

# BOLTING

Basics, Tips  
& Best Practices



*Featuring...*

**SmartBolts®**

Direct Tension Indicating Fasteners™



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Stress Indicators Incorporated is a solutions-driven engineering and manufacturing firm based in Maryland, USA. Formed in 1992, we provide innovative Visual Indication Systems™ solutions for customers worldwide.

Stress Indicators Incorporated invented and developed SmartBolts® technology and commercialized the products to enable broad industry acceptance. All SmartBolts® are manufactured from quality fasteners at our USA facility.

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# BOLTING Basics, Tips & Best Practices

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## **Introduction**

This Special Report contains three parts and one feature. *BOLTING Basics, Tips & Best Practices* includes a three-step guide on the basics of specifying your bolt, it breaks down the different type of bolt heads, threads, finishes, materials, and everything you need to consider when designing your bolt. In the second part, we dive into the torque-tension relationship: what it is, the factors that affect it, and the variability of torque charts. This part also includes a brief discussion on gasket creep: what it is, and the factors that affect it. We've also included a special feature on SmartBolts and the advantages associated with using the SmartBolts Visual Indication System. In part four, you will find ten frequently asked questions on bolting, a list of bolting terms, and units of measure in relation to bolts.

# **Part One**

## **Basics of Specifying a Bolt**

# Step One: Specifying the Basics of a Fastener

## Selecting a Head Type

**Hex Bolt (HXBT):** A hex headed threaded fastener. It is commonly used in conjunction with a washer and a nut.

**Hex Head Cap Screw (HHCS):** In addition to the features of a hex bolt, these threaded fasteners have a washer face beneath the head and a chamfered thread point. The flat washer face provides a higher quality bearing surface than Hex Bolts. These ‘screws’ are designed for use in tapped holes, but are still an excellent choice for through bolting applications. This is the most commonly found head type in industrial applications.



**Hex Flange Bolt (HFLB):** These bolts also contain an external hex drive, and feature an enlarged bearing surface that extends beyond the hex head like a built-in washer.

**Heavy Hex Cap Screw (HVCS):** Similar to hex head cap screws, these structural fasteners have an increased width across the flats. They also commonly have a unique thread length.

**Socket Head Cap Screw (SHCS):** These fasteners with a cylindrical head have an internal hex drive into which the hexagonal ends of an Allen wrench will fit. Often, these fasteners are used in applications requiring the fastener to be counterbored.<sup>1</sup>



**Studs:** These headless fasteners are threaded on both ends or along the entire length. When fully threaded they are referred to as either studs or threaded rods. When used with a blind hole they may contain a drive to assist with installation.<sup>2</sup>

### The Importance of Using Correct Units

Confirm which standard system of units your project requires before purchasing your bolts. This is very important to verify – a multi-million dollar project can fail with the miscalculation of a single fastener type. In 1999, NASA lost an unmanned space mission as a result of a [mix-up between metric and imperial units](#). Its \$125 million Mars Climate Orbiter probe was destroyed because its altitude-control system used imperial units but its navigational software used metric units.

## Select Your System of Units

The two main systems of units are inch and metric. In most cases the system of units required is set because the mating thread is already established. It is important to ensure that the proper size thread be specified in order to avoid unsafe and improper threading.

If you have the opportunity to design your bolted joint from scratch, consider what the most convenient units are for you and your customers.

<sup>1</sup> Image Source – Socket Screws from Armafix. (n.d.).

<sup>2</sup> Image Source – Steel Bolts. (n.d.).

It is generally best practice to use a consistent system of units throughout your machinery.

### Choose Your Material

**Steel:** Steel is the most common fastener material and is available in plain as well as various surface finishes.

When selecting steel fasteners it is important to consider the grade or class of material. In metric systems, material strength is organized into classes. With imperial systems, material strength is organized into various grades. Low grade steels like grade 2 or class 4.8 are not commonly heat treated. The use of these grades should be limited to none critical low performance bolted joints. When additional strength and performance is needed, a common choice is to use grade 5 or class 8.8 fasteners with a hardness of 27-33 HRC. For even greater strength, grade 8 or class 10.9 fasteners can be specified. These fasteners have a hardness from 33-39 HRC. ASTM A574 OR Class 12.9 rated material can commonly be found when using socket head cap screws. For more information on some of the most commonly used grades/classes see the chart below.

Units	Grade	Description
Inch	Grade 5	SAE J429 Grade 5 is an inch property grade of medium carbon (or alloy) steel.
	Grade 8	SAE J429 Grade 8 is an inch property grade of medium carbon alloy steel.
Metric	Class 8.8	ISO 898-1 Class 8.8 is a metric property class of medium carbon steel.
	Class 10.9	ISO 898-1 Class 10.9 is a metric property class of carbon alloy steel.

