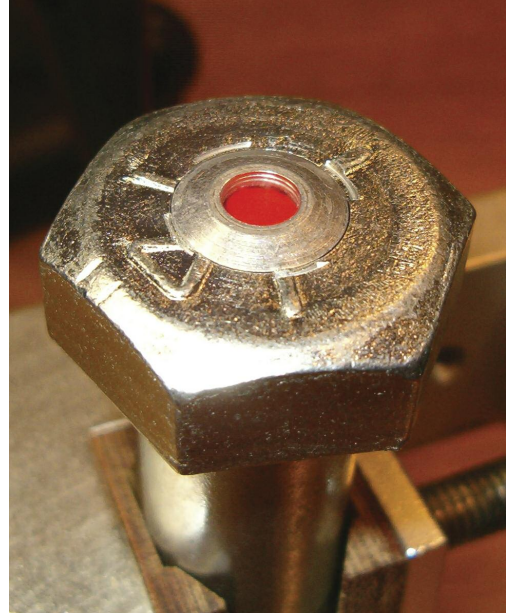


## MAKING THE CASE FOR

# Tension Indicating Fasteners



TECHNICAL SUPPORT

by Charles Popenoe

When design engineers specify fasteners for product assemblies, systems or structures, they typically calculate the preload required for each bolted joint, then choose fasteners to meet those requirements based on their strength and material properties. However, not all bolted joints in a design or installation have equal importance. In addition to these requirements, special consideration must be given to bolted joints that are critical to product operation, safety and reliability.

Characteristics of *critical joints* include those bolted joints subject to:

- loosening and retightening;
- vibration or temperature variations;
- frequent inspection requirements;
- difficult wrench access;
- end-user service or adjustments; and
- failure resulting in costly downtime or accidents.

For these critical bolted joints, improved methods of measuring the load on the fastener at installation and throughout the service life of the fastener can be the most important factors ensuring long-term joint reliability. With advances in bolting technology, design engineers now have the option to specify **Direct Tension Indicating (DTI) Fasteners**, which provide significant advantages compared to ordinary bolts for establishing and maintaining the specified clamp force on the joint.

### Direct Tension Indicators (DTIs)

The pitfalls of attempting to use torque measurement to determine joint clamp force are well known and will not be repeated here. In contrast, DTIs respond to fastener tension ONLY, ignoring torque inputs, thus providing a much more accurate measure of clamp force. DTIs can be as simple as single-use DTI washers or as complex as bolts connected to expensive ultrasonic load sensing equipment. DTI fasteners fall between these two extremes in both cost

and complexity. Unlike single-use alternatives such as DTI washers, DTI fasteners are designed for reuse and to continuously indicate clamp load throughout fastener service life. The best direct tension-indicating methods are based on calculating strain in the fastener shank by measuring elongation as tension is applied.

DTI fasteners typically are ordinary fasteners that have been retrofitted with a gage pin installed in the bolt shank. This gage pin is fixed at the base of a machined hole and serves to measure elongation of the shank under tension. Following are examples of alternative methods manufacturers have developed to turn this minuscule deflection into a user-friendly means to estimate tension:

- *Tactile*: A knob can no longer be turned by hand when proper tension is achieved.
- *Meter*: A small meter in the head shows the percentage of proof load of the fastener.
- *Retracting disc*: Deflection of a reference disc is interpreted using a hand-held electronic device.
- *Visual*: A colored indicator in the head changes from a bright red to black as tension is applied to the fastener.

For critical joints, DTI fasteners provide advantages over ordinary fasteners in design, installation and maintenance by providing a continuous indication that adequate clamp force is present.

