. Additional gauges are provided free-of-charge to inspectors who request them through the TurnaSure website. Feeler gauges can definitively determine if a DTI is adequately compressed, and the bolt assembly sufficiently tensioned.

INSPECTION (Cont.)

Figure 4 below depicts the use of a feeler gauge to check the gap between the 'bumps' on a typical TurnaSure LLC DTI.

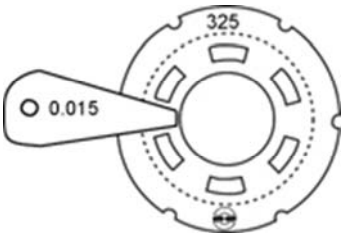


Figure 4

When inserted the feeler gauge must be pointed at the center of the bolt and be at the center of the space. "Notches" in the O.D. of the DTI assist in feeler gauge inspection. (Figure 4).

Ironworkers or other bolting installers typically develop a 'feel' for installation and can install DTIs to the correct gap by eye. Provided that good snugging practices are followed, ironworkers may note the rotation (turn) from 'snug' necessary to sufficiently flatten the DTI and use this as a guide during tightening. Thereafter, a quick visual inspection will verify that the bolts have been adequately tightened. Inspectors will want to verify that the correct gap has been achieved using a feeler gauge on a limited number of DTIs, typically two (2) per connection and 10% overall, and then compare the other gaps by eye.

First-time users of DTIs should note that the ease with which inspection can be performed most often means that substantially all of the bolting assemblies are verified for tension by inspectors. Detailing errors, obstructions to installation tools, and difficult to tighten bolts are much more likely to be detected. It is suggested that this information be handled professionally, as DTIs do not cause these issues, although DTIs do make these issues visually obvious.

INSPECTION (Cont.)

TurnaSure LLC recommends that bolting inspectors obtain relevant qualifications and perform their work consistent with the Code of Ethics applicable to American Welding Society (AWS) Certified Welding Inspectors (CWIs) holding a 'Structural Bolting Endorsement'. Alternatively, bolting inspectors may obtain qualifications through the International Code Council (ICC) and thereby obtain certification as a 'Structural Steel & Bolting Special Inspector'.

Fully compressed DTIs should not be rejected. Some inspectors judge, and some poorly written project specifications imply, that a bolting assembly which has a fully compressed DTI is "overtensioned." No specific definition of "overtensioned" exists in structural bolting literature. Most experts believe that unless a tensioned bolt has broken it is acceptable. As stated in Section 9.2.4 of the RCSC Specification, *"A pretension that is greater than that specified in Table 8.1 shall not be cause for rejection."* For additional reference, see Volume 36, No. 1 of the *Engineering Journal*, "*The Effects of Over-Compressing ASTM F959 Direct Tension indicators on A325 Bolts Used in Shear Connections.*"

It should be noted that the stresses on a structural bolt during tightening are a combination of tensile stresses resulting from increasing bolt tension during tightening as well as torsional stresses induced by the wrench during tightening. The combination of those stresses determines if/when a bolt will break. Once the tightening operation is completed, the torsional stresses from the tightening tool substantially dissipate, leaving the bolt with reserve capacity for additional tensile stresses – as might result from prying forces in a seismic or other in-service event. A good rule of thumb is that an 'overtightened' bolt is one which has been fractured into pieces during installation.

REUSE OF DIRECT TENSION INDICATORS ON HIGH STRENGTH STRUCTURAL BOLTS

Reuse of Direct Tension Indicators (DTIs) which were previously installed on a fully tensioned structural bolting assembly is not recognized by TurnaSure as acceptable. DTIs, like other structural fastener components, are tightened into yield and plastically deform during installation. Thus, reuse of such fasteners cannot be assumed to be sound engineering practice. Admittedly, the RCSC Specification permits the reuse of plain finish ASTM F3125 Grade A325/A325M bolts and is currently silent on the issue of reuse or retightening of DTIs, or for that matter, Twist-Off bolts. TurnaSure does not recommend reuse of *any* structural fasteners. Tightening to 'snug' repeatedly, or anything short of fully tensioning at least once, is not considered a reuse.

