Chapter V.—FASTENING DEVICES.

BOLTS are usually designated for size by their diameters measured at the cylindrical stem or body, and by their lengths measured from the inner side of the head to the end of the thread, so that if a nut be used, the length of the bolt, less the thickness of the nut and washer (if the latter be used), is the thickness of work the bolt will hold. If the work is tapped, and no nut is used, the full length of the bolt stem is taken as the length of the bolt.

A *black* bolt is one left as forged. A finished bolt has its body, and usually its head also, machine finished, but a finished bolt sometimes has a black head, the body only being turned.

A square-headed bolt usually has a square nut, but if the nut is in a situation difficult of access for the wrench, or where the head of the bolt is entirely out of sight (as secluded beneath a flange) the nut is often made hexagon. A machine-finished bolt usually has a machine-finished and hexagon nut. Square nuts are usually left black.

The heads of bolts are designated by their shapes, irrespective of whether they are left black or finished. Fig. 370 represents the various forms: *a*, square head; *b*, hexagon head; *c*, capstan head; *d*, cheese head; *e*, snap head; *f*, oval head, or button head; *g*, conical head; *h*, pan head; *i*, countersink head.

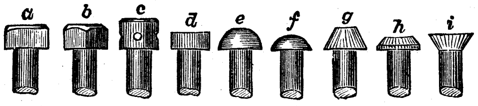

Fig. 370.

The square heads *a* are usually left black, though in exceptional cases they are finished. Hexagon heads are left black or finished as circumstances may require; when a bolt head is to receive a wrench and is to be finished, it is usually made hexagon. Heads *c* and *d* are almost invariably finished when used on operative parts of machines, as are also *e* and *f*. Heads *g* are usually left black, while *h* and *i* are finished if used on machine work, and left black when used as rivets or on rough unfinished work.

The heads from *e* to *i* assume various degrees of curve or angle to suit the requirements, but when the other end of the bolt is threaded to receive a nut, some means is necessary to prevent them from rotating in their holes when the nut is screwed up, thus preventing the nut from screwing up sufficiently tight. This is accomplished in woodwork by forging either a square under the head, as in Fig. 371, or by forging under the head a tit or stop, such as shown in Figs. 372 and 373 at P. Since, however, forging such stops on the bolt would prevent the heads from being turned up in the lathe, they are for lathe-turned bolts put in after the bolts have been finished in the lathe, a hole being subsequently drilled beneath the head to receive the pin or stop, P, Fig. 372, which may be tightly driven in. A small slot is cut in the edge of the hole to receive the stop.

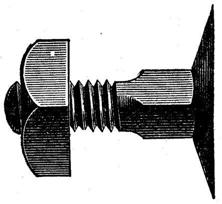

Fig. 371.

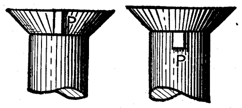

Fig. 372.

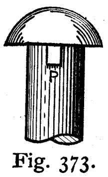

Fig. 373.

Bolts are designated for kinds, as in Fig. 374, in which *k* is a machine bolt; *l* a collar bolt, from having a collar on it; *m* a cotter bolt, from having a cotter or key passing through it to serve in place of a nut; *n* a carriage bolt, from having a square part under the head to sink in the wood and prevent the bolt from turning with the nut; and *o* a countersink bolt for cases where the head of the bolt comes flush.

The simple designation "machine bolt" is understood to mean a black or unfinished bolt having a square head and nut, and threaded, when the length of the bolt will admit it, and still leave an unthreaded part under the bolt head, for a length equal to about four times the diameter of the bolt head. If the bolt is to have other than a square head it is still called a machine bolt, but the shape of the head or nut is specially designated as "hexagon head machine bolt," this naturally implying that a hexagon nut also is required.

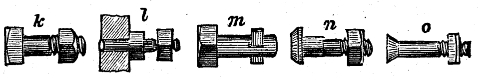

Fig. 374.

In addition to these general names for bolts, there are others applied to special cases. Thus Fig. 375 represents a patch bolt or a bolt for fastening patches (as plate C to plate D), its peculiarity being that it has a square stem A for the wrench to screw it in by. When the piece the patch bolt screws into is thin, as in the case of patches on steam boilers, the pitch of the thread may, to avoid leakage, be finer than the usual standard.

In countersink head bolts, such as the patch bolt in Fig. 375, the head is very liable to come off unless the countersink in the work (as in C) is quite fair with the tapped hole (as in D) because the thread of the bolt is made a tight fit to the hole, and all the bending that may take place is in the neck beneath the head, where fracture usually occurs. These bolts are provided with a square head A to screw them in by, and are turned in as at B to a diameter less than that at the bottom of the thread, so that if screwed up until they twist off, they will break in the neck at B.

Instead of the hole being countersunk, however, it may be cupped or counterbored, as in Fig. 376, in which the names of the various forms of the enlargement of holes are given. The difference between a faced and a counterbored hole is that in a counterbored hole the head or collar of the pin passes within the counterbore, the use of the counterbore being in this case to cause the pin to stand firmly and straight. The difference between a dished and a cupped is merely that cupped is deeper than dished, and that between grooved and recessed is that a recess is a wide groove.

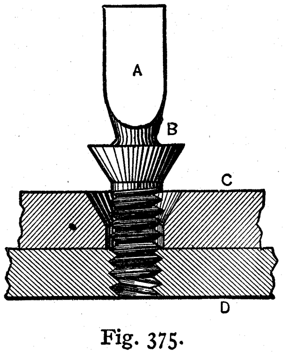

Fig. 375.

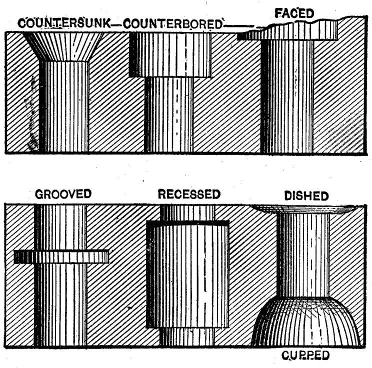

Fig. 376.

Eye bolts are those having an eye in place of a head, as in Fig. 377, being secured by a pin passing through the eye, or by a second bolt, as in the figure. When the bolt requires to pivot, that part that is within the eye may be made of larger diameter than the thread, so as to form a shoulder against which the bolt may be screwed firmly home to secure it without gripping the eye bolt.

Fig. 378 represents a foundation bolt for holding frames to the stone block of a foundation. The bolt head is coned and jagged with chisel cuts. It is let into a conical hole (widest at the bottom) in the stone block, and melted lead is poured around it to fill the hole and secure the bolt head.

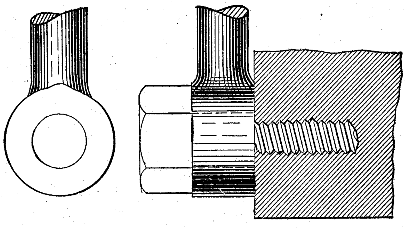
Fig. 377.

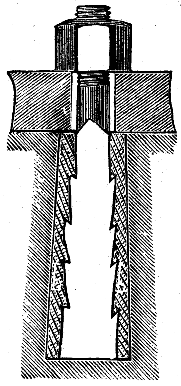
Fig. 378.

Another method of securing a foundation bolt head within a stone block is shown in Fig. 379; a similar coned hole is cut in the block, and besides the bolt head B a block W is inserted, the faces of the block and bolt being taper to fit to a taper key K, so that driving K locks both the bolt and the block in the stone. When the bolt can pass entirely through the foundation (as when the latter is brickwork) it is formed as in Fig. 380, in which B is a bolt threaded to receive a nut at the top. At the bottom it has a keyway for a key K, which abuts against the plate P To prevent the key from slackening and coming out, it has a recess as shown in the figure at the sectional view of the bolt on the right of the illustration, the recess fitting down into the end of the keyway as shown.

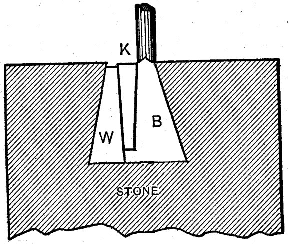

Fig. 379.

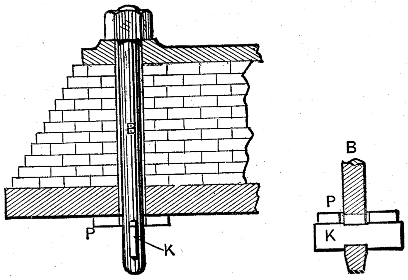

Fig. 380.

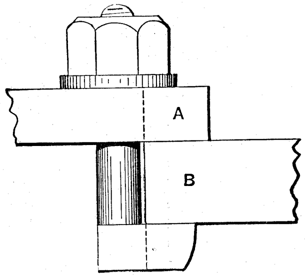

Fig. 382.

Another method is to give the bolt head the form at B in Fig. 381, and to cast a plate with a rectangular slot through, and with two lugs A C. The plate is bricked in and a hole large enough to pass the bolt head through is left in the brickwork. The bolt head is passed down through the brickwork in the position shown at the top, and when it has passed through the slot in the plate it is given a quarter turn, and then occupies the position shown in the lower view, the lugs A C preventing it from turning when the nut is screwed home. The objection to this is that the hole through the brickwork must be large enough to admit the bolt head. Obviously the bolt may have a solid square head, and a square shoulder fitting into a square hole in the plate, the whole being bricked in.

Figs. 382 and 383 represent two forms of hook bolt for use in cases where it is not desired to have bolt holes through both pieces of the work. In Fig. 382 the head projects under the work and for some distance beneath and beyond the washer, as is denoted by the dotted line, hence it would suspend piece A from B or piece B from A. But in Fig. 383 the nut pressure is not beneath the part where the hook D grips the work, hence the nut would exert a pressure to pull piece B in the direction of the arrow; hence if B were a fixed piece the bolt would suspend A from it, but it could not suspend B from A.

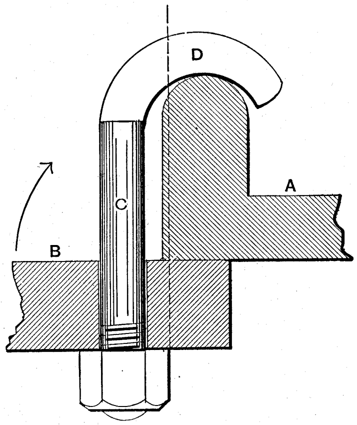

Fig. 383.

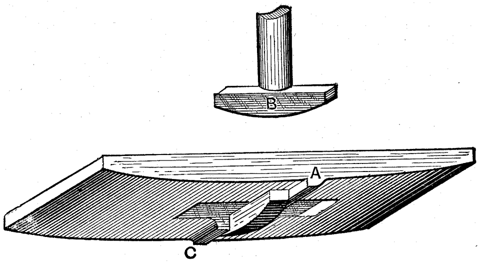

Fig. 381.

In woodwork the pressure of the nut is apt to compress the wood, causing the bolt head and nut to sink into the wood, and to obviate this, anchor plates are used to increase the area receiving the pressure; thus in Fig. 384 a plate is tapped to serve instead of a nut, and a similar plate may of course be placed under the bolt head.

The Franklin Institute or United States Standard for the dimensions of bolt heads and nuts is as follows. In Fig. 385, D represents the diameter of the bolt, J represents the short diameter or width across flats of the bolt head or of the nut, being equal to one and a half times the diameter of the bolt, plus $\frac{1}{16}$ inch for finished heads or nuts, and plus $\frac{1}{8}$ inch for rough or unfinished heads or nuts. K represents the depth or thickness of the head or nut, which in finished heads or nuts equals the diameter of the bolt minus $\frac{1}{16}$ inch, and in rough heads equals one half the distance between the parallel sides of the head, or in other words one half the width across the flats of the head.

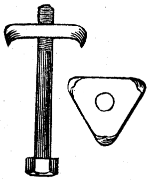
Fig. 384.

H represents the thickness or depth of the nut, which for finished nuts is made equal to the diameter of the bolt less $\frac{1}{16}$ inch, and therefore the same thickness as the finished bolt head, while for rough or unfinished nuts it is made equal to the diameter of the bolt or the same as the rough bolt head. I represents the long diameter or

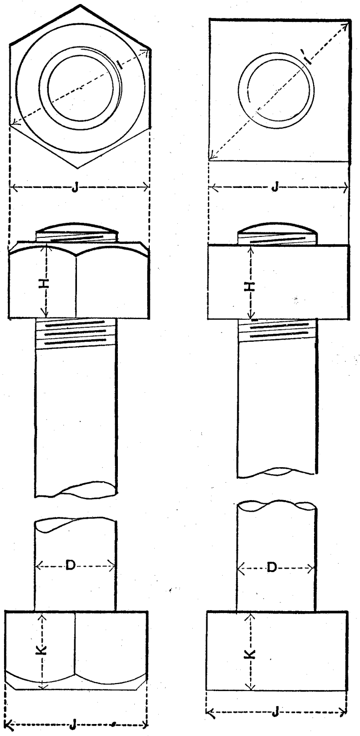

Fig. 385.

diameter across corners, which, however, is a dimension not used to work to, and is inserted in the following tables merely for reference:—

TABLE OF THE FRANKLIN INSTITUTE STANDARD DIMENSIONS FOR THE HEADS OF BOLTS AND FOR THEIR NUTS, WHEN BOTH HEADS AND NUTS ARE OF HEXAGON FORM, AND ARE POLISHED OR FINISHED.

