Instruction Manual for Installing HIGH-STRENGTH BOLTS

with

DIRECT TENSION INDICATORS

(ASTM F959)

INCH SERIES EDITION

TurnaSure LLC

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TurnaSure LLC 20th Ed. Aug 2014

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INTRODUCTION

High-strength bolts are well established as economical and efficient devices for connecting structural steel. When North American 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 and inspectors should be thoroughly familiar with this specification.

Direct Tension Indicators (DTIs) are recognized by many engineers as the most reliable method for ensuring correct installation of high-strength bolts for slip-critical connections and connections requiring fully pretensioned bolts.

This manual is written for engineers, construction superintendents, inspectors and ironworkers to assist them in the proper installation of high-strength bolts using DTIs. This will ensure that bolts have been tensioned to the values required whether used in slip-critical connections, connections subjected to direct tension, or shear/bearing connections requiring fully pretensioned bolts. These instructions are also valid when DTIs are specified for use with high strength bolts in other connections as a device to ensure that all bolts have actually been tensioned.

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 many other subjects relative to high-strength bolting.

TurnaSure LLC has years of high-strength bolting experience and provides a range of consultation activity including seminars, site visits, tool recommendations, specification commentary and training programs. In addition TurnaSure LLC prepares instructional DVDs, published 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.

A metric series edition of this manual is available upon request, or you can download a PDF version from our website.

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 the desired clamping force will be induced in the connection interface. Service loads are then transferred by frictional resistance in the joint interface rather than by bearing on the bolt shanks and hole faces. 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 types of joints is highly undesirable, hence the development of the slip-critical connection. (Figure 1)

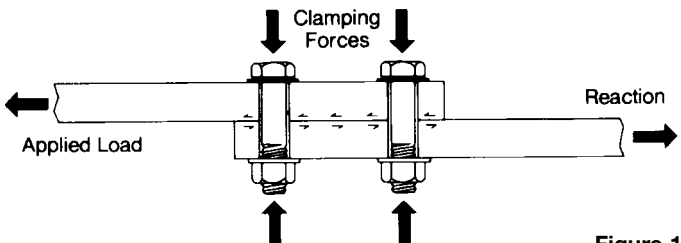


Figure 1

When tension loads are applied in the direction of the bolt axis, tensioning 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)

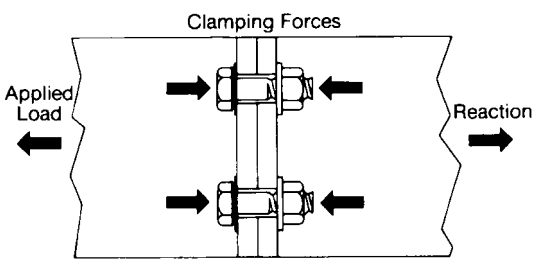


Figure 2

DIRECT TENSION INDICATORS (DTIs)

Direct Tension Indicators (DTIs) are simple and extremely accurate devices for ensuring that bolts have been installed above the specified minimum tension value. Used properly they positively ensure the correct amount of 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 of bolt tension. DTIs measure tension regardless of applied torque.**

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

When a DTI is installed on a bolt with the "bumps" placed against the underside of the bolt head there are noticeable gaps between the "bumps." As the nut is turned and the bolt tensioned, the "bumps" flatten. When the "bumps" are flattened so that the gaps have been reduced to the required dimension, 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. (Figure 3)

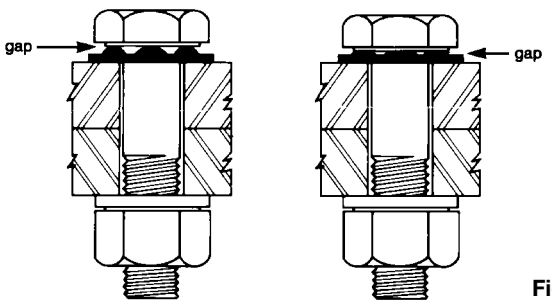


Figure 3

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

Most often DTIs are installed under the bolt head and the nut turned. For plain finish (uncoated) DTIs, when the bolt is properly tensioned the gap will be less than 0.015" in more than half of the spaces. Coated DTIs are installed using a 0.005" criteria. To assure that the DTI is properly installed, feeler gages, 0.015" and 0.005" thick, are provided with DTI shipments. To ensure that the DTI is properly compressed, and the bolt tensioned, the appropriate feeler gage must be refused in a given number of gaps between the "bumps." (Table 1 lists the number of "bumps" for each size and grade of DTI and the required number of gage refusals in the gaps.)

