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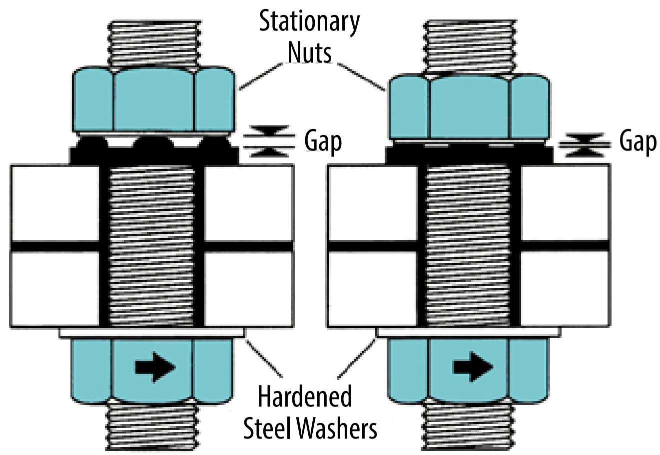
DTI's

Direct Tension Indicators



Before Tensioning **After Tensioning**

- **Patented bolt load measuring technology**
- **Eliminates fugitive emissions**
- **Verifies correct tension for secure joints**
- **Bolt load achieved regardless of bolt condition and torque applied**
- **Simple to install and inspect with standard tools, no special training**
- **Low cost alternative to ultrasonic measuring**

FASTORQ TOTAL ASSURANCE GUARANTEE

DTI 1-YEAR WARRANTY

LEADING PROVIDER OF BOLT LOADING & REMOVAL SOLUTIONS

2013

DTI's

Correct Tension for Secure Joints

A bolted joint obtains its superior characteristics through proper clamping force on the gasket contact surfaces. The clamping force, or bolt load is caused by correctly tensioned bolts. If the bolts have not reached required tension, there is insufficient clamping force and the joint is not up to specification. If excessive clamping force is used, the bolt, gasket, and/or the flange may be damaged. In either case, a leak is the probable result. Therefore, it is imperative that the proper clamping force is achieved. Direct Tension Indicators provide the means to measure bolt tension (bolt load).

Correct Tension for Secure Joints

- **Accuracy –** The bolt is tightened to a specified DTI gap which has been achieved directly by clamping force, or tension. This means you are measuring the actual outcome of your efforts instead of work input. Accuracy is not affected by bolt grip length.
- **Consistency –** Direct Tension Indicators are manufactured in small lots, and each lot is tested for consistency. A test report is kept and its lot number is marked on each DTI. In use, if the DTI's are compressed to the gap specified, each bolt is proved to be tensioned over the minimum, and under the maximum load.
- **Cost Savings –** Inspection is cost effective with Direct Tension Indicators because they are in use as long as the fastener is, do not required any special training to use or to inspect, and they help prevent rework.
- **Versatility –** The DTI can be used under the bolt head or at the nut end with a hardened washer, and it will take up to a 1:20 bevel (see figure 4).
- **Simplicity and Ease of Installation –** DTI's are easy to install with standard tools – proper clamping force is unmistakable.
- **Ease of Inspection –** The Direct Tension Indicator provides immediate visual proof that the bolt has been correctly tensioned. All you need is a feeler gauge.
- **Standardization –** Direct Tension Indicators are made to fit bolts manufactured to ASTM A193-B7 and B16, as well as equivalent metric sizes and specifications. DTI's can be manufactured and tested for use with customer specified bolt materials.

Figure 1

Direct Tension Indicators measure clamping forces (bolt load)

The Direct Tension Indicator (DTI) is a specially hardened washer with protrusions on one face (see figure 1). The DTI is placed under the bolt head or nut, and the protrusions create a gap. As the bolt is tensioned, the clamping force flattens the protrusions, reducing the gap (see figure 2).

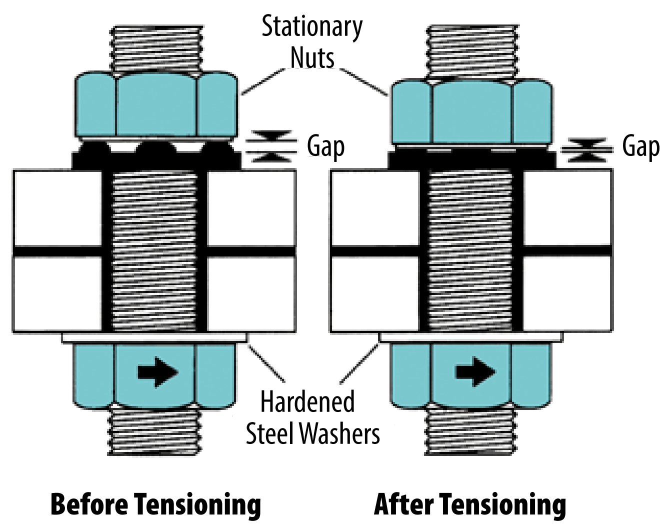


Figure 2

What Could be Simpler?

Correct bolt tension is evaluated by simply observing the remaining gap. A "no-go" feeler gauge is used to insure that minimum specified bolt tension is achieved. A "go" feeler gauge is used to insure that maximum specified bolt tension is not exceeded. DTI's stay on the job, providing permanent visual and measurable proof that the bolt is correctly tensioned to specification. Gap corresponds to bolt load verified by a test certificate traceable to NIST.

