DEFINITIONS OF SCREWS & THREAD TERMS

Screw Thread
A ridge or uniform section in the form of a helix on the external or internal surface of a cylinder, or in the form of a conical spiral on the external or internal surface of a cone.

External Thread
An external thread is a thread on the outside of a member.

Internal Thread
An internal thread is a thread on the inside of a member.

Major Diameter
The largest diameter of the thread of the screw or nut. The term "major diameter" replaces the term "outside diameter" as applied to the thread of a screw and also the term full diameter as applied to the thread of a nut.

Minor Diameter
The smallest diameter of the thread of a screw or nut. The term "minor diameter" replaces the term "core diameter" as applied to the thread of a screw and also the term "inside diameter" as applied to the thread of a nut.

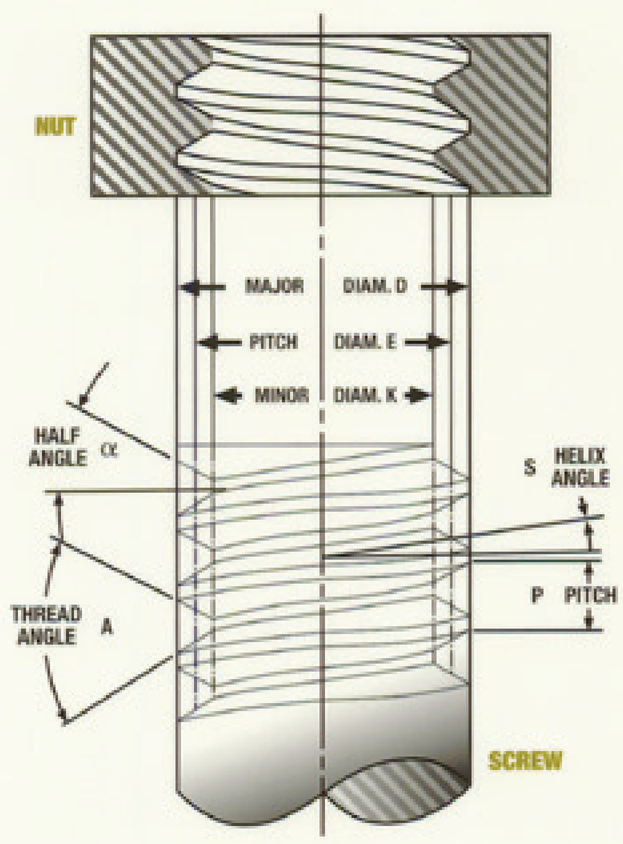
Pitch Diameter
On a straight screw thread, the diameter of an imaginary cylinder, the surface of which would pass through the threads at such points as to make equal the width of the threads and the width of the spaces cut by the surface of the cylinder. On a taper screw thread, the diameter, at a given distance from a reference plane perpendicular to the axis of an imaginary cone, the surface of which would pass through the threads at such points as to make equal the width of the threads and the width of the spaces cut by the surface of the cone.

Pitch
The distance from a point on a screw thread to a corresponding point on the next thread measured parallel to the axis.

The pitch in inches:

$$\frac{1}{\text{Number of threads per inch}}$$

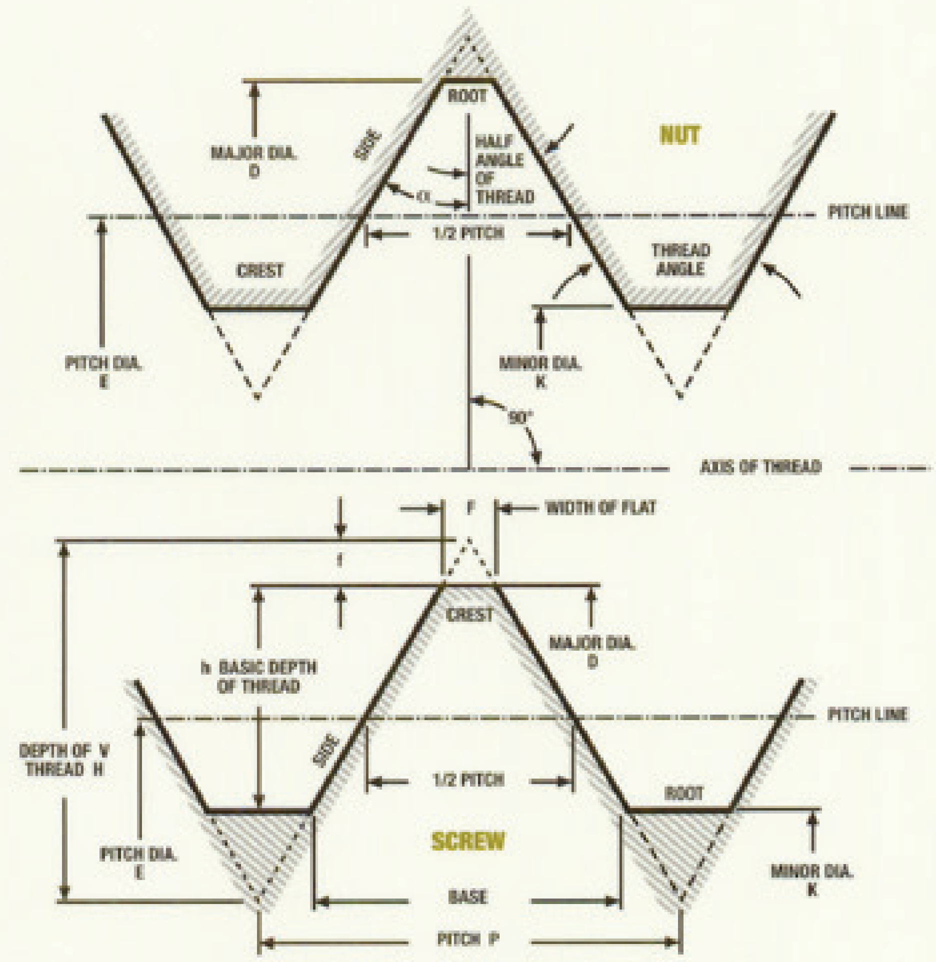
Half Angle of Thread
The angle included between a side of the thread and the normal to the axis, measured in an axial plane.



Angle of Thread
The angle included between the sides of the thread measured in an axial plane.

Helix Angle
The angle made by the helix, or conical spiral, of the thread at the pitch diameter with a plane perpendicular to the axis.

Crest
The surface of the thread corresponding to the major diameter of the screw and the minor diameter of the nut.



Lead
The distance a screw thread advances axially in one turn. On a single threaded screw the lead and pitch are identical; on a double threaded screw the lead is two times the pitch; on a triple threaded screw the lead is three times the pitch, etc.

Root
The surface of the thread corresponding to the minor diameter of the screw and the major diameter of the nut.

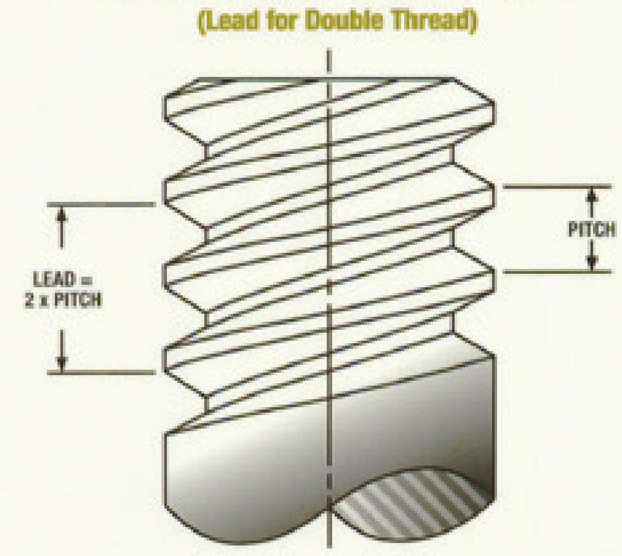
Side or Flank
The surface of the thread which connects the crest with the root.

Axis of a Screw
The longitudinal central line through the screw.

Base of Thread
The bottom section of the thread; the greatest section between the two adjacent roots.

Depth of Thread
The distance between the crest and the base of the thread measured normal to the axis.

EXAMPLE OF MULTIPLE THREADED SCREW (Lead for Double Thread)



Number of Threads
The number of threads in one inch of length.

Length of Engagement
The length of contact between two mated threaded parts measured axially.

Depth of Engagement
The depth of thread contact of two mated parts, measured radially.

Pitch Line
An element of the imaginary cylinder or cone as specified under "Pitch Diameter".

Thickness of Thread
The distance between the adjacent sides of the thread measured along or parallel to the pitch line.

Mean Area
The term "mean area of a screw," when used in specifications and for other purposes, designates the cross-sectional area computed from the mean of the basic pitch and minor diameters.

UNIFIED INCH SCREW THREADS (TPI) COARSE UNC

Size	Major Diameter	Threads Per Inch	Pitch Diameter	Minor Diameter External	Minor Diameter Internal	Minor Diameter Area	Tensile Stress Area
#	inch	tpi	inch	inch	inch	sq. inch	sq. inch
#1	0.073	64	0.0629	0.0544	0.0561	0.00218	0.00263
#2	0.086	56	0.0744	0.0648	0.0667	0.0031	0.0037
#3	0.099	48	0.0855	0.0741	0.0764	0.00406	0.00487
#4	0.112	40	0.0958	0.0822	0.0849	0.00496	0.00604
#5	0.125	40	0.1088	0.0952	0.0979	0.00672	0.00796
#6	0.138	32	0.1177	0.1008	0.1042	0.00745	0.00909
#8	0.164	32	0.1437	0.1268	0.1302	0.01196	0.014
#10	0.19	24	0.1629	0.1404	0.1449	0.0145	0.0175
#12	0.216	24	0.1889	0.1664	0.1709	0.0206	0.0242
1/4	0.25	20	0.2175	0.1905	0.1959	0.0269	0.0318
5/16	0.3125	18	0.2764	0.2464	0.2524	0.0454	0.0524
3/8	0.375	16	0.3344	0.3005	0.3073	0.0678	0.0775
7/16	0.4375	14	0.3911	0.3525	0.3602	0.0933	0.1063
1/2	0.5	13	0.45	0.4084	0.4167	0.1257	0.1419
9/16	0.5625	12	0.5084	0.4633	0.4723	0.162	0.182
5/8	0.625	11	0.566	0.5168	0.5266	0.202	0.226
3/4	0.75	10	0.685	0.6309	0.6417	0.302	0.334
7/8	0.875	9	0.8028	0.7427	0.7547	0.419	0.462
1	1	8	0.9188	0.8512	0.8467	0.551	0.606
1-1/8	1.125	7	1.0322	0.9549	0.9704	0.693	0.763
1-1/4	1.25	7	1.1572	1.0799	1.0954	0.89	0.969
1-3/8	1.375	6	1.2667	1.1766	1.1946	1.054	1.155
1-1/2	1.5	6	1.3917	1.3016	1.3196	1.294	1.405
1-3/4	1.75	5	1.6201	1.5119	1.5335	1.74	1.9
2	2	4.5	1.8557	1.7353	1.7594	2.3	2.5
2-1/4	2.25	4.5	2.1057	1.9853	2.0094	3.02	3.25
2-1/2	2.5	4	2.3376	2.2023	2.2294	3.72	4
2-3/4	2.75	4	2.5876	2.4523	2.4794	4.62	4.93
3	3	4	2.8376	2.7023	2.7294	5.62	5.97
3-1/4	3.25	4	3.0876	2.9523	2.9794	6.72	7.1
3-1/2	3.5	4	3.3376	3.2023	3.2294	7.92	8.33
3-3/4	3.75	4	3.5876	3.4523	3.4794	9.21	9.66
4	4	4	3.8376	3.7023	3.7294	10.61	11.08

THREADED CLASSES

Classes of thread are distinguished from each other by the amounts of tolerance and allowance specified. External threads or bolts are designated with the suffix "A"; internal or nut threads with "B".

Classes 1A and 1B

For work of rough commercial quality where loose fit or spin-on-assembly is desirable.

Classes 2A and 2B

The recognized standard for normal production of the great bulk of commercial bolts, nuts and screws.

Classes 3A and 3B

Used where a closed fit between mating parts for high quality work is required.

Class 5

For a wrench fit. Used principally for studs and their mating tapped holes. A force fit requiring the application of high torque for semi-permanent assembly.

UNIFIED INCH SCREW THREADS (TPI) FINE UNC

Size	Major Diameter	Threads Per Inch	Pitch Diameter	Minor Diameter External	Minor Diameter Internal	Minor Diameter Area	Tensile Stress Area
#	inch	tpi	inch	inch	inch	sq. inch	sq. inch
#0	0.06	80	0.0519	0.0451	0.0465	0.00151	0.0018
#1	0.073	72	0.064	0.0565	0.058	0.00237	0.00278
#2	0.086	64	0.0759	0.0674	0.0691	0.00339	0.00394
#3	0.099	56	0.0874	0.0778	0.0797	0.00451	0.00523
#4	0.112	48	0.0985	0.0871	0.0894	0.00566	0.00661
#5	0.125	44	0.1102	0.0979	0.1004	0.00716	0.0083
#6	0.138	40	0.1218	0.1082	0.1109	0.00874	0.01015
#8	0.164	36	0.146	0.1309	0.1339	0.01285	0.01474
#10	0.19	32	0.1697	0.1528	0.1562	0.0175	0.02
#12	0.216	28	0.1928	0.1734	0.1773	0.0226	0.0258
1/4	0.25	28	0.2268	0.2074	0.2113	0.0326	0.0364
5/16	0.3125	24	0.2854	0.2629	0.2674	0.0524	0.058
3/8	0.375	24	0.3479	0.3254	0.3299	0.0809	0.0878
7/16	0.4375	20	0.405	0.378	0.3834	0.109	0.1187
1/2	0.5	20	0.4675	0.4405	0.4459	0.1486	0.1599
9/16	0.5625	18	0.5264	0.4964	0.5024	0.189	0.203
5/8	0.625	18	0.5889	0.5589	0.5649	0.24	0.256
3/4	0.75	16	0.7094	0.6763	0.6823	0.351	0.373
7/8	0.875	14	0.8286	0.79	0.7977	0.48	0.509
1	1	12	0.9459	0.9001	0.9098	0.625	0.663
1-1/8	1.125	12	1.0709	1.0258	1.0348	0.812	0.856
1-1/4	1.25	12	1.1959	1.1508	1.1598	1.024	1.073
1-3/8	1.375	12	1.3209	1.2758	1.2848	1.26	1.315
1-1/2	1.5	12	1.4459	1.4008	1.4098	1.521	1.581

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COARSE VS. FINE THREAD COMPARISONS

Coarse Threads

- Stripping strengths are greater for the same length of engagement.
- Less likely to cross-thread.
- Quicker assembly and disassembly.
- Tap better in brittle material.
- Larger thread allowances accommodate thicker plating, coatings and are therefore less likely to seize in corrosion prone applications.
- Less prone to stripping when fastened into lower strength materials.
- Better fatigue resistance because of less concentration to stress at thread root radius.
- The height of each thread is greater than the corresponding fine thread so there is more material between each thread making flank engagement greater.
- Less susceptible to being nicked or damaged, so they do not have to be "handled with care" as much as fine threads.
- Coarse threads are much less likely to experience thread galling than fine threads.
- Aerospace applications generally use coarse threads on sized 8–32 and smaller.
- Coarse threads are used when threaded into aluminum or cast iron because the finer threads tend to strip more easily in these materials.
- Are stronger when assembled with lower strength nut or tapped hole materials.
- Stronger for bolt/screw/nut sizes over one inch.
- They start more easily than fine thread, particularly in awkward positions and require less time to tighten.

Fine Threads

- Are stronger in tapped hole materials normally used in design and significantly increase joint clamping force.
- Allow for greater adjustment accuracy because of their smaller helix angle. Can be threaded closer to the head since thread die chamfer is a function of pitch.
- Are better for tapping thin-walled members because tapping torque is lower for short engagement lengths.
- Are stronger for fastener sizes one inch diameter and smaller, gaining strength advantage as size decreases.
- Maintains joint tightness and clamping force better due to the smaller helix angle of the thread.
- Aerospace applications generally use fine thread fasteners due to their increased strength.
- Stronger than the corresponding coarse threaded bolts of the same hardness.
- Stronger in both tension and shear due to having a slightly larger tensile stress area and minor diameter.
- They have less of a tendency to loosen under vibration due to their having a smaller helix angle than coarse threads.
- Shorter thread depth allows for threading in thin wall applications.
- Where length of engagement is limited, fine threads provide greater strength.
- Their larger minor diameters develop higher torsional and transverse shear lengths.
- Fine threads require less torque to develop equivalent bolt preloads.
- Fine threads are more susceptible to thread galling than coarse threads.
- Fine threads need longer thread engagements and are more prone to damage (nicking) and thread fouling.
- They are less suitable for high-speed assembly since they are more likely to seize when being tightened.

The suitability of either a coarse or fine thread series for a specific application has to be determined on a case-by-case basis. Analyze, experiment and test to obtain the greatest level of confidence in the design of critical bolted joints in specific applications.

No. **5** in a Series

DECIMAL EQUIVALENTS CHART

Drill Size	MM	Decimal Inches	Drill Size	MM	Decimal Inches	Drill Size	MM	Decimal Size	Drill Size	MM	Decimal Size
	0.10	0.0039	45	2.08	0.0820	5	5.22	0.2055	7/16	11.11	0.4375
	0.20	0.0079	44	2.18	0.0860	4	5.31	0.2090	29/64	11.15	0.4531
	0.25	0.0098	43	2.26	0.0890	3	5.41	0.2130	15/32	11.91	0.4688
	0.30	0.0118	42	2.37	0.0935	7/32	5.56	0.2188		12.00	0.4724
80	0.34	0.0135	3/32	2.38	0.0938	2	5.61	0.2210	31/64	12.30	0.4844
79	0.37	0.0145	41	2.44	0.9600	1	5.79	0.2280	1/2	12.70	0.5000
1/64	0.40	0.0156	40	2.50	0.9800	A	5.94	0.2340		13.00	0.5118
78	0.41	0.0160	39	2.53	0.9950	15/64	5.95	0.2344	33/64	13.10	0.5156
77	0.46	0.0180	38	2.58	0.1015		6.00	0.2360	17/32	13.49	0.5312
	0.50	0.0197	37	2.64	0.1040	B	6.05	0.2380	35/64	13.89	0.5469
76	0.51	0.0200	36	2.71	0.1065	C	6.15	0.2420		14.00	0.5512
75	0.53	0.0210	7/64	2.78	0.1094	D	6.25	0.2460	9/16	14.29	0.5625
74	0.57	0.0225	35	2.79	0.1100	1/4	6.35	0.2500	37/64	14.68	0.5781
	0.60	0.0236	34	2.82	0.1110	E	6.35	0.2500		15.00	0.5906
73	0.61	0.0240	33	2.87	0.1130	F	6.53	0.2570	19/32	15.08	0.5938
72	0.64	0.0250	32	2.95	0.1160	G	6.63	0.2610	39/64	15.48	0.6094
71	0.66	0.0260		3.00	0.1181	17/64	6.75	0.2656	5/8	15.88	0.6250
	0.70	0.0276	31	3.05	0.1200	H	6.76	0.2660		16.00	0.6299
70	0.71	0.0280	1/8	3.18	0.1250	I	6.91	0.2720	41/64	16.27	0.6406
69	0.74	0.0282	30	3.26	0.1285		7.00	0.2756	21/32	16.67	0.6562
	0.75	0.0295	29	.45	0.1360	J	7.04	0.2770		17.00	0.6693
68	0.84	0.0330	28	3.57	0.1405	K	7.14	0.2810	43/64	17.07	0.6719
1/32	0.79	0.0313	9/64	3.57	0.1406	9/32	7.14	0.2812	11/16	17.46	0.6875
	0.80	0.0315	27	3.66	0.1440	L	7.37	0.2900	45/64	17.86	0.7031
67	0.81	0.0320	26	3.73	0.1470	M	7.49	0.2850		18.00	0.7087
66	0.84	0.0330	`25	3.80	0.1495	19/64	7.54	0.2969	23/32	18.26	0.7188
65	0.89	0.0350	24	3.86	0.1520	N	7.67	0.3020	47/64	18.65	0.7344
	0.90	0.0354	23	3.91	0.1540	5/16	7.94	0.3125		19.00	0.7480
64	0.91	0.0360	5/32	3.97	0.1562		8.00	0.3150	3/4	19.05	0.7500
63	0.94	0.0370	22	3.99	0.1570	O	8.03	0.3160	49/64	19.45	0.7656
62	0.97	0.0380		4.00	0.1575	P	8.20	0.3230	25/32	19.84	0.7812
61	0.99	0.0390	21	4.04	0.1590	21/64	8.33	0.3281		20.00	0.7874
	1.00	0.0394	20	4.09	0.1610	Q	8.43	0.3320	51/64	20.24	0.7969
60	1.02	0.0400	19	4.22	0.1660	R	8.61	0.3390	13/16	20.64	0.8125
59	1.04	0.0410	18	4.31	0.1695	11/32	8.73	0.3438		21.00	0.8268
58	1.07	0.0420	11/64	4.37	0.1719	S	8.784	0.3480	53/64	21.03	0.8281
57	1.09	0.0430	17	4.39	0.1730		9.00	0.3543	27/32	21.43	0.8483
56	1.18	0.0465	16	4.50	0.1770	T	9.09	0.3580	55/64	21.84	0.8594
3/64	1.19	0.0469	15	4.57	0.1800	23/64	9.13	0.3594		22.00	0.8661
55	1.32	0.0520	14	4.62	0.1820	U	9.35	0.3680	7/8	22.23	0.8750
54	1.40	0.0550	13	4.70	0.1850	3/8	9.53	0.3750	57/64	22.62	0.8906
53	1.51	0.0595	3/16	4.76	0.1875	V	9.56	0.3770		23.00	0.9055
1/16	1.59	0.0625	12	4.80	0.1890	W	9.80	0.3680	29/32	23.02	0.9062
52	1.61	0.0635	11	4.85	0.1910	25/64	9.92	0.3906	59/64	23.42	0.9219
51	1.70	0.0670	10	4.91	0.1935		10.00	0.3937	15/16	23.81	0.9375
50	1.78	0.0700	9	4.98	0.1960	X	10.08	0.3970		24.00	0.9449
49	1.85	0.0730		5.00	0.1968	Y	10.26	0.4040	61/64	24.21	0.9531
48	1.93	0.0760	8	5.05	0.1990	13/32	10.32	0.4062	31/32	24.61	0.9688
5/64	1.98	0.0781									
47	1.99	0.0785	7	5.11	0.2010	Z	10.49	0.4130		25.00	0.9843
	2.00	0.0787	13/64	5.16	0.2031	26/74	10.72	0.4219	63/64	25.00	0.9844
46	2.06	0.0810	6	5.18	0.2040		11.00	0.4331	1"	25.40	1.0000

FACTORS AFFECTING TORQUE-TENSION RELATIONSHIPS IN BOLTED JOINTS

A summary of the most critical variables in fastener applications

FASTENER MATERIAL

A well-accepted equation for computing torque-tension relationships in bolted joints is:

$$T = \frac{KDW}{12}$$

Where T = torque, lb-ft; K = friction factor (a constant); D = bolt diameter, inches; and W = bolt tension, lb.

Typical values of friction factor K are:

MATERIAL

Lubricated Steel 0.11
Cadmium Plated Steel 0.15
Unplated Steel 0.20
Stainless Steel 0.30

This range of possible friction conditions has a very practical significance in terms of the torque required to produce a specific bolt tension. For example, assume a 1/2 inch diameter bolt is to be torqued to a preload of 10,000 lb. tension in assembly. If the bolt is made of steel and lubricated,

$$T = \frac{0.11\,(0.5)\,(10{,}000)}{12} = 46 \text{ lb-ft}$$

However, if the bolt is made of stainless steel,

$$T = \frac{0.30\,(0.5)\,(10{,}000)}{12} = 125 \text{ lb-ft}$$

For average conditions (represented by unplated alloy steel bolts and nuts with dry threads), a friction factor of K = 0.20 is generally used for calculations.

FASTENER-JOINT MATERIAL COMBINATIONS

The torque required to tighten a screw or bolt properly depends on both the fastener material and the material into which it is driven. For example, here are the approximate torques required for proper tightening of a size 10-24 (3/16) steel machine screw in various materials:

MATERIAL	TORQUE (LB-IN)	MATERIAL	TORQUE (LB-IN)
Fiber	6	Copper	10.5
Magnesium	8	Brass	14
Aluminum	8	Steel	14
Zinc	9.5		

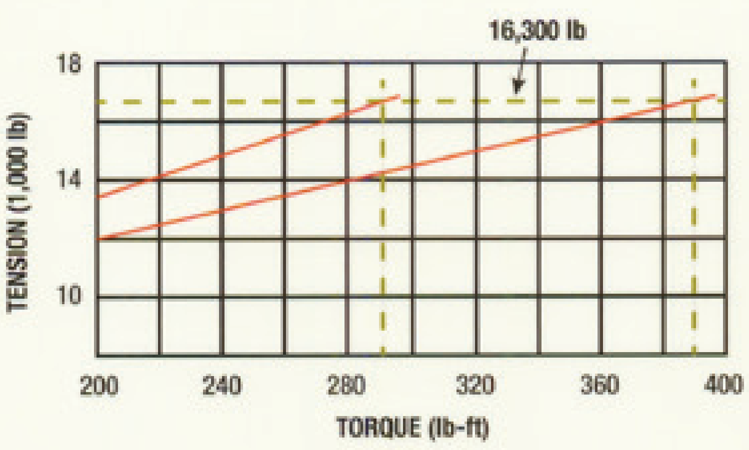
For comparison, torque required for a comparable brass screw driven in brass is 12.5 lb-in. Torque requirements are also affected by the length of thread engagement. The following table gives comparative values for a size 12-24 steel machine screw driven in steel:

ENGAGEMENT (IN.)	TORQUE (LB-IN.)	ENGAGEMENT (IN.)	TORQUE (LB-IN.)
1/32 to 3/64	8	5/64 to 7/64	17.5
3/64 to 5/64	14	7/64 and over	21

JOINT MATERIALS

The ability of the joint material to support the fastener bearing load is an important factor in torque-tension relationships.

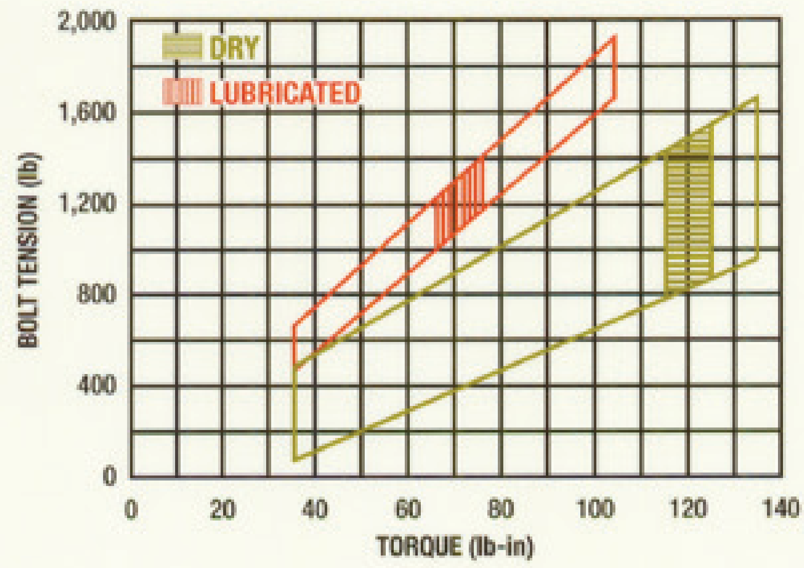
The chart shows torque-tension plots for a 9/16-18 bolt tightened to a tension of 16,300 lb in two different materials. The upper plot is for a material with a hard bearing surface. Torque required was 290 lb-ft. Lower plot is for a material with a comparatively soft bearing surface. Torque required here was 390 lb-ft. Joints with gaskets and various types of lockwashers are subject this effect. Manufacturers of both products can supply pertinent data on this subject.



Courtesy of Skidmore-Wilhelm

FASTENER LUBRICATION

Effect of lubrication on torque-tension relationships is shown by the chart which is based on results obtained with a 9/16-18 steel bolt driven into aluminum. For a non-lubricated bolt, torques of 115 to 125 lb-in were required to develop tensions of 800 to 1400 lb. For a lubricated bolt, torque values ranged from 65 to 75 lb-in for 1000 to 1250 lb tension range.



Torque values are affected in various ways by different types of lubricants. Wax on either the bolt or nut, or both, also acts to reduce the torque requirements.

FASTENER PLATING

The type of plating on the surface of the elements of the bolt assembly has a direct effect on the coefficient of friction and, hence, the torque-tension relationship. The following chart illustrates this effect. It is based on results obtained with 1/4-20 steel bolt, nut and washer assembly, using different plating combinations.

	PLATING CONDITION			COEFFICIENT OF FRICTION					
Case	Bolt	Nut	Washer		0.1	0.2	0.3	0.4	0.5
1	Plain	Cadmium	Plain		•				
2	Cadmium	Plain	Plain			•			
3	Cadmium	Cadmium	Plain			•			
4	Zinc	Plain	Plain			•			
5	Zinc	Plain	Zinc				•		
6	Plain	Zinc	Plain					•	
7	Zinc	Zinc	Plain						•

For a torque of 10 lb-ft on the bolt, the following tension values were obtained:

PLATING	CONDITION	TENSION (LB)
Case 1	Plain – Cadmium – Plain	2805
Case 4	Zinc – Plain – Plain	1866
Case 5	Zinc – Plain – Zinc	1546
Case 7	Zinc – Zinc – Plain	960

Many other plating combinations have been tested with similar results.

FASTENER QUALITY

Quality of both the fastener components and the joint members has an effect on torque-tension relationships. The finish on the nut face; the quality and fit of the threads on both the bolt and nut; and the finish on the face of the joint must be considered in determining the proper tightening torque. An actual example demonstrates typical results:

> In a joint using a rough finished connecting rod and nut, a torque of 145 lb-ft was required to develop a tension of 13,000lb. When a smooth finished connecting rod and nut were used, the torque requirement for this tension was reduced to 80 lb-ft.

Publisher's comment: Always review these six critical variables when designing and suggesting fastening applications and/or different types of fasteners. Always test all applications and never think of one as not being a critical application!

