



DIRECT TENSION INDICATORS **INSTRUCTION MANUAL**

**for installation of high-strength structural
bolting assemblies for preloading**

(Also known as Preloaded Assemblies or HSFG)

in accordance with BS EN 14399-9:2018
(for installation according to k-Class K0
as per BS EN 14399-1:2015, Table 1)

**UK
CA**

0038

EN 15048-1 & EN 14399-1

CE

0343

BAPP

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Introduction

High-strength structural bolting assemblies for preloading, also known as preloaded bolting assemblies (previously HSFG – “High Strength Friction Grip”) are well established as an economical and efficient method of providing connections in structural steelwork.

The rules for the use of high-strength structural bolting assemblies for preloading in steel structures within Europe are defined in European Standards EN 1090-2, 1090-3 and EN 1993 (Eurocode 3).

High-strength structural bolting assemblies for preloading are tightened to produce a preload in the bolt which generates frictional resistance to movement between the plies of the connection. These assemblies can be used in any type of structural steelwork joint, but more especially where the following factors apply:

1. Fatigue
2. Vibration
3. Load Reversal
4. Dimensional Stability

The basic requirement of the high-strength structural bolting assemblies for preloading is that a correct and reproducible preload in the bolt is achieved.

Bolting assemblies with Direct Tension Indicators (DTI) washer, a form of high-strength structural bolting assembly for preloading, are one of several such methods of ensuring that the preload is consistently achieved. Among the many advantages of the system is the repeatable bolt preload that can be achieved without reliance on the lubrication that has been applied to the bolting assembly.

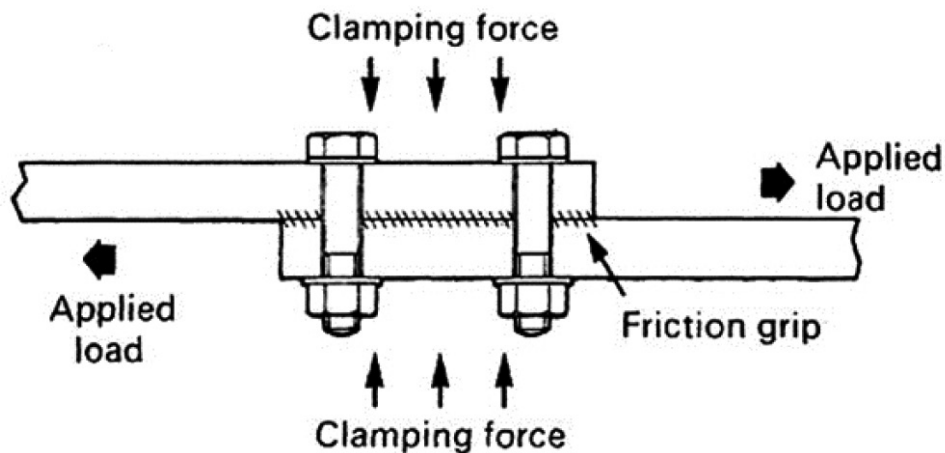
This booklet is written for Engineers, Supervisors, Inspectors and Erection Staff, to assist them in the correct installation of high-strength structural bolting assemblies for preloading with DTIs.

TurnaSure LLC has many years of experience in the supply of DTIs for use in structural steelwork worldwide and can provide a range of technical support including technical reports and information on fastener specifications.

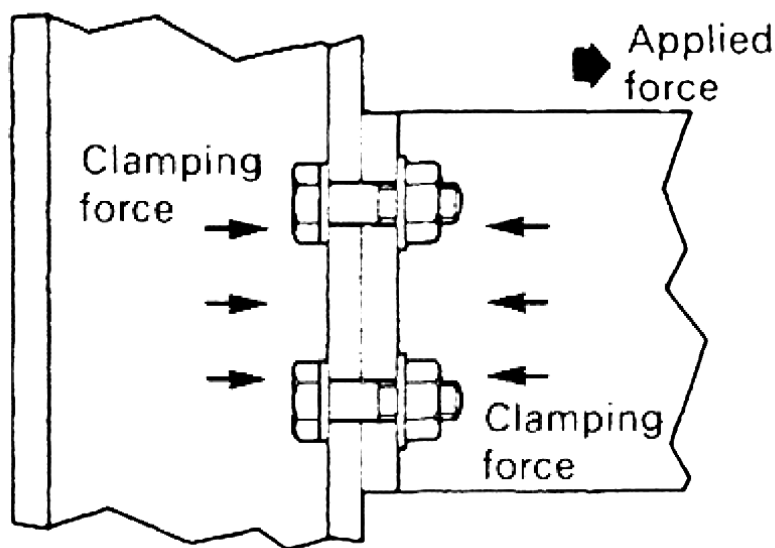
BAPP Group of Companies is a supplier and distributor of CE and UKCA marked high-strength structural bolting assemblies for preloading.

