CHAPTER 21
THREADED FASTENERS

Joseph E. Shigley
Professor Emeritus
The University of Michigan
Ann Arbor, Michigan

This chapter is intended to cover the description, uses, materials, and sizes of threaded fasteners. The amount of data available concerning this subject is extremely large, so the intent here is to provide the information necessary for the usual machine-design task of selecting such fasteners. The data contained in this chapter have been compiled in part from the standards listed in Ref. [21.1].

21.1 SCREW THREADS

Standard screw threads consist of the *Unified inch series* and the *metric series.* Two profiles have been standardized in the metric series; these are called the M and MJ profiles. Figure 21.1 shows that both the Unified and metric M threads utilize the same profile.

The metric MJ profile has a rounded fillet at the root of the external thread and a larger minor diameter of both the internal and external threads. This profile is used for applications requiring a high fatigue strength and is also employed in aerospace applications.

The Unified-series profile, shown in Fig. 21.1, is designated as UN. Another unified profile, designated as UNR, has a rounded root on the external thread.

Unified thread standards are based on the nominal size (major diameter) and the number of threads per inch. The three standards *coarse* (UNC), *fine* (UNF), and *extra fine* (UNEF) are listed in Table 21.1 and are called the *standard series.* Typical specifications would be written

¼–20 UNC or ¼–20 UNRC

Both these designations specify a nominal size of ¼ in and 20 threads per inch.

A *constant-pitch* unified series consisting of 4, 6, 8, 12, 16, 20, 28, and 32 threads per inch has also been standardized. These are used mostly for sizes over 1 in, and 8 UN, 12 UN, and 16 UN are the preferred pitches.

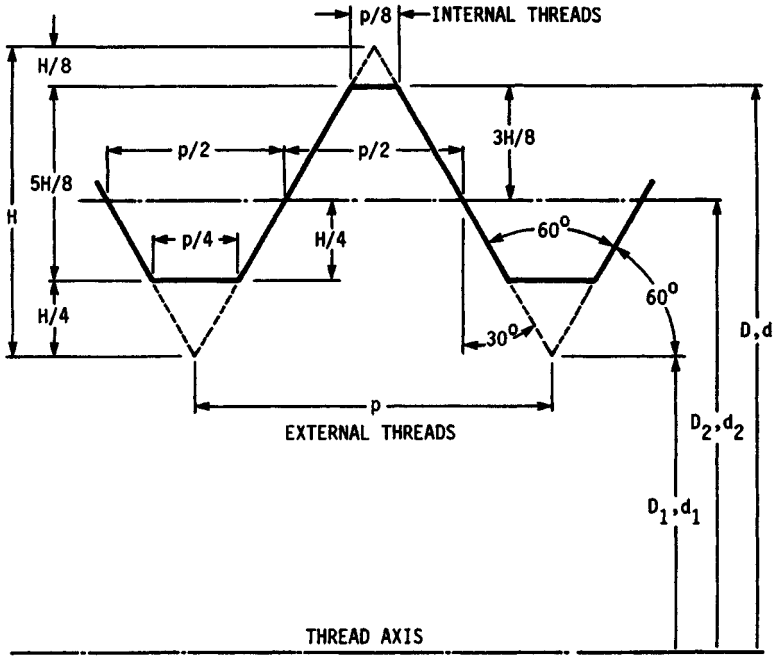


FIGURE 21.1 Basic thread profile for unified (UN) and metric (M) threads (ISO 68). $D(d)$ = basic major diameter of internal (external) thread; $D_1(d_1)$ = basic minor diameter of internal (external) thread; $D_2(d_2)$ = basic pitch diameter of internal (external) thread; p = pitch; $H = 0.5\sqrt{3}p$.

As shown in Table 21.2, the metric series consists of a coarse thread and, often, several fine threads. These are specified by giving the size or major diameter and the pitch (see Fig. 21.1). Typical specifications would be written

$$\text{M } 70 \times 1.5 \qquad \text{or} \qquad \text{MJ } 70 \times 1.5$$

which specifies a major diameter of 70 mm and a pitch of 1.5 mm.

Unified threads may be further designated as UN A for external threads and UN B for internal threads. The tolerance classes are 1A, 2A, and 3A for external threads and 1B, 2B, and 3B for internal threads. Class 2 is for general use, class 3 is a tight fit used where great accuracy is required, and class 1 is a loose fit which permits very easy assembly and allows the possibility of nicks on the threads.

Metric threads utilize the international tolerance grades (see Chap. 19).

21.1.1 Choosing the Pitch

The Unified coarse-thread series (UNC or UNRC) and the metric coarse-thread series (M or MJ) provide the most resistance to internal thread stripping. Consequently, coarse threads should be used for materials such as brass, cast iron, aluminum, and other lower-strength materials. However, the coarse-thread series are

TABLE 21.1 Standard Series of UN and UNR Screw Threads†

Nominal size	Basic major diameter	Threads per inch		
		Coarse, UNC	Fine, UNF	Extra-fine, UNEF
0	0.0600		80	
1	0.0730	64	72	
2	0.0860	56	64	
3	0.0990	48	56	
4	0.1120	40	48	
5	0.1250	40	44	
6	0.1380	32	40	
8	0.1640	32	36	
10	0.1900	24	32	
12	0.2160	24	28	32
1/4	0.2500	20	28	32
5/16	0.3125	18	24	32
3/8	0.3750	16	24	32
7/16	0.4375	14	20	28
1/2	0.500	13	20	28
9/16	0.5625	12	18	24
5/8	0.6250	11	18	24
3/4	0.7500	10	16	20
7/8	0.8750	9	14	20
1	1.0000	8	12	20
1 1/8	1.1250	7	12	18
1 1/4	1.2500	7	12	18
1 3/8	1.3750	6	12	18
1 1/2	1.5000	6	12	18

†All dimensions in inches.

TABLE 21.2 Standard Diameter-Pitch Combinations for Metric M Screw Threads†

Basic major diameter			Pitch	
Preferred	First option	Second option	Coarse	Fine
1.6	...	...	0.35	
2	...	...	0.4	
2.5	...	...	0.45	
3	...	...	0.5	
	3.5	...	0.6	
4	...	...	0.7	
5	...	...	0.8	
6	...	...	1	

TABLE 21.2 Standard Diameter-Pitch Combinations for Metric M Screw Threads† (*Continued*)

Basic major diameter			Pitch	
Preferred	First option	Second option	Coarse	Fine
8	...	...	1.25	1
10	...	...	1.5	1.25 or 0.75
12	...	...	1.75	1.25 or 1
	14	...	2	1.5 or 1.25‡
	15	...	...	1
16	...	...	2	1.5
	...	17	...	1
	18	...	...	1.5
20	...	...	2.5	1.5 or 1
	22	...	2.5§	1.5
24	...	...	3	2
	...	25	...	1.5
	27	...	3¶	2
30	...	...	3.5	2 or 0.5
	33	...	...	2
	...	35¶	...	1.5
36	...	...	4	2
	39	...	...	2
	...	40	...	1.5
42	...	...	4.5	2
	45	...	...	1.5
48	...	...	5	2
	...	50	...	1.5
	...	55	...	1.5
56	...	...	5.5	2
	60	...	...	1.5
64	...	...	6	2
	...	65	...	1.5
	...	70	...	1.5
72	...	...	6	2
	...	75	...	1.5
80	...	...	6	1.5
	85	...	...	2
90	...	...	6	2
	95	...	...	2
100	...	...	6	2
	105	...	...	2
110	...	...	...	2
	120	...	...	2
	130	...	...	2
140	...	...	...	2
	150	...	...	2
160	...	...	...	3
	170	...	...	3
180	...	...	...	3
	190	...	...	3
200	...	...	...	3

†All dimensions in millimeters.
‡Only for engine spark plugs.
§Only for high-strength structural steel bolts.
¶Only for nuts for bearings.

also widely used with other materials because mass-produced fasteners are usually made with coarse threads and hence are the most economical. The coarse-thread series should also be used whenever fast assembly is needed or when dropping or handling the fasteners may damage the threads by causing nicks or dents.

The Unified fine-thread series (UNF or UNRF) and metric fine-thread series (M and MJ) find their greatest use where a high fastener strength is required and where vibration may be a problem. The shallow depth of thread, and hence larger minor diameter, increases the strength of the external member. It also permits a smaller wall thickness for the internal member.

Extra-fine-series screw threads are useful for thin nuts, on thin-wall tubing, and where parts may require a very fine adjustment.

21.1.2 Pipe Threads

The profile of pipe threads is similar to the UN profile except that there is a taper of 1 on 16 based on the outside diameter. The last few threads will be imperfect because of the taper and the chamfer on the thread-cutting die. Table 21.3 gives the basic dimensions of Unified-inch-series standard pipe threads.

21.2 BOLTS

The symbols used to indicate the dimensions of square and hex bolt heads are shown in Fig. 21.2. See Table 21.4 for head dimensions. The washer or bearing face shown in Fig. 21.2*b* is standard for the *heavy structural hex bolt* (Table 21.4) and for the *finished hex bolt.* A finished hex bolt is identical to a hex cap screw (see Table 21.13). The basic thread length for bolts is

$$L_T = \begin{cases} 2D + 0.25 & L \le 6 \\ 2D + 0.50 & L > 6 \end{cases} \tag{21.1}$$

TABLE 21.3 Basic Dimensions of Standard Pipe Threads†

Nominal pipe size	Outside diameter	Threads per inch	Thread length on OD (approx.)
$\frac{1}{16}$	0.3125	27	0.261
$\frac{1}{8}$	0.405	27	0.264
$\frac{1}{4}$	0.540	18	0.402
$\frac{3}{8}$	0.675	18	0.408
$\frac{1}{2}$	0.840	14	0.534
$\frac{3}{4}$	1.050	14	0.546
1	1.315	$11\frac{1}{2}$	0.683
$1\frac{1}{4}$	1.660	$11\frac{1}{2}$	0.707
$1\frac{1}{2}$	1.900	$11\frac{1}{2}$	0.723
2	2.375	$11\frac{1}{2}$	0.757
$2\frac{1}{2}$	2.875	8	1.138
Over $2\frac{1}{2}$	.....	8	

†All dimensions in inches.