**Stainless Steel:** Stainless steel is a special steel alloy containing at least 18% chromium and 8% nickel which provide significant corrosion resistance. Since stainless steel cannot USUALLY be hardened through heat treating it is commonly cold worked to gain its strength. Two frequently used grades are A2 vs. A4 stainless steels. These classifications represent 304 and 316 materials, respectively. While both materials offer corrosion resistance, 316 stainless steels are preferred for use in marine environments. A4 is also available in higher strength options than A2, with some special grades approaching strengths of grade 5 fasteners.<sup>3</sup>



**Other Alloys:** When steel and stainless steel fasteners don't meet design requirements other types of alloys may be used. Aluminum for instance, is a lightweight with an impressive strength to weight ratio. However, due to strength limitations and a susceptibility to fatigue use of aluminum in critical applications should be carefully considered. Other high nickel alloys are commonly used when high temperature resistance is a requirement.

<sup>3</sup> Image Source – Stainless Steel Hex Bolt In MM Multibrand 6x35 6mm Dia 35mm Length. (n.d.).

## Step Two: Pick Your Bolt Dimensions & Thread Length

### Specify Your Bolt Dimensions

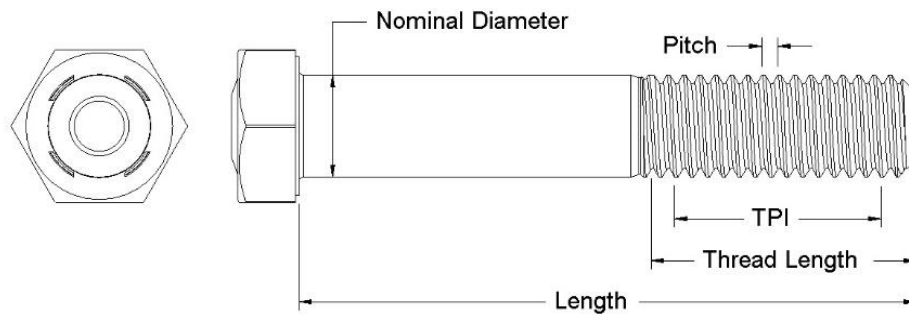
The following table provides a description for different bolt dimensions:

Bolt Dimension	Description
Nominal Diameter	Standard (Rounded) size of the unthreaded body or major diameter of the threads.
TPI/Pitch	The pitch is the distance between two successive thread crests or roots. Pitch is usually specified for metric fasteners. TPI stands for “threads per inch” and is used with inch fasteners. Pitch is equal to the reciprocal of TPI.
Length	The length of a bolt as measured from underneath the head (Bearing surface).

Metric Fasteners: *Nominal diameter – Pitch x Length* (i.e. M24 – 3.0 x 90mm)

US Fasteners: *Nominal diameter – Threads Per Inch (TPI) x Length* (i.e. 3/4" – 10 x 3.5")

The illustration below details these measurements:



### Select Your Preferred Thread Type

There are two standard thread styles, coarse and fine. Coarse threads have a stronger thread stripping resistance but a lower tensile strength to an equivalent bolt size with a fine thread. With adequate thread engagement, fine threads benefit from an increase in tensile strength. Another benefit to choosing fine threads is when tapping a relatively thin-walled material.

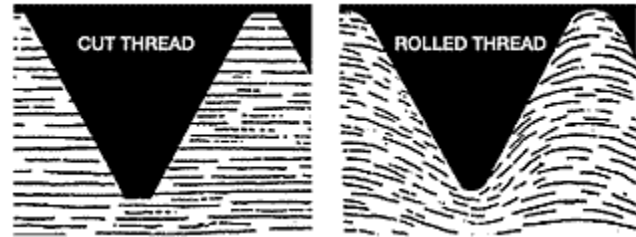
Another aspect to consider is full vs. partial thread lengths. Thread length is measured from the end of a fastener to the last fully formed thread.

Finish	Description
Partial	The fastener shank is partially threaded to a standardized thread length based on the nominal diameter and length of the fastener.
Full	The fastener shank is fully threaded for the total length of the fastener.



Threads can be manufactured by two methods – cut or roll-forming. Cut threads are created with a machine that physically removes the material using cutting tools.

Rolled threads use pressure to form threads between special threading dies. Since material is not removed, rolled threads offer a continuous grain structure which can improve a threads fatigue resistance.



## Step Three: Optimize Your Bolt

### Select a Finish

It is generally important to choose a finish that can withstand your anticipated environment.

**Plain (Black)** – Plain, or black finishes are bare metal with a simple cosmetic black coating and should have a light coating of oil to resist corrosion. The cosmetic coating does not provide increased corrosion protection.



**Zinc Plated** – Zinc plated finishes offer galvanic protection by acting as a sacrificial layer to protect the underlying steel. Clear and yellow chromate finishes are commonly used to preserve the life of the zinc plating.<sup>4</sup>

**Hot Dipped Galvanized** – Hot dip galvanizing is generally specified for outdoor application and is a thick zinc based finish. It is necessary to ensure the use of compatible components that can tolerate the thicker finish.<sup>5</sup>



**Aluminum Zinc Flake** – Commonly supplied under proprietary brands, this newer coating provides significant corrosion protection without the risk of hydrogen embrittlement. It can also be sourced with or without the use of chromium.