Forensic value of previously installed DTIs

DTIs which were installed on structural bolting assemblies in the past can, if the need arises, be used to prove what level of tension the structural bolts were tightened to when originally installed. Provided there is any gap whatsoever remaining in the installed DTIs, verification of installed bolting assembly tension can be demonstrated using a Compression Load Analyzer following removal of the structural bolting assembly from the connection. Any further flattening of the residual gap of a used DTI will require a load equal to or greater than the previously installed load. The above noted test is best left for cases of arbitration, should one arise. For example, an erector may wish to prove that structural bolts were tightened above minimum requirements as part of a defense against claims suggesting otherwise. Similarly, it may be observed that installed (not yet tightened) bolting assemblies have started to get some surface corrosion, and subsequent tightening sufficient to adequately flatten the DTIs will indicate that the condition of the bolts, although perhaps unsightly due to exposure, was nonetheless satisfactory.

Tightening of Large Diameter Structural Bolting Assemblies

ASTM F959/F959M and ASTM F3125 Grades A325, A325M, A490, A490M, F1852, F2280 are limited to diameters less than or equal to 1-1/2in/M36. For diameters above 1-1/2in/M36 users are directed to ASTM A449, ASTM A354, and ASTM F2437 respectively for large diameter fasteners suitable for use in structural applications. The instructions in this manual are equally applicable to DTIs procured to ASTM F2437/F2437M for use with large diameter structural bolting assemblies.

Users of large diameter structural bolting assemblies are advised that greater care in specification is warranted for these fasteners. For example, something as simple as substitution of one thread form for another can result in substantially different tensile strength requirements. (e.g. A 2in 4-1/2 thread-per-inch A354BD bolt has a minimum tensile strength 40kips lower than the same bolt with 8 threads-per-inch. Thus, it is important that the designer communicate to the bolt supplier and the DTI supplier what the minimum specified tension is for their application to ensure that matching components are provided.

Similarly, A490/A490M has a maximum tensile strength requirement to protect against environmental service factors detrimental to service; whereas A354 does not have a maximum tensile strength.

Many practical matters may also arise as a result of specifying large diameter structural bolting assemblies, including inability to perform Pre-Installation Verification Testing because equipment or tooling of adequate capacity may not be available on the jobsite to test the supplied bolting assemblies.

Tooling capable of tightening large diameter structural bolting assemblies is discussed on page 19.

BOLT TENSIONING USING DTIs

METHOD #1

DTI Under the Bolt Head–Turn the Nut to Tension

This method can detect trapped bolts and is therefore most commonly used for multiple ply or jumbo connections with long bolts (typically large ASTM F3125 Grade A490/A490M bolts).

ASSEMBLY

Place the DTI under the bolt head with the 'bumps' facing the underside of the bolt head as shown in Figure 5a. Place a hardened F436/F436M washer under the nut. DTIs can be oriented with the 'bumps' facing in either direction in the configuration shown in Figure 5b.

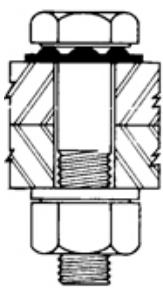


Figure 5a

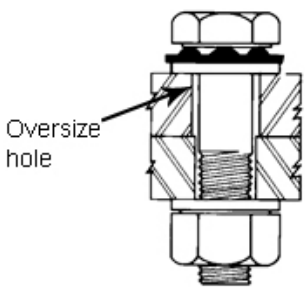


Figure 5b

Notes on Figure 5b: The washer requirements of Table 6.1 of the RCSC Specification require that a slotted or oversized hole under the bolt head (or nut) be covered by a hardened flat washer as shown between the DTI and the bolt hole in Figure 5b, and if the bolt is also an F3125 Grade A490/A490M larger than 1in/M24 the hardened washer must be at least 5/16in/8mm thick. For a long-slotted hole, an external cover plate of sufficient size to completely cover the slot should be provided. DTIs cannot be substituted for flat washers required by the RCSC.

For structural bolting assemblies 1in/M24 and above in which F436/F436M washers are used under the DTI, verify that the Inside Diameter (I.D.) of F436/F436M washers is compatible with the DTIs. Normal sized holes (nominal size + 1/16in/+2mm max) either in a hardened washer or in the structural steel prevents DTIs from dishing. TurnaSure can assist in the procurement of correct washers.

A suitable alternative to Figure 5b is to invert the DTI so that the 'bumps' are against the hardened washer as shown in Figure 5c. This configuration is advantageous when hardened washers with 'over-sized' holes (> nominal diameter +1/16in/+2mm) have been supplied with the structural bolting assemblies as may happen with bolt diameters 1in/M24 and above.