Theory of high-strength structural bolting assemblies for preloading

The principle of preloaded connections relies upon tensioning each bolt in the connection to a specified minimum preload so that clamping force sufficient to resist movement of the plies will be induced at the connection interface(s). Shear loads are then transferred by frictional resistance at 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 these loads.



When axial tensile loads are applied to the bolt through the bolted connection, preloading of the connection to a specified minimum is also important, particularly if the loads are cyclical and could induce loosening or fatigue failure of the bolts. The clamping force developed at the specified minimum bolt preload should be greater than the applied loads. This will prevent the plies from separating or the bolts from developing any significant increase in axial tensile stress over the installed preload stress.



Tightening of high-strength structural bolting assemblies for preloading

The essential requirement for preloaded connections is that the individual bolts are correctly tightened to the specified minimum preload. EN 1993.1.8 (Eurocode 3) specifies that to develop the necessary clamp force in the connection each bolt must be preloaded to 70% of the nominal bolt tensile strength. The permitted methods of preloading in EN 1090-2:2018 are dependent on either movement of the nut along the bolt thread by a specified amount or the application of a calculated value of torque (turning moment) to the nut.

Methods that depend on displacement of the nut:

1. The direct tension indicator (DTI) method depends on the deformation of protrusions that have been extruded from the face of a washer. The DTI is calibrated so that when a specified average gap is reached the required preload is achieved. According to BS EN 14399, this method is called installation according to k-Class K0.
2. The Highway Agency part-turn method requires each bolt to be tightened by torque to bring the steelwork into contact (torque varies by bolt diameter, batch etc.). A part-turn, up to 1/3 of a turn, is then applied to develop the required preload.

Methods that depend on the application of torque:

1. The Combined method requires the bolt to be torqued to 75% of the required preload. The required single torque is calculated from data obtained from the specified test in BS EN 14399-2. A further rotation is then applied to develop the required preload. The torque figure for installation is supplied by the manufacturer of the assembly. According to BS EN 14399, this method is called installation according to k-Class K1.
2. The Torque method uses two values of torque calculated from data obtained from the specified test in BS EN 14399-2. Assemblies are tightened initially with the first torque value and then once again with the second torque value. Both torque figures for installation are supplied by the manufacturer of the assembly. According to BS EN 14399, this method is called installation according to k-Class K2.
3. HRC method bolts (Tension Control bolts) are tightened using a special wrench where the nut is rotated while reacting against the splined bolt end. HRC bolts are calibrated so that when sufficient torque resists further movement of the nut the spline shears at a breakneck and the required preload is achieved.

All methods require sufficient lubrication of the nut thread or bolt thread to achieve the required preload.

All preloaded assemblies supplied for installation according to k-Class K1 or K2 can be installed with a Direct Tension Indicator washer and classed as k-Class K0. In this instance, supplied torque figures doesn't apply.

Before installation

Make sure that bolt assembly property class (grade) match with DTI supplied.

Bolt's grade 8.8 shall be installed with DTI grade H8, and Bolt's grade 10.9 shall be installed with DTI grade H10.

The grade of the DTI is stamped on the face of the washer as on below example.



The right length of the bolt needs to be showing (before tightening) a minimum of four (4) full threads from the shank to the bearing face of the nut and at least a minimum of one (1) full thread protruding above the nut.

The protrusion of the DTI needs to face towards the nut, if installing under the nut, or towards the bolt head if installed under the bolt head.

Any additional washer required for installation of DTI needs to be placed on top of the protrusions as shown in figures 1 to 4.

Do not apply any additional lubrication. BS EN 14399 assemblies are supplied pre-lubricated.

The use of water-displacing liquids like WD-40 is forbidden as can negatively impact the lubrication already applied on the product (bolt thread or the nut).

Nut shall be free running on the thread of the assembly and initial tightening shall be done by hand. The torque wrenches can be used for assistance during installation, by final inspection shall be carried out using a designated feeler gauge.

The surface of contact around the hole and components of the assemblies shall be cleaned to bare metal from any surface coating like galvanising or paint. The corrosion protection of the steelwork can be restored after the installation and this shall be done as soon as possible after installation.

