

Bolt Torquing / Tensioning

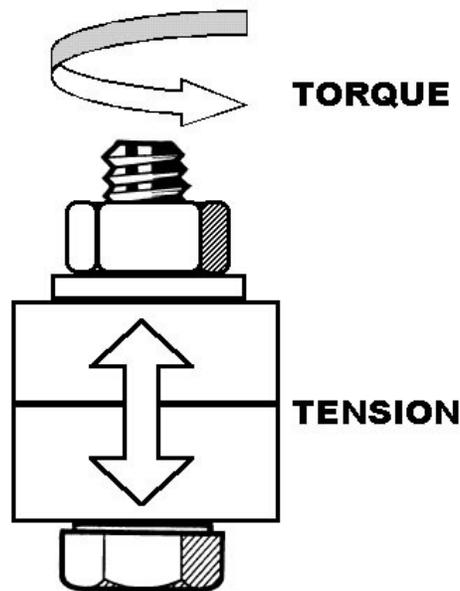
Manual Torque Wrenches and Adapters



Manual Torque Wrench Fastener Installation

- **Overview**

The function of a fastener such as a bolt is to hold or clamp two surfaces together. In order for the bolt to properly perform this function, the correct amount of torque needs to be applied to the bolt with properly lubricated and undamaged threads. This applied torque will cause the bolt to stretch and act as a spring to clamp and hold the joint together.



The amount of bolt tension or stretch is what determines a properly fastened joint. If the bolt is not stretched enough, the joint will be loose and could possibly lead to failure. Too much stretch can weaken the bolt and also possibly lead to failure.

The relationship between torque and bolt tension can be influenced by several factors, these being: the type of lubricant used on the threads, the material from which the bolt and nut are made, the type of washers used, the class, finish, and condition of the threads.

To demonstrate these relationships, a study was performed to show how dramatically these factors influence the amount of clamping force on a joint.

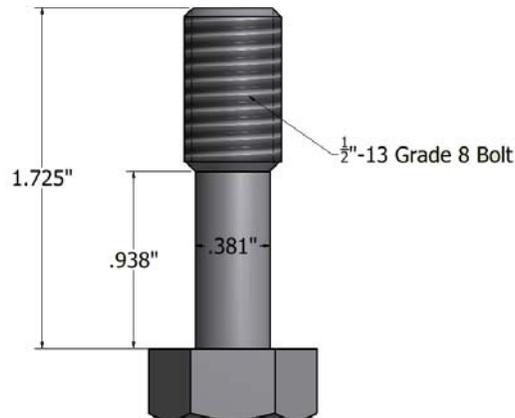
Study Summary

This study was performed to calculate the amount of bolt stretch and clamping force that is generated by a fastener that is properly lubricated, has clean and undamaged threads, and where the installation is performed with a properly calibrated torque wrench. This clamping force will then be compared to the clamping force generated by the following installation conditions:

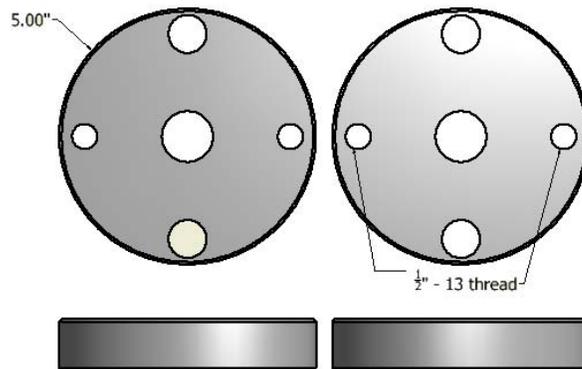
- 1) Installation with an improperly calibrated torque wrench

- 2) Installation with a non-lubricated fastener
- 3) Installation with damaged threads on fastener

Fasteners Used for Study:



Test Plates

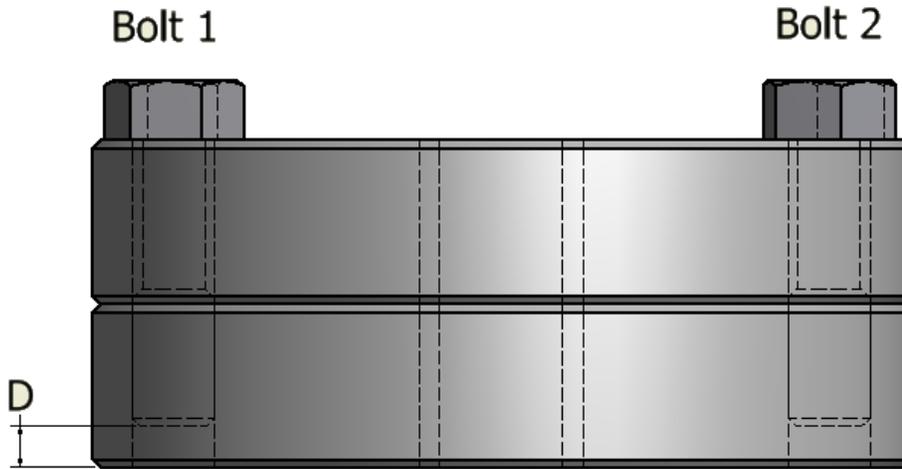


Torque Wrench Used: 30-250 Ft-lb Micro-Adjustable Wrench with 1/2" square drive

Lubricant Used: Molycote GN Metal Assembly Paste

Test #1 – Calibrated Torque Wrench / Clean and Lubricated Threads

Our Test #1 was set up to show how a properly assembled and torqued joint would behave. Thread gauges were used to check both the male threads on the bolt as well as the female threaded holes in the test plate. We verified the set points of the torque wrench using an electronic torque tester with an accuracy of +/- .5%. The bolts had their bottom surfaces ground flat, perpendicular to the bolt's axis. The bolt threads were properly lubricated and then used to attach the test plates together as shown.



The bolts were torqued to an initial torque of 10 Ft-lbs. At this point, the depth D was measured to provide a base point for the bolt length. The bolts were each then torqued to a final torque value of 65 Ft-lbs. The depth D was again measured for each bolt. The difference between the initial D and final D gave us the amount of bolt stretch. The results were as follows:

	Initial D	Final D	Stretch
Bolt 1	.238"	.233"	.005"
Bolt 2	.241"	.236"	.005"

Using the following equation for the bolt stretch, we can calculate the clamping force for each bolt:

$$\text{Stretch (S)} = \frac{FL}{AE}$$

F = clamping force

L = initial bolt length (1.725")

A = cross sectional area of bolt (.1142 square inches)

E = Modulus of Elasticity (30000000 psi)

Using the stretch value of .005", we can calculate for the clamping force F.

$$F = \frac{SAE}{L}$$

L

$$F = \frac{(.005'')(.1142 \text{ square inches})(30000000 \text{ psi})}{1.725''}$$

$$F = 9930 \text{ pounds per bolt}$$

With the clamping force now calculated based on the bolt stretch, we installed the test plate assembly into a hydraulic testing rack as shown below.



The test rack was designed so that it would attach to and hydraulically pull the plates apart. The purpose behind the test was to incrementally increase the amount of force used to pull on the plates up to the point where separation occurs between the plates. This would indicate the point at which the clamping force has been overcome and provides us with a way to verify what that clamping force actually is.

The test rack is equipped with a single acting hydraulic ram with an effective area of 11.05 square inches. The hydraulic pressure is indicated on a 10,000 psi gage which has been calibrated using a Fluke P-3116-3 Dead Weight Tester which has an accuracy of .015% of the reading.

The results for the pull test on our Test #1 assembly are as follows:

Force Applied (lbs)	Separation at Bolt #1	Separation at Bolt #2
13260	None	None
14365	None	None
15470	None	None
16575	None	None
17680	None	None
18785	None	None
19890	.001"	.001"

With separation occurring evenly at 19890 pounds, it translates into 9945 pounds of clamping force per bolt. This is within .2% of our calculated value based on the bolt stretch.

Test #1 Summary

The purpose of this first test was to provide us with a baseline to compare to in subsequent tests. We have shown that by using a properly calibrated torque wrench along with clean and lubricated threads, this fastener when torqued down to a value of 65 Ft-lbs will provide 9945 pounds of clamping force.

In this test, the theory has been validated in practice.

The following tests will show the impact that such things as torque wrench calibration, lubrication and thread condition can have on the clamping force.

Test #2 – Out of Calibration Wrench / Clean and Lubricated Threads

In this test, the condition of the threads and lubrication were the same as in Test #1. The only difference was that the set point of the wrench was dropped to 50 Ft-lbs. This was intended to simulate what could happen if a wrench is out of calibration. The bolts were torqued down and the test plate assembly was placed into the hydraulic testing rack. The results were as follows:

Force Applied (lbs)	Separation at Bolt #1	Separation at Bolt #2
8840	None	None

9945	None	None
11050	None	None
12155	None	None
13260	None	None
14365	None	None
14917	.001"	.001"

This shows us that a clamping force of only 7459 per bolt is generated versus the expected value of 9945.

In this test, theory is not supported by the practice.