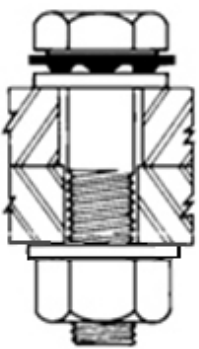


Figure 5c

TENSIONING

For plain finish (uncoated) DTIs turn the nut until the gap between the nut and the DTI face is reduced to less than 0.015in/0.4mm in *more than half* of the entry spaces. For coated or Type 3 'weathering steel' DTIs turn the nut until the gap between the nut and the DTI face is reduced to less than 0.005in/0.125mm in *more than half* of the entry spaces. When turning the nut, prevent the bolt head from spinning with a wrench.

METHOD #2

DTI Under the Nut–Turn the Nut to Tension

This method is commonly used for splices in deep sections or blind applications where it is advantageous to monitor installation during tightening, allowing the installer to quickly and visually judge the work.

ASSEMBLY

Place the DTI under the nut with the 'bumps' facing either the hardened washer (Figure 6a) or a hardened heavy hex nut (Figure 6b). Washer placement is optional, under or over the DTI, except when there is an 'oversized' or 'slotted' hole, as the RCSC dictates washer use over such holes as depicted under the bolt head in Figure 6b and the hardened nut in Figure 6c.

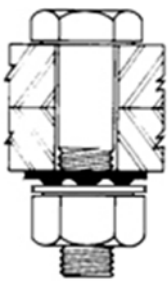


Figure 6a

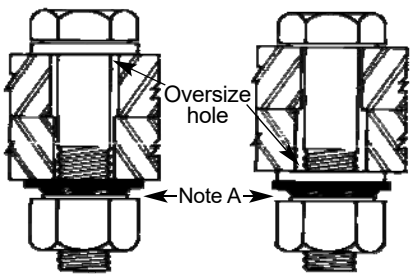


Figure 6b **Figure 6c**

Note A: TurnaSure 'curved protrusion' DTIs (See Page 27) do not require hardened washers between a hardened nut and the DTI.

TENSIONING

For plain finish (uncoated) DTIs as well as coated DTIs or Type 3 'weathering steel' DTIs turn the nut until the gap between the nut and the DTI face is reduced to less than 0.005in/0.125mm in *more than half* of the entry spaces. When turning the nut, prevent the bolt head from spinning with a wrench.

METHOD #3

DTI Under the Bolt Head–Turn the Bolt Head to Tension

This method is typically used for convenience in box sections or blind connections and/or when architectural considerations make use of this configuration desirable.

ASSEMBLY

Place the DTI under the bolt head with the 'bumps' facing the bolt head as shown in Figures 7a thru 7c.

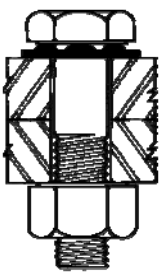


Figure 7a

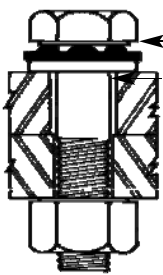


Figure 7b

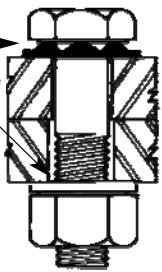


Figure 7c

Note B: TurnaSure 'curved protrusion' DTIs do not require hardened washers between the bolt head and the DTI. DTIs with the older design "straight-sided" protrusions as depicted in Figures 10 and 11 on page 27 would still require an F436/F436M washer between the turned element and the DTI.

It is also suitable to install the DTI such that the protrusions are facing an F436/F436M hardened washer as shown in Figure 7d. This configuration may be advantageous when larger diameter (1in+/M24+) structural bolting assemblies have been supplied with hardened washers that have an over-sized inside diameter greater than the nominal diameter +1/16in/+2mm.

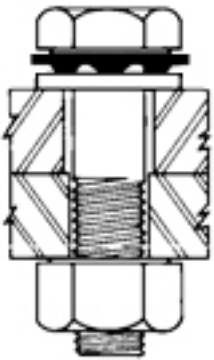


Figure 7d

TENSIONING

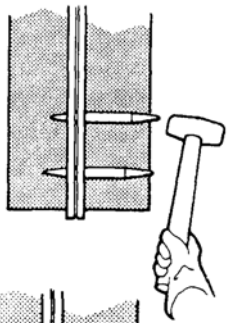
For plain finish (uncoated) DTIs as well as coated DTIs or Type 3 'weathering steel' DTIs turn the nut until the gap between the nut and the DTI face is reduced to less than 0.005in/0.125mm in *more than half* of the entry spaces. When turning the nut, prevent the bolt head from spinning with a wrench.