Diameter at top of Thread.	Diameter at bottom of Thread.	Number of Threads per Inch.	Diameter across Flats, or short Diameter.	Thickness or Depth.
1/4	·185	20	7/16	3/16
5/16	·240	18	17/32	1/4
3/8	·294	16	5/8	5/16
7/16	·345	14	23/32	3/8
1/2	·400	13	13/16	7/16
9/16	·454	12	29/32	1/2
5/8	·507	11	1	9/16
3/4	·620	10	1 3/16	11/16
7/8	·731	9	1 3/8	13/16
1	·837	8	1 9/16	15/16
1 1/8	·940	7	1 3/4	1 1/16
1 1/4	1·065	7	1 15/16	1 3/16
1 3/8	1·160	6	2 1/8	1 5/16
1 1/2	1·284	6	2 5/16	1 7/16
1 5/8	1·389	5 1/2	2 1/2	1 9/16
1 3/4	1·491	5	2 11/16	1 11/16
1 7/8	1·616	5	2 7/8	1 13/16
2	1·712	4 1/2	3 1/16	1 15/16
2 1/4	1·962	4 1/2	3 7/16	2 3/16
2 1/2	2·176	4	3 13/16	2 7/16
2 3/4	2·426	4	4 3/16	2 11/16
3	2·629	3 1/2	4 9/16	2 15/16
3 1/4	2·879	3 1/2	4 15/16	3 3/16
3 1/2	3·100	3 1/4	5 5/16	3 7/16
3 3/4	3·377	3	5 11/16	3 13/16
4	3·567	3	6 1/16	3 15/16
4 1/4	3·798	2 7/8	6 7/16	4 3/16
4 1/2	4·028	2 7/8	6 13/16	4 7/16
4 3/4	4·256	2 5/8	7 3/16	4 11/16
5	4·480	2 1/2	7 9/16	4 15/16
5 1/4	4·730	2 1/2	7 15/16	5 3/16
5 1/2	4·953	2 3/8	8 5/16	5 7/16
5 3/4	5·203	2 3/8	8 11/16	5 11/16
6	5·423	2 1/4	9 1/16	5 15/16

Note that square heads are supposed to be always unfinished, hence there is no standard for their sizes if finished.

The Franklin Institute standard dimensions for hexagon and square bolt heads and nuts when the same are left unfinished or rough, as forged, are as follows:—

Bolt Diameter in Inches.	Diameter across corners, or long diameter of hexagon heads	Diameter across corners or long diameter of square heads.	Short diameter, or diameter across flats for square or hexagon heads and nuts.	Thickness or depth for square or hexagon heads.
	Inch.	Inch.	Inch.	Inch.
1/4	37/64	7/10	1/2	1/4
5/16	11/16	10/12	19/32	19/64
3/8	51/64	63/64	11/16	11/32
7/16	9/10	1 7/64	25/32	25/64
1/2	1	1 15/64	7/8	7/16
9/16	1 1/8	1 23/64	31/32	31/64
5/8	1 7/32	1 1/2	1 1/16	17/32
3/4	1 7/16	1 49/64	1 1/4	5/8
7/8	1 21/32	2 1/32	1 7/16	23/32
1	1 7/8	2 19/64	1 5/8	13/16
1 1/8	2 2/32	2 9/16	1 13/16	29/32
1 1/4	2 5/16	2 53/64	2	1
1 3/8	2 17/32	3 3/32	2 3/16	1 3/32
1 1/2	2 3/4	3 23/64	2 3/8	1 3/16
1 5/8	2 31/32	3 5/8	2 9/16	1 9/32
1 3/4	3 3/16	3 57/64	2 3/4	1 3/8
1 7/8	3 13/32	4 5/32	2 15/16	1 15/32
2	3 5/8	4 27/64	3 1/8	1 9/16
2 1/4	4 1/16	4 61/64	3 1/2	1 3/4
2 1/2	4 1/2	5 31/64	3 7/8	1 15/16
2 3/4	4 29/32	6	4 1/4	2 1/8
3	5 3/8	6 17/32	4 5/8	2 5/16
3 1/4	5 13/16	7 1/16	5	2 1/2
3 1/2	6 7/64	7 39/64	5 3/8	2 11/16
3 3/4	6 21/32	8 1/8	5 3/4	2 7/8
4	7 3/32	8 41/64	6 1/8	3 1/16
4 1/4	7 9/16	9 3/16	6 1/2	3 1/4
4 1/2	7 31/32	9 3/4	6 7/8	3 7/16
4 3/4	8 13/32	10 1/4	7 1/4	3 5/8
5	8 27/32	10 49/64	7 5/8	3 13/16
5 1/4	9 9/32	11 23/64	8	4
5 1/2	9 23/32	11 7/8	8 3/8	4 3/16
5 3/4	10 5/32	12 3/8	8 3/4	4 3/8
6	10 19/32	12 15/16	9 1/8	4 9/16

The depth or thickness of both the hexagon and square nuts when left rough or unfinished is, according to the above standard, equal to the diameter of the bolt.

The following are the sizes of finished bolts and nuts according to the present Whitworth Standard. The exact sizes are given in decimals, and the nearest approximate sizes in sixty-fourths of an inch:—

Diameter of bolts.	Width of nuts across flats.		Height of bolt heads.	
1/8	·338	21/64 *f*	·1093	7/64
3/16	·448	29/64 *b*	·1640	5/32
1/4	·525	33/64 *f*	·2187	7/32
5/16	·6014	19/32 *f*	·2734	17/64
3/8	·7094	45/64 *f*	·3281	21/64
7/16	.8204	53/64 *b*	·3828	3/8 *f*
1/2	·9191	29/32 *b*	·4375	7/16
9/16	1·011	1 1/64 *b*	·4921	31/64 *f*
5/8	1·101	1 3/32 *f*	·5468	35/64
11/16	1·2011	1 13/64 *b*	·6015	19/32 *f*
3/4	1·3012	1 19/64 *f*	·6562	21/32
13/16	1·39	1 25/64 *b*	·7109	45/64 *f*
7/8	1·4788	1 31/64 *b*	·7656	49/64
15/16	1·5745	1 37/64 *b*	·8203	13/16 *f*
1	1·6701	1 43/64 *b*	·875	7/8
1 1/8	1·8605	1 55/64 *f*	·9843	63/64
1 1/4	2·0483	2 3/64 *f*	1·0937	1 3/32
1 3/8	2·2146	2 7/32 *b*	1·2031	1 13/64
1 1/2	2·4134	2 13/32 *f*	1·3125	1 5/16
1 5/8	2·5763	2 37/64 *b*	1·4128	1 27/64
1 3/4	2·7578	2 3/4 *f*	1·5312	1 17/32
1 7/8	3·0183	3 1/16 *f*	1·6406	1 41/64
2	3·1491	3 5/32 *b*	1·75	1 3/4
2 1/8	3·337	3 11/32 *b*	1·8523	1 55/64
2 1/4	3·546	3 35/64 *b*	1·9687	1 31/32
2 3/8	3·75	3 3/4	2·0781	2 5/64
2 1/2	3·894	3 57/64 *f*	2·1875	2 3/16
2 5/8	4·049	4 3/64 *f*	2·2968	2 19/64
2 3/4	4·181	4 3/16 *b*	2·4062	2 13/32
2 7/8	4·3456	4 11/32 *f*	2·5156	2 33/64
3	4·531	4 17/32 *b*	2·625	2 5/8

The thickness of the nuts is in every case the same as the diameter of the bolts: *f* = full, *b* = bare.

When bolts screw directly into the work instead of passing through it and receiving a nut, they come under the head of either tap bolts, set screws, cap screws, or machine screws. A tap bolt is one in which the full length of the stem or body is threaded, and differs from a set screw, which is similarly threaded, in the respect that in a set screw the head is square and its diameter is the same as the square bar of steel or iron (as the case may be) from which the screw was made, while in the tap bolt the head is larger in diameter than the bar it was made from. Furthermore a tap bolt may have a hexagon head, which is usually left unfinished unless ordered to be finished, as is also the case with set screws.

Cap screws are made with heads either hexagon, square, or round, and also with a square head and round collar, as in Fig. 386, the square heads being of larger diameter than the iron from which they were made. When the heads of cap screws are finished they are designated as "milled heads."

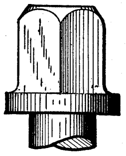

Fig. 386.

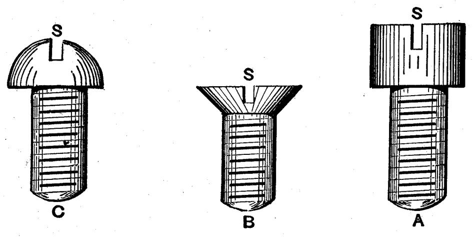

Fig. 387.

A machine screw is a small screw, such as in Fig. 387, the diameter of the body being made to the Birmingham wire gauge, the heads being formed by upsetting the wire of which they are made. They have saw slots S for a screw driver, the threads having special pitches, which are given hereafter. The forms of the heads are as in Fig. 387, A being termed a Fillister, B a countersink, and C a round head. The difference between a Fillister head of a machine screw and the same form of head in a cap screw is that the former is upset cold, and the latter is either forged or cut out of the solid metal.

When the end of a screw abuts against the work to secure it, it is termed a set screw. The ordinary form of set screw is shown in Fig. 389, the head being square and either black or polished as may be required. The ends of the set screws of commerce, that is to say, that are kept on sale, are usually either pointed as at A, Fig. 388, slightly bevelled as at B, or cupped as at D. If left flat or only slightly bevelled as at B, they are liable, if of steel and not hardened, or if of iron and case-hardened only, to bulge out as at C. This prevents them from slacking back easily or prevents removal if necessary, and even though of hardened steel they do not grip very firmly. On this account their points are sometimes made conical, as at A. This form, however, possesses a disadvantage when applied to a piece of work that requires accurate adjustment for position, inasmuch as it makes a conical indentation in the work, and unless the point be moved sufficiently to clear this indentation the point will fall back into it; hence the conical point is not desirable when the piece may require temporary fixture to find the adjustment before being finally screwed home. For these reasons the best form of set screw end is shown at D, the outside of the end being chamfered off and the inside being cupped, as denoted by the dotted lines. This form cuts a ring in the work, but will hold sufficiently for purposes of adjustment without being screwed home firmly.

In some cases the end of the set screw is tapped through the enveloping piece (as a hub) and its end projects into a plain hole in the internal piece of the work, and in this case the end of the thread is turned off for a distance of two or three threads, as at A in Fig. 390. Similarly, when the head of the screw is to act or bear upon the work, the thread may be turned off as at B in the figure.

When a bolt has no head, but is intended to screw into the work at one end, and receive a nut at the other, it is termed a stud or standing bolt. The simplest form of standing bolt is that in which it is parallel from end to end with a thread at each end, and an unthreaded part in the middle, but since standing bolts or studs require to remain fixed in the work, it is necessary to screw them tightly into their places, and therefore firmly home. This induces the difficulty that some studs may screw a trifle farther into the work than others, so that some of the stud ends may project farther through the nuts than others, giving an appearance that the studs have been made of different lengths. The causes of this may be slight variations in the tapping of the holes and the threading of the studs. If those that appear longest are taken out and reduced to the lengths of the others, it will be found sometimes that the stud on the second insertion will pass farther into the work than at the first, and the stud will project less through the nut than the others. To avoid this those protruding most may be worked backward and forward with the wrench and thus induced to screw home to the required distance, but it is better to provide to the stud a shoulder against which it may screw firmly home; thus in Fig. 391 is a stud, whose end A is to screw into the work, part B is to enter the hole in the work (the thread in the hole being cut away at the mouth to receive B). In this case the shoulder between B and C screwing firmly against the face of the work, all the studs being made of equal length from this shoulder to end E, then the thickness of the flange or work secured by the nut being equal, the nuts will pass an equal distance on end D, and E will project equally through all the nuts. The length of the plain part C is always made slightly less than the thickness of the flange or foot of the work to be bolted up, so that the nut shall not meet C before gripping the flange surface.

There are, however, other considerations in determining the shape and size of the parts A and C of studs.

Thus, suppose a stud to have been in place some time, the nut on end E being screwed firmly home on the work, and perhaps somewhat corroded on E. Then the wrench pressure applied to the nut will be in a direction to unscrew the stud out of the work, and if there be less friction between A and the thread in the work than there is between D and the thread in the nut, the stud and not the nut will unscrew. It is for this purpose that the end A requires firmly screwing into the work. But in the case of much corrosion this is not always sufficient, and the thread A is therefore sometimes made of a larger diameter than the thread at D. In this case the question at once arises, What shall be the diameter of the plain part C?

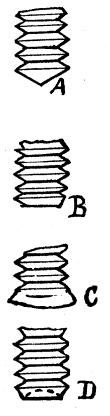

Fig. 388.

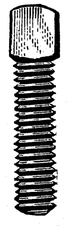

Fig. 389.

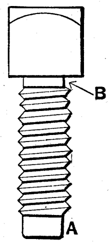

Fig. 390.

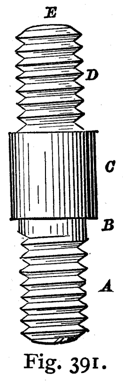

Fig. 391.

If it be left slightly larger than D, but the depth of the thread less than A, then it may be held sufficiently firmly by the fit of the threads (without the aid of screwing against a shoulder) to prevent unscrewing when releasing the nut, and may be screwed within the work until its end projects the required distance; thus all the studs may project an equal distance, but there will be the disadvantage that when the studs require removing and are corroded the plain part is apt to twist off, leaving the end A plugging the hole. The plain part C may be left of same diameter as A, both being larger than D; but in this case the difficulty of having all the studs project equally when screwed home, as previously mentioned, is induced; hence C may be larger than A, and a shoulder left at B, as in the figure; this would afford excellent facility for unscrewing the stud to remove it, as well as insuring equal projection of E. The best method of all is, so far as quality goes, to make the plain part C square, as in Fig. 392, which is an English practice, the square affording a shoulder to screw up against and secure an equal projection while serving to receive a wrench to put in or remove the stud. In this case the holes in the flange or piece bolted up being squared, the stud cannot in any case unscrew with the nut. The objection to this squared stud is that the studs cannot be made from round bar iron, and are therefore not so easily made, and that the squaring of the holes in the flange or part of the work supported by the stud is again extra work, and for these reasons studs with square instead of cylindrical mid-sections have not found favor in the United States.