Test #3 – Calibrated Wrench / Clean and Non-Lubricated Threads

In this test, a calibrated torque wrench was used, set and verified at 65 Ft-lbs. The threads on both the fastener and hole were clean, but no lubrication was used. The results of this test were as follows:

Force Applied (lbs)	Separation at Bolt #1	Separation at Bolt #2
5525	None	None
6630	None	None
7735	None	None
8840	None	None
9945	None	None
11050	.001"	.002"

The uneven amount of separation shows that the clamp forces generated by the bolts were not equal. The average force per bolt was 5525 pounds, well below our value of 9945 in Test #1. What this shows us is that with the bolts not being lubricated, a greater amount of the input torque is absorbed by the system friction, causing less to be applied to bolt stretch and clamping force.

In this test, theory is not supported by the practice.

Test #4 – Calibrated Wrench / Damaged and Non-Lubricated Threads

In this test, a calibrated torque wrench was used, set and verified at 65 Ft-lbs. The threads on both the fastener were damaged, and no lubrication was used. The results of this test were as follows:

Force Applied (lbs)	Separation at Bolt #1	Separation at Bolt #2
3315	None	None
4420	None	None
5525	None	None
6630	None	None
7735	None	None
8840	.001"	.002"

Again we see that there is an uneven amount of separation on the bolts. The average force per bolt is only 4420 lbs which is 56% lower than our clamp force in the initial test.

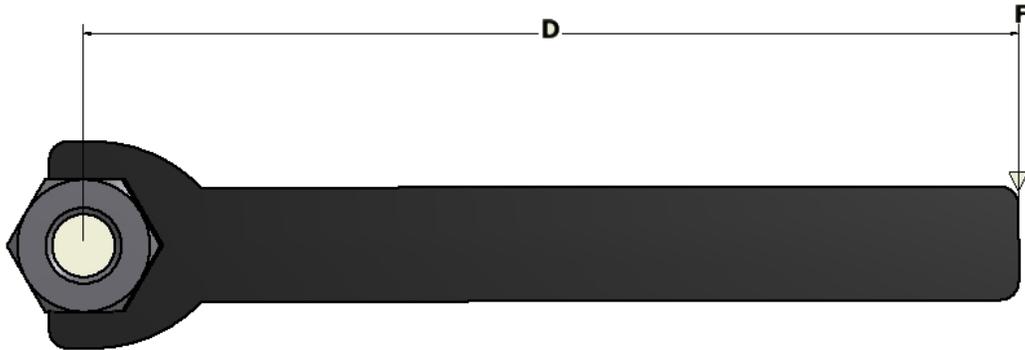
In this test, theory is not supported by the practice.

Test Conclusions

These tests show that there is more to torquing down a fastener than simply setting a torque wrench and installing the fastener. Factors such as wrench calibration, thread condition and thread lubrication have a significant impact on the final clamping force of that fastener. This clamping force being what holds the joint together and prevents potential failures at that joint.

- **Torque Definition, Formula, and Units**

Torque is defined as a force which when applied tends to produce rotation. Its magnitude is a product of the force applied and distance.



In the case of this wrench above, a Force **F** applied at a Distance **D** from the center of the fastener as shown:

$$\mathbf{T \text{ (Torque)} = F \times D}$$

Torque is expressed in the following common units of measurement

- in.lbs. (Inch pounds)
- ft.lbs (Foot pounds)
- Nm (Newton meters)

Unit conversions are:

- 1 Foot Pound = 12 Inch Pounds
- 1 Inch Pound = .11298 Newton Meters
- 1 Foot Pound = 1.356 Newton Meters

- **Manual Torque Wrenches and Adapters**

There are several different methods that can be used to tension a fastener. There are the methods that apply torque to the fastener itself either hydraulically, pneumatically, or mechanically. There are also methods that attach to and stretch the fastener to achieve the proper amount of clamping force.

Below will be detailed the most common fastener torquing method, the use of manual torque wrenches and adapters.

Micro- Adjustable Torque Wrenches

The Micro-Adjustable style torque wrenches have the ability to be adjusted to different torque values within the operating range of the wrench. They feature a micrometer style adjustment ring which can be turned and locked into place at the desired torque setting. These type of wrenches are often referred to as “click” style wrenches due to the fact that when the torque set point is reached, an audible “click” can be heard and also felt through the handle.

This style wrench is available in a fixed ratcheting head style:



Micro Adjustable Torque Wrench - Fixed Ratcheting Head

It is also available as an interchangeable shank head style:



Micro Adjustable Torque Wrench - Interchangeable Head

These wrenches have an accuracy of within $\pm 4\%$ clockwise and $\pm 6\%$ counterclockwise of any setting from 20% of full scale to full scale.

Shank Size	Diameter
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J	.425"
Y	.560"
X	.735"

Pre-Set Torque Wrenches

Pre set torque wrenches are used in applications where one specific torque is required in a repetitive operation. These wrenches feature the same “click” style operation as the micro-adjustable wrenches. They also feature the interchangeable shank head style. These wrenches also have an accuracy of within $\pm 4\%$ clockwise and $\pm 6\%$ counterclockwise of any setting from 20% of full scale to full scale.