For bridge applications see **INSTALLATION INSTRUCTIONS FOR BRIDGE APPLICATIONS PER AASHTO** on page 26 of this manual.

RECOMMENDED BOLT INSTALLATION PROCEDURE

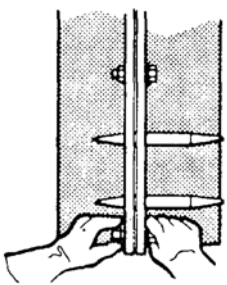
Step 1

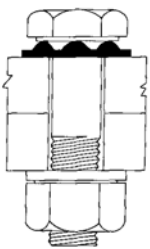
Bring the members to be joined together and align the holes with drift pins. (Bolts should not be used as drift pins to achieve alignment.)



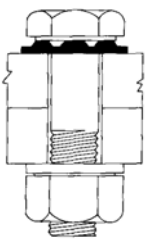
Step 2

Fill the remaining holes with high strength bolts, nuts, washers, and DTIs of the correct size and grade. Partially tension the bolts to snug the connection. Partial tension is evidenced by slight, but visible, flattening of the DTI protrusions. At this point there will be about 50% of the minimum specified tension in the bolt. This amount of tension should be sufficient to produce a snug connection. Work from the center (or a point of intimate contact) of the connection to the free edges.





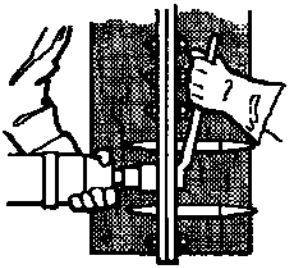
No Tension



Partial Tension
“ Snug”

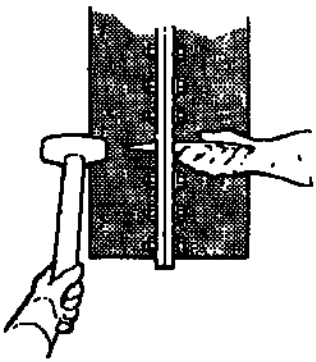
Step 3

Tension the bolts until the average gap on each DTI is as specified. W ork from the center (or a point of intimate contact) of the connection toward the edges. Leave the drift pins in during this operation. Premature removal of the drift pins may cause trapping of the bolts by joint slippage.



Step 4

Knock out the remaining drift pins, replacing them with bolts, nuts, washers, and DTIs. Tighten these bolts.



Notes

On A490/A490M bolts, it is advisable to stop tightening before all of the gaps are closed completely. There is no need to tension these bolts (which have less ductility than A325/A325M bolts) that much. However a bolting assembly with a DTI that has 'zero gap' should not be cause for rejection. When using impact wrenches, final tightening should be accomplished in ~10 seconds or less. Large A490/A490M bolts may take as long as 20 seconds. If these limits are exceeded check to see that the correct tools are being used or that one of the problems listed on pages 16 thru 18 is not being encountered.

Dry or Rusty Threads or Nut Faces –Usually caused by poor storage conditions or adverse environmental exposure conditions (rain, dust, corrosion) after initial installation and snugging operations and before performance of final tensioning. Use of dry or rusty bolts, nuts, or washers should not be permitted. Ideally nuts, bolts, washers, and DTIs should be kept in *protective storage* with containers not opened until immediately before use. Just as importantly, the time between initial installation of structural bolts and final tensioning should be minimized as much as possible, with final tightening taking place as soon as members are plumb and square. Corrosion and rust significantly increase the amount of torque required to tension structural bolts, and often make it impossible to do so without risking bolt breakage during tightening. Ideally all nuts should be lubricated with wax or similar lubricants by the supplier, particularly on large A490/A490M assemblies. Lubricant on the face of the nut is very desirable, as the interface between the turned element and the surface below it (typically a hardened washer) consumes the greatest proportion of the torque used in tightening. If it is necessary to lubricate bolts on site at the time of installation Castrol 140 Industrial Stick- Wax (#08039-BTCS 15oz.) or Relton Stick-Kut (#15-SK 15oz.) is recommended. Stick-wax is available from many sources including TurnaSure LLC. **The necessity of adequate lubricant to achieve specified pretension in bolting assemblies cannot be over-emphasized.**

Galvanized Nuts and Bolts –Hot dipped galvanized nuts have threads tapped oversize after galvanizing. Mechanically galvanized nuts are tapped before galvanizing. Galvanized nuts should be lubricated, preferably with a dye so the lubricant can be seen. A Rotational Capacity test, which is most often required, should be performed on samples from every lot combination shipped to ensure that the bolting assemblies can be tensioned without seizing, stripping, or breaking.