Table 1

Bolt Size	Type 325		Type 490	
	Bumps	≥ Refusals	Bumps	≥ Refusals
1/2"	4	3	5	3
5/8"	4	3	5	3
3/4"	5	3	6	4
7/8"	5	3	6	4
1"	6	4	7	4
1 1/8"	6	4	7	4
1 1/4"	7	4	8	5
1 3/8"	7	4	8	5
1 1/2"	8	5	9	5

Should the specifications or conditions of installation call for an average gap of less than 0.005" the feeler gage must be refused in no fewer than one less than the total number of spaces.

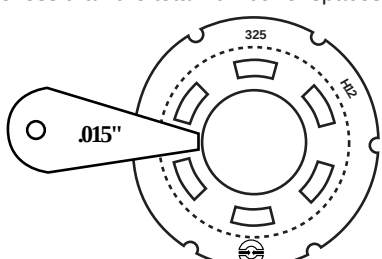


Figure 4

When inserted the feeler gage 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 gage inspection. (Figure 4).

Usually, ironworkers or other bolting installers develop a “feel” for installation and can install DTIs to the correct gap by eye. Provided that good snugging practices are followed, ironworkers often note the rotation 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 gage on a limited number of DTIs and then compare other gaps by eye.

Fully compressed DTIs should not be rejected. Some inspectors judge that a bolt which has fully compressed a DTI is “overtensioned.” No specific definition of “overtensioned” exists in bolt literature. Most experts believe that unless a tensioned bolt has broken it is acceptable. Further support for this recommendation can be found in a report published in 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.

REUSE OF DIRECT TENSION INDICATORS ON HIGH STRENGTH STRUCTURAL BOLTS

The question has been raised as to whether it is permissible to reuse Direct Tension Indicators (DTIs). The reuse of DTIs is not recognized by TurnaSure as a viable and accurate means to assure that required clampforce has been generated in slip-critical or tension connections. DTIs, like other fasteners, plastically deform during use. Thus, reuse of such fasteners cannot be assumed to be sound engineering practice. Admittedly, the RCSC Specification is currently silent on the issue of reuse or retightening of DTIs, or for that matter, Twist-Off bolts.

DTIs which have been installed on fully tightened bolts can also be verified for proper bolt load in 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 that a load equal to or greater than the previously installed load be induced. The above noted test is best left for cases of arbitration, should one arise.

BOLT TENSIONING USING PLAIN FINISH DTIs

METHOD #1

DTI Under the Bolt Head–Turn the Nut to Tension

For multiple plies and long bolts (typically large A490 bolts) this method will detect trapped bolts.

ASSEMBLY

Place the DTI under the bolt head with the bumps facing the underside of the bolt head. Place a hardened F436 washer under the nut. (Figure 5a)

With a short-slotted or oversized hole under the bolt head add a hardened flat washer between the DTI and the hole, and if the bolt is also an A490 larger than 1" the hardened washers must be at least 5/16" thick. For a long-slotted hole, an external cover plate of sufficient size to completely cover the slot should be provided. (Figure 5b) *See Table 6.1 of the RCSC Specification for detailed washer requirements.*

Check that the washer hole diameter conforms to the most current revision of ASTM F436 especially for sizes 1" and above, because prior to 2004 ASTM F436 allowed for washer I.D. considerably greater than the nominal diameter of the bolt and greater than a normal sized hole in the connection itself. TurnaSure can assist in the procurement of correct washers. Normal sized holes either in a hardened washer or in the structural steel also helps prevent DTIs from dishing.