Recommended Installation Procedure

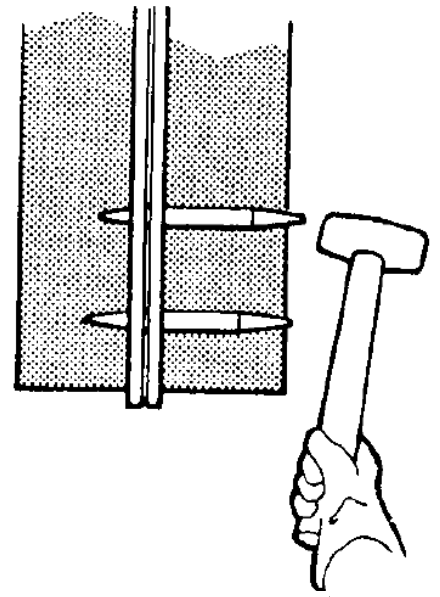
The DTI washer along with the assembly can be used only once. Once force been applied on the assembly and there is a need to adjust the construction, a fresh assembly with a DTI washer need to be used. This is due to the fact, that once compression of the protrusions cannot be undone and lubrication applied on the assembly been worn through the force applied.

The bolting assemblies and its components should be kept in clean, dry and ventilated area to prevent corrosion and deterioration of the lubrication.

Recommended Installation Procedure

Step 1

Bring the steel sections to be joined together and align the holes with drift pins. Bolts should not be used as drift pins to achieve alignment; this could result in thread damage that prevents the bolting assemblies with DTI washer from working correctly.



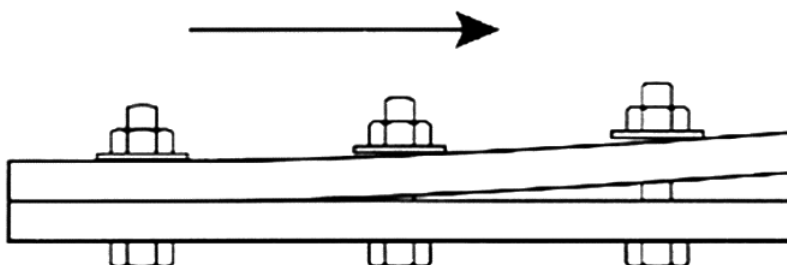
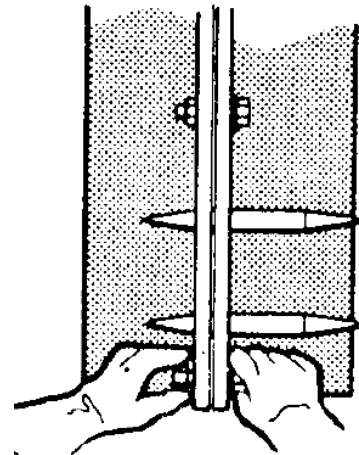
Step 2

Fill the remaining holes with bolting assemblies with DTI washer of the correct size. Partially tension the assemblies to snug the connection, this is achieved when the steel sections are in contact and the protrusions of the DTIs are just starting to be deformed. At this point, there will be approximately 50% of the minimum specified bolt preload applied.

Assemblies can be partially tensioned by:

1. Using a standard air or electric wrench.
2. Using a manual spanner or torque wrench.

When tightening a pattern of assemblies, work from the most rigid part of the connection to the free edges.



Recommended Installation Procedure

Step 3

Tension the assemblies until the DTIs are flattened to the specified average gap. Again, work from the most rigid part of the connection towards the free edges. Leave the drift pins in during this stage of the process. Premature removal of the drift pins may cause trapping of the assemblies by joint slippage.