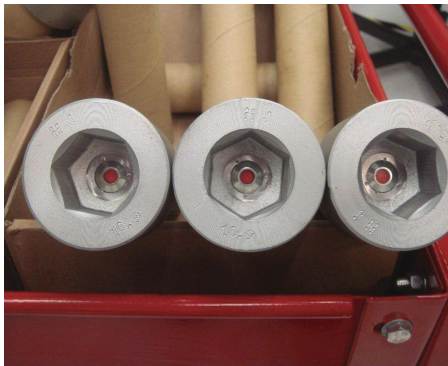
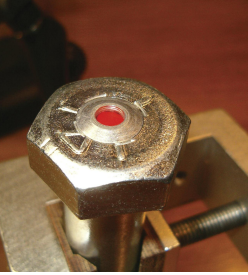
### Cost Justification and Fastener Total Installed Cost

While direct tension indicating fasteners are the elegant engineering solution to many bolting problems, they are necessarily more expensive than ordinary bolts. Therefore, a cost analysis must be completed to discover if an option with greater initial cost is justified. This can be done by calculating the **Fastener Total Installed Cost** of each option. The total installed cost accounts for the initial cost of the fastener as well as projected cost savings on design, installation, maintenance, and by reducing downtime and losses due to joint failure.

To understand how this analysis is done, let's take a look at a hypothetical factory where DTI fasteners are used in critical joints of four key operational systems.

- Production machining: one workpiece after the next must be securely bolted to the table to protect against a damaging shift during machining.
- Overhead cranes: anchor bolts need to be properly tensioned and inspected regularly on structures subject to dynamic loads. Torque may be an insufficient means to estimate the bolt tensions for this application.
- Electrical busway (distributes electricity throughout the factory): joint bolts must be properly tensioned to ensure safety from arcs and heat build-up and avoid blown circuits and downtime.
- End-product critical joints: OEMs that use DTI fasteners differentiate their products from the competition, offer greater product reliability, ease maintenance inspection and field service, and reduce product warranty and liability costs.

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DTI SmartBolts® produced for a wind turbine manufacturer.



DTI SmartBolts® produced for an amusement park ride manufacturer.

Follow through Illustration 1 and 2 detailing the potential savings using DTI fasteners. Note that in the examples, general assumptions have been made about the time and cost of certain activities.

## DTI SmartBolts® from Stress Indicators, Inc.

All of the examples in Illustration 1 and 2 are real-world applications of visual tension indicating DTI SmartBolts® from Stress Indicators, Inc. of Gaithersburg, Maryland. Stress Indicators is the leading manufacturer of tension indicating fasteners in the U.S. and serves customers worldwide. One can easily imagine many applications in industrial operations and products that would benefit from the use of SmartBolts® and other DTI fasteners in critical bolted joints.

When loose, the DTI SmartBolt® indicator is an eye-catching fluorescent red. As the bolt is tightened, the indicator darkens through maroon to black. SmartBolts® are designed to indicate at the tension specified for the customer's application. When the

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### ILLUSTRATION 1. MODULAR ELECTRICAL BUSWAY

The bolts that join segments must be properly tensioned to ensure reliable operation.

#### Current "default" method:

1/2-13x4" Grade 5 "torque control" bolts – head is designed to shear off at a specified torque.

**Initial cost per bolt: \$3 each**

**Total of 300 bolts = \$900**

#### Installation:

Wrench is used to tighten each bolt until head shears off to leave ordinary hex head. Installation time: 30 seconds per bolt.

#### Maintenance:

Every six months, the torque of the joint bolts must be checked.

#### Downtime must be scheduled.

The entire busway system must be powered down and each bolt tested with a calibrated torque wrench. This example estimates the procedure will take four workers 10 hours at \$30 per hour, twice per year.

**Total: \$2,400 per year.**

#### Cost of downtime:

For this example, we estimate \$100/hr. (In many cases, cost of lost productivity during downtime will be greater). Ten hours of downtime to service busway, twice per year.

**Total: \$2,000 per year.**

#### Other factors:

During maintenance, if a single loose bolt is missed in the inspection process, it could result in a costly accident. Loose joints may result in blown circuits and dangerous arcs, creating a safety and fire hazard.

**Total installed cost after one year:**

**\$5,300**

#### DTI bolt method:

1/2-13x4" Grade 5 bolts retrofitted with a direct tension indicator designed to visually indicate a specified tension.

**Initial cost per bolt: \$12 each**

**Total of 300 bolts = \$3,600**

#### Installation:

Wrench is used to tighten each bolt until bolt indicator turns from red to black. Installation time: 30 seconds per bolt.