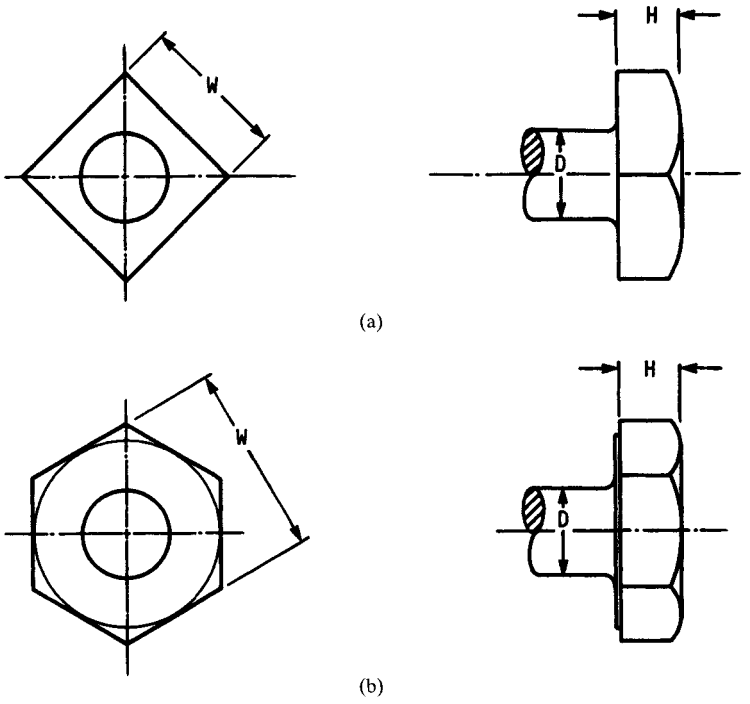


FIGURE 21.2 Bolt heads. (*a*) Square; (*b*) hex; the washer or bearing face is used only on heavy hex structural bolts.

where L = bolt length, measured under the head, and L_T = thread length, in inches.

Head dimensions for metric hex bolts are listed in Table 21.5. The heavy hex structural bolt is the only one of these with a bearing face. The thread length is

$$L_T = \begin{cases} 2D + 6 & L \le 125 \quad D \le 48 \\ 2D + 12 & 125 \le L \le 200 \\ 2D + 25 & L > 200 \end{cases} \tag{21.2}$$

Here L and L_T are in millimeters.

Standards for bolt materials and the corresponding head markings are listed in Tables 21.6, 21.7, and 21.8. The property class number in Table 21.8 is a code derived from the tensile strength S_{ut} and the yield strength S_y. If we designate the class number by the symbol $X.Y$, then $X = S_{ut}/100$ and $Y = S_y/S_{ut}$. Bolts in metric sizes are normally manufactured to SAE and ASTM specifications too. For fillet dimensions, see Tables 21.9 and 21.10.

Typical heads for *round-head* or *carriage bolts* are shown in Fig. 21.3, and head dimensions are given in Tables 21.11 and 21.12. Other standard bolts are step bolts, which have a square neck with a larger-diameter head, and several countersunk-head bolts with and without square necks. The bolts listed in Table 21.12 are the only round-head metric bolts that are standardized at this writing. Round-head bolts are made to the same material specifications as hex bolts and use the same head markings.

TABLE 21.4 Dimensions of Square- and Hex-Head Bolts (Inch Series)

Nominal size	Head type							
	Square		Regular hex†		Heavy hex‡		Structural hex	
	W	*H*	*W*	*H*	*W*	*H*	*W*	*H*
1/4	3/8	11/64	7/16	11/64				
5/16	1/2	13/64	1/2	7/32				
3/8	9/16	1/4	9/16	1/4				
7/16	5/8	19/64	5/8	19/64				
1/2	3/4	21/64	3/4	11/32	7/8	11/32	7/8	5/16
5/8	15/16	27/64	15/16	27/64	1 1/16	27/64	1 1/16	25/64
3/4	1 1/8	1/2	1 1/8	1/2	1 1/4	1/2	1 1/4	15/32
7/8	1 5/16	19/32	1 5/16	27/64	1 7/16	27/64	1 7/16	25/64
1	1 1/2	21/32	1 1/2	43/64	1 5/8	43/64	1 5/8	29/64
1 1/8	1 11/16	3/4	1 11/16	3/4	1 13/16	3/4	1 13/16	11/16
1 1/4	1 7/8	27/32	1 7/8	27/32	2	27/32	2	25/32
1 3/8	2 1/16	29/32	2 1/16	29/32	2 1/16	29/32	2 3/16	27/32
1 1/2	2 1/4	1	2 1/4	1	2 3/8	1	2 3/8	15/16

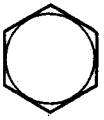
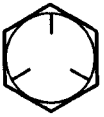
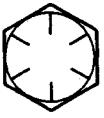
†Also available in standard sizes up to 4 in.
‡Also available in standard sizes up to 3 in.

TABLE 21.5 Dimensions of Metric Hex Bolts (Metric Series)†

Nominal diameter	Thread pitch	Type of bolt					
		Regular‡		Heavy		Structural	
		W	*H*	*W*	*H*	*W*	*H*
M5	0.8	8	3.58				
M6	1	10	4.38				
M8	1.25	13	5.68				
M10	1.5	16	6.85				
M12	1.75	18	7.95	21	7.95		
M14	2	21	9.25	24	9.25		
M16	2	24	10.75	27	10.75	27	10.75
M20	2.5	30	13.40	34	13.40	34	13.40
M22	2.5	..	....	..	....	36	14.90
M24	3	36	15.90	41	15.90	41	15.90
M27	3	..	....	..	....	46	17.90
M30	3.5	46	19.75	50	19.75	50	19.75
M36	4	55	23.55	60	23.55	60	23.55

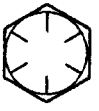
†Head dimensions are maximum. All dimensions in millimeters.
‡Also available in standard sizes to 100 mm.

TABLE 21.6 SAE Grade Markings for Steel Bolts

SAE grade no.	Size range incl.	Proof strength,† kpsi	Tensile strength,† kpsi	Material	Head marking
1	¼–1½			Low- or medium-carbon steel	
2	¼–¾	55	74		
	⅞–1½	33	60		
5	¼–1	85	120	Medium-carbon steel, Q & T	
	1⅛–1½	74	105		
5.2	¼–1	85	120	Low-carbon martensite steel, Q & T	
7	¼–1½	105	133	Medium-carbon alloy steel, Q & T‡	
8	¼–1½	120	150	Medium-carbon alloy steel, Q & T	
8.2	¼–1	120	150	Low-carbon martensite steel, Q & T	

†Minimum values.
‡Roll threaded after heat treatment.
SOURCES: See "Helpful Hints," by Russell, Burdsall & Ward Corp., Mentor, Ohio 44060; and Chap. 23.

TABLE 21.7 ASTM Grade Markings for Steel Bolts

ASTM designation	Size range incl.	Proof strength,† kpsi	Tensile strength,† kpsi	Material	Head marking
A307	¼ to 4			Low-carbon steel	
A325 type 1	½ to 1 1⅛ to 1½	85 74	120 105	Medium-carbon steel, Q & T	
A325 type 2	½ to 1 1⅛ to 1½	85 74	120 105	Low-carbon martensite steel, Q & T	
A325 type 3	½ to 1 1⅛ to 1½	85 74	120 105	Weathering steel, Q & T	
A354 grade BC				Alloy steel, Q & T	
A354 grade BD	¼ to 4	120	150	Alloy steel, Q & T	
A449	¼ to 1 1⅛ to 1½ 1¾ to 3	85 74 55	120 105 90	Medium-carbon steel, Q & T	
A490 type 1	½ to 1½	120	150	Alloy steel, Q & T	
A490 type 3				Weathering steel, Q & T	

†Minimum values.

SOURCES: See "Helpful Hints," by Russell, Burdsall & Ward Corp., Mentor, Ohio 44060; and Chap. 23.

TABLE 21.8 Metric Mechanical-Property Classes for Steel Bolts, Screws, and Studs

Property class	Size range incl.	Proof strength, MPa	Tensile strength, MPa	Material	Head marking
4.6	M5–M36	225	400	Low- or medium-carbon steel	
4.8	M1.6–M16	310	420	Low- or medium-carbon steel	
5.8	M5–M24	380	520	Low- or medium-carbon steel	
8.8	M16–M36	600	830	Medium-carbon steel, Q & T	
9.8	M1.6–M16	650	900	Medium-carbon steel, Q & T	
10.9	M5–M36	830	1040	Low-carbon martensite steel, Q & T	
12.9	M1.6–M36	970	1220	Alloy steel, Q & T	

SOURCES: "Helpful Hints," by Russell, Burdsall & Ward Corp., Mentor, Ohio 44060; see also Chap. 23 and SAE standard J1199, and ASTM standard F568.

TABLE 21.9 Under-the-Head Fillet Radii for Hex Bolts (Inch Series)

	Regular and heavy		Heavy structural	
Size	Maximum	Minimum	Maximum	Minimum
¼–½	0.03	0.01	0.031	0.009
⅝–⅞	0.06	0.02	0.062	0.021
1–1½	0.09	0.03	0.093	0.062

TABLE 21.10 Under-the-Head Fillet Radii for Hex Bolts (Metric Series)†

Size	Regular and heavy (min.)	Heavy structural (min.)
M5	0.2	
M6	0.3	
M8–M10	0.4	
M12–M16	0.6	0.6
M20–M22	0.8	0.8
M24	0.8	1.0
M27	. .	1.2
M30	1.0	1.2
M36	1.0	1.5

†All dimensions in millimeters.

21.3 SCREWS

21.3.1 Hexagon Head

Hex screw heads resemble those shown in Fig. 21.2*b*, and they all have a washer or bearing face. Basic dimensions of the *cap screw* and the *heavy screw* in the inch series are given in Table 21.13. Three metric series are standardized. These are the *cap screw,* the *formed screw,* which has an indentation in the head, and the *heavy screw;* see Table 21.14 for basic dimensions of these. Hex screws are made to the same material specifications as bolts and utilize the same head markings (see Tables 21.6, 21.7, and 21.8). Use Eq. (21.1) or (21.2) to determine the basic length of thread.

21.3.2 Sockets and Keys

Figure 21.4 illustrates the standard hex and spline socket, and the products in Fig. 21.5 illustrate the variety. Socket screws are driven with a socket key, as in Fig. 21.4*c,* or with a length of hex or spline stock, called a *bit.* The bit is used for driving by inserting it into a standard socket wrench or power driver. Dimensions of standard keys are given in Tables 21.15, 21.16, and 21.17. Metric splines have not as yet been standardized.