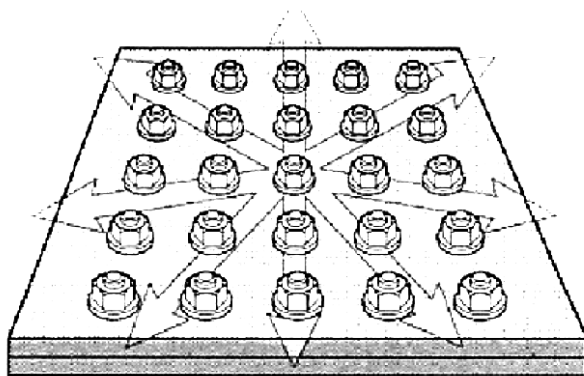
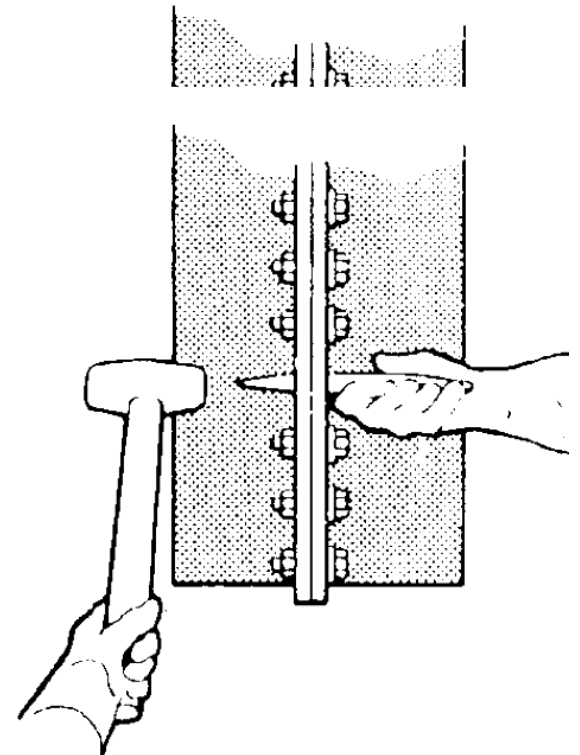
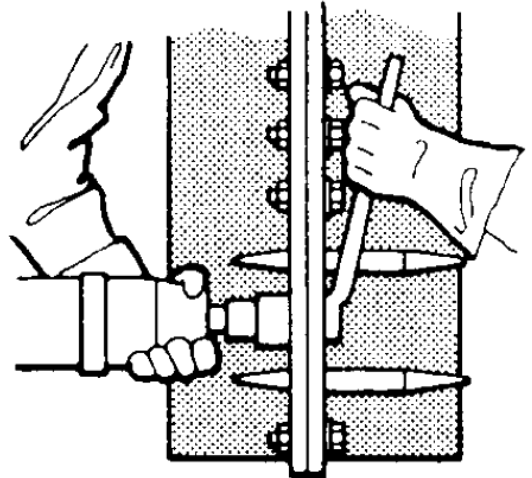
This is especially critical with bolting assemblies with DTI washer where the DTI is fitted under the nut and tightened by the nut. If the bolt is trapped by the plies of the connection the correct tension may not be generated in the bolt.

Step 4

Knock out the remaining drift pins and replace them with DTI assemblies and tighten them to the specified gap.

Systematic Tightening

Connections should be snugged and tensioned systematically. A pattern for snugging the connection is chosen that draws the parts together without any excessive bending. The initial tightening should start at the most rigid part of the connection. With a single or double row of assemblies, where the steel is in contact, working toward the end where there is no contact. In an assembly pattern, such as a large web splice plate in a girder, start at the centre and work out toward the free edges of the plate. The same pattern should be used when the assemblies are finally tensioned.



Configuration of bolting assemblies with DTI washers

The DTI washer can be assembled under either the bolt head or nut. Similarly, the assemblies can be tightened by rotation of either the nut or bolt head. This depends on access for the tightening wrench. Because tightening of a bolting assemblies with DTI washer is not dependent on torque, there are no restrictions on the method of assembly used with DTIs.

The following four diagrams show the configuration of bolting assemblies with DTI washer that are specified in the latest amendment of BS EN 1090-2 (2018).

Based on the selected configuration and grade of the bolts, additional washers may be required.

Nominal hole diameter for EN 14399 preloaded assemblies shall be +2 mm for up to M24 diameter and +3 mm for M27 and above.

For larger (oversized) holes, as per BS EN 1090-2, a plate washer shall be used with a hole that matches the requirements of the nominal hole diameter.

When assembled as shown in **Figure 2 (most common application)** and tightened with the latest lightweight electric wrenches, there are significant advantages that include ease of installation, a relatively quiet and vibration-free operation, that can be carried out by a single operator.

