Cooper & Turner

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High Strength Structural Bolting Assemblies for Preloading BS EN 14399–3 PC 8.8 Hex

Use of High Strength Structural Bolting Assemblies for Preloading BS EN 14399–3 PC 8.8 Hex with Direct Tension Indicators (DTI's)

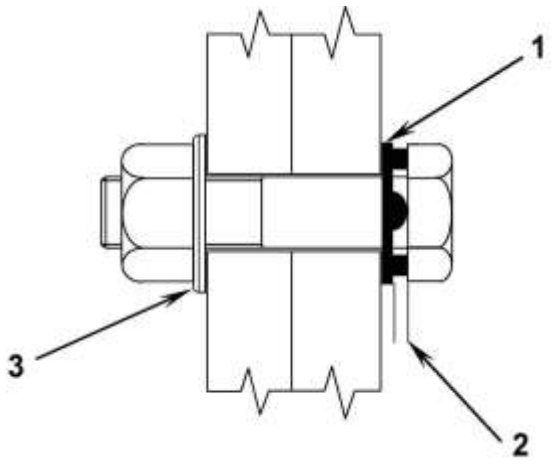
DTI fitted under bolt head tightened by nut rotation and DTI fitted under nut with a nut face washer tightened by nut rotation

Assembly Configuration - DTI fitted under bolt head

The most common assembly configuration for BS EN 14399-3 property class 8.8 hexagon head bolting assemblies is when the DTI is fitted under the bolt head and the assembly is tightened by nut rotation, as follows:-

a) BS EN 14399-3 property class 8.8 hexagon head bolt (marked 8.8 HR)
b) BS EN 14399-9 Direct tension indicator (marked H8) (component identified as 1 below)
c) BS EN 14399-6 hardened chamfered washer (marked H) (component identified as 3 below)
d) BS EN 14399-3 property class 10 nut (marked 10 HR)

The components shall be assembled as shown below (Figure1) with the direct tension indicator fitted under the bolt head and with the indicator protrusions bearing directly under the bolt head. The bolt and the direct tension are placed in the steelwork and at the other side of the connection the hardened chamfered washer is fitted with the plain side of the washer placed against the steelwork and the chamfered side facing outwards.
Note: The washers have a chamfer on the inside diameter with a corresponding chamfer (on the same side of the washer) on the outside diameter.
The nut is assembled with the side containing the marking facing outwards and the smooth unmarked side of the nut against the chamfered washer.
In this configuration the indicator protrusions shall always bear against the bolt head – NO OTHER WAY WILL DO



KEY **1 Direct Tension Indicator**
2 Gap
3 Washer according to EN 14399-6

Assembly configuration for EN 14399-3 Property Class 8.8 with DTI fitted under the bolt head - Tightened by nut rotation
Figure 1

Use of High Strength Structural Bolting Assemblies for Preloading BS EN 14399–3 PC 8.8 Hex with Direct Tension Indicators (DTI's)

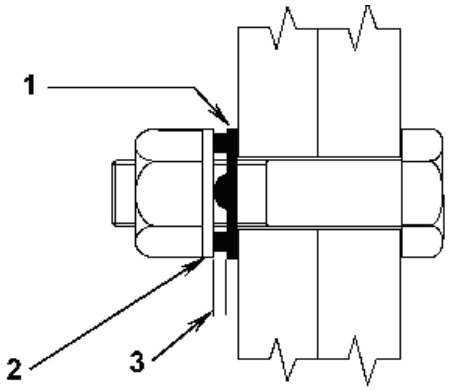
DTI fitted under bolt head tightened by nut rotation and DTI fitted under nut with a nut face washer tightened by nut rotation

Assembly Configuration - DTI fitted under the nut

The alternative assembly configuration for BS EN 14399-3 property class 8.8 hexagon head bolting assemblies is when the DTI is fitted under the nut with a nut face washer and the assembly is tightened by nut rotation, as follows:-

a) BS EN 14399-3 property class 8.8 hexagon head bolt (marked 8.8 HR)
b) BS EN 14399-9 Direct tension indicator (marked H8) (component identified as 1 below)
c) BS EN 14399-9 nut face washer (marked HN) (component identified as 2 below)
d) BS EN 14399-3 property class 10 nut (marked 10 HR)

