for maximum tightening torque

in minimum working space . . .

TORQUE MULTIPLIERS

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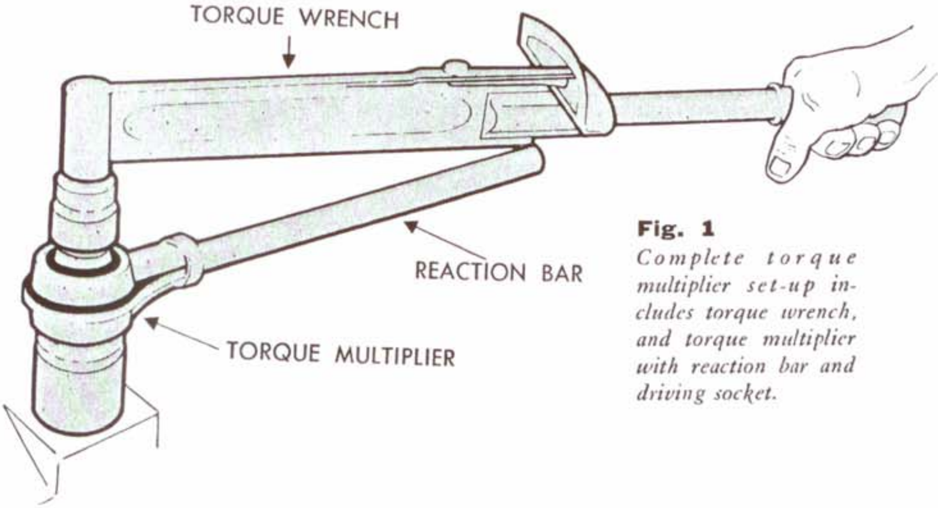

Fig. 1
Complete torque multiplier set-up includes torque wrench, and torque multiplier with reaction bar and driving socket.

ABOUT THIS TABLE—

To use bolt strength effectively for the most permanent holding power, fasteners are tightened nearly to within 90% of the elastic limit. The ideal is considered to be within 90% of the elastic limit or about 65% of the ultimate strength. This table provides a quick guide to torque-tension relationships for average applications. When either the ultimate strength or elastic limit of a fastener is known, the desired tension may be matched to the chart to determine the torque requirement.

Torque-tension values in the table are based on fasteners which are lubricated with a heavy oil and graphite mixture. Bolts should be lubricated under the head as well as at the thread. Any high stress lubricant such as Never-Seez, Fel-Pro C-5, Molykote, or others should give similar tension values. When engine oil is used as a lubricant or when fasteners are used as furnished in the manufacturers container, an increase in torque of 20% is advisable. Similarly, torque values should be reduced by 20% when new plated bolts are used.

For sizes over 1 in., data are based on 8-thread series fasteners. In this size range, torque-tension values for UNC thread series fasteners will vary slightly. However, the data given in the table should be applicable on a size-for-size basis for most general assembly work.

Nominal Size (in.)	Threads per Inch	Thread Root Diam. (in.)	Thread Root Area (sq. in.)	For 7,500 psi Bolt Stress	
				Torque (ft-lb)	Tension (lb)
1/4	20	0.185	0.027	1	203
5/16	18	0.240	0.045	2	388
3/8	16	0.294	0.068	3	510
7/16	14	0.345	0.093	5	698
1/2	13	0.400	0.126	8	945
9/16	12	0.454	0.162	12	1215
5/8	11	0.507	0.202	15	1515
3/4	10	0.620	0.302	25	2265
7/8	9	0.731	0.419	40	3143
1	8	0.838	0.551	62	4133
1-1/8	8	0.963	0.728	89	5460
1-1/4	8	1.088	0.929	125	6968
1-3/8	8	1.213	1.155	170	8663
1-1/2	8	1.338	1.405	200	10540
1-5/8	8	1.463	1.680	275	12600
1-3/4	8	1.588	1.980	375	14850
1-7/8	8	1.713	2.304	500	17280
2	8	1.838	2.652	550	19140
2-1/4	8	2.088	3.423	795	25670
2-1/2	8	2.338	4.292	1100	32190
2-3/4	8	2.588	5.259	1480	39445
3	8	2.838	6.324	1930	47430

Simply stated, torque multipliers increase the output of torque wrenches. In practice, they are used to tighten fasteners when working space is limited or a large torque must be applied.

Basically a torque multiplier consists of a gear train housed in a metal casting. The cast housing incorporates a square drive opening for insertion of the torque wrench; a socket or similar element for mounting the multiplier, either directly or with attachments, to the bolt or nut to which torque is to be applied; and a fitting for a reaction bar, which is merely a metal rod used to brace the multiplier against a stationary supporting object. A complete torque multiplier set-up is shown in Fig. 1.