PROBLEMS COMMONLY ENCOUNTERED (Cont.)

Damaged Threads –Usually caused by forcing the bolt through misaligned holes with a 'beater' or sledge, as damaged threads can cause the nut to "freeze up" upon tightening. Bolts should not be used as drift pins or barrel pins to align steel.

Trapped Bolts –Usually caused by slippage in the joint as a result of not using or removing drift pins before enough bolts have been tensioned to prevent joint slippage. Trapped bolts cannot develop tension along their entire length.

Bolts Too Long –The nut runs up against the thread run-out before the bolt is properly tensioned, or so few threads remains within the grip that excessive torque is needed as bolt stretch concentrates in the threaded portion. (Bolt threads must be at least flush with the end of the nut; however, >3 thread stick-out from the nut face is inadvisable.)

Unexpected (low) Readings in Bolt Tension Calibrator – Usually caused by inappropriate configurations used in the calibrator because the correct face plates and/or back plates were not available. Placement of washers, shims, face plates with over-sized holes or beveled holes under DTIs for testing invalidates testing. Even brand new test plates and/or bushings have been known to be supplied with inappropriate chamfered holes unsuitable for use in testing. It is important that during testing the configuration of the structural bolting assembly and the DTI, as well as the material used in the 'grip', and on which side tightening is performed, replicates as closely as possible the conditions in the steel.

Tightening of bolts in the Bolt Tension Calibrator using air-impact tools causes inaccurate readings. The needle indicating tension on a bolt tension calibrator will not come to rest at an accurate reading of bolt assembly tension when subject to vibration. (If the needle is 'jumping' during the test, the result cannot be relied upon. (See AASHTO 11.5.6.4.7a which does not allow use of impact wrenches for final tightening during testing, for example.)

Recommended Nuts –Nuts with less than 175,000psi/1200MPa proof stress may gall, are prone to stripping and generally require more torque to tension bolts. Heavy Hex nuts manufactured to ASTM A563 DH, DH3/ASTM A563 10S, 10S3 are recommended when bolts are to be tensioned.

Oversized Hardened Washer ID –Above 7/8in/M22, because ASTM F436/F436M allows a washer I.D. 3/16in/3.5mm greater than the diameter of the bolt, "special" ASTM F436/F436M hardened washers with a smaller inside diameter consistent with a "normal size" hole (i.e. nominal size +1/16in/2mm) are available for applications where the washer will be placed under the DTI.

Hot Forged Bolts –Hot forged bolts occasionally have excessive die fins, burrs, or swells under the bolt head which might prevent DTIs from properly contacting the washer face of the bolt. If necessary, this condition can be avoided by installing the DTI under the nut.

Oversized Holes –Hardened washers are required to cover over-sized and slotted holes. Requirements are spelled out in Table 6.1 of the *RCSC Specification*. Use of DTIs does not relieve the contractor of the obligation to use hardened washers, extra-thick hardened washers, or plate washers when otherwise required to do so by the RCSC.

Applicability of Test Results –In the event that a given lot of DTIs, in combination with a given lot of structural bolts, in a specific assembly configuration, does not result in satisfactory results – does not mean the bolt lot or DTI lot is substandard. It means that the specific configuration should not be used for bolts and DTIs from that lot combination. Acceptable results will almost certainly result by using a different configuration and/or use of the DTIs on different lot(s) of bolts.

TOOL SELECTION AND PERFORMANCE

Air-driven impact wrenches are frequently used for installing high-strength structural bolting assemblies. These wrenches require between 25 and 120 cu. ft./min. of air at a pressure of 100psi, at the tool, while running, to deliver adequate torque. The torque required to install a high-strength bolt to the correct tension varies from lot to lot with the size and grade of the bolt, and with the bolt and nut thread condition. **There are no specific relationships between torque and tension, and the RCSC Specification forbids the use of a 'standardized torque' for tensioning. (i.e. Using a torque chart)**

Assuming the wrench is of adequate size, (and the structural bolting assemblies are not dry or rusty), if problems are encountered in compressing DTIs within the time span noted, check the equipment for:

- Insufficient air pressure at the compressor.
- Excessive condensation in the line and at the tool.
- Too many tools running at one time.
- Too long an air-line, or leaks in the air-line.
- Blockage of the inlet or outlet filter on the tool.