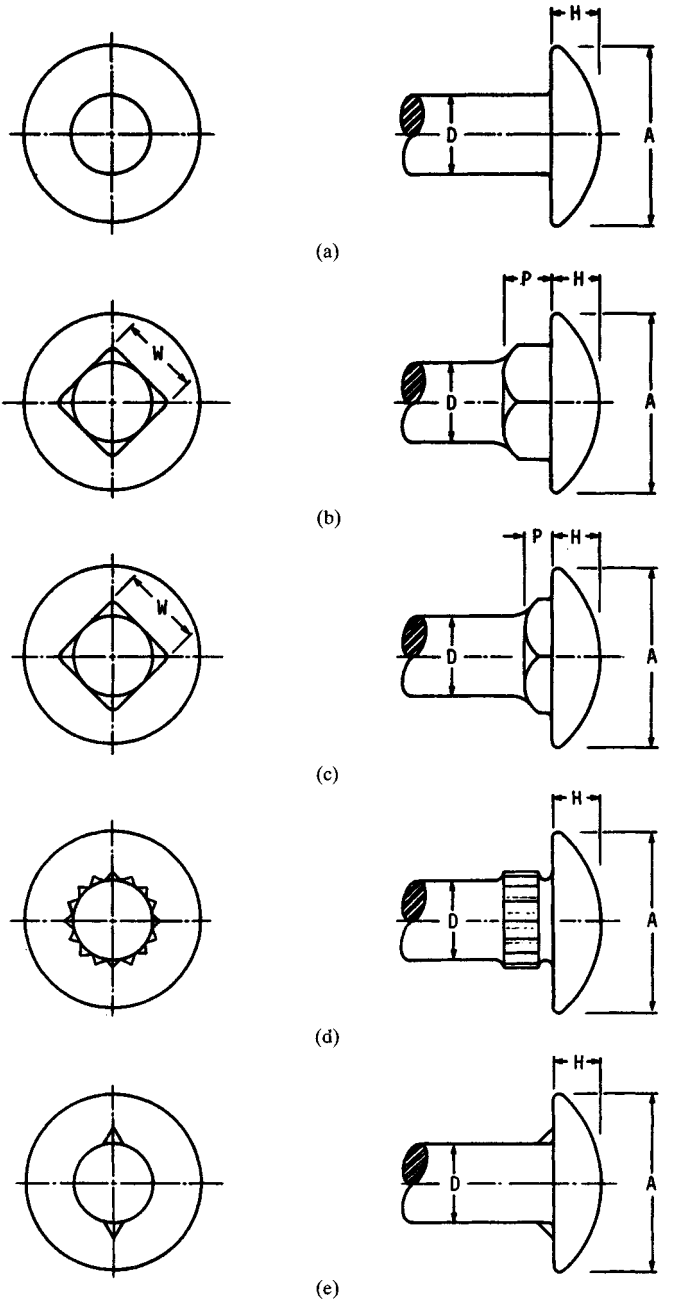


FIGURE 21.3 Some types of round-head bolts. (*a*) Plain; (*b*) regular square-neck; (*c*) short square-neck; (*d*) rib-neck; (*e*) fin-neck.

TABLE 21.11 Some Basic Dimensions of Round-Head Bolts (Inch Series)†

Nominal size	Max. head diameter A	Max. head height H	Max. square width W‡
No. 10	0.469	0.114	0.199
$\frac{1}{4}$	0.594	0.145	0.260
$\frac{5}{16}$	0.719	0.176	0.324
$\frac{3}{8}$	0.844	0.208	0.388
$\frac{7}{16}$	0.969	0.239	0.452
$\frac{1}{2}$	1.094	0.270	0.515
$\frac{5}{8}$	1.344	0.344	0.642
$\frac{3}{4}$	1.594	0.406	0.768
$\frac{7}{8}$	1.844	0.469	0.895
1	2.094	0.531	1.022

†Short square-neck and rib-neck bolts are standardized only to $\frac{3}{4}$ in; fin-neck bolts are standard only to $\frac{1}{2}$ in.
‡Not applicable to plain, rib-neck, or fin-neck bolts.

TABLE 21.12 Some Basic Dimensions of Round-Head Short Square-Neck Metric Bolts

Nominal size	Thread pitch	Max. head diameter A	Max. head height H	Max. square width W
M6	1	14.2	3.6	6.48
M8	1.25	18.0	4.8	8.58
M10	1.5	22.3	5.8	10.58
M12	1.75	26.6	6.8	12.70
M14	2	30.5	7.9	14.70
M16	2	35.0	8.9	16.70
M20	2.5	43.0	10.9	20.84

21.3.3 Socket-Head Cap Screws

Figure 21.6*a* illustrates a *socket-head cap screw,* and Fig. 21.6*c* shows a *flat countersunk-head cap screw. Socket button-head cap screws* resemble Fig. 21.8*a,* but have a hex or spline driving socket instead of the slot. Head dimensions for these, in inch and metric sizes, are given in Tables 21.18 to 21.23 inclusive.

Thread-length formulas are

$$L_T = 2D + 0.50 \text{ in} \qquad L_T = 2D + 12 \text{ mm} \tag{21.3}$$

Shorter cap screws are threaded full length.

Alloy-steel cap screws, in both inch and metric sizes, should contain an alloying element, such as chromium, nickel, molybdenum, or vanadium, in such quantities as to ensure that a hardness range of 36 to 45 R_C is achieved.

TABLE 21.13 Basic Dimensions of Hex Cap Screws (Finished Hex Bolts) and Heavy Hex Screws (Inch Series)

Nominal size	Fillet radii		Fastener type			
			Hex cap screw		Heavy hex screw	
	Maximum	Minimum	*W*	*H*	*W*	*H*
1/4	0.025	0.015	7/16	5/32		
5/16	0.025	0.015	1/2	13/64		
3/8	0.025	0.015	9/16	15/64		
7/16	0.025	0.015	5/8	9/32		
1/2	0.025	0.015	3/4	7/16	7/8	5/16
9/16	0.045	0.020	13/16	23/64		
5/8	0.045	0.020	15/16	25/64	1 1/16	23/64
3/4	0.045	0.020	1 1/8	15/32	1 1/4	15/32
7/8	0.065	0.040	1 5/16	35/64	1 7/16	35/64
1	0.095	0.060	1 1/2	39/64	1 5/8	39/64
1 1/8	0.095	0.060	1 11/16	11/16	1 13/16	11/16
1 1/4	0.095	0.060	1 7/8	25/32	2	25/32
1 3/8	0.095	0.060	2 1/16	27/32	2 3/16	27/32
1 1/2	0.095	0.060	2 1/4	1 15/16	2 3/8	15/16

TABLE 21.14 Basic Dimensions of Metric Hex Screws†

Nominal diameter	Thread pitch	Type of screw			Height *H*	Fillet radius§
		Cap‡ *W*	Formed‡ *W*	Heavy‡ *W*		
M5	0.8	8	8	..	3.65	0.2
M6	1	10	10	..	4.15	0.3
M8	1.25	13	13	..	5.50	0.4
M10	1.5	16	16	..	6.63	0.4
M12	1.75	18	18	21	7.76	0.6
M14	2	21	21	24	9.09	0.6
M16	2	24	24	27	10.32	0.6
M20	2.5	30	30	34	12.88	0.8
M24	3	36	36	41	15.44	0.8
M30	3.5	46	..	50	19.48	1.0
M36	4	55	..	60	23.38	1.0

†All dimensions in millimeters.
‡Maximum.
§Minimum.

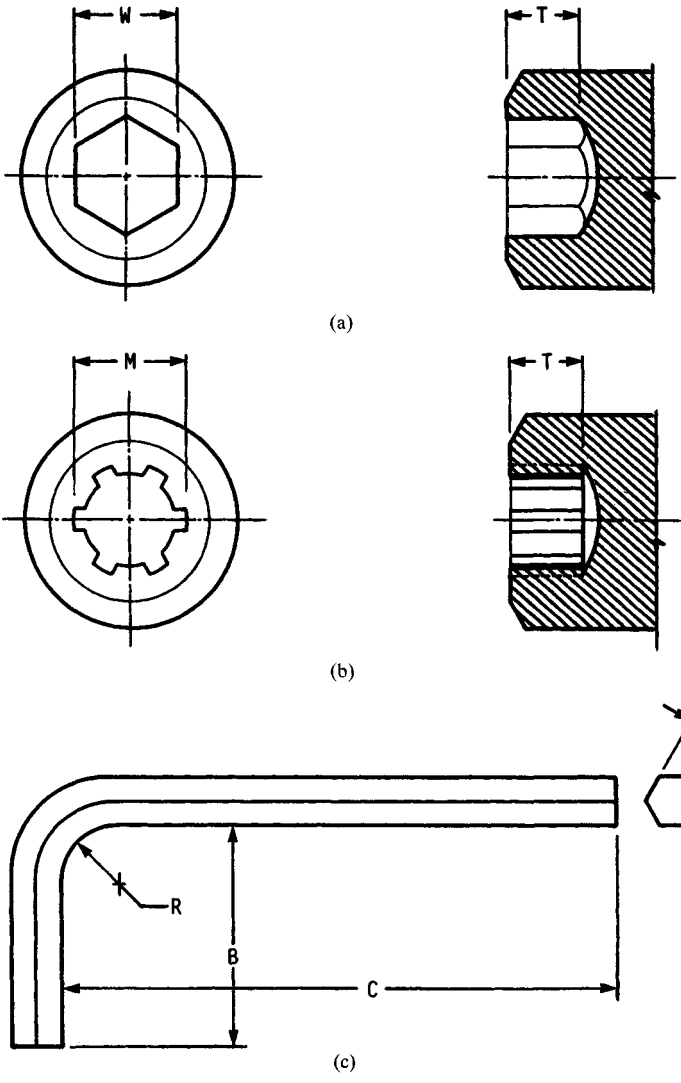


FIGURE 21.4 Standard socket shapes. (*a*) Forged hex socket; (*b*) forged spline; (*c*) hex-socket key.

21.3.4 Shoulder Screws

The nominal size D_S shown for the shoulder screw in Fig. 21.6*b* is related to the maximum and minimum shoulder diameters by the relation

$$D_S(\text{max}) = D_S - 0.002 \qquad D_S(\text{min}) = D_s - 0.004 \tag{21.4}$$

Sizes, in the inch series, are tabulated in Table 21.24.

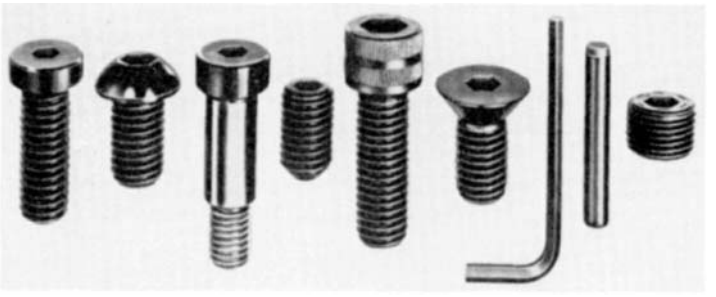


FIGURE 21.5 Hex-socket fasteners. From left to right, the parts are identified as a low socket-head cap screw, a button-head socket cap screw, a socket shoulder screw, a socket set screw, a socket-head cap screw, a socket flat-head cap screw, a hexagon key, a dowel pin, and a socket pressure plug. *(Holo-Krome Company.)*

TABLE 21.15 Hex-Socket Key Sizes (Inch Series)

Nominal width *W*	Short arm *B*		Long arm *C*	
	Maximum	Minimum	Shorts†	Longs†
0.028	0.312	0.125	1.312	2.688
0.035	0.438	0.250	1.312	2.766
0.050	0.625	0.438	1.750	2.938
1/16	0.656	0.469	1.844	3.094
5/64	0.703	0.516	1.969	3.281
3/32	0.750	0.562	2.094	3.469
7/64	0.797	0.609	2.219	3.656
1/8	0.844	0.656	2.344	3.844
9/64	0.891	0.703	2.469	4.031
5/32	0.938	0.750	2.954	4.219
3/16	1.031	0.844	2.844	4.594
7/32	1.125	0.938	3.094	4.969
1/4	1.219	1.031	3.344	5.344
5/16	1.344	1.156	3.844	6.094
3/8	1.469	1.281	4.344	6.844
7/16	1.594	1.406	4.844	7.594
1/2	1.719	1.531	5.344	8.344
9/16	1.844	1.656	5.844	9.094
5/8	1.969	1.781	6.344	9.844
3/4	2.219	2.031	7.344	11.344
7/8	2.469	2.281	8.344	12.844
1	2.719	2.531	9.344	14.344

†Maximum.