Tests on four 1 1/4" diameter B7 Bolts

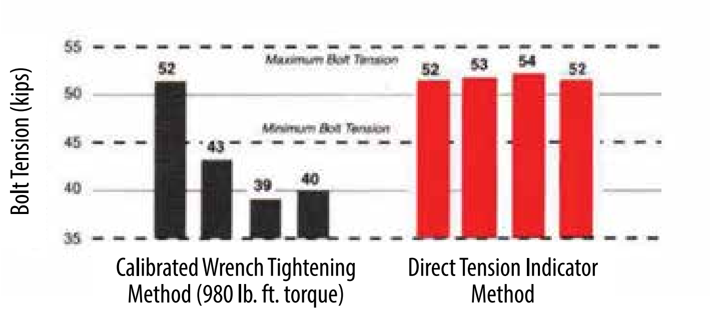


Figure 3

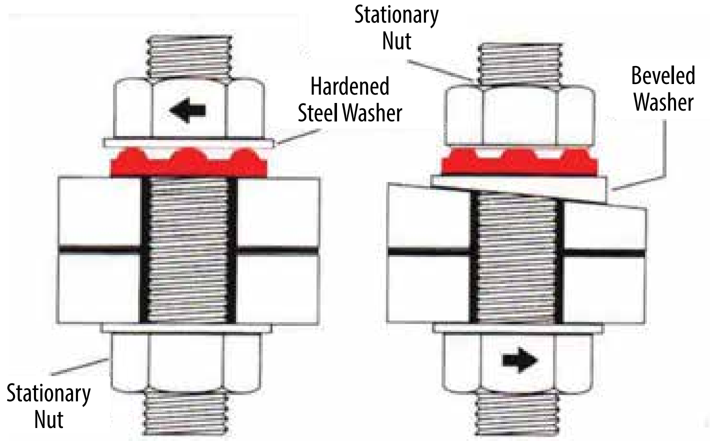
For Example:

A 1 1/4" diameter B7 bolt loaded to 50% of minimum yield will have a clamping force (tension) of 52,500 pounds. A DTI for this 1 1/4" B7 bolt will have a remaining gap of .039" at 52,500 pounds of load. A "no-go" feeler gauge .039" thick will indicate 52,500 pounds load when it is refused at one half or more of the openings between protrusions. A "go" feeler gauge .002" thinner, or .037" thick, when it is accepted at one half or more of the openings, will indicate that excessive load has not been applied. A test certificate relating gap to bolt load is provided with each lot of DTI's manufactred. Test certificates are also available relating customer specified load to gap.

Figure 3 shows the variation in bolt load (tension) on four 1 1/4" bolts which were all torqed to 980 ft. lbs. without using Direct Tension Indicators. Four more 1 1/4" bolts from the same lot were tightened using DTI's to a .039" gap. The variation in bolt load using DTI's was far less. With uniform bolt load, your fastened joint is more reliable.

DTI's provide precise measurement of clamping forces regardless of bolt condition.

Broadly defined, torque is the force, or work, required to tension a bolt. This is measured by calibrated wrenches. But the amount of work, or torque, required to properly tension bolts is significantly affected by the condition of the threads. As friction between nut and bolt threads increases, the amount of work required to install a bolt to a specific tension increases. The Direct Tension Indicators measure the resulting tension (bolt load). Input torque or procedures may change, but the bolt load indicated by the Direct Tension Indicators will be accurate.



When the DTI is installed under the nut being turned, a hardened steel washer must be used betweeen the nut and the DTI.

DTI's can be used with bevel washers to accomodate over a 1:20 bevel.

Figure 4

DTI's measure bolt load achieved – regardless of bolt condition or torque applied.

Most installation problems in the field are caused by bolt conditions. *Corrosion and dirt* – bolts that have been exposed to atmospheric conditions and weather in the field require extra work to tighten to the specified tension because of corrosion and dirt that has accumulated in the bolt threads. Therefore the mechanic may need to use a wrench of greater torque capacity.

Another way of overcoming the extra work caused by thread corrosion and dirt is by using clean, lubricated nuts and bolts. For example, lubricants such as moly or nickel paste can reduce the coefficient of friction by as much as 50 percent.

Given a wrench of sufficient capacity, and fasteners that are clean and lubricated, the time taken to properly install the bolt should be greatly reduced.

DTI's
Questions and Answers

QUESTION	ANSWER
Will using DTI's change my torque or tension requirements?	**No.** Direct Tension Indicators measure bolt load, but do not change requirements.
If there are great temperature fluctuations in the joint: Will DTI's cause relaxation in the bolt load?	**No.** If the fasteners are tensioned according to specification, temperature creep may still occur but DTI's neither increase or decrease it.
If the stud/bolt is over-tensioned can I back the nut off and use the same DTI again?	**No.** Once the protrusions on the DTI's are compressed past the designated amount, a new DTI must be used.
If enough clamping force has not been achieved when the gap is measured, do we need to start from the beginning again?	**No.** If the "no-go" gauge still fits in the gap, simply create more tension (and therefore more clamping force) until the "no-go" gauge does not fit but the "go" gauge still does fit.
Is it possible for my company to get a demonstration of the Direct Tension Indicators?	**Yes.** We are happy to provide additional information and demonstrations. We even have a video on DTI's.
Has there been any testing to confirm the information on DTI's?	**Yes.** Please refer to the technical reports section of this brochure. Then call (800) 231-1075 or (281) 449-6466 for any reports you would like to receive.

FACTS:

Torquing a stud or bolt creates tension
Tension in the stud/bolt creates clamping force on the joint
Clamping force (also referred to as bolt load) on the joint, in the correct amounts, holds the gasket properly and creates a secure critical joint.

Stress relaxation and fatigue

Stress relaxation tests conducted over long periods on cold worked steel show that no measurable cold creep is experienced at temperatures below 302°F (150°C). This is confirmed by tests on Direct Tension Indicators which, after bolting up to indicated load at ambient temperature, show no relaxation in bolt tension after 2,700,000 cycles. The load tests conducted were from 0 to 0.6 times proof load on bolts tightened to proof load with DTI's.

Technical reports

The Direct Tension Indicator has been thoroughly tested. A comprehensive study entitled "Bolt Tension Control with a Direct Tension Indicator", was conducted in August 1972 by J.H.A. Stuick, A.O. Oyeledun, and J.W. Fisher of the Fritz Engineering Laboratory, Lehigh University, Bethlehem Pennsylvania. The description and results of this and other tests are available in the following series of technical reports and may be obtained on request.