Figure 1 - Installing DTI under the bolt head when the nut is rotated

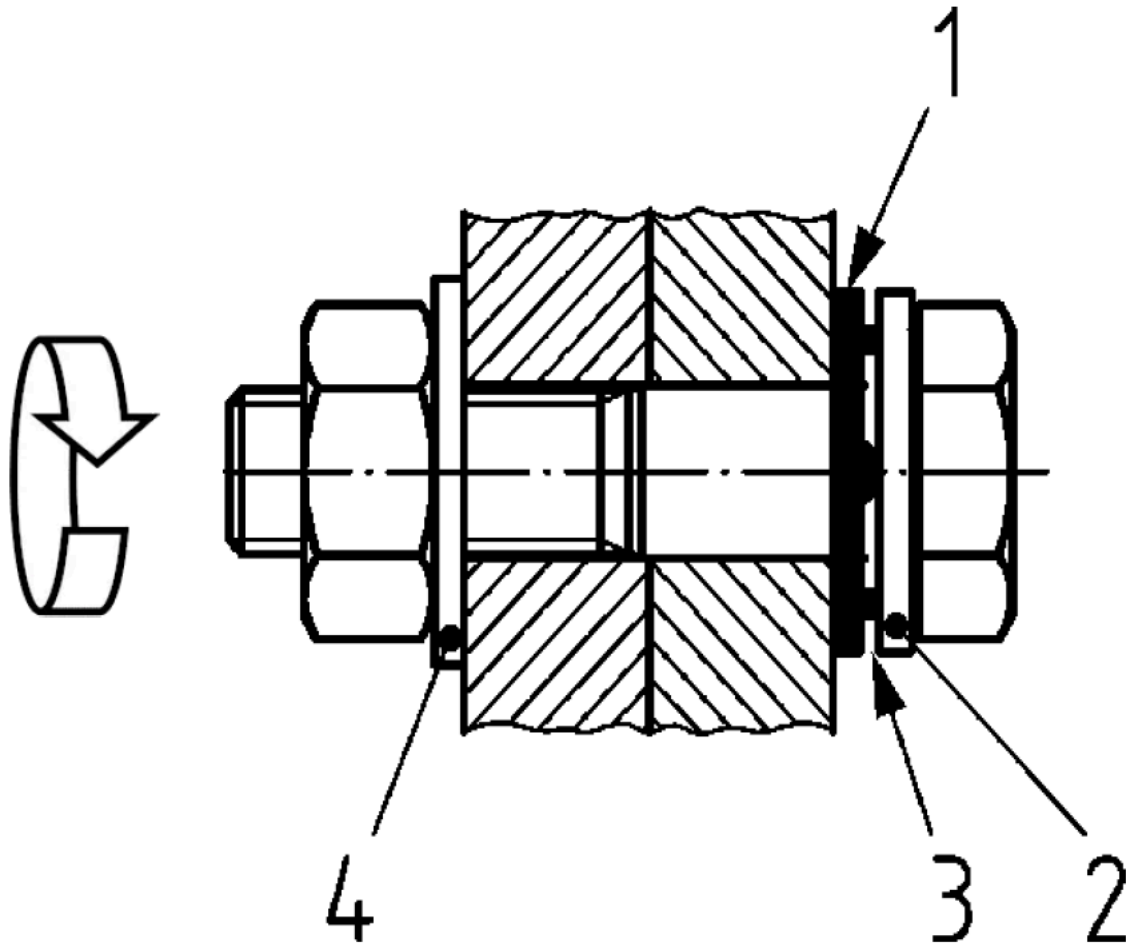


Figure 1

Key:

1. Direct tension indicator
2. Bolt face washer (BS EN 14399-9, marked HB, chamfered towards the bolt head)
(not required for bolt grade 8.8)
3. Gap
4. Plain washer to BS EN 14399-5, or Plain chamfered washer to BS EN 14399-6
(chamfer towards the nut)