**Other Finishes** – Sometimes it is necessary to use custom coatings that provide even greater corrosion protection, cosmetic appeal, or more consistent friction performance, for example.

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<sup>4</sup> Image Source – HHC 5/8. (n.d.).

<sup>5</sup> Image Source – Tin Zinc Plating. (n.d.).

## Upgrade to a Tension Indicating Fastener

### 1) **Customize your fastener with a Visual Tension Indicator & gain the benefits of the SmartBolts Visual Indication System.**

SmartBolts are unique in that they allow users to visually inspect fasteners at-a-glance. An indicator located on the bolt head indicate whether a bolted joint is loose or tight with a clear, visible display that gradually darkens from bright red to black as the fastener is tightened. SmartBolts are simple: the indicator works on the most accurate principle for tension measurement – actual fastener elongation under load.

### 2) **Specify fastener preload.**

Fastener preload is the tensile force to be developed during installation. It can be designated using klpf, KIPS, or kN (*for additional information on these units, refer to the units of measure on page 22*). SmartBolts are designed to produce a clear and repeatable shift in color from red to black as an installer tightens the fastener to the designated preload. In addition to making technicians' maintenance jobs easier and more efficient, they act as an extra source of security for machinery, structures and the personnel responsible for operating and maintaining these critical joints.

### 3) **Identify the project type and include a mention of environmental concerns.**

SmartBolts are often used in harsh and hazardous conditions. We include these concerns in our analysis to ensure that SmartBolts will perform in accordance with our stringent quality goals.

### 4) **Visit the SmartBolts website**

To order your SmartBolts go to <http://www.smartbolts.com/find-your-smartbolt/>. There you will find the option of picking between pre-engineered bolts and custom bolts.

# **Part Two**

## The Torque-Tension Relationship

## The Torque-Tension Relationship

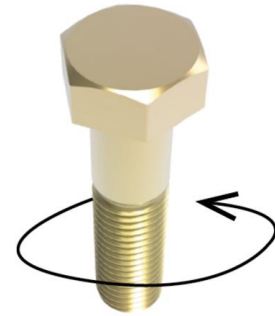
What is the torque-tension relationship and how do the two properties relate? Torque is the rotational force used to turn the nut or fastener head in a bolted joint. As torque is applied to the nut, it attempts to climb up the threads of the bolt reducing the grip length; however, when the components within the grip resist, the bolt is forced to stretch. As the bolt elongates, it behaves like a spring and develops tension, also known as preload. The tension developed with the bolt has an equal and opposite reaction<sup>6</sup> on the bolted components, which creates the all-important clamp force, the compressive force holding the bolted joint members together.

The torque value is actually a calculated quantity from the short form torque-preload equation. Bickford (1995) states the equation as  $T = K \cdot F \cdot D$ , where T, K, F, and D are the input torque, the “nut factor,” the achieved preload, and bolt’s nominal diameter, respectively (Bickford, 1995, p. 226).

The torque-tension relationship is hard to predict when you take into consideration all the factors that affect the nut factor (An expansion on this topic can be found in the article: [The Torque-Tension Relationship Gets Stretched.](#))

### Measure Tension not Torque

Since torque is a rotational force, it’s only an indicator of how hard it is to turn a bolt. Tension, on the other hand, is the stretch in a bolt that provides the clamping force. It is necessary to develop adequate tension in order to provide bolted joint security. In *torque chart 1*, it should be noted that whether the bolt is lubricated or not, this should not change the tension that needs to be applied. In the lubricated column, this torque chart is assuming a nut factor (k) of 0.1, it is only when this assumption holds true that an application of 75 ft. lbs. of torque would develop 18,000 lbs. of tension. In the dry bolt column, for the same amount of tension, we now have to apply 150 ft.



**Torque = Rotational Force**  
Measuring torque gives variable results because friction is unknown.



**Tension = Stretching Force**  
Measuring direct tension takes into account everything you need to know.

### ASTM A490

Bolt Size	TPI	Tension (lbs)		Tightening Torque Range (ft lbs) (Min - Max)	
		Min	Max	Lubricated	Plain
1/2	13	15,000	18,000	63 - 75	125 - 150
5/8	11	24,000	29,000	125 - 151	250 - 302
3/4	10	35,000	42,000	219 - 263	438 - 525
7/8	9	49,000	59,000	357 - 430	715 - 860
1	8	64,000	77,000	533 - 642	1,067 - 1,283
1 1/8	7	80,000	96,000	750 - 900	1,500 - 1,800
1 1/4	7	102,000	122,000	1,063 - 1,271	2,125 - 2,542
1 3/8	6	121,000	145,000	1,386 - 1,661	2,773 - 3,323
1 1/2	6	148,000	178,000	1,850 - 2,225	3,700 - 4,450

**Torque Chart 1** - A torque chart for an ASTM A490 indicating the tightening torque range for both lubricated and plain bolts.

<sup>6</sup> Usually, but not always. See p. 182 of Bickford for more information on the exceptions..

lbs. of torque to develop the same amount of tension (18,000 lbs.) because it is assuming a nut factor (K) of 0.2.