- #23 Corrosion-Exposed Structures
- #24 Unloading and Reloading
- #25 Stress Relaxation
- #26 Fatigue
- #29 A490 Tightening
- #30 Time Trials of Tightening Methods

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DTI's
Technical Report #23

Accelerated corrosion tests on high strength bolts & 'Coronet' Load Indicators

Introduction

A feature of the 'Coronet' Load Indicator, as describes in Leaflet 61/1A, is the gap left between the underside of the bolt head and the face of the Indicator to permit the insertion of a feeler gage. The correct bolt tension is produced when the gap is reduced to an average of 1.015" in exposed positions there appeared to be a possibility that moisture would enter through the gap and corrode the bolt and plates.

An independent Laboratory undertook to investigate the susceptibility of the assembly to corrosion.

Preparation

A number of specimens were prepared, each comprising two Mild Steel plates 6" x 6" x ¾" thick, shot blasted and drilled with four 15/16" holes for 7/8" bolts with centers 1-1/2" from each edge. The plates were clamped together with 7/8" black High Strength Bolts using the following bolt and washer assemblies:

(a) Pairs 1 and 2. Plain hardened washer under the bolt heads and tightened to 480 ft-lbs. On a torque wrench.

(b) Pairs 4 and 5.'Coronet' Load Indicators and tightened to give an average gap of 0.015"

(c) Pair 6. 'Coronet' Load Indicators and tightened to give an average gap of .015".

The edges of the plates were then sealed with waterproof Denso tape to prevent moisture entering between them, and in order to observe the effect of painting, some specimens were given different treatment on each quarter:

1st quarter	No paint.
2nd quarter	1 coat Red Lead.
3rd quarter	2 coats Red Lead.
4th quarter	2 coats Red Lead. 2 coats Micaseous Iron Oxide.

Test procedure

The specimens were exposed for 2 months in an atmosphere of 100% humidity at 40° - 45°C. into which for 5 days a week sulphur dioxide was introduced for one hour, to simulate industrial atmospheres. For a further 7 months, the specimens were left in an enclosed space, high humidity being maintained by the presence of an open topped water reservoir. Temperature and humidity were allowed to fluctuate according to prevailing climatic conditions.

This treatment may be expected to reproduce the effects of a 20 year exposure under normal service conditions.

On completion of the test, the plates were dismantled and the condition of each bolt and thread within the joint carefully observed.

Results

Light rusting was apparent on specimens assembled with 'Coronet' Load Indicators without painting, and on those with only one coat of Red Lead. Specimens with two coats of Red Lead or the full paint treatment showed no sign of corrosion.

Conclusion

The normal thickness of paint film applied to structural steelwork is sufficient to seal the 0.015" gap of a 'Coronet' Load Indicator and prevent corrosion of the bolt.

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DTI's
Technical Report #24

Coronet Load Indicators – load/gap relationship on unloading and loading

Introduction

When tightening a group of bolts in a joint, the tightening of the later bolts may cause flexure of the plies with consequent relaxation of tension in the bolts initially tightened. It is customary to minimize this effect by tightening in a pattern from the center of the joint outwards and if necessary, repeating the sequence to obtain even tension in all bolts. These tests investigate whether load relaxation in a high strength bolt results in a measurable increase in Load Indicator gap.

Summary

It was found that Coronet Load Indicators would show loss of load by a gap increased from the original full load measurement. Re-tightening until the gap was slightly less than the original full load measurement restored the tension.

Procedure

A 7/8" diameter A325 High Strength Bolt was fitted with Coronet Load indicator under the head and tightened in a Norbar load meter to an average indicator gap of 0.015" then untightened at approximately 4-1/2" kip steps, average gap noted, and finally re-tightened back to the original load.

The test was repeated on two further bolts.

Results

Test 1		Test 2		Test 3	
Load Kips	**Gap Inches**	**Load Kips**	**Gap Inches**	**Load Kips**	**Gap Inches**
Down		**Down**		**Down**	
37.4	0.015	39.6	0.015	38.0	0.015
34.2	0.0152	35.2	0.0154	25.8	0.016
28.7	0.0154	29.4	0.0158	21.3	0.016
24.2	0.0158	25.6	0.0162	15.7	0.0168
18.8	0.0164	21.1	0.0166	11.2	0.0176
14.4	0.0166	16.4	0.017	5.2	0.0188
5.8	0.0184	12.1	0.0174		
		2.5	0.0194		
Up		**Up**		**Up**	
36.8	0.0148	37.4	0.015	34.8	0.015
37.7	0.0144	40.0	0.014	37.8	0.0136

N.B.—The Coronet Load indicators used in these tests were calibrated to give a minimum bolt tension of 36.05 kips at 0·015" average gap. ASTM A325 has since increased the required tension to 39.25 kips. Coronet Load Indicators have been modified accordingly.

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DTI's
Technical Report #25

Stress relaxation test on high strength bolt and Coronet Load Indicator

Introduction

The design of a high strength bolted joint depends on the maintenance of static tension in the bolts throughout their working life. The test examines relaxation over a number of years.

Summary

Over a period of eight years there was no measurable loss of tension.

Procedure

A 7/8″ diameter bolt was tightened in a simulated joint with a Coronet Load Indicator under the bolt head and a flat round washer under the nut. Measurements of overall bolt length and Indicator gap were taken at intervals.

Observations

The slight variations which have occurred throughout these tests will be seen to go up and down and are considered to be due to ambient temperature variation.