• Adapter Use and Torque Calculations

One aspect that is essential when using manual torque wrenches is to properly understand when torque calculations are needed in setting the wrench and how to make these calculations. Below are formulas that can be used for both the fixed ratcheting head style as well as interchangeable head style wrenches.

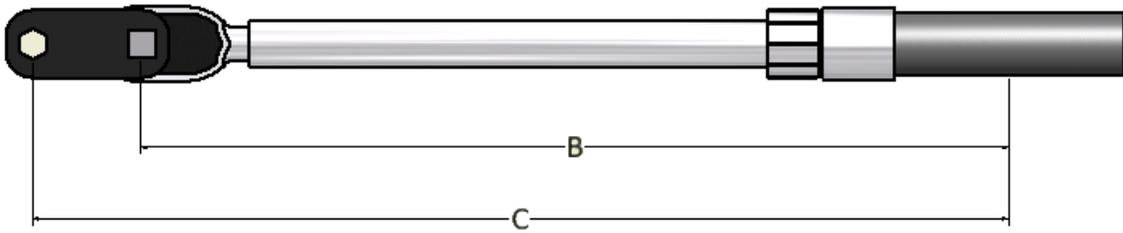
- 1) Fixed Ratcheting Head Style – Used with Socket



$$t \text{ (Torque Setting on Torque Wrench)} = T \text{ (Torque on Fastener)}$$

No Calculations Required

- 2) Fixed Ratcheting Head Style – Used with Adapter



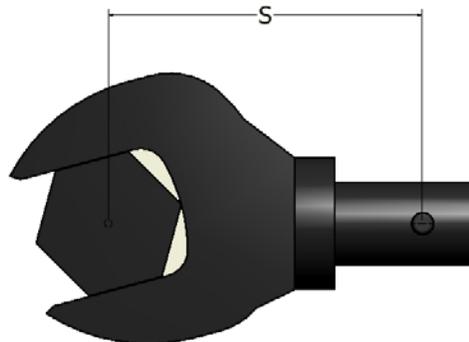
t = Torque Setting On Wrench
 T = Torque on Fastener

$$t = T \times \frac{B}{C}$$

3) Interchangeable Head Style – When Used With a Standard Length Adapter



t (Torque Setting on Torque Wrench) = T (Torque on Fastener)
 No Calculations Required



Standard Adapter Length (S)
 From Center of Fastener to
 Center of Retaining Pin

- J shank - 2.50"
- Y shank - 3.00"
- X shank - 4.50"

The above represents the current standard adapter lengths for the different shank sizes. Older wrenches may have different “click” arm calibration. It is always recommended to check torque wrench setting using a torque analyzer.

- **Torque Wrench Verification**

When using torque wrenches, it is essential that their accuracy is checked on a regular basis. These testers can be used for periodic wrench calibration and also are helpful in checking accuracy of torque calculations when using adapters as described above.

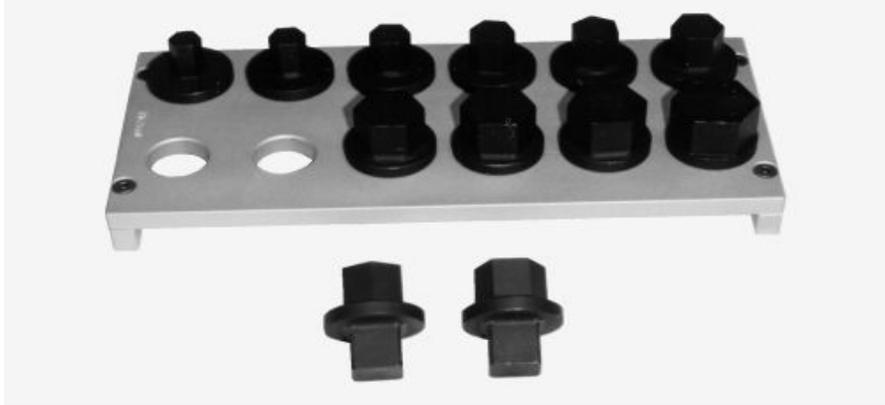


Tesco Torque Wrench Tester – T18961

This tester operates between 30.0 and 1500.0 Nm (22.0 to 1106.0 Ft-lbs)

Guaranteed classification to BS7882:2008, Class 1 or better over the primary calibration range (20% to 100% of full scale), Class 1 equates to +/-0.5% of reading

This electronic tester can be used in conjunction with adapter sets that are available in ranges of both standard and metric sizes.



Tesco Standard Adapter Set (1/2" through 1-1/4")
T57580



Tesco Metric Adapter Set (6 mm through 32 mm)
T86060