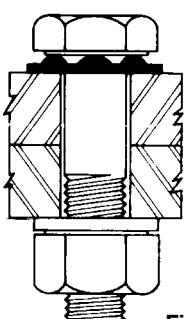


Figure 5a

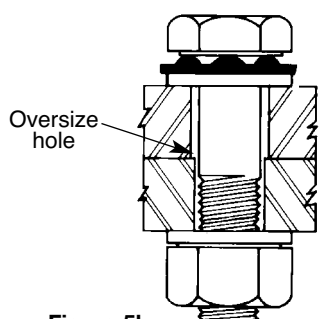


Figure 5b

TENSIONING

Turn the nut until the gap between the bolt head and the DTI face is reduced to less than 0.015˝ in more than half of the entry spaces. When turning the nut, prevent the bolt head from spinning with a wrench.

BOLT TENSIONING USING PLAIN FINISH DTIs (Continued)

METHOD #2

DTI Under the Nut–Turn the Nut to Tension

Use of this method saves the need for a hardened washer on standard connection not involving multiple plies or large A490 bolts.

ASSEMBLY

Place the DTI under the nut with the bumps facing the nut. (Figure 6a)

With a short-slotted or oversized hole under the bolt head or nut, add a hardened flat washer, and, if the bolt is an A490 and larger than 1" the hardened washers must be at least 5/16" thick. For a long-slotted hole, an external cover plate of sufficient size to completely cover the slot should be provided. (Figures 6b and 6c) *See Table 6.1 of the RCSC Specification for detailed washer requirements.*

Note A: The new TurnaSure DTIs do not need hardened washers between an ASTM A563 DH nut and DTI. DTIs with the older design "straight-sided" protrusions as depicted in Figures 12 and 13 on page 20 would still require an F436 washer between the turned element and the DTI.

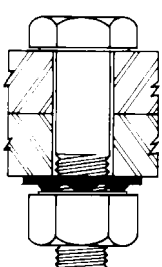


Figure 6a

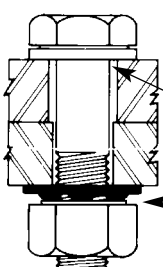


Figure 6b

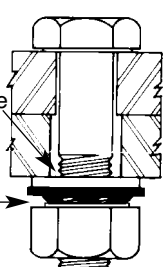


Figure 6c

TENSIONING

Turn the nut until the gap between the nut and the DTI face is reduced to less than 0.005" in more than half of the entry spaces. When turning the nut, prevent the bolt head from spinning with a wrench.

BOLT TENSIONING USING PLAIN FINISH DTIs (End)

METHOD #3

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

Use of this method is typically done if method #1 or #2 can not be used or when box sections or other 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. (Figure 7a)

With a short-slotted or oversized hole under the bolt head or nut, add a hardened flat washer, and, if the bolt is an A490 and larger than 1" the hardened washers must be at least 5/16" thick. For a long-slotted hole, an external cover plate of sufficient size to completely cover the slot should be provided. (Figure 7b and 7c) *See Table 6.1 of the RCSC Specification for detailed washer requirements.*

Note B: TurnaSure 'curved protrusion' DTIs do not need hardened washers between the bolt head and DTI.

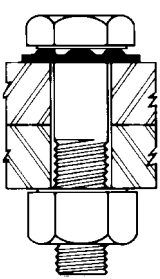


Figure 7a

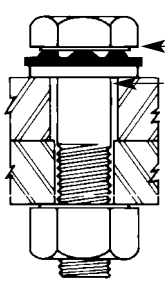


Figure 7b

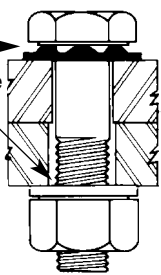


Figure 7c

TENSIONING

Turn the bolt head until the gap between the bolt head and the DTI is reduced to less than 0.005˝ in more than half of the spaces. When turning the bolt head, prevent the nut from spinning with a wrench.

BOLT TENSIONING USING COATED DTIs OR TYPE-3 WEATHERING STEEL DTIs

METHOD #1

DTI Under the Bolt Head–Turn the Nut to Tension

DTIs are most often assembled under the bolt head wherever possible. Assembly and tensioning should proceed as with "plain." For galvanized and epoxy coated or weathering steel DTIs the gap between the bolt head and the DTI face should be reduced to less than 0.005" in more than half of the entry spaces. (Figure 8a)

**The use of flat hardened washers per the provisions of the RCSC Specification varies with the bolt strength, hole size and yield strength of connected steel and tightening method. Please refer to Table 6.1 of the RCSC Specification for Structural Joints Using High-Strength Bolts for detailed washer and plate washer requirements.*

For bridge applications see **INSTALLATION INSTRUCTIONS FOR BRIDGE APPLICATIONS PER AASHTO**, found on the inside back cover of this manual.