The components shall be assembled as shown below (Figure 2) with the direct tension indicator fitted under the nut. The bolt is placed in the steelwork and at the other side of the connection the direct tension indicator is fitted with the flat side placed against the steelwork and the indicator protrusions facing outwards. The nut face washer is fitted over the bolt threads so that it sits on top of the indicator protrusions and the nut is assembled with the side containing the marking facing outwards and the smooth unmarked side of the nut against the nut face washer.
In this configuration the indicator protrusions shall always bear against the nut face washer – NO OTHER WAY WILL DO



KEY **1 Direct Tension Indicator**
2 Nut face washer
3 Gap

Assembly configuration for EN 14399-3 Property Class 8.8 with DTI fitted under the nut– Tightened by nut rotation
Figure 2

Initial Tightening

The bolt head shall be prevented from rotation and each assembly shall be brought to 'snug tight' condition by nut rotation. The tightening process shall be carried out from bolt to bolt within the group, starting from the most rigid part of the connection and moving progressively towards the least rigid part.
Note: The most rigid part of a cover plate connection of an 'I' section is commonly in the middle of the connection bolt group.
The 'snug tight' condition of a fastener assembly shall be when initial deformation of the DTI protrusions begins. This first step shall be completed for all bolts in one connection prior to commencement of the second step.

Final Tightening

When all the assemblies in a connection have been snug tightened then final tightening can commence. Tightening shall be carried out progressively from the most rigid part of the connection to the least rigid part. Tightening shall continue until the specified indicator gap has been achieved (see Table 1)
Do not expect the indicator gaps to be equal around the circumference. Due to the tightening operation the direct tension indicator invariably pulls down more on one side than the other. The direct tension indicator is designed to accommodate this and the average gap will always give the correct tension.

Table 1	
Thickness of feeler gauge	
Direct tension indicator position	Thickness of feeler gauge
Under bolt head, when nut is rotated (Figure 1)	0.4mm
Under nut with a nut face washer, when nut is rotated (Figure 2)	0.25mm

The average specified indicator gap shall be determined using the following measurement procedure; the feeler gauge shall be used as a 'no go' inspection tool. The feeler gauge shall be pointed at the centre of the bolt see Figure 3 and shall refuse to enter the number of refusal spaces specified in Table 2. It is advisable to leave some small gap to prevent accidental overtightening and breakage but if the gap has been completely closed inadvertently this is not considered by Cooper & Turner to be cause for rejection.

Table 2	
Feeler gauge requirements	
Number of indicator protrusions	Minimum number of feeler gauge refusals
4	3
5	3
6	4
7	4
8	5
9	5

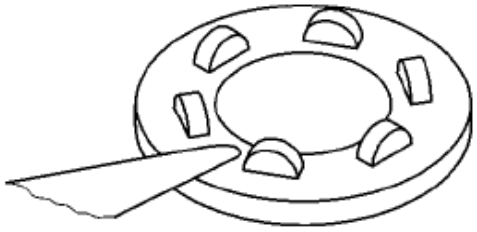


Figure 3 - Checking the indicator gap (example with six protrusions)

When the Direct Tension Indicators are installed in accordance with Cooper & Turner's instructions then the shank tension achieved will be in the range shown below in Table 3

DTI fitted under bolt head tightened by nut rotation and DTI fitted under nut with a nut face washer tightened by nut rotation

Table 3		
Nominal bolt diameter	Shank tension kN	
	H8 for 8.8	
	min	max
M16	88	106
M20	137	164
M22[1)]	170	204
M24	198	238
M27[1)]	257	308
M30	314	377
M36	458	550
[1)] Non – preferred sizes. Can only be supplied if the quantity required is sufficient to warrant manufacture.		