TABLE 21.16 Spline-Socket Key Sizes (Inch Series)

Nominal size *M*	Short arm *B*		Long arm *C*	
	Maximum	Minimum	Shorts†	Longs†
0.033‡	0.312	0.125	1.312	
0.048	0.438	0.250	1.312	
0.060	0.625	0.438	1.750	
0.072	0.656	0.469	1.844	
0.096	0.703	0.516	1.969	
0.111	0.750	0.562	2.094	
0.133	0.797	0.609	2.219	3.656
0.145	0.844	0.656	2.344	3.844
0.168	0.891	0.703	2.469	4.031
0.183	0.938	0.750	2.594	4.219
0.216	1.031	0.844	2.844	4.594
0.251	1.125	0.938	3.094	4.969
0.291	1.219	1.031	3.344	5.344
0.372	1.344	1.156	3.844	6.094
0.454	1.469	1.281	4.344	6.844
0.595	1.719	1.531	5.344	8.344
0.620	1.844	1.656	5.844	9.094
0.698	1.844	1.656	5.844	
0.790	1.969	1.781	6.344	

†Maximum.
‡This size has only four splines.

TABLE 21.17 Basic Maximum Dimensions of Metric Hex Keys†

Nominal size *W*	Short arm *B*	Long arm *C*	
		Shorts	Longs
0.7	5.5	34	62
0.9	9	34	62
1.3	13.5	44	84
1.5	14	45	90
2	16	50	100
2.5	18	56	112
3	20	63	126
4	25	70	142
5	28	80	160
6	32	90	180
8	36	100	200
10	40	112	224
12	45	125	250
14	56	140	280
17	63	160	320
19	70	180	360
22	80	200	400
24	90	224	448
27	100	250	500

†All dimensions in millimeters.

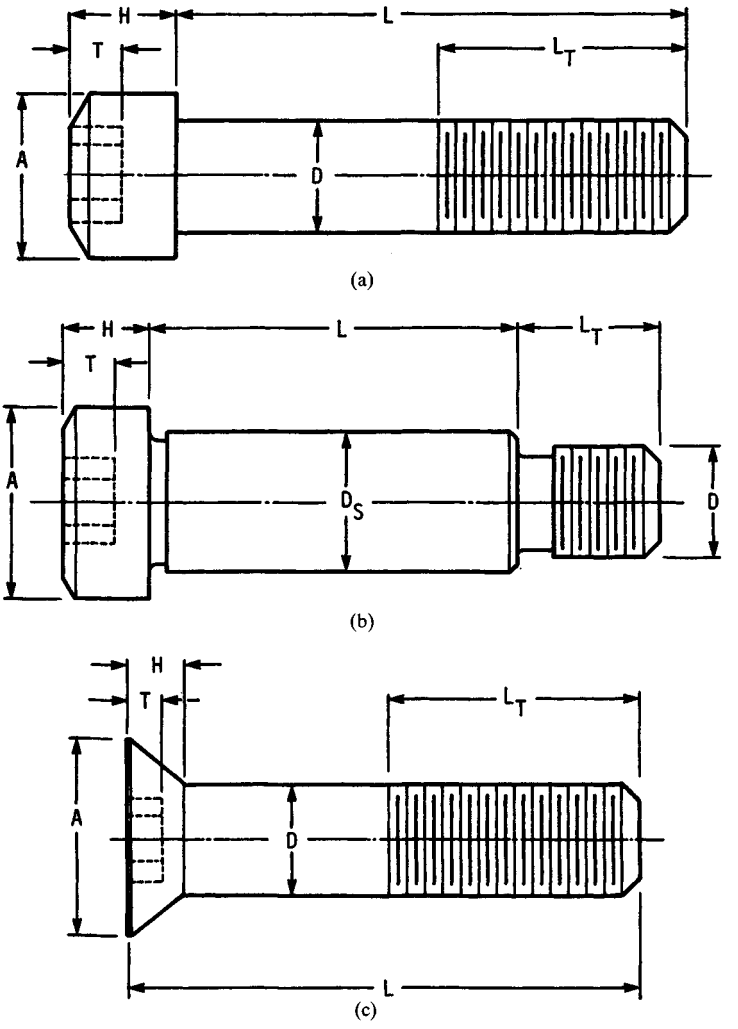


FIGURE 21.6 Socket screws. (*a*) Cap screw; (*b*) shoulder screw; (*c*) flat-head screw.

The maximum and minimum shoulder diameters for metric sizes are

$$D_S(\max) = D_S - \begin{cases} 0.013 & D_S \le 10 \\ 0.016 & 10 < D_S \le 20 \\ 0.020 & D_S > 20 \end{cases}$$

$$D_S(\min) = D_S - \begin{cases} 0.049 & D_S \le 10 \\ 0.059 & 10 < D_S \le 20 \\ 0.072 & D_S > 20 \end{cases} \qquad (21.5)$$

TABLE 21.18 Basic Dimensions of Socket-Head Cap Screws (Inch Series)

Nominal size D	Max. head diameter A	Max. head height H	Hex size W	Spline size M	Socket depth† T
0	0.096	0.060	0.050	0.060	0.025
1	0.118	0.073	1/16	0.072	0.031
2	0.140	0.086	5/64	0.096	0.038
3	0.161	0.099	5/64	0.096	0.044
4	0.183	0.112	3/32	0.111	0.051
5	0.205	0.125	3/32	0.111	0.057
6	0.226	0.138	7/64	0.133	0.064
8	0.270	0.164	9/64	0.168	0.077
10	0.312	0.190	5/32	0.183	0.090
1/4	0.375	0.250	3/16	0.216	0.120
5/16	0.469	0.312	1/4	0.291	0.151
3/8	0.562	0.375	5/16	0.372	0.182
7/16	0.656	0.438	3/8	0.454	0.213
1/2	0.750	0.500	3/8	0.454	0.245
5/8	0.938	0.625	1/2	0.595	0.307
3/4	1.125	0.750	5/8	0.620	0.370
7/8	1.312	0.875	3/4	0.698	0.432
1	1.500	1.000	3/4	0.790	0.495
1 1/8	1.688	1.125	7/8	....	0.557
1 1/4	1.875	1.250	7/8	....	0.620
1 3/8	2.062	1.365	1	....	0.682
1 1/2	2.250	1.500	1	....	0.745

†Minimum.

where D_S is, of course, in millimeters.

See Tables 21.24 and 21.25 for basic dimensions of shoulder screws. These are made of the same material and of the same hardness as specified for cap screws.

21.3.5 Set Screws

Socket set screws (Fig. 21.7) are available in both inch and metric sizes with either hex or spline sockets for the inch series and hex sockets for the metric series. The cone point in Fig. 21.7*b* comes in seven different variations.

Square-head set screws (not shown) have a width across flats equal to the nominal size of the screw. The head height is three-quarters of the nominal size. These have a reduced-diameter neck just below the head.

21.3.6 Slotted-Head Cap Screws

The three standard head styles of the inch-series slotted-head cap screws are shown in Fig. 21.8, and the basic head dimensions are given in Table 21.26. The slot width is

TABLE 21.19 Basic Dimensions of Socket-Head Cap Screws (Metric Series)†

Nominal size *D*	Max. head diameter *A*	Max. head height *H*	Hex size *W*	Spline size *M*	Socket depth‡ *T*
M1.6	3.00	1.60	1.5	1.829	0.80
M2	3.80	2.00	1.5	1.829	1.00
M2.5	4.50	2.50	2.0	2.438	1.25
M3	5.50	3.00	2.5	2.819	1.50
M4	7.00	4.00	3.0	3.378	2.00
M5	8.50	5.00	4.0	4.648	2.50
M6	10.00	6.00	5.0	5.486	3.00
M8	13.00	8.00	6.0	7.391	4.00
M10	16.00	10.00	8.0	....	5.00
M12	18.00	12.00	10.0	....	6.00
M16	24.00	16.00	14.0	....	8.00
M20	30.00	20.00	17.0	....	10.00
M24	36.00	24.00	19.0	....	12.00
M30	45.00	30.00	22.0	....	15.00
M36	54.00	36.00	27.0	....	18.00

†All dimensions in millimeters.
‡Minimum.

TABLE 21.20 Basic Dimensions of Socket Flat-Head Cap Screws (Inch Series)

Nominal size *D*	Max. head diameter *A*	Max. head height *H*	Hex size *W*	Spline size *M*	Socket depth† *T*
0	0.138	0.044	0.035	0.048	0.025
1	0.168	0.054	0.050	0.060	0.031
2	0.197	0.064	0.050	0.060	0.038
3	0.226	0.073	1/16	0.072	0.044
4	0.255	0.083	1/16	0.072	0.055
5	0.281	0.090	5/64	0.096	0.061
6	0.307	0.097	5/64	0.096	0.066
8	0.359	0.112	3/32	0.111	0.076
10	0.411	0.127	1/8	0.145	0.087
1/4	0.531	0.161	5/32	0.183	0.111
5/16	0.656	0.198	3/16	0.216	0.135
3/8	0.781	0.234	7/32	0.251	0.159
7/16	0.844	0.234	1/4	0.291	0.159
1/2	0.938	0.251	5/16	0.372	0.172
5/8	1.188	0.324	3/8	0.454	0.220
3/4	1.438	0.396	1/2	0.454	0.220
7/8	1.688	0.468	9/16	....	0.248
1	1.938	0.540	5/8	....	0.297
1 1/8	2.188	0.611	3/4	....	0.325
1 1/4	2.438	0.683	7/8	....	0.358
1 3/8	2.688	0.755	7/8	....	0.402
1 1/2	2.938	0.827	1	....	0.435

†Minimum.

TABLE 21.21 Basic Dimensions of Socket Flat-Head Cap Screws (Metric Series)†

Nominal size *D*	Max. head diameter *A*	Max. head height *H*	Hex size *W*	Socket depth‡ *T*
M3	6.72	1.85	2	18
M4	8.96	2.69	2.5	20
M5	11.20	3.18	3	22
M6	13.44	3.58	4	24
M8	17.92	4.42	5	28
M10	22.40	6.01	6	32
M12	26.88	6.85	8	36
M16	33.60	8.10	10	44
M20	40.32	8.70	12	52
M24	40.42	16.05	14	60

†All dimensions in millimeters.
‡Minimum.
SOURCE: Unbrako, Division of SPS, Jenkintown, Pa. 19046

TABLE 21.22 Basic Dimensions of Socket Button-Head Cap Screws (Inch Series)

Nominal size *D*	Max. head diameter *A*	Max. head height *H*	Hex size *W*	Spline size *M*	Socket depth† *T*
0	0.114	0.032	0.035	0.048	0.020
1	0.139	0.039	0.050	0.060	0.028
2	0.164	0.046	0.050	0.060	0.028
3	0.188	0.052	1/16	0.072	0.035
4	0.213	0.059	1/16	0.072	0.035
5	0.238	0.066	5/64	0.096	0.044
6	0.262	0.073	5/64	0.096	0.044
8	0.312	0.087	3/32	0.111	0.052
10	0.361	0.101	1/8	0.145	0.070
1/4	0.437	0.132	5/32	0.183	0.087
5/16	0.547	0.166	3/16	0.216	0.105
3/8	0.656	0.199	7/32	0.251	0.122
1/2	0.875	0.265	5/16	0.372	0.175
5/8	1.000	0.331	3/8	0.454	0.210

†Minimum.