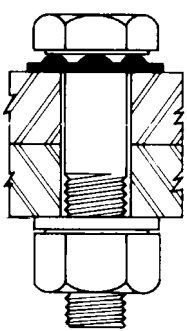


Figure 8a

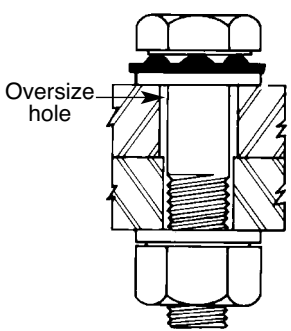


Figure 8b

BOLT TENSIONING USING COATED DTIs OR TYPE-3 WEATHERING STEEL DTIs (Continued)

METHOD #2

DTI Under the Nut–Turn the Nut to Tension, or

METHOD #3

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

The DTIs should be compressed to a gap of less than 0.005" in more than half of the entry spaces. (Figures 9a and 10a)

The use of flat hardened washers per the provisions of the RCSC Specification *varies with the bolt strength, hole size, and yield strength of connected steel and tightening method. Please refer to Table 6.1 of the RCSC Specification for Structural Joints Using High-Strength Bolts for detailed washer and plate washer requirements.* (Figures 9b, 9c, 10b and 10c)

Check that the washer hole diameter conforms to the most current revision of ASTM F436 especially for sizes 1" and above, because prior to 2004 ASTM F436 allowed for washer I.D considerably greater than the nominal diameter of the bolt and greater than a normal sized hole in the connection itself. TurnaSure can assist in the procurement of correct washers. Normal sized holes either in a hardened washer or in the structural steel ensures that the DTI is properly supported and prevents dishing.

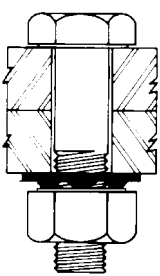


Figure 9a

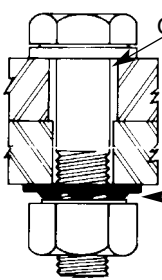


Figure 9b

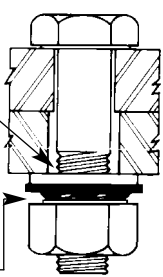


Figure 9c

BOLT TENSIONING USING COATED DTIs OR TYPE-3 WEATHERING STEEL DTIs (End)

Note C: TurnaSure 'curved protrusion' DTIs do not need hardened washers between the nut and DTI. DTIs with the older design "straight-sided" protrusions as depicted in Figures 12 and 13 on page 20 would still require an F436 washer between the turned element and the DTI.

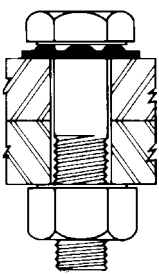


Figure 10a

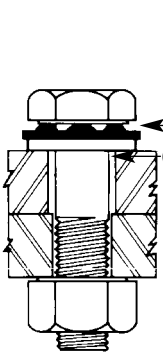


Figure 10b

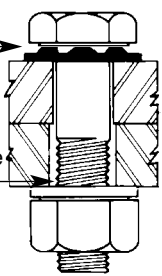


Figure 10c

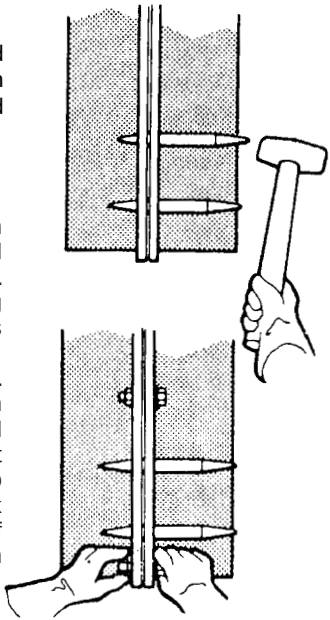
RECOMMENDED BOLT INSTALLATION PROCEDURE

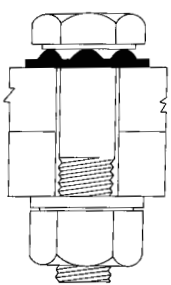
Step 1

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.)