Inspection note: The only way to verify that the shank tension has been achieved is by use of the appropriate feeler gauge as detailed above.
The calibrated torque wrench method is not sufficiently accurate for inspecting Direct Tension Indicator tightened assemblies, as it only measures resistance to turning. It should not be used in any circumstances.

Dimensions of Holes for BS EN 14399-3 Assemblies

The nominal clearance for round holes is the difference between the nominal hole diameter and nominal bolt diameter. The hole sizes shown in Table 4 are in accordance with BS EN 1090-2:2008+ A1:2011

Table 4					
Nominal clearances for bolts (mm)					
Nominal bolt diameter (mm)	16	20	22	24	27 and over
Normal round holes (mm)	2				3
Tolerance on hole diameter ± 0.5mm					

Note: Direct Tension Indicators will not function correctly if fitted against hole sizes larger than those specified above. If the connection design permits the use of oversize or slotted holes and these holes are present in an outer ply of the connection then a plate washer, having a normal clearance round hole, shall be fitted against the over size or slotted hole. Information regarding plate washers is contained in BS EN 1090-2:2008+ A1:2011

Grip lengths for BS EN 14399-3 PC 8.8 Assemblies with DTI's
Table 5 below is provided for guidance only. Whilst this information is provided in good faith, no member of the Andaray group of companies shall be under any responsibility or liability in respect of errors or information that is found to be incorrect or for any reliance the user may place on it.
The bolt thread lengths shown in BS EN 14399-3:2005 do not provide, for some of the shorter bolt lengths, the minimum four threads in the grip required by BS EN 1090-2. Cooper & Turner recognised this fact and have for a number of years manufactured certain of their BS EN 14399-3 assemblies with longer thread lengths to satisfy the minimum threads in the grip required by BS EN 1090-2. Table 5 therefore only applies to Cooper & Turner manufactured BS EN 14399-3 PC 8.8 assemblies with one washer (either a BS EN 14399-6 washer when the DTI is fitted under the bolt head or a BS EN 14399-9 Nut Face Washer when the DTI is fitted under the nut) and a Direct Tension Indicator.

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DTI fitted under bolt head tightened by nut rotation and DTI fitted under nut with a nut face washer tightened by nut rotation