If the tool is merely sluggish, blow it out with solvent to clean it and relubricate it with a light oil, SAE 5 or 10. When tensioning large bolts, (Grade A490, A490M, A354, A449) electric and hydraulic wrenches should be considered as an alternative to traditional air-driven impact wrenches. Quiet and powerful electric operated installation wrenches are increasingly popular for installation of structural bolting assemblies. See the charts on pages 21 and 22 for suitable wrenches for inch and metric fasteners respectively.

In addition, non-impacting air-powered wrenches from Hytorc (www.hytorc.com) and others provide suitable alternatives to traditional air-impact guns. Fastener distributors can help you choose a tool for lease or purchase suitable for your application.

For tightening of large diameter (>1-1/2in/M36) high-strength structural bolting assemblies, consider the use of hydraulic wrenches – such as those available from Fastorq. http://www.fastorq.com/

TOOL SELECTION AND PERFORMANCE (Cont.)

The charts below give a rough guide to suitable air-driven tools for inch series and metric series structural bolt assemblies.

Inch Series

Bolt Size A325	Bolt Size A490	Chicago Pneumatic	Ingersoll Rand	Norbar	CLECO
5/8"	–	610/6041	2934/2906	PT500	WS2110
3/4"	–	610/6500	2934/2920	PT1000	WS2110
7/8"	3/4"	611/6060	2940/2920	PT1000	WS2110
1"	7/8"	6120/6110	2950/2934	PT1500	WS2120
1 1/8"	1"	6120/6110	2950/2940	PT2000	WS2120
1 1/4"	1 1/8"	6210*/614	5980/2940	PT6/PT2000	–
1 3/8"	1 1/4"	614*	5980/2940	PT7/PT4500	–
1 1/2"	–	614*	5980/2940	PT7/PT4500	–

*Only if the bolt and nut are well lubricated.

Metric Series

Bolt Size A325M	Bolt Size A490M	Chicago Pneumatic	Ingersoll Rand	Norbar	CLECO
M16	–	610/6041	2934/2906	PT500	WS2110
M20	–	610/6500	2934/2920	PT1000	WS2110
M22	M20	611/6060	2940/2920	PT1000	WS2110
M24	M22	6120/6110	2950/2934	PT1500	WS2120
M27	M24	6120/6110	2950/2940	PT2000	WS2120
M30	M27	6210*/614	5980/2940	PT6/PT2000	–
M33	M30	614*	5980/2940	PT7/PT4500	–
M36	–	614*	5980/2940	PT7/PT4500	–

*Only if the bolt and nut are well lubricated.

The electric-powered installation tools listed in the table below for inch series structural bolting assemblies enable tightening control based upon output torque or angle, and are available from GWY Inc. www.gwyinc.com

Bolt		Preinstallation Verification Tension, kips	Torque Control Tool		Rotation Control Tool
Diameter	Grade		SR-Series	STC-Series	
1/2	A325	13	SR-31E	STC-3AE	TN-20EZ
	A490	16			
5/8	A325	20	SR-51E	STC-5AE	
	A490	25			
3/4	A325	29	SR-71E	STC-7AE	TN-22EZ
	A490	37			
7/8	A325	41	SR-121E	STC-12AE	TN-24EZA
	A490	51			
1	A325	54	SR-171E	STC-21AE	TN-30EZ
	A490	67			
1 1/8	A325	59	SR-211E		
	A490	84			
1 1/4	A325	75		STC-50AE	TN-33EZ
	A490	107			
1 3/8	A325	89			TN-39EZ
	A490	127			
1 1/2	A325	108			
	A490	155			

TOOL SELECTION AND PERFORMANCE (Cont.)