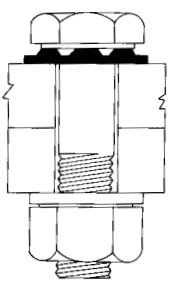
Step 2

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 as much as 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.





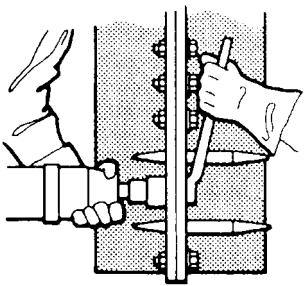
No Tension



Partial Tension "Snug"

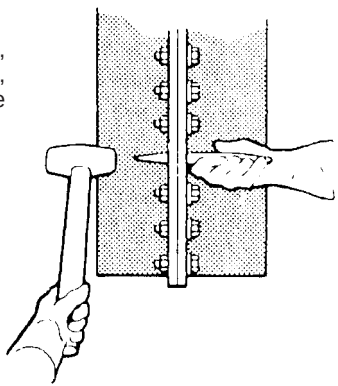
Step 3

Tension the bolts until the average gap on each DTI is as specified. Again, work 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 bolts, try not close all the gaps to nil. There is no need to tension these bolts (which have less ductility than A325 bolts) that much. However a nil gap should not be cause for rejection. If there is a concern about “overtensioning,” remove a sample number of bolts from the work and inspect them for deformation by running the nut down to the thread runout. If the nut runs down there is no excessive elongation. Note however removed bolts should not be reused.

When using impact wrenches, final tightening should be accomplished in 10 seconds or less. Large A490 bolts may take as long as 20-30 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 14 and 15 is not being encountered.

PROBLEMS COMMONLY ENCOUNTERED WHEN TENSIONING BOLTS

Dry or Rusty Threads or Nut Faces–Usually caused by poor storage conditions or passage of time between snugging of bolts and start-up of final tensioning. Dry or rusty bolts, nuts, or washers should not be permitted. Ideally nuts, bolts, washers, and DTIs should be kept in dry storage and their containers not opened until immediately before use. Rust significantly increases the amount of torque required to tension a bolt. Ideally nuts should be wax dipped before use, particularly on large A490 bolts. Lubricant on the face of the nut is very desirable. If it is necessary to lubricate bolts at the site at the time of installation Castrol Industrial STICK WAX Lubricant is recommended. It is available from many sources including TurnaSure LLC. **The necessity of adequate lubricant to achieve the desired level of bolt pretension cannot be over-emphasized.**

Galvanized Nuts and Bolts–Hot dipped galvanized nuts should have threads tapped oversize after galvanizing. Mechanically galvanized nuts are tapped before galvanizing. The nuts should be dipped in a wax lubricant, preferably with dye so the lubricant can be seen. A Rotational Capacity test, which is mandatory and described in A325, should be performed on samples from every lot combination shipped to assure that the bolts can be tensioned without either seizure or stripping the nut threads.

Damaged Threads–Usually caused by forcing the bolt through misaligned holes, this will cause the nut to "freeze."

Trapped Bolts–Usually caused by slippage in the joint as a result of not using or removal of 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 runout before the bolt is properly tensioned or so little thread remains within the grip that excessive torque is needed as bolts stretch concentrates in the threaded portion. (>3 thread stick-out from the nut face is inadvisable.)

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

PROBLEMS COMMONLY ENCOUNTERED WHEN TIGHTENING BOLTS (Continued)

Omission of Hardened Washers under the Turned Element– Hardened washers are not required by the RCSC Specification for all high-strength bolt installations where tensioning is required. However, the use of hardened washers under the turned element significantly reduces the torque required to tension a bolt and is recommended by TurnaSure LLC whether DTIs are used or not.

Oversized Hardened Washer ID–Above 7/8", because ASTM F436 allows a washer I.D. 1/8" greater than the diameter of the bolt, engineers may wish to consider "special" ASTM F436 hardened washers with a smaller inside diameter consistent with a "normal size" hole.