DTI Technical Report No-25.doc Page 1 of 1

Results Bolt length before tightening – 3.983″

Date Readings Taken	Duration Hrs.	Length After Bolting	Load Indicator Gap at Each Measuring Point				Average Gap	Bolt Extension
7/26/63	Nil	3.9920″	.013″	.015″	.016″	.016″	.015″	.0090″
8/16/63	(500)	3.9920″	.013″	.013″	.015″	.016″	.0142″	.0090″
11/29/63	(3000)	3.9918″	.016″	.016″	.014″	.013″	.0147″	.0088″
9/15/66	(10000)	3.9920″	.016″	.016″	.014″	.014″	.015″	.0090″
11/5/66	(20000)	3.9923″	.016″	.016″	.014″	.013″	.014″	.0093″
12/29/66	(30000)	3.9922″	.015″	.014″	.016″	.013″	.014″	.0090″
6/8/71	(8 years)	3.9923″	.016″	.016″	.014″	.013″	.014″	.0093″

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DTI's
Technical Report #26

Fatigue test on high strength bolts and 'Coronet' Load Indicators

Introduction

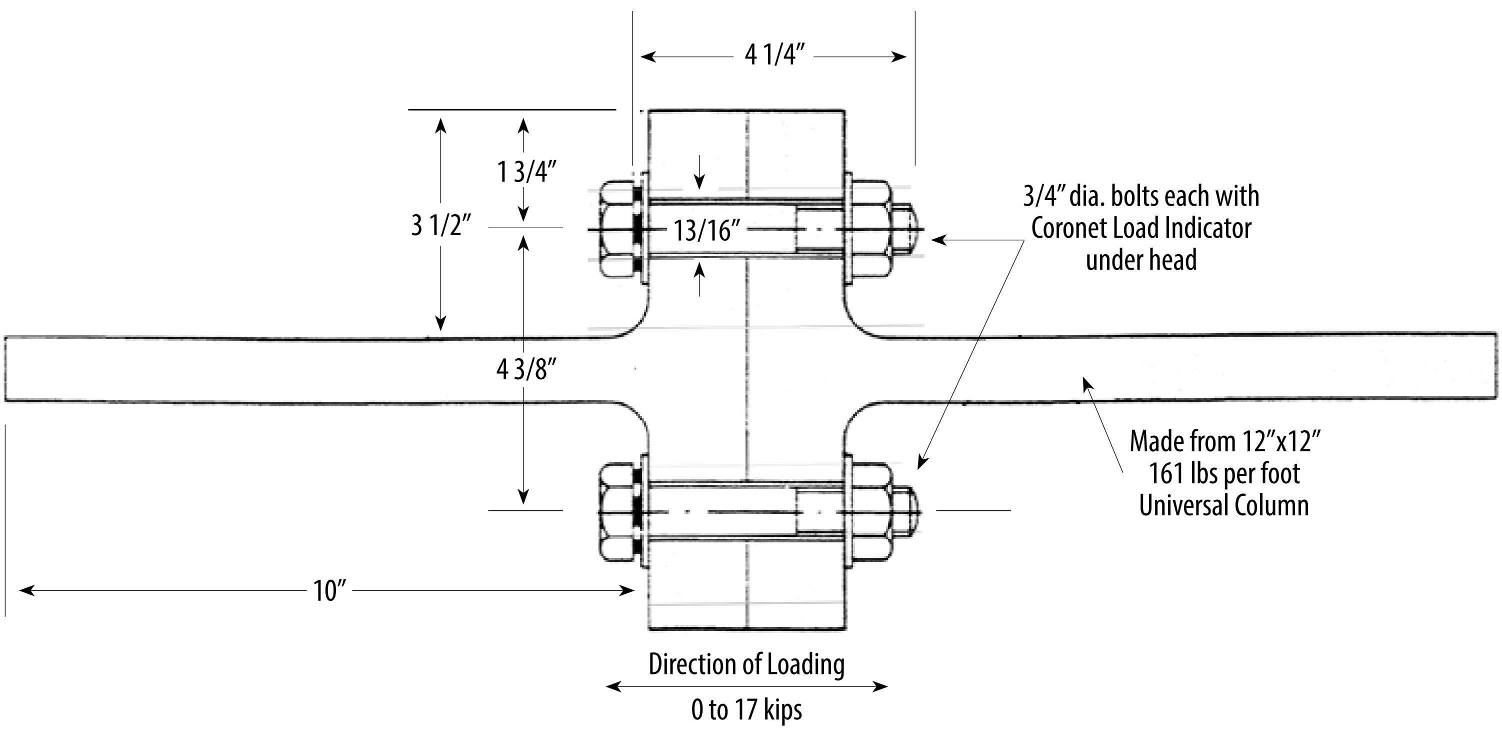
It was desired to investigate the effect of vibration and axail load reversals on High Strength Bolts tightened to proof load using "Coronet" Load Indicators to register axail tension. ASTM A325 ¼" diameter Bolts were used, together with the appropriate Load Indicators. The "Specification for Structural Joints using ASTM A325 or A490 bolts" limits the applied tension in A325 bolts to 36,000 p.s.i. and 40,000 p.s.i. for bridges and buildings respectively. The maximum applied load of 17 kips used in this test gives stress of 39,000 p.s.i. which is in excess of the 36,000 p.s.i. limit for bridges where fatigue conditions are involved.

Summary

The assembly was subjected to 2,718,600 stress cycles between 0 and 0.6 x proof load without fracture. No change of bolt length was recorded.

Procedure

The test specimen comprised of two tee sections as shown in the diagram which were assembled with two ¾" diameter High Strength Bolts and 'Coronet' Load Indicators. The bolts were tightened until the average Indicator gap was 0.015" which corresponds to the proof load of 28.4 kips. The assembly was set up in a Losenhauser-U.H.S. 60 fatigue testing machine at the Laboratories of the British Welding Research Association at Abingdon Hall, Cambridge, England. Measurements of Indicator gaps and bolt lengths were taken at intervals during the test.



Fatigue Test Assembly

DTI's
Technical Report #26 Cont.