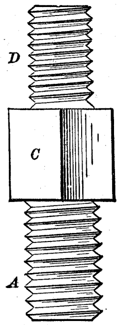

Fig. 392.

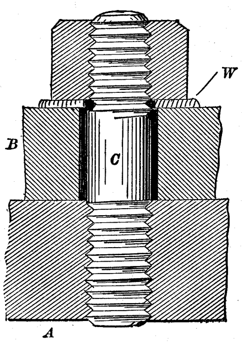

Fig. 393.

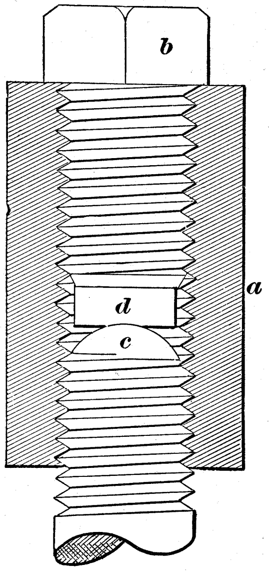

Fig. 394.

An excellent method of preventing the stud from unscrewing with the nut is to make the end A longer than the nut end, as in Fig. 393, so that its threads will have more friction; and this has the further advantage that in cast iron it serves also to make the strength of the thread equal to that of the stud. As the faces of the nuts are apt when screwed home to score or mark the face of the work, it adds to the neatness of the appearance to use a washer W beneath the nut, which distributes the pressure over a greater area of work surface.

In some practice the ends A of studs are threaded taper, which insures that they shall fit tight and enables their more easy extraction.

An excellent tool for inserting studs of this kind to the proper distance is shown in Fig. 394. It consists of a square body *a* threaded to receive the stud whose end is shown at *c*. The upper end is threaded to receive an adjusting screw *b*, which is screwed in so that its end *d* meets the end *c* of the stud. It is obvious that *b* may be so adjusted that when *a* is operated by a wrench applied to its body until its end face meets the work and the stud is inserted to the proper depth, all subsequent studs may be put into the same depth.

When the work pivots upon a stem, as in Fig. 305, the bolt is termed a standing pin, and as in such cases the stem requires to stand firm and true it is usual to provide the pin with a collar, as shown in the figure, and to secure the pivoted piece in place with a washer and a taper pin because nuts are liable to loosen back of themselves. Furthermore, a pin and washer admit of more speedy disconnection than a nut does, and also give a more delicate adjustment for end fit.

In drilling the tapping holes for standing bolts, it is the practice with some to drill the holes in cast iron of such a size that the tap will cut three-quarters only of a full thread, the claim being that it is as strong as a full thread. The difference in strength between a three-quarter and a full thread in cast iron is no doubt practically very small indeed, while the process of tapping is very much easier for the three-quarter full thread, because the tap may, in that case, be wound continuously forward without backing it at every quarter or half revolution, as would otherwise be necessary, in order to give the oil access to the cutting edges of the tap—and oil should always be used in the process of tapping (even though on cast iron it causes the cuttings to clog in the flutes of the tap, necessitating in many cases that the tap be once or twice during the operation taken out, and the cuttings removed) because the oil preserves the cutting edges of the tap teeth from undue abrasion, and, therefore, from unnecessarily rapid dulling. With a tap having ordinarily wide and deep flutes, and used upon a hole but little deeper than the diameter of the tap, the cuttings due to making a three-quarter full thread will not more than fill the flutes of the tap by the time its duty is performed. We have also to consider that with a three-quarter full thread it is much easier to extract the standing bolt when it is necessary to do so, so that all things considered it is permissible to have such a thread, providing the tapping hole does not pass through into a cylinder or chamber requiring to be kept steam-tight, for in that case the bolt would be almost sure to leak. As a preventive against such leakage, the threads are sometimes cut upon the standing bolts without having a terminal groove, and are then screwed in as far as they will go; the termination of the thread upon the standing bolt at the standing or short end being relied upon to jam into and close up the thread in the hole. A great objection to this, however, is the fact that the bolts are liable to screw into the holes to unequal depths, so that the outer ends will not project an equal distance through the nuts, and this has a bad appearance upon fine work. It is better, then, in such a case, to tap the holes a full thread, the extra trouble involved in the tapping being to some extent compensated for in the fact that a smaller hole, which can be more quickly drilled, is required for the full than for the three-quarter thread.

The depth of the tapping hole should be made if possible equal to one and a half times the diameter of the tap, so that in case the hole bottoms and the tap cannot pass through, the taper, and what is called in England the second, and in the United States the plug tap, will finish the thread deep enough without employing a third tap, for the labor employed in drilling the hole deeper is less than that necessary to the employment of a third tap. If the hole passes through the work, its depth need not, except for cast-iron holes, be greater than $\frac{1}{8}$ inch more than the diameter of the bolt thread, which amount of excess is desirable so that in case the nut corrodes, the nut being as thick as the diameter of the tap, and therefore an inch less than the depth of the hole at the standing end, will be more likely to leave the stud standing than to carry it with it when being unscrewed.

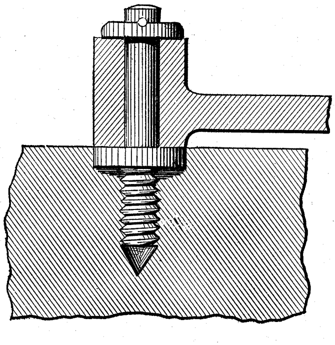

Fig. 395.

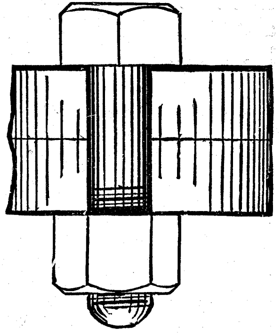

Fig. 396.

When it is desirable to provide that bolts may be quickly removed, the flanges may be furnished with slots, as in Fig. 396, so that the bolts may be passed in from the outside, and in this case it is simply necessary to slacken back the nut only. It is preferable, however, in this case to have the bolt square under the head, as in Fig. 397, so as to prevent the bolt from turning when screwing up or unscrewing the nut. The bolt is squared at A, which fits easily into the flange. The flanges, however, should in this case be of ample depth or thickness to prevent their breakage, twice the depth of the nut being a common proportion.

In cases where it is inconvenient for the bolt head to pass through the work a T groove is employed, as in Fig. 398. In this case the bolt head may fit easily at A B to the sides A B of the groove, so that while the bolt head will slide freely along the groove, the head, being square, cannot turn in the slot when the nut is screwed home. This, however, is more efficiently attained when there is a square part beneath the bolt head, as in Fig. 399, the square A of the bolt fitting easily to the slot B of the groove.

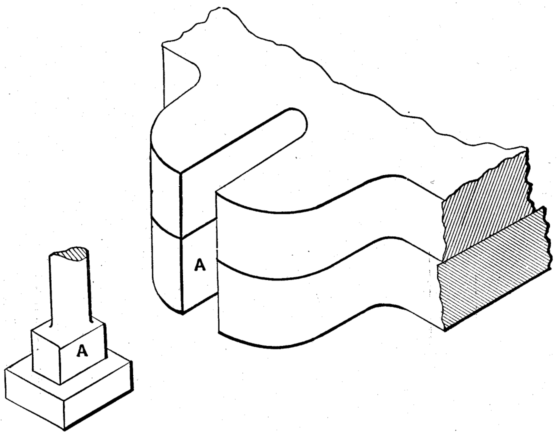

Fig. 397.

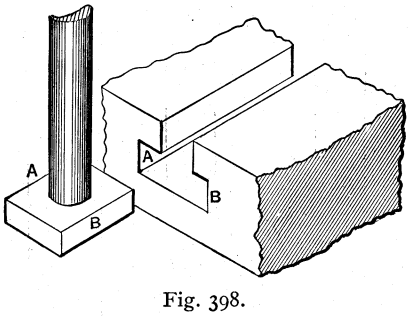

Fig. 398.

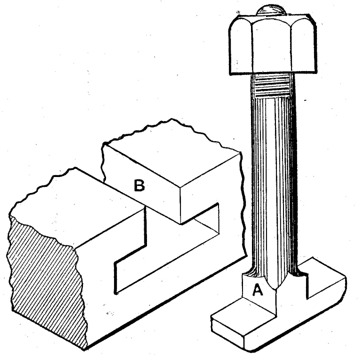

Fig. 399.

When it is undesirable that the slots run out to the edge of the work they may terminate in a recess, as at A in Fig. 400, which affords ingress of the bolt head to the slot; or the bolt head may be formed as in Fig. 401, the width A B of the bolt head passing easily through the top A B of the slot, and the bolt head after its insertion being turned in the direction of the arrow, which it is enabled to do by reason of the rounded corners C D. In this case, also, there may be a square under the head to prevent the bolt head from locking in the slot, but the corners of the square must also be rounded as in Fig. 402.

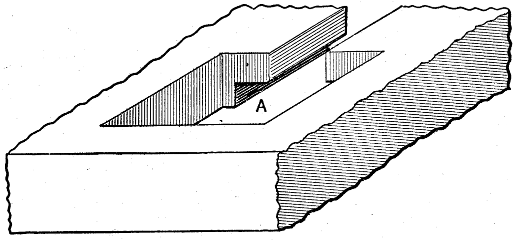

Fig. 400.

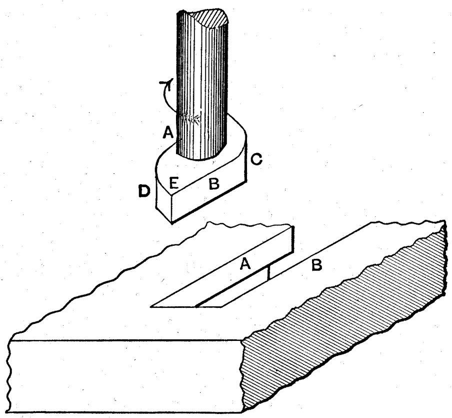

Fig. 401.

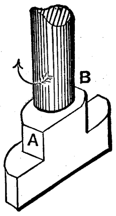

Fig. 402.

The underneath or gripping surface of a bolt head should be hollow, as at A in Fig. 403, rather than rounding as at B, because, if rounding, the bolt will rotate with the nut when the latter grips the work surface. It should also be true with the axial line of the bolt so as to bear fairly upon the work without bending. The same remarks apply to the bedding surface of the nut, because to whatever amount the face is out of true it will bend the threaded end of the bolt, and this may be sufficient to cause the bolt to break.

In Fig. 404, for example, is shown a bolt and nut, neither of which bed fair, being open at A and B respectively, and it is obvious that the strain will tend to bend or break the bolt across the respective dotted lines C, D. In the case of the nut there is sufficient elasticity in the thread to allow of the nut forcing itself to a bed on the work, the bolt bending; but in the case of the bolt head the bending is very apt to break off the bolt short in the neck under the head. In a tap bolt where the wrench is applied to the bolt head, the rotation, under severe strain, of the head will usually cause it to break off in all cases where the bolt is rigidly held, so that it cannot cant over and allow the head to bed fair.

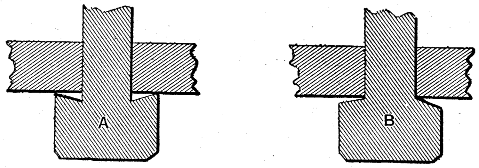

Fig. 403.

A plain tap bolt should be turned up along its body, because if out of true the hole it passes through must be made large enough to suit the eccentricity of the bolt, or else a portion of the wrench pressure will be expended in rotating the bolt in the hole instead of being expended solely in screwing the bolt farther into the work.

It is obvious therefore, that if a tap bolt be left black the hole it passes through must be sufficiently large to make full allowance for the want of truth in the bolt. For the same reasons the holes for tapped bolts require to be tapped very true.

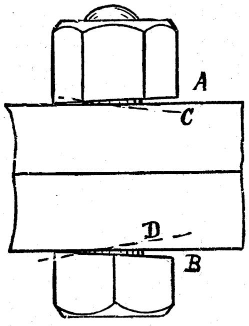

Fig. 404.

Black studs possess an advantage (over tap bolts) in this respect, inasmuch as that if the holes are not tapped quite straight the error may be to some extent remedied by screwing them fully home and then bending them by hammer blows.

Nuts are varied in form to suit the nature of the work. For ordinary work, as upon bolts, their shape is usually made to conform to the shape of the bolt head, but when the nut is exposed to view and the bolt head hidden, the bolt end and the nut are (for finished work) finished while the bolt heads are left black.

The most common form of hexagon nut is shown in Fig. 405, the upper edge being chamfered off at an angle of about 40°. In some cases the lower edge is cut away at the corners, as in Fig. 405 at A, the object being to prevent the corners of the nut from leaving a circle of bearing marks upon the work, but this gives an appearance at the corners that the nut does not bed fair. Another shape used by some for the end faces of deep nuts, that is to say, those whose depth exceeds the diameter of the bolt, is shown in Fig. 406. Nuts of extra depth are used when, from the nut being often tightened and released, the thread wear is increased, and the extra thread length is to diminish the wear.

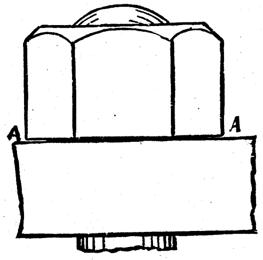

Fig. 405.

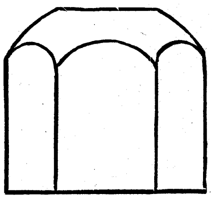

Fig. 406.

To avoid the difficulty of having some of the bolt ends project farther through some nuts than others on a given piece of work, as is liable to occur where the flanges to be bolted together are not turned on all four radial faces, the form of nut shown in Fig. 407 is sometimes employed, the thread in the nut extending beyond the bolt end.