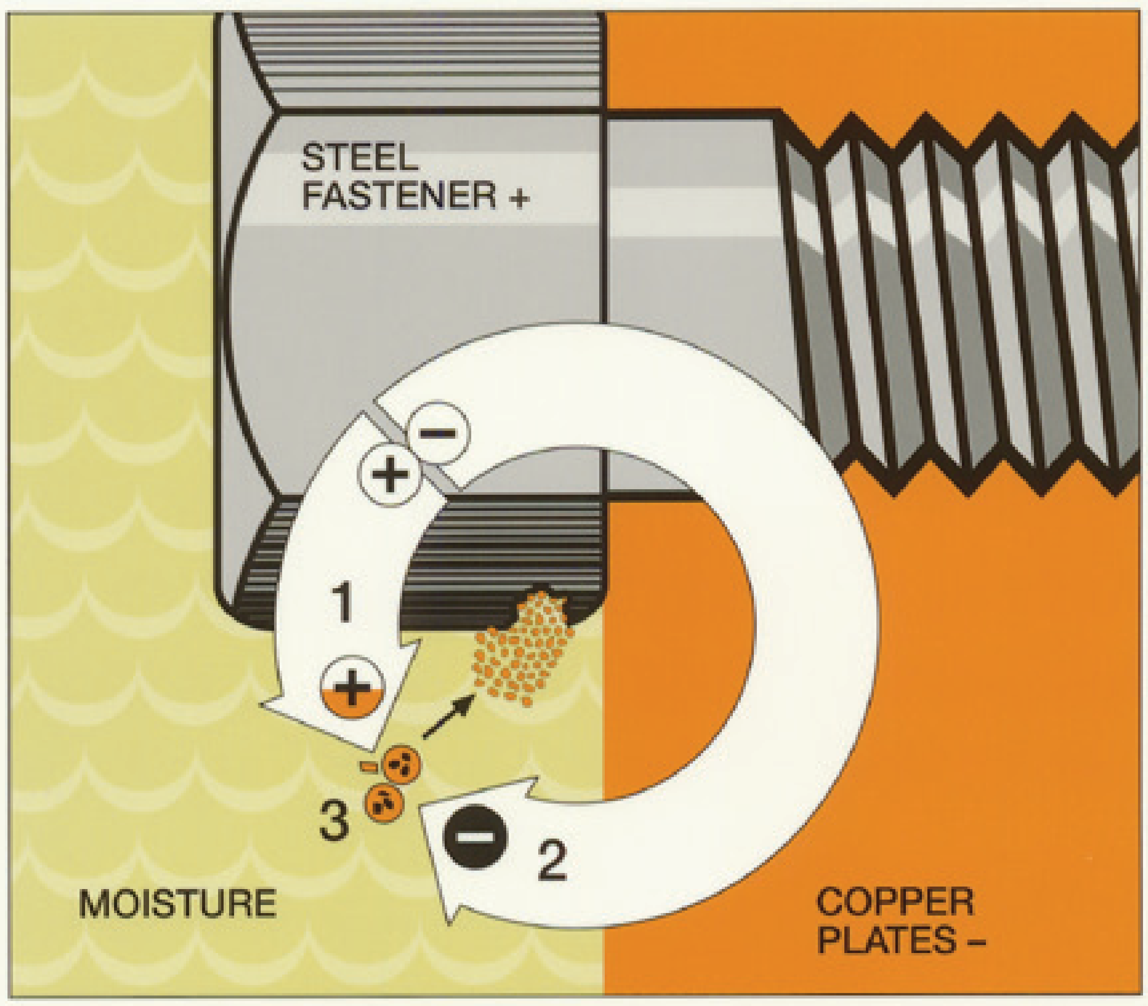
FASTENER CORROSION

What is corrosion?

Corrosion is the wearing away or alteration of a metal by galvanic (electrochemical) reaction or by direct chemical attack. An example is the rusting of iron or steel.

Direct attack corrosion

Atmospheric corrosion is an example of direct chemical attack. Present in the atmosphere are oxygen, carbon dioxide, water vapor, sulfur and chlorine compounds. The severity of attack is directly related to the amount of water vapor, sulfur and chlorine compounds present.



On contact of steel and copper in moisture, atoms of iron divide.

1. Positive particles of metal dissolve in the moisture, absorbing oxygen and hydrogen, becoming ferrous ions.
2. Negative charged electrons flow through steel to copper into the moisture where they combine with oxygen and water, becoming hydroxyl ions.
3. Hydroxyl ions combine with ferrous ions, producing iron oxide (rust), the corrosion product.

Galvanic corrosion (electromechanical)

All metals have a specific relative electrical potential. When metals of different electrical potential, such as steel and copper, are in contact in the presence of moisture (electrolyte), a low energy electric current flows from the metal having the higher position in the galvanic series to the one having the lower position.

This is called "galvanic" action. One result is that corrosion of the metal having the higher position (steel in this example) is accelerated. Corrosion may be thought of as a by-product, something akin to the forming of ash when wood burns.

Actually, the mechanism is an anode reaction, a cathode reaction, the conduction of electrons through the metal from anode to cathode, and the conduction of ions through the electrolyte solution. Corrosion occurs in the anode area, while the cathode area is protected.

It is important to know from which of two metals current will flow. A guide is provided by the arrangement of metals and alloys set forth in the galvanic series chart shown below.

Many different types of corrosion have been identified. Most are electrochemical in nature. Thus, crevice or cell corrosion, stress or fatigue corrosion, deposit and impingement attack and intergranular corrosion are all forms of galvanic corrosion caused by localized galvanic cells of different potentials.

Direct attack

Select the material most likely to resist the corrosive environment to which the fastener will be subjected.

Galvanic attack

1. If possible, use the same or similar metals in an assembly, especially where an electrolyte may be present.
2. When dissimilar metals are used together in the presence of an electrolyte, separate them with a dielectric material such as insulation, paint or coating.
3. Avoid combinations where the area of the less noble material is relatively small. The current density is greater when the current flows from the small area to the large than in the reverse situation. Typically, the fastener will be small compared to the rest of the assembly. The fastener alloy, if not the same as the material being joined, should be lower in the galvanic series.
4. The galvanic process can be used to advantage by coupling the part to be protected to pieces of less noble metal which are not functional and can thus corrode sacrificially.

Galvanic series chart

This representative sample of dissimilar materials indicates relative potential for galvanic corrosion. Coupling metals widely separated on the chart is most likely to cause corrosion. Under ordinary circumstances, no serious galvanic action will result from the coupling of metals within the same group (such as brass and copper).

Anode (least noble)	Magnesium Magnesium Alloys
	Zinc
	Aluminum 1100
	Cadmium
	Aluminum 2024-T4
	Steel or Iron Cast Iron
	Chromium Iron (active)
	Ni-Resist
	Type 304 Stainless (active) Type 316 Stainless (active)
	Hastelloy "C"
electric current flows from anode to cathode	Lead Tin Solders Lead, Tin
	Nickel (active) Inconel
	Hastelloy "B"
	Brass, Copper, Bronze Copper-nickel Alloys, Monel
	Silver Solder
	Nickel (passive) Inconel (passive)
	Chromium-iron (passive)
	Type 304 Stainless (passive) Type 316 Stainless (passive)
	Silver
Cathode (most noble)	Titanium
	Graphite, Gold, Platinum

Avoid irregular stresses

As a general rule in using mechanical fasteners, avoid irregular stresses in design. Even high stresses in bolted assemblies do not necessarily impair corrosion-resistance as long as they are uniform.

THREAD / SCREW DRILL & TAP CHART

				TAP DRILLS				CLEARANCE HOLE DRILLS			
				Aluminum, Brass, & Plastics		Stainless Steel, Steels & Iron		All Materials			
MACHINE SCREW SIZE				75% THREAD		50% THREAD		CLOSE FIT		FREE FIT	
# or Dia.	Major Dia.	Threads Per Inch	Minor Dia.	Drill Size	Decimal Equiv.	Drill Size	Decimal Equiv.	Drill Size	Decimal Equiv.	Drill Size	Decimal Equiv.
0	.0600	80	.0447	3/64	.0469	55	.0520	52	.0635	50	.0700
1	.0730	64	.0538	53	.0595	1/16	.0625	48	.0760	46	.0810
		72	.0560	53	.0595	52	.0635				
2	.0860	56	.0641	50	.0700	49	.0730	43	.0890	41	.0960
		64	.0668	50	.0700	48	.0760				
3	.0990	48	.0734	47	.0785	44	.0860	37	.1040	35	.1100
		56	.0771	45	.0820	43	.0890				
4	.1120	40	.0813	43	.0890	41	.0960	32	.1160	30	.1285
		48	.0864	42	.0935	40	.0980				
5	.125	40	.0943	38	.1015	7/64	.1094	30	.1285	29	.1360
		44	.0971	37	.1040	35	.1100				
6	.138	32	.0997	36	.1065	32	.1160	27	.1440	25	.1495
		40	.1073	33	.1130	31	.1200				
8	.1640	32	.1257	29	.1360	27	.1440	18	.1695	16	.1770
		36	.1299	29	.1360	26	.1470				
10	.1900	24	.1389	25	.1495	20	.1610	9	.1960	7	.2010
		32	.1517	21	.1590	18	.1695				
12	.2160	24	.1649	16	.1770	12	.1890	2	.2210	1	.2280
		28	.1722	14	.1820	10	.1935				
		32	.1777	13	.1850	9	.1960				
1/4	.2500	20	.1887	7	.2010	7/32	.2188	F	.2570	H	.2660
		28	.2062	3	.2130	1	.2280				
		32	.2117	7/32	.2188	1	.2280				
5/16	.3125	18	.2443	F	.2570	J	.2770	P	.3230	Q	.3320
		24	.2614	I	.2720	9/32	.2812				
		32	.2742	9/32	.2812	L	.2900				
3/8	.3750	16	.2983	5/16	.3125	Q	.3320	W	.3860	X	.3970
		24	.3239	Q	.3320	S	.3480				
		32	.3367	11/32	.3438	T	.3580				
7/16	.4375	14	.3499	U	.3680	25/64	.3906	29/64	.4531	15/32	.4687
		20	.3762	25/64	.3906	13/32	.4062				
		28	.3937	Y	.4040	Z	.4130				
1/2	.5000	13	.4056	27/64	.4219	29/64	.4531	33/64	.5156	17/32	.5312
		20	.4387	29/64	.4531	15/32	.4688				
		28	.4562	15/32	.4688	15/32	.4688				
9/16	.5625	12	.4603	31/64	.4844	33/64	.5156	37/64	.5781	19/32	.5938
		18	.4943	33/64	.5156	17/32	.5312				
		24	.5114	33/64	.5156	17/32	.5312				
5/8	.6250	11	.5135	17/32	.5312	9/16	.5625	41/64	.6406	21/32	.6562
		18	.5568	37/64	.5781	19/32	.5938				
		24	.5739	37/64	.5781	19/32	.5938				
11/16	.6875	24	.6364	41/64	.6406	21/32	.6562	45/64	.7031	23/32	.6562
3/4	.7500	10	.6273	21/32	.6562	11/16	.6875	49/64	.7656	25/32	.7812
		16	.6733	11/16	.6875	45/64	.7031				
		20	.6887	45/64	.7031	23/32	.7188				
13/16	.8125	20	.7512	49/64	.7656	25/32	.7812	53/64	.8281	27/32	.8438
7/8	.8750	9	.7387	49/64	.7656	51/64	.7969	57/64	.8906	29/32	.9062
		14	.7874	13/16	.8125	53/64	.8281				
		20	.8137	53/64	.8281	27/32	.8438				
15/16	.9375	20	.8762	57/64	.8906	29/32	.9062	61/64	.9531	31/32	.9688
1	1.000	8	.8466	7/8	.8750	59/64	.9219	1-1/64	1.0156	1-1/32	1.0313
		12	.8978	15/16	.9375	61/64	.9531				
		20	.9387	61/64	.9531	31/32	.9688				

TENSILE STRENGTH OF BOLTS & HEX HEAD CAP SCREWS PART 1

Size	ASTM A325 (Structural Bolts)		ASTM A490 (Structural Bolts)		ASTM A449 (Bolts / Cap Screws)		ASTM A354, Gr. BD (Bolts)		ASTM A193, Gr. B7 (B7 Thd Rod / Bolts)	
	PSI	Pounds	PSI	Pounds	PSI	Pounds	PSI	Pounds	PSI	Pounds
NC THREADS										
1/4-20					120,000	3,800	150,000	4,750	125,000	3,975
5/16-18					120,000	6,300	150,000	7,850	125,000	6,550
3/8-16					120,000	9,300	150,000	11,650	125,000	9,700
7/16-14					120,000	12,750	150,000	15,950	125,000	13,300
1/2-13	120,000	17,050	150,000	21,300	120,000	17,050	150,000	21,300	125,000	17,750
9/16-12					120,000	21,850	150,000	27,300	125,000	22,750
5/8-11	120,000	27,100	150,000	33,900	120,000	27,100	150,000	33,900	125,000	28,250
3/4-10	120,000	40,100	150,000	50,100	120,000	40,100	150,000	50,100	125,000	41,750
7/8-9	120,000	55,450	150,000	69,300	120,000	55,450	150,000	69,300	125,000	57,750
1-8	120,000	72,700	150,000	90,900	120,000	72,700	150,000	90,900	125,000	75,750
1 1/8-7	105,000	80,100	150,000	114,450	105,000	80,100	150,000	114,450	125,000	95,400
1 1/4-7	105,000	101,700	150,000	145,350	105,000	101,700	150,000	145,350	125,000	121,150
1 3/8-6	105,000	121,300	150,000	173,250	105,000	121,300	150,000	173,250	125,000	144,400
1 1/2-6	105,000	147,500	150,000	210,750	105,000	147,500	150,000	210,750	125,000	175,650
1 3/4-5					90,000	171,000	150,000	285,000	125,000	237,500
2-4 1/2					90,000	225,000	150,000	375,000	125,000	312,500
NF THREADS										
1/4-28					120,000	4,350	150,000	5,450	125,000	4,550
5/16-24					120,000	6,950	150,000	8,700	125,000	7,250
3/8-24					120,000	10,550	150,000	13,200	125,000	11,000
7/16-20					120,000	14,250	150,000	17,800	125,000	14,850
1/2-20					120,000	19,200	150,000	24,000	125,000	20,000
9/16-18					120,000	24,350	150,000	30,400	125,000	25,400
5/8-18					120,000	30,700	150,000	38,400	125,000	32,000
3/4-16					120,000	44,750	150,000	56,000	125,000	46,650
7/8-14					120,000	61,100	150,000	76,400	125,000	63,650
1-12					120,000	79,550	150,000	99,400	125,000	82,900
1-14							150,000	101,900	1235,000	84,900
1 1/8-12					105,000	89,900	150,000	128,400	125,000	107,000
1 1/4-12					105,000	112,650	150,000	161,000	125,000	134,150
1 3/8-12					105,000	138,100	150,000	197,200	125,000	164,400
1 1/2-12					105,000	166,000	150,000	237,200	125,000	197,650

Ultimate Tensile Load: Maximum tensile-applied load or force a fastener can support prior to, or coincidental with, its fracture. Normally expressed in pounds.

TENSILE STRENGTH OF BOLTS & HEX HEAD CAP SCREWS PART 2

Size	ASTM A307, Gr. A (Hex Bolts / Thd Rod)		SAE J429, Gr. 2[1] (Cap Screws)		SAE J429, Gr. 5 (Cap Screws)		SAE J429, Gr. 8 (Cap Screws)	
	PSI	Pounds	PSI	Pounds	PSI	Pounds	PSI	Pounds
NC THREADS								
1/4-20	60,000	1,900	74,000	2,350	120,000	3,800	150,000	4,750
5/16-18	60,000	3,100	74,000	3,900	120,000	6,300	150,000	7,850
3/8-16	60,000	4,650	74,000	5,750	120,000	9,300	150,000	11,600
7/16-147/16-14	60,000	6,350	74,000	7,850	120,000	12,800	150,000	15,900
1/2-13	60,000	8,500	74,000	10,500	120,000	17,000	150,000	21,300
9/16-12	60,000	11,000	74,000	13,500	120,000	21,800	150,000	27,300
5/8-11	60,000	13,550	74,000	16,700	120,000	27,100	150,000	33,900
3/4-10	60,000	20,050	74,000	24,700	120,000	40,100	150,000	50,100
7/8-9	60,000	27,700	60,000	27,700	120,000	55,400	150,000	69,300
1-8	60,000	36,350	60,000	36,400	120,000	72,700	150,000	90,900
1 1/8-7	60,000	45,800	60,000	45,800	105,000	80,100	150,000	114,400
1 1/4-7	60,000	58,150	60,000	58,100	105,000	101,700	150,000	145,400
1 3/8-6	60,000	69,300	60,000	69,300	105,000	121,300	150,000	173,200
1 1/2-6	60,000	84,300	60,000	84,300	105,000	147,500	150,000	210,800
1 3/4-5	60,000	114,000						
2-4 1/2	60,000	150,000						
NF THREADS								
1/4-28			74,000	2,700	120,000	4,350	150,000	5,450
5/16-24			74,000	4,300	120,000	6,950	150,000	8,700
3/8-24			74,000	6,500	120,000	10,500	150,000	13,200
7/16-20			74,000	8,800	120,000	14,200	150,000	17,800
1/2-20			74,000	11,800	120,000	19,200	150,000	24,000
9/16-18			74,000	15,000	120,000	24,400	150,000	30,400
5/8-18			74,000	18,900	120,000	30,700	150,000	38,400
3/4-16			74,000	27,600	120,000	44,800	150,000	56,000
7/8-14			60,000	30,500	120,000	61,100	150,000	76,400
1-12			60,000	39,800	120,000	79,600	150,000	99,400
1-14			60,000	40,700	120,000	81,500	150,000	101,900
1 1/8-12			60,000	51,400	105,000	89,900	150,000	128,400
1 1/4-12			60,000	64,400	105,000	112,700	150,000	161,000
1 3/8-12			60,000	78,900	105,000	138,100	150,000	197,200
1 1/2-12			60,000	94,900	105,000	166,000	150,000	237,200

Ultimate Tensile Load: Maximum tensile-applied load or force a fastener can support prior to, or coincidental with, its fracture. Normally expressed in pounds.

Note 1: Grade 2 requirements for sizes 1/4 through 3/4 inches apply only to bolts and screws 6 inches and shorter in length. For bolts and screws over 6 inches in length, Grade 1 requirements shall apply (same as ASTM A307, Grade A).

MECHANICAL REQUIREMENTS FOR STAINLESS STEEL & NON-FERROUS FASTENERS

		BOLTS, SCREWS & STUDS						NUTS	
		Full Size Bolts, Screws, Studs		Machine Test Specimens of Bolts, Screws, Studs					
		Yield (2) Strength	Tensile Strength	Yield (2) Strength	Tensile Strength	Elongation (3)	Hardness Rockwell	Proof Load Stress	Hardness Rockwell
Grade (1)	General Description of Material	Minimum psi	Minimum psi	Minimum psi	Minimum psi	% Minimum	Minimum	psi	Minimum
303A	Austenitic Stainless Steel – Sol. Annealed	30,000	75,000	30,000	75,000	20	B75	75,000	B75
304-A	Austenitic Stainless Steel – Sol. Annealed	30,000	75,000	30,000	75,000	20	B75	75,000	B75
304	Austenitic Stainless Steel – Cold Worked	50,000	90,000	45,000	85,000	20	B85	90,000	B85
304-SH	Austenitic Stainless Steel – Strain Hardened	See Note A	See Note A	See Note A	See Note A	15	C25	See Note A	C20
305-A	Austenitic Stainless Steel – Sol. Annealed	30,000	75,000	30,000	75,000	20	B70	75,000	B70
305	Austenitic Stainless Steel – Cold Worked	50,000	90,000	45,000	85,000	20	B85	90,000	B85
305-SH	Austenitic Stainless Steel – Strain Hardened	See Note A	See Note A	See Note A	See Note A	15	C25	See Note A	C20
316-A	Austenitic Stainless Steel – Sol. Annealed	30,000	75,000	30,000	75,000	20	B70	75,000	B70
316	Austenitic Stainless Steel – Cold Worked	50,000	90,000	45,000	85,000	20	B85	90,000	B85
316-SH	Austenitic Stainless Steel – Strain Hardened	See Note A	See Note A	See Note A	See Note A	15	C25	See Note A	C20
XM7-A	Austenitic Stainless Steel – Sol. Annealed	30,000	75,000	30,000	75,000	20	B70	75,000	B70
XM7	Austenitic Stainless Steel – Cold Worked	50,000	90,000	45,000	85,000	20	B85	90,000	B85
384-A	Austenitic Stainless Steel – Sol. Annealed	30,000	75,000	30,000	75,000	20	B70	75,000	B70
384	Austenitic Stainless Steel – Cold Worked	50,000	90,000	45,000	85,000	20	B85	90,000	B85
410-H	Martensitic Stainless Steel – Hardened and Tempered	95,000	125,000	95,000	125,000	20	C22	125,000	C22
410-HT	Martensitic Stainless Steel – Hardened and Tempered	135,000	180,000	135,000	180,000	12	C36	180,000	C36
416-H	Martensitic Stainless Steel – Hardened and Tempered	95,000	125,000	95,000	125,000	20	C22	125,000	C22
416-HT	Martensitic Stainless Steel – Hardened and Tempered	135,000	180,000	135,000	180,000	12	C36	180,000	C36
430	Ferritic Stainless Steel	40,000	70,000	40,000	70,000	20	B75	70,000	B75
464-HF	Naval Brass	15,000	52,000	14,000	50,000	25	B56	52,000	B56
464	Naval Brass	27,000	60,000	25,000	57,000	25	B65	60,000	B65
462	Naval Brass	27,000	52,000	24,000	50,000	20	B65	52,000	B65
642	Aluminum Bronze	35,000	72,000	35,000	72,000	15	B75	72,000	B75
630	Aluminum Bronze	50,000	105,000	50,000	105,000	10	B90	105,000	B90
614	Aluminum Bronze	40,000	75,000	40,000	75,000	30	B70	75,000	B70
510	Phosphor Bronze	35,000	60,000	35,000	60,000	15	B60	60,000	B60
675	Manganese Bronze	22,000	55,000	22,000	55,000	20	B60	55,000	B60
655-HF	Silicon Bronze	20,000	52,000	18,500	50,000	20	B60	52,000	B60
655	Silicon Bronze	38,000	70,000	36,000	68,000	15	B75	70,000	B75
651	Silicon Bronze	45,000	75,000	42,500	72,000	8	B75	75,000	B75
661	Silicon Bronze	38,000	70,000	38,000	70,000	15	B75	70,000	B75
NICU-A-HF	Nickel-Copper Alloy A	25,000	70,000	25,000	70,000	20	B70	70,000	B70
NICU-A	Nickel-Copper Alloy A	40,000	80,000	40,000	80,000	20	B80	80,000	B80
NICU-B	Nickel-Copper Alloy B	40,000	80,000	40,000	80,000	20	B80	80,000	B80
NICU-K(7)	Nickel-Copper Aluminum Alloy	90,000	130,000	90,000	130,000	20	C24	130,000	C24
2024-T4	Aluminum Alloy	40,000	55,000	40,000	55,000	14	B70	55,000	B70
6061-T6	Aluminum Alloy	35,000	42,000	35,000	42,000	12	B50	42,000	B50

Note A

Austenitic stainless steel, strain hardened bolts, screws, studs and nuts shall have the following strength properties.

	BOLTS, SCREWS & STUDS				NUTS
	Tested Full Size		Machine Test Specimens		
Product Size	Yield Strength	Tensile Strength	Yield Strength	Tensile Strength	Proof Load Stress
Inches	Minimum psi	Minimum psi	Minimum psi	Minimum psi	psi
Up to 5/8 in.	100,000	125,000	90,000	115,000	125,000
Over 5/8 to 1 in.	70,000	105,000	65,000	100,000	105,000
Over 1 to 1-1/2 in.	50,000	90,000	45,000	85,000	90,000

Keys to Table (above)

1 Legend of Grade Designations
- A Solution Annealed
- SH Strain Hardened
- H Hardened and Tempered at 1100°F min.
- HT Hardened and Tempered at 525°F +/- 50°F

2 Yield Strength is the stress at which an offset of 0.2% of gauge length occurs for all stainless steels.

3 Elongation is determined using a gauge length of 2 in. or 4 diameters of test specimen in accordance with Federal Standard 151, Method 211.

ASTM & SAE GRADE MARKINGS & MECHANICAL PROPERTIES FOR STEEL FASTENERS

Identification Grade Mark	Specification	Fastener Description	Material	Nominal Size Range (in.)	MECHANICAL PROPERTIES Proof Load (psi)	Yield Strength Min. (psi)	Tensile Strength Min (psi)
No Grade Mark	SAE J429 Grade 1	Bolts, Screws, Studs	Low or Medium Carbon Steel	1/4 thru 1-1/2	33,000	36,000	60,000
	ASTM A307 Grades A&B		Low Carbon Steel	1/4 thru 4	—	—	
	SAE J429 Grade 2		Low or Medium Carbon Steel	1/4 thru 3/4 Over 3/4 to 1-1/2	55,000 33,000	57,000 36,000	
No Grade Mark	SAE J429 Grade 4	Studs	Medium Carbon Cold Drawn Steel	1/4 thru 1-1/2	—	100,000	115,000
B5	ASTM A193 Grade B5		AISI 501	1/4 thru 4	—	80,000	100,000
B6	ASTM A193 Grade B6		AISI 410			85,000	110,000
B7	ASTM A193 Grade B7		AISI 4140, 4142, or 4105	1/4 thru 2-1/2 Over 2-1/2 thru 4 Over 4 thru 7	— — —	105,000 95,000 75,000	125,000 115,000 100,000
B16	ASTM A193 Grade B16		CrMoVa Alloy Steel			105,000 95,000 85,000	125,000 115,000 100,000
B8	ASTM A193 Grade B8		AISI 304	1/4 and larger	—	30,000	75,000
B8C	ASTM A193 Grade B8C		AISI 347				
B8M	ASTM A193 Grade B8M		AISI 347				
B8T	ASTM A193 Grade B8T	Bolts, Screws, Studs for High-Temperature Service	AISI 321	1/4 and larger	—	30,000	75,000
B8	ASTM A193 Grade B8		AISI 304 Strain Hardened	1/4 thru 3/4 Over 3/4 thru 1 Over 1 thru 1-1/4 Over 1-1/4 thru 1-1/2	— — — —	100,000 80,000 65,000 50,000	125,000 115,000 105,000 100,000
B8C	ASTM A193 Grade B8C		AISI 347 Strain Hardened				
B8M	ASTM A193 Grade B8M		AISI 316 Strain Hardened			95,000 80,000 65,000 50,000	110,000 100,000 95,000 90,000
B8T	ASTM A193 Grade B8T		AISI 321 Strain Hardened			100,000 80,000 65,000 50,000	125,000 115,000 105,000 100,000

Identification Grade Mark	Specification	Fastener Description	Material	Nominal Size Range (in.)	MECHANICAL PROPERTIES Proof Load (psi)	Yield Strength Min. (psi)	Tensile Strength Min (psi)
L7	ASTM A320 Grade L7	Bolts, Screws, Studs for Low-Temperature Service	AISI 4140, 4142, or 4145	1/4 thru 2-1/2	—	105,000	125,000
L7A	ASTM A320 Grade L7A		AISI 4037				
L7B	ASTM A320 Grade L7B		AISI 4137				
L7C	ASTM A320 Grade L7C		AISI 8740				
L43	ASTM A320 Grade L43		AISI 4340	1/4 thru 4	—	105,000	125,000
B8	ASTM A320 Grade B8	Bolts, Screws, Studs for Low-Temperature Service	AISI 304	1/4 thru 2-1/2	—	105,000	125,000
B8C	ASTM A320 Grade B8C		AISI 347				
B8T	ASTM A320 Grade B8T		AISI 321				
B8F	ASTM A320 Grade B8F		AISI 303 or 303Se				
B8M	ASTM A320 Grade B8M		AISI 316				
B8	ASTM A320 Grade B8		AISI 304	1/4 thru 3/4 Over 3/4 thru 1 Over 1 thru 1-1/4 Over 1-1/4 thru 1-1/2	— — — —	100,000 80,000 65,000 50,000	100,000 80,000 65,000 50,000
B8C	ASTM A320 Grade B8C		AISI 347				
B8F	ASTM A320 Grade B8F		AISI 303 or 303Se				
B8M	ASTM A320 Grade B8M		AISI 316				
B8T	ASTM A320 Grade B8T		AISI 321				

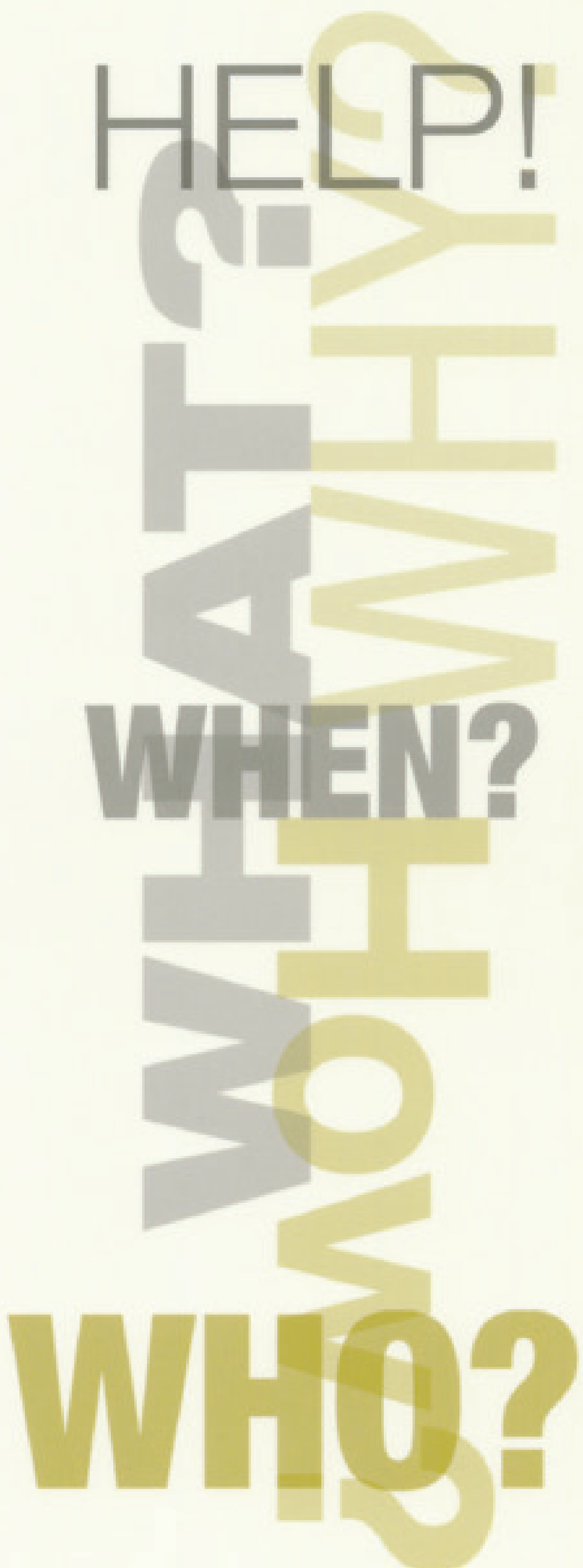
ASTM, SAE & ISO GRADE MARKINGS & MECHANICAL PROPERTIES FOR STEEL FASTENERS

Identification Grade Mark	Specification	Fastener Description	Material	Nominal Size Range (in.)	MECHANICAL PROPERTIES Proof Load (psi)	Yield Strength Min. (psi)	Tensile Strength Min (psi)
	SAE J429 Grade 5	Bolts, Screws, Studs	Medium Carbon Steel, Quenched and Tempered	1/4 thru 1 Over 1 to 1-1/2	85,000 74,000	92,000 81,000	120,000 105,000
	ASTM A449			1/4 thru 1 Over 1 to 1-1/2 Over 1-1/2 thru 3	85,000 74,000 55,000	92,000 81,000 58,000	120,000 105,000 90,000
	SAE J429 Grade 5.1	Sems	Low or Medium Carbon Steel, Quenched and Tempered	No. 6 thru 3/8	85,000	—	120,000
	SAE J429 Grade 5.2	Bolts, Screws, Studs	Low Carbon Martensitic Steel, Quenched and Tempered	1/4 thru 1	85,000	92,000	120,000
A325	ASTM A325 Type 1	High Strength Structural Bolts	Medium Carbon Steel, Quenched and Tempered	1/2 thru 1 1-1/8 thru 1-1/2	85,000 74,000	92,000 81,000	120,000 105,000
A325	ASTM A325 Type 2		Low Carbon Martensitic Steel, Quenched and Tempered	1/2 thru 1	85,000	92,000	120,000
A325	ASTM A325 Type 3		Atmospheric Corrosion Resisting Steel, Quenched and Tempered	1/2 thru 1 1-1/8 thru 1-1/2	85,000 74,000	92,000 81,000	120,000 105,000
BB	ASTM A354 Grade BB	Bolts, Studs	Alloy Steel, Quenched and Tempered	1/4 thru 2-1/2 2-3/4 thru 4	80,000 75,000	83,000 78,000	105,000 100,000
BC	ASTM A354 Grade BC				105,000 95,000	109,000 99,000	125,000 115,000
	SAE J429 Grade 7	Bolts, Screws	Medium Carbon Alloy Steel, Quenched and Tempered[4]	1/4 thru 1-1/2	105,000	115,000	133,000

Identification Grade Mark	Specification	Fastener Description	Material	Nominal Size Range (in.)	MECHANICAL PROPERTIES Proof Load (psi)	Yield Strength Min. (psi)	Tensile Strength Min (psi)
	SAE J429 Grade 8	Bolts, Screws, Studs	Med. Carbon Alloy Steel, Quenched and Tempered	1/4 thru 1-1/2	120,000	130,000	150,000
	ASTM A354 Grade BD		Alloy Steel, Quenched and Tempered[4]				
No Grade Mark	SAE J429 Grade 8.1	Studs	Medium Carbon Alloy or SAE 1041 Modified Elevated Temperature Drawn Steel	1/4 thru 1-1/2	120,000	130,000	150,000
A490	ASTM A490	High Strength Structural Bolts	Alloy Steel, Quenched and Tempered	1/2 thru 1-1/2	120,000	130,000	150,000 min. 170,000 max.
No Grade Mark	ISO R898 Class 4.6	Bolts, Screws, Studs	Medium Carbon Steel, Quenched and Tempered	All sizes thru 1-1/2	33,000	36,000	60,000
No Grade Mark	ISO R898 Class 5.8				55,000	57,000	74,000
8.8 or 88	ISO R898 Class 8.8		Alloy Steel, Quenched and Tempered		85,000	92,000	120,000
10.9 or 109	ISO R898 Class 10.9				120,000	130,000	150,000

FASTENING APPLICATION TROUBLESHOOTING

When a fastening application involves fastener performance or fastener product quality complaint(s), consider the following in an effort to understand the reason(s) for the problem, the scope, and how to evaluate and solve it:



Who is the supplier? When was the product supplied? What are the part numbers? Ask for a copy of the purchase order. What is the date and number on the purchase order? What is the lot number? Note any certifications included with the order. Ask for a copy of any prints of the fastener(s) or application. Ask for a copy of the shipping documents and the invoice.