#### Maintenance:

Every six months, the DTI bolts must be inspected for proper indicator color. There is no need to power the system down. An inspector visually inspects the indicator of each bolt. He makes note of the location of each bolt that is no longer black and therefore needs to be re-tightened. He then schedules the downtime needed to tighten just those loose bolts. There is no need for a calibrated torque wrench. This example estimates the procedure will take five hours for one worker at \$30 per hour, twice per year.

**Total: \$300 per year.**

#### Cost of downtime:

One hour to tighten only loose bolts, twice per year.

**Total: \$200 per year.**

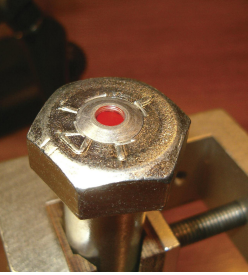
#### Other factors:

Tightening by measuring tension rather than torque provides a more reliable means of ensuring that critical joints maintain necessary clamp load during the thermal cycling of the busway.

**Total installed cost after one year:**

**\$4,100**

**Five-year savings using DTI bolts: \$16,800**



Machining fixtures using our products.

last trace of red disappears from the indicator, design tension is achieved. DTI SmartBolts® are accurate to within +/- 10% of design tension. Stress Indicators also has a new precision product, the HR (high-resolution) SmartBolt®, which improves accuracy to +/- 5%.

SmartBolts® are fully reusable and should last as long as the fastener itself. In most retrofits, there is no loss of strength to the fastener. Stress Indicators determines if any loss of strength results from the modification, using finite element analysis and other calculation methods. SmartBolts® are typically retrofitted into hex-head cap screws in shank diameters from 7/16" to 1-1/4" (M10xM32). Stress Indicators recently expanded its capabilities to convert M36 socket head capscrews into DTI SmartBolts® for a large domestic wind turbine manufacturer.

SmartBolts® solve bolted joint preload concerns for OEMs such as General Electric and Siemens, as well as end-users such as NASA Manned Space Flight Center, FMI's Morenci Copper Mine and the National Weather Service. Visit [www.smartbolts.com](http://www.smartbolts.com) to learn more about Stress Indicators' products as well as how these and other customers use SmartBolts® for their critical bolted joints. ■

SmartBolts® is a registered trademark of Stress Indicators, Inc. Patents issued and pending.

## ILLUSTRATION 2. MACHINING STATIONS

### Securing each workpiece with hold-down bolts.

**Current "default" method:**  
5/8-11x2" Grade 8 hex head bolts

**DTI bolt method:**  
5/8-11x2" Grade 8 hex head bolts retrofitted with a direct tension indicator designed to visually indicate a specified tension.

**Cost of the bolts: \$1.25 each**

**Cost of the bolts: \$15 each**

**Number of bolts:**  
Four bolts per station x 20 stations, for a total of 80 bolts.

**Total of 80 bolts = \$1,200**

**Total: \$100**

**Installation:**  
Torque wrench. Time: 30 seconds

**Installation:**  
Box wrench is used to tighten until bolt indicator turns from red to black. Installation time: 30 seconds.

**Operation:**  
Bolts need to be loosened and tightened each time a new workpiece is mounted for machining. Ten workpieces are machined at each station, per shift. This represents 800 separate loosening and tightening events each shift. There is no visible indication to show that a bolt has not been tightened.

**Operation:**  
Same as described at left. A simple visual inspection verifies that each bolt has been properly tightened, the workpiece is secure, and machining can safely proceed.

**Losses:**  
If the workpiece is not securely mounted to the machining station, it could result in damage to the workpiece and cutting tool. For this example, estimate the lost workpiece and tooling amounts to \$100 per event. With 800 loosening and tightening events in each eight-hour shift, we can estimate one loss event occurring each week.

**Losses:**  
**Minimal (one per year) = \$100**

**Total loss: \$5,000 per year.**

**Total installed cost after one year: \$5,100**

**Total installed cost after one year: \$1,300**

Breakeven number of incidents avoided, after which DTI fasteners are cost effective: **11**

**Five-year savings using DTI bolts: \$23,400**