As an example of the application of this nut, suppose a cylinder cover to be held by bolts, then the cylinder flange not being turned on its back face is usually of unequal thickness; hence to have the bolt ends project equally through the nuts, each bolt would require to be made of a length to suit a particular hole, and this would demand that each hole and bolt be marked so that they may be replaced when taken out, without trying them in their places. Another application of this nut is to make a joint where the threads may be apt to leak. In this case the mouth of the hole is recessed and coned at the edge; the nut is chamfered off with a similar cone, and a washer W, Fig. 408, is placed beneath the nut to compress and conform to the coned recess; thus with the aid of a cement of some kind, as red or white lead (usually red lead), a tight joint may be made independent of the fit of the threads.

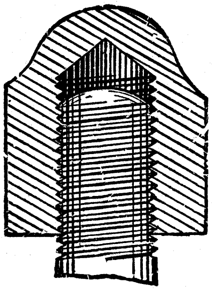

Fig. 407.

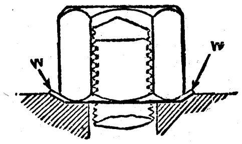

Fig. 408.

When the hole through which the bolt passes is considerably larger in diameter than the bolt, the flange nut shown in Fig. 409 is employed, the flange covering the hole. A detached washer may be used for the same purpose, providing that its hole fit the bolt and it be of a sufficient thickness to withstand the pressure and not bend or sink into the hole.

Circular nuts are employed where, on account of their rotating at high speed, it is necessary that they be balanced as nearly as possible so as not to generate unbalanced centrifugal force. Fig. 410 represents a nut of this kind: two diametrically opposite flat sides, as A, affording a hold for the wrench. Other forms of circular nuts are shown in Figs. 411 and 412. These are employed where the nuts are not subject to great strain, and where lightness is an object.

That in Fig. 411 is pierced around its circumference with cylindrical holes, as A, B, C, to receive a round lever or rod or a wrench, such as shown in Fig. 459.

That shown in Fig. 412 has slots instead of holes in its circumference, and the form of its wrench is shown in Fig. 461.

When nuts are employed upon bolts in which the strain of the duty is longitudinal to the bolt, and especially if the direction of motion is periodically reversed, and also when a bolt is subject to shocks or vibrations, a single nut is liable to become loose upon the bolt, and a second nut, termed a check nut, jamb nut, or safety nut, becomes necessary, because it is found that if two nuts be employed, as in Fig. 413, and the second nut be screwed firmly home against the first, they are much less liable to come loose on the bolt.

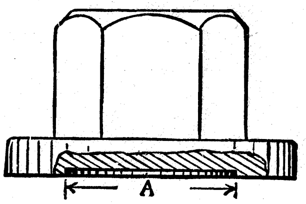

Fig. 409.

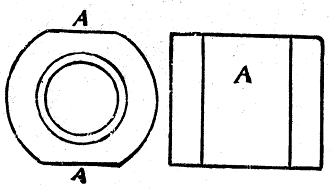

Fig. 410.

Considerable difference of practice exists in relation to the thickness of the two nuts when a check nut is employed. The first or ordinary nut is screwed home, and the second or check nut is then screwed home. If the second nut is screwed home as firmly as the first, it is obvious that the strain will fall mainly on the second. If it be screwed home more firmly than the first, the latter may be theoretically considered to be relieved entirely of the strain, while if it be screwed less firmly home, the first will be relieved to a proportionate degree of the strain. It is usual to screw the second home with the same force as applied to the first, and it would, therefore, appear that the first nut, being relieved of strain, need not be so thick as the first, but it is to be considered that, practically, the first nut will always have some contact with the bolt threads, because from the imperfections in the threads of ordinary bolts the area and the force of contact is not usually the same nor in the same direction in both nuts, unless both nuts were tapped with the same tap and at about the same time.

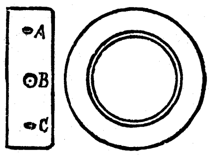

Fig. 411.

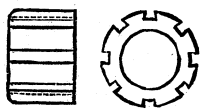

Fig. 412.

When, for example, a tap is put into the tapping machine, it is at its normal temperature, and of a diameter due to that temperature, but as its work proceeds its temperature increases, notwithstanding that it may be freely supplied with oil, because the oil cannot, over the limited area of the tap, carry off all the heat generated by the cutting of a tap rotated at the speeds usually employed in practice. As a result of this increase of temperature, we have a corresponding increase in the diameter of the tap, and a variation in the diameter of the threads in the nuts. The variation in the nuts, however, is less than that in the tap diameter, because as the heated tap passes through the nut it imparts some of its heat to the nut, causing it also to expand, and hence to contract in cooling after it has been tapped, and, therefore, when cold, to be of a diameter nearer to that of the tap.

Furthermore, as the tap becomes heated it expands in length, and its pitch increases, hence here is another influence tending to cause the pitches of the nut threads to vary, because although the temperature of the tap when in constant use reaches a limit beyond which, so long as its speed of rotation is constant, it never proceeds; yet, when the tap is taken from the machine to remove the tapped nuts which have collected on its shank, and it is cooled in the oil to prevent it from becoming heated any more than necessary, the pitch as well as the diameter of the tap is reduced nearer to its normal standard.

So far, then, as theoretical correctness, either of pitch or diameter in nut threads, is concerned, it could only be attained (supposing that the errors induced by hardening the tap could be eliminated) by employing the taps at a speed of rotation sufficiently slow to give the oil time to carry off all the heat generated by the cutting process. But this would require a speed so comparatively slow as not to be commercially practicable, unless followed by all manufacturers. Practically, however, it may be considered that if two nuts be tapped by a tap that has become warmed by use, they will be of the same diameter and pitch, and should, therefore, have an equal area and nature of contact with the bolt thread, supposing that the bolt thread itself is of equal and uniform pitch. But the dies which cut the thread upon the bolt also become heated and expanded in pitch. But if the temperature of the dies be the same as that of the tap, the pitches on both the bolt and in the nut will correspond, though neither may be theoretically true to the designated standard.

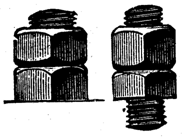
Fig. 413.

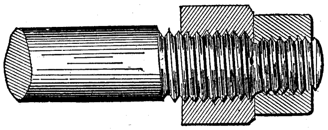
Fig. 414.

In some machines for nut tapping the tap is submerged in oil, and thus the error due to variations of temperature is practically eliminated, though even in this case the temperature of the oil will gradually increase, but not sufficiently to be of practical moment.

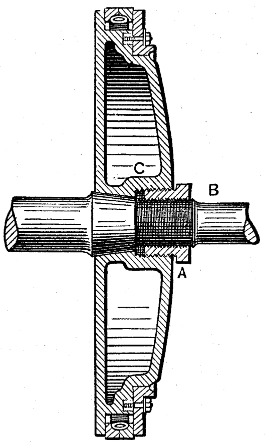

Fig. 415.

Let it now be noted that from the hardening process the taps shrink in length and become of finer pitch, while the dies expand and become of coarser pitch, and that this alone precludes the possibility of having the nut threads fit perfectly to those on the bolt. It becomes apparent, then, that only by cutting the threads in the lathe, and with a single-toothed lathe tool that can be ground to correct angle after hardening, can a bolt and nut be theoretically or accurately threaded. Under skilful operation, however, both in the manufacture of the screw-cutting tools and in their operation, a degree of accuracy can be obtained in tapped nuts and die-threaded bolts that is sufficient with a single nut for ordinary uses, but in situations in which the direction of pressure on the nut is periodically reversed, or in which it is subject to shocks or vibrations, the check nut becomes necessary, as before stated.

An excellent method of preventing a nut from slackening back of itself is shown in the safety nut in Fig. 414; it consists of a second nut having a finer thread than the first one, so that the motion of the first would in unscrewing exceed that of the second, hence the locking is effectually secured.

Work may be very securely fastened together by the employment of what are called differential screws, the principle of whose action may be explained with reference to Fig. 415, which is extracted from "Mechanics." It represents a piston head and piston rod secured together by means of a differential screw nut. The nut contains an internal thread to screw on the rod, and an external one to screw into the piston head, but the internal thread and that on the rod differ from the external one, and that in the head by a certain amount, as say one tenth of the pitch. The nut itself is furnished with a hexagonal head, and when screwed into place draws the two parts together with the same power as a screw having a pitch equal to the difference between the two pitches.

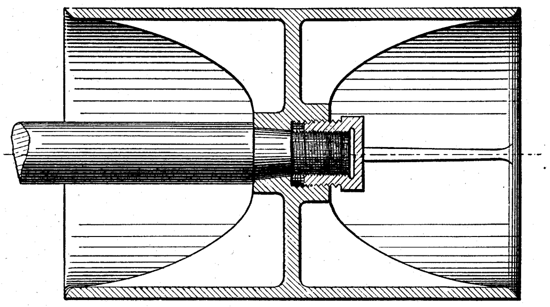
Fig. 416.

When putting the parts together the nut is first screwed upon the rod B. The outside threads are then entered into the thread in the piston C, and by means of a suitable wrench the nut is screwed into the proper depth. As shown in the engraving, the nut goes on to the rod a couple of threads before it is entered in the piston. The tightening then takes place precisely as though the nut had a solid bearing on the piston and a fine thread on the rod, the pitch of which is equal to the difference between the pitches of the two threads. Fig 416 shows its application to the securing of a pump plunger upon the end of a piston-rod. In this case, as the rod does not pass through the nut, the latter is provided with a cap, which covers the end of the rod entirely.

The principle of the differential screw may be employed to effect very fine adjustments in place of using a very fine thread, which would soon wear out or wear loose. Thus in Fig. 417 is shown the differential foot screws employed to level astronomical instruments. C D is a foot of the instrument to be levelled. It is threaded to receive screw A, which is in turn threaded to receive the screw B, whose foot rests in the recess or cup in E F. Suppose the pitch of screw A is 30 per inch, and that of B is 40, and we have as follows. If A and B are turned together the foot C D is moved the amount due to the pitch of A. If B is turned within A the foot is moved the amount due to the pitch of B. If A is turned the friction of the foot of B will hold B stationary, and the motion of C D will equal the difference between the pitches of the threads of A and B. Thus one revolution of A forward causes it to descend through C D $\frac{1}{30}$ inch (its pitch), tending to raise C D $\frac{1}{30}$

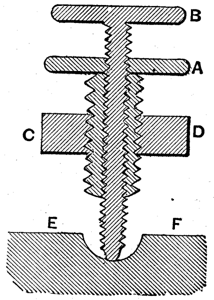

Fig. 417.

inch. But while doing this it has screwed down upon the thread of B $\frac{1}{40}$ inch (the pitch of B) and this tends to lower C D, hence C D is moved $\frac{1}{120}$ inch, because $\frac{1}{30} - \frac{1}{40} = \frac{1}{120}$.

To cause a single nut to lock itself and dispense with the second or jamb nut, various expedients have been employed. Thus in Fig. 418 is shown a nut split on one side; after being threaded the split is closed by hammer blows, appearing as shown in the detached nut. Upon screwing the nut upon the bolt the latter forces the split nut open again by thread pressure, and this pressure locks the nut. Now there will be considerable elasticity in the nut, so that if the thread compresses on its bearing area, this elasticity will take up the wear or compression and still cause the threads to bind. Sometimes a set screw is added to the split, as in Fig. 419, in which case the split need not be closed with the hammer.

Another method is to split the nut across the end as shown in Fig. 420, tapping the nut with the split open, then closing the split by hammer blows. Here as before the nut would pass easily upon the bolt until the bolt reached the split, when the subsequent threads would bind. In yet another design, shown in Fig. 421, four splits are made across the end, while the face of the nut is hollowed, so that a flat place near each corner meets the work surface. The pressure induced on these corners by screwing the nut home is relied on in this case to spring the nut, causing the thread at the split end to close upon and grip the bolt thread.

Check nuts are sometimes employed to lock in position a screw that is screwed into the work, thus screws that require to be operated to effect an adjustment of length (as in the case of eccentric rods and eccentric straps) are supplied with a check nut, the object being to firmly lock the screw in its adjusted position.

The following are forms of nuts employed to effect end adjustments of length, or to prevent end motion in spindles or shafts that rotate in bearings.

Fig. 422 shows two cylindrical check nuts, the inner one forming a flange for the bearing. The objection to this is that in screwing up the check nut the adjustment of the first nut is liable to become altered in screwing up the second one, notwithstanding that the first be held by a lever or wrench while the second is screwed home.

Another method is to insert a threaded feather in the adjustment nut and having at its back a set screw to hold the nut in its adjusted position, as in Fig. 423. In this case the protruding head of the set screw is objectionable. In place of the feather the thread of the spindle may be turned off and a simple set screw employed, as in Fig. 424; here again, however, the projecting set screw head is objectionable. The grip of an adjustment nut may be increased by splitting it and using a pinching or binding screw, as in Fig. 425, in which case the bore of the thread is closed by the screw, and the nut may be countersunk to obviate the objection of a projecting head. For adjusting the length of rods or spindles a split nut with binding screws, such as shown in Fig. 426, is an excellent and substantial device. The bore is threaded with a right-hand thread at one end and a left-hand one at the other, so that by rotating the nut the rod is lengthened or shortened according to the direction of rod rotation. Obviously a clamp nut of this class, but intended to take up lost motion or effect end adjustment, may be formed as in Fig. 427, but the projecting ears or screw are objectionable.

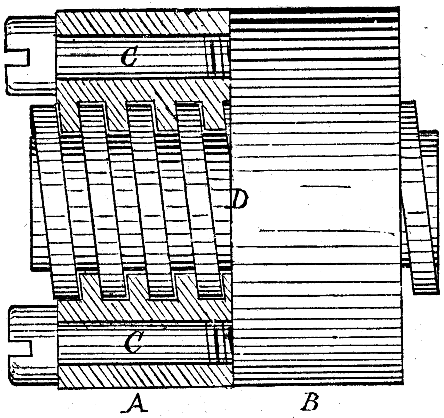

Fig. 429.