Describe the problem with as many details as you have. Remember details such as materials, temperature(s), moisture, physical environment, torque methods used, test reports and the other mating parts.

How many, or what percentage, of the fasteners received have been used in the problem condition described in the complaint?

Review the fastener industry standards and what allowance(s) are allowed for quantities of non-conforming parts.

What is the grade or class of the fasteners? In your description, include thread series, head style, drive recess, material, plating or finish, and secondary operations on the fastener (drilled head or shank, nylon patch, etc.).

Ask about the method of installation, the speed of installation, and any lubricants that might have been used in the application.

Inquire about any hole preparation (hole diameter, drilling, tapping, countersinking, etc.).

Have there been any recent changes to the application, the fasteners used, or the method of fastening?

Take photos of the application and fasteners in question.

Ask for several samples of the fasteners, mating parts or other items involved for further evaluation and testing under your direction.

Offer a timeline to determine the outcome of your evaluation and what corrective action might be taken immediately or in the near future. Always stay in contact with the complainant and let them know how you are moving forward in your evaluation and solution.

Your goal is to have the right fastener with the proper installation methods to keep bolted joints from failure.

solved!

STAINLESS STEELS & EXOTIC METALS

Stainless steels achieve "stainless" characteristics by virtue of their ability to form a tight adherent film of iron-chromium oxide which strongly resists attack by the atmosphere and a wide variety of industrial gases and chemicals. This effect, plus the superior high temperature strength characteristics exhibited by many of these alloys, accounts for their wide use at ordinary and elevated temperatures with a wide choice of mechanical properties and several distinct levels of corrosion resistance.

These steels may be subdivided into the following four groups:

1 **Martensitic** stainless steels are iron-chromium alloys which are hardenable by heat treatment. Representative of this group are Types 410, 420, 431 and 440C.

2 **Ferritic** stainless steels are iron-chromium alloys which cannot be hardened significantly by heat treatment. Representative of this group are Types 405 and 430.

3 **Austenitic** stainless steels are iron-chromium-nickel and iron-chromium-manganese-nickel alloys which are hardenable by cold working. Representative of this group are Types 201, 304, and 316.

4 **Precipitation hardening** stainless steels are iron-chromium-nickel alloys with additional elements which are hardenable by solution treating and aging.

Alloys in the first two groups are magnetic in all conditions; those in the third group are slightly magnetic in the cold worked condition, but non-magnetic in the annealed condition in which they are most often used. Alloys in the fourth group are magnetic in the precipitation hardened condition.

18-8 Stainless Steel

This is the most popular type of stainless used in the production of fasteners. Its composition is approximately 18% chromium and 8% nickel, thus the name 18-8. Several grades of stainless are included in this classification including 302, 303, 304 and 305. These all have good strength and corrosion resistance.

316 Stainless Steel

This is more corrosion resistant than 18-8, but also more expensive. It is composed o approximately 18% chromium and 12% nickel with the addition of 2% to 4% molybdenum. It also maintains its strength at higher temperatures than 18-8.

410 Stainless Steel

It has approximately 12% chromium with no nickel. It is not very corrosion resistant and is magnetic, but it can be heat treated to become harder.

Alloy 20

This alloy has approximately 20% chromium and 34% nickel plus 3% to 4% molybdenum. It is very corrosion resistant and is especially popular when in contact with sulfuric acid.

Brass

This metal is approximately 65% copper and 35% zinc. It offers a good combination of strength, corrosion resistance and workability.

Nickel Copper 400

This alloy is approximately 70% nickel and 30% copper. It has excellent strength and corrosion resistance and is used in salt water marine and other chemical environments.

Titanium

This has a very high strength to weight ratio, as well as good corrosion resistance.

Inconel

Registered trademark of Inco Ltd.

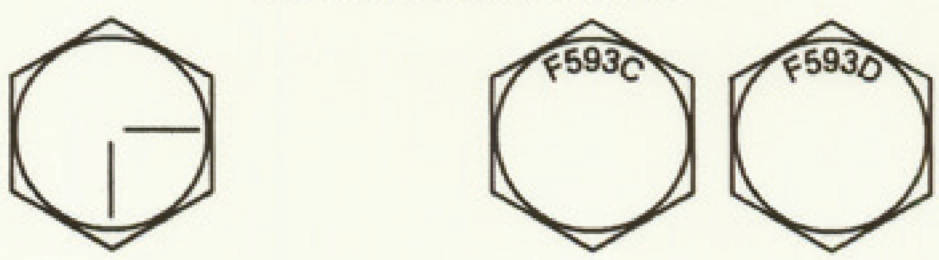
Composed of approximately 77% nickel and 15% chromium. It offers superior strength and good corrosion at high temperatures.

Silicon Bronze

It is composed of approximately 96% copper, 3% silicon and 1% manganese. It is more corrosion resistant and tougher than brass. It is widely used in the electrical industry.

TORQUE GUIDE CHARTS – STAINLESS STEEL

18-8 STAINLESS STEEL HEX HEAD CAP SCREWS
UNC – Unified National Coarse Thread



Present Head Markings All Diameters — New Head Markings 1/4" – 5/8" Dia. 3/4" – 1" Dia.

Size	Clamp Load (lb)	Assembly Torque Dry (ft lb)	Assembly Torque Lub (ft lb)	Min Tensile (lb)
1/4 – 20	1350	6	5	2780
1/4 – 28	1500	7	5	3020
5/16 – 18	2200	12	9	4400
5/16 – 24	2400	13	10	4700
3/8 – 16	3200	20	16	6500
3/8 – 24	3700	23	17	9000
1/2 – 13	5900	50	37	11900
1/2 – 20	6700	56	42	12800
5/8 – 11	9500	100	75	18800
5/8 – 18	10800	113	84	20400
3/4 – 10	14100	177	132	27600
3/4 – 16	15700	197	148	29600
7/8 – 9	11700	171	128	37900
1 – 8	15300	256	192	49700
1-1/8 – 7	19300	363	272	62700
1-1/4 – 7	24500	512	384	78800
1-3/8 – 6	29200	671	503	94400
1-1/2 – 6	35600	891	668	114000

316 STAINLESS STEEL HEX HEAD CAP SCREWS
UNC – Unified National Coarse Thread

Present Head Markings All Diameters — New Head Markings 1/4" – 5/8" Dia. 3/4" – 1" Dia.

Size	Clamp Load (lb)	Assembly Torque Dry (ft lb)	Assembly Torque Lub (ft lb)	Min Tensile (lb)
1/4 – 20	2100	9	7	4600
1/4 – 28	2400	10	7	5000
5/16 – 18	3400	18	13	7400
5/16 – 24	3800	20	15	7900
3/8 – 16	5100	32	24	10900
3/8 – 24	5700	36	27	15000
1/2 – 13	9350	78	58	19800
1/2 – 20	10550	88	66	21400
5/8 – 11	14950	156	117	31400
5/8 – 18	16850	176	132	34000
3/4 – 10	20300	276	121	42300
3/4 – 16	22670	308	191	45400
7/8 – 9	16850	246	213	58100
1 – 8	22900	368	290	69500
1-1/8 – 7	25400	386	411	87800
1-1/4 – 7	32200	548	480	110300
1-3/8 – 6	38400	629	629	125900
1-1/2 – 6	46700	835	835	152000

NON-FERROUS TORQUE TABLE

Suggested Torque Values (in. lb.)

The following suggested tightening torques provide an excellent starting point for determining torque requirements. Remember, you may need to vary these numbers somewhat based on the individual joint or the amount of fastener lubrication.

Bolt Size	18-8 Stainless Steel	Brass	Silicon Brass	Aluminum 2024-T4	316 Stainless Steel	Monel	Nylon
2 – 56	2.5	2.0	2.3	1.4	2.6	2.5	0.44
2 – 64	3.0	2.5	2.8	1.7	3.2	3.1	
3 – 48	3.9	3.2	3.6	2.1	4.0	4.0	
3 – 56	4.4	3.6	4.1	2.4	4.6	4.5	
4 – 40	5.2	4.3	4.8	2.9	5.5	5.3	1.19
4 – 48	6.6	5.4	6.1	3.6	6.9	6.7	
5 – 40	7.7	6.3	7.1	4.2	8.1	7.8	
5 – 44	9.4	7.7	8.7	5.1	9.8	9.6	
6 – 32	9.6	7.9	8.9	5.3	10.1	9.8	2.14
6 – 40	12.1	9.9	11.2	6.6	12.7	12.3	
8 – 32	19.8	16.2	18.4	10.8	20.7	20.2	4.30
8 – 36	22.0	18.0	20.4	12.0	23.0	22.4	
10 – 24	22.8	18.6	21.2	13.8	23.8	25.9	6.61
10 – 32	31.7	25.9	29.3	19.2	33.1	34.9	8.20
1/4″ – 20	75.2	61.5	68.8	45.6	78.8	85.3	16.00
1/4″ – 28	94.0	77.0	87.0	57.0	99.0	106.0	20.80
5/16″ – 18	132.0	107.0	123.0	80.0	138.0	149.0	34.90
5/16″ – 24	142.0	116.0	131.0	86.0	147.0	160.0	
3/8″ – 16	236.0	192.0	219.0	143.0	247.0	266.0	
3/8″ – 24	259.0	212.0	240.0	157.0	271.0	294.0	
7/16″ – 14	376.0	317.0	349.0	228.0	393.0	427.0	
7/16″ – 20	400.0	357.0	371.0	242.0	418.0	451.0	
1/2″ – 13	517.0	422.0	480.0	313.0	542.0	584.0	
1/2″ – 20	541.0	443.0	502.0	328.0	565.0	613.0	
9/6″ – 12	682.0	558.0	632.0	413.0	713.0	774.0	
9/6″ – 18	752.0	615.0	697.0	456.0	787.0	855.0	
5/8″ – 11	1110.0	907.0	1030.0	715.0	1160.0	1330.0	
5/8″ – 18	1244.0	1016.0	1154.0	798.0	1301.0	1482.0	
3/4″ – 10	1530.0	1249.0	1416.0	980.0	1582.0	1832.0	
3/4″ – 16	1490.0	1220.0	1382.0	958.0	1558.0	1790.0	
7/8″ – 9	2328.0	1905.0	2140.0	1495.0	2430.0	2775.0	
7/8″ – 14	2318.0	1895.0	2130.0	1490.0	2420.0	2755.0	
1″ – 8	3440.0	2815.0	3185.0	2205.0	3595.0	4130.0	
1″ – 14	3110.0	2545.0	2885.0	1995.0	3250.0	3730.0	
1-1/8″ – 7	413.0	337.0	383.0	265.0	432.0	499.0	
1-1/8″ – 12	390.0	318.0	361.0	251.0	408.0	470.0	
1-1/4″ – 7	523.0	428.0	485.0	336.0	546.0	627.0	
1-1/4″ – 12	480.0	349.0	447.0	308.0	504.0	575.0	
1-1/2″ – 6	888.0	727.0	822.0	570.0	930.0	1064.0	
1-1/2″ – 12	703.0	575.0	651.0	450.0	732.0	840.0	

This table is offered as the suggested maximum torquing values for threaded products and is only a guide. All values shown on the chart, except for nylon, represent a safe working torque; in the case of nylon only, the figures represent breaking torque.

ROOM TEMPERATURE TENSILE STRENGTH OF COMMON FASTENER ALLOYS

Grade	Minimum Ultimate Tensile Strength	General Use
Carbon steels	100,000 psi to 175,000 psi	Often used for nuts
Alloy steels	100,000 psi to 180,000 psi	Used for bolts and screws
Tool steel (H-11)	Up to 260,000 psi	High strength fasteners
Austenitic stainless steels (300 series)	75,000 psi (carbide solution treated) 100,000 psi to 125,000 psi (strain hard)	Corrosion resistant fasteners
Martensitic stainless steels (400 series)	90,000 psi to 140,000 psi	Less corrosion resistance than 300 series
Precipitation hardenable (PH) stainless steels (17-4PH, A286)	80,000 psi to 180,000 psi	Corrosion resistance similar to 300 series stainless
PH nickel based alloys (Inconel 718, Inconel X750, Waspaloy)	140,000 psi to 180,000 psi 225,000 psi (hardened)	Superior corrosion resistance, elevated temperature strength
Non-HT nickel based alloys (Alloy 20, Inconel 600, Inconel 625, Inconel 686)	80,000 psi to 120,000 psi (annealed) Up to 180,000 psi (strain hardened)	Corrosion resistance in severe environments
Nickel-copper alloy (Monel 400)	80,000 psi	Corrosion resistance in a variety of environments including seawater
Nickel-copper-aluminum alloy (K-500)	160,000 psi	Corrosion resistance in a variety of environments including seawater
Cobalt based alloys (MP35N, MP159)	Up to 260,000 psi	Superior corrosion resistance
Titanium alloys (commercially pure; alpha-beta alloys)	35,000 psi to 80,000 psi (annealed) 140,000 psi to 190,000 psi (hardened)	Light weight, excellent corrosion resistance
Copper based alloys	30,000 psi to 70,000 psi	Electrical conductivity, heat transfer, corrosion resistance

Source: *ASM Metals Handbook*

SUMMARY OF FASTENER MATERIALS

Material	Surface Treatment	Useful Design Temperature Limit, °F	Ultimate Tensile Strength at Room Temperature, ksi	Comments
Carbon steel	Zinc plate	−65 to 250	55 and up	—
Alloy steels	Cadmium plate, nickel plate, zinc plate, or chromium plate	−65 to limiting temperature of plating	Up to 300	Some can be used at 900°F
A-286 stainless	Passivated per MIL-S-5002	−423 to 1200	Up to 220	—
17-4PH stainless	None	−300 to 600	Up to 220	—
17-7PH stainless	Passivated	−200 to 600	Up to 220	—
300 series stainless	Furnace oxidized	−423 to 800	70 to 140	Oxidation reduces galling
410, 416, and 430 stainless	Passivated	−250 to 1200	Up to 180	47 ksi at 1200°F; will corrode slightly
U-212 stainless	Cleaned and passivated per MIL-S-5002	1200	185	140 ksi at 1200°F
Inconel 718 stainless	Passivated per QQ-P-35 or cadmium plated	−423 to 900 or cadmium plate limit	Up to 220	—
Inconel X-750 stainless	None	−320 to 1200	Up to 180	136 ksi at 1200°F
Waspaloy stainless	None	−423 to 1600	150	—
Titanium	None	−350 to 500	Up to 160	—

WEIGHT CONVERSIONS

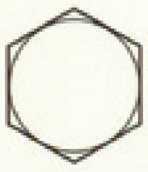
To obtain the approximate weight, multiply the desired conversion factor by the weight of the bolt, nut, screw, rod, or stud made of regular low carbon steel.

Material	Conversion Factor
18-8 (300 series) Stainless Steel	1.011
410 Stainless Steel	.989
Alloy Steel and Low Carbon Steel	1.01
Alloy C276	1.13
Alloy 400	1.12
Alloy 500	1.082
Alloy 625	1.085
Alloy 800	1.029
Aluminum	.353
Aluminum Bronze	1.042
Brass	1.082
Copper	1.145
Cupronickel	1.141

Material	Conversion Factor
Hastelloy B*	1.187
Hastelloy C*	1.146
High Silicon Bronze	1.088
Inconel**	1.085
K-Monel**	1.082
Low Silicon Bronze	1.117
Manganese Bronze	1.067
Monel**	1.127
Naval Brass	1.074
Nickel	1.13
Nylon	.14
Phosphor Bronze	1.124
Titanium Alloy	.576

*Trademark of Cabot Corporation
**Trademark of International Nickel Corporation

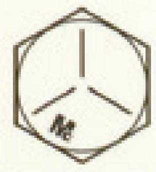
HEX HEAD CAP SCREWS
GENERAL INFORMATION



GRADE 2 Low or Medium Carbon Steel

Diameter	Proof Load	Yield Strength	Tensile Strength	CORE HARDNESS Rockwell Min.	Max.
1/4" – 3/4"	55,000	57,000	74,000	B80	B100
> 3/4" – 1-1/2"	33,000	36,000	60,000	B70	B100

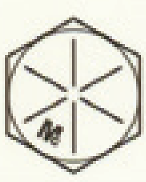
Size	Clamp Load (lb)	Assembly Torque Dry (ft lb)	Min. Lub (ft lb)	Tensile (lb)
1/4 – 20	1320	6	5	2700
1/4 – 28	1500	7	6	2900
5/16 – 18	2160	11	11	4400
5/16 – 24	2400	12	12	4700
3/8 – 16	3200	20	15	6400
3/8 – 24	3620	23	17	8800
1/2 – 13	5850	50	35	11500
1/2 – 20	6600	55	40	12500
5/8 – 11	9350	100	75	18500
5/8 – 18	10550	110	85	20000
3/4 – 10	13800	175	130	27000
3/4 – 16	15400	200	150	29000
7/8 – 9	11450	170	125	30000
1 – 8	15000	250	190	39500
1-1/8 – 7	18900	350	270	50000
1-1/4 – 7	24000	500	380	63000
1-3/8 – 6	28600	670	490	75500
1-1/2 – 6	34800	870	650	91000



GRADE 5 Medium Carbon Steel, Quenched and Tempered

Diameter	Proof Load	Yield Strength	Tensile Strength	CORE HARDNESS Rockwell Min.	Max.
1/4" – 1"	85,000	92,000	120,000	C25	C34
> 1" – 1-1/2"	74,000	81,000	105,000	C19	C30

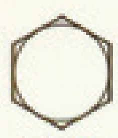
Size	Clamp Load (lb)	Assembly Torque Dry (ft lb)	Min. Lub (ft lb)	Tensile (lb)
1/4 – 20	2000	8	7	4450
1/4 – 28	2300	10	8	4840
5/16 – 18	3350	17	13	7190
5/16 – 24	3700	19	14	7670
3/8 – 16	4950	30	23	10530
3/8 – 24	5600	35	25	14400
1/2 – 13	9000	75	55	19000
1/2 – 20	10500	90	65	20500
5/8 – 11	14400	150	110	30100
5/8 – 18	16370	180	130	32600
3/4 – 10	21300	260	200	44200
3/4 – 16	23800	300	220	47400
7/8 – 9	29450	320	320	53100
1 – 8	38600	640	480	69500
1-1/8 – 7	42300	800	600	87800
1-1/4 – 7	53800	1120	840	110300
1-3/8 – 6	64100	1460	1100	132200
1-1/2 – 6	7800	1910	1460	159600



GRADE 8 Carbon Alloy Steel, Quenched and Tempered

Diameter	Proof Load	Yield Strength	Tensile Strength	CORE HARDNESS Rockwell Min.	Max.
1/4" – 1-1/2"	120,000	130,000	150,000	C33	C39

Size	Clamp Load (lb)	Assembly Torque Dry (ft lb)	Min. Lub (ft lb)	Tensile (lb)
1/4 – 20	2850	12	9	6600
1/4 – 28	3250	14	10	7200
5/16 – 18	4700	25	18	10700
5/16 – 24	5200	25	20	11500
3/8 – 16	7000	45	35	15800
3/8 – 24	7900	50	35	21600
1/2 – 13	12750	110	80	28600
1/2 – 20	14370	120	90	30800
5/8 – 11	20350	220	170	45200
5/8 – 18	23000	240	180	49000
3/4 – 10	30100	380	280	66300
3/4 – 16	33500	420	320	71100
7/8 – 9	41600	600	460	91000
1 – 8	54500	900	680	119200
1-1/8 – 7	68900	1280	960	150500
1-1/4 – 7	87200	1820	1360	189200
1-3/8 – 6	104000	2380	1780	226700
1-1/2 – 6	126500	3160	2360	273600



No Markings

GRADE 2 Fasteners
Low or Medium Carbon Steel

Often referred to as "hardware" quality, these fasteners are typically made of low carbon steel. They are ideally suited for holding wood pieces together (in combination with appropriate nuts and washers) or general hardware use where higher strength is not required.

There is no grade marking on the head of Grade 2 fasteners, although many manufacturers will put a distinguishing company identification on the head.

3 Radial Lines

GRADE 5 Fasteners
Medium Carbon Steel, Quenched and Tempered

Grade 5 fasteners are made of medium carbon steel. These fasteners are then quenched and tempered for the additional strength necessary for most automotive uses and other applications where strength is a moderate concern.

The grade marking on the head of a Grade 5 fastener is three equally-spaced lines coming out from the center of the head. Manufacturers' identifications are added for traceability.

6 Radial Lines

GRADE 8 Fasteners
Medium Carbon Alloy Steel, Quenched and Tempered

Grade 8 fasteners are manufactured of medium carbon alloy steel for the most demanding applications. These fasteners are then quenched and tempered to superior strength and hardness qualities.

The grade marking on a Grade 8 fastener is six equally-spaced lines coming out from the center of the head. The manufacturer's mark is necessary for traceability.

Yield Strength is the load at which the fastener exhibits a specified elongation at a specific load.

Tensile Strength is the minimum total load that will fail the fastener.

Clamp Load – 75% x Proof x Stress Area. Also called the fastener preload or initial load. The "Clamp" Load is the true maximum load of any fastener.

Proof Load is the load which the fastener must withstand without a permanent set.

Torque Dry assumes a coefficient of friction of 0.20.

Torque Lubricated assumes a coefficient of friction of 0.15.

Minimum Tensile – minimum load at which the fastener will fail. Minimum safe working load is 4:1.

A325 is the designation for "structural" Grade 5 bolts which have larger head dimensions.

TORQUE & TENSION IN BOLTS

Bolts, one of the most widely used fasteners in the industry, are usually tightened by applying torque to the head and/or nut. As the bolt is tightened, it is stretched (preloaded). Preload tension is necessary to keep the bolt tight, increase join strength, create friction between parts, and improve fatigue resistance. The recommended preload force F_i is:

For reusable connections: $F_i = 0.75 A_t S_p$

For permanent connections: $F_i = 0.9 A_t S_p$

where A_t is the tensile area of the bolt and S_p is the proof strength of the bolt. Although the above formulas look rather straightforward, the preload tension F_i is not easy to measure or control. A common practice is to relate the preload tension F_i to a quantity that is easier to measure, the applied torque T. This torque, usually achieved by a torque wrench, the turn-of-nut, or an indicating washer, is:

$$T = KF_i d$$

where d is the nominal outside diameter of the bolt and K is the correction factor that depends on the material, size, surface friction, and threading of the bolt. For most small- to mid-size bolts, K is between 0.15 and 0.3.

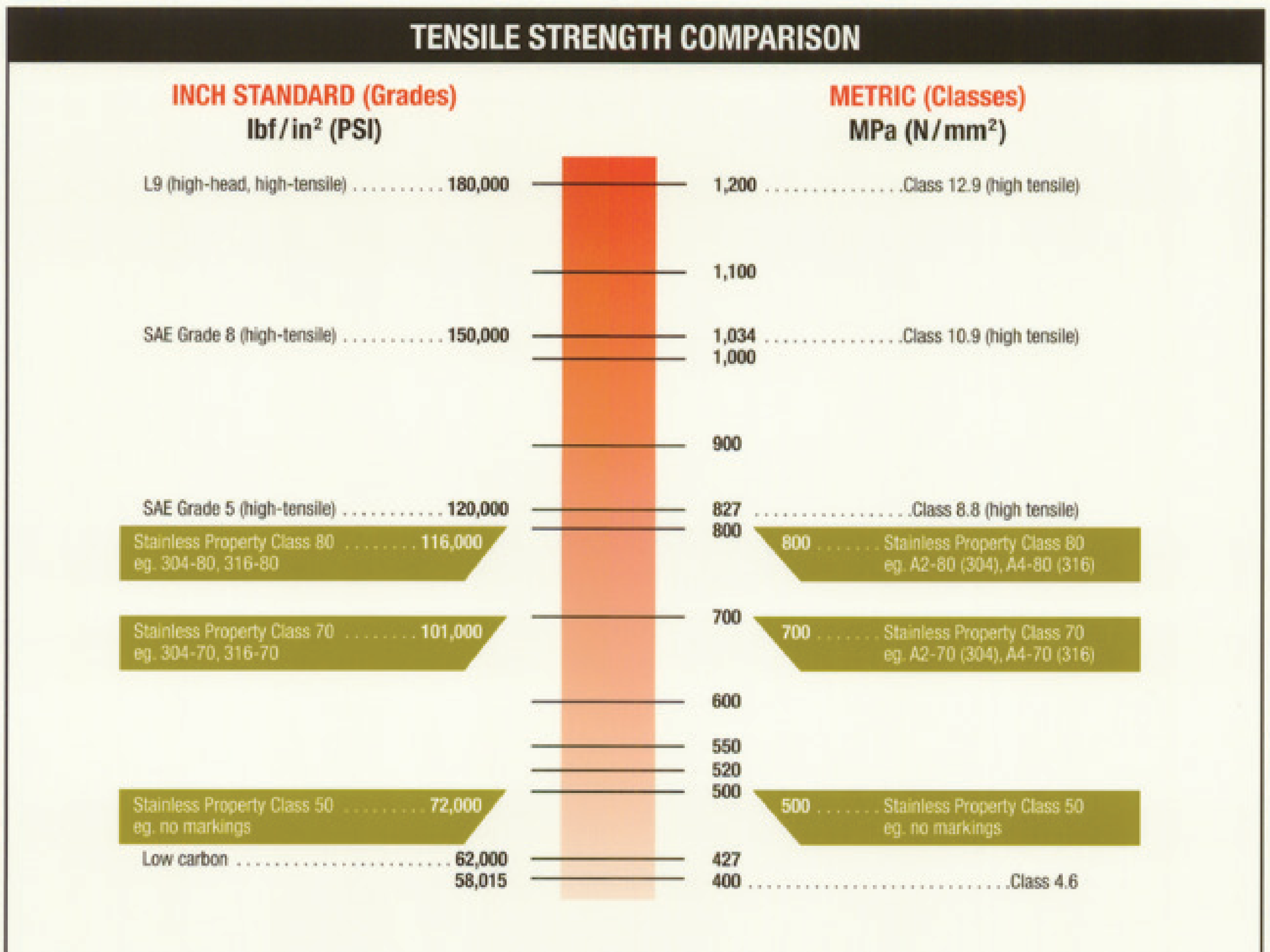
As a rough approximation:

dry (unlubricated) mid-size steel bolts:	$K = 0.2$
non-plated black finish:	$K = 0.3$
zinc-plated:	$K = 0.2$
cadmium-plated:	$K = 0.16$
lubricated:	$K = 0.15 \sim 0.18$

A more complicated torque formula is given as:

$$T = F_i \left\{ \frac{P}{2\pi} + \frac{D_b \mu_k}{2\cos\theta} + \frac{D_n \mu_k}{2} \right\}$$

where P is the lead (pitch) of the thread, D_b is the average mean diameter of the bolt, D_n is the average mean diameter of the nut, μ_k is the coefficient of friction, and θ is one half of the thread angle (usually 30°). This formula, although more complete, is seldom used, for the large errors (sometimes as much as 25%) involved in torque wrench readout usually renders using a more accurate formula pointless.