Hot Forged Bolts–Hot forged bolts must be free of die fins, burrs and excessive swelling under the bolt heads which might prevent DTIs from properly contacting the washer face of the bolt. If necessary, to avoid this condition consider installing the DTI under the nut.

Oversized Holes–Hardened washers are required to cover oversized 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 or plate washers when otherwise required to do so by the RCSC.

AIR-TOOL SELECTION AND PERFORMANCE

Air driven impact wrenches are frequently used for installing high-strength bolts. These wrenches require between 25 and 120 cu. ft./min. of air at a pressure of 100psi, at the tool, while running, to deliver a particular torque. The torque required to install a high-strength bolt to the correct tension varies 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.**

Assuming the wrench is of adequate size, if problems are encountered in compressing DTIs within the time span noted, check the equipment for:

- Insufficient air pressure at the compressor.
- 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.
- Broken 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.

The chart below gives a rough guide to the suitable tool, based on our field experience.

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.

When tensioning large A490 bolts, hydraulic torque wrenches should be considered as an alternative to air driven impact wrenches. Quiet and powerful electric operated installation wrenches are increasingly popular for installation of heavy hex structural bolts. Contact your bolt distributor for information on how to lease or purchase these tools.

CHECKING FOR CONFORMANCE TO SPECIFICATIONS

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. Where required, test certificates should accompany product to the job site. Bolt certificates should state tensile strength and hardness. Nut certificates should state hardness and proof-load. Hardened washer certificates should identify that they are in a hardness range of 38 to 45 Rockwell C. DTIs should be marked to identify the lot number, manufacturer, and Type (325 or 490).

TurnaSure LLC DTIs are carefully tested throughout the manufacturing process utilizing statistical process control procedures. The finished product is tested by an independent accredited laboratory in A Digital Compression Load Analyzer with a dial gage.

Certification of testing, according to ASTM F959 requires up to 29 pieces per lot, without failure, in the as-shipped condition, coated or uncoated, be tested, following ASTM F1470 Guide for Fastener Sampling.

Laboratory duplication of the ASTM product performance test by the user should not be required. There should be no attempt to reproduce the product performance test in the field. Instead, the following test of the DTI and bolt/nut/washer assembly in a bolt tension calibrator is suggested. This will assist the user in qualifying all of the 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, it 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 bolts in accordance with the project requirements.

Assemble the bolt, nut, washer, and DTI in a bolt tension calibrator as shown in Figure 5.

Verify that the tension calibrator has been certified and calibrated 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 jurisdication in the construction location. Apply any noted variations to the load readings during testing on the calibrator.

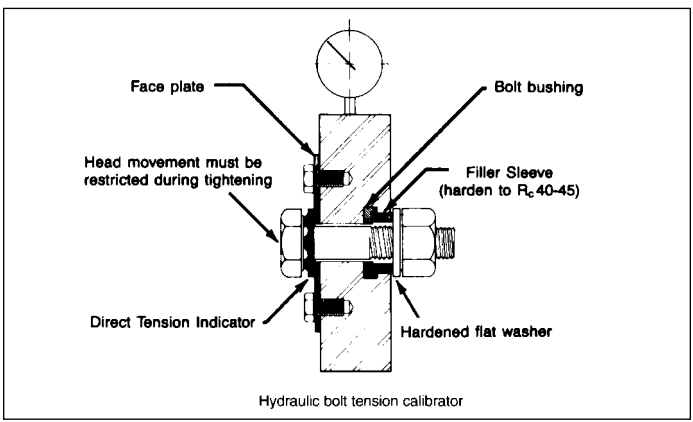


Figure 5

Tension the bolt to the minimum required bolt tension and check that the applicable feeler gage enters at least the proper number of spaces (tension and spaces given in Table II). A 0.015" feeler gage is used when an uncoated DTI is installed under the bolt head and the nut is turned, Method #1. A 0.005" feeler gage is used with Methods #2 and #3 and with coated DTIs in any arrangement. The load should be increased on the calibrator as smoothly as possible so as to avoid "fallback" where the load cell "bleeds off" and the calibrator starts to show a lower load than the actual peak bolt load. At this point the assembly has demonstrated the ability to reach the desired tension prior to compression of the number of bumps which are required to be compressed in the work.