Where there is sufficient length to admit it an adjustment nut, such as in Fig. 428, is a substantial arrangement. The nut A is threaded on the spindle and has a taper threaded split nut to receive the nut B. Nut A effects the end adjustment by screwing upon the spindle, and is additionally locked thereon by screwing B up the taper split nut, causing it to close upon and grip the spindle.

Lost motion in square threads and nuts may be taken up by forming the nut in two halves, A and B, in Fig. 429 (A being shown in section) and securing them together by the screws C C. The lost motion is taken up by letting the two halves together by filing away the joint face D of either half, causing the thread in the nut to bear against one side only of the thread of the screw. The same end may be accomplished in nuts for **V**-shaped threads by forming the nut either in two halves, as shown in Fig. 430, in which A is a cap secured by screws B, the joint face C being filed away to take up the lost motion. Or the nut may be in one piece with the joint C left open, the screws B crossing the nut upon the screw by pressure. In this case the nut closes upon the circumference of the thread, taking up the wear by closing upon both sides of the thread instead of on one side only as in the case of the square thread.

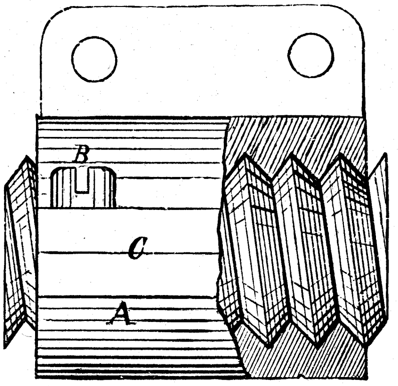

Fig. 430.

In cases where nuts are placed under rapid vibration or motion they are sometimes detained in their places by pins or cotters. The simplest form of pin used for this purpose is the split pin, shown in Fig. 431. It is made from half round wire and is parallel, and does not, therefore, possess the capability of being tightened when the nut has become loosened from wear. As the wire from which these pins are made is not usually a full half circle the pins should, if the best results are to be obtained, be filed to fit the hole, and in doing this, care should be taken to have the pin bear fully in the direction of the split which is longitudinal to the bolt, as shown in Fig. 432, where the pin is shown with its ends opened out as is required to prevent the pin from coming out. If the pin bears in a direction across the bolt as at A D, in Fig. 433, it will soon become loose

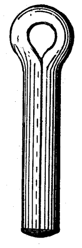

Fig. 431.

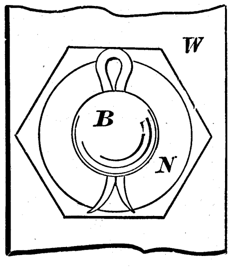

Fig. 432.

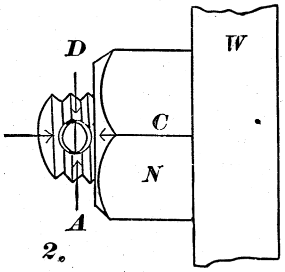

Fig. 433.

Pins of this class are sometimes passed through the nut itself

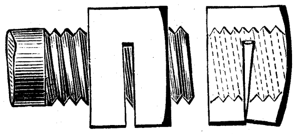
Fig. 418.

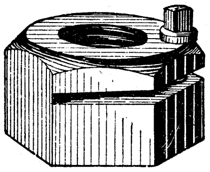
Fig. 419.

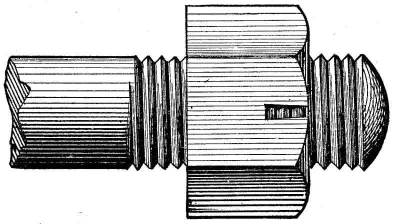
Fig. 420.

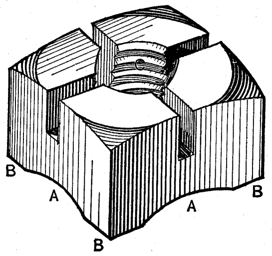

Fig. 421.

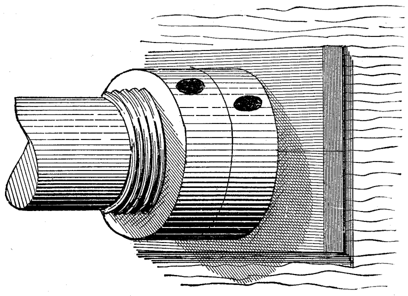
Fig. 422.

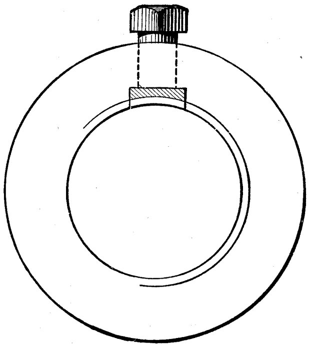
Fig. 423.

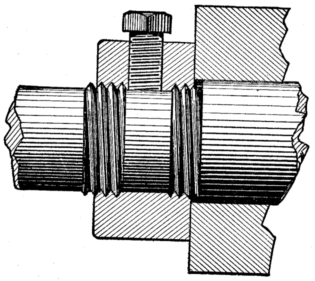
Fig. 424.

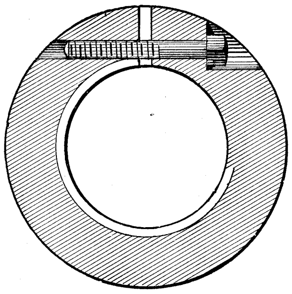
Fig. 425.

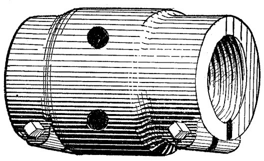
Fig. 426.

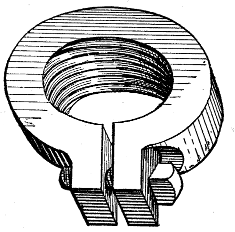
Fig. 427.

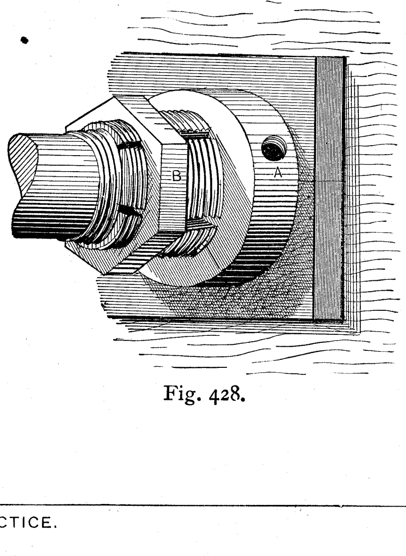

Fig. 428.

as well as through the bolt; but when this is the case, there is the objection that the nut cannot be screwed up to take up any wear, because in that case the hole in the nut would not come fair with that in the bolt, and the pin could not be inserted. When, therefore, such a pin passes through the nut, lost motion must be taken up by placing an additional or a thicker washer behind the nut. The efficiency of this pin as a locking device is much increased by passing it through the nut, because its bearing, and, therefore, wearing area, is increased, and the pin is prevented from bending after the manner shown in Fig. 434, as it is apt to do under excessive wear, with the result that the end pressure of the nut almost shears or severs the pin close to the perimeter of the bolt.

To enable the pin to take up the wear, it is a good plan to file on it a flat place, which must be parallel to the sides of the pin-head and placed against the nut-face. The hole in the bolt is in this case made to fall slightly under the nut, as in Fig. 435, so that the flat place is necessary to enable the pin to enter. By filing the flat place taper, the lost motion that may ensue from wear may be taken up by simply driving the pin in farther.

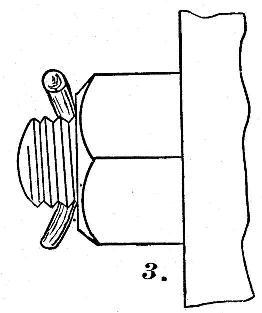

Fig. 434.

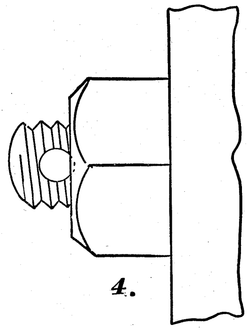

Fig. 435.

In place of this class of split pin, solid taper pins are sometimes used, but these, if employed in situations where they are subject to jar and vibration, are apt sometimes to come loose, especially if they be given much taper, because in that case they do not wedge so tightly in the hole. But if a taper pin be made too nearly parallel, it will drive through too easily, and has less capability to take up the play due to wear. An ordinary degree of taper is about $\frac{5}{8}$ inch per foot of length, but in long pins having ample bearing area, $\frac{1}{2}$ inch per foot of length is ample. To prevent taper pins from coming loose from vibration, they are sometimes forged split at the small end, as in Fig. 436, and opened out at that end after the manner shown in Fig. 432. This forms a very secure locking device, and one easily applied. The split ends are closed by hammer blows to remove the pin, and it is found that such pins may be opened and closed many times without breaking, even though made of cast steel. The heads and ends are rounded so as to prevent them from swelling from the hammer blows necessary to drive them in and out. When a taper pin is passed through a nut and bolt, it simply serves as a locking device to secure the nut in position, and the lost motion due to wear must be taken up by the application of a washer beneath the nut, as already described. If, however, the taper pin be applied outside the nut, it may be made to take up the wear, by filing on it a flat place, and locating the hole in the bolt so that it will fall partly beneath the nut, as shown in Fig. 435. In this case, the nut may be screwed up to take up the wear, and the pin by being driven farther in will still bear against the nut and prevent its slacking back.

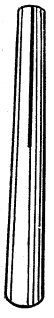

Fig. 436.

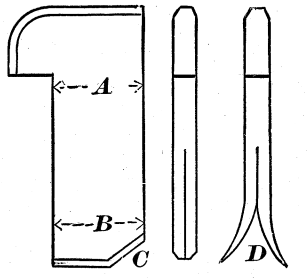

Fig. 437.

Another and excellent locking device for bolts or nuts, is the cotter shown in Fig. 437, which is sometimes forged solid and sometimes split, as in the figure. By being made taper from A to B, it will take up the wear if driven farther in. Its width gives it strength in the direction in which it acts to lock, the overhanging head is to drive it out by, and the bevelled corner C is to enable its easy insertion, because if left sharp it would be liable to catch against the edge of the cotter-way and burr up. If made split, its ends are opened out after it is inserted, as shown at D. When closing the ends of either split cotters or split pins to extract them it is better to close one side first and bend it over a trifle too much, so that, when closing the other side, by the time the pin is straightened the two ends will be closed together, and extraction becomes easy.

A very safe method in the case of a single nut or bolt head is to provide a separate plate, as in Fig. 438. The plate P is provided with three sides, corresponding to the sides of the hexagon, as shown, and in the middle of these sides are cut the notches A B C, so that by giving the nut N one-twelfth of a turn its corners D E would be held by the notches B C, S being a small screw to hold P. It is obvious that a simple set screw passed through the walls of the nut would grip the bolt thread and serve to hold the nut, but this would damage the bolt thread, and, furthermore, that thread would under jar or vibration compress and let the set screw come loose.

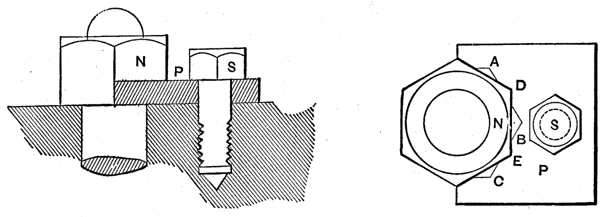

Fig. 438.

A better plan than this is to provide a thick washer beneath the nut and let a set screw pass through the washer and grip the bolt, fastening or setting up the set screw after the nut is screwed home. This, however, makes the washer a gripping piece and in no wise serves to lock the nut. In addition to the washer a pin may project through the radial face of the washer and into the work surface, which will prevent, in connection with the set screw, both the bolt and the washer from turning.

When a bolt has no thread but is secured by a taper pin, set screw, cotter, or device other than a nut, it is termed a pin. So, likewise, a cylindrical piece serving as a pivot, or to hold two pieces together and having no head, is termed a pin.

The usual method of securing a pin is by a set screw or by a taper pin and a washer; and since the term *pin* applying to both may lead to misunderstanding, the term bolt will here be applied to the large and the term pin to the small or securing pin only.

The object of pins and washers is to secure an exact degree of fit and permit of rapid connection or disconnection. An application of a taper pin and washer to a double eye is shown in Fig. 439. It is obvious, in this case, the pin E will drive home until it fills the hole through the bolt, and hence always to the same spot, so that the parts may be taken apart and put together again rapidly, while the fit is self-adjusting, providing that the pin fills the hole, bears upon the groove in the washer, and is driven home, so that by first letting the pin bind the washer W slightly too tight, and then filing the radial faces of the joint to a proper fit (which will ease the bearing of the pin on the washer), an exact degree of fit and great accuracy may be obtained, whereas when a nut is used it is difficult to bring the nut to the exact same position when screwing it home. When the joints are to be thus fitted, it is a good plan to drill the pin-hole (through the bolt) so that its centre falls coincident with the face of the washer; to then file out the grooves in the washer not quite deep enough. The pin may then be filed to fit the hole through the bolt, but left slightly too large, so that it shall not pass quite far enough through the bolt. The joint faces may then be filed true, and when finished, the parts may be put together, and the groove through the washer and hole through the bolt may be simultaneously finished by reaming with a taper reamer. This will leave the job a good fit, with a full bearing, without much trouble, the final reaming letting the taper pin pass to its proper distance through the bolt.