The gear train of a torque multiplier increases the mechanical advantage of the torque wrench in direct proportion to the gear ratio of the multiplier. Standard production torque multipliers provide ratios of 4 to 1, 4.33 to 1, and 6 to 1.

This increase in mechanical advantage is not obtained without some penalty. In this instance, wrench travel is increased in direct proportion to the gear ratio. For example, to rotate the output drive of a 4 to 1 multiplier one full turn, the torque wrench must be rotated through four full turns. For one turn of a 6 to 1 multiplier, the wrench must rotate six turns. Because of frictional losses in the multiplier gear train a torque loss factor of 10% must be anticipated.

Torque multipliers are made in several different size and capacity ranges. As a result, it is possible to match the correct torque wrench with the lightest, most compact, and most economical multiplier capable of doing the required job.

As a checklist for selecting the necessary components for a particular torque multiplication, the following factors should be considered:

1. Maximum torque to be applied.
2. Limitations in working space.
3. Capacity of torque multiplier.
4. Compatibility of torque multipliers with torque wrenches.
5. Location of stationary members which can be used to brace the reaction bar.

WHEN IS A MULTIPLIER NEEDED?

Generally, a torque multiplier is called for when:

1. A measured torque must be applied to bolts, studs, or nuts that have a nominal diameter of 1 in. or more.
2. Small bolts must be accurately tightened in a working space that prevents use of a torque wrench with a long arm length.

Torque wrenches are based on the principle of the simple mechanical lever. That is, torque is the product of the force applied and the lever length or arm length. In mathematical terms,

$$FL = T \tag{1}$$

where F = force exerted on the torque wrench, L = lever length or arm, and T = torque.

The average individual can pull with a force of 100 lb without losing safe footing. Therefore, the design of torque wrenches is standardized on the basis of 100 lb of force being applied by the operator near full scale capacity of the wrench.

Based on this standardized maximum force of 100 lb, torque wrench lever length can be readily determined by Equation 1 when the required tightening torque is established. Because of the many variables that can affect torque-tension relationships, it is generally recommended that tighten-

Table 1 Torque-Tension Relationships for Steel Bolts and Studs in General Assembly Work

For 15,000 psi Bolt Stress		For 30,000 psi Bolt Stress		For 45,000 psi Bolt Stress		For 60,000 psi Bolt Stress		
Torque (ft-lb)	Tension (lb)	Torque (ft-lb)	Tension (lb)	Torque (ft-lb)	Tension (lb)	Torque (ft-lb)	Tension (lb)	Nominal Size (in.)
2	405	4	810	6	1215	8	1620	1/4
4	675	8	1350	12	2025	16	2700	5/16
6	1020	12	2040	18	3060	24	4080	3/8
10	1395	20	2790	30	4185	40	5580	7/16
15	1890	30	3780	45	5670	60	7560	1/2
23	2430	45	4860	68	7290	90	9720	9/16
30	3030	60	6060	90	9090	120	12120	5/8
50	4530	100	9060	150	13590	200	18120	3/4
80	6285	160	12570	240	18855	320	25140	7/8
123	8265	245	16530	368	24795	490	33060	1
178	10920	355	21840	533	32760	710	43680	1-1/8
250	13935	500	27870	750	41805	1000	55740	1-1/4
340	17325	680	34650	1020	51975	1360	69300	1-3/8
400	21075	800	42150	1200	63225	1600	84300	1-1/2
550	25200	1100	50400	1650	75600	2200	100800	1-5/8
750	29700	1500	59400	2250	89100	3000	118800	1-3/4
1000	34560	2000	69120	3000	103680	4000	138240	1-7/8
1100	38280	2200	79560	3300	119340	4400	159120	2
1590	51345	3180	102690	4770	154035	6360	205380	2-1/4
2200	64380	4400	128760	6600	193140	8800	257520	2-1/2
2960	78885	5920	157770	8880	236655	11840	315540	2-3/4
3860	94860	7720	189720	11580	284580	15440	379440	3

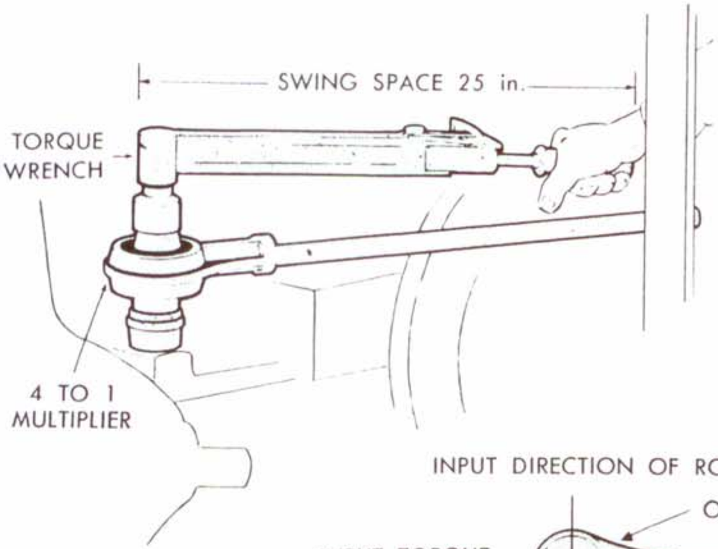

Fig. 2
Torque multiplier is used to reduce torque-wrench lever length.