Figure 2 - Installing DTI under the nut when the nut is rotated

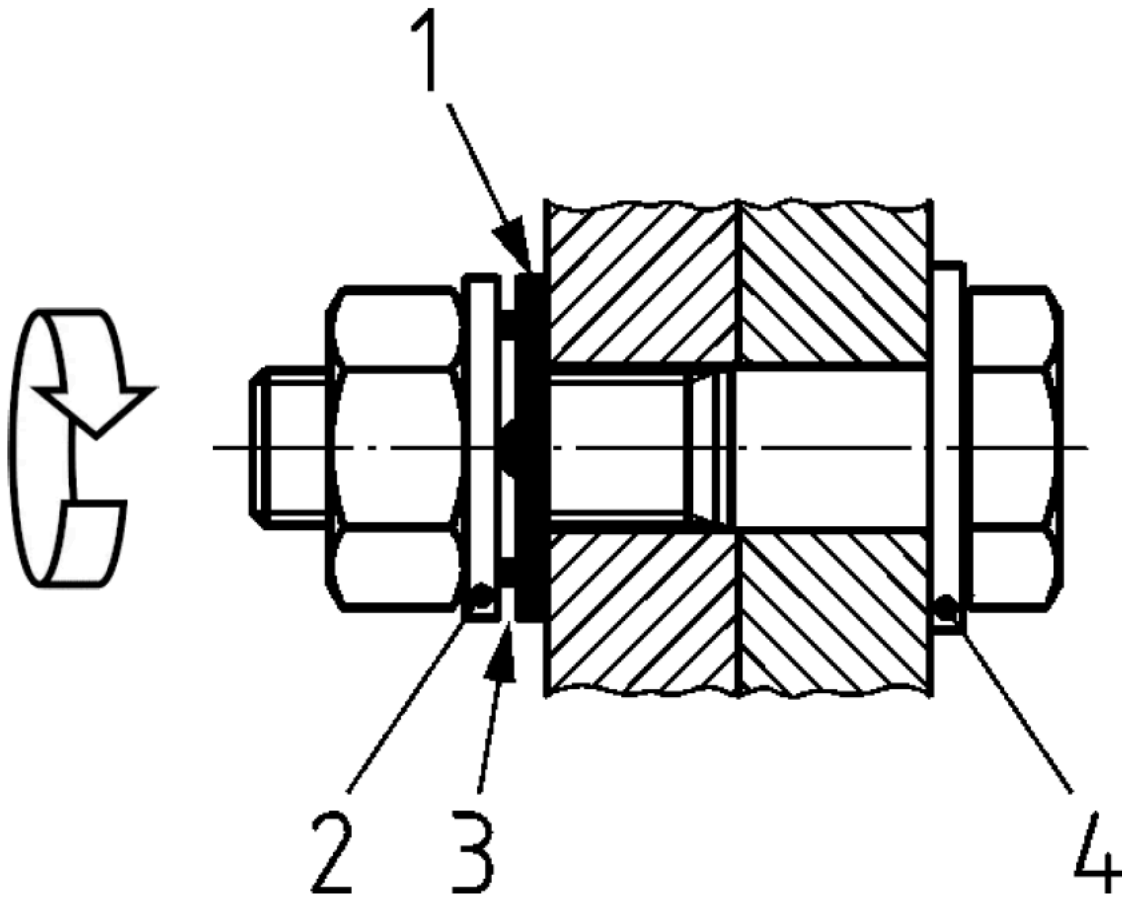


Figure 2

Key:

1. Direct tension indicator
2. Nut face washer (BS EN 14399-9, marked HN)
(required for both bolt grades, 8.8 and 10.9)
3. Gap
4. Plain chamfered washer to BS EN 14399-6 (chamfer towards the bolt head)
(not required for bolt grade 8.8)

Figure 3 - Installing DTI under the nut when the bolt head is rotated

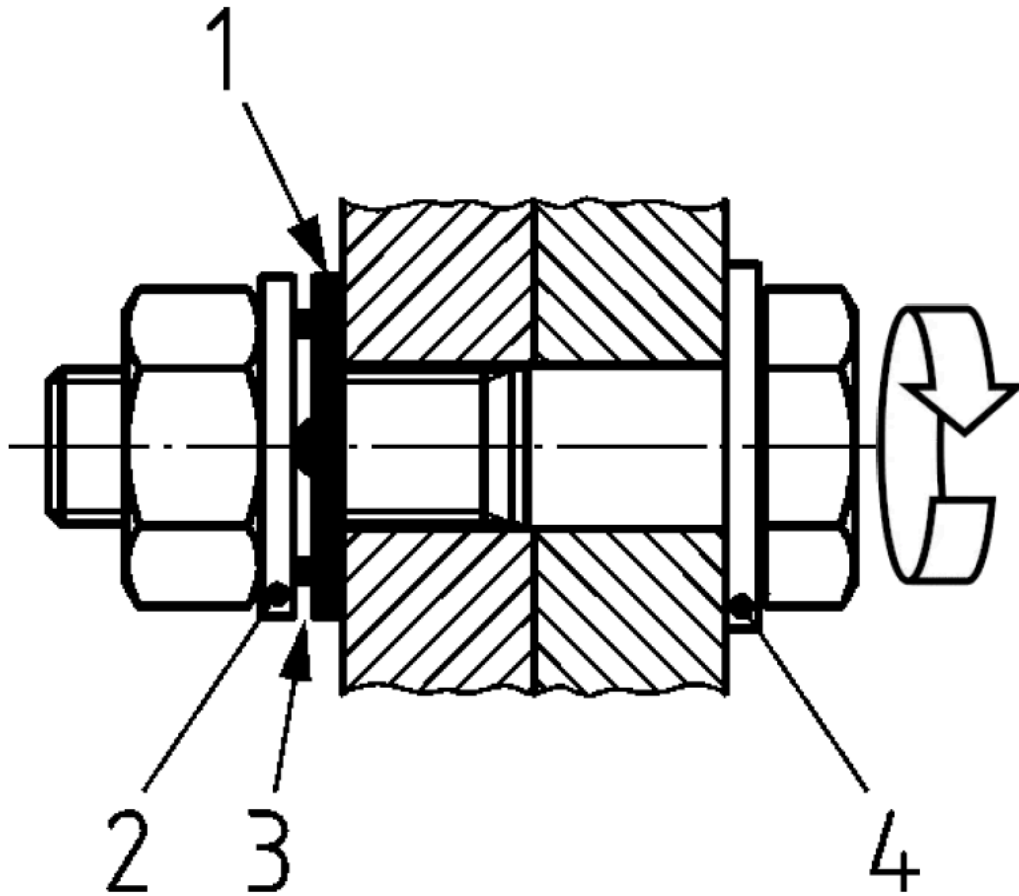


Figure 3

Key:

1. Direct tension indicator
2. Nut face washer (BS EN 14399-9, marked HN)
(required for both bolt grades, 8.8 and 10.9)
3. Gap
4. Plain chamfered washer to BS EN 14399-6 (chamfer towards the bolt head)