Taper pins are sometimes employed to secure in position a bolt that rotates, or one that requires locking in position, in situations in which there is no room for the bolt end to project and receive a nut or washer. Examples of these kinds are shown in section in Figs. 440 and 441. In 441, B is a stud pin, to rotate in the bore of A. C is a semi circular groove in B, and P a taper pin entering one-half in the groove C and one-half in B, thus preventing B from moving endwise in A, while at the same time permitting its free rotation. In this case it is best to fit B to its place, a fit tight enough to hold it firmly while the pin-hole is drilled and reamed through A and B simultaneously, then B can be put in the lathe, and the groove cut in to coincide with the half-hole or groove caused in the pin by the drilling, and after the groove is turned the stud pin may be eased to the required degree of working fit. The process for Fig. 440 is precisely the same, except that no groove turning or easing of the pin will be necessary, because the pin being locked in position may be left a tight fit. If, however, it is considered desirable to give the taper pin in Fig. 440 a little draft, so that any looseness (that may occur to the pin or stud) from wear may be taken up, then after the taper pin-hole has been drilled and reamed, the pin or stud (D in the figure) may be taken out, and its taper pin-hole *in the arm E* may be filed out all the way through on one side, as denoted by the dotted half-circle. This will give draft to the pin and allow it to drive farther through and grip the pin as it wears smaller.

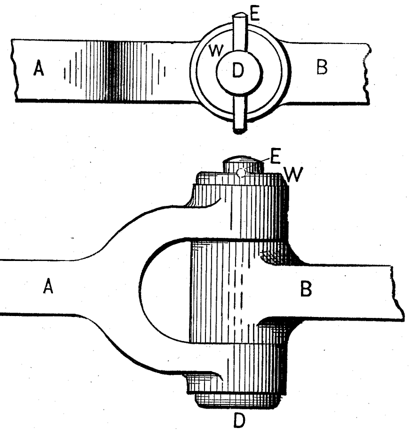

Fig. 439.

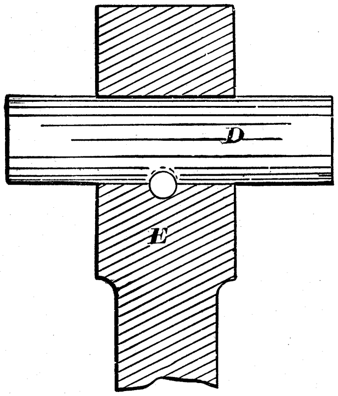

Fig. 440.

If a bolt and nut fit too tightly in their threads the nut may be wound back and forth upon the bolt under free lubrication, which will ease the fit by wearing away or compressing that part of the thread surface that is in contact. If this should not suffice we may generally ease a nut that fits so tight that it cannot be screwed upon the bolt with an ordinary wrench, by screwing the nut on a thread or two, then rest it on an iron block, and lightly hammer its sides; it will loosen its fit, and if continued, the nut may be made to pass down the bolt comparatively easily. Now, in this operation, it is not that the nut has been stretched, but that the points of contact on the threads have become compressed and imbedded; we have, in other words, caused the shape of each thread to conform nearer to that of the other than it is practicable to make them, because of reasons explained in the remarks on screw threads, and on taps.

To remove nuts or bolts that have become corroded in their places, we may adopt the following methods:—

If the nuts are so corroded that they will not unscrew with an ordinary wrench, we may, if the standing bolts and the wrench are strong enough to stand it, place a piece of gas or other pipe on the end of the wrench, so as to get a longer leverage; and, while applying the power to the wrench, we may strike the end face of the nut a few sharp blows with the hammer, interposing a set chisel, if the nut is a small one, so as to be sure to strike the nut in the proper place, and not rivet the screw end. If the joint is made with tap bolts we may strike the bolt heads with the hammer direct, using as before a light hammer and sharp blows, which will, in a majority of cases, start the thread, after which the wrench alone will usually suffice to unscrew it. If, however, this is not effective, we should take a thick washer, large enough in its bore to pass over the nut, and heat it to a yellow heat and place it over the nut, and the nut heating more rapidly than the stud or standing bolt, will be proportionately expanded and loosened; and, furthermore, the iron becomes stronger by being heated, providing the temperature does not exceed about 400°. If standing bolts or studs are employed on the joint, the heating is still advantageous, for the increase of strength more than compensates for the expansion. In this case the heating, however, may be performed more slowly, so that the hole may also become heated, and the bolt, therefore, not made a tighter fit by its excessive expansion. So also, in taking out the standing bolts or studs, heating them will often enable one to extract them without breaking them off in the hole, which would necessitate drilling out the broken piece or part. If, however, this should become necessary, we may drill a hole a little smaller than the diameter of the bottom of the bolt thread, and then drive into the hole a taper square reamer, as shown in Fig. 442, in which W represents the work, R the square reamer, and S the drilled screw end, and then, with a wrench applied to the reamer, unscrew the bolt thread. If this plan fails there is no alternative, after drilling the hole, but to take a round-nosed cape or cross-cut chisel and cut out the screw as nearly as possible, then pick out the thread at the entrance of the hole, and insert a plug tap to cut out the remaining bolt thread.

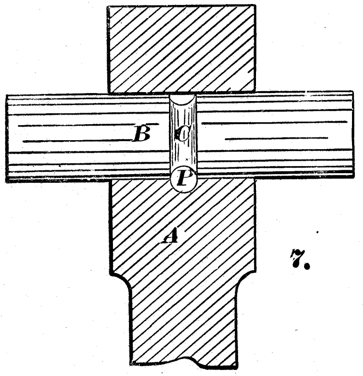

Fig. 441.

To take out a standing bolt, take two nuts and screw them on the bolt end; then hold the outer one still with a wrench and unscrew the inner one tightly against it. We may then remove the wrench from the outer or top nut, and unscrew the bolt by a wrench applied to the bottom or inner one. If the thread of a standing bolt has become damaged or burred, we can easily correct the evil by screwing a solid die or die nut down it, applying a little oil to preserve the cutting edge of the nut. If it is found impossible to take off a corroded nut without twisting off the standing bolt, it is the better plan to sacrifice the nut in order to save the bolt; and we may first hold a hammer beneath the nut, and take a cold chisel, and holding it so that the cutting edge stands parallel with the chamfered edge of the nut, and slanting it at an angle obtuse to the direction in which the nut in unscrewing would travel, strike it a few sharp blows, using a light hand-hammer; and this will often start it, especially if the nut is heated as before directed. The hammer held beneath the nut should be a heavy one, and should be pressed firmly against the square or hexagon side of the nut, the object being to support it, and thus prevent the standing bolt from bending or breaking, as it would otherwise be very apt to do. If this plan succeeds, the nut may, for rough work, be used over again, the burr raised by the chisel head being hammered down to close it as much as possible before filing it off. By holding the chisel precisely as directed, the seating of the nut acts to support it, and thus aids the heavy hammer in its duty. If this procedure fails we may cut the nut off, and thus preserve the bolt.

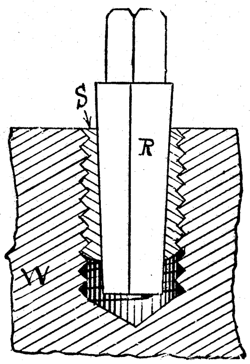

Fig. 442.

To do this, we must use a cross-cut or cape chisel, and cut a groove from the end face to the seating of the nut—a narrow groove will do, and two may be cut if necessary; light cuts should be taken, and the chisel should be ground at a keen angle, so that it will keep to its cut when held at an angle, as nearly parallel to the centre line of the length of the bolt as possible, in which case the force of the blows delivered upon the chisel head will be in a direction not so liable to bend the bolt. The groove or grooves should be cut down nearly to the tops of the bolt threads, and then a wrench will unscrew the nut or else cause it to open if one, and break in halves, if two grooves were cut.

After the nuts are all taken off, we may take a hammer and two or three wedges, or chisels (according to the size of the joint), and drive them an equal distance into the joint, striking one chisel first, and the diametrically opposite one next, and going over all the wedges to keep an equal strain upon each. If the joint resists this method, we may take a hammer and strike blows between the standing bolts on the outside face, interposing a block of hard wood to prevent damage to the face, and holding the wood so that the hammer strikes it endwise of the grain; and this will, in most cases, loosen the material of which the joint is made, and break the joint. If, however, the joint, after repeated trials, still resists, we may employ the hammer without the interposition of the wood, using a copper or lead hammer, if one is at hand, so as not to cause damage to the face of the work. To facilitate the entrance of the wedges, grooves should be cut in the joint of one face, their widths being about an inch, and their depth $\frac{1}{16}$ inch.

WASHERS.—Washers are placed upon bolts for the following purposes. First, to provide a smooth seating for the nut in the case of rough castings. Second, to prevent the nut corners from marking and marring the surface of finished work. Thirdly, to give a neat finish, and in some cases to increase the bearing area of the nut and provide an elastic cushion to prevent the nut from loosening. Washers are usually of wrought iron, except in the case of brass nuts, when the washers also are of brass. The standard sizes adopted by the manufacturers in the United States for wrought iron washers is given in the following table:—

MANUFACTURERS' STANDARD LIST.

Adopted by "The Association of Bolt and Nut Manufacturers of the United States," at their meeting in New York, December 11th, 1872.

Diameter.	Size of Hole.	Thickness Wire Guage.	Size of Bolt.
$\frac{1}{2}$	$\frac{1}{4}$	No. 18	$\frac{3}{16}$
$\frac{5}{8}$	$\frac{5}{16}$	,, 16	$\frac{1}{4}$
$\frac{3}{4}$	$\frac{5}{16}$	,, 16	$\frac{1}{4}$
$\frac{7}{8}$	$\frac{3}{8}$	,, 16	$\frac{5}{16}$
1	$\frac{7}{16}$	,, 14	$\frac{3}{8}$
$1\frac{1}{4}$	$\frac{1}{2}$	,, 14	$\frac{7}{16}$
$1\frac{3}{8}$	$\frac{9}{16}$	,, 12	$\frac{1}{2}$
$1\frac{1}{2}$	$\frac{5}{8}$	,, 12	$\frac{9}{16}$
$1\frac{3}{4}$	$\frac{11}{16}$	,, 10	$\frac{5}{8}$
2	$\frac{13}{16}$	,, 10	$\frac{3}{4}$
$2\frac{1}{4}$	$\frac{15}{16}$	,, 9	$\frac{7}{8}$
$2\frac{1}{2}$	$1\frac{1}{16}$	,, 9	1
$2\frac{3}{4}$	$1\frac{1}{4}$	,, 9	$1\frac{1}{8}$
3	$1\frac{3}{8}$	,, 9	$1\frac{1}{4}$
$3\frac{1}{2}$	$1\frac{1}{2}$	,, 9	$1\frac{3}{8}$

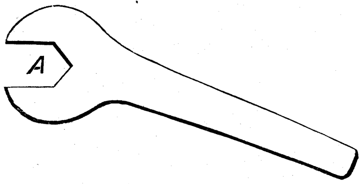

Fig. 443.

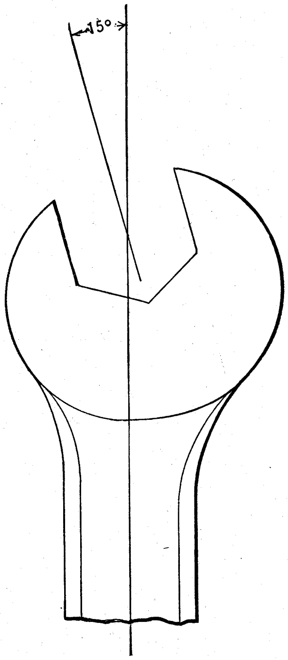

Fig. 444.

The various forms of wrenches employed to screw nuts home or to remove them are represented in the following figures. Fig. 443 represents what is known as a solid wrench, the width between the jaws A being an easy fit to the nuts across the flats. The opening between the jaws being at an angle to the body enables the wrench to be employed in a corner which would be too confined to receive a wrench in which the handle stood in a line with the jaws, because in that common form of wrench the position of the jaws relative to the handle would be the same whether the wrench be turned over or not, whereas with the jaws at an angle as in the figure, the wrench may be applied to the nut, rotating it a certain distance until its handle meet an abutting piece, flange, or other obstruction, and then turned over and the jaw embracing the same two sides of the nut the handle will be out of the way and may again operate the nut.

In some cases each end of the wrench is provided with jaws, those at one end standing at the same angle but being on the opposite side of the wrench.

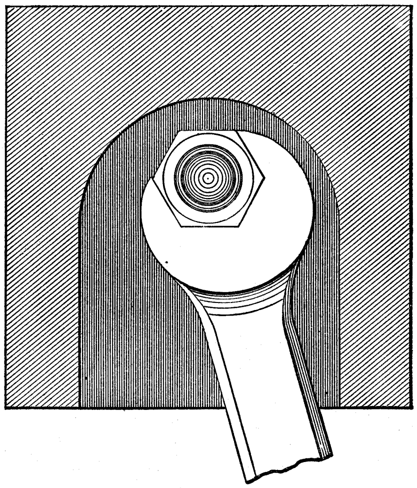
Fig. 445.

The proper angle of the jaws to the centre line of the jaws may be determined as follows:—The most desirable angle is that which will enable the wrench to operate the nut with the least amount of wrench-motion, an object that is of great importance in cases where an opening has to be provided to admit the wrench to the nut, it being desirable to leave this opening as small as possible so as to impair the solidity of the work as little as practicable. For a hexagon nut this angle may be shown to be one of 15°, as in Fig. 444.

In Fig. 445, for example, the wrench is shown in the position in which it will just engage the nut, and at the first movement it will move the nut to the position shown in Fig. 446. The wrench is then turned upside down and placed upon the nut as in Fig. 447, and moved to the position shown in Fig. 448, thus moving the nut the sixth part of a revolution, and bringing it to a position corresponding to that in Fig. 445, except that it has moved the nut around to a distance equal to one of its sides. Since the wrench has been moved twice to move the nut this distance, and since there are six sides, it will take twelve movements to give the nut a full revolution, and, there being 360° in the circle, each movement will move the nut 30°, or one-twelfth of 360°, and one-half of this must be the angle of the gripping faces of the jaws to the body of the wrench. The width of the opening in the work to admit the wrench in such a case as in Fig. 445 must be not less than 30°, plus the width of the wrench handle, at the radius of the outer corner of the opening.