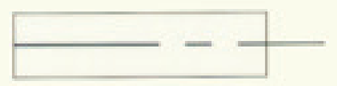
ACCURATE CONVERSION FACTORS

- 1000 PSI (lbf/in²) = 6.8948 MPa
- 1 MPa = 145,038 PSI (lbf/in²)

HARDNESS CONVERSIONS FOR INDUSTRIAL FASTENERS

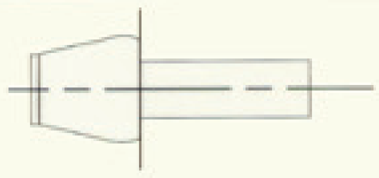
Brinell Indentation Diameter (mm)	Brinell Hardness Number		Rockwell Hardness Number		Rockwell Superficial Hardness Number Superficial Diamond Penetrator			Tensile Strength (approx.) 1000 psi
	Standard Ball	Tungsten-Carbide Ball	B Scale	C Scale	15N Scale	30N Scale	45N Scale	
2.45		627	58.70	89.60	76.30	65.10		347
2.50		601		57.30	89.00	75.10	63.50	328
2.55		578		56.00	88.40	73.90	62.10	313
2.60		555		54.70	87.80	72.70	60.60	298
2.65		534		53.50	87.20	71.60	59.20	288
2.70		514		52.10	86.50	70.30	57.60	274
2.75		495		51.00	85.90	69.40	56.10	264
2.80		477		49.60	85.30	68.20	54.50	252
2.85		461		48.50	84.70	67.20	53.20	242
2.90		444		47.10	84.00	65.80	51.50	230
2.95	429	429		45.70	83.40	64.60	49.90	219
3.00	415	415		44.50	82.80	63.50	48.40	212
3.05	401	401		43.10	82.00	62.30	46.90	202
3.10	388	388		41.80	81.40	61.10	45.30	193
3.15	375	375		40.40	80.60	59.90	43.60	184
3.20	363	363		39.10	80.00	58.70	42.00	177
3.25	352	352		37.90	79.30	57.60	40.50	170
3.30	341	341		36.60	78.60	56.40	39.10	163
3.35	331	331		35.50	78.00	55.40	37.80	158
3.40	321	321		34.30	77.30	54.30	36.40	152
3.45	311	311		33.10	76.70	53.30	34.40	147
3.50	302	302		32.10	76.10	52.20	33.80	143
3.55	293	293		30.90	75.50	51.20	32.40	139
3.60	285	285		29.90	75.00	50.30	31.20	136
3.65	277	277		28.80	74.40	49.30	29.90	131
3.70	269	269		27.60	73.70	48.30	28.50	128
3.75	262	262		26.60	73.10	47.30	27.30	125
3.80	255	255		25.40	72.50	46.20	26.00	121
3.85	248	248		24.20	71.70	45.10	24.50	118
3.90	241	241	100.00	22.80	70.90	43.90	22.80	114
3.95	235	235	99.00	21.70	70.00	42.90	21.50	111
4.00	229	229	98.20	20.50	69.70	41.90	20.10	109
4.05	223	223	97.30					104
4.10	217	217	63.40					103
4.15	212	212	95.50					100
4.20	207	207	94.60					99
4.25	201	201	93.80					97
4.30	197	197	92.80					94
4.35	192	192	91.90					92
4.40	187	187	90.70					90
4.45	183	183	90.00					89
4.50	179	179	89.00					88
4.55	174	174	87.80					86
4.60	170	170	86.80					84
4.65	167	167	86.00					83
4.70	163	163	85.00					82
4.80	156	156	82.90					80
4.90	149	149	80.80					73
5.00	143	143	78.70					71
5.10	137	137	76.40					67
5.20	131	131	74.00					65
5.30	126	126	72.00					63
5.40	121	121	69.00					60
5.50	116	116	67.60					58
5.60	111	111	65.70					56

COLD HEADING



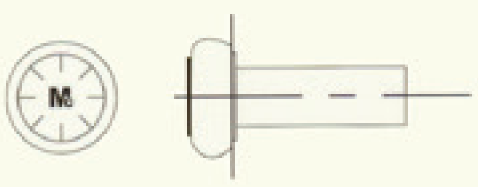
Cut-off

A blank is cut off from a coil. The diameter and length of the cut-off relates to the product diameter, finished bolt length and head size. The raw material is carbon alloy steel meeting the requirements of SAE and ASTM specifications. The raw material has been pickled, annealed and coated prior to the manufacturing process.



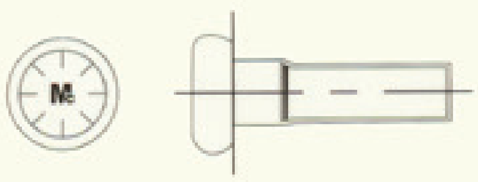
Upset

The end of the blank is deformed prior to forming the bolt head. Metal is moved in a controlled manner to assure head concentricity and integrity with the body of the bolt.



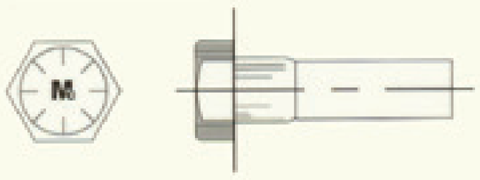
Head

A "BUTTON," whose diameter is slightly larger than the across corners dimension of the finished hex head, is formed. The "BUTTON" height is equal to the finished head height. The headmark is put on in this operation. The washer face, which provides good bearing contact, and the fillet radius, which contributes to bolt strength and head/body integrity, are formed during heading.



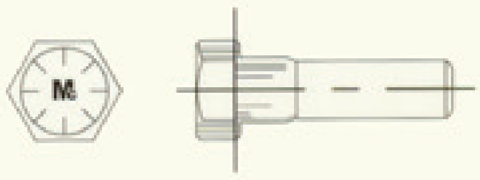
Extrude

The blank is pushed into a die where a portion of the body diameter is extruded down to the pitch diameter of the thread in preparation for thread rolling.



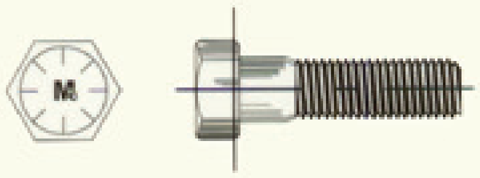
Trim

Excess material is sheared from the "BUTTON" forming the finished hex head. A trimmed hex provides sharp corners which enhance wrenchability.



Point

Material is machined from the end of the bolt blank forming a chamfer which contributes to better assembly with mating parts and reduces the possibility of thread damage to the starting threads.



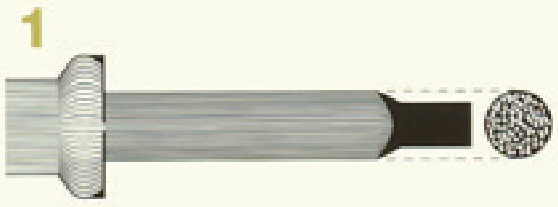
Roll Thread

Threads are formed as the blank passes through a set of flat-faced reciprocating roll threading dies. The final thread form is smooth, accurate and consistent. The thread conforms to the ANSI B1.1 standard for UNRC or UNRF screw threads. Contributing to bolt strength and durability are features such as a controlled thread root radius and controlled transition between the thread runout and body of the bolt.

Cold Heading vs. Machining

COLD HEADING Below (1) is a cold headed part formed from the diameter of wire shown (2). Unbroken metal flow lines (grain) greatly increase fatigue life and enhance load-carrying ability.

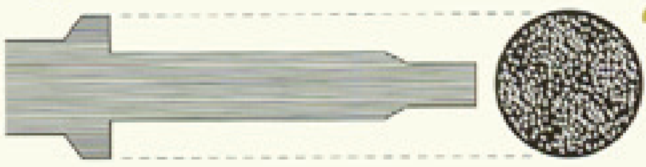
1



2

MACHINING Illustrated below is a representation of a bolt (3) produced by machining a large diameter bar or wire (4). Grain or metal flow lines are broken through the head and washer section, which creates planes of weakness.

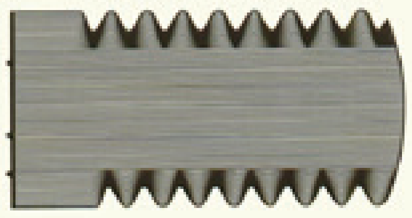
3



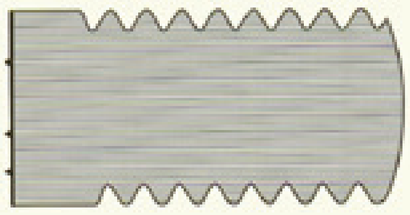
4

Thread Rolling vs. Thread Cutting

THREAD ROLLING No metal is cut away, the grain flow lines are unbroken and curve around the thread profiles. The cold rolling stresses the roots in compression, significantly fatigue strength. Smooth roll dies create burnished roots and smooth flanks free from cutter tool marks, reducing potential galling and stress risers.



THREAD CUTTING The grain flow lines are cut and planes of weakness are created.



THREAD GALLING

Thread galling, aka cold welding

"Thread galling" or "cold welding," as the term is often called, occurs during the installation of bolts and nuts where the bolts are twisting off and/or the bolt's threads are seizing to the nut's threads. Thread galling seems to be most prevalent with fasteners made of stainless steel, aluminum, titanium and other alloys that self-generate an oxide surface film for corrosion protection. During the tightening of the fastener, pressure builds between the sliding contacting thread surfaces and breaks down the protective oxide coatings. Possibly, the coatings are wiped off and interface metal high points shear, friction increases, and the fasteners lock together. This cumulative clogging-shearing-locking action causes increasing adhesion. Galling leads to fusing and seizing—the actual freezing together of threads because of the heat generated. If tightening is continued, the fastener can be twisted off or its threads stripped out.

Thread roughness

Thread roughness is another factor affecting thread galling in stainless steel fastener applications. Rolled threads offer a smoother surface than cut threads. The rougher the thread's flanks, the greater the likelihood of thread galling. Although it may seem the bolt is the problem because it is breaking, in reality, it is the internal threaded fastener, the nut. This is because the bolt has smooth rolled threads from the rolled threading process. Internal threads are always cut threads, producing rougher thread flanks than the bolts they mate with. Thread galling problems are inconsistent largely because of the inconsistencies in the tapping operation. Rougher-than-normal internal threads may be the result of the use of dull taps, or the tapping operation may have been done at an inappropriately high RPM.

Here are four suggestions to minimize thread galling in stainless steel fasteners:

1. Use coarse threads with 2A-2B fit instead of fine threads. UNC coarse threads have a greater thread allowance than UNF fine threads and are more tolerant to abuse during handling.

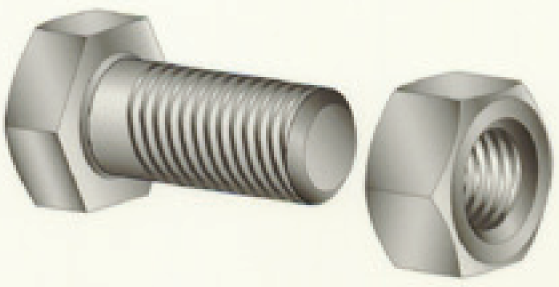
2. Slowing down the installation RPM speed will frequently reduce or sometimes completely solve the problem. As heat from friction increases during installation with too rapid RPM, so does the tendency for occurrence of thread galling. In general, a stainless steel bolt of a given size should be driven slower than a steel bolt of the same size. Slow down the wrench speed!

3. Lubricating the internal and/or external threads frequently eliminates thread galling. Suggested lubricants should contain substantial amounts of molybdenum disulfide (moly), graphite, mica or talc. Some proprietary extreme pressure waxes may also be effective. However, you must be aware of the end use of the fasteners before settling on a lubricant. Stainless steel in certain environments precludes the use of some lubricants; for example, the food processing equipment industry. In application, if the problem is repetitive, try to supply fasteners with a pre-applied lubrication to eliminate future galling problems. Also note that the use of lubricants will change the torque-tension relationship.

4. Using different stainless alloy grades for the bolt and nut reduces thread galling. The key here is the mating of materials having different hardness numbers. Different stainless steel alloys work-harden at different rates. Try using type 316 stainless and 304 stainless for your components, and increase the likelihood of eliminating thread galling in the application.

Knowing why thread galling occurs and how to remedy it can save you a customer. Don't panic: Try these suggestions. One of them, or a combination, will most likely solve the problem.

HOW TO WRITE A FASTENER DESCRIPTION



The correct fastener description is the very first step in delivering the requested fasteners to meet the customer's demands. The following recommended notations come from more than four decades of buying and selling fasteners.

Never take shortcuts; the consequences can be very damaging and very costly!

Start with the quantity: Note the total amount required or the total of release quantities.

Diameter in inches, or mm for metric

Thread count (TPI) or pitch (metric)

Length: Inches or millimeters (mm) for metrics

Fastener type: See Poster No. 33 for fastener types, No. 34 for point styles, No. 41–43 for head styles and No. 44–46 for drive recesses. Note any unique, special features, such as secondary operations and any other important information.

Manufacturer's part number: Note the specific manufacturer if known or requested.

Head style: See Poster No. 41–43

Drive recess: See Poster No. 44–46

Material: Note any material specifications.

Grade or property class

Finish or plating: Note specifications and see Poster No. 29–30.

Company part number: Add your company part number at this time, if required.

Country of origin: Note: Made in the USA ONLY, Import OK, or it does not matter

Samples: Do you need to submit samples to the customer for his approval?

A critical part of the fastener description process:
Nearly 80 percent of fasteners used in the United States are common, standard commodity type fasteners that will meet your description from the above information, but that is where it all ends. The "specials" (non-standard, modified, engineered fasteners) are where a lot of problems begin because of incomplete descriptions and information. Think of this next step as continuing your fastener description as a fact-finding journey with questions and answers. Remember: You are asking questions to gather information to better serve your customer.

Request a print or samples: If it's a "special" or a standard fastener with modifications

Note any secondary operations: For example, drilling, slotting, threading, tapping, pointing, broaching, applying locking element, O-ring addition (include any dimensional information)

Heat-treating requirements: Note any specifications requested or required.

Specifications: Note any industry specs or reference (ASTM, ANSI, IFI, DIN, etc.).

Testing requirements: Note any chemical, dimensional, mechanical or physical test reports required or requested.

Certifications: RoHS, DFAR, PPAP, ISO or others

Packaging requirements or kitting: Note any special labeling requirements or barcoding.

Delivery date or release schedule: Be specific with date (not "about two to three weeks").

Method of shipment: Pick-up, supplier delivery, VMI program, drop-ship, UPS, FedEx or other package service, motor freight or air freight

Control number(s): Purchase order number, RFQ, contract number, job number or other reference number

Credit: Current, past due, credit limit (at it, near it or over it), taxable or non-taxable. If there are any problems with your company credit requirements, take care of them immediately!

Additional comments:
Provide any other information that might be helpful in determining the selling price and delivery schedule. Because of the rapidly changing global fastener market, always double-check pricing history. Make note of any internal pricing schedules or discounts. If a "special" is requested that you have supplied previously, do not just re-quote the past price; check to see current delivery availability and costs. Remember to check and include your freight costs! Do not overstate any portion of this order or inquiry (for example, promising quicker delivery lead times on "specials" or quality specifications you know you cannot deliver on). You will lose a customer forever if you overpromise and underperform.

Make notes if the buyer is known as a "price buyer." Does he split purchase orders with other suppliers or make normal business procedures very difficult and a hassle? Is he unreasonable or reasonable to deal with? Make any other notes that might affect you supplying the correct fasteners on time and making the event profitable for your company.

HOW TO CUT FASTENER COSTS

Here are some basic rules for maintaining high quality while cutting fastener costs!

- **Use standard design fasteners wherever possible.** Specify cold-headed fasteners for increased shear strength and lower costs. Cold heading eliminates waste and offers a selection of head designs not possible with screw machine parts.
- **Cut variety of standard types and sizes.** Larger inventory of fewer fasteners means less stocking and ordering headaches; lower drilling, tapping, punching and tooling costs; and avoiding the high cost of small-quantity orders. Better inventory control and fewer SKUs to manage and purchase.
- **Use ANSI standard specifications wherever possible.** Use these tolerances for economy:

  Diameters: Frac. +.015, Dec. +.003

  Lengths: Frac. +1/64, Dec. +010

  Angles: +2 degrees

  Drilled holes: +.005

  Avoid sharp corners on blueprint designs. Allow for a radius of .005 to .010; otherwise, they will increase cost.
- **Use Class 2A and 2B thread tolerances.** Class 2A external thread to fit Class 2B internal thread is the most frequently used thread tolerance. This gives a general purpose fit, providing sufficient clearance to minimize fastener-driving difficulties during installation. Class 2A thread form allows for a minimum plating buildup.
- **Determine if a standard design fastener will meet the design application objective.** If there already exists a standard screw design that will meet the design application, it is best to use it. It will be more readily available, with generally quicker delivery, and it will cost less.
- **Steel material selection.** Use low-carbon steel wherever possible. Use heat-heated fasteners for more strength in smaller sizes to reduce size, weight and cost.
- **Use multi-function fasteners.** Fasteners can do more than just hold two parts together. They can replace an assembly operation, replace extra parts, or perform other functions, thereby increasing production while cutting costs and reducing rejections. Good examples are: Sems® Screws, Keps® Nuts, thread-cutters and self-drillers.
- **Don't use custom-designed fasteners** unless no standard-designed fasteners will suffice for the fastening application. Cost savings will be significant with standard fastener usage!
- **Use plated and/or phosphated fasteners where the application warrants** (rather than solid, more expensive materials) to solve corrosive or surface reaction problems. Food industry and saltwater environments are notable exceptions.
- **Use recommended materials on adjacent parts.** Avoid galvanic action (corrosion) between non-compatible metals; use surface-treated fasteners.
- **Order maximum quantities** to be used for a certain period of time, even if delivered at different times. Allow enough lead time. Review and evaluate all the Vendor Managed Inventory (VMI) programs offered by your suppliers.
- **Provide up-to-date drawings and specifications.** Include sample parts and/or manufacturers' part numbers if available.
- **Adhere to IFI industry tolerances for additional cost savings.** Keep design requirements as uncomplicated as possible. Consolidate lengths, diameters, materials, head styles and drive recesses for the benefit of "standardization."
- **Involve your suppliers in the design and application method.** Sometimes, a newer, more efficient, or lower-costing fastener can be recommended. Ask for suggestions in improving fastener installation in the work cell (angle or position of installation, tool choices, etc.). Use special-designed or engineered fasteners when the application calls for them. Don't be determined to eradicate all special fasteners. Sometimes two or three expensive fasteners or parts can be replaced by a one-piece, special, cold-headed fastener that has a lower in-place cost and is superior in quality.
- **The real cost of fasteners.** Purchase price is not a fastener's real cost! The real cost, or the full cost, is the "in-place" cost. Consider the purchase price, plus labor cost to prepare the application (that is, drilling, tapping, punching), the installation cost, plus the downtime cost and added labor to replace it if it breaks or fails on the assembly line, plus any replacement costs necessary in the field. The "in-place" cost of a fastener can be five to 20 times the cost of a fastener. Order fasteners capable of performing the fastening application required, not necessarily the cheapest fastener.

Standardization is the key to saving money! Use standard, commonly used fastener types, styles and sizes. Use as few varieties and sizes as possible, thus cutting costs and saving money. Do not over-specify tensile strength, corrosion, plating, weight, vibration resistance, etc. However, be aware there are times a "special" fastener will reduce costs, improve the fastening application and increase production. Never substitute a fastener without checking with engineering first!

WORKING WITH YOUR HEAT TREATER

You can benefit in knowing how to order heat-treating processes based on your customer's desired parameters in the finished metal fasteners. By becoming familiar with this guide, you will better understand the effect that heat treating has on your fasteners and be more knowledgeable of heat-treating processes that will meet your specifications and the processing that meets your certifications.

Your fasteners are valuable to your business; they are the conduits for continuing relationships with your customers. This guide is informative to the point of increasing your interest in protecting your fasteners during the heat-treating process cycle. A heat treater is a specialist in the processing of metals. An experienced and reputable heat treater is able to diagnosis and recommend a preferred treatment for your fasteners or other metal parts only if he knows everything possible about the material he will be working with. Therefore, it is important that the fasteners you send to a heat treater for processing include written information with the following details.

ORDERING HEAT TREATING

Recommended Information to Include with Your Purchase Orders

1. Parts Identifications for Packing and Shipping:

A. Fasteners submitted for heat treatment should be carefully identified with appropriate packing slip or purchase order.

B. The number of fasteners for each part number or lot should be noted. Weights or similar data can be used where applicable.

C. Often times, a Material Lot Code can be helpful when tracking orders after the processing, and it is a key component to be listed on the processing certification.

2. Drawings and CAD Illustrations:

A. All purchase orders for fasteners being processed the first time should include the drawings and all applicable specifications. If the drawings must be returned, note this on the purchase order. Otherwise, the drawings will be stored with your job order at the heat treater.

B. Processing information pertinent to the heat treater should be noted, such as dimensional tolerances required, allowance required for stock removal, finishing operations that follow, and additional treatments or hardness tests.

3. Material Designation:

A. Specify the SAE or AISI material designation wherever possible.

B. The material trade name or purchase specification can be substituted.

C. The use of general terms, such as "oil hardening tool steel," is incomplete information. Be more specific to prevent your fasteners from undergoing the wrong treatments. When applicable, send copy of material certification, which can be used by the process metallurgist to fine-tune the processing. This is especially important for work-strengthened material.

D. You need to know if your metal in the fasteners was cold formed in the mill, and if it was, make sure to tell the heat treater. Ask your supplier to contact the mill, if necessary, to obtain this information. Stress relieving might have to be performed prior to the actual processing.

4. Processing Information is Critical for Quality Heat Treating:

A. The processing of your fasteners should be described as best as possible with information you have available. If you are not sure about a type of process, call your competent heat-treating company for information about a process that will meet the quality standards for the finished fasteners. They will help you write the processing order that will prevent unwanted results.

B. General terms, such as "annealing," should be more fully explained to avoid misinterpretation, especially when using a heat-treating facility that is operating their equipment manually.

C. Case hardening treatments should specify the method of reading the case depth (effective or total case depth) and the range allowed prior to grinding. Case hardening depth needs to be specified in thousandths. Keep in mind that tighter tolerances for case depth are now achievable with heat treaters that provide automated heat treating. A "normal" case spread of ten thousands can be set on automated equipment to not exceed a four thousands' case range. Thus, you can be more specific on your hardening specifications.

D. Special operations or finishing treatments such as vapor blast, sand blast, plating, etc., should be specified.

E. Treatments requiring other finishing processes, such as machining, should be carefully noted.

F. If certified heat treating is required to meet specifications in the automotive, aerospace, military, medical, high-tech, etc., industries, a copy of the specification should accompany the work. For error-free processing and guaranteed repeatability, it is best to send your fasteners to a heat treater that operates automated processing with sensor-control technology that documents the entire process. The automated logic-control systems provide time-stamped, electronic records that prove the process was performed to meet ISO, Nadcap, AMS and CQI-9, Department of Defense certifications and other specifications.

G. Segregation and lot control, along with defined racking parameters, should become a glue that holds the times and temperatures of the processing together. What is not seen or documented is as critical as what is on the certification.

5. Hardness Requirements:

A. Hardness requirements should state the hardness test required (Rockwell, Brinell, etc.) and range.

B. For tool steels, a three-point hardness range is desirable, such as "Rockwell C60-62." Five to six points should be allowed on hardness below Rockwell C50.

C. Inspection locations should be noted. Critical areas in which hardness tests are not allowed should be also noted.

D. Know the processor's sampling plan or SOP. The locations for batch processing and the frequency and number, for continuous processing, are critical to process verification or statistical analysis.

E. Stock removal allowed for preparing surfaces for hardness checking should be noted, if critical.

F. Fasteners requiring heat treating to a specified strength should be accompanied by tensile test specimens. Conversion from tensile strength to hardness is not reliable and should be done only with your customer's written approval.

G. Often times, it helps to have the processor keep the sampled fasteners identified and segregated for QC verification. These samples, along with the internal or third-party verification fasteners, can form the basis of archived objective evidence should questions arise later.

6. Tolerance Requirements:

A. Specify the dimensional tolerances required after heat treatment. On critical work, it is recommended that you consult with an experienced heat treater prior to ordering processing.

B. Finished surfaces should be carefully noted.

7. Related Information for Ordering Heat Treating:

A. Develop a close working relationship with your heat treater, who can guarantee times, temperatures and atmospheres supported with repeatable performance. Leading edge, automated heat treating eliminates the guesswork involved in manually operated heat-treating equipment.

B. Processing is a very precise service that should be considered a critical finishing step in your metal fabrication. For that reason, a reputable, certified heat treater will encourage a working relationship with you to enhance your understanding of the processes and methods used, as well as allow the heat treater to get to know your company's needs and requirements.

C. The heat treater will help you better understand the processing steps and soak times required and the related delivery schedules for the particular metal processing you are requesting.

D. A reputable heat treater will want to know the ultimate utilization of your fasteners.

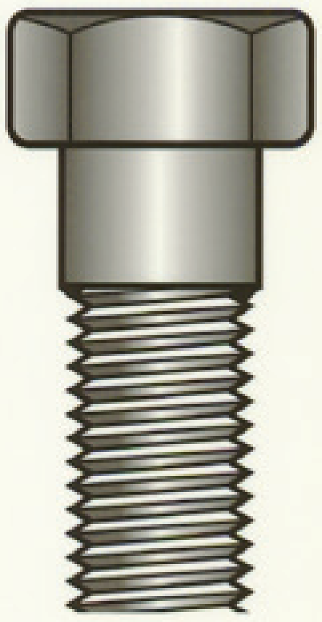
E. Prior to any processing, or at least on the first order, have the processor identify the key information fields on the certification. Since no unified system exists, this will prevent delays during final document review.

Source: Phoenix Heat Treating

ALLOY STRENGTH CHARACTERISTICS PART 1

TENSILE STRENGTH

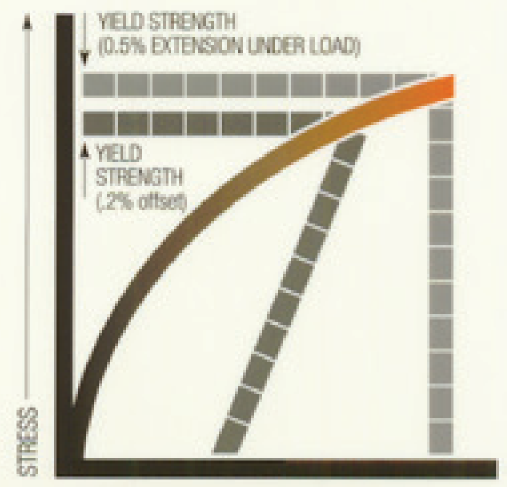
Tensile strength or ultimate strength is that property of a material which determines how much load it can withstand without breaking. It is calculated by determining the tensile stress corresponding to the maximum load observed in a tension test. The tensile strength of a bar of metal is the load needed to pull the bar apart; it is expressed in pounds per square inch, obtained by dividing this load by the cross sectional area of the bar. Cold working raises the tensile strength of most metals and alloys. Heat treatment can often be used to increase or reduce the tensile strength.



YIELD STRENGTH

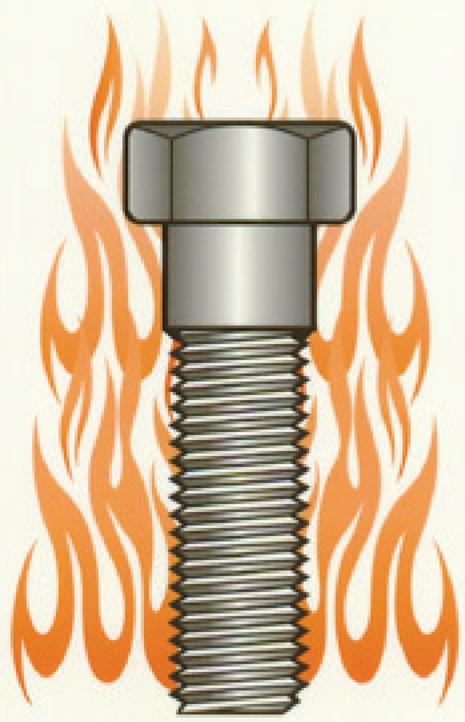
Yield strength is a measure of the resistance of a material to plastic deformation; that is, to taking of a permanent set under load. Yield strength is usually determined by one of two methods: 1) **offset** or 2) **strain under load.**

1. Offset yield strength is determined from a stress-strain diagram. It is the stress corresponding to the intersection with the curve of a line that is parallel to the straight line portion of the curve, and intersects the 0 stress axis at a strain equal to a specified offset. This offset figure is usually specified at .2%. The diagram shows this relationship—both a .2% and a .5% offset.
2. Where the stress-strain behavior of an alloy is known, yield strength may be given as a stress corresponding to a specified strain—a quantity that can be determined by direct measurement, and without a stress-strain diagram.



HEAT TREATMENT

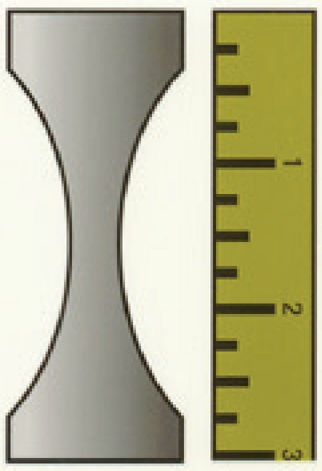
The strength and ductility of metals can be significantly altered by various types of heating operations. Heat treatment refers to any of a number of operations involving the heating of the parts in appropriate furnaces, gas-fired or electric, often with controlled atmosphere, and the subsequent cooling at controlled rates. Judicious selection of the thermal cycles can result in either an increase in strength and hardness, generally with a decrease in ductility, or a lowering of strength and hardness with an increase in ductility. In the manufacture of fasteners the strength and ductility of the parts can in this way be adjusted, within limits, to fit the particular application.



ELONGATION

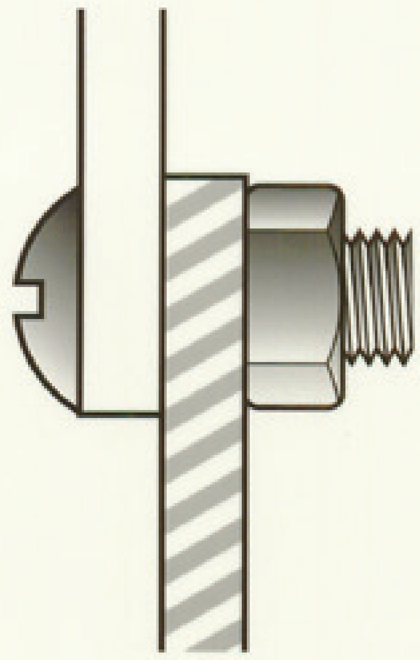
When a bar of metal is subjected to a tensile load, it elongates. At first this elongation is elastic in that when the load is released, the bar reverts to its initial length. With greater loads, however, the bar becomes permanently elongated; it has stretched plastically and has a permanent set. The extension of a material to rupture is the stretch span. The percent of elongation is calculated by dividing the total increase in gaged length by the original gaged length and multiplying by 100.