Fatigue test on high strength bolts and 'Coronet' Load Indicators

Results Test load 0 to 17 kips

Cycles	Bolt #1						Bolt #2					
						Bolt Length Inches						Bolt Length Inches
	Before Tightening:					4.733	Before Tightening:					4.728
	After Tightening:					4.741	After Tightening:					4.738
	Load Indicator Gaps – Inches						Load Indicator Gaps – Inches					
	1	2	3	4	Avg.		1	2	3	4	Avg.	
0	.009	.017	.020	.012	.0145	4.741	.022	.010	.006	.019	.0142	4.735
55500	.009	.017	.020	.012	.0145	4.741	.022	.010	.006	.019	.0142	4.735
698200	.009	.017	.020	.012	.0145	4.741	.022	.010	.006	.019	.0142	4.735
1253600	.009	.017	.020	.012	.0145	4.741	.022	.010	.006	.019	.0142	4.735
1887500	.009	.017	.020	.012	.0145	4.741	.022	.010	.006	.019	.0142	4.735
2381900	.009	.017	.020	.012	.0145	4.741	.022	.010	.006	.019	.0142	4.735
2718600	.010	.018	.020	.012	.015	4.741	.022	.010	.007	.020	.0147	4.735

Bolt #1: Bolt Extension	Inches	Bolt #2: Bolt Extension	Inches
Before Test:	**.008**	**Before Test:**	**.007**
After Test:	**.008**	**After Test:**	**.007**

Cycles endured – 2,718,6000
No fractures observed.

Discussion of Results

There is a small increase of 0.0005" in the average Indicator gap on both bolts at 2,718,600 cycles. However it is too small to effect any measurable change in the bolt lengths and is likely to be due to some very slight seating.

The test shows that High Strength Bolts with 'Coronet' Load Indicators will safely withstand the maximum designed fatigue loading permitted by "The Specification for Structural Joints using ASTM A325 or A490 bolts."

DTI Technical
Report No-26.doc

DTI's
Technical Report #27

Independent Laboratory Tests on 'Coronet' Load Indicators and High Strength Bolts.

Messrs. Sandberg, the consulting inspecting and testing engineers of 40, Grosvenor Gardens, London, S.W.1., carried out a series of tests on 'Coronet' Load Indicators and High Strength Bolts. The tests were supervised by Mr. G.K. Wood, M.I. Mech.E., M.T. Loco. E. of Messrs. Sandberg, whose report as follow:

Introduction

The bolts, nuts and load indicator washers were selected at random from the warehouse of Cooper & Turner Ltd.., by our inspector and were submitted to us in sealed bags. It was requested that a series of loading tests be carried out on the load indicator washers and also a series of mechanical tests be carried out on the bolts.

The following materials were available:
27--3-3/4" long x 7/8" dia. Bolts with nuts representative of 4000 identical sized bolts. 3--5-1/2" long x 7/8" dia. Bolts with nuts representative of 2000 identical sized bolts. 54-load indicators for 7/8" dia. bolts representative of 7000 identical sized indicators. The twenty-seven bolts had been divided into three lots with three tests per lo tobe carried out. The fifty-four load indicator washers had been divided into three lots with a series of three test to be carried out on each lot. Thus six washers were available for each test with only the first one to be tested. However, if this one washer failed, the remaining five were to be tested.

Load Indicator Test Method of Testing

A North Bar Load Meter No. 2, supplied by Cooper & Turner Ltd., was used for the load test measurements. This was calibrated prior to and after testing, against our Universal Tensile Testing Machine (Grade A) and the readings obtained are tabulated below:

The method of testing was to place a bolt, fitted with a load indicator washer, through the Load Meter and to tighten a nut on the other side by means of a ratchet wrench. The gap between the washer and the underside of the bolt head was measured at the four positions by means of feeler gauges until an estimated average gap of 0.015" was reached. The Load Meter readings were taken and recorded against the gap between the load washer and the bolt head. In some cases the load was increased until the gap was reduced to nil.

Explanatory Notes

The hysteresis effect of the calibration of the Load Meter "Prior to Test" is caused by the sluggish operation of the hydraulic system after standing idle. This is largely mitigated by thorough exercising of the instrument before use, and is confined by the calibration figures taken:"After Test", which show an almost negotiable hysteresis effect, and confirm the degree of accuracy of the instrument. It will be noted that even after allowing for maximum hysteresis, all interpolated test loads fall within the specified load range for each Load Indicator.

North Bar Load Meter No. 2

Universal Tensile Machine (Load in Kips)	Prior to Test Ascending Load – Decending Load		After Test Ascending Load – Decending Load	
	(in Kips)	(in Kips)	(in Kips)	(in Kips)
11.2	10.3	11.9	10.07	11.04
22.4	21.2	23.6	22.0	22.06
33.6	32.0	35.3	33.2	34.0
44.8	42.8	46.6	44.5	45.1
56.0	53.8		55.5	

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Technical Report #27 Cont.

Results 'Coronet' Load Indicators

Since these test were carried out, ASTM A325 had revised the minimum tension for 7/8″ from 36.05 kips to 39.25 kips. 'Coronet' Load Indicators have been modified accordingly.

LOT NO. 1

Test #	Load Meter Reading	GAP				
		1	2	3	4	Average
1	37.0 kips	0.015″	0.017″	0.017″	0.012″	0.01525″
	38.2 kips	0.015″	0.018″	0.015″	0.010″	0.0145″
Interpolated load for gap of 0.015″ = 37.6 kips						
2	39.2 kips	0.013″	0.017″	0.019″	0.017″	0.0165″
	40.6 kips	0.010″	0.013″	0.016″	0.015″	0.0135″
Interpolated load for gap of 0.015″ = 39.5 kips						
3	39.2 kips	0.017″	0.014″	0.015″	0.018″	0.016″
	40.0 kips	0.016″	0.012″	0.013″	0.017″	0.0145″
Interpolated load for gap of 0.015″ = 39.6 kips						
Nil gap 52.4 kips						

LOT NO. 2

Test #	Load Meter Reading	GAP				
		1	2	3	4	Average
1	39.0 kips	0.018″	0.011″	0.010″	0.018″	0.0125″
Nil gap 50.3 kips						
2	36.1 kips	0.015″	0.019″	0.023″	0.018″	0.01875″
	38.4 kips	0.010″	0.016″	0.018″	0.012″	0.014″
Interpolated load 0.015″ gap = 39.4 kips						
3	39.1 kips	0.017″	0.017″	0.015″	0.015″	0.016″
	39.5 kips	0.016″	0.016″	0.014″	0.014″	0.015″
Load at 0.015″ gap = 39.4 kips						

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DTI's
Technical Report #27 Cont.