In *torque chart 2*, the lubricated column is assuming a nut factor (K) of 0.15, and the dry column is again assuming a nut factor (K) of 0.2. Thus, the reliability of the torque-tension relationship is highly dependent on the nut factor. What is the nut factor?

The **nut factor** is a grouping of the assumptions associated with the torque-tension relationship into one number. It exists to streamline and simplify all of the many factors affecting the use of torque measurement to achieve the desired result – precise clamp force on the joint. The many factors influencing the torque-tension relationship include the material, size, plating, surface finish, thread lubricants, corrosion and wear of fasteners, nuts and washers, among other things. The nut factor conveniently summarizes all of these variables. It is an *empirical value* that linearly models the rate at which tension is developed within a fastener when torque is applied.

A point of caution when using torque charts is to make sure that you understand the nut factor being implied. For instance, if you were to use the lubricated torque value from *torque chart 1*, but the actual torque-tension relationship ends up behaving more like the *Torque Chart 2 – A torque chart for an SAE Grade 5 bolt*, the lubricated bolt from *torque chart 2* then the tension that is actually developed will undershoot the target designed tension of 18,000 lbs. by approximately 6,000 lbs. To reiterate, this means that even though you may think that 18,000 lbs. of tension has been created, in reality only 12,000 lbs. has been developed.

You may be wondering why each torque chart implied different nut factors for lubricated bolts. Well, an experiment was conducted by the Department of Mechanical Engineering at Oakland University, examining this very factor. The experiment was conducted using three types of lubricants (Solid Film, Grease, and Oil) to better understand the effect of lubricant on the friction and torque-tension relationship. To learn more about the experiment [click here](#) to read the *Effect of Lubrication on Friction and Torque-Tension Relationship in Threaded Fasteners*.

DIAMETER & THREADS PER INCH	USS/SAE GRADE 5				
	TENSILE STRENGTH MIN. PSI	PROOF LOAD LB	CLAMP LOAD LB	TORQUE DRY FT LB	LUBRICATED FT LB
1/4-20	120,000	2,700	2,020	8	6.3
1/4-28	120,000	3,100	2,320	10	7.2
5/16-18	120,000	4,450	3,340	17	13
5/16-24	120,000	4,900	3,700	19	14
3/8-16	120,000	6,600	4,950	30	23
3/8-24	120,000	7,450	5,600	35	25
7/16-14	120,000	9,050	6,780	50	35
7/16-20	120,000	10,100	7,570	55	40
1/2-13	120,000	12,100	9,050	75	55
1/2-20	120,000	13,600	10,200	85	65
9/16-12	120,000	15,500	11,600	110	80
9/16-18	120,000	17,300	12,950	120	90
5/8-11	120,000	19,200	14,400	150	110
5/8-18	120,000	21,800	16,350	170	130
3/4-10	120,000	28,400	21,300	260	200
3/4-16	120,000	31,700	23,780	300	220
7/8-9	120,000	39,300	29,450	430	320
7/8-14	120,000	43,300	32,450	470	350
1-8	120,000	51,500	38,600	640	480
1-14	120,000	57,700	43,300	720	540

When using anti-seize, reduce the lubed chart reading by 20% to properly torque. Always lubricate and use lubed torque values.

**NOTES:**

The above recommended assembly torques are offered as a guide only. Torque specifications, especially for critical joints, should be determined under actual assembly conditions due to the many variables involved which are difficult to predict and do affect the torque-tension relationship.

The above recommended clamp loads are based on 75% of the minimum specified proof loads for each grade and size.



In conclusion, using the measurement of torque to ensure bolted joint security is not the most reliable way to guarantee that your bolts are properly tensioned. Keep in mind that many factors can affect the amount of torque applied to a bolt. Therefore, it is critical for us to work to identify and control the nut factor (K) for a bolted joint when using torque control methods to avoid undershooting or overshooting the target designed tension.

## **Gasket Creep<sup>7</sup>**

### **What is Gasket Creep?**

Gaskets have many mechanical characteristics which have an important effect on joint behavior. One important mechanical characteristic is creep relaxation a.k.a. gasket creep. This occurs when a bolt preload is being developed, during assembly of a joint, and the gasket is compressed. The change in the thickness of the gasket will depend on its “compressibility” and on the amount of bolt load created during assembly. When the compressive stress is maintained for a long time, the gasket will slowly continue to get thinner and slightly wider, which allows the bolts’ clamping the joint to relax. According to Bickford, gasket creep is measured in several different ways, including:

**Pure Creep**, which is the loss of thickness of the gasket under a constant compressive stress load. This can only be measured in a test rig, since the clamping force exerted by the bolts in a conventional flange will decrease as the gasket creeps.

**Pure Relaxation**, is the loss of compressive stress on a gasket loaded under constant deflection conditions. Measuring pure relaxation would require very high-tech equipment.

**Creep Relaxation**, occurs under a steadily reduced compressive load on the gasket. Creep relaxation is a combination of both pure creep and pure relaxation. For example, the gasket is loaded by tightening bolts, when the gasket creeps it becomes thinner. This results in the bolts relaxing which leads to a domino effect of loss in bolt elongation, bolt tension, clamping force, and, therefore, stress on the gasket.