The electric-powered installation tools listed in the table below for metric series structural bolting assemblies enable tightening control based upon output torque or angle, and are available from GWY Inc. www.gwyinc.com

Bolt		Preinstallation Verification Tension, kN	Torque Control Tool		Rotation Control Tool
Diameter	Grade		SR-Series	STC-Series	
<M16	A325M	–	SR-31E	STC-3AE	TN-20EZ
	A490M	–			
M16	A325M	91			
	A490M	114	SR-51E	STC-5AE	
M20	A325M	142			
	A490M	179	SR-71E	STC-7AE	TN-22EZ
M22	A325M	176			
	A490M	221	SR-121E	STC-12AE	TN-24EZA
M24	A325M	205			
	A490M	257	SR-171E	STC-21AE	TN-30EZ
M27	A325M	267			
	A490M	334	SR-211E		
M30	A325M	326		STC-50AE	TN-33EZ
	A490M	408			
M33	A325M	–			TN-39EZ
	A490M	–			
M36	A325M	475			
	A490M	595			

CHECKING FOR CONFORMANCE TO SPECIFICATION

Identification and Certification

Inspectors should verify that all fastener components conform to applicable ASTM standards before use. Manufacturer Identification marks should be clearly visible on all fasteners. DTIs should be marked to identify the lot number, manufacturer, and Type.

Trademark

The trademark of TurnaSure LLC is shown on the cover of this booklet. DTIs marked with it have been manufactured by TurnaSure.

Grade and Size

Each DTI is marked with a series of numbers. “325” signifies the DTI is for use with A325 bolts; “8.8” signifies the DTI is for use with A325M bolts; “490” for A490 bolts; “10.9” for A490M bolts. DTIs for use with Type 3 weathering steel bolts are marked “325-3”/“8.8-3” or “490-3”/”10.9-3” for inch and metric respectively. Type 3 DTIs are the replacement for epoxy coated DTIs previously used on atmospheric corrosion resistant steel structures. Nominal size is not marked on Type 325 or Type 490 DTIs, however they can be identified by the close fit over the bolt. Nominal Size is marked on 8.8 and 10.9 metric DTIs.

Lot Number

For the purpose of complete traceability ASTM requires each DTI be marked with a lot number. The lot number will take the form of letters and/or numbers impressed on the top surface of the DTI.

Production Controls

TurnaSure LLC DTIs are carefully inspected and tested throughout the manufacturing process utilizing statistical process control. The finished product is tested by an independent accredited laboratory in A Digital Compression Load Analyzer. ASTM F959/F959M and F2437/F2437M require that samples from each lot be tested in the as-shipped condition (coated or uncoated) following ASTM F1470 Guide for Fastener Sampling and ASTM F606/F606M Test Methods for Mechanical Properties of Fasteners.

CHECKING FOR CONFORMANCE TO SPECIFICATION

Laboratory duplication of the ASTM product performance test by the user should not be required. It is not possible to reproduce the ASTM product performance test in the field.

A test of the bolt/nut/washer & DTI assembly in a bolt tension calibrator is recommended, even when it is not required by the project specifications. This will assist the user in qualifying all of the fastener components as suitable for use in the condition in which they reached the project site, and also verifies that the tools to be used for bolt tightening are of adequate capacity. Lastly, this testing provides a means of assurance that the ironworkers or bolting installers are familiar with the bolting method and can demonstrate mastery of the skills necessary to install structural bolting assemblies in accordance with the project requirements.

The most common misunderstanding about DTIs is that inability to flatten them adequately during final tightening, or breaking bolts while trying to do so, is not due to the DTIs "being too strong". It is due to the surface condition of the bolting assemblies having become degraded before final tightening. The DTIs are merely a messenger pointing out that something is wrong. (See Problems Commonly Encountered on page 16.) The most common solution is to back the nuts off, apply stick-wax to the nut face (most importantly) and some to the threads, and try again.

Field Pre-Installation Verification Test

Before starting field testing, verify that the *bolt tension calibrator* has been calibrated and certified for use within the last year. The certification document provides a traceable comparison of the calibrator's readings with those established by the U.S. National Institute of Standards and Technology or the standards agency having jurisdiction for the project. Apply any noted correction factors to the load readings during testing.

Field Pre-Installation Verification Test (cont.)

Inspect face plates, bushings, and shims for excessive wear and/or beveled holes and over-sized holes. Do not use face plates that are excessively worn, concave, or polished. Do not use bushings or shims with beveled or over-sized holes under DTIs during testing.

Assemble the bolt, nut, washer, and DTI in a *bolt tension calibrator* in exactly the same configuration as is to be used in the structural steel, including which element is to be turned (bolt head or nut). See Figure 8 as an example for Method 1.