Results 'Coronet' Load Indicators

Since these test were carried out, ASTM A325 had revised the minimum tension for 7/8″ from 36.05 kips to 39.25 kips. 'Coronet' Load Indicators have been modified accordingly.

LOT NO. 3

Test #	Load Meter Reading	GAP				
		1	2	3	4	Average
1	38.0 kips	0.017″	0.017″	0.012″	0.017″	0.0145″
2	39.4 kips	0.016″	0.015″	0.015″	0.015″	0.01525″
	40.0 kips	0.016″	0.014″	0.015″	0.015″	0.015″
Load Indicator 0.015″ gap = 40.0 kips						
3	38.6 kips	0.014″	0.016″	0.018″	0.016″	0.016″
	39.4 kips	0.011″	0.015″	0.016″	0.014″	0.014″
Interpolated load for gap of 0.015″ = 39.0 kips						

Bolt Tests Proof load and ultimate load test were carried out on six bolts. The results obtained are tabulated below:

	Proof Load	Initial Length of Bolt	Length of Bolt After Test
Bolt #1	36.0 kips	5.843″	5.843″
Bolt #2	36.0 kips	5.845″	5.845″
Bolt #3	36.0 kips	5.840″	5.840″

	Ultimate Load	Position of Failure	
Bolt #4	67.0 kips	Failed in Threads	
Bolt #5	67.5 kips	Failed in Threads	
Bolt #6	68.4 kips	Failed in Threads	
B.S.3139	53.1 kips		

Elongation and reduction of area tests were carried out on three of the bolts.
The three specimens were prepared and tested in accordance with standard procedures.

	Elongation (percent)	Reduction of Area (percent)	
Specimen # 1	19.0	49.5	
Specimen # 2	17.8	51.8	
Specimen # 3	19.3	46.8	
A325	14 min.	35 min.	

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DTI's
Technical Report #28

'Coronet' Load Indicator tests on out of parallel faces.

Introduction

The Specification for Structural Joints Using A325 or A490 Bolts allow a surface slope of 1 :20. This test examines the effect of taper on the 'Coronet' Load Indicator when fitted under the head.

Summary

The permitted flange taper does not affect the performance of the 'Coronet' Load Indicator, which registers the required minimum bolt tension at an average gap of 0.015".

Procedure

A 7/8" diameter A325 bolt was assembled with a load indicator and a 2! bevel washer under the head to simulate the out-of –parallel condition. The assembly was tightened in a Norbar Load Meter until an average indicator gap of 0.015" was reached, and the load read.

The test was repeated for five additional bolts.

Test #	Load Indicator Gaps Thousandths of an Inch	Average Gap Inches	Bolt Load Kips
1	3, 7, 17, 27, 22	0.0152	38.4
2	3, 6, 16, 29, 21	0.0150	37.6
3	5, 5, 12, 28, 25	0.0150	37.4
4	4, 7, 24, 20, 18	0.0146	38.1
5	10, 9, 25, 25, 6	0.0150	37.6
6	15, 25, 29, 6, 2	0.0154	37.4

Required minimum bolt tension 36 kips.*out on three of the bolts.

Discussion of Results

In practice, it has been found that the protrusions of the Load Indicator rarely close down equally around the Indicator circumference under applied load. Even with flat surfaces there is likely to be some lack of alignment due to rolling tolerances and the practical difficulty of drilling the hole exactly normal to the surface, The tests show that the 'Coronet' Load Indicator is able to accommodate these variations in alignment and at an average gap of 0.015", the minimum bolt tension will be achieved.

*Since these tests were carried out, A325 has revised the minimum bolt tension from 36 to 39.25 kips. 'Coronet' Load indicators have been modified accordingly.

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DTI's
Technical Report #29

Tests on the tightening of A490 bolts.

Introduction

The tests investigate the Turn-of-Nut and 'Coronet' Load indicator methods of tightening A490 bolts and compare the resulting tensions with the required minimum bolt tensions. Tightening was continued and note taken of the further rotation of the nut to produce bolt failure.

Summary

The 'Coronet' Load Indicator provides a more accurate register of A490 bolt tension than the Turn-of- Nut Method and leaves adequate safety margin between load at specified gap and ultimate.

Procedure

Twelve 3-3/4" x 7/8" A490 bolts were machined on the head and shank end to permit accurate measurement of overall length.

Specification requirements are:
Min. Bolt Tension 51.7 kips
Min. Ultimate Load 69.3 kips

Sample details:
Bolt Lot No. 7117/1
C.L.I. Lot No. 8004/5

(i) Turn-of-Nut Method

A bolt was set up in a solid steel bar rigidly fixed to a column. The assembly included flat round washers under the head and nut such that there was ¼" of thread protruding from the nut. The overall length was measured and preliminary tightening carried out with spud wrench and a mark made across the nut and bolt shank end. The nut was then tightened half a turn relative to the bolt, and the overall length again measured.

The bolt was transferred to a load meter and tightened until the overall length recorded was the same as had been shown under a half turn in the solid steel bar. This method eliminated any inaccuracy that might have been introduced by the compression of the load meter capsule. The load meter reading was recorded.

To avoid damage to the load meter, the bolt was returned to the solid bar to continue the test to failure. After tightening to the loaded length previously obtained after half a turn, the further rotation of the nut to breaking point was observed.

The test was repeated on an additional five bolts.

Turn-of-Nut Method Results

Sample	Initial Length Inches	Length Under 1/4" turn Inches	Extension Inches	Load Meter Reading Kips	Further turn of nut to Failure
1	4.283	4.323	.040	61.6	¾
2	4.260	4.294	.034	65.0	½
3	4.289	4.323	.034	66.4	½
4	4.264	4.309	.045	68.4	½
5	4.277	4.311	.034	66.0	½
6	4.281	4.322	.041	62.8	½

DTI's
Technical Report #29 Cont.