The percent elongation at rupture is significant because it is a measure of ductility. The degree of ductility of metals depends on factors such as composition, cold working, and heat treatment. It generally decreases as the strength and hardness increase.



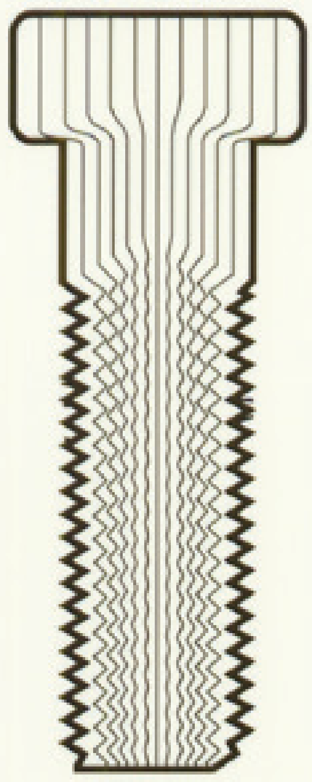
SHEAR STRENGTH

Shear is transverse rupture. It is caused by a pushing or pulling force at 90° from the axis of a part. Thus, a rivet used as a pulley axle will shear if the load on the pulley exceeds the shear value of the rivet. Shear strength in pounds per square inch is defined as the load in pounds to cause rupture divided by the cross sectional area in square inches of the part along the rupture plane. As a rough rule of thumb, shear strength is generally from one-half to two-thirds the tensile strength.



COLD WORKING

Cold working is the plastic deformation of metals at temperatures below that which will cause re-crystallization. This cold working is accompanied by an increase in strength and hardness, called work hardening, and a decrease in ductility. The cold working effects of forming bolt and screw heads, of extruding bolt shanks, and of roll threading increase strength values, often considerably.



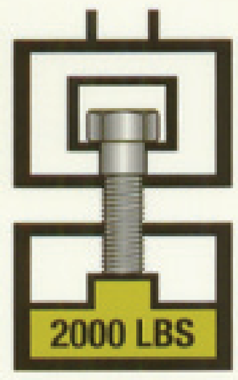
ALLOY STRENGTH CHARACTERISTICS PART 2

STRENGTH-TO-WEIGHT RATIO

In applications where load supporting parts are to be lifted or moved against the pull of gravity, the strength-to-weight ratio (SWR) becomes an important figure. It is defined as the ratio of the tensile strength to the density of a material, the density being the weight per unit volume. Some typical properties, including SWR, of selected materials are listed in the chart below. This is by no means the full range of properties available in corrosion-resistant fastener alloys (mild steel is included for comparison).

MATERIAL	TYPICAL TENSILE STRENGTH LBS./SQ. IN.	DENSITY LBS./CU. IN.	STRENGTH-TO-WEIGHT RATIO INCHES X 10^{-5}	RELATIVE CORROSION-RESISTANCE* 1 – BEST 4 – LOWEST	RELATIVE COST A – LOWEST D – HIGHEST
Martensitic Stainless Steel (410, 416)	180,000	.280	6.4	3	B
Aluminum (2024-T4)	60,000	.098	6.1	3	B
Austenitic Stainless Steel (18-8) Strain hardened	125,000	.290	4.3	2	C
Titanium Commercially pure	50,000	.163	3.1	1	D
Nylon	12,000	.041	2.9	1	C
Austenitic Stainless Steel (18-8) Annealed	80,000	.290	2.8	2	C
Monel 400	80,000	.319	2.5	1	D
Silicon Bronze	75,000	.308	2.4	2	C
Brass	60,000	.308	2.0	3	C
Mild Steel	50,000	.282	1.8	4	A

*General ratings only



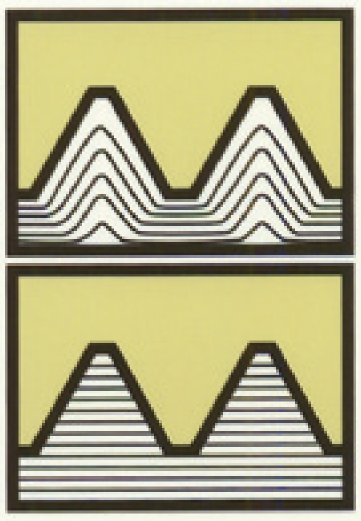
FATIGUE

Fatigue can be defined as the failure of a metallic material due to varying stresses placed on the material. These stresses are cyclic first in one direction, and then another. The simplest form of fatigue is that which occurs when thin metal is bent back and forth, and finally broken.
In tension-tension conditions which normally are the conditions of usage, the fatigue strength of a material can be improved by placing the outer fibers of the metal in compression. This compression then must first be overcome before the tension forces act on the metal.
In bolt manufacture, this is achieved by extruding the blank diameter down to a size suitable for roll threading, and then rolling the thread on this extruded section.
Both the extrusion and the rolling operation assist in the formation of this compressed area. Improvement is also obtained by the use of cold drawn material which places the outer fibers of the metal in compression. In actual usage fatigue life of bolts can be improved by loading the bolt to just beneath the yield strength of the material.

THREAD STRENGTH

Thread forms on fasteners can be manufactured by the processes of cutting, rolling, or grinding. For given metallic material, the best quality, highest strength thread is produced by rolling. This is because the plastic deformation, or cold working, involved in rolling the threads results in:

1. More accurate, more uniform thread dimensions, giving better fit between threaded parts and fewer concentrated loads at points of misfit.
2. Smoother thread surfaces and, thus, fewer scratches and other markings to initiate cracks.
3. Higher yield, tensile, shear and other strength properties to better withstand service loads.



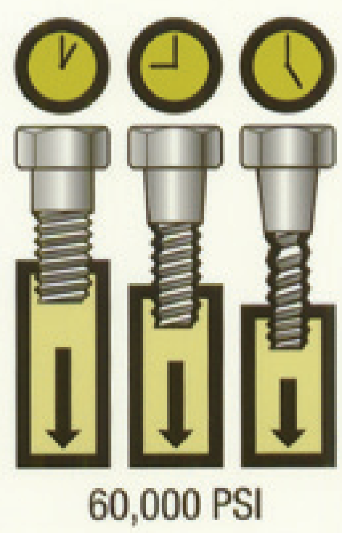
STRESS CORROSION

Stress corrosion is a type of corrosion which affects metal under the combined action of internal stresses due to cold working and external stresses due to enduring high tensile effects in a corrosive environment. It can lead to brittle failure in parts which would normally yield plastically rather than crack. Various metals have different susceptibilities to stress corrosion, and for a given metal the susceptibility varies with the magnitude of the stresses, the shape of the part, its surface condition, and the nature of the corrosive environment. Proper stress relieving, annealing, torquing, and cold working all can play a part in reducing stress corrosion.

CREEP

At ordinary temperatures, metals under load normally change their dimensions only when the load is changed. At elevated temperatures, however, dimensional changes take place even under constant load, that is, metals—and other materials—**creep.** For example, a bolt under constant tensile load at a high temperature will elongate continuously. The higher the temperature the more rapid is the creep, i.e., the higher the **creep rate.** This effect can lead to loosening of fasteners and ultimately to rupture. The resistance to such high temperature dimensional change under load is the **creep strength.** It is usually designated either as:

1. The constant **stress (load divided by cross-sectional area)** which will produce a specified amount of dimensional change in a given time at a given temperature, or;
2. The constant stress that will produce a specified creep rate at a given temperature.



FASTENER PLATING/ COATING & FINISHES PART 1

PLATING, COATING OR FINISH	FOR USE ON	DEGREE OF CORROSION RESISTANCE	CHARACTERISTICS
Anodizing	Aluminum	Excellent	Acid electrolytic treatment with frosty-etched appearance. Hard oxide surface gives excellent protection and reduced porosity. Tempered alloys can be dyed any color Type 1, Class 2. Good paint base and good for close tolerance parts.
Baking of Case Hardened Parts	Steel	Process to lessen hydrogen embrittlement	Electroplated fasteners which are case-hardened should be baked for a minimum of four hours within the temperature range of 375–450°F no later than four hours after the plating process. This baking process does not guarantee that hydrogen embrittlement will not still be present after baking or that it will not occur at a later date while in service. Specialized testing or a substitute part may be required, depending on the application.
Black Nickel	All metals	Excellent	Generally used as a matching finish without lacquer coating.
Black Oxide	Ferrous metals and stainless steel	Good	A "conversion coating" which means it is formed by a chemical reaction with the metal to form an integral surface, as opposed to an "applied coating" which bonds with the metal. An oil finish is applied as a rust inhibitor. No risk of hydrogen embrittlement. An attractive black finish.
Black Phosphate	Steel	Very good	Standard finish on retaining rings, drywall and particle board screws. Color is dull black to a bright black appearance.
Black Phosphate and Oil	Steel	Very good	Standard coating on black phosphate. Non-drying petroleum oil is 1100 mg per sq/ft minimum. Oil serves as a rust inhibitor and a lubricant. Some fasteners with this plating call out required salt-spray test. Common fasteners include frame bolts, spring nuts, floorboard screws and Grade GT locknuts.
Black Zinc	All metals	Fair	A shiny black appearance with fair rust-resistance qualities.
Blue Polymer	Steel	Very good to excellent	Polymer is a barrier coating because it creates a seal around the fastener which resists corrosion and abrasion. A phosphate-zinc base is initially applied to the fastener, followed by the polymer which bonds to the sub-coating. Commonly used to coat and identify concrete screws.
Brass, Electroplated, Lacquered	Usually steel	Fair	Brass electroplated which is then lacquered. Recommended for indoor decorative use only.
Bright Nickel	Most metals	Excellent indoors. Good outdoors if thickness at least 0.0005 in.	Electroplated silver-color finish. Used for appliances, hardware, etc.
Bronze, Electroplated, Lacquered	Usually steel	Fair	Has color similar to 80% copper, 20% zinc alloy. Electroplated and then lacquered. Recommended for indoor decorative use only.
Cadmium, Electroplated (Waxed)	Most metals	Excellent	Bright silver-gray, dull gray, or black finish. Particularly effective corrosion protection, coloring and paint bonding. Good electrical conductivity quality. Not suggested unless absolutely necessary due to toxic content and extremely high cost.
Chromate (Clear)	Zinc and cadmium-plated fasteners	Very good to excellent	A secondary dipping process after plating increasing corrosion resistance, adding brilliance.
Chrome	Usually steel	Good	Chrome plating is applied in two methods. Hard-chrome deposits a thick layer of chrome on the fastener. This gives the part a very hard finish and superior wear resistance but does not offer much protection to corrosion. A nickel-chrome finish is achieved by applying a flash of chrome on top of nickel plating. This process offers resistance to tarnishing and corrosion.
Chromium, Electroplated	Most metals	Good (improves with copper and nickel undercoats)	Bright blue-white, lustrous finish. Has relatively hard surface. Used for decorative purposes or to add wear resistance.
Color Chromate Finish	Steel	Very good to excellent	Olive drab, blue (used often for metric fasteners), bronze, red and other colors. A secondary dipping process after plating increasing corrosion resistance.
Color Phosphate Coatings	Steel	Superior to regular phosphate and oiled surfaces	Chemically produced color coating. Available in blue, green, red, purple, and other colors.
Copper, Electroplated	Most metals	Fair	Used for nickel and chromium plate undercoat. Can be blackened and relieved to obtain antique, statuary and Venetian finishes.

FASTENER PLATING/ COATING & FINISHES PART 2

PLATING, COATING OR FINISH	FOR USE ON	DEGREE OF CORROSION RESISTANCE	CHARACTERISTICS
Dacrotized	Steel	Excellent and used for treated lumber	Dacrotized is a pollution free ceramic coating for screws used with treated lumber. Coating is comparable to the corrosion resistance of hot-dip galvanized fasteners. Plating can typically withstand a 500-hour salt spray test. There is no risk of hydrogen embrittlement with Dacrotized plating.
Dichromate	Zinc and cadmium-plated fasteners	Very good to excellent	A secondary dipping in various colors such as yellow, brown, green or iridescent after plating increasing corrosion resistance and color finish.
Dull Nickel	Most metals	Same as bright nickel	Whitish cast can be obtained by mechanical surface plating or a special satin bath.
Electroless Nickel	Most metals and metalized plastics	Excellent	Electroless nickel is an auto-catalytic reaction used to deposit a coating of nickel on a substrate. Even coatings on parts surface can be achieved and flexibility in plating volume and thickness are advantages.
Hot-dipped Aluminum	Steel	Very good	Gives maximum corrosion protection. Dull grayish color. Requires thread size adjustments to permit ease of assembly.
Hot-dipped Tin	All metals	Excellent	Silver-gray color. Excellent corrosion, like electroplated tin, but thickness is harder to control. Plating is often used in the food handling industry because it resists organic acids.
Hot-dipped Zinc Galvanizing	All metals	Very good to excellent	Gives maximum corrosion protection. Dull gray in color. Requires thread size adjustments to permit ease of assembly. During the galvanizing process, steel reacts with molten zinc, forming layers of zinc-iron alloy layers which are metallurgically bonded to the steel surface. This hard barrier has a low corrosion rate and resists mechanical damage. Often specified for harsh environments.
Lacquering, Clear	All metals	Improves corrosion resistance	Used for decorative finishes. Color matched for color and lustre.
Lead-Tin	Steel	Fair to good	Silver-gray dull coating. Applied in hot-dip method. Helps lubricity.
Mechanical Plating	Steel	Very good	Dull gray with a smooth finish. Corrosion protection depends on coating thickness. Good coverage in recesses and thread roots. Mechanical plating reduces the risk of hydrogen embrittlement forming with the fasteners. Minimizes the need for the precautionary practice of baking the fasteners soon after plating. This plating process is common for lockwashers made from spring steel to be plated this way to avoid brittleness after baking.
Passivation of Stainless Fasteners	Stainless steel	Very good	This process enhances stainless steel's corrosion resistance. The fasteners are dipped in a solution which removes surface imperfections and produces a slight film on the surface of the parts.
Rust Inhibitors	All metal	Varies with type of inhibitor	Oils, solvents, greases, etc. Vary in color and film thickness. Used to protect fasteners in transit and temporary storage.
Silver, Electroplated	All metals	Excellent	Decorative, expensive and excellent electrical conductor. It resists thread galling when mated parts are under extreme pressure or exposed to extreme heat.
Tin, Electroplated	All metal	Excellent	Silver gray in color. Excellent corrosion protection for fasteners in contact with food. Improves lubricity on steel fasteners.
Wax	Most plated fasteners	Fair, used as a lubricate	Used for ease of assembly. Standard plating for thread rolling screws and locknuts.
Zinc, Electroplated (Clear)	All metal	Very good	Blue to blue-white color. Most popular of all commercial platings because it is relatively economical and offers good corrosion resistance in environments not subject to excessive moisture. Commercial zinc plating has a standard minimum thickness of 0.00015 inches. Class 2A thread allowances in sizes No. 8 and smaller may not accommodate this thickness. To avoid any reduction in the strength properties of these screws, a thinner coating may be acceptable.
Zinc & Green, Electroplated	Steel	Very good	Used for "grounding screws" in electrical applications.
Zinc or Manganese	Steel	Good	Black in color. Added protection when oiled with a non-drying petroleum oil containing corrosion inhibitors. Good lubricity.

GALVANIC CORROSION

Galvanic corrosion occurs when two dissimilar metals are in contact in the presence of an electrolyte, which is a medium through which an electrical current can flow (i.e. moisture). The rate of corrosion depends upon the amount and concentration of the electrolyte as well as the difference in electrical potential (anodic-cathodic relationship) of the metals as shown in the Galvanic Corrosion Chart (shown at right).

A highly anodic material in contact with another highly cathodic material will corrode much more quickly than two highly cathodic materials or when the materials used are closer together on the Galvanic Corrosion Chart. The metal in the higher position on the chart corrodes at a faster rate. This occurs due to the conduction of electrons through the metals from anode (+) to cathode (–), and a conduction of ions through the electrolyte solution, with salt water being even more damaging due to the high concentration of dissolved salts. It is important to know from which the dissimilar metals the current will flow when selecting materials.

When corrosion does occur, the anodic material is the most likely to corrode, whereas the cathodic material is the least likely to corrode. To reduce the likelihood of galvanic corrosion in a fastened joint, it's recommended to choose materials that are grouped together in the Galvanic Corrosion Chart. Recommendations include:

- Select materials that are as close together as possible in the Galvanic Corrosion Chart.
- Provide a barrier between the two metals, such as a non-metallic washer or gasket, paint or jointing compound.
- Design the fastener as the cathode so that the cathodic area is as small as possible to the anode area.
- Use a metallic finish on the fastener that is close on the chart to the mating metal.
- Use a non-conductive and inert finish on the fastener.

GALVANIC CORROSION CHART

Corroded End (+) (Anodic, Least Noble)

Magnesium
Magnesium Alloys
Zinc
Beryllium
Aluminum 1100, 3003, 3004, 5052, 6053
Cadmium
Aluminum 2017, 2024, 2117
Mild Steel 1018, Wrought Iron
Cast Iron, Low Alloy, High Strength Steel
HSLA Steel, Cast Iron
Chrome Iron (Active)
430 Stainless Steel (Active)
302, 303, 321,347, 410, 416 Stainless Steel (Active)
Ni-Resist
316, 317 Stainless Steel (Active)
Carpenter 20Cb-3 Stainless Steel (Active)
Aluminum Bronze (CA687)
Hastelloy C (Active), Inconel 625 (Active), Titanium (Active)
Lead-Tin Solder
Lead
Tin
Inconel 600 (Active)
Nickel (Active)
60% Ni 15% Cr (Active)
80%Ni 20% Cr (Active)
Hastelloy B (Active)
Naval Brass (CA464), Yellow Brass (CA268)
Red Brass (CA230), Admiralty Brass (CA443)
Copper (CA102)
Manganese Bronze (CA675), Tin Bronze (CA903, 905)
410, 416 Stainless Steel (Passive), Phosphor Bronze (CA521, 524)
Silicon Bronze (CA651, 655)
Nickel Silver (CA732, 735, 745,752, 754,757,765,770, 794)
Copper – Nickel 90-10
Copper – Nickel 80-20
430 Stainless Steel (Passive)
Copper – Nickel 70-30
Nickel Aluminum Bronze (CA630, 632)
Monel 400, K500
Silver Solder
Nickel (Passive)
60% Ni 15% Cr (Passive)
Inconel 600 (Passive)
80% Ni 20% Cr (Passive)
Chrome Iron (Passive)
302, 303, 304, 321, 347 Stainless Steel (Passive)
316, 317 Stainless Steel (Passive)
Carpenter 20Cb-3 Stainless Steel (Passive), Incoloy 825 (Passive)
Silver
Titanium (Passive), Hastelloy C & C276 (Passive), Inconel 625 (Passive)
Graphite
Zirconium
Gold
Platinum

Electric Current Flows from Positive (+) Anode to Negative (–) Cathode

Protected End (–) (Cathodic or Most Noble)

WRENCH & BIT SIZES

BOLT & SCREW WRENCH/SOCKET SIZES

Dia./Size	Hex Cap Screws	Hex & Tap Bolts	Hvy. Hex Bolts	Square Bolts	Lag Screws	Hex Flange	12 Pt. Flange	Askew Head
1/4	7/16	7/16	—	3/8	7/16	3/8	1/4	—
5/16	1/2	1/2	—	1/2	1/2	1/2	5/16	—
3/8	9/16	9/16	11/16	9/16	9/16	9/16	3/8	9/16
7/16	5/8	5/8	—	5/8	5/8	5/8	7/16	—
1/2	3/4	3/4	7/8	3/4	3/4	3/4	1/2	3/4
9/16	13/16	—	—	—	—	13/16	9/16	—
5/8	15/16	15/16	1-1/16	15/16	15/16	15/16	5/8	15/16
3/4	1-1/8	1-1/8	1-1/4	1-1/8	1-1/8	1-1/8	3/4	1-1/8
7/8	1-5/16	1-5/16	1-7/16	1-5/16	1-5/16	—	7/8	1-5/16
1"	1-1/2	1-1/2	1-5/8	1-1/2	1-1/2		1"	1-1/2
1-1/8	1-11/16	1-11/16	1-13/16	1-11/16	1-11/16		1-1/8	—
1-1/4	1-7/8	1-7/8	2"	1-7/8	1-7/8		1-1/4	—
1-3/8	2-1/16	2-1/16	2-3/16	2-1/16	—		1-3/8	—
1-1/2	2-1/4	2-1/4	2-3/8	2-1/4			1-1/2	—
1-5/8	2-7/16	2-7/16	2-9/16	—				
1-3/4	2-5/8	2-5/8	2-3/4					
1-7/8	2-13/16	2-13/16	2-15/16					
2"	3"	3"	3-1/8					
2-1/4	3-3/8	3-3/8	3-1/2					
2-1/2	3-3/4	3-3/4	3-7/8					
2-3/4	4-1/8	4-1/8	4-1/4					
3"	4-1/2	4-1/2	4-5/8					
3-1/4	—	4-7/8	5"					
3-1/2		5-1/4	5-3/8					
3-3/4		5-5/8	5-3/4					
4"		6"	6-1/8					

TORX PLUS® SOCKET SCREW DRIVE RECESS

Dia./Size	Socket Cap Screw	Flat Head	Button Head	Shoulder Screw	Low Head	Set Screw
#0	6IP					
#1	7IP					
#2	8IP		6IP			
#3	8IP		—			
#4	10IP	10IP	8IP			
#5	10IP	10IP	—			7IP
#6	15IP	15IP	10IP			6IP & 7IP (UNF)
#8	25IP	20IP	15IP		15IP	8IP
#10	27IP	25IP	25IP		20IP	10IP
1/4	30IP	30IP	27IP	20IP	27IP	15IP & 20IP (UNF)
5/16	45IP	40IP	40IP	27IP	30IP	25IP & 27IP (UNF)
3/8	50IP	45IP	45IP	40IP	40IP	27IP & 30IP (UNF)
7/16	55IP	50IP	—	—	—	40IP
1/2	55IP	50IP	55IP	45IP	50IP	45IP
5/8	70IP	55IP	60IP	55IP		55IP
3/4	80IP	60IP	—	60IP		60IP
7/8	100IP	—		—		70IP
1"	100IP					70IP

HI-TORQUE® DRIVE INSERT BITS

Nominal Screw Size	0	1	2	3	4	5	6	8	10	1/4	5/16	3/8	7/16	1/2	9/16	5/8	3/4
Hi-Torque Recess	0	0	0	1	1	1	1	2	3	4	5	6	7	8	9	10	12

HEX KEY SIZES FOR SOCKET SCREW DRIVE RECESSES

Dia./Size	Socket Set	1960 Socket Cap	36' Series Socket Cap	Shoulder Screws	Flat Head	Button Head	Low Head	Square Head Set Screws
#0	.028	.050			.035	.035	—	—
#1	.035	1/16			.050	.050	—	Wrench Size*
#2	.035	5/64			.050	.050	—	
#3	.050	5/64			1/16	1/16	—	
#4	.050	3/32	5/64		1/16	1/16	.050	
#5	1/16	3/32	3/32		5/64	5/64	1/16	
#6	1/16	7/64	3/32		5/64	5/64	1/16	
#8	5/64	9/64	1/8		3/32	3/32	5/64	
#10 (3/16)	3/32	5/32	5/32		1/8	1/8	3/32	3/16
1/4	1/8	3/16	3/16	1/8	5/32	5/32	1/8	1/4
5/16	5/32	1/4	7/32	5/32	3/16	3/16	5/32	5/16
3/8	3/16	5/16	5/16	3/16	7/32	7/32	3/16	3/8
7/16	7/32	3/8	5/16	—	1/4	—	7/32	7/16
1/2	1/4	3/8	3/8	1/4	5/16	5/16	1/4	1/2
5/8	5/16	1/2	1/2	5/16	3/8	3/8	5/16	5/8
3/4	3/8	5/8	9/16	3/8	1/2	—	—	3/4
7/8	1/2	3/4	9/16	—	9/16			7/8
1"	9/16	3/4	5/8	1/2	5/8			1"
1-1/8	9/16	7/8	3/4	—	3/4			1-1/8
1-1/4	5/8	7/8	3/4	5/8	7/8			1-1/4
1-3/8	5/8	1"	3/4	—	7/8			1-3/8
1-1/2	3/4	1"	1"	7/8	1"			1-1/2
1-3/4	1"	1-1/4	1-1/4	1"				
2"		1-1/2	1-3/8	1-1/4				
2-1/4		1-3/4						
2-1/2		1-3/4						
2-3/4		2"						
3"		2-1/4						
3-1/4		2-1/4						
3-1/2		2-3/4						
3-3/4		2-3/4						
4"		3"						

NUT WRENCH SIZES

Dia./Size	Finished Hex Nuts, Jam, Slotted, Castle	Heavy Hex Nuts, Jam, Slotted, 2-H	Hex Serrated Flange, Large Flange Nuts	Regular Square	Heavy Square
1/4	7/16	1/2	7/16	7/16	1/2
5/16	1/2	9/16	1/2	9/16	9/16
3/8	9/16	11/16	9/16	5/8	11/16
7/16	11/16	3/4	11/16	3/4	3/4
1/2	3/4	7/8	3/4	13/16	7/8
9/16	7/8	15/16	7/8	—	—
5/8	15/16	1-1/16	15/16	1"	1-1/16
3/4	1-1/8	1-1/4	1-1/8	1-1/8	1-1/4
7/8	1-5/16	1-7/16		1-15/16	1-7/16
1"	1-1/2	1-5/8		1-1/2	1-5/8
1-1/8	1-11/16	1-13/16		1-11/16	1-13/16
1-1/4	1-7/8	2"		1-7/8	2"
1-3/8	2-1/16	2-3/16		2-1/16	2-3/16
1-1/2	2-1/4	2-3/8		2-1/4	2-3/8
1-5/8	2-7/16	2-9/16			
1-3/4	2-5/8	2-3/4			
1-7/8	2-13/16	2-15/16			
2"	3"	3-1/8			
2-1/4	3-3/8	3-1/2			
2-1/2	3-3/4	3-7/8			
2-3/4	4-1/8	4-1/4			
3"	4-1/2	4-5/8			
3-1/4	4-7/8	5"			
3-1/2	5-1/4	5-3/8			
3-3/4	5-5/8	5-3/4			
4"	6"	6-1/8			

DRIVER INSERT BITS

Dia./Size	Machine Screw	Wood Screw	Tapping Screw	Cross-Recess Flat/Oval	Cross-Recess Flat/Oval U/C	Hex Ind. Washer	Cross-Recess Trim Head	100 Degree Flat Head
#0	0	0	0	0	0	—	—	0
#1	0	0	0	0	0	1/8		0
#2	1	1	1	1	1	1/8		1
#3	1	1	1	1	1	3/16		1
#4	1	1	1	1	1	3/16	1	1
#5	1 or 2	2	2	2	1 or 2	3/16	1	—
#6	2	2	2	2	2	1/4	1	2
#7	—	2	2	2	2	1/4	—	—
#8	2	2	2	2	2	1/4	2	2
#9	—	2	2	—	—	5/16	2	2
#10	2 or 3	3	2	2	2	5/16	2	—
#12	3	3	3	3	3	3/8	2 or 3	—
#14	—	3	3	3	—	3/8	2 or 3	3
1/4	3	—	3	3	3	1/2	3	4
#16	—	3	3	3	—	1/2	—	—
#18	—	4	4	4	—	9/16	—	—
5/16	3 or 4	—	4	4	4	9/16	4	4
#20	—	4	4	4	—	5/8	—	—
#24	—	4	4	4	—	3/4	—	—
3/8	4	—	4	4	4			
7/16	4	—	4	4	4			
1/2	4		4	4	4			
9/16	4							
5/8	5							
3/4	5							

ROBERTSON (SQUARE DRIVE) INSERT BIT SIZES

COLOR-CODED SYSTEM

Screw Dia.	Color	Screw Dia.	Color	Screw Dia.	Color
1	Orange # 00	5	Green # 1	9	Red # 2
2	Orange # 00	6	Green # 1	10	Red # 2
3	Yellow # 0	7	Green # 1	12	Black # 3
4	Yellow # 0	8	Red # 2	14	Black # 3

SLOTTED & TORX® MACHINE SCREW DRIVE RECESSES BITS

Dia./Size	Slotted Bit	Torx®	Dia./Size	Slotted Bit	Torx®	Dia./Size	Slotted Bit	Torx®
#2	00	—	#6	1-2	TX-15	#12	3-4	TX-27
#3	00-0	—	#8	2-3	TX-20	1/4	4-5	TX-30
#4	0-1	TX-10	#10	3-4	TX-25	5/16	6-6	TX-40

NUT WRENCH SIZES

Dia./Size	Small Pattern Hex M/Sc. Nuts	Hex & Square M/Sc. Nuts
#0	1/8	5/32
#1	1/8	5/32
#2	5/32	3/16
#3	5/32	3/16
#4	3/16	1/4
#5	1/4	5/16
#6	1/4	5/16
#8	1/4 (5/16)	11/32
#10 (3/16)	1/4 (5/16)	3/8
#12	5/16	7/16
1/4		7/16
5/16		9/16
3/8		5/8