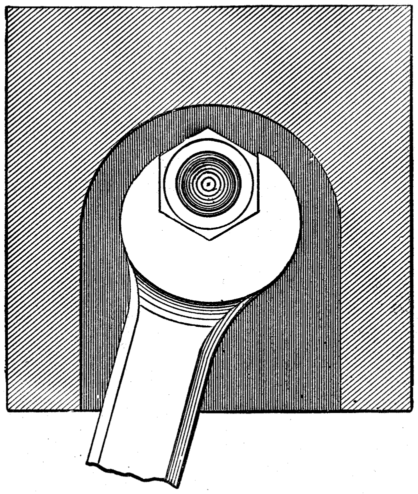
Fig. 446.

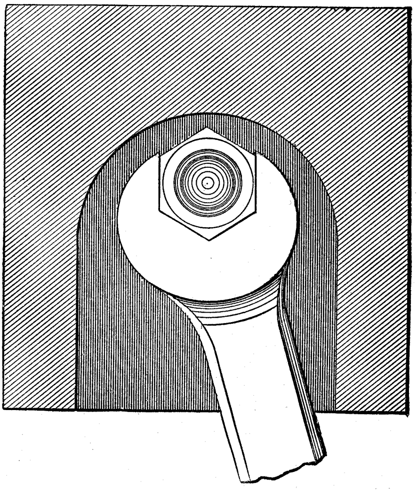
Fig. 447.

In the case of wrenches for square nuts it is similarly obvious that when the nut makes one-eighth of a revolution its sides will stand in the same position to receive the wrench that the nut started from, and in one-eighth of a revolution there are 45°. As the wrench is applied twice to the same side of the nut, its jaws must stand at one half this angle (or $22\frac{1}{2}$°) to the handle.

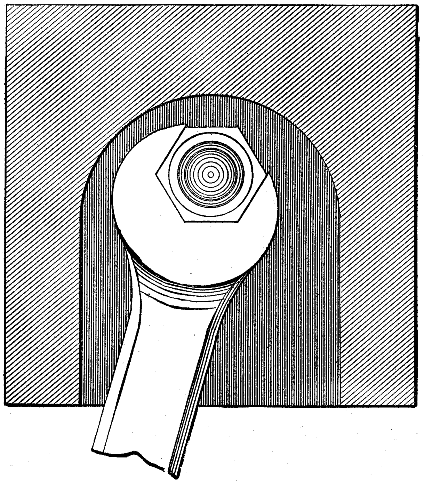
Fig. 448.

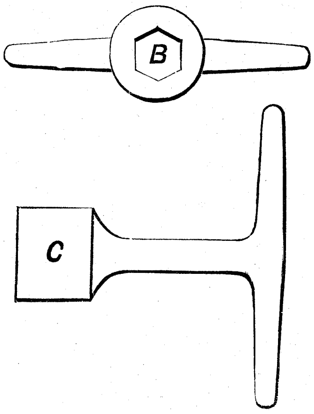

Fig. 449.

When a nut is in such a position that it can only be operated upon from the direction of and in a line with the axis of the bolt, a box wrench such as shown in Fig. 449, is employed, the cavity at B fitting over the bolt head; but if there is no room to admit the cross handle, a hub or boss is employed instead, and this hub is pierced with four radial holes into which the point of a round lever may be inserted to turn the wrench. Adjustable wrenches that may be opened and closed to suit the varying sizes of nuts are represented in Figs. 450, 451, and 452. In Fig. 450, A is the fixed jaw solid upon the square or rectangular bar E, and passing through the wooden handle D. B is a sliding jaw embracing E, and operated thereon by the screw C, whose head is serrated to afford a good finger grip. Various modifications of this form of wrench are made; thus, for example, in Fig. 451 A is the jaw, B a slotted shank, C the handle, all made in one piece. D is the movable jaw having a sleeve extension D′, and recesses which permit the jaw to slide on the shank longitudinally, but which prevent it from turning. The movable jaw is run to and from the nut or bolt head to be turned, by means of the screw G.

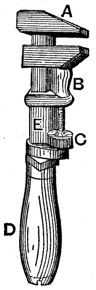

Fig. 450.

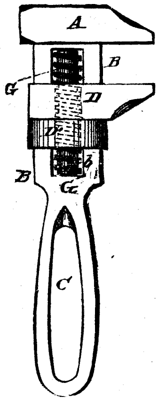

Fig. 451.

In another class of adjustable wrench the jaws slide one within the other; thus in Fig. 452, the fixed jaw of the wrench forms a part of the handle, and is hollowed out and slotted to receive the stem of the loose jaw, which plays therein, being guided by ribs in the slot, which take into grooves in the stem of the loose jaw. A screw with a milled head and a grooved neck serves to propel the loose jaw, being stopped from moving longitudinally by a partly open fixed collar on the fixed jaw, which admits the screw and engages the grooved neck of the same. The threaded extremity of the screw engages a female screw in the loose jaw, and while the same are engaged the screw cannot be released from the embrace of the fixed collar, as it requires considerable lateral movement to accomplish this.

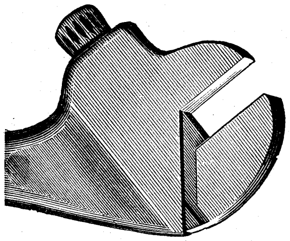

Fig. 452.

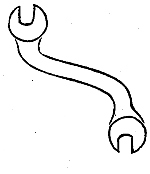

Fig. 453.

Adjustible wrenches are not suited for heavy work because the jaws are liable to spring open under heavy pressure and thus cause damage to the edges of finished nuts, and indeed these wrenches are not suitable for ordinary use on finely finished work unless the duty be light. Furthermore, the jaws being of larger size than the jaws of solid wrenches, will not pass so readily into corners, as may be seen from the S wrench shown in Fig. 453. In the adjustable S wrench in Fig. 454, each half is provided with a groove at one end and a tongue in the other, so that when put together the tongues are detained in the grooves. To open or close the wrench a right and left-hand screw is tapped into the wrench as shown, the head being knurled or milled to afford increased finger-grip.

In all wrenches the location of contact and of pressure on the nut is mainly at the corners of the nut, and unless the wrench be a very close fit, the nut corners become damaged. A common method of avoiding this is to interpose between the wrench jaw and the nut a piece of soft metal, as copper, sheet zinc, or even a piece of leather. The jaws of the wrench are also formed to receive babbitt metal linings which may be renewed as often as required. To save the trouble of adjusting an accurately fitting wrench to the nut, Professor Sweet forms the jaws as in Fig. 455, so that when moved in one direction the jaws will pass around the nut without gripping it, but when moved in the opposite direction the jaws will grip the nut but not damage the corners, while to change the direction of a nut rotation it is simply necessary to turn the wrench over.

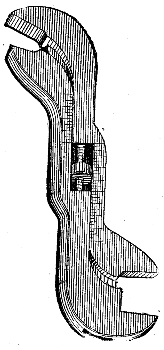

Fig. 454.

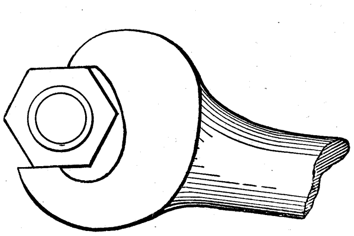

Fig. 455.

Fig. 456 represents a key wrench which is suitable for nuts of very large size. The sliding jaw J is held by the key or wedge S, which is operated by hammer blows. The projection at R is necessary to give sufficient bearing to the sliding jaw.

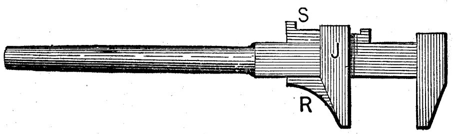

Fig. 456.

For use in confined places where but little handle-motion is obtainable, the ratchet wrench is employed, consisting of a lever affording journal bearing to a socket that fits the head of the bolt. The socket is provided with a ratchet or toothed wheel in which a catch or pawl engages. Fig. 457 represents the Lowell Wrench Company's ratchet wrench in which a lag screw socket is shown affixed. The socket is removable so that various sizes and shapes may be used with the same wrench. Each socket takes two sizes of square and one of hexagon heads or nuts. So long as the screw runs easily, it can be turned by the wooden handle more conveniently and faster than by the fingers, and independently of the ratchet motion. When this can no longer be done with ease, the twelve-inch handle is brought into use to turn the screw home.

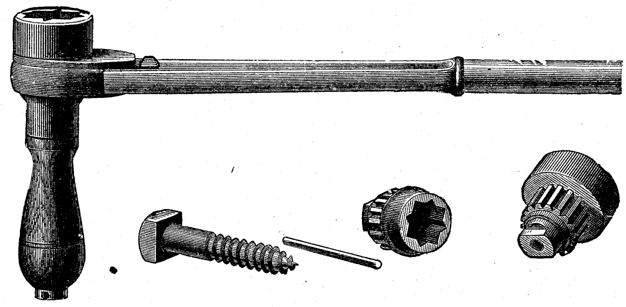

Fig. 457.

For carriage bolts used in woodwork that turn with the nut notwithstanding the square under the head (as they are apt to do from decay of the wood or from the bolt gradually working loose) the form of wrench shown in Fig. 458 is exceedingly useful, it is driven into the wood by hammer blows at A. The bevelled edges cause the jaws to close upon the head in addition to the handle-pressure.

For circular nuts such as was shown in Fig. 411, the pin wrench

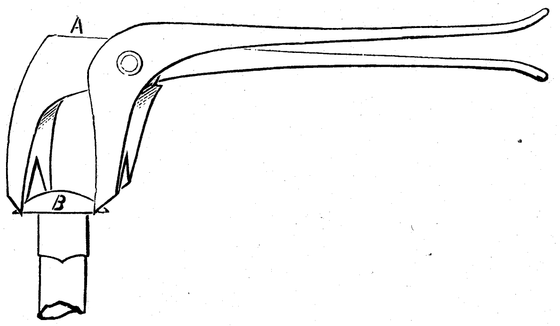

Fig. 458.

or spanner wrench shown in Fig. 459 is employed, the pin P fitting into the holes in the nut circumference. The pin P should be parallel and slope very slightly in the direction of A, so that it may not meet and bruise the mouths of the pin-holes, A, B, C. The pin must, of course, pass easily into the pin-holes, and would, if vertical, therefore meet the edge of the hole at the top, bruising it and causing the wrench to spring or slip out, as would be the case if the pin stood in the direction of B.

It is obvious that to reverse the motion of the nut it is necessary to reverse the position of the wrench, because the handle end

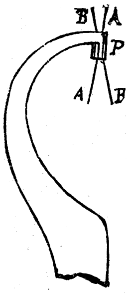

Fig. 459.

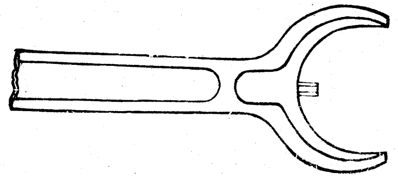

Fig. 460.

must, to enable the wrench to grip the work, travel in advance of the pin end. To avoid this necessity Professor Sweet forms the wrench as in Fig. 460, in which case it can operate on the nut in either direction without being reversed.

When a circular nut has its circumference provided with notches as was shown in Fig. 412 the wrench is provided with a rectangular piece as shown in Fig. 461. This piece should slope in the direction of A for the reasons already explained with reference to the cylindrical pin in Fig. 459. It is obvious, however, that

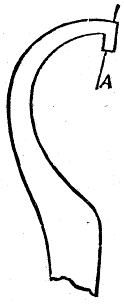

Fig. 461.

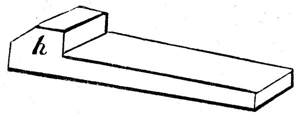

Fig. 462.

this wrench also may be made upon Professor Sweet's plan, in which case the pin should be straight.

KEYS AND KEYWAYS.—Keys and keyways are employed for two purposes—for locking permanently in a fixed position, and for locking and adjusting at the same time. Keys that simply permanently lock are usually simply embedded in the work, while those that adjust the parts and secure them in their adjusted position usually pass entirely through the work. The first are termed sunk keys and keyways, the latter adjusting keys and through keyways.

The usual forms of sunk keyways are as follows:—Fig. 462 represents the common sunk key, the head *h* forming a gib for use in extracting the key, which is done by driving a wedge between the head and the hub of the work.

The flat key, sunk key, and feather shown in Fig. 463, are alike of rectangular form, their differences being in their respective

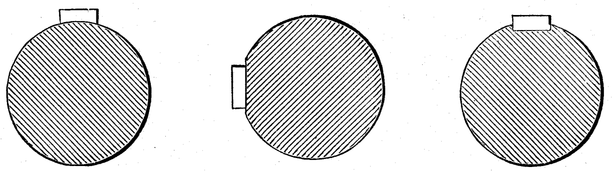

Fig. 463.

thicknesses, which is varied to meet the form of keyway which receives them. The flat key beds upon a flat place upon the shaft, the sunk key beds in a recess provided in the shaft, and the feather is fastened permanently in position in the shaft. The hollow key is employed in places where the wheel or pulley may require moving occasionally on the shaft, and it is undesirable that the latter have any flat place upon it or recess cut in it. The flat key is used where it is necessary to secure the wheel more firmly without weakening the shaft by cutting a keyway in it. The sunk key is that most commonly used; it is employed in

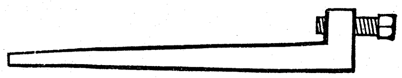

Fig. 464.

all cases where the strain upon the parts is great. The feather is used in cases where the keyway extends along the shaft beyond the pulley or wheel, the feather being fast in the wheel, and its protruding part a working fit in the shaft keyway. This permits the wheel to be moved along the shaft while being driven through the medium of the feather along the keyway or spline. The heads of the taper keys are sometimes provided with a set screw as in Fig. 464, which may be screwed in to assist in extracting the key.