### **Factors Affecting Creep**

There is no way to avoid gasket creep, because “a good gasket material must have some plasticity to allow it to mate intimately with all the imperfections of the flange surfaces.” The amount of creep that will occur depends on the materials it is made of, and its construction. Furthermore, there a number of other factors that can affect gasket creep, including:

**Initial Thickness**, creep relaxation is relative to the thickness of the gasket. For example, a ¼ inch thick fiber gasket will relax almost 4 times as much as a 1/16 inch thick gasket made from the same material.

**Time**, most creep relaxation occurs within the first 15-20 minutes after preloading. It will also continue to creep slowly for several hours, and maybe even forever.

**Temperature**, this is one of the major factors that affects creep relaxation. High temperatures can increase the amount of creep by a factor of 10 or more.

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<sup>7</sup> Source – Bickford, J. H. (1995) p 655 - 662.

**Applied Loads**, the amount of initial stress placed on the gasket affects its creep rate. The higher the load, the higher the amount of creep produced.

**Bolt Stiffness**, does not affect a gasket's creep-relaxation properties, it will however affect the relationship between the loss of thickness of the gasket and the loss of clamping force or compressive stress on the gasket.



# **Part Three**

## *Special Feature: Advantages of SmartBolts*

## Advantages of Using SmartBolts

A SmartBolt is an ordinary bolt that has been embedded with a Direct Tension Indicator that allows you to measure bolt tension. This technology uses color to indicate tension. The changes in color are proportional to bolt stretch, which ensures accurate and reliable measurements. Our customers have reported that visual bolt inspections offer cost-savings and performance benefits compared to traditional maintenance methods which require that workers check each bolt with a torque wrench.

- SmartBolts improve the safety and reliability of your equipment.
- The real-time visual alert of tension allows for hands-free inspection.
- Service life is extended with full repeatability, reusability, and no wearable parts.
- Install and inspect on-the-go with no training required.
- Avoid costly downtime with SmartBolts.
- Any bolt can virtually be made into a SmartBolt.

**Visual bolt inspections are up to 10 times faster.** When many bolts need to be inspected, there is considerable value in reducing the time required to inspect each bolt.

**Visual bolt inspections are hands-free.** In cases where bolts are difficult to access, visual inspection enables a worker to perform inspection without touching the bolts.

**Visual bolt inspections promote safe work practices.** Sometimes, bolts are in hazardous places. While security of these bolts is critical to operations, it's also critical to ensure personnel are not placed in harm's way.

**Visual bolt inspections are more accurate.** Traditional inspection methods often use torque measurement, which can be unreliable because of hidden friction factors. SmartBolts bypass this limitation by measuring bolt tension directly.

**Visual bolt inspections provide increasing value over time.** A regular and comprehensive bolted joint inspection plan can ensure that your equipment remains reliable, high-performing and safe for many years to come. Visual bolt inspections provide immediate benefits that reduce both the short and long-term costs associated with maintenance, and improve your operations so they can perform at their optimal level.



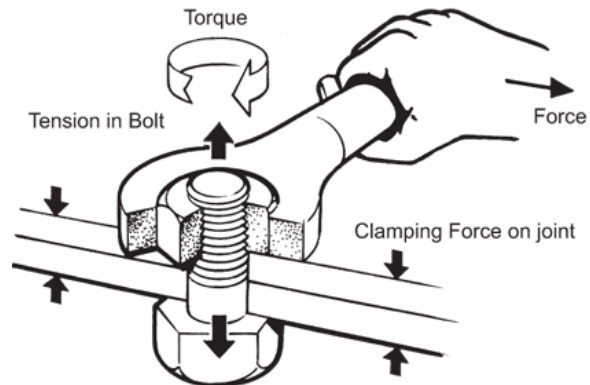
# **Part Four**

## **FAQs & Bolting Terms**

## Frequently Asked Questions (FAQs)

### 1) What happens as a bolt is tightened?

When using a traditional wrench to tighten a bolt, the torque applied to the nut causes it to slide up the inclined plane of the threads. This relative motion between the nut and the bolt attempts to reduce the distance between the bearing surfaces of the bolt and nut. This dimension is the grip length of the bolted joint. When the joint members within the grip resist, the bolt begins to stretch like a stiff spring, developing tension and simultaneously compressing the components together creating the all-important clamp force.<sup>8</sup>



### 2) Should I tighten the bolt head or the nut?

Either is acceptable, however a torque value defined for tightening the head does not necessarily apply to tightening the nut. Tightening the head vs. the nut can result in different nut factors and therefore change the torque required to achieve proper preload.