Tests on the tightening of A490 bolts.

(ii) 'Coronet' Load Indicator Method

A bolt was set up in the load meter with a Load Indicator under the head in place of a flat round washer and 3/16" of bolt protruding from the nut. The initial length was recorded and the bolt tightened until a 0.015" average gap was measured (See Cooper & Turner Leaflet 61/1A for measuring procedure) Note was taken of the load meter reading. After unloading, the overall length was checked to confirm that the 0.2% proof stress had not been exceeded. The bolt was then transferred to the solid bar and tightened with a fresh load indicator under the head to the 0.015" average gap condition. Nut and bolt ends were marked and the further rotation of the nut to failure noted.

The test was repeated on an additional five bolts.

'Coronet' Load Indicator Method Results

Sample	Initial Length Inches	C.L.I. Average Gap x 1000 Inches	Load Meter Reading Kips	Length after Unloading Inches	Extension Inches
7	4.3514	15.5	15.0	4.3525	0.0011
8	4.3400	15.0	57.4	4.3430	0.0030
9	4.3235	15.5	58.8	4.3240	0.0005
10	4.3535	15.5	57.5	4.3545	0.0010
11	4.3590	15.5	58.3	4.3595	0.0005
12	4.3470	15.5	56.0	4.3475	0.0005

Reloading

Sample	C.L.I. Average Gap x 1000 Inches	Turns to obtain Average Gap*	Further turns to Failure
7	15.0	¾	1-1/4
8	15.2	¾	1-1/4
9	12.7	¾	1
10	15.1	¾	2
11	14.1	¾	1
12	12.5	¾	1-1/4

*This rotation of nut also includes the amount required to compress the C.L.I. protrusions.

Discussion of results

It has been shown that the Turn-of-Nut method on A490 bolts produces bolt tensions close to the minimum ultimate load.

The 'Coronet' Load Indicator can be depended upon to give a consistently safe proper tension in A490 bolts.

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DTI's
Technical Report #30

Comparison of tightening methods for high strength bolts.

W.S. Atkins & Partners, Consulting engineers P.A. Management Consultants Ltd. (Product Research and Development department)

Introduction

Customer response suggested that many users of high strength bolting systems believe that there is a time-saving factor in the use of Coronet Load Indicators.

Cooper & Turner decided to establish whether this had any validity and this reports sets down the method and results of a series of controlled tests carried out with the co-operation of the British Steel Corporation during August, 1970. The time study was undertaken by P.A. Management Consultants Ltd., Product Research & Development Department, and the tests were supervised by W.S. Atkins & Partners, Consulting Engineers.

Summary

Three basic systems of bolting were compared: (1) The torque or calibrated wrench method:

(2) The Turn-of-Nut method: (3) The Coronet Load Indicator method.

Timings were made of each step. A minimum time saving of 13% was shown by the Coronet Load Indicator method compared with the other two systems. This savings was increased to 33% with the omission of initial spud wrench tightening.

Procedure

A test piece as shown in Fig. 1 was prepared, into which could be inserted 72 – ¼" dia. Bolts through 13/16" dia. holes. The plate was divided into three equal areas of 24 holes and all three systems were used during any one particular sequence. For each sequence the separate elements of preliminary tightening, final tightening and checking were completed for all the systems before passing on to the next element. In order to minimize the effects of operator fatigue or familiarity, which might slow down or quicken the tightening times, the positions of each group were cycled and tightening was always carried out starting from the same side and proceeding in the same order.

The tightening technique for each system was as follows:

1) Torque or Calibrated Wrench method

(a) All bolts were inserted by hand and nuts snugged with a spud wrench.

(b) The pneumatic impact wrench was calibrated by use of a load cell to cut out when a bolt tension 10% higher than the minimum specified was achieved.

(c) The bolts were tightened with the calibrated impact wrench.

(d) A normal torque wrench was calibrated in the load cell to indicate a torque 5% above that necessary to obtain the minimum tension.

(e) The manual torque wrench was used for inspection testing of the tightened bolts.

2) Turn-of-Nut Method

(a) All bolts were inserted by hand and nuts snugged with a spud wrench.

(b) The nuts were checked for adequate preliminary tightening and the necessary mark made on the nut and protruding thread with a chisel.

(c) The bolts were tightened to half turn of the nut using the pneumatic impact wrench.

(d) The marks were visually inspected to ensure the required rotation of the nut.

3) Coronet Load Indicator method

(a) The Coronet Load Indicators were placed under the heads of the bolts and the bolts were inserted by hand. Nuts were then snugged with a spud wrench.

(b) The bolts were tightened to the required 0.015" average Indicator gap using the pneumatic impact wrench.

(c) The gap was checked.

The tests were repeated five times and the results are shown in appendix 1. Tests 1 to 3 follow precisely the methods described above. In practice there will be occasions where the plies are sufficiently well drawn together by fitting-up bolts to make preliminary tightening with a spud wrench unnecessary in the torque control and Coronet Load Indicator methods: tests 4 and 5 were therefore carried out with the spud wrench tightening eliminated from these methods. An impact wrench was used for the Turn-of-Nut initial tightening.

DTI's
Technical Report #30 Cont.

Comparison of tightening methods for high strength bolts.