Fig. 465 represents an application of keys to a square shaft

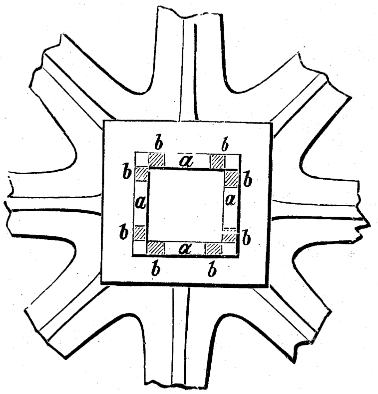

Fig. 465.

that has not been planed true. The wheel is hung upon the shaft and four temporary gib-headed keys are inserted in the spaces *a*, *a*, *a*, *a*, in Fig. 465. (It may be mentioned here that similar heads are generally forged upon keys to facilitate their withdrawal while fitting them to their seats, the heads being cut off after the key is finally driven home.) These sustain the wheel while the permanent keys, eight in number, as shown in the figure at *b*, *b*, *b*, *b*, *b*, *b*, *b*, *b*, are fitted, the wheel being rotated and tested for truth from a fixed point, the fitting of the keys being made subservient to making the wheel run true.

The proportions of sunk keys are thus given by the Manchester

(England) rule. The key is square in cross section and its width or depth is obtained by subtracting ½ from the diameter of the shaft and dividing the sum thus obtained by 8, and then adding to the subtrahend ¼.

Example.—A shaft is 6 inches in diameter, what should be the cross section dimensions of its key diameter of shaft?

$$6 - \tfrac{1}{2} = 5\tfrac{1}{2},\ \cdot 5\tfrac{1}{2} \div 8 = \cdot 687,\ \text{and}\ \cdot 687 + \cdot 25 = \frac{\cdot 937}{1000}\ \text{inch.}$$

In general practice, however, the width of a key is made slightly greater than its depth, and one-half its depth should be sunk in the shaft.

Taper keys are tapered on their surfaces A and B in Fig. 466, and are usually given ⅛-inch taper per foot of length. There is a tendency either in a key or a set screw to force the hub out of true in the direction of the arrow. It therefore causes the hub bore to grip the shaft, and this gives a driving duty more efficient than the friction of the key itself. But the sides also of the key being a sliding fit they perform driving duty in the same manner as a feather which fits on the sides A,D in Fig. 467, but are clear either top or bottom. In the figure the feather is supposed to be fast in the hub and therefore free at C, but were it fast in the shaft it would be free on the top face.

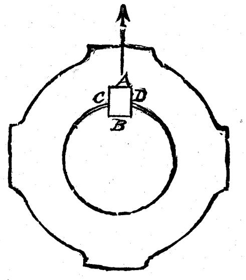

Fig. 466.

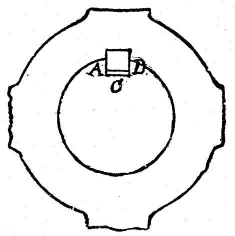

Fig. 467.

Fig. 468 represents a shaft held by a single set screw, the strain being in the direction of the arrow, hence the driving duty is performed by the end of the set screw and the opposite half circumference of the bore and shaft. On account, however, of the small area of surface of the set screw point the metal of the shaft is apt, under heavy duty and when the direction of shaft rotation is periodically reversed, to compress (as will also the set screw point unless it is of steel and hardened), permitting the grip to become partly released no matter how tightly the set screw be screwed home. On this account a taper key will under a given amount of strain upon the hub perform more driving duty, because the increased area of contact prevents compression. Furthermore, the taper key will not become loose even though it suffer an equal amount of compression. Suppose, for example, that a key be driven lightly to a fair seating, then all the rest of the distance to which the key is driven home causes the hub to stretch as it were, and even though the metal of the key were to compress, the elasticity thus induced would take up the compression, preventing the key from coming loose. It is obvious, then, that set screws are suitable for light duty only, and keys for either heavy or light duty. It is advanced by some authorities that keys are more apt to cause a wheel or pulley to run out of true than a set screw, but such is not the case, because, as shown in Figs. 466 and 468, both of them tend to throw the wheel out of true in one direction; but a key may be made with proper fitting to cause a wheel to run true that would not run true if held by a set screw, as is explained in the directions for fitting keys given in examples in vice work.

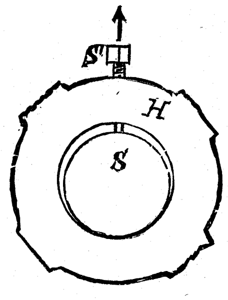

Fig. 468.

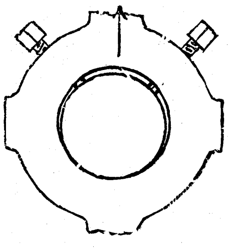

Fig. 469.

If two set screws be used they should both be in the same line (parallel to the shaft axis) or else at a right angle one to the other as in Fig. 469, so that the shaft and bore may drive by frictional contact on the side opposite to the screws. Theoretically the contact of their surface will be at a point only, but on account of the elasticity of the metal the contact will spread around the bore in the arc of a circle, the length of the arc depending upon the closeness of fit between the pulley bore and the shaft. If the bore is a close fit to the shaft it is by reason of the elasticity of the metal relieved of contact pressure on the side on which the set screw or key is to an amount depending upon the closeness of the bore fit, but this will not in a bore or driving fit to the shaft be sufficient to set the wheel out of true.

If two set screws are placed diametrally opposite they will drive by the contact of their ends only, and not by reason of their inducing frictional contact between the bore and the shaft.

A very true method of securing a hub to a shaft is to bore it larger than the shaft and to a taper of one inch to the foot. A bushing is then bored to fit the shaft and turned to the same taper as the hub is turned, but left, say, $\frac{1}{100}$ inch larger in diameter and ¼ or ⅜ longer. The bush is then cut into three pieces and these pieces are driven in the same as keys, but care must be taken to drive them equally to keep the hub true.

Feathers are used under the following conditions:—When the wheel driven by a shaft requires to slide along the shaft during its rotation, in which case the feather is fast in the wheel and the shaft is provided with a keyway or spline (as it is termed when the sliding action takes place), of the necessary length, the sides of the feather being a close but sliding fit in the spline while fixed fast in the wheel.

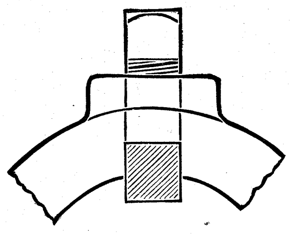

Fig. 470.

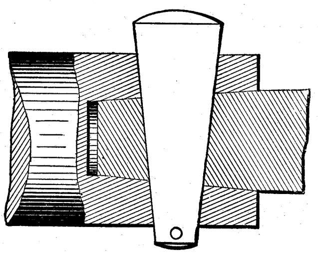

Fig. 471.

It is obvious that the feather might extend along the shaft to the requisite distance and the spline or keyway be made in the wheel: but in this case the work is greater, because the shaft would still require grooving to receive the feather, and the feather instead of being the simple width of the wheel would require to be the width of the wheel longer than the traverse of the wheel on the shaft. Nor would this method be any more durable, because the keyway's bearing length would be equal to the width of the wheel only.

When a feather is used to enable the easy movement of a wheel from one position to another a set screw may be used to fix the wheel in position through the medium of the feather as is shown in Fig. 470.

Through keys and keyways are employed to lock two pieces, and sometimes to enable the taking up of the wear of the parts. Fig. 471 represents an example in which the key is used to lock a taper shaft end into a socket by means of a key passing through both of them. When the keyway is completely filled by the key as in the figure it is termed a solid key and keyway, indicating that there is no draft to the keyway. Fig. 472 represents a key and keyway having draft. One edge, A C, of the key binds against the socket edges only, and the other edge E binds against the edge B of the enveloped piece or plug, so that by driving in the key with a hammer the two parts are forced together. The space or distance between the edge D and the key, and between edges E and F, is termed the draft. The amount of this draft is made equal to the taper of the key, hence, when the key is driven in so that its head comes level with the socket or work surface, the draft will be all taken up and the key will fill the keyway.

Draft is given to ensure all the strain of the key forcing the parts together, to enable the key to be driven in to take up any wear and to adjust movable parts, as straps, journal boxes or brasses, &c. When the bore of the socket and the end of the rod are parallel, the end of the rod F, Fig. 473, should key firmly against the end E of the socket, while the end D of the socket should be clear of the shoulder on the rod; otherwise instead of the key merely compressing the metal at F it will exert a force tending to burst the end F from G of the rod, furthermore, the area of contact at the shoulder D being small the metal would be apt to compress and the key would soon come loose.

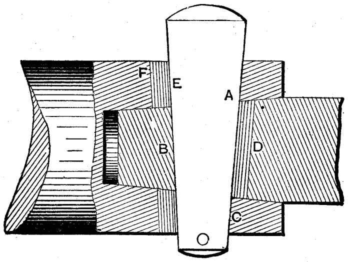

Fig. 472.

In some cases two keys are employed passing through a sleeve, the arrangement being termed a coupling, or a butt coupling.

The usual proportions for this class of key, when the rod ends and socket boxes are parallel, is width of key equals diameter of socket bore, thickness of key equals one-fourth its width, with a taper edgeways of about $\frac{1}{4}$ inch in 10 inches of length.

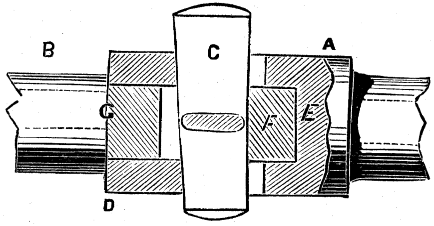

Fig. 473.

As the keys in through keyways often require to be driven in very tight, and as the parts keyed together often remain a long time without being taken apart and in some situations become rusted together, it is often a difficult matter to get them apart. First, it is difficult to drive it out because the blows swell the end of the key so that it cannot pass through the keyway, and secondly, driving the socket off the plug of the two parts keyed together often damages the socket and may bend the rod to which it is keyed. Furthermore, as the diameter of the socket is usually not more than half as much again as the diameter of the plug, misdirected blows are apt to fall upon the rod instead of upon the socket end and damage it. Hence, a piece of copper, of lead, or a block of wood should always be placed against the socket end to receive the hammer blows. To force a plug out of a socket, we may use reverse keys. These are pieces formed as shown in Fig. 474. A, A and B, B are edge and face views respectively of two pieces of metal, formed as shown, which are inserted in the keyway as shown in Fig. 475, in which A is the plug or taper end of a rod and B the socket, C is one and D the other of the reverse keys, while E is a taper key inserted between them, B driving E through the keyway, A and B are forced apart. The action of the reverse keys is simply to reverse the direction of the draft in the keyway so that the pressure due to driving E through the keyway is brought to bear upon the rod end in the part that was previously the draft side of the keyway, and in like manner upon the keyway in the socket on the side that previously served as draft.

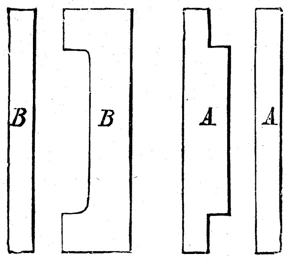

Fig. 474.

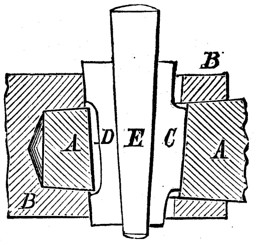

Fig. 475.

Reverse keys are especially serviceable to take off cross heads, piston heads, keyed crank-pins, and parts that are keyed very firmly together.

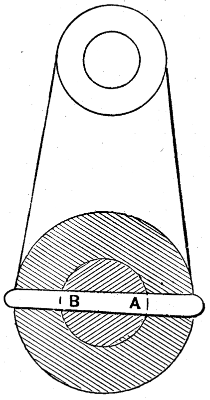

Fig. 476.

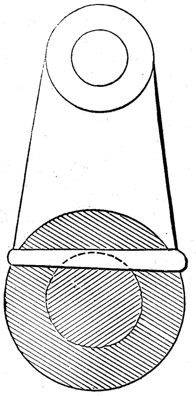

Fig. 477.

Hubs are sometimes fastened to their shafts by pins passing through both the hub and the shaft. These pieces may be made parallel or taper, but the latter obviously secures the most firmly. If the pin is located as in Fig. 476, its resisting strength is that due to its cross sectional area at A and B. But if the pin be located as in Fig. 477 it secures the hub more firmly, because it draws the bore (on the side opposite to the pin) against the shaft, causing a certain amount of friction, and, furthermore, the area resisting the pressure of the hub is increased, and that pressure is to a certain degree in a crushing as well as a shearing direction.

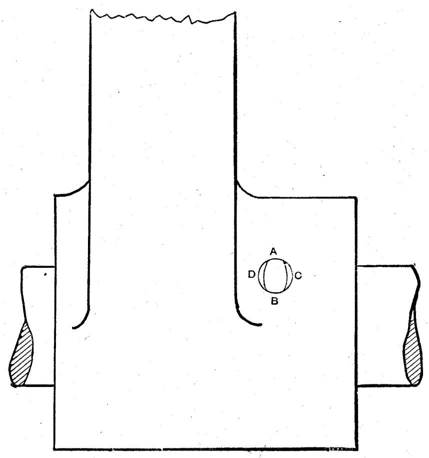

Fig. 478.

If unturned pins are used and the holes are rough or drilled but not reamed, it is better that two sides of the pin should be eased off with a file or on the emery wheel, so that all the locking pressure of the pin shall fall where it is the most important that it should—that is, where it performs locking duty. This is shown in Fig. 478, the hole being round and the pin being very slightly oval (not, of course, so much as shown in the drawing), so that it will bind at A B, and just escape touching at C,D, so that all the pressure of contact is in the direction to bind the hub to the shaft.