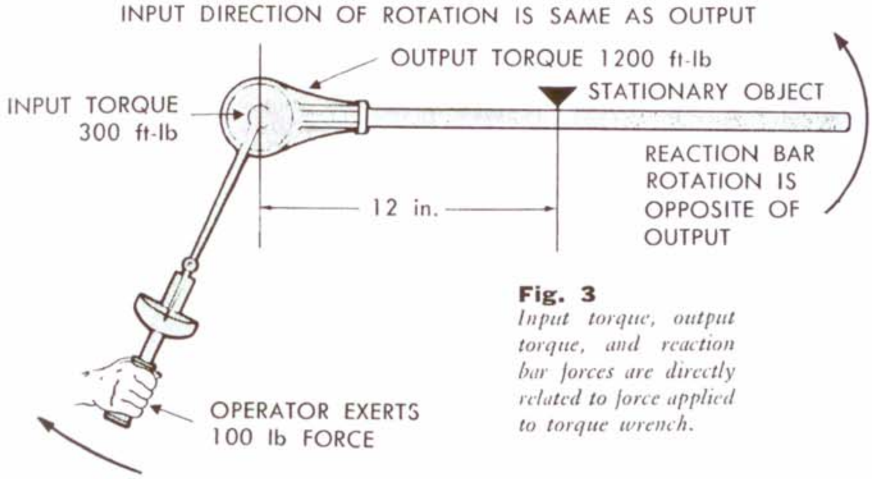

Fig. 3
Input torque, output torque, and reaction bar forces are directly related to force applied to torque wrench.

ing torques be determined by actual measurements on the job. The torque-tension values given in Table 1 are representative data for general assembly work.

As an example of wrench lever length calculations, consider the requirements for a 1-3/8 in. bolt, torqued to a stress of 60,000 psi, Table 1. To obtain the required minimum clamping force of 69,300 lb, it is necessary to apply a torque of 1360 ft-lb. By Equation 1, $L = 1360/100 = 13.6$ ft. Therefore, to convert a wrenching force of 100 lb to a torque of 1360 ft-lb, lever length of the torque wrench must be 13.6 ft.

The inefficiency and possible safety hazards involved in using a 13.6 ft. lever length, either for occasional or repetitive production operations, point up the advantages of using torque multipliers. By using a 4 to 1 torque multiplier, the required lever length is reduced to $L = 13.6/4 = 3.4$ ft.

The greatest torque requirement listed in Table 1 is 15,440 ft-lb for a 3 in. bolt tightened to 60,000 psi. Without a multiplier, the lever length required to apply this torque would be (Equation 1) $L = 15{,}440/100 = 154.4$ ft. However, if a 6 to 1 torque multiplier is used, the lever length can be reduced to $L = 154.4/6 = 25.7$ ft. This lever length can be further reduced by adding a 4 to 1 multiplier to the system. Then, the required lever length becomes $L = 25.7/4 = 6.4$ ft.

SPACE LIMITATIONS

Up to this point, only the problems created by the torque requirements of relatively large fasteners have been considered. Far more common are those situations in which confined working space makes reduction of torque wrench lever length desirable.

A typical situation of this type is depicted in Fig. 2. Here, the bolt being tightened requires a torque of 600 ft-lb. If a torque wrench is used without a torque multiplier, the lever length would have to be 6 ft. However, a lever of this length would strike the obstruction as it is rotated. By using a 4 to 1 torque multiplier, required lever length for the torque wrench would be reduced to $L = 6/4 = 1\text{-}1/2$ ft or 18 in., which would clear the obstruction easily.

The available space through which the torque wrench lever can be rotated is called the swing space. If ratchets are used with a torque multiplier, the wrench may be rotated within an arc of 30°, or less, while the tightening operation is accomplished.