Figure 4 - Installing DTI under the bolt head when the bolt head is rotated

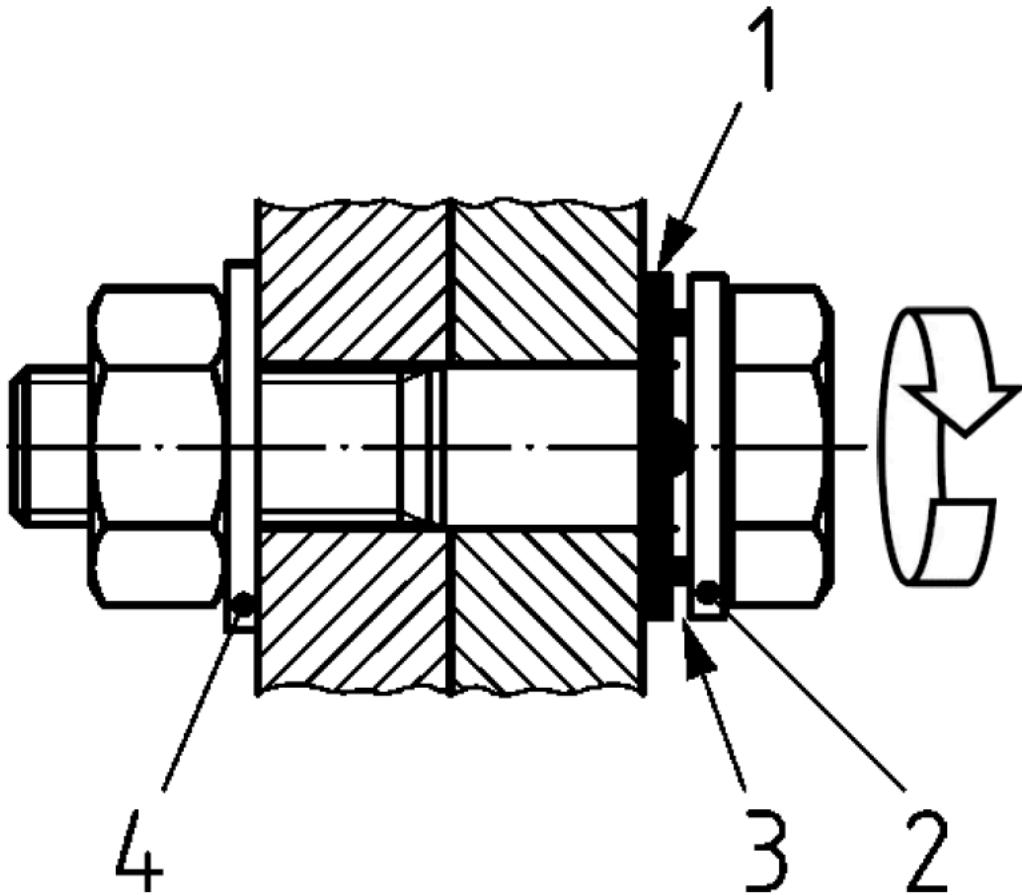


Figure 4

Key:

1. Direct tension indicator
2. Bolt face washer (BS EN 14399-9, marked HB, chamfered towards the bolt head)
(required for both bolt grades, 8.8 and 10.9)
3. Gap
4. Plain chamfered washer to BS EN 14399-6 (chamfer towards the nut)
(not required for bolt grade 8.8)