TABLE 21.23 Basic Dimensions of Socket Button-Head Cap Screws (Metric Series)†

Nominal size *D*	Max. head diameter *A*	Max. head height *H*	Hex size *W*	Socket depth‡ *T*
M3	5.70	1.65	2	1.04
M4	7.60	2.20	2.5	1.30
M5	9.50	2.75	3	1.56
M6	10.50	3.30	4	2.08
M8	14.00	4.40	5	2.60
M10	17.50	5.50	6	3.12
M12	21.00	6.60	8	4.16
M16	28.00	8.80	10	5.20

†All dimensions in millimeters.
‡Minimum.

TABLE 21.24 Basic Dimensions of Socket Shoulder Screws (Inch Series)

Shoulder diameter D_S	Max. head diameter A	Max. head height H	Hex size W	Socket depth† T	Thread size D	Thread length L_T
1/4	0.375	0.188	1/8	0.094	10	0.375
5/16	0.438	0.219	5/32	0.117	1/4	0.438
3/8	0.562	0.250	3/16	0.141	5/16	0.500
1/2	0.750	0.312	1/4	0.188	3/8	0.625
5/8	0.875	0.375	5/16	0.234	1/2	0.750
3/4	1.000	0.500	3/8	0.281	5/8	0.875
1	1.312	0.625	1/2	0.375	3/4	1.000
1 1/4	1.750	0.750	5/8	0.469	7/8	1.125
1 1/2	2.125	1.000	7/8	0.656	1 1/8	1.500
1 3/4	2.375	1.125	1	0.750	1 1/4	1.750
2	2.750	1.250	1 1/4	0.937	1 1/2	2.000

†Minimum.

TABLE 21.25 Basic Dimensions of Socket-Head Shoulder Screws (Metric Series)†

Shoulder diameter D_S	Max. head diameter A	Max. head height H	Hex size W	Socket depth‡ T	Thread size D	Thread length L_T
6.5	10.00	4.50	3	2.4	M5	9.75
8.0	13.00	5.50	4	3.3	M6	11.25
10.0	16.00	7.00	5	4.2	M8	13.25
13.0	18.00	9.00	6	4.9	M10	16.40
16.0	24.00	11.00	8	6.6	M12	18.40
20.0	30.00	14.00	10	8.8	M16	22.40
25.0	36.00	16.00	12	10.0	M20	27.40

†All dimensions in millimeters.
‡Minimum.

$$J = \begin{cases} 0.160D + 0.024 & D \le 1 \\ 0.160D & 1 < D \le 1\frac{1}{2} \end{cases} \tag{21.6}$$

The slot depth varies, depending on the head type and the nominal size.

Slotted-head cap screws are normally made from carbon steel conforming to ASTM A307 properties (see Table 21.7). However, they can also be obtained in grade ASTM A449 material and properties.

21.3.7 Machine Screws

We can keep track of the many types of machine screws by classifying them as follows:

1. Flat countersunk head (80 degrees)
   a. Regular or undercut
   b. Slotted or cross-recessed

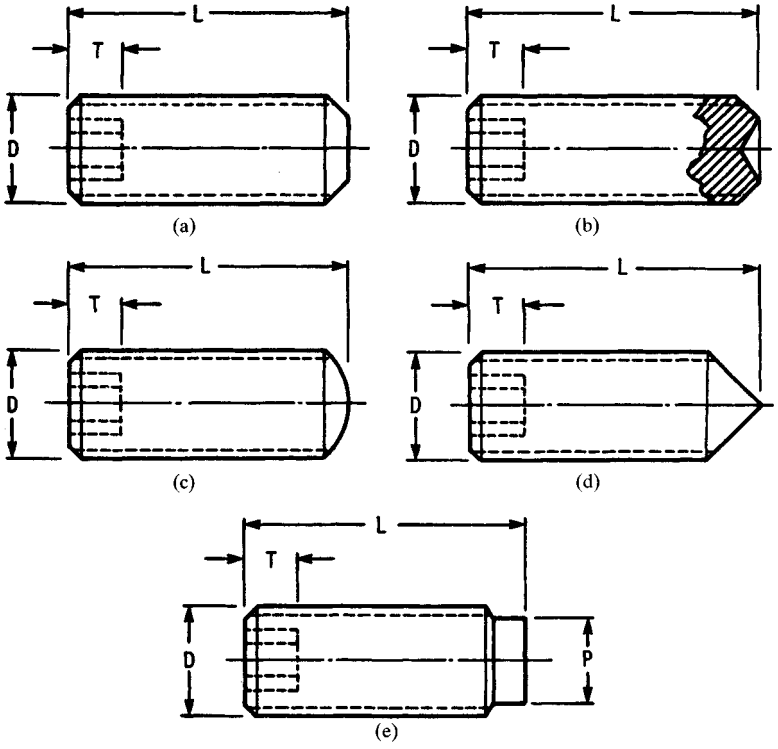


FIGURE 21.7 Socket set screws. (*a*) Flat point; (*b*) cup point; (*c*) oval point; (*d*) cone point; (*e*) half-dog point.

2. 100-degree flat countersunk head
   - *a.* Regular or close tolerance
   - *b.* Slotted or cross-recessed
3. Oval countersunk head
   - *a.* Regular or undercut
   - *b.* Slotted or cross-recessed
4. Flat countersunk trim head
   - *a.* Regular or short
   - *b.* Cross-recessed
5. Oval countersunk trim head
   - *a.* Regular or short
   - *b.* Cross-recessed
6. Pan head
   - *a.* Slotted or cross-recessed
7. Fillister head
   - *a.* Slotted and cross-drilled
   - *b.* Slotted or cross-recessed
8. Truss head
   - *a.* Slotted or cross-recessed

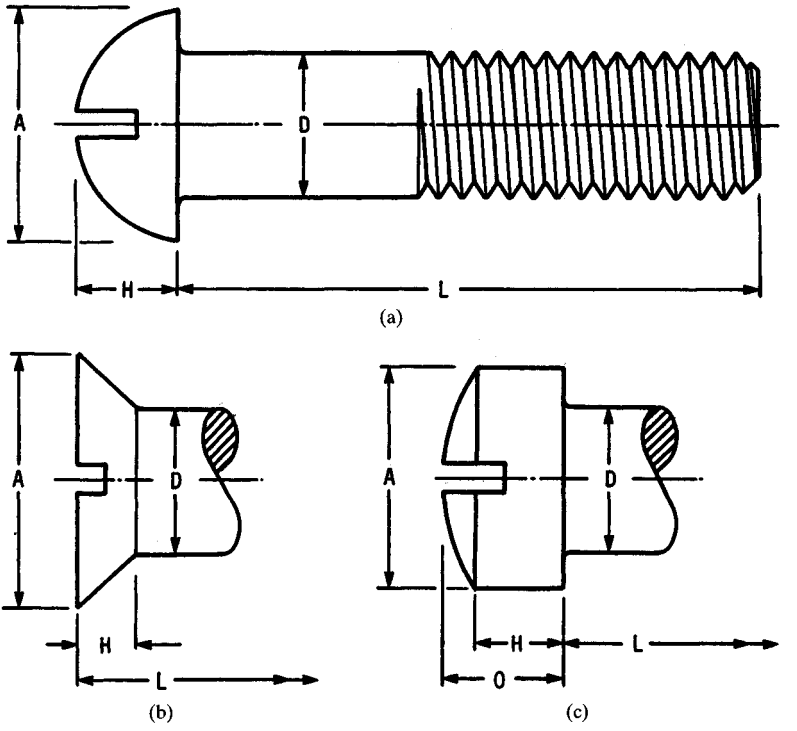


FIGURE 21.8 Slotted-head cap screws. (*a*) Round head; (*b*) flat countersunk head; (*c*) fillister head.

TABLE 21.26 Basic Head Dimensions of Slotted-Head Cap Screws (Inch Series)

Nominal size	Flat head†		Round head†		Fillister head†		
	A	*H*	*A*	*H*	*A*	*H*	*O*
1/4	0.500	0.140	0.437	0.191	0.375	0.172	0.216
5/16	0.625	0.177	0.562	0.245	0.437	0.203	0.253
3/8	0.750	0.210	0.625	0.273	0.562	0.250	0.314
7/16	0.812	0.210	0.750	0.328	0.625	0.297	0.368
1/2	0.875	0.210	0.812	0.354	0.750	0.328	0.413
9/16	1.000	0.244	0.937	0.409	0.812	0.375	0.467
5/8	1.125	0.281	1.000	0.437	0.875	0.422	0.521
3/4	1.375	0.352	1.250	0.546	1.000	0.500	0.612
7/8	1.625	0.423	....	....	1.125	0.594	0.720
1	1.875	0.494	....	....	1.312	0.656	0.803
1 1/8	2.062	0.529					
1 1/4	2.312	0.600					
1 3/8	2.562	0.665					
1 1/2	2.812	0.742					

†Maximum.

9. Binding head
   a. Slotted or cross-recessed
10. Hex head
   a. Indented
   b. Slotted
   c. Indented and slotted
11. Hex washer head
   a. Indented
   b. Indented and slotted

The *round-head* machine screw is obsolete. Use the *pan-head* screw, instead; it has more driving power. Most of the head types outlined here are illustrated in Figs. 21.9 to 21.11, some slotted and some with cross-recesses.

