CHAPTER XI.—DRILLING AND BORING IN THE LATHE.

FOR drilling in the lathe, the twist drill is employed not only on account of its capacity to drill true, straight, and smooth holes, but also because its flutes afford free egress to the cuttings and obviate the necessity of frequently withdrawing the drill to clear the hole of the cuttings.

In the smaller sizes of twist drill, the stem or shank is made parallel, as in Fig. 1040, while in the larger sizes it is made taper, as in Fig. 1041, for reasons which will appear hereafter.

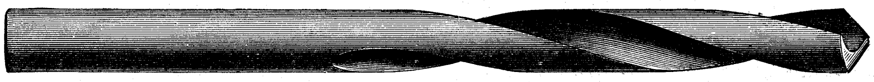

Fig. 1040.

The taper shanks of twist drills are given a standard degree of taper of $\frac{5}{8}$ inch per foot of length, which is termed the Morse taper. A former standard, termed the American standard, is still used to a limited extent, its degree of taper being $\frac{9}{16}$ inch per foot.

Parallel shanked twist drills are driven by chucks, while taper, shanked ones, are driven by sockets, such as in Fig. 1042, from C to D, fitting into the lathe centre hole, while the bore at the other end is the Morse standard taper, to receive the drills E E, which have a projection such as shown at A, which by fitting into a slot that meets the end of the taper holes in the socket, lock the drill and prevent its revolving in the socket, while affording a means of forcing the drill out by inserting a key K, as shown in the figure.*

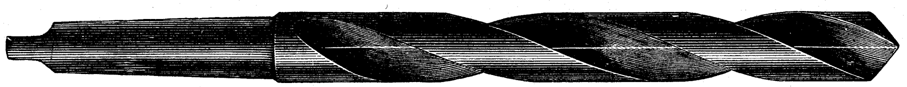

Fig. 1041.

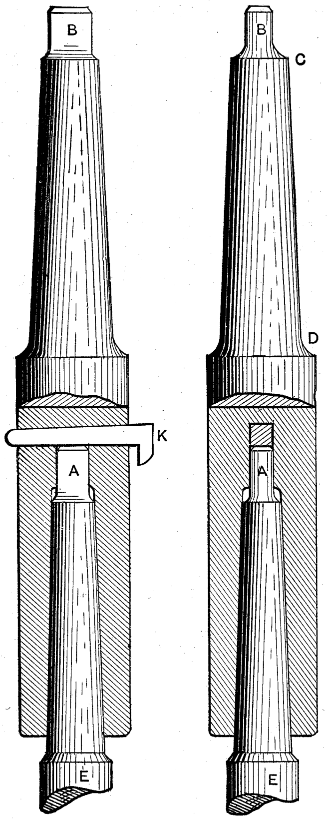

Fig. 1042.

Each socket takes a certain number of different sized drills, the shanks of the smaller drills being in some cases longer than the drill body.

Number	I	socket receives	drills from	$\frac{1}{6}$	to	$\frac{19}{32}$	inch	inclusive.
,,	2	,,	,,	$\frac{5}{8}$	,,	$\frac{29}{32}$	,,	,,
,,	3	,,	,,	$\frac{15}{16}$	,,	$1\frac{1}{4}$	,,	,,
,,	4	,,	,,	$1\frac{9}{32}$	,,	2	,,	,,
,,	5	,,	,,	$2\frac{1}{32}$	,,	$2\frac{1}{2}$	,,	,,

These sockets are manufactured ready to receive the drills, but are left unturned at the shank end so that they may be fitted to the particular lathe or machine in which they are to be used, no standard size or degree of taper having as yet been adopted.

A twist drill possesses three cutting edges marked A, B, C respectively in Fig. 1043, and of these C is the least effective, because it cannot be made as keen as is desirable for rapid and clean cutting, and therefore necessitates that the drill be given an unusually fine rate of feed as compared with other cutting tools.

The *land* of the drill—or, in other words, the circumference between the flutes—is backed off to give clearance, as is shown in Fig. 1044, a true circle being marked with a dotted line, and the drill being of full diameter from A to B only. The object of this clearance is to prevent the drill from seizing or grinding against the walls of the hole, as it would otherwise be apt to do when the outer corner wore off, as is likely to be the case.

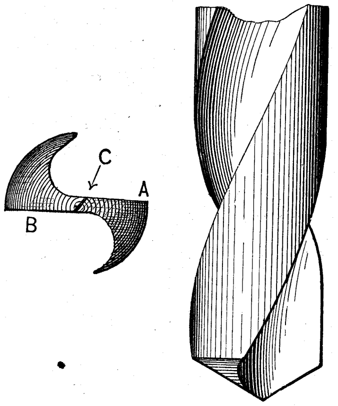

Fig. 1043.

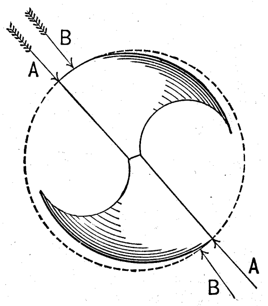

Fig. 1044.

Twist drills having three and more flutes have been devised and made, but the increased cost and the weakness induced by the extra flutes have been found to more than counterbalance the gain due to an increase in the number of cutting edges. Further, the increase in the number of flutes renders the grinding of the drill a more delicate and complicated operation.

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* See also Shanks and Sockets for Drills used in the Drilling Machine.

The keenness and durability of the cutting edge of a twist drill are governed by the amount of clearance given by the grinding to the cutting edge, by the angle of one cutting edge to the other, and by the degree of twist of the flute. Beginning with the angle of the front face, we shall find that it varies at every point in the diameter of the drill, being greatest at the outer corner and least at the centre of the drill, whatever degree of spirality the groove or flute may possess. In Fig. 1045, for