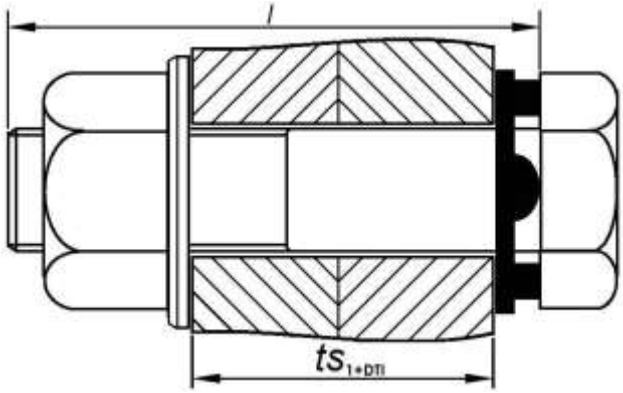

Figure 4 - DTI under bolt head

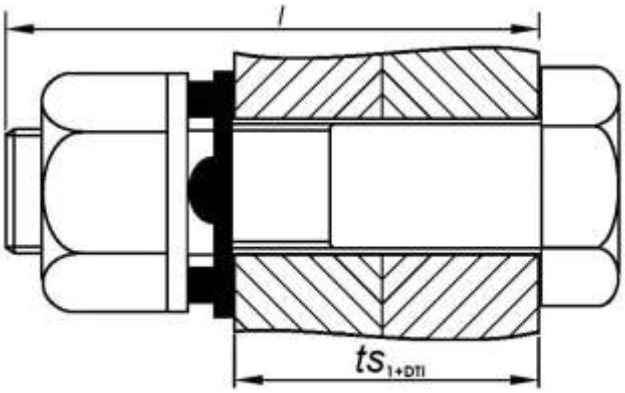

Figure 5 - DTI under nut

Table 5

Grip Lengths with one washer and a DTI ts_{1+DTI}

Thread *d*	M16		M20		M22[1)]		M24		M27[1)]		M30		M36	
Bolt Length *l*	$ts_{1+DTI\ min}$ and $ts_{1+DTI\ max}$													
nominal	min	max	min	max	min	max	min	max	min	max	min	max	min	max
45	10	16												
50	13	21												
55	13	26	13	22	13	20								
60	24	31	17	27	13	25	17	22						
65	29	36	17	32	18	30	17	27	16	24				
70	34	41	27	37	18	35	22	32	16	29	20	26		
75	39	46	32	42	28	40	22	37	16	34	20	31		
80	44	51	37	47	33	45	22	42	24	39	20	36		
85	49	56	42	51	38	50	36	47	24	43	30	41	23	34
90	54	61	47	56	43	55	41	52	34	48	30	46	23	39
95	59	66	52	61	48	60	46	57	39	53	30	51	33	44
100	64	71	57	66	53	65	51	62	44	58	40	56	33	49
110	74	81	67	76	63	75	61	72	54	68	50	66	33	59
120	84	91	77	86	73	85	71	82	64	78	60	76	49	69
130	88	100	81	96	77	94	75	92	68	88	64	86	53	78
140	98	110	91	106	87	104	85	102	78	98	74	96	63	88
150	108	120	101	116	97	114	95	112	88	108	84	106	73	98
160	118	128	111	124	107	122	105	120	98	116	94	114	83	106
170							115	130	108	126	104	124	93	116
180							125	140	118	136	114	134	103	126
190							135	150	128	146	124	144	113	136
200							145	160	138	156	134	154	123	146

[1)] Non – preferred sizes. Can only be supplied if the quantity required is sufficient to warrant manufacture.

For the calculation of grip lengths ts_{1+DTI} the following formulae have been used

$ts_{1+DTI\ max} = l_{min} - m_{max} - h_{max} - 1P - h_{2\ max}$

$ts_{1+DTI\ min} = l_{gmax} + 4P - h_{min} - h_{1\ min}$

where

ts_{1+DTI} grip length; the total thickness of the clamped parts between the nut bearing face and the bolt bearing face less the thickness of the washer and the DTI (mm)

l length of the bolt (mm)

m height of the nut (mm)

h washer thickness (mm)

P thread pitch (mm)

h_1 DTI material thickness (mm)

h_2 DTI thickness over protrusions (mm)

l_g distance from the bearing face to the first full form (full profile) thread (mm)

NOTE: This table is provided for guidance only, see disclaimer at bottom of page

Corrosion

BS EN 14399-3 assemblies, bolts, nuts, washers and Direct Tension Indicators, will corrode if not properly protected. They must be kept in a clean dry and well ventilated store. It is important that only the number required for immediate installation are taken from the stores in order that none are allowed to lie about on site and deteriorate.

Painting should be carried out at an early stage after tightening. This is particularly important in marine or other corrosive environments.

The metallic coatings applied to structural fasteners are only intended to give temporary protection during storage and installation – early painting will still be required. Research has shown that susceptibility to stress corrosion cracking, environmentally induced brittle failure and hydrogen embrittlement increases with tensile strength. The presence of a metallic coating lowers the threshold of the tensile strength at which these phenomena may occur. This means under certain conditions a metallic coating may reduce corrosive resistance, rather than enhance it and the specifier must take account of site environment in deciding the suitability or otherwise of a coating. Special care must be taken in the storage of these items and early protection by painting.

Installation Tips

Check that all the bolts, nuts, washers and Direct Tension Indicators are the required property class / designation before fixing.