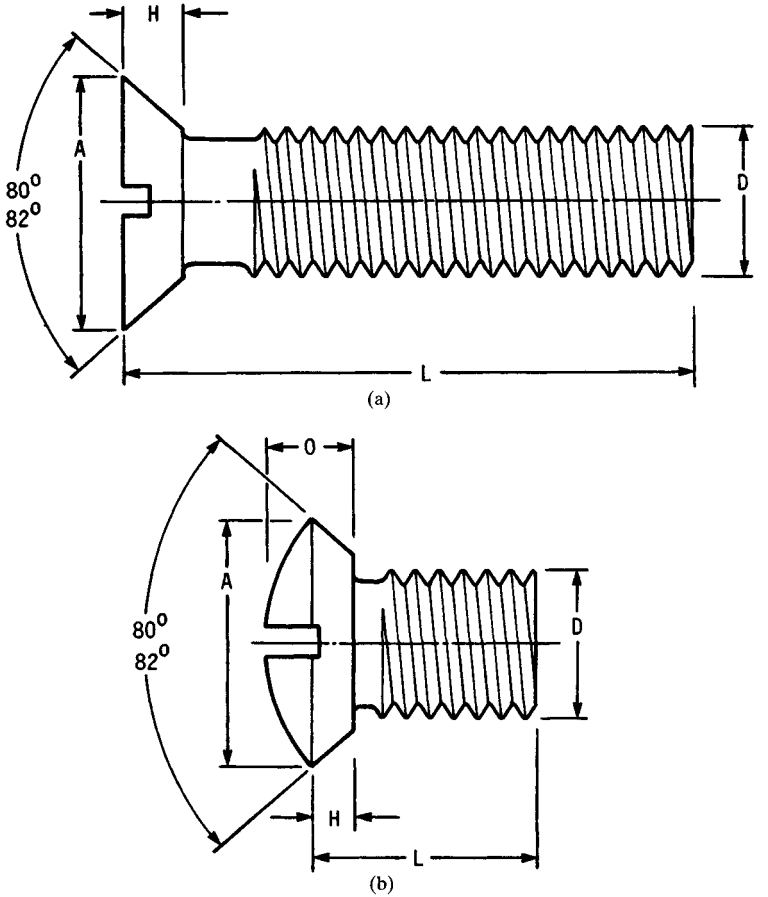


FIGURE 21.9 (*a*) Slotted flat countersunk-head machine screw; also available with 100-degree head; (*b*) short or undercut slotted oval countersunk-head machine screw. Note the difference between the body of a machine screw and that of a cap screw. Compare this figure with Fig. 21.8*a*.

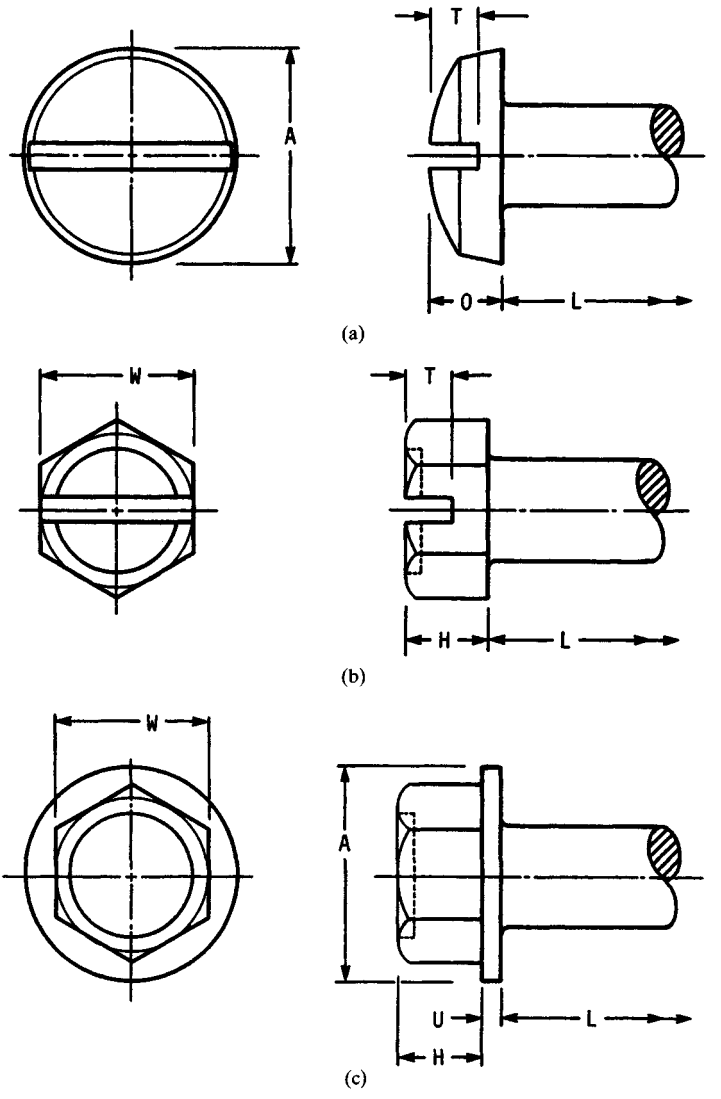


FIGURE 21.10 (*a*) Slotted binding-head machine screw; the edge angle is 5 degrees; (*b*) slotted and indented hex-head machine screw; (*c*) hex washer-head machine screw. Both hex screws in this figure may be obtained with or without slots and/or indentations.

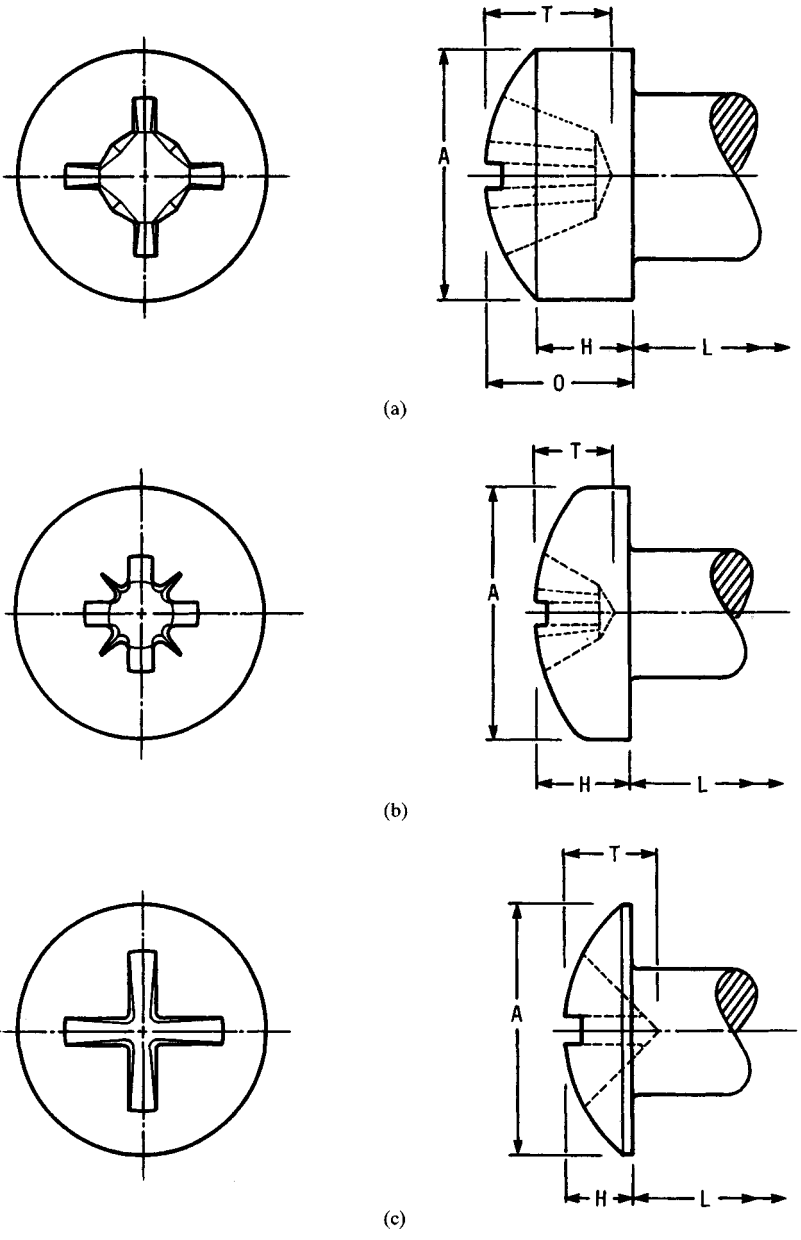


FIGURE 21.11 The three standard recesses. (*a*) Fillister-head machine screw with Type 1 cross-recess. This recess has a large center opening, tapered wings, and a blunt bottom. (*b*) Pan-head machine screw with Type 1A cross-recess. This recess has a large center opening, wide straight wings, and a blunt bottom. (*c*) Truss-head machine screw with Type 2 cross-recess. This recess has two intersecting slots with parallel sides. The sides converge to a slightly truncated apex at the bottom.

Figure 21.9 illustrates the difference between a regular and an undercut machine screw. Note also the reduced body diameter in this figure and compare it with that of cap screws. See Table 21.32 for undercut lengths.

Figure 21.11 is intended to illustrate the three standard cross-recesses, but it also illustrates three additional head styles. Use Table 21.32 to find the driver sizes for cross-recessed heads. Three more head styles are illustrated in Fig. 21.10.

Trim-head screws are not illustrated; the head diameters are smaller, and the screws are driven only with cross-recessed drivers. Long trim-head screws have a short shoulder and then a reduced body diameter. Short ones have a neck instead of the shoulder.

Tables 21.27 to 21.33 inclusive give the basic dimensions for all machine-screw head styles except the close-tolerance 100-degree flat countersunk-head screw.

Normal thread lengths are 1 in for screw sizes No. 5 and smaller and 1½ in for larger sizes. Steel machine screws are usually made from carbon steel having a minimum tensile strength of 60 kpsi.

21.4 NUTS

Flat nuts, such as the *square* or *flat hex* in Fig. 21.12, have only a chamfered top. All other hex nuts, except the castle, have chamfered tops and bottoms that are cham-

TABLE 21.27 Basic Head Dimensions of Flat Countersunk-Head Machine Screws†

Nominal size D	Head diameter‡ A	Head thickness‡ H		
		Regular, 80 degrees		
		Long	Undercut	100-degree head
0	0.119	0.035	0.025	0.026
1	0.146	0.043	0.031	0.031
2	0.172	0.051	0.036	0.037
3	0.199	0.059	0.042	0.043
4	0.225	0.067	0.047	0.049
5	0.252	0.075	0.053	
6	0.279	0.083	0.059	0.060
8	0.332	0.100	0.070	0.072
10	0.385	0.116	0.081	0.083
12	0.438	0.132	0.092	
¼	0.507	0.153	0.107	0.110
5/16	0.635	0.191	0.134	0.138
⅜	0.762	0.230	0.161	0.165
7/16	0.812	0.223	0.156	
½	0.875	0.223	0.156	
9/16	1.000	0.260		
⅝	1.125	0.298		
¾	1.375	0.372		

†All dimensions in inches.
‡Maximum.

TABLE 21.28 Total Head Heights *O* for Oval Countersunk-Head Machine Screws†

Nominal size *D*	Total head height ‡ *O*		Nominal size *D*	Total head height‡ *O*	
	Long	Undercut		Long	Undercut
0	0.056	0.046	12	0.200	0.161
1	0.068	0.056	1/4	0.232	0.186
2	0.080	0.065	5/16	0.290	0.232
3	0.092	0.075	3/8	0.347	0.278
4	0.104	0.084	7/16	0.345	0.279
5	0.116	0.094	1/2	0.354	0.288
6	0.128	0.104	9/16	0.410	
8	0.152	0.123	5/8	0.467	
10	0.176	0.142	3/4	0.578	

†Head dimensions *A* and *H* are the same as for regular 80-degree flat-head machine screws (Table 21-27). All dimensions are in inches.
‡Maximum.