Inspection of Assembled DTIs

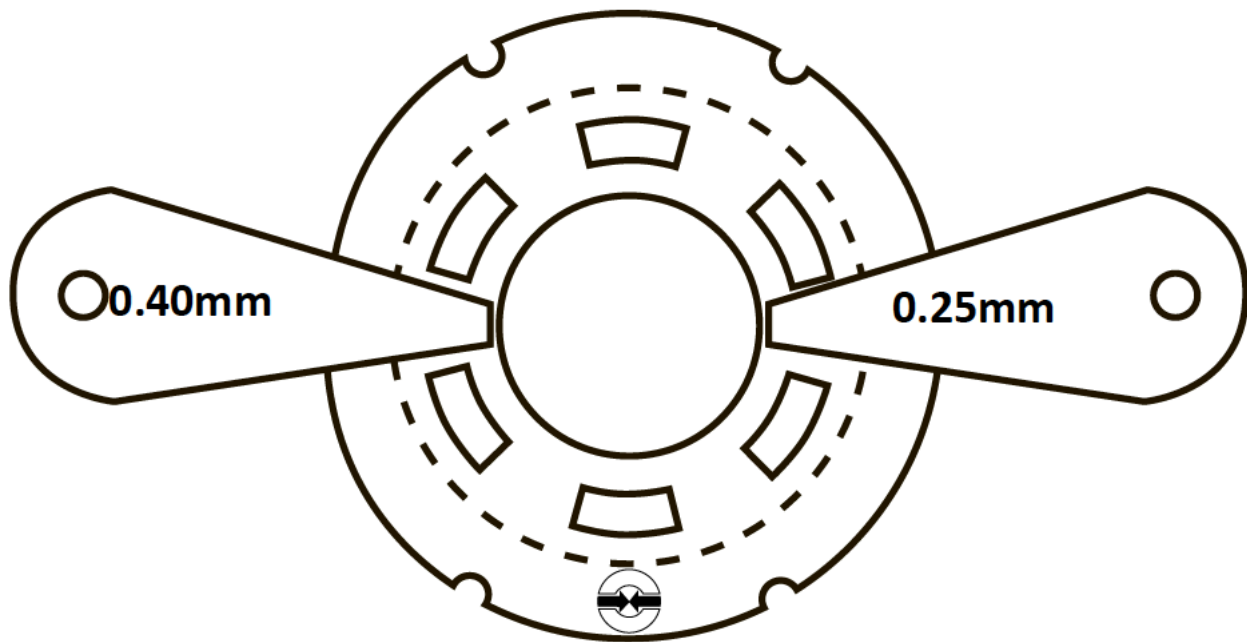


Figure 5

The feeler gauge required is specified in Table 1 for all configurations of DTI assemblies:

Table 1 – Thickness of the feeler gauge

Direct tension indicator positions	Designation H8 and H10 Thickness of feeler gauge
Under bolt head, when the nut is rotated (Figure 1)	0.40mm
Under nut, when the bolt is rotated (Figure 3)	
Under nut, when the nut is rotated (Figure 2)	0.25mm ¹
Under bolt head, when the bolt is rotated (Figure 4)	

Inspection of Assembled DTIs

Due to variations in steelwork components, it is unusual for bolting assemblies with DTI washer to flatten the protrusions of the DTI evenly, see Figure 6.

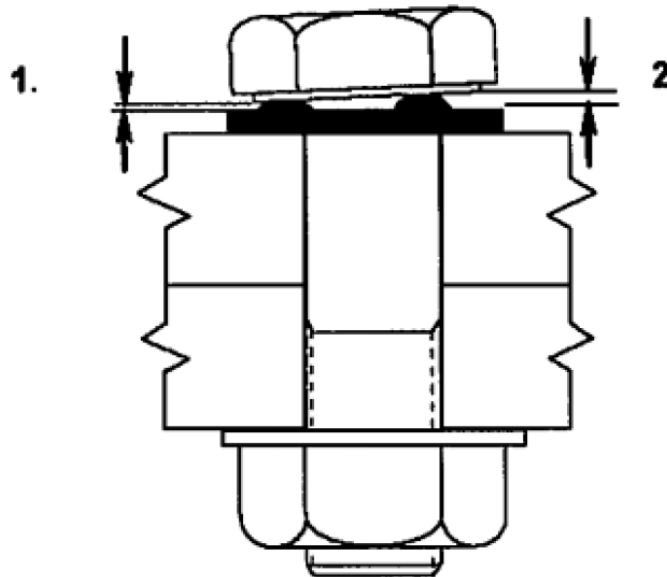


Figure 6 – Under bolt head fitting

Key

1. 'No go' gap if refusal occurs.
2. 'Go' gap if refusal does not occur.

To standardize the method of checking that the assembly is correctly tightened BS EN 1090-2 and BS EN 14399-9 specify the number of gaps for each type of DTI that the feeler gauge must not enter, see Table 2. There is no maximum number of feeler gauge refusals on a fully tightened structural bolting assembly.

Table 2 – Feeler gauge refusals

Number of direct tension indicator protrusions	Minimum number of feeler gauge refusals
4	3
5	3
6	4
7	4
8	5
9	5

Lubrication

The bolting assemblies with DTI washers shall meet the preload (F_p , C) values as specified in Table 3.

Table 3 – Minimum force in kN

Property Class	Bolt diameter in mm							
	12	16	20	22	24	27	30	36
8.8/H8	47	88	13	170	198	257	314	458
10.9/H10	59	110	172	212	247	321	393	572

Lubrication

Lubrication is critical to any preloaded structural bolting assembly. High-strength structural bolting assemblies for preloading require sufficient lubrication to achieve the minimum preload and further rotation.

CE and UKCA compliance

To comply with BS EN 14399-1, high-strength structural bolting assemblies for preloading shall be supplied by one manufacturer and shall include bolt, nut, relevant washer(s) and direct tension indicators.

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