### 3) What is the difference between tension and torque?

Tension is the stretch or elongation in a bolt that provides the clamping force in a joint. On the other hand, torque is an indirect indication of tension; it is the amount of rotational force required to spin the nut along the threads of a bolt.<sup>9</sup>

### 4) What is the torque to yield tightening method?

The torque to yield tightening method is the concept of tightening a fastener so that a high preload is achieved by tightening the yield point of the fastener's material. In order to do this accurately, special equipment is required; the equipment monitors the tightening process. Ultimately, as the fastener is being tightened the equipment will monitor the torque verses the angle of rotation of the fastener. If it were to deviate from the specified gradient by a certain amount the tool halts the tightening process. The deviation is an indication that the fastener material has been yielded.

### 5) What is bolt preload and why is it important?

Preload is the tension created in a fastener when it is tightened. This tensile force in the bolt creates a compressive force in the bolted joint known as clamp force. For practical purposes, the clamp force in an unloaded bolted joint is assumed to be equal and opposite of the preload.<sup>10</sup> If proper preload, and thus clamp force, is not developed or maintained, the likelihood of a variety of problems such as fatigue failure, joint



<sup>8</sup> Image Source – Torque Information. (n.d.).

<sup>9</sup> Image Source – Torque Device & DIGI-TORC Series. (n.d.).

<sup>10</sup> Usually, but not always. Review Bickford (p. 192, Bickford, 1995) for more information on the exceptions.

separation, and self-loosening from vibration can plague the bolted joint leading to joint failure.

## 6) Why do bolts come loose?

There can be many possible causes for bolts to loosen in service. When we say “loosen” here we mean lose their tension, or preload. Here are five major causes:

- Vibration which can create relative transverse movement of the bolted materials leading to self-loosening of the nut.
- Relaxation of the bolted joint after tightening due to embedment or gasket creep.
- Elastic interactions occur when multiple bolts are present in a bolted joint. The additional force applied to the joint members by tightening a bolt can affect the amount of tension on the other previously tightened bolts. Elastic interactions can either increase or decrease bolt preload making it even more difficult to predict.
- Temperature fluctuation of the components.
- Insufficient initial preload developed at installation



*Bolts have to operate in all kinds of conditions*

The design of the bolted joint can minimize relaxation and embedment, and ensuring sufficient preload at installation can reduce the effects of vibration and likelihood of relative transverse movement. In other words, properly designed bolted joints that are properly preloaded should not self-loosen!

## 7) What is proof load & how is it different from yield strength & ultimate strength?

Each of these are basic mechanical properties that help define the expected tensile strength<sup>11</sup> performance of a specific fastener and can be measured in units of force. In USCS and SI systems, force is measured in pound-force (lbf) and Newtons (N), respectively. Since the strength of fasteners is generally quite large, it is also common to see these forces listed in kilopound-force (klbf) and kilonewton (kN).

Proof load is defined as the maximum tensile force that can be applied to a bolt that will not result in plastic deformation. In other words, the material must remain in its elastic region when loaded up to its proof load. Proof load is typically between 85-95% of the yield strength. Yield strength can be defined as the tensile force that will produce a specified amount of permanent deformation (most commonly 0.2%) within a specific fastener.

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<sup>11</sup> The term strength in this context differs from stress by being defined for a specific bolt's stress area and presented in units of force. Worth mentioning is that “strength” is also commonly used interchangeably with stress and presented in units of pounds per square inch (psi) for USCS or Megapascals (MPa) for SI. In this case, the value represents a more general property that can be applied to a variety of stress areas to derive the limits of applied forces. In other words, the ultimate tensile strength of the fastener material (MPa) can be presented as the ultimate tensile strength (kN) of a specific size fastener.

Ultimate tensile strength can be defined as the maximum force a specific fastener must withstand before fracture.

### 8) How do coatings or platings affect the torque-tension relationship?<sup>12</sup>

A coating/plating will change the surface of the fastener; most coatings increase the lubricity of the fastener. This will reduce the amount of friction or surface roughness, which leads to more energy going into stretching the bolt when tightened, rather than losing energy to friction between the threads.

### 9) How does one prevent thread galling?<sup>13</sup>

There is no way to completely eliminate/prevent galling, however there are different methods used to minimize it:

- Lubricating threads
- Adding a PTFE coating
- Reducing the class of fit
- Reducing the rotational speed during installation
- Avoid using prevailing torque locknuts
- Use of rolled threads instead of cut threads
- Use proper installation torque<sup>14</sup>



### 10) What are the benefits of using thread lubrication on bolts?

- **Controlling Friction** – When tightening a bolt, this could cause galling, seizing, and fastener wear. A properly lubricated bolt will prevent these events from occurring by reducing the overall amount of friction.
- **Assisting with Proper Tension** – Unexpected nut factors can radically reduce fastener preload, even when following prescribed torque. Selecting the proper lubricant that will overcome one nut factor, will allow you to be closer to achieving proper preload.
- **Reduces Corrosion** – Using the correct lubricant, you can reduce and prevent corrosion from moisture and chemicals. The lubricant will create a barrier on the bolt to protect it from corrosion.
- **Aids in Break-out** – Bolts assembled using lubricant are easier to break-out. By using lubricant during installation, you can avoid galling that is associated with bolt break-out.
- **Reduces Damage** – If a bolt fails in a critical joint, the consequences can be severe. Anything from loss of production, financial damage, material leaks, to hazardous emissions, and worker injury can occur. These events can be reduced by adding the proper lubricant to your bolting procedure, since it assists in achieving proper preload.