TABLE 21.29 Basic Head Dimensions of Flat and Oval Countersunk Trim-Head Machine Screws (Available Only with Cross-Recessed Heads)†

Nominal size *D*	Shoulder diameter‡§	Head diameter‡ *A*	Flat head height *H*	Oval head height¶ *O*
4	0.112	0.199	0.052	0.086
5	0.125	0.225	0.060	0.099
6	0.138	0.225	0.052	0.091
6	0.138	0.252	0.068	0.112
8	0.164	0.252	0.052	0.096
8	0.164	0.279	0.069	0.117
10	0.190	0.332	0.085	0.141
12	0.216	0.332	0.069	0.125
12	0.216	0.385	0.101	0.166
1/4	0.250	0.385	0.080	0.146
1/4	0.250	0.438	0.112	0.187
5/16	0.312	0.438	0.075	0.150
5/16	0.312	0.507	0.116	0.202
3/8	0.375	0.635	0.155	0.265

†All dimensions are in inches.
‡Maximum.
§Screws having nominal lengths over 1 1/8 in for sizes No. 5 and smaller and over 2 in for sizes No. 6 and larger have a shoulder of this diameter and about 1/16 in long beneath the head.
¶This is the total height. The side height *H* is the same as for flat-head trim screws.

TABLE 21.30 Basic Head Dimensions of Pan- and Truss-Head Machine Screws†

	Pan head		Truss head	
Nominal size *D*	Diameter *A*	Height *H*	Diameter *A*	Height *H*
0	0.116	0.044	0.131	0.037
1	0.142	0.053	0.164	0.045
2	0.167	0.062	0.194	0.053
3	0.193	0.071	0.226	0.061
4	0.219	0.080	0.257	0.069
5	0.245	0.089	0.289	0.078
6	0.270	0.097	0.321	0.086
8	0.322	0.115	0.384	0.102
10	0.373	0.133	0.448	0.118
12	0.425	0.151	0.511	0.134
1/4	0.492	0.175	0.573	0.150
5/16	0.615	0.218	0.698	0.183
3/8	0.740	0.261	0.823	0.215
7/16	0.863	0.305	0.948	0.248
1/2	0.987	0.348	1.073	0.280
9/16	1.041	0.391	1.198	0.312
5/8	1.172	0.434	1.323	0.345
3/4	1.435	0.521	1.573	0.410

†All values are maximum; all dimensions are in inches.

TABLE 21.31 Basic Head Dimensions of Binding- and Fillister-Head Machine Screws†

	Fillister head			Binding head	
Nominal size *D*	Diameter *A*	Height *H*	Height *O*	Diameter *A*	Height *O*
0	0.096	0.043	0.055	0.126	0.032
1	0.118	0.053	0.066	0.153	0.041
2	0.140	0.062	0.083	0.181	0.050
3	0.161	0.070	0.095	0.208	0.059
4	0.183	0.079	0.107	0.235	0.068
5	0.205	0.088	0.120	0.263	0.078
6	0.226	0.096	0.132	0.290	0.087
8	0.270	0.113	0.156	0.344	0.105
10	0.313	0.130	0.180	0.399	0.123
12	0.357	0.148	0.205	0.454	0.141
1/4	0.414	0.170	0.237	0.525	0.165
5/16	0.518	0.211	0.295	0.656	0.209
3/8	0.622	0.253	0.355	0.788	0.253
7/16	0.625	0.265	0.368		
1/2	0.750	0.297	0.412		
9/16	0.812	0.336	0.466		
5/8	0.875	0.375	0.521		
3/4	1.000	0.441	0.612		

†All values are maximum; all dimensions are in inches.

TABLE 21.32 Undercut Lengths for Flat and Oval Countersunk-Head Machine Screws and Driver Sizes for Type I and IA Cross-Recesses†

Nominal size	Undercut lengths (or less)	Driver size	Nominal size	Undercut lengths (or less)	Driver size
0	1/8	0	10	5/16	2
1	1/8	0	12	3/8	3
2	1/8	1	1/4	7/16	3
3	1/8	1	5/16	1/2	4
4	3/16	1	3/8	9/16	4
5	3/16	2	7/16	5/8	4
6	3/16	2	1/2	3/4	4
8	1/4	2	9/16	....	4

†Type II drivers have the same point size for all screw sizes.

TABLE 21.33 Basic Head Dimensions for Regular-Hex- and Washer-Hex-Head Machine Screws†

Nominal size *D*	Head height *H*	Width across faults *W*		Washer face	
		Regular hex	Washer hex	Diameter *A*	Thickness *U*
1	0.044	0.120			
2	0.050	0.120	0.125	0.166	0.016
3	0.055	0.181	0.125	0.177	0.016
4	0.060	0.181	0.188	0.243	0.019
5	0.070	0.181	0.188	0.260	0.025
6	0.093	0.244	0.250	0.328	0.025
8	0.110	0.244	0.250	0.348	0.031
10	0.120	0.305	0.312	0.414	0.031
12	0.155	0.305	0.312	0.432	0.039
1/4	0.190	0.367	0.375	0.520	0.050
5/16	0.230	0.489	0.500	0.676	0.055
3/8	0.295	0.551	0.562	0.780	0.063

†All values are maximum; all dimensions are in inches.

fered or washer-faced, as in Fig. 21.12*c* and *d*. *Castle nuts* (Fig. 21.12*f*) are made in both styles, washer-faced or with chamfered bottoms.

Most styles can also be classified as regular, thick, or heavy. A thick nut has the same width *W* across flats as a regular nut, but the height *H* is greater. A *jam nut* is a thin hex nut. A *heavy nut* is larger in both dimensions, *W* and *H*, than the regular style.

It is convenient to outline these varieties of head styles with their accepted names and indicate in which table the dimensions are to be found:

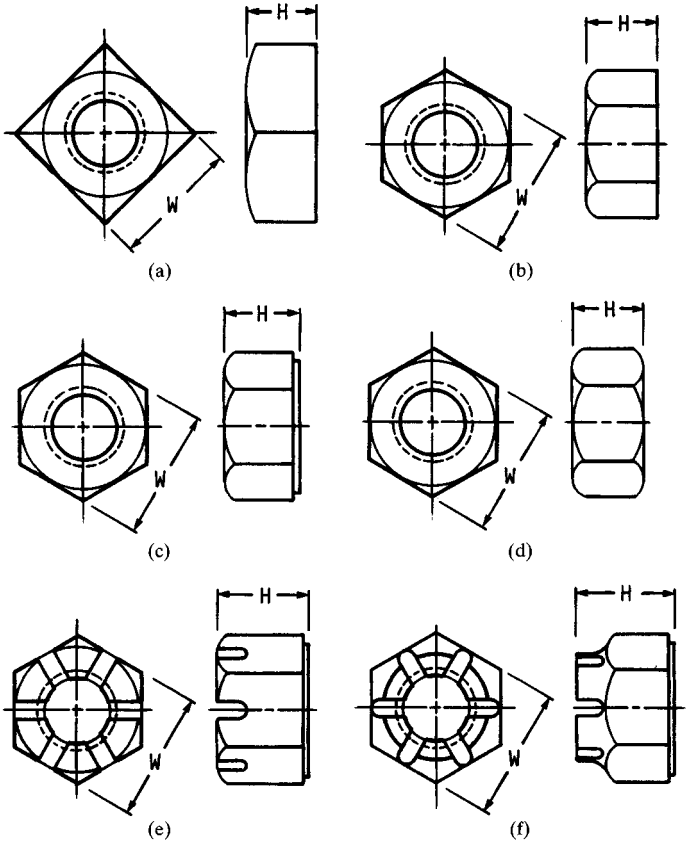


FIGURE 21.12 Types of nuts. (*a*) Square; (*b*) hex flat; (*c*) hex with washer face; (*d*) double-chamfered hex; (*e*) slotted hex; (*f*) hex castle.

1. Flat nuts
   - *a.* Square (Table 21.34)
   - *b.* Heavy square (Table 21.34)
   - *c.* Hex (Table 21.35)
   - *d.* Hex jam (Table 21.35)
   - *e.* Heavy hex (Table 21.39)
   - *f.* Heavy hex jam (Table 21.39)
2. Nuts with washer-faced or chamfered bottoms
   - *a.* Hex (Table 21.35)
     - (1) Metric style 1 (Table 21.36)
   - *b.* Hex jam (Table 21.35)
     - (1) Metric (Table 21.36)
   - *c.* Hex slotted (Table 21.35)
     - (1) Metric (Table 21.36)

TABLE 21.34 Basic Dimensions of Square Nuts (Inch Series)

Nominal size	Regular		Heavy	
	W	*H*	*W*	*H*
1/4	7/16	7/32	1/2	1/4
5/16	9/16	17/64	9/16	5/16
3/8	5/8	21/64	11/16	3/8
7/16	3/4	3/8	3/4	7/16
1/2	13/16	7/16	7/8	1/2
5/8	1	35/64	1 1/16	5/8
3/4	1 1/8	41/64	1 1/4	3/4
7/8	1 5/16	49/64	1 7/16	7/8
1	1 1/2	7/8	1 5/8	1
1 1/8	1 11/16	1	1 13/16	1 1/8
1 1/4	1 7/8	1 3/32	2	1 1/4
1 3/8	2 1/16	1 13/64	2 3/16	1 3/8
1 1/2	2 1/4	1 5/16	2 3/8	1 1/2

TABLE 21.35 Basic Dimensions of Hex, Hex Jam, Hex Flat, Hex Flat Jam, Hex Slotted, Hex Thick, and Hex Thick Slotted Nuts (Inch Series)

Nominal size *D*	Width *W*	Height *H*				
		Hex and hex slotted	Hex jam	Hex flat	Hex flat jam	Hex thick and thick slotted
1/4	7/16	7/32	5/32	...	...	9/32
5/16	1/2	17/64	3/16	...	...	21/64
3/8	9/16	21/64	7/32	...	...	13/32
7/16	11/16	3/8	1/4	...	...	29/64
1/2	3/4	7/16	5/16	...	...	9/16
9/16	7/8	31/64	5/16	...	...	39/64
5/8	15/16	35/64	3/8	...	...	23/32
3/4	1 1/8	41/64	27/64	...	...	13/16
7/8	1 5/16	1/4	31/64	...	...	29/32
1	1 1/2	55/64	35/64	...	...	1
1 1/8	1 11/16	31/32	39/64	1	5/8	1 5/32
1 1/4	1 7/8	1 1/16	23/32	1 3/32	3/4	1 1/4
1 3/8	2 1/16	1 11/64	25/32	1 13/64	13/16	1 3/8
1 1/2	2 1/4	1 9/32	27/32	1 5/16	7/8	1 1/2

TABLE 21.36 Basic Dimensions of Metric Hex Nuts†

Nominal size *D*	Width across flats‡ *W*	Height H‡		
		Style 1	Style 2 or slotted	Jam
M1.6	3.2	1.3		
M2	4	1.6		
M2.5	5	2.0		
M3	5.5	2.4	2.9§	
M3.5	6	2.8	3.3§	
M4	7	3.2	3.8§	
M5	8	4.7	5.1	2.7
M6	10	5.2	5.7	3.2
M8	13	6.8	7.5	4.0
M10	16	8.4	9.3	5.0
M12	18	10.8	12.0	6.0
M14	21	12.8	14.1	7.0
M16	24	14.8	16.4	8.0
M20	30	18.0	20.3	10.0
M24	36	21.5	23.9	12.0
M30	46	25.6	28.6	15.0
M36	55	31.0	34.7	18.0

†All dimensions are in millimeters.
‡Maximum.
§Not standard in slotted style.