Results

Average results for each test series were as follows: Key: **T** – torque (calibrated wrench) **N** – turn-of-nut **C** – Coronet (Time is in minutes per 24 bolts)

	Tests 1–3			Tests 4–5		
	T	N	C	T	N	C
Hand place & hand tighten	6.25	6.70	6.52	–	–	–
Hand place only	–	–	–	3.56	3.58	4.86
Spud tighten	2.39	3.02	3.22	–	5.37	–
Final tighten	6.75	6.52	5.32	13.49	5.14	3.99
Inspect	9.17	2.24	1.22	8.11	1.69	1.65
Total	25.10	18.78	16.28	25.26	15.78	10.50

It will be appreciated that the testing was carried out in ideal shop conditions and these figures may not be achievable on site. However, the comparison of the results will in no way be affected by this consideration. It will be seen that the Coronet Load indicator method was the quickest of the three methods, both with or without initial spud wrench tightening, the comparison being:

Time saved by Coronet Load Indicator:

Compared with	Tests 1 – 3	Tests 4 – 5
Turn-of-Nut	13%	33%
Torque Control	35%	58%

Appendix 1 –Individual test results

Key: **T** – torque (calibrated wrench) **N** – turn-of-nut **C** – Coronet

TEST #	Place Bolts by Hand			Spud Tighten			Final Tighten			Inspect		
	T	N	C	T	N	C	T	N	C	T	N	C
1	7.31	8.01	7.66	2.93	3.64	3.93	8.19	7.81	5.18	6.82	3.07	1.28
2	5.87	6.69	6.28	2.23	2.56	2.56	6.90	6.07	5.67	9.47	2.27	1.44
3	5.69	6.23	5.60	2.03	2.88	3.19	5.02	5.70	5.11	12.73	1.39	.93
Average	6.25	6.70	6.52	2.39	3.02	3.19	6.75	6.52	5.32	9.17	2.24	1.22
4	3.79	3.14	5.17	–	4.63	–	12.00	5.08	4.46	9.39	1.59	.96
5	3.32	4.01	4.54	–	6.10	–	14.98	5.20	3.52	6.83	1.80	2.34
Average	3.56	3.58	4.86	–	5.36	–	13.49	5.14	3.99	8.11	1.69	1.65

TEST #	TOTAL TIME (Times are minutes per 24 Bolts)		
	T	N	C
1	25.25	22.53	18.05
2	24.47	17.59	15.95
3	25.47	16.20	14.83
Average	25.10	18.78	16.28
4	25.18	14.44	10.59
5	25.13	17.11	10.40
Average	25.26	15.78	10.50

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DTI's
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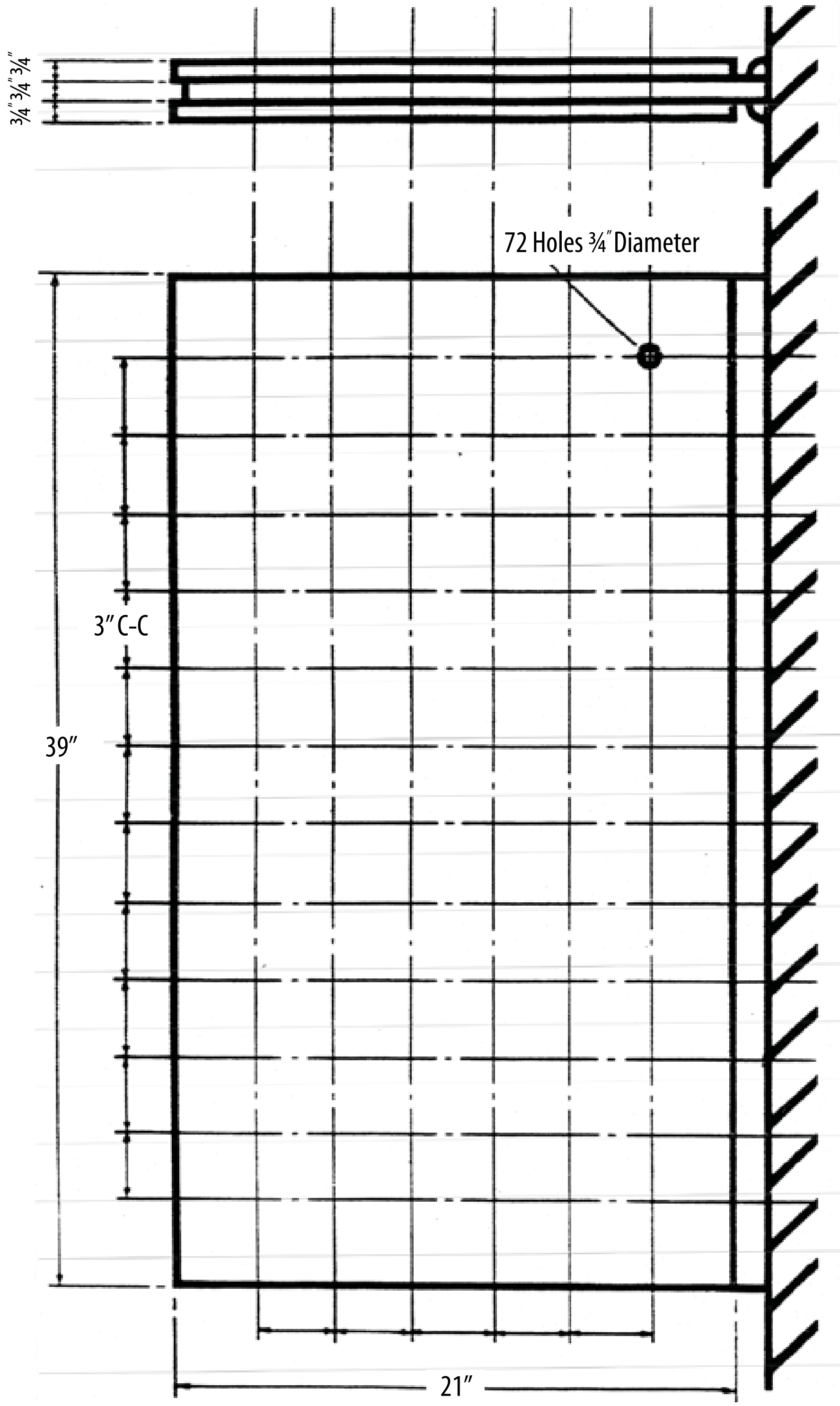
Comparison of tightening methods for high strength bolts.

Fig. 1
Test Piece



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