Next tension the bolt until the point where the feeler gage refuses to enter the number spaces in Table II. The tension in the bolt as measured by the 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 minimum tensile 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 and/or make it impossible to read the gage accurately.

Table II

TYPE 325					
Nominal Bolt Diameter (in.)	**Minimum Bolt Tension (kips)**	**Minimum Bolt Tensile Strength (kips)**	**DTI Spaces**	**Feeler-Gage Entries**	**Feeler-Gage Refusals**
1/2"	12	17	4	2	3
5/8"	19	27	4	2	3
3/4"	28	40	5	3	3
7/8"	39	55	5	3	3
1"	51	73	6	3	4
1-1/8"	56	80	6	3	4
1-1/4"	71	102	7	4	4
1-3/8"	85	121	7	4	4
1-1/2"	103	148	8	4	5
TYPE 490					
Nominal Bolt Diameter (in.)	**Minimum Bolt Tension (kips)**	**Minimum Bolt Tensile Strength (kips)**	**DTI Spaces**	**Feeler-Gage Entries**	**Feeler-Gage Refusals**
1/2"	15	21	5	3	3
5/8"	24	34	5	3	3
3/4"	35	50	6	3	4
7/8"	49	69	6	3	4
1"	64	91	7	4	4
1-1/8"	80	114	7	4	4
1-1/4"	102	145	8	4	5
1-3/8"	121	173	8	4	5
1-1/2"	148	211	9	5	5

For bridge applications see **INSTALLATION INSTRUCTIONS FOR BRIDGE APPLICATIONS PER AASHTO**, found on the inside back cover.

DTI IDENTIFICATION MARKINGS

TRADEMARK

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

GRADE AND SIZE

Each DTI is marked with a series of numbers. “325” signifies the DTI is for use with A325 bolts, “490” for A490 bolts. DTIs for use with Type 3 weathering steel A325 bolts are marked “325-3”. Such DTIs are the newer versions that are produced from a weathering steel and thus do not require epoxy coating to protect them from excessive corrosion. Size is not marked on Type 325 or Type 490 DTIs, however they can be identified by the close fit over the bolt.

LOT NUMBER

For purposes of absolute traceability ASTM requires each DTI be marked with a lot number. The lot number will take the form of a letter followed by either one or more numbers.

Figure 11 illustrates the new and improved Type 325 DTI design.

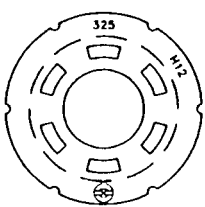


Figure 11

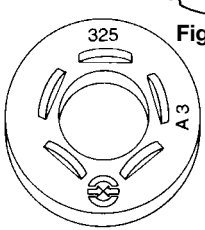


Figure 12

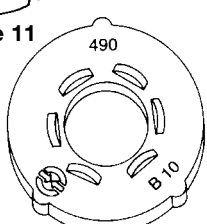


Figure 13

Older designs look like Figures 12 & 13.

INSTALLATION INSTRUCTIONS FOR BRIDGE APPLICATIONS PER AASHTO

The AASHTO LRFD Bridge Construction Specifications 3rd Edition (inclusive of Interim Revisions thru 2014), provide detailed instructions for Pre-Installation Verification testing and Bolting Installation using DTIs in Section 11 Part 11.5.6.4.7.

The major 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 0.005″ for installation of plain finish DTIs under the bolt head, not 0.015″ as stated in this Installation Manual. The 0.015″ gap was selected as convenient for building installation where plain DTIs are typically installed within an enclosed structure where bolted connections are not subject to weathering. As tests have shown that paint systems typically used on bridges will “bridge” a gap of 0.005″ successfully, but may not “bridge” a gap of 0.015″, and since many states specify galvanized fasteners, AASHTO has set a maximum gap of 0.005″ for “plain” and “coated” DTIs in all connections.

TurnaSure LLC does not recommend complete flattening of Type 490 DTIs on uncoated A490 bolts to the point where a 0.005” gage is refused in all spaces, as this risks bolt breakage during installation. Preferrably at least one space remains open, although complete flattening in all spaces should not be cause for rejection.

Note, 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 0.005″ 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. 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.

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