Ensure that the bolts fit the holes freely – forcing the bolts into the holes by means of hammering would damage the threads

The Direct Tension Indicator protrusions must always bear against the bolt head (see Figure 1) or a nut face washer (see Figure 2) – NO OTHER WAY WILL DO

Never allow the bolt head to spin on the Direct Tension Indicator protrusions

Hand wrenches may be satisfactory for tightening smaller diameters of bolts, but power tools or torque multipliers must be used for sizes above M20 diameter. It is most important that impact wrenches have adequate capacity to tighten bolts within about 15 seconds (slightly longer if gear driven wrenches used). Prolonged impacting can damage the bolt assembly to such an extent that the bolt may be fractured.

In selecting a tool, it is wise to choose one which has a torque output in excess of the theoretical figure required for tightening the largest bolt for which it will be needed, thus making some allowance for loss of performance due to wear, air leakage etc., and to help overcome the energy absorbed by higher than usual thread friction or 'springy' joints.

In order to obtain optimum tool performance the tool manufacturer's specification regarding air pressure, air flow volume and hose size must be followed.

The only way to confirm that a particular tool is suitable is by judging its performance in bolt tightening under actual site conditions.

Where steelwork is to be left exposed, tightening, inspection and painting should be carried out within the shortest time to prevent corrosion

The Direct Tension Indicator is a precision made measuring device and on no account should it be given any further treatment after leaving the supplier

A Direct Tension Indicator does not make an assembly any more difficult to tighten – it simply leaves a permanent witness that the assembly has been tightened to the correct tension

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DTI fitted under bolt head tightened by nut rotation and DTI fitted under nut with a nut face washer tightened by nut rotation

Problems tightening BS EN 14399-3 assemblies

The causes of the occasional problems encountered in trying to obtain the specified Direct Tension Indicator gaps when tightening BS EN 14399-3 assemblies can be generally categorised under three headings:-

1) Fit – Ensure that the bolts fit the holes freely and that poor alignment of the holes is not causing the bolts to trap.

2) Tooling – Using adequate capacity impact wrenches and satisfactory thread condition, the tightening operation should be completed within about 15 seconds (slightly longer if gear driven wrenches used). If it is not check for dry, rusty or damaged threads, poor fit, bad hole alignment or for a tool fault

3) Additional Lubrication – The nuts which Cooper & Turner supply with their BS EN 14399-3 assemblies are lubricated but in certain circumstances e.g. if the assemblies have experienced less than ideal storage conditions, additional lubrication may be necessary.

During the tightening of BS EN 14399-3 assemblies high frictional stress can develop and the likelihood of this occurring is greater when the assemblies have one of the thicker sacrificial coatings i.e. galvanizing or sherardizing, but it can occur with zinc electroplating and occasionally with self colour products. In certain circumstances the frictional stress can lead to torsional failure of the bolts before the proof load is achieved. This high frictional stress can be reduced by the application of a suitable high pressure lubricant which should be applied both to the nut threads and the nut washer face. In Cooper & Turner's experience the most effective and economical lubricant for this purpose is tallow*.

The use of a high pressure lubricant in the way described has no detrimental effect whatsoever on the functioning of the installed BS EN 14399-3 assemblies. The lubricant simply allows the torque applied to the nut to be more efficiently transferred into bolt shank tension and since the shank tension in the assembly is indicated by the Direct Tension Indicator gap, the reduction in the installation torque is of no consequence.

* In the UK, tallow is generally available from plumbers' merchants. In parts of the world where tallow may not be available a product called 'stick wax', manufactured by a number of companies including Johnson and Castrol, is used for on-site lubrication of fasteners, alternatively a grease with a high molybdenum content may be effective. The high pressure lubricant selected should be of medium to high viscosity and should be applied both to the nut threads and nut washer face in order to prevent the possibility of contaminating the inner faces of the BS EN 14399-3 joint.

Final Note

The recommendations detailed in this data sheet are a summary of our experience.

The final responsibility for the specification and the use of High Strength Structural Bolting Assemblies for Preloading BS EN 14399–3 Property Class 8.8 with Direct Tension Indicators must lie with the Designer, Consultant or Engineer, who must satisfy themselves that what they are specifying is what they themselves know from their own experience to be suitable, for the particular application for which they are responsible.