FASTENER DRIVE TRADE NAMES & TRADEMARKS

Acument Global Technologies
Torx®, Torx Plus®, E-Torx®

Alcoa
Hi-Torque®, Hi-Torque/Connie®

AVA Specialty Fasteners, Ltd.
Quadrex

Bryce Fastener Mfg.
Key-Rex™, Keyed-Lok®, Penta-Plus™, Hex-Pin™, Tam-Globe™

Copper Industries
Sel-O-Fit®

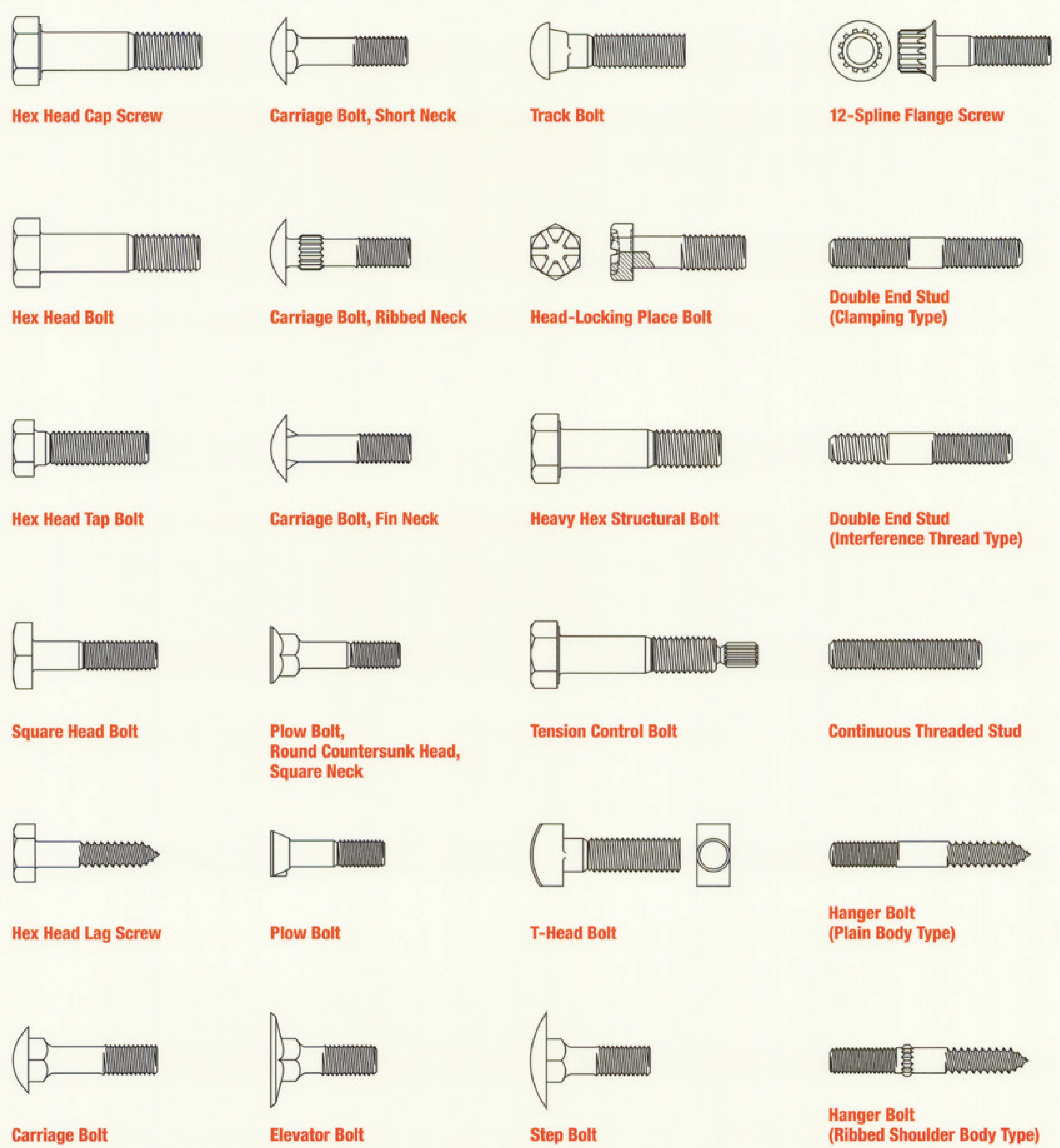
Phillips Screw Company
Phillips®, Phillips II®, ACR® Phillips®, Pozidriv®, Pozisquare® Driv, Phillips Square-Driv®, Torq-Set®, Tri-Wing®, Mortorq®, Hexstix®, Pozilock®

Robertson
Robertson®, Scrulox® 8

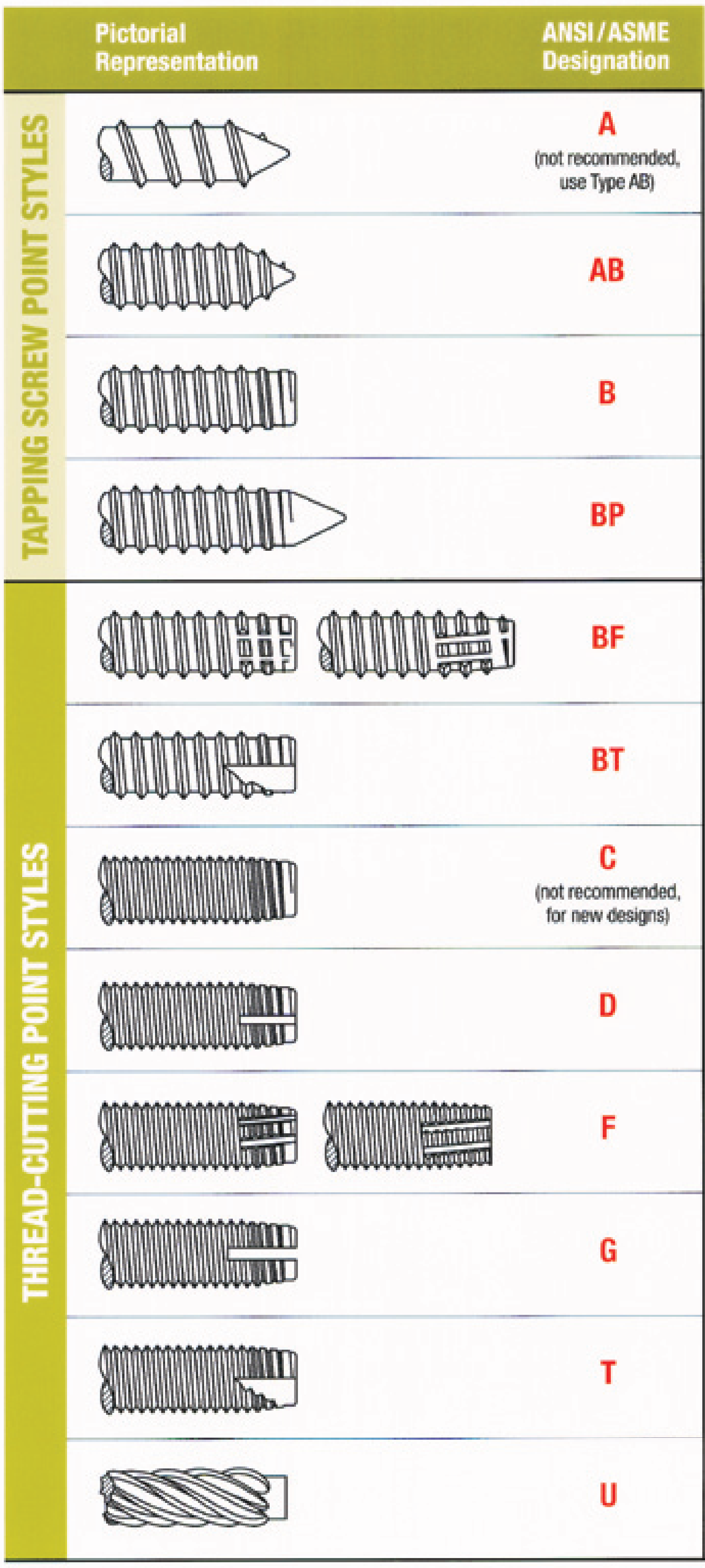
Tamperproof Screw Co.
Opsit®

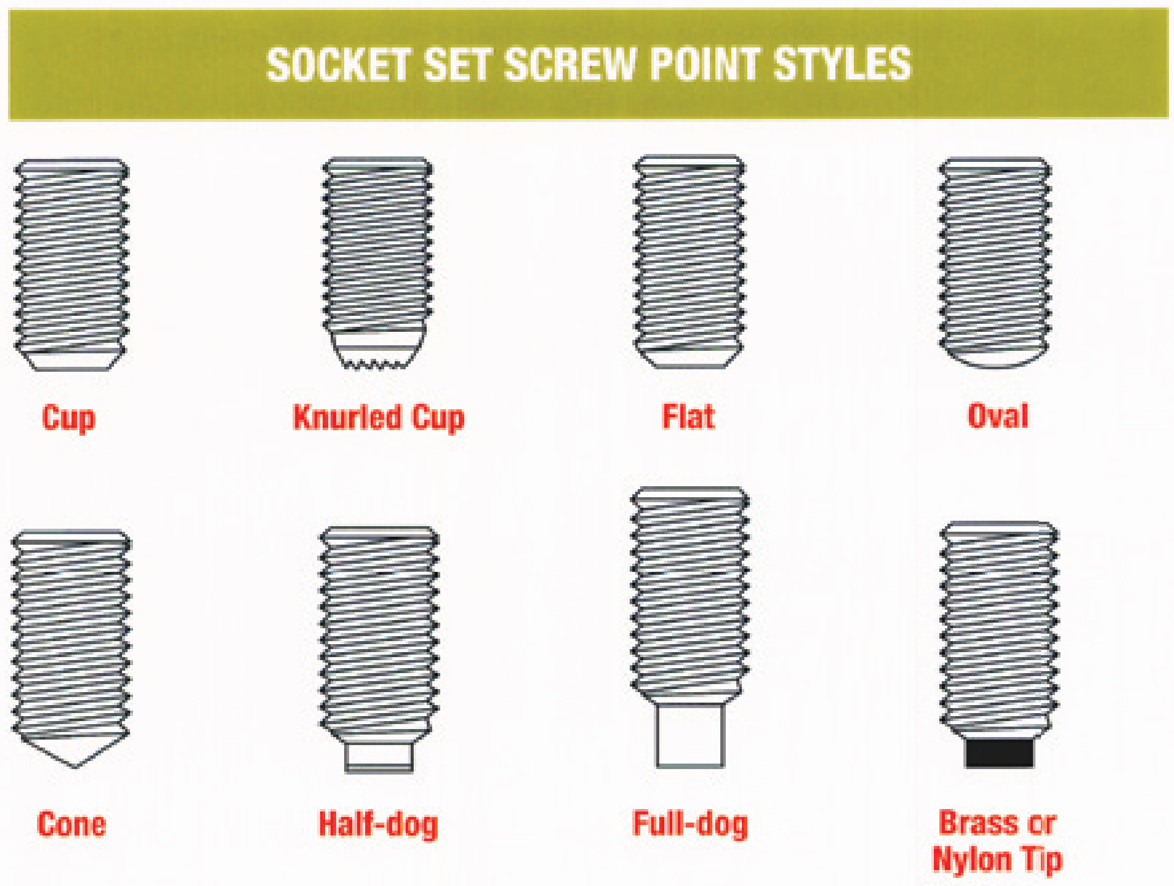
Uni-Screw
Uni-Screw®

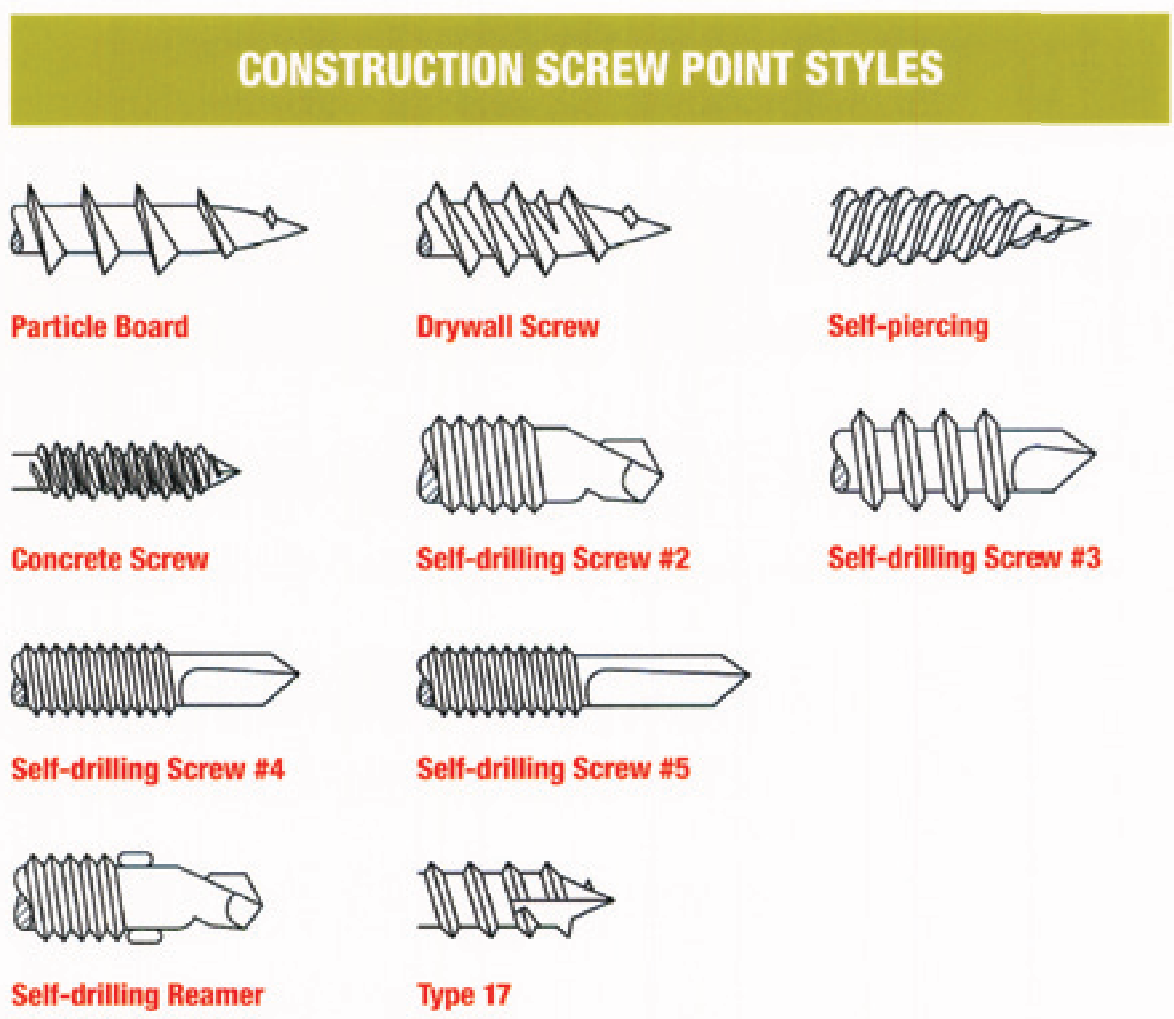
FASTENER VISUALS™
TYPES OF FASTENERS



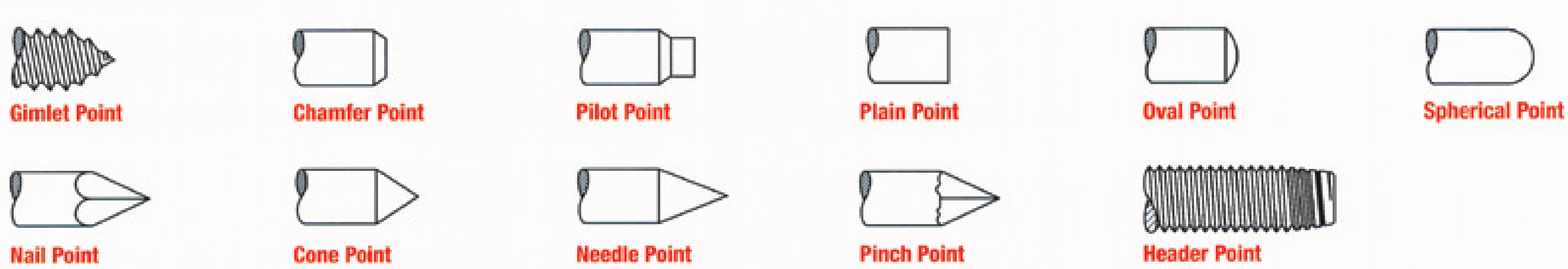
FASTENER VISUALS™
POINT STYLES





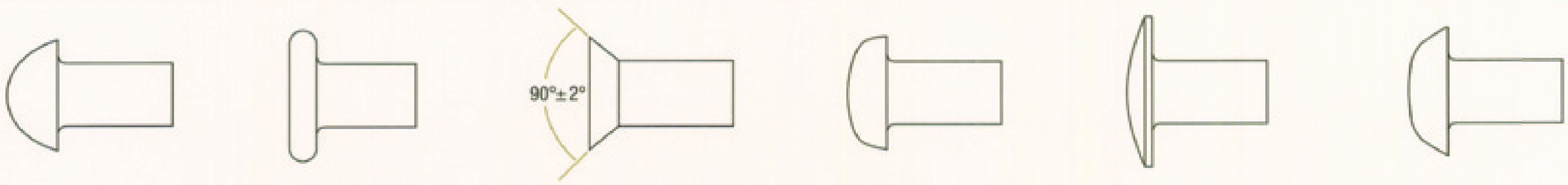


MISCELLANEOUS POINTS



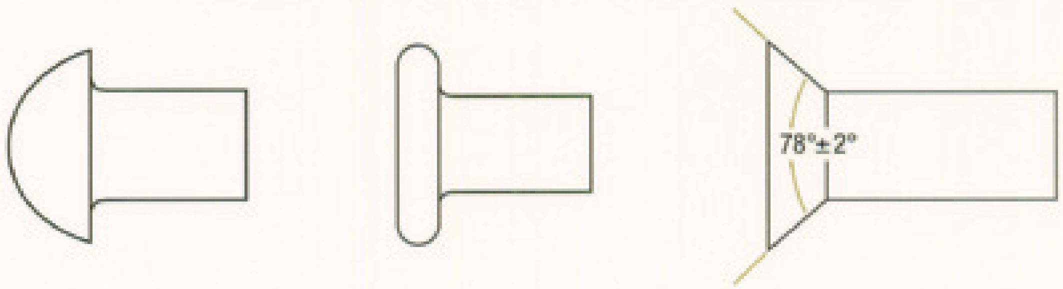
FASTENER VISUALS™
RIVETS PART 1

Small Rivets (less than 7/16" diameter)



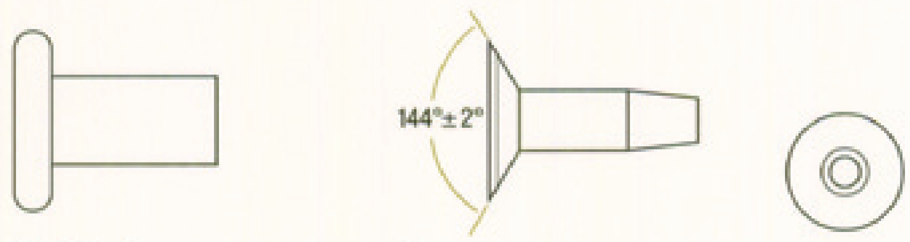
Round Head | Flat Head | Countersunk Head | Pan Head | Truss Head | Universal Head

Large Rivets (1/2" and greater diameter)



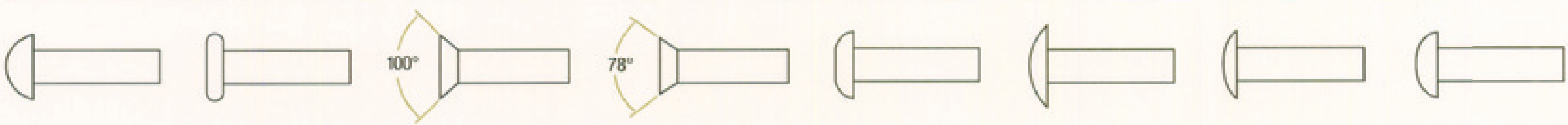
Round Head | Flat Head | Countersunk Head

Tinners Rivet & Copper Belt Rivet and Burr



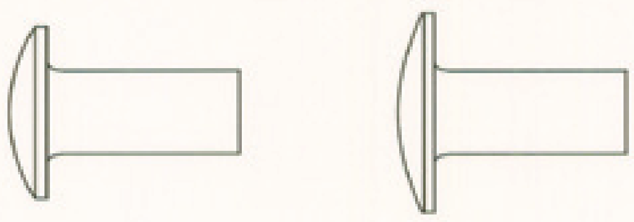
Flat Head Tinners Rivet | Copper Belt Rivet | Copper Burr

Aluminum Rivet Head Styles



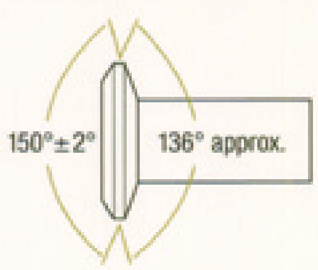
Round Head | Flat Head | 100° Countersunk Head | 78° Countersunk Head | Universal Head | Brazier Head | Modified Brazier Head | Mushroom Head

Semi-tubular Rivets



Oval Head Straight Hole | Truss Head Straight Hole

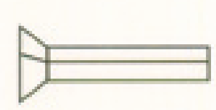
Standard Brake & Clutch Rivet



Brass Escutcheon Pin

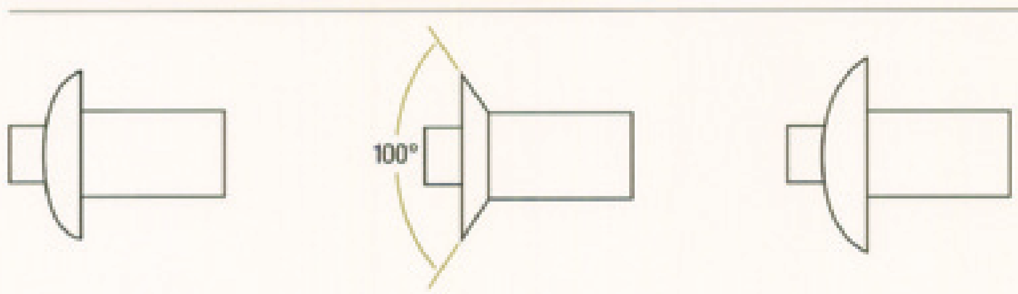
Oval Head

Copper Brake Band Rivet



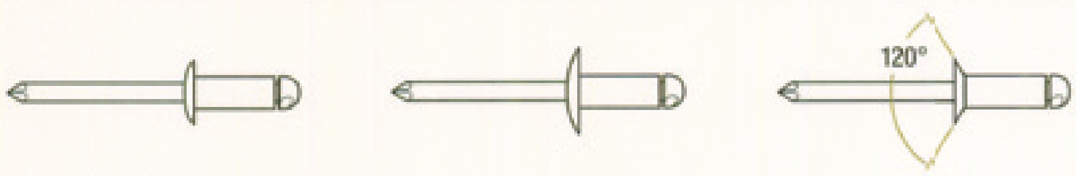
Countersunk Head

Aluminum & Steel Drive Rivets



Universal Head | 100° Countersunk Head | Full Brazier Head

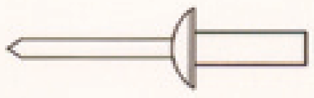
Blind Rivets – Open End



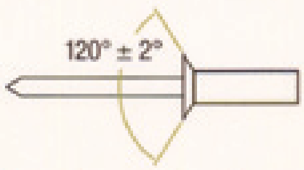
Dome Head | Large Flange Head | Countersunk Head

FASTENER VISUALS™
RIVETS PART 2

Blind Rivets – Closed End

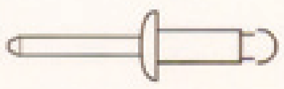


Dome Head



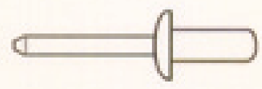
Countersunk Head

Tribex Blind Rivet



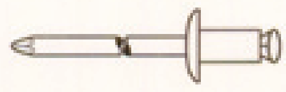
Dome Head

Multigrip Blind Rivet

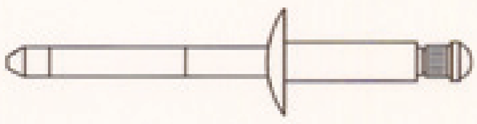


Dome Head

Dome Peel Blind Rivet

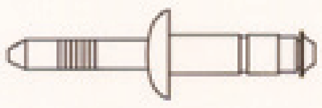


Q® Rivet



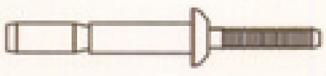
Protruding Head

Avinox II Blind Rivet

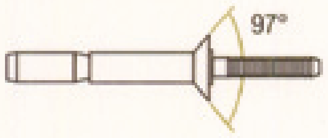


Low Profile Head

Blind Lock Rivets



Dome Head



Countersunk Head

riv·et *noun* \'ri-vət\

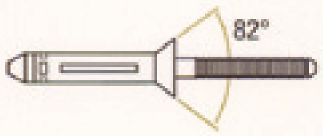
: a special kind of metal bolt or pin that is used to hold pieces of metal together

: a headed pin or bolt of metal used for uniting two or more pieces by passing the shank through a hole in each piece and then beating or pressing down the plain end so as to make a second head

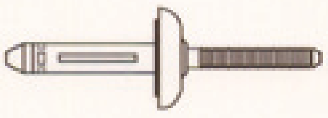
ORIGIN OF RIVET

Middle English, clinch on a nail, rivet, from Old French, from *river* to attach, rivet, probably from *rive* border, edge, bank, from Latin *ripa*. First Known Use: 15th century

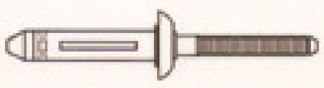
Bulb-tite® Blind Rivets



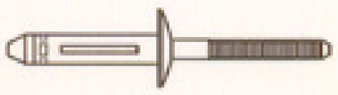
82° Countersunk Head



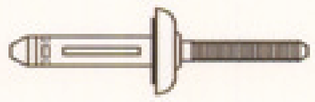
Dome Head, Protruding Crown



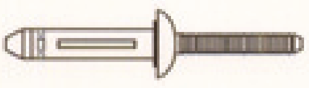
Dome Head, Recessed Crown



Flat Head, Low Profile

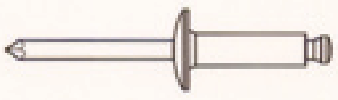


Large Flange Head, Protruding Crown

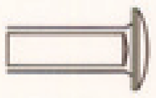


Shavable Brazier Head

2-Piece Mate Rivet

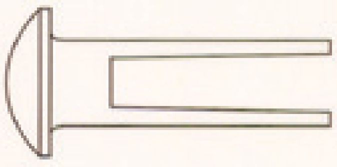


Blind Rivet

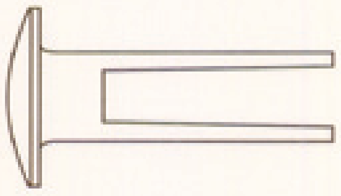


Tubular Component

Standard Split Rivets



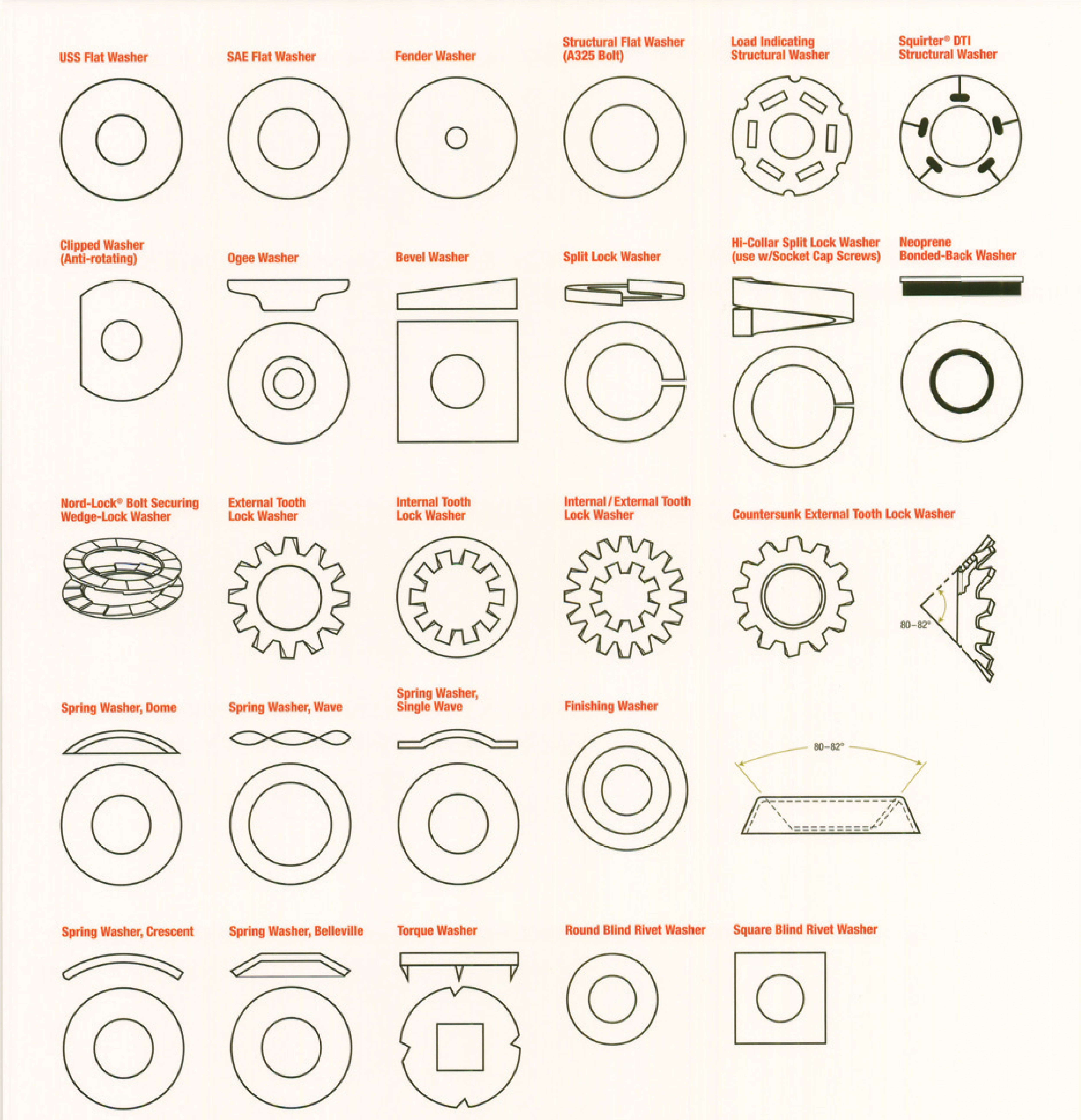
Oval Head



Truss Head

NOTE: There are several similar rivet types that have a wide variety of trade names. Please do an Internet search to locate a specific supplier or manufacturer.