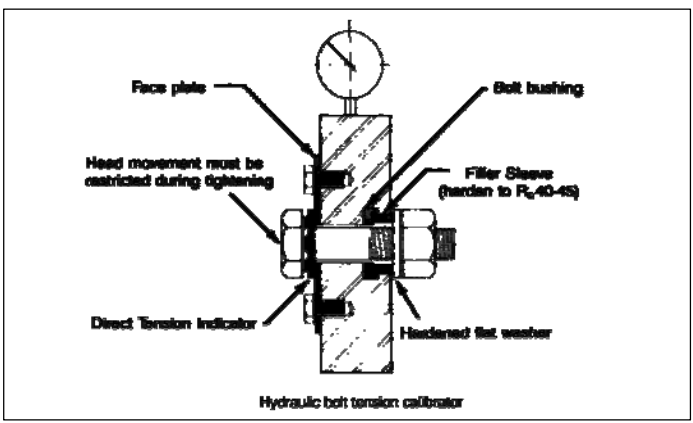


Figure 8

Tension the bolting assembly to the minimum required bolt tension and check that the applicable feeler gauge enters *half or more* of the spaces. The load should be increased on the calibrator as smoothly as possible, and both the peak load and the "fallback" load should be noted – as the calibrator starts to show a lower load than the actual peak bolting assembly load.

Field Pre-Installation Verification Test

At this point the assembly has demonstrated the ability to reach the desired tension prior to compression of the required number of 'bumps' to be compressed in the work.

Next, tighten the bolting assembly until the point where the feeler gauge is refused in *more than half* of the spaces between the protrusions or 'bumps' on the DTI. The tension in the bolting assembly as measured by the *bolt tension calibrator* must be less than the minimum tensile strength of the bolt. At this point the assembly has demonstrated the ability to compress the 'bumps' to the gap required in the work without exceeding the strength of the bolt.

If air-driven impact wrenches are being used during this test, caution is advised, as excessive vibration can sometimes damage the *bolt tension calibrator,* makes it impossible to read the gauge accurately, and causes the needle to come to rest at an arbitrary and inaccurate reading. It is strongly advised that a non-impacting wrench be used for final tightening in this test. (i.e. As AASHTO requires)

INSTALLATION INSTRUCTIONS FOR BRIDGE APPLICATIONS PER AASHTO

The AASHTO LRFD Bridge Construction Specifications 3rd Edition (inclusive of Interim Revisions thru 2016), provide detailed instructions for Pre-Installation Verification testing and Bolting Installation using DTIs in Section 11 Part 11.5.6.4.7.

One difference between the instructions given in the AASHTO Specifications and those presented in this manual is the requirement that the AASHTO gap closure requirement is always 0.005in/0.125mm regardless of finish or coatings.

AASHTO includes an additional test requirement during Pre-Installation Verification Testing whereby each test is followed by running the nut up the length of the bolt thread to check for 'excessive plastic deformation' – an undefined criterion uniquely and strangely only applicable to structural bolts used with DTIs.

INSTALLATION INSTRUCTIONS FOR BRIDGE APPLICATIONS PER AASHTO

AASHTO Article 11.5.6.4.7 has two parts, *7a Verification, and 7b Installation,* and an accompanying Commentary. Verification assures that before the DTI is compressed to an average gap of 0.005in/0.125mm the tension in the bolt will be at least 1.05 times the minimum required bolt tension. It also assures that when the DTI is all but completely compressed, the bolt will not have excessive ' permanent inelastic deformation'.

In the event of a conflict between the Instructions provided herein, and those in a reference standard, the instructions contained within this manual shall take precedence unless prohibited by code. All Pre-Installation Verification tests should be performed with the fasteners configured in the bolt tension calibrator just as they are to be configured when installed in the structural steel.

DTI Design Type – Figure 9 below illustrates the newer and improved curved protrusion type DTI. Figures 10 and 11 depict older designs.

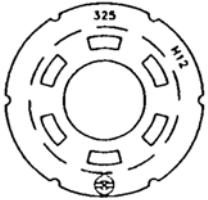


Figure 9

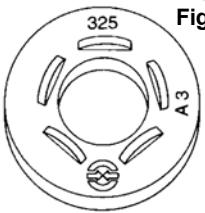


Figure 10

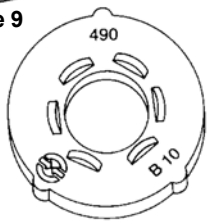


Figure 11

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