That being said, please keep in mind that different types of bolts require different lubricants. It is important to take the time to find the right lubricant for the bolt you are using. The one-size-fits-all approach is not appropriate in this particular context.

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<sup>12</sup> Source – Engineering Frequently Asked Questions. (2016).

<sup>13</sup> Source – Engineering Frequently Asked Questions. (2016).

<sup>14</sup> Image Source – Thread Galling. (n.d.).

## Units of Measure used in Bolting

**KIPS:** A non-SI unit. It is an Imperial unit of force. It equals 1,000 pounds-force, used primarily by American architects and engineers to measure engineering loads.

**Kilopounds-force (klbf):** A measure of tensile force or clamp force on a bolt as it is tightened. The symbol klbf is used when it is necessary to clearly distinguish it as a unit of force rather than mass. The name comes from combining the words “kilo” and “pound”; it is occasionally called a kilopound.

**kN (kilonewtons):** A measure of tensile force or clamp force on a bolt as it is tightened. Design Tension, Proof Strength, and Ultimate Strength are expressed in kN for Metric series SmartBolts®.

**SI:** The International System of Units, an evolution of the metric system.

**Stress:** An engineering value that is defined as force per unit area. For bolts, it is often expressed in PSI (pounds per square inch). The metric parallel measure is MPa (Mega Pascals).

**USCS:** The U.S. Customary System, an evolution of the British Imperial System.<sup>15</sup>



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<sup>15</sup> Image Source – CDI Dial Torque Wrench Dual Scale. (n.d.).

## Bolting Terms

**Clamp Force:** The compressive force on the joint members that occurs from the developed tensile force when a bolt is tightened. Clamp force is what holds your bolted joint together, not torque.<sup>16</sup>

**Creep Strain:** The tendency for a bolt to move slowly or deform permanently under the influence of constant mechanical stresses or high temperature levels.

**Design Tension:** The tensile force on the bolt, measured in klf or kN, at which SmartBolts® are designed to indicate the “Tight” color, black. “Tight” shows the bolt has been properly installed and Preload is established.

**Elastic Interaction:** In a bolted joint with multiple fasteners, as each fastener is tightened a variation in individual fastener preload will occur.

**Embedment:** Localized yielding of bolted joint components resulting in a change of grip length consequently causing relaxation of the bolted joint.

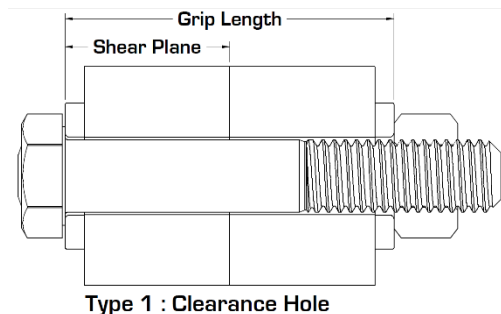
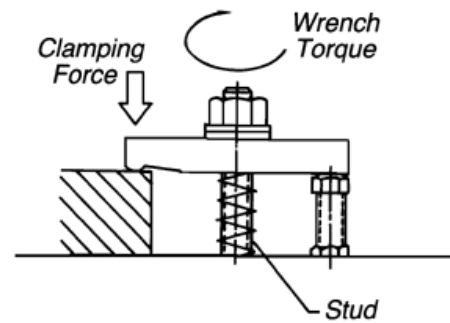
**Galling:** This occurs during installation when pressure and friction cause bolt threads to seize to the threads of a nut or tapped hole. If a fastener has seized up from galling it is almost impossible to remove without cutting the bolt.

**Grip Length:** The combined thickness of all components joined together between the bolt head and nut.

**Minimum Grip Length:** With respect to SmartBolts®, if a Minimum Grip Length is denoted, there is a limit to how far the nut can be run up the shank during installation before it begins to impact the accuracy of the SmartBolts® indicator. Customers may contact the factory to learn what the specified minimum grip length is for a particular SmartBolts® model, if it applies.

**Modified Proof Strength:** The proof strength of the bolt after conversion into a SmartBolt. In all but the shortest bolt lengths, this strength is identical to the bolt proof strength before modification.

**Nut Factor:** A constant (K) that attempts to model all of the many variables (such as friction) that affect the torque-tension relationship. Torque charts depend on an assumption of the nut factor,



<sup>16</sup> Image Source – Clamping Force. (n.d.).



but it is very difficult to predict and measure. (A full explanation of the nut factor problem can be found in our blog post: [Torque Measurements and the Nut Factor Problem.](#))

**Preload:** The tensile force developed during installation (tightening) of a bolt.

**Proof strength:** The tensile strength of a bolt beyond which permanent elongation of the bolt may occur. SmartBolts® are designed to operate in tensile loads from zero up to proof strength. This is called the elastic region of the bolt.