The following procedure can be used to select the correct torque wrench and multiplier for use in a given swing space:

1. Determine the torque required.
2. Measure the swing space.
3. Select a torque wrench with a lever length

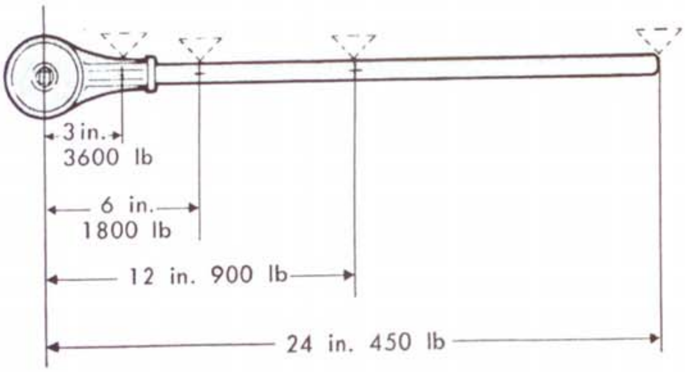

Fig. 4
Reaction bar force is directly related to distance from center of output drive.

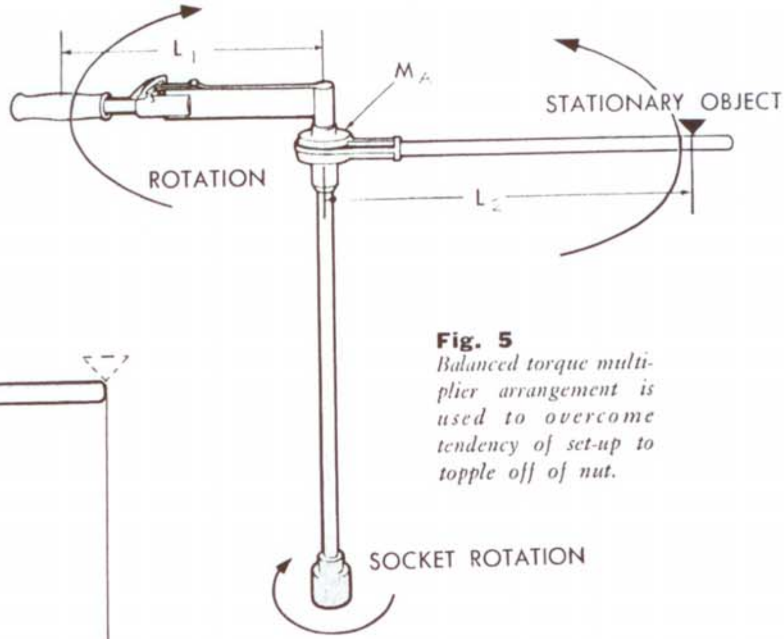

Fig. 5
Balanced torque multiplier arrangement is used to overcome tendency of set-up to topple off of nut.

short enough so that it can be rotated at least 30° within the swing space.

4. Choose a multiplier that, in combination with the torque wrench, will develop the required amount of torque when a force of 100 lb is applied by the operator.

For example, in the situation shown in Fig. 2, the torque required is 600 ft-lb. Maximum swing space is 25 in. A torque wrench with a lever length of 1.5 ft, which fits the space, has a capacity of 150 ft-lb. By using a multiplier with a 4 to 1 ratio, the required 600 ft-lb torque output is provided within the available swing space.

These requirements also could have been met by using a combination of a 100 ft-lb capacity torque wrench (1 ft lever length) and a 6 to 1 multiplier. However, the 6 to 1 multiplier would be heavier, bulkier, and more expensive than the 4 to 1 unit.

As a general rule, it is good practice to use the longest practical lever length for the swing space with the lowest cost multiplier that will do the job.

REACTION BARS

Reaction bars are used to prevent the housing of the torque multiplier from rotating when force is applied to the torque wrench. Consider the situation shown in Fig. 3. Here, a force of 100 lb is being applied to a torque wrench which has a 3 ft lever arm. Thus, the input torque at the multiplier is 300 ft-lb. The output torque applied to the bolt being tightened with a 4 to 1 multiplier is 1200 ft-lb.

The torque wrench and torque multiplier also apply torque to the reaction bar. However, in this case, the input torque applied by the wrench and the reaction torque developed by the bolt at the multiplier output oppose each other, so that the torque applied to the reaction bar is 900 ft-lb–the difference between the input torque of 300 ft-lb and the output torque of 1200 ft-lb. This torque is converted to force when the reaction bar presses against a stationary object.

The amount of force applied at any point along the length of the reaction bar depends upon the distance from that point to the center of the multiplier drive. From the basic torque relationship, Equation 1,

$$P = \frac{T_r}{L_r}$$

where P = force applied by reaction bar, T_r = reaction bar torque, and L_r = distance from point of force application along reaction bar to center of multiplier output drive.

For the condition depicted in Fig. 3, then, the reaction bar will apply a force of 900 lb against a stationary object at a distance of 1 ft from the center of the multiplier output drive.