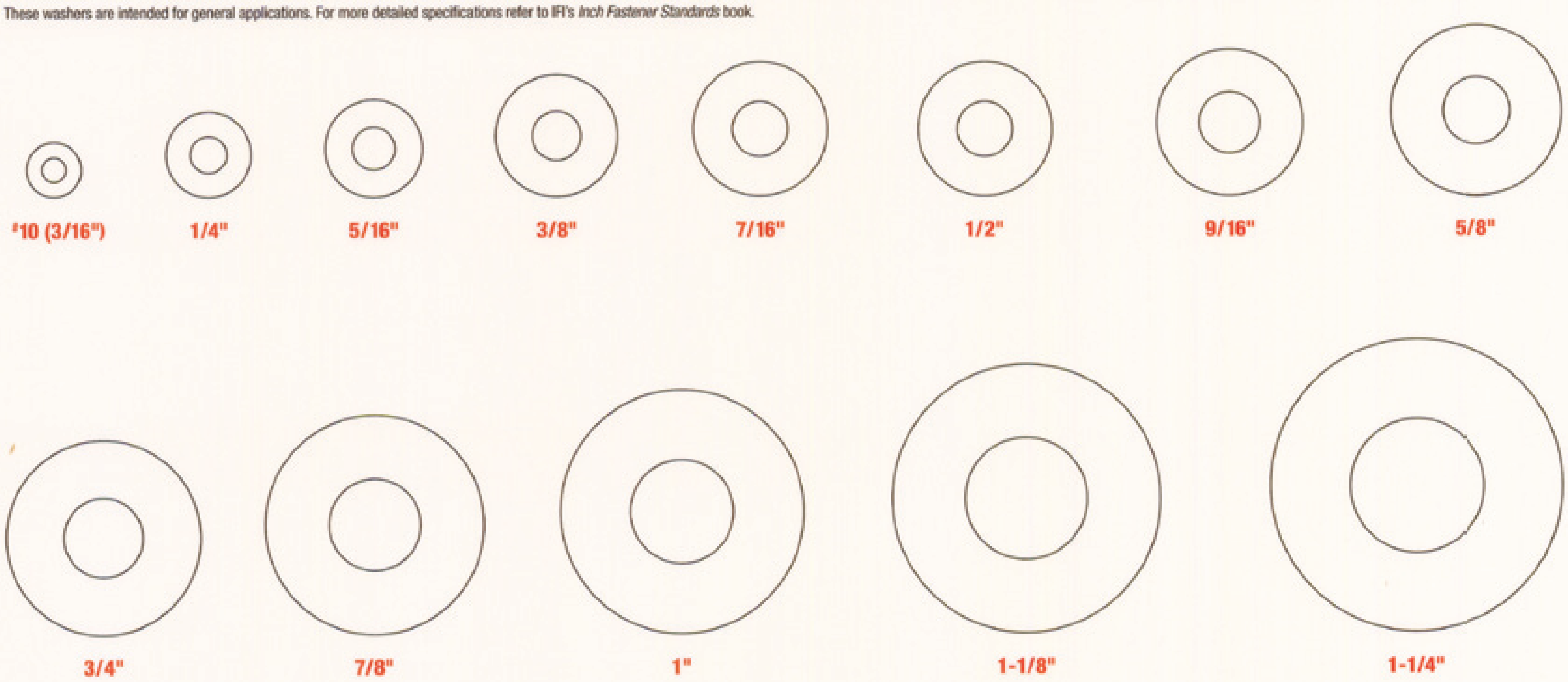
FASTENER VISUALS™
WASHERS PART 1



FASTENER VISUALS™
WASHERS PART 2

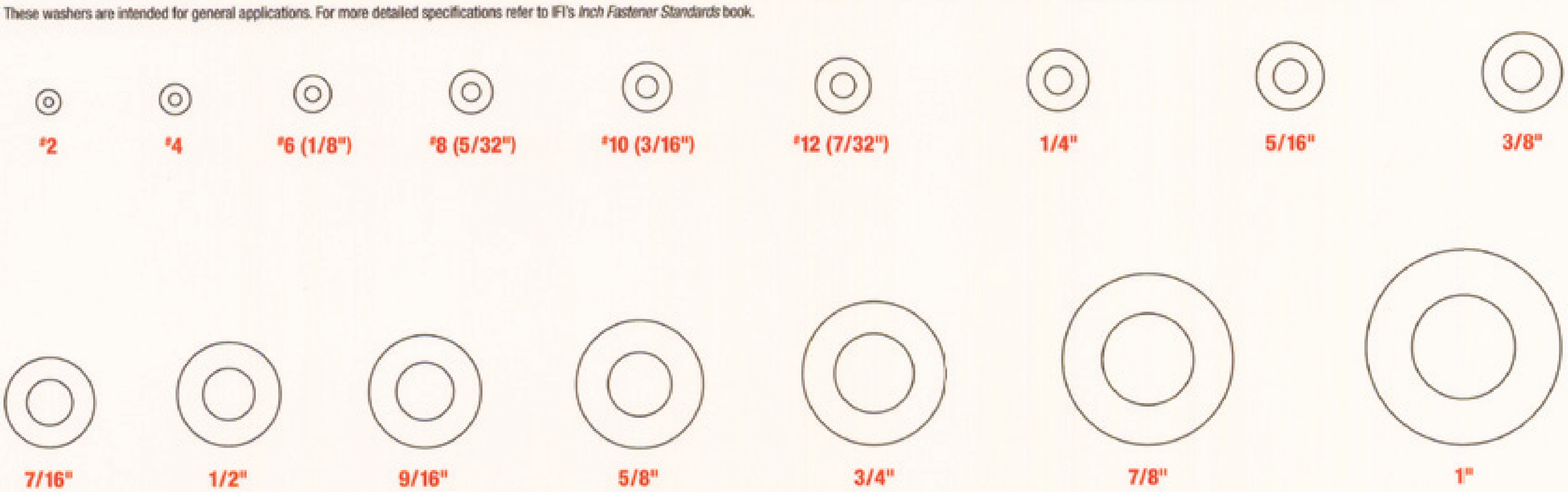
Quick & Easy Washer Size Guide: USS Grade 2 Steel Flat Washer Sizes

These washers are intended for general applications. For more detailed specifications refer to IFI's *Inch Fastener Standards* book.

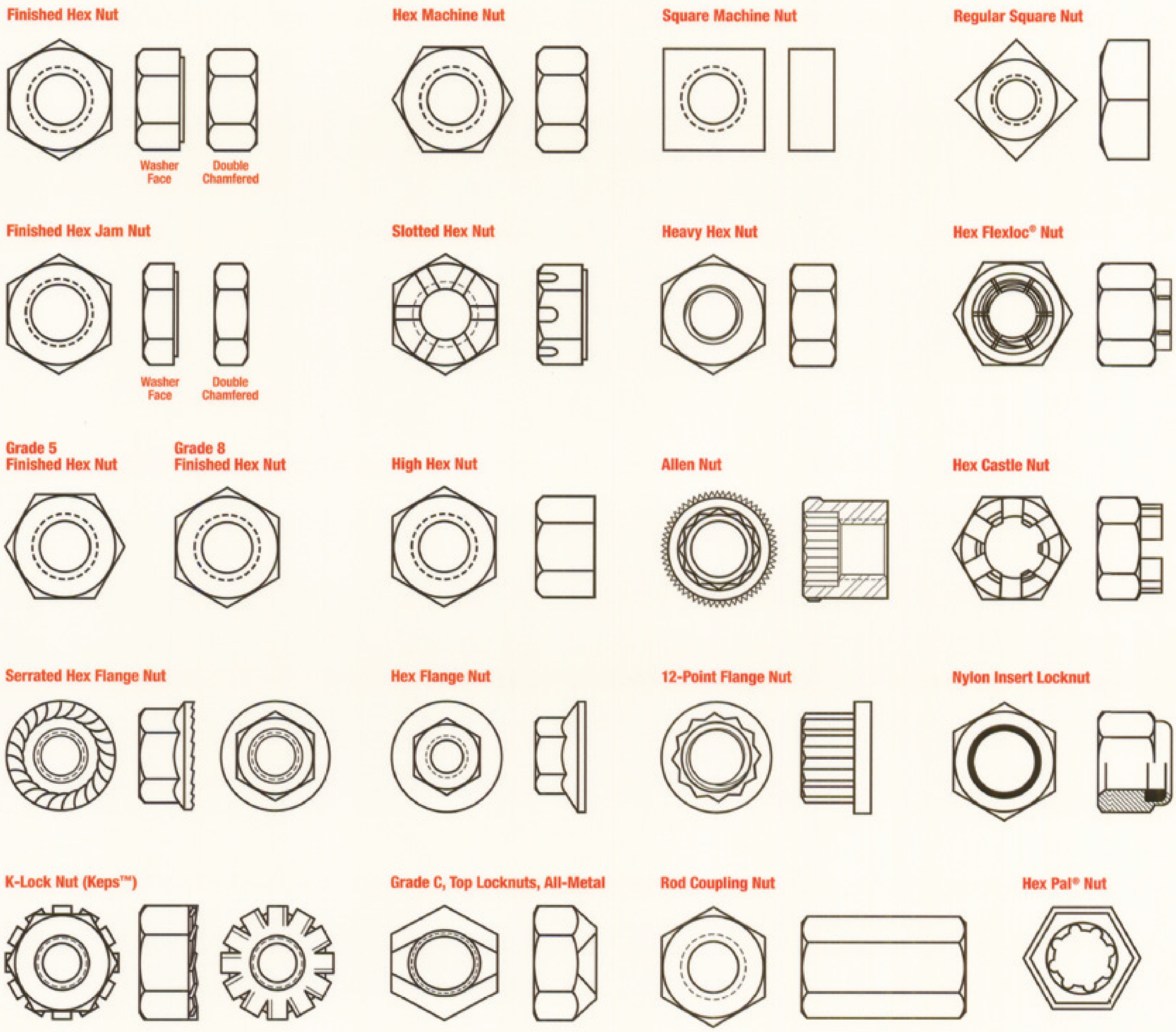


Quick & Easy Washer Size Guide: SAE Grade 2 Steel Flat Washer Sizes

These washers are intended for general applications. For more detailed specifications refer to IFI's *Inch Fastener Standards* book.

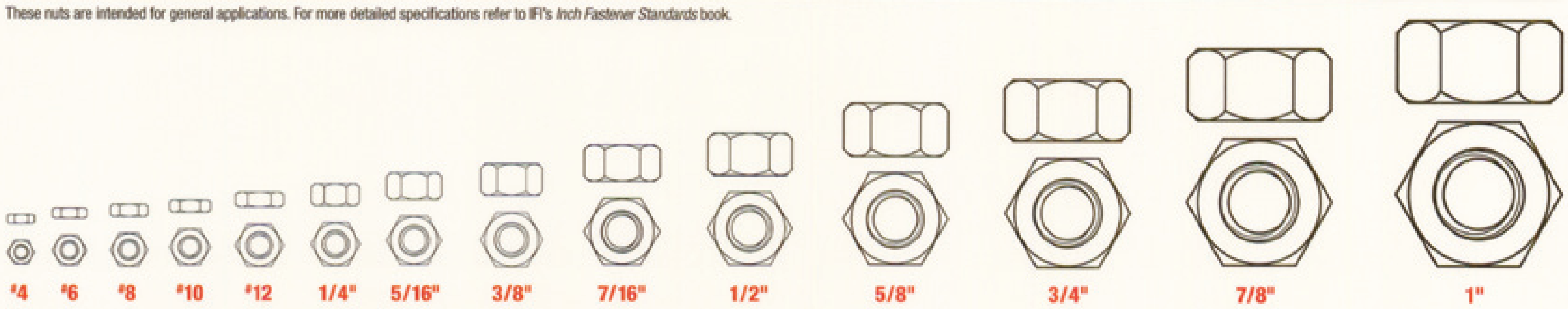


FASTENER VISUALS™
NUTS PART 1



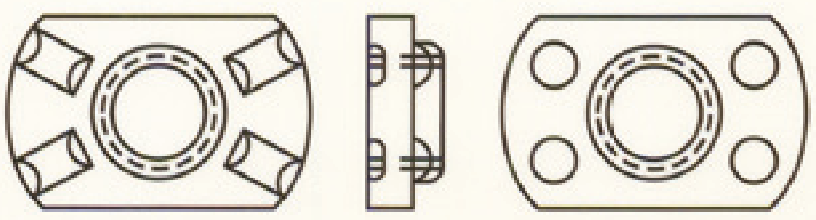
Quick & Easy Nut Size Guide

These nuts are intended for general applications. For more detailed specifications refer to IFI's *Inch Fastener Standards* book.

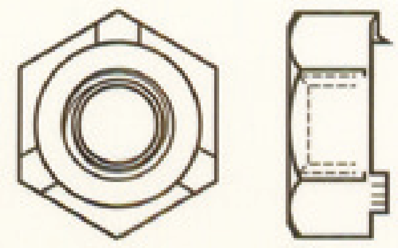


FASTENER VISUALS™
NUTS PART 2

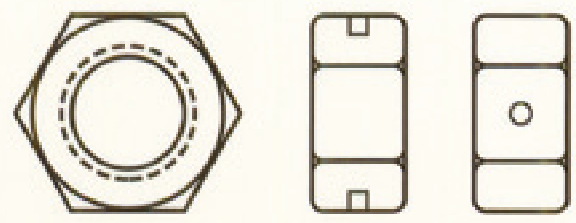
Flat Weld Nut



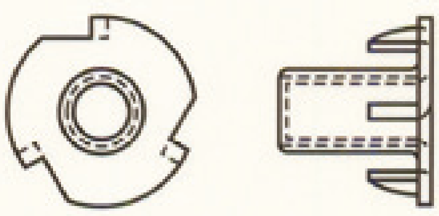
Hex Weld Nut



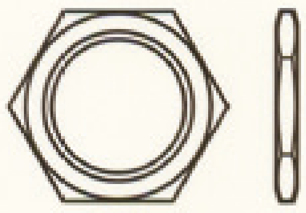
Two-Way Reversible Hex Locknuts



3-Prong Wood Tee Nuts

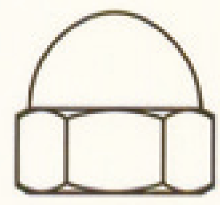


Hex Panel Nut

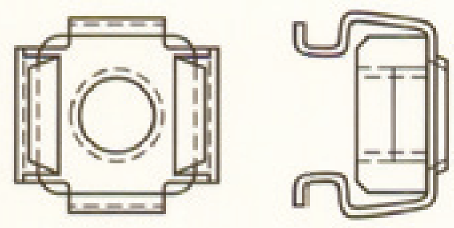


Steel Spring Nut

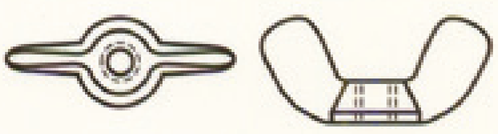
Low-Crown Hex Acorn Nut



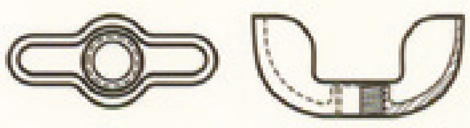
Gage Nut



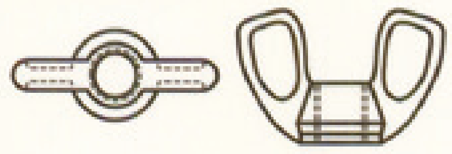
Cold Forged/ Pressed Steel Wing Nut



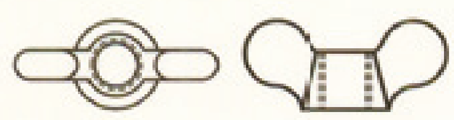
Stamped Wing Nut



Zinc Die-Cast Wing Nut



Malleable Iron Wing Nut



ASTM A194

The ASTM A194 specification covers carbon, alloy and stainless steel nuts intended for use in high-pressure and/or high-temperature service. Unless otherwise specified, the American National Standard Heavy Hex Series (ANSI 18.2.2) shall be used. Nuts up to and including 1 inch nominal size shall be UNC Series Class 2B fit. Nuts over 1 inch nominal size shall be either UNC Series Class 2B fit or 8 UN Series Class 2B fit. High strength ASTM A194 grade 2H nuts are common in the marketplace and are often substituted for ASTM A563 grade DH nuts due to the limited availability of DH nuts in certain diameters and finishes.

Grade Identification Marking[1]	Specification	Material	Nominal Size (in.)	Tempering Temp. °F	Proof Load Stress (ksi)	Hardness Rockwell Min	Hardness Rockwell Max	See Note
	ASTM A194 Grade 2	Medium Carbon Steel	1/4 – 4	1000	150	159	352	1, 2, 3
	ASTM A194 Grade 2H	Medium Carbon Steel, Quenched and Tempered	1/4 – 4	1000	175	C24	C38	1, 2
	ASTM A194 Grade 2HM	Medium Carbon Steel, Quenched and Tempered	1/4 – 4	1000	150	159	237	1, 2, 3
	ASTM A194 Grade 4	Medium Carbon Alloy Steel, Quenched and Tempered	1/4 – 4	1100	175	C24	C38	1, 2
	ASTM A194 Grade 7	Medium Carbon Alloy Steel, Quenched and Tempered	1/4 – 4	1100	175	C24	C38	1, 2
	ASTM A194 Grade 7M	Medium Carbon Alloy Steel, Quenched and Tempered	1/4 – 4	1100	150	159	237	1, 2, 3
	ASTM A194 Grade 8	Stainless AISI 304	1/4 – 4	—	80	126	300	4
	ASTM A194 Grade 8M	Stainless AISI 316	1/4 – 4	—	80	126	300	4

NOTES

1. The markings shown for all grades of A1294 nuts are for cold formed and hot forged nuts. When nuts are machined from bar stock, the nut must additionally be marked with the letter B. The letters H and M indicate heat treated nuts.
2. Properties shown are those of coarse and 8-pitch thread heavy hex nuts.
3. Hardness numbers are Brinell Hardness.
4. Nuts that are carbide-solution treated require additional letter A—8A or 8MA.
5. All nuts shall bear the manufacturer's identification mark. Nuts shall be legibly marked on one face to indicate the grade and process of the manufacturer. Marking of wrench flats or bearing surfaces is not permitted unless agreed upon between manufacturer and purchaser. Nuts coated with zinc have an asterisk (*) marked after the grade symbol. Nuts coated with cadmium shall have a plus sign (+) marked after the grade symbol.
6. Other less common grades exist, but are not listed here.

ASTM A194 Information Source: *Inch Fastener Standards, 7th edition*, Cleveland: Industrial Fasteners Institute, 2003. N-80—N-81.

ASTM A563

The ASTM A563 specification covers the chemical and mechanical requirements for carbon and alloy steel nuts used on bolts, studs, and externally threaded fasteners. The chart below addresses grade marking and mechanical requirements. According to the A563 specification, "The requirements for any grade of nut may, at the supplier's option, and with notice to the purchaser, be fulfilled by furnishing nuts of one of the stronger grades specified herein unless such a substitution is barred in the inquiry and purchase order." This is important because some nut grades are not readily available in certain sizes and finishes. Additionally, the specification allows for the substitution of ASTM A194 grade 2H nuts in lieu of A563 grade DH nuts due to the lack of availability of grade DH nuts in nominal sizes 3/4" and larger.

Hot-dip galvanized nuts must be tapped oversize to allow for the added thickness of the zinc on the threads of the externally threaded fastener. These allowances are available per specifications A153, C1.C.

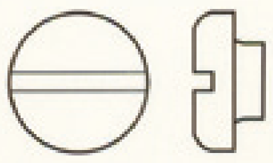
Grade Identification Marking	Specification	Material	Nominal Size (in.)	Proof Load Stress (ksi)	Hardness Rockwell Min	Hardness Rockwell Max	See Note
No Mark	ASTM A563 Grade O	Carbon Steel	1/4 – 1-1/2	69	B55	C32	2, 3
	ASTM A563 Grade A	Carbon Steel	1/4 – 1-1/2	90	B68	C32	2, 3
	ASTM A563 Grade B	Carbon Steel	1/4 – 1 > 1 – 1-1/2	120 105	B69	C32	2, 3
	ASTM A563 Grade C	Carbon Steel, may be Quenched and Tempered	1/4 – 4	144	B78	C38	4
	ASTM A563 Grade C3	Atmospheric Corrosion Resistant Steel, may be Quenched and Tempered	1/4 – 4	144	B78	C38	4, 6
	ASTM A563 Grade D	Carbon Steel, may be Quenched and Tempered	1/4 – 4	150	B84	C38	5
	ASTM A563 Grade DH	Carbon Steel, Quenched and Tempered	1/4 – 4	175	C24	C38	5
	ASTM A563 Grade DH3	Atmospheric Corrosion Resistant Steel, Quenched and Tempered	1/4 – 4	175	C24	C38	4, 6

NOTES

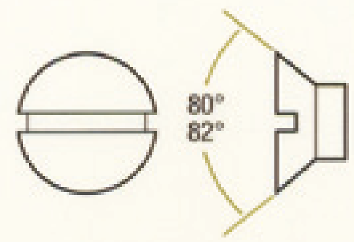
1. In addition to the indicated grade marking, all grades, except A563 grades O, A, and B, must be marked for manufacturer identification.
2. Nuts are not required to be marked unless specified by the purchaser. When marked, the identification marking shall be the grade letter O, A, or B.
3. Properties shown are those of nonplated or noncoated coarse thread nuts.
4. Properties shown are those of coarse thread heavy hex nuts.
5. Properties shown are those of coarse thread heavy hex nuts. Other nut styles and fine threads may apply.
6. The nut manufacturer, at his option, may add other markings to indicate the use of atmospheric corrosion resistant steel.

ASTM A563 Information Source: *Inch Fastener Standards, 7th edition*, Cleveland: Industrial Fasteners Institute, 2003. N-80—N-81.

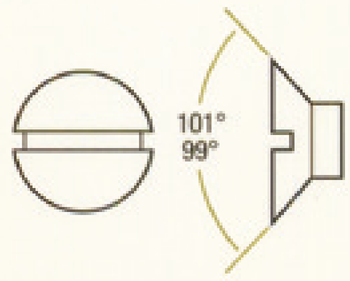
FASTENER VISUALS™
HEAD STYLES PART 1



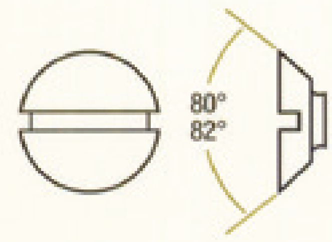
Slotted Pan Head



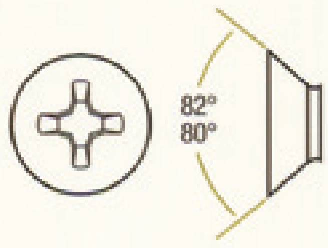
Slotted 82° Flat Countersunk Head



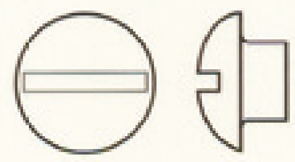
Slotted 100° Flat Countersunk Head



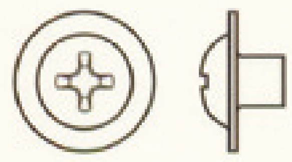
Slotted 82° Flat Undercut Countersunk Head



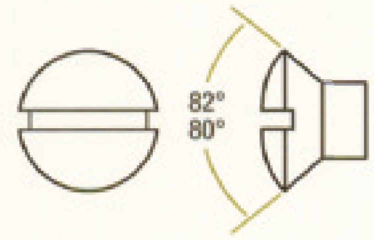
Cross Recessed 82° Flat Countersunk Trim



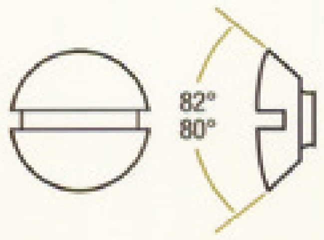
Slotted Round Head



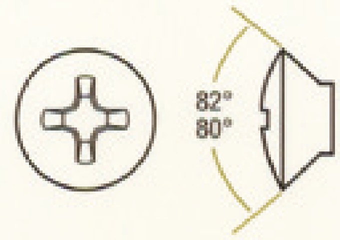
Cross Recessed Type I Round Washer Head



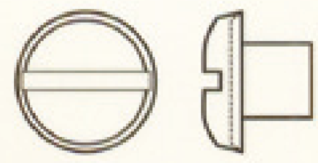
Slotted 82° Oval Countersunk Head



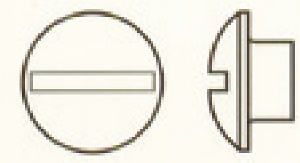
Slotted 82° Oval Undercut Countersunk Head



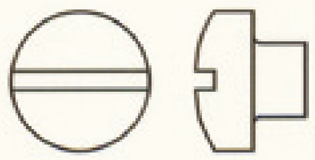
Cross Recessed 82° Oval Countersunk Trim Head



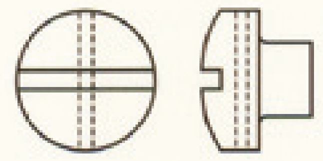
Slotted Binding Undercut Head



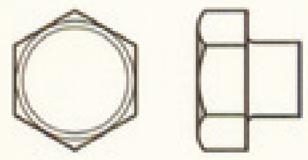
Slotted Truss Head



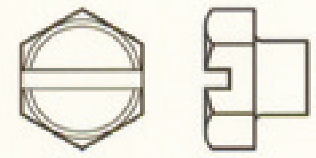
Slotted Fillister Head



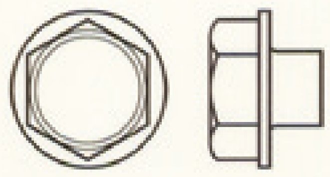
Drilled, Slotted Fillister Head



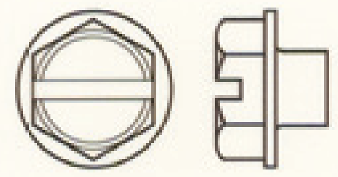
Indented Hex Head



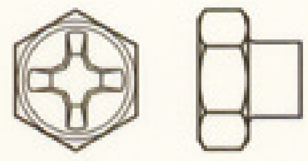
Indented Slotted Hex Head



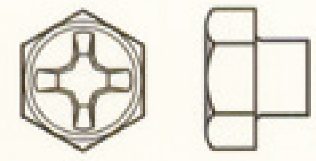
Indented Hex Washer Head



Indented Slotted Hex Washer Head

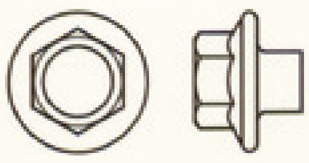


Cross Recessed Indented Type I Hex Head

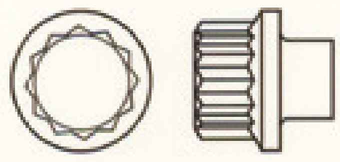


Cross Recessed Trimmed Type 1 Hex Head

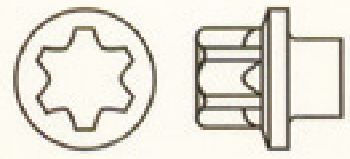
FASTENER VISUALS™
HEAD STYLES PART 2



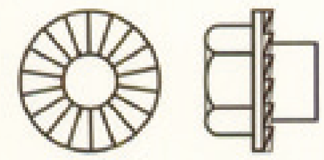
Hex Flange Screw



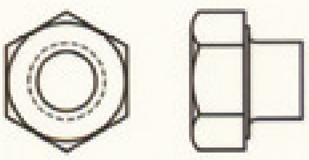
12-Point Flange Screw



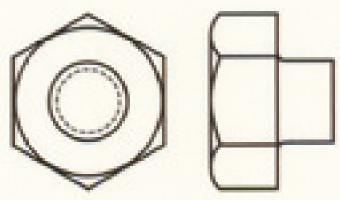
External Torx®
Flange Screw



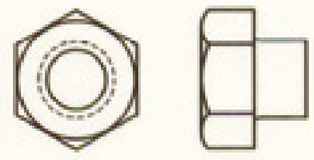
Serrated Washer Hex Head



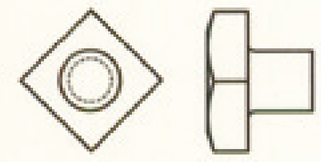
Hex Head Cap Screw
(Note: Washer Face)



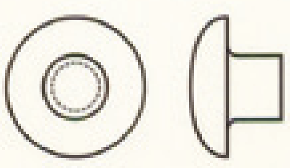
Heavy Hex Head Bolt



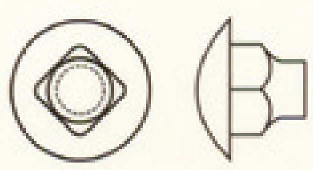
Hex Head Bolt



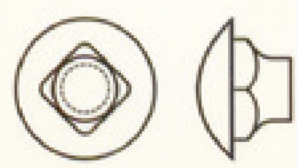
Square Head Bolt



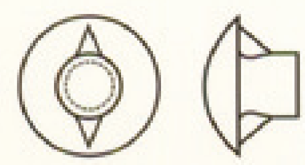
Round Head Bolt



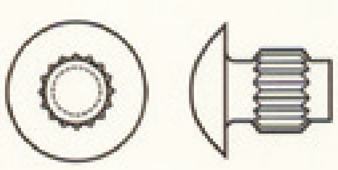
Round Head Square Neck
Carriage Bolt



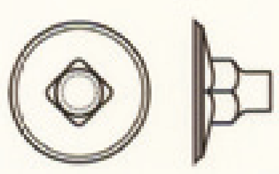
Round Head Short Square
Neck Carriage Bolt



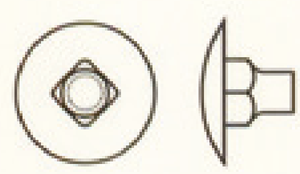
Round Head Fin Neck
Carriage Bolt



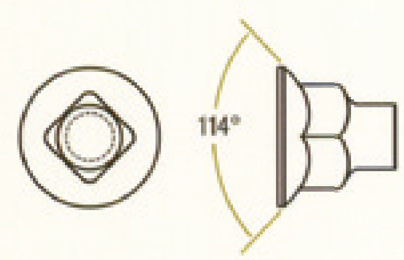
Round Head Ribbed Neck
Carriage Bolt



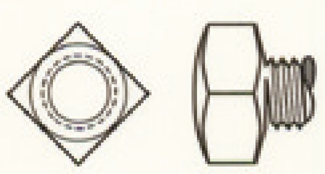
Flat Countersunk Head
Elevator Bolt



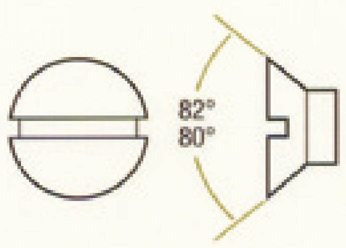
Step Bolt



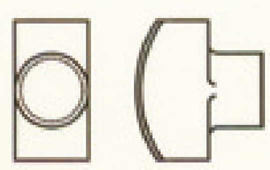
114° Countersunk
Square Neck Bolt



Square Head Set Screw

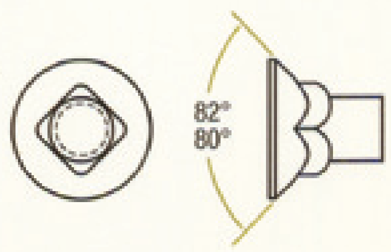


Slotted 82° Flat Countersunk
Head Cap Screw

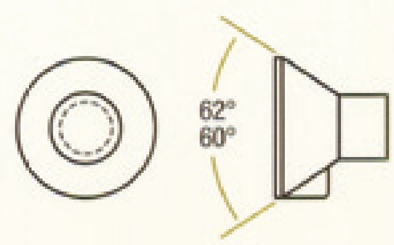


T-Head Bolt

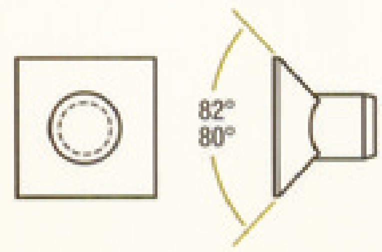
FASTENER VISUALS™
HEAD STYLES PART 3



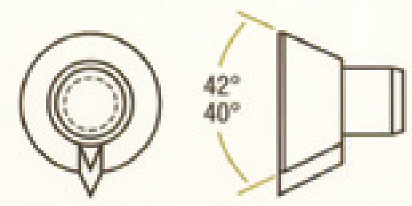
No. 3 Head Plow Bolt
(Round, Countersunk, Square Neck)



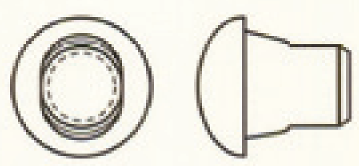
No. 7 Head Plow Bolt
(Round, Countersunk, Reverse Key)



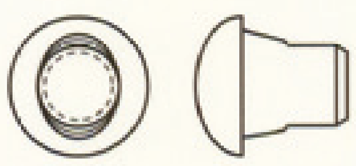
No. 4 Repair Head Plow Bolt
(Square Head, Countersunk)



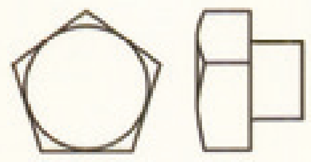
No. 6 Repair Head Plow Bolt
(Round, Countersunk, Heavy Key)



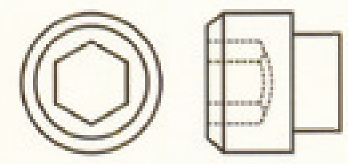
Oval Neck Track Bolt



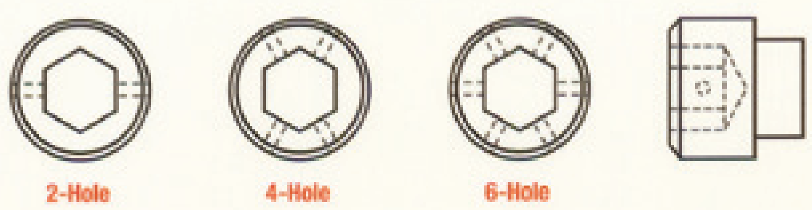
Elliptic Neck Track Bolt



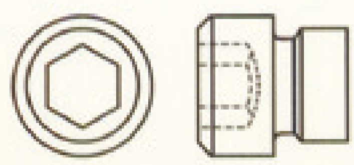
Penta Head



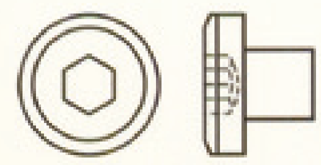
Hex Socket Head Cap Screw



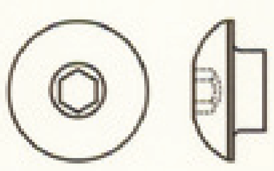
Socket Cap Screw Drilled Head



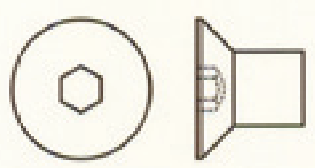
Hex Socket Head Shoulder Screw
(Stripper Bolt)



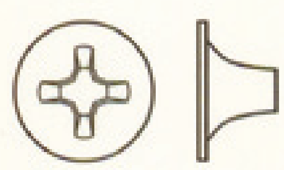
Hex Socket Low Head Cap Screw



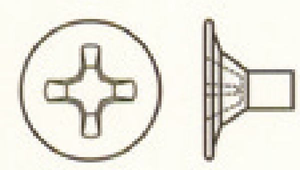
Hex Socket Button Head Cap Screw



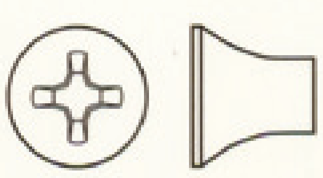
Hex Socket Flat Head Cap Screw



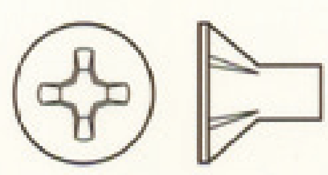
Bugle Head
(Cross Recessed)



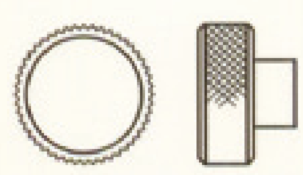
Wafer Head
(Cross Recessed)



Trim Head
(Cross Recessed)



Self-sinking Head
(Cross Recessed)

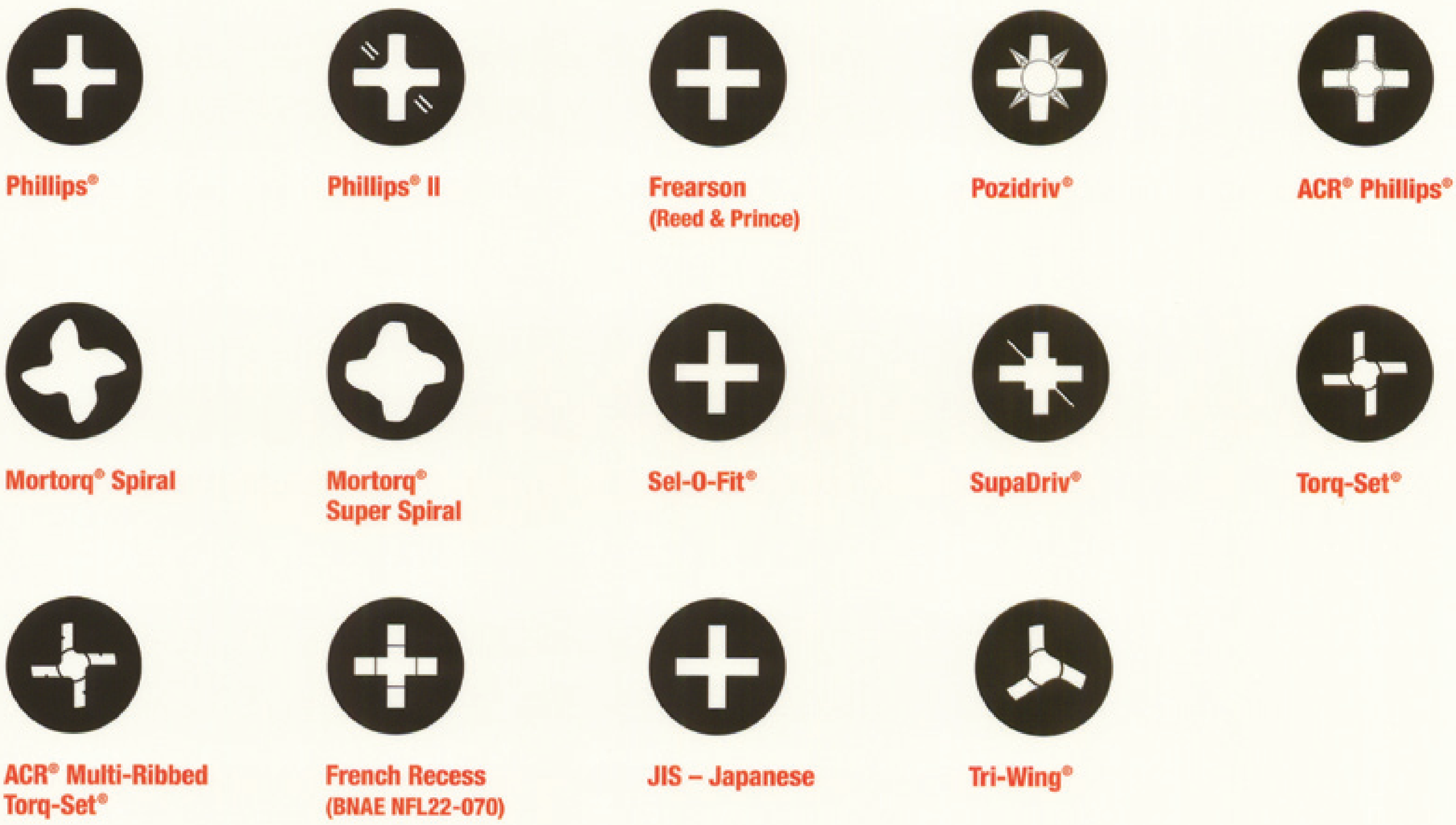


Knurled Head Thumb Screw

FASTENER VISUALS™
HEAD DRIVES / DRIVE RECESSES PART 1

Slotted Types

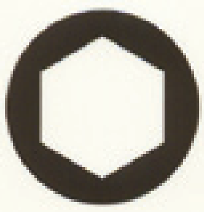
Cruciform Types

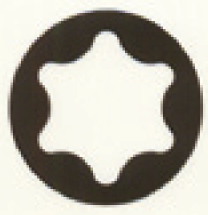


External Drives

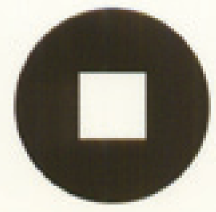
FASTENER VISUALS™
HEAD DRIVES / DRIVE RECESSES PART 2

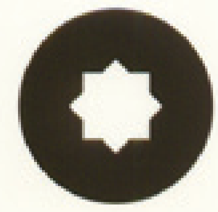
Socket Recess

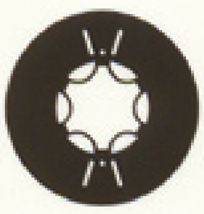

Hex Socket (Allen® Head)

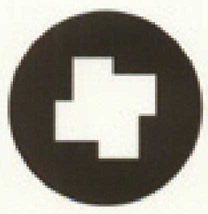

Torx® Drive


Torx® Plus

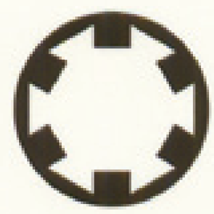

Robertson® Drive

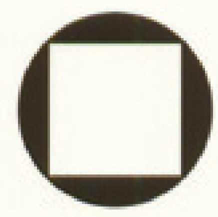

Scrulox® 8 (Double Square)


Hexstix®


LOX®


Uni-Screw®

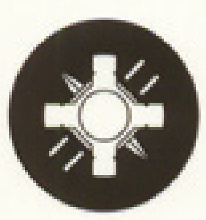

Bristol 6-Spline Drive

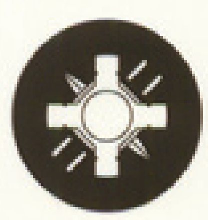

Pipe Plug Square Insert


Clutch

Combination Drives (Combo Head)

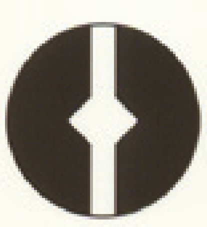

Quadrex®


Phillips® Square-Driv®

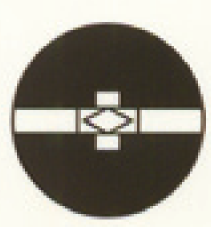

Pozisquare® Driv

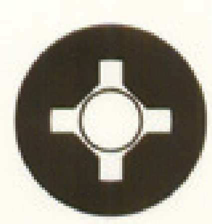

Phillips® Hex


Hex Slotted



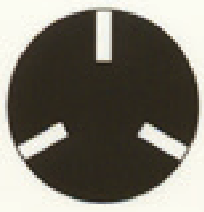
Square Slotted (2 variations)


Phillips® Slotted


Recex®

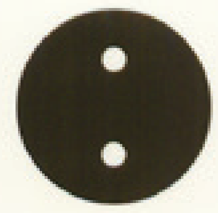
FASTENER VISUALS™
HEAD DRIVES / DRIVE RECESSES PART 3

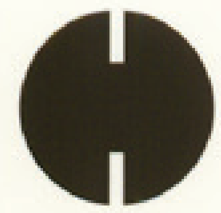
Tamper-Resistant


Holt® Head


One-Way Slot


Penta-Plus™

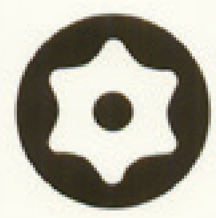

Spanner "Snake Eyes"

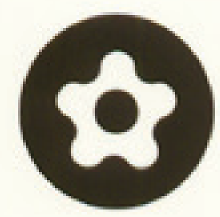

Notched Spanner

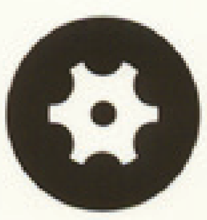

Tri-Wing® Security

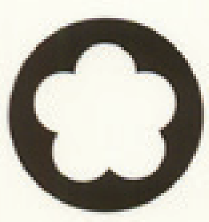

Hex-Pin™


Phillips®/Cross


Tamper Pin Security


Torx-Plus® Security
(5 lobe)


Tam-6-Lobe™


Pentalobe


Clutch Slot Security


Opsit® Security

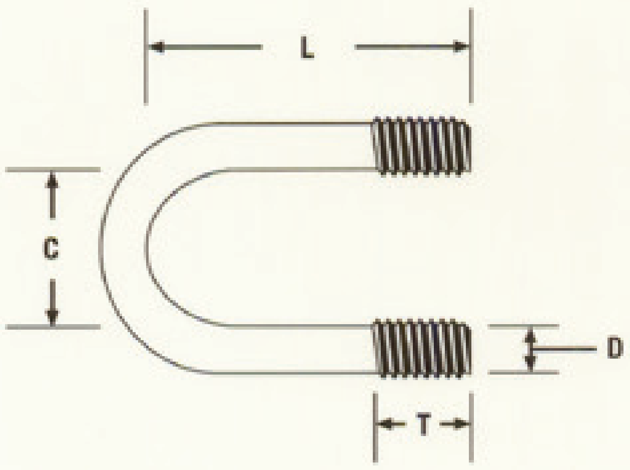

Keyed-Lok® Security


Key-Rex™

Tamper-resistant screws are used for security purposes. The head of this type of screw is difficult to reverse. It requires special tools or mechanisms like spanners, tri-wings, torxes, square drivers, etc. In some screws, the head can be removed by breaking it off after installation.

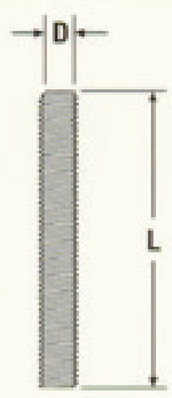
STANDARD SIZE U-BOLTS & MEASURING STUDS & BENT BOLTS

TYPE 137 STANDARD PIPE SIZE U-BOLTS

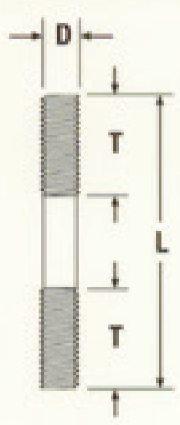


Pipe Size	DIMENSIONS D	C	L	T	Approx. Wt. Per 100 (low carbon)
1/2"	1/4"	1-5/16"	3-1/4"	2-3/8"	7.4
3/4"	1/4"	1-1/8"	3-5/16"	2-3/8"	7.7
1"	1/4"	1-1/8"	3-7/16"	2-3/8"	8.1
1/3"	3/8"	1-5/16"	3-1/4"	2-3/8"	19.0
3/4"	3/8"	1-1/8"	3-5/16"	2-3/8"	19.7
1"	3/8"	1-3/8"	3-7/16"	2-3/8"	21.0
1-1/4"	3/8"	1-11/16"	3-3/4"	2-3/8"	22.5
1-1/2"	3/8"	2"	4"	2-1/2"	24.3
2"	3/8"	2-7/16"	4-1/2"	2-1/2"	27.3
2-1/2"	1/2"	2-15/16"	5-1/4"	3"	57.3
3"	1/2"	3-9/16"	5-13/16"	3"	63.5
3-1/2"	1/2"	4-1/16"	6-5/16"	3"	69.4
4"	1/2"	4-9/16"	6-13/16"	3"	74.9
5"	1/2"	5-5/8"	7-13/16"	3"	86.7
6"	5/8"	6-3/4"	9-1/2"	3-3/4"	162.0
8"	5/8"	8-3/4"	11-1/2"	3-3/4"	200.4
10"	5/8"	10-7/8"	13-13/16"	4"	364.6
12"	7/8"	12-7/8"	16-1/16"	4-1/4"	561.7
14"	7/8"	14-1/8"	17-5/16"	4-1/4"	618.8
16"	7/8"	16-1/8"	19-5/16"	4-1/4"	676.6
18"	1"	18-1/8"	21-11/16"	4-3/4"	1040.0
20"	1"	20-1/8"	23-11/16"	4-3/4"	1130.0
24"	1"	24-1/8"	27-11/16"	4-3/4"	1330.0
30"	1"	30-1/8"	33-11/16"	4-3/4"	1620.0
36"	1"	36-1/8"	39-11/16"	4-3/4"	1900.0

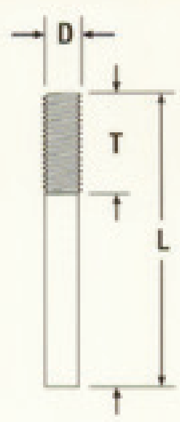
HOW TO MEASURE STUDS AND BENT BOLTS



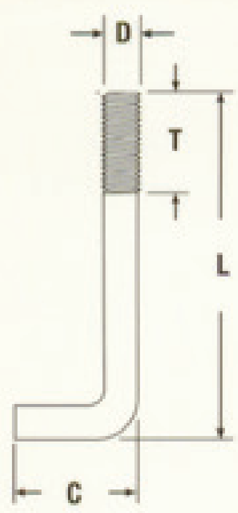
(D x L)
All Thread Stud



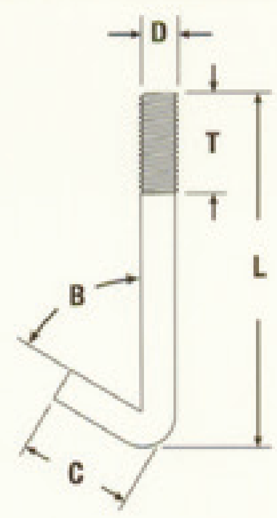
(D x L x T x T)
Double End
Stud



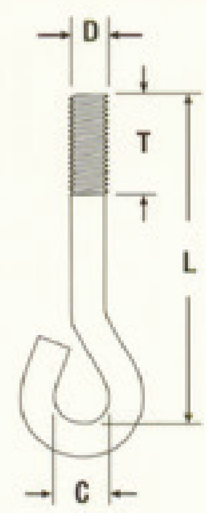
(D x L x T)
Single End
Stud



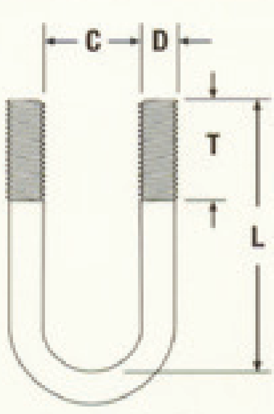
(D x L x C x T)
Anchor Bolt



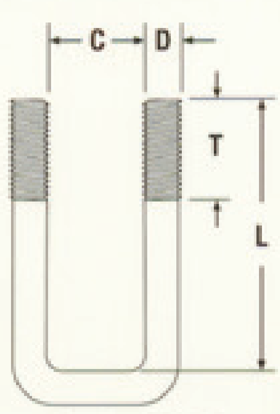
(D x L x C x B x T)
Hook Bolt
B = Degrees



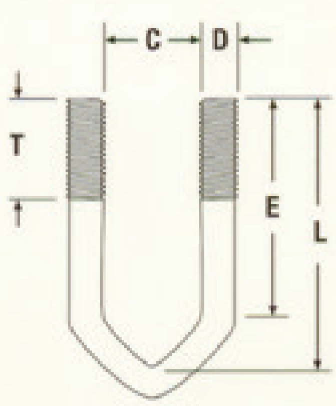
(D x L x C x T)
Eye-Bolt



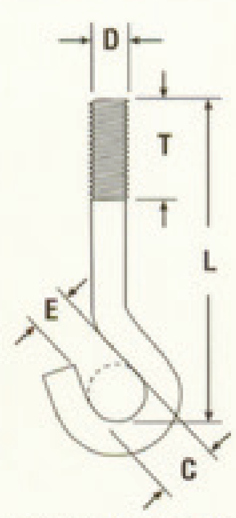
(D x L x C x T)
U-Bolt



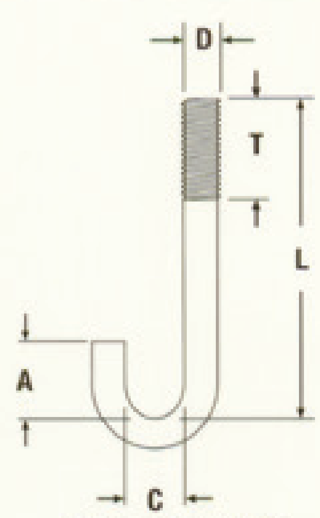
(D x L x C x T)
Square Bend
U-Bolt



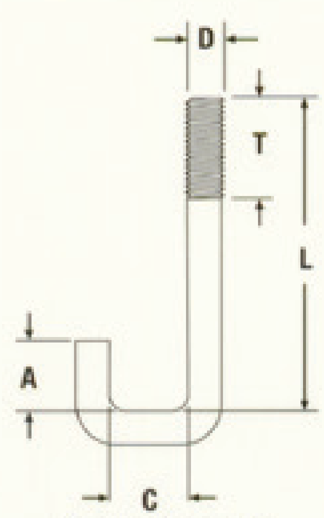
(D x L x C x E x T)
V-Bolt



(D x L x C x E x T)
Bent J-Bolt



(D x L x C x A x T)
J-Bolt



(D x L x C x A x T)
Square Bend
J-Bolt

FASTENER ABBREVIATIONS

18-8	Stainless steel with 18% chrome and 8% nickel, also known as 304 stainless steel
2, 5 or 8	Strength grade of hex head cap screws and nuts
2A (3A)	Class of thread fit for inch screws
2B (3B)	Class of thread fit for inch nuts
2H	Nut strength level designation (ASTM A194 Grade 2H Heavy Hex Nuts)
17	Type 17 screw point
17-4 PH	Martensitic stainless steel alloy
2024 – T4	Aluminum alloy used on fasteners
302 – 304	Common grades of stainless steel fasteners
316	Grade of stainless steel used for fasteners
410	Grade of stainless steel used for fasteners
6g	Class of thread fit for metric screws
6H	Class of thread fit for metric nuts
6061 – T6	Aluminum alloy used on fasteners
6262 – T9	Aluminum alloy used on fasteners
7075 – T73	Aluminum alloy used on Fasteners
A193	ASTM spec for alloy steel and stainless for bolts, high pressure and high temperature
A194	ASTM spec for carbon and alloy steel for nuts, high pressure and high temperature
A286	Incoloy® Alloy
A307	ASTM spec for carbon steel bolts and studs
A325	ASTM spec for structural bolts
A490	ASTM spec for structural bolts
A563	ASTM spec for carbon and alloy steel nuts
A	Type "A" tapping screw
AB	Type "AB" tapping screw
ABS	Class of plastic material – based on acrylonitrile-butadiene-styrene copolymers
AISI	American Iron and Steel Institute, specifies chemical composition of steel
ALU	Aluminum material, specify type (ex: 6061-T6)
AN	Precedes a dimensional specification for aircraft fasteners developed by ASG
ANSI	American National Standards Institute
AS	Alloy steel
ASME	American Society of Mechanical Engineers
ASTM	American Society of Testing and Materials
B	When followed by a number (ex: B-90) hardness measured on the Rockwell B Scale, or an abbreviation for Type "B" tapping screws, or an abbreviation for boron
Bake	Heat treat process used in plating to prevent hydrogen embrittlement
BF	Type BF thread former/cutter
BHN	Hardness measured with a Brinell Hardness Tester
BHSC	Button head socket cap screw
BHT	Button head Torx® socket cap screw
Bind	Binding head
Bl Ox	Black oxide
BR	Brass material
BRZ	Bronze material
BS	British Standard
BSF	British Standard fine thread
BSW	British Standard Whitworth thread
BT	Bolt (on drawings)
C	When followed by a number (ex: C-35) hardness measured on the Rockwell C Scale, or an abbreviation for carbon steel, stands for national coarse thread and Type C Screw T/F
CB	Carriage bolt
CH	Case hardened (type of heat treatment)
CL	Class (metric material/strength specifications)
CP	Cotter pin
C/R	Cross recess drive (i.e., Phillips drive) or chamfer/radius
Cad	Cadmium plating
CAD	Computer-aided design/drafting
Cad/Wax	Cadmium plating with a topcoat of wax
CARR	Carriage bolt(s)
COO	Country of origin
CPR	Copper material
CR	Chrome
CRS	Cold rolled/drawn/finished steel, 1008-1020 unless specified
CRES	Corrosion resistant steel (usually refers to 18-8 or 316 stainless steel)
CS	Countersunk screw or carbon steel
CSL	Castle hex nuts
CT	Coarse thread
D	Type D or Type 1 thread former/cutter
DAC (Dac 320)	Dacromet coating
D/C	Double chamfered nut (distinguished from a washer face)
D/E	Double end stud
Dia.	Diameter
Dich	Di-Chromate
DIN	German Standards Organization
Dri-Seal	Pipe thread
ET	External thread
EXT	External tooth lock washers
F	Type F thread former/cutter
F436	Hardened flat washer with dimensions per ASTM F436
F844	Unhardened, general purpose flat washers
FB	Flange bolt
FBS	Floorboard screws
FH	Flat head
FHCS	Flat head cap screw
FHSC	Flat head socket cap screw
Fil	Fillister head
Flng	Hex flange bolt or nut
Fndr	Fender washer
FT	Fine thread
FTI	Fastener Training Institute
F/T	Fully threaded (i.e., stud)
FW	Flat washer
G	Grade
Galv (Galvi)	Galvanized, typically hot dipped galvanized
Gr.	Grade, refers to strength level of hex head screws and/or nuts (i.e., Gr. 5, Gr. 8)
Hardened	A product that has been heat treated
HB	Hex bolt, or hardness reading measured on the Brinell Scale
HD	Head
H.T.	Heat treated
HCS	Hex head cap screw
H.D.G.	Hot dipped galvanized
HHCS	Hex head cap screws
HHMB	Hex head machine bolt
HRB	Hardness measured on the Rockwell B Scale
HRC	Hardness measured on the Rockwell C Scale
HVHX	Heavy hex head bolt
HWH	Hex washer head
HWHS	Hex washer head, slotted
HX	Hex
IFI	Industrial Fastener Institute
IH; (Ind Hex)	Indented hex
In.	Inch
INT	Internal tooth lock washer
Int/Ext	Internal tooth and external tooth lock washer
ISO	International Standards Organization
ISIR	Initial sample inspection report
IT	Internal thread
J429	SAE Standard that specifies mechanical and material requirements for externally threaded fasteners
J995	SAE Standard that specifies mechanical and material requirements for steel nuts
JMNT	Jam nut
K	Short hand for the number 1,000 *(see M)*
ksi	1,000 pounds per square inch
lbs	Pounds
LB	Body length of screws or lag bolt
LCS	Low carbon steel
LG	Grip length (distance from head to full threads) on screws
LH	Left hand thread
L/W	Lock washer
M	Metric or short hand for the number 1,000 *(see K)*
MAFDA	Mid-Atlantic Fastener Distributors Association
MB	Machine bolt
Mfg	Manufacturer
MFDA	Metropolitan Fastener Distributors Association
mm	Millimeter
Mod.	Modified
MS	Machine screw
MSNT	Machine screw nut
MTR	Material test report
MWFA	Mid-West Fastener Association
NC	United National coarse thread
NCFA	North Coast Fastener Association
NE (NU, NTE, NTU)	Designations that define the thickness of nylon insert lock nuts
NEFDA	New England Fastener Distributors Association
NF	United National fine thread
NFDA	National Fastener Distributors Association
Nom	Nominal reference to dimensions
NPT	National tapered pipe thread
NT; (& NT)	Nut; or the fastener must include a nut
OH; (OV)	Oval head
P	Thread pitch
Pac-West	Pacific-West Fastener Association
P/B	Plow bolt
PH	Phillips head (drive recess)
Phil	Phillips drive
Pl	Plain finish
PN	Pan head
P/N	Part number
Phos (P & O)	Phosphate and oil coating (typically zinc phosphate and oil)
Pozidriv®	Special cross recess drive (registered trademark of Camcar Textron)
PPAP	Production part approval process
psi	Pounds per square inch
PT	Partial thread or point
PZ	Pozidriv® style of cross recess (registered trademark of Camcar Textron)
R	Radius
RD	Round head or right hand thread
RT	Rolled threads
S	Slotted
SAE	Society of Automotive Engineers; used for "small" OD on washers; and fine thread
SBR	Silicon bronze
Sc	Screw
SD	Square drive
SEFA	Southeastern Fastener Association
SHCS	Socket head cap screws
Skt	Socket
SL; (Slot)	Slotted drive recess
SMS	Sheet metal screws
SPL	"Special"
Sq	Square, can refer to head or nut
Std	Standard
STRIP	Stripper bolt (socket shoulder screw)
SS; S/S	Stainless steel
SSS	Socket set screws
STFDA	Specialty Tools & Fastener Distributors Association
STL; (st)	Steel
SWFA	Southwestern Fastener Association
TB	Tab bolt
T/C	Thread cutter
T/F	Thread former
T.H.	Through hardened (type of heat treatment)
Ti	Titanium
TIR	Total indicator reading
T/S	Tapping screws
TPI	Threads per inch
TT; (TR)	Taptite® thread (Reminc), tri-roundular or truss head
TTH	Threaded to the head
Type 1 (23, 25)	Thread cutting or thread forming screws
Type AB (F, T)	Thread cutting or thread forming screws
U	Type U thread former/cutter
U/C FL	Undercut flat head
UNC	United National coarse thread
UNRC	United National coarse thread with radius root (standard rolled thread form)
UNF	United National fine thread
UNFR	United National fine thread with radius root (standard rolled thread form)
UNJ	United National thread with large radius root (special fatigue resistant thread)
UNR	United National thread with radius root
USS	United States Standard; used on "large" OD washers
UTS	Ultimate tensile strength
WAC	Width across corners, measurement used on nuts, bolts and screw heads
WAF	Width across corners, measurement used on nuts, bolts and screw heads
W/F	Washer face (often refers to hex head cap screws and hex nuts)
W/N	With nuts
Wng	Wing nuts or screws
W/O	Without, i.e., nuts or washers
WS	Wood screws
YS	Yield Strength
Zn	Zinc, usually referring to zinc plating (assumed to be zinc with clear chromate)
Zn/C (ZC)	Zinc plating with clear chromate topcoat
Zn Phos	Zinc phosphate and oil *(same as Phos, P & O)*
Zn/Wax	Zinc plating with a topcoat of wax
ZN/Y (ZY)	Zinc plating with yellow chromate topcoat