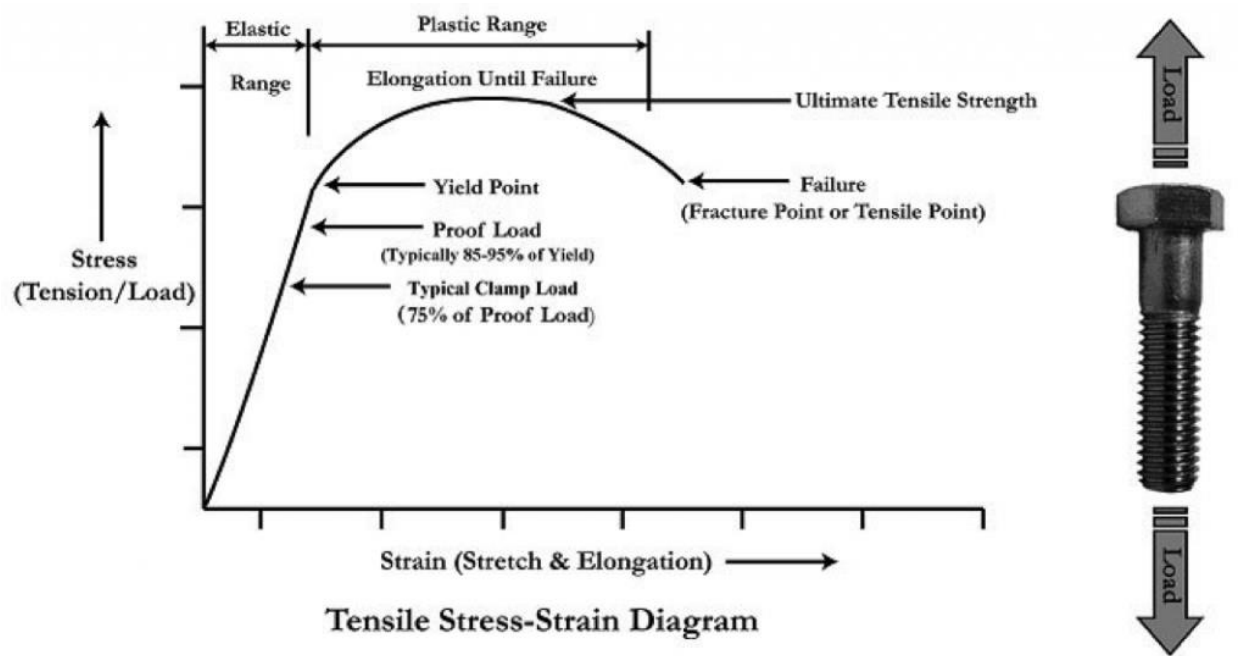
**Strain:** With respect to bolts under tensile force, strain is the measure of elongation of the bolt as it is stretched.

**Stress Area:** The effective cross sectional area of the threaded region in a bolt.

**Tension:** The stretch or elongation in a bolt that provides the clamping force.

**Torque:** The amount of energy it takes to spin the nut up along the threads of a bolt. A twisting or rotational force given in units of pound-feet (lb-ft) or Newton-meters (Nm). Torque is related to bolt tension by the nut factor, which is difficult to predict.

**Ultimate Strength:** The maximum tensile load that a bolt can withstand before breaking.



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# SmartBolts®

Visual Indication System™

## Get Peace of Mind when you...

### Know at a Glance your Bolted Joints are Secure™



### TORQUE is **NOT** Always TIGHT

Measuring torque only tells you how difficult it is to turn the bolt. It provides little information about bolt tension, the force that is actually holding your critical joints together.

The SmartBolts built-in visual tension indicator turns from **red** to **black** when proper tension has been reached and is completely reversible for the life of the fastener.

### SmartBolts are on the Job Worldwide...

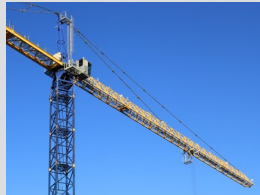
- ✓ Keeping production up and running
- ✓ Saving inspection time and maintenance
- ✓ Helping prevent accidents



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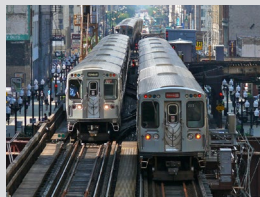
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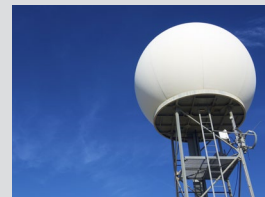
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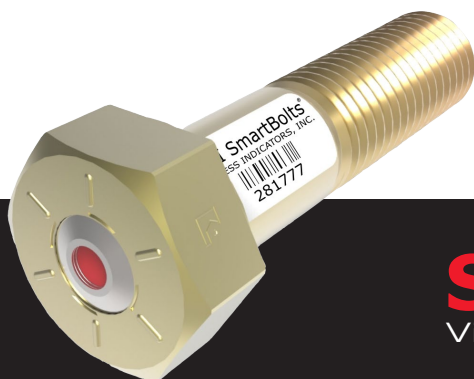
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