TABLE 21.37 Basic Dimensions of Metric Heavy Hex Nuts†

Nominal size *D*	Width across flats‡ *W*	Height‡ *H*	Nominal size *D*	Width across flats‡ *W*	Height‡ *H*
M12	21	12,3	M24	41	24.2
M14	24	14.3	M27	46	27.6
M16	27	17.1	M30	50	30.7
M20	34	20.7	M36	60	36.6
M22	36	23.6	M42	70	42.0

†All dimensions are in millimeters.
‡Maximum.

d. Hex thick (Table 21.35)
  (1) Metric style 2 (Table 21.36)
e. Hex thick slotted (Table 21.35)
f. Heavy hex (Table 21.38)
  (1) Metric (Table 21.37)
g. Heavy hex jam (Table 21.38)
h. Hex castle (Table 21.38)

3. Machine screw nuts
   a. Hex (Table 21.40)
   b. Square (Table 21.40)

TABLE 21.38 Basic Dimensions of Heavy Hex, Heavy Hex Jam, Heavy Hex Slotted, and Heavy Hex Castle Nuts (Inch Series)

	Heavy hex			Hex castle	
		Height H			
Nominal size D	Width W	Plain or slotted	Jam	Width W	Height H
$\frac{1}{4}$	$\frac{1}{2}$	$\frac{15}{64}$	$\frac{11}{64}$	$\frac{7}{16}$	$\frac{9}{32}$
$\frac{5}{16}$	$\frac{9}{16}$	$\frac{19}{64}$	$\frac{13}{64}$	$\frac{1}{2}$	$\frac{21}{64}$
$\frac{3}{8}$	$\frac{11}{16}$	$\frac{23}{64}$	$\frac{15}{64}$	$\frac{9}{16}$	$\frac{13}{32}$
$\frac{7}{16}$	$\frac{3}{4}$	$\frac{27}{64}$	$\frac{17}{64}$	$\frac{11}{16}$	$\frac{29}{64}$
$\frac{1}{2}$	$\frac{7}{8}$	$\frac{31}{64}$	$\frac{19}{64}$	$\frac{3}{4}$	$\frac{9}{16}$
$\frac{9}{16}$	$\frac{15}{16}$	$\frac{35}{64}$	$\frac{21}{64}$	$\frac{7}{8}$	$\frac{39}{64}$
$\frac{5}{8}$	$1\frac{1}{16}$	$\frac{39}{64}$	$\frac{23}{64}$	$\frac{13}{16}$	$\frac{23}{32}$
$\frac{3}{4}$	$1\frac{1}{4}$	$\frac{47}{64}$	$\frac{27}{64}$	$1\frac{1}{8}$	$\frac{13}{16}$
$\frac{7}{8}$	$1\frac{7}{16}$	$\frac{55}{64}$	$\frac{31}{64}$	$1\frac{5}{16}$	$\frac{29}{32}$
1	$1\frac{5}{8}$	$\frac{63}{64}$	$\frac{35}{64}$	$1\frac{1}{2}$	1
$1\frac{1}{8}$	$1\frac{13}{16}$	$1\frac{7}{64}$	$\frac{39}{64}$	$1\frac{11}{16}$	$1\frac{5}{32}$
$1\frac{1}{4}$	2	$1\frac{7}{32}$	$\frac{23}{32}$	$1\frac{7}{8}$	$1\frac{1}{4}$
$1\frac{3}{8}$	$2\frac{1}{16}$	$1\frac{11}{32}$	$\frac{25}{32}$	$2\frac{1}{16}$	$1\frac{3}{8}$
$1\frac{1}{2}$	$2\frac{3}{8}$	$1\frac{15}{32}$	$\frac{27}{32}$	$2\frac{1}{4}$	$1\frac{1}{2}$

TABLE 21.39 Basic Dimensions of Heavy Hex Flat and Heavy Hex Flat Jam Nuts (Inch Series)

		Height H	
Nominal size D	Width across flats W	Regular	Jam
$1\frac{1}{8}$	$1\frac{13}{16}$	$1\frac{1}{8}$	$\frac{5}{8}$
$1\frac{1}{4}$	2	$1\frac{1}{4}$	$\frac{3}{4}$
$1\frac{3}{8}$	$2\frac{13}{16}$	$1\frac{3}{8}$	$\frac{13}{16}$
$1\frac{1}{2}$	$2\frac{3}{8}$	$1\frac{1}{2}$	$\frac{7}{8}$
$1\frac{3}{4}$	$2\frac{3}{4}$	$1\frac{3}{4}$	1
2	$3\frac{1}{8}$	2	$1\frac{1}{8}$

Carbon steel nuts usually are made to conform to ASTM A563 Grade A specifications or to SAE Grade 2.

21.5 TAPPING SCREWS

Self-tapping screws are available in all head styles and in sizes up to and including ⅜ in. They are hardened sufficiently to form their own mating threads when driven. In

TABLE 21.40 Basic Dimensions of Machine-Screw Nuts†

Nominal size D	Width W	Height‡ H	Nominal size D	Width W	Height‡ H
0	$\frac{5}{32}$	0.050	8	$\frac{11}{32}$	0.130
1	$\frac{5}{32}$	0.050	10	$\frac{3}{8}$	0.130
2	$\frac{3}{16}$	0.066	12	$\frac{7}{16}$	0.161
3	$\frac{3}{16}$	0.066	$\frac{1}{4}$	$\frac{7}{16}$	0.193
4	$\frac{1}{4}$	0.098	$\frac{5}{16}$	$\frac{9}{16}$	0.225
5	$\frac{5}{16}$	0.114	$\frac{3}{8}$	$\frac{5}{8}$	0.257
6	$\frac{5}{16}$	0.114			

†All dimensions are in inches; dimensions apply to both hex and square nuts.
‡Maximum.

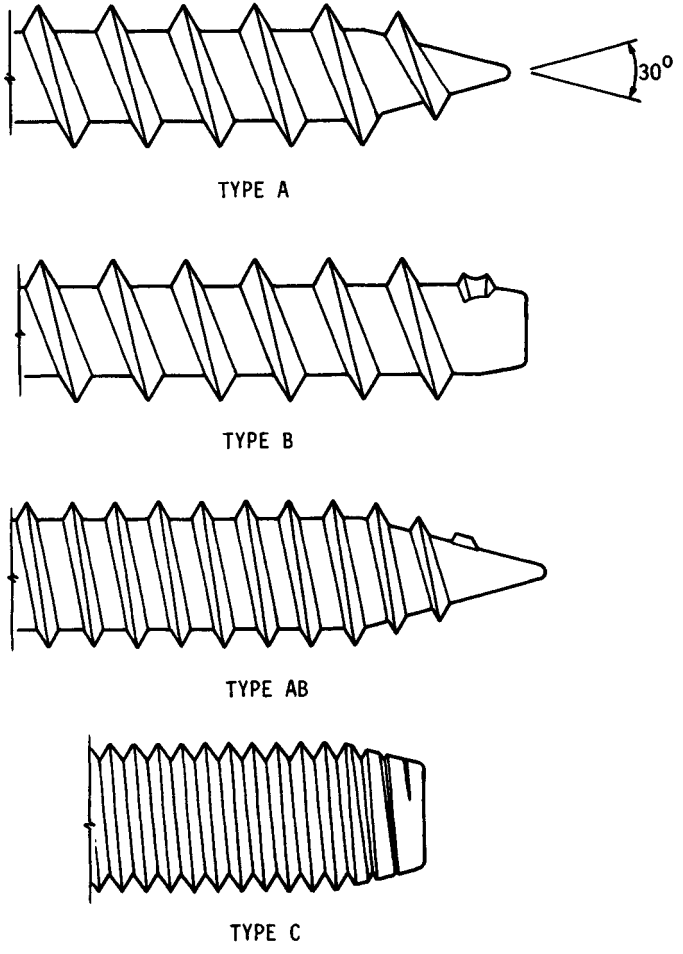


FIGURE 21.13 Thread-forming screws.

fact, at least one manufacturer has developed a screw which both drills and taps in a single operation.

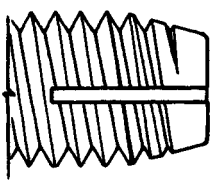
Thread-forming screws are used when sufficient joint stresses can be developed to guard against loosening. The Type A screw (Fig. 21.13) has a gimlet point and is used to join sheet metal. It is sometimes used instead of a wood screw.

The Type B screw has a blunt point and, sometimes, a finer pitch than the Type A. With the finer pitch, it has a greater range of applications and is used in heavier sheet metal and nonferrous castings.

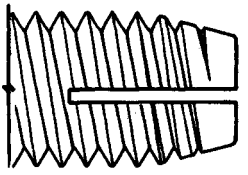
The Type AB screw is similar to Type A but has a finer pitch, which permits it to be used in more brittle materials, such as plastics or zinc die castings. It is also used as a wood screw.

The Type C screw has machine-screw threads, a blunt point, and tapered threads at the start, as shown in Fig. 21.13. This screw is useful for thick sections but may require large driving torques.

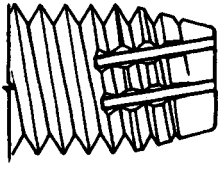
Thread-cutting screws (shown in Fig. 21.14) are used instead of thread-forming screws to lessen the driving torque and the internal stresses. Types D, G, F, and T all have machine-screw threads and an end taper with a blunt point. They are used for various die castings, cast iron, brass, plastics, and sheet steel.



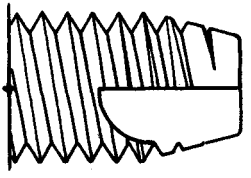
TYPE D



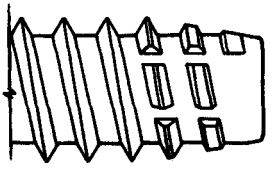
TYPE G



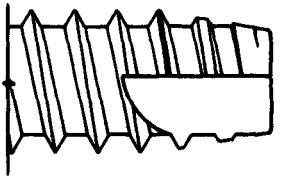
TYPE F



TYPE T



TYPE BF



TYPE BT

FIGURE 21.14 Thread-cutting screws.

Types BF and BT screws (shown in Fig. 21.14) have additional cutting edges and a greater chip-storage capacity. They are useful for various plastics and compositions.

Thread-rolling screws (not shown) have a unique point and body shape to make starting easier and to lessen the driving torque. The thread rolling cold-works the material, thus contributing to the strength of the joint.

REFERENCE

21.1 "Codes and Standards; Fasteners," in *ASME Publications Catalog,* American Society of Mechanical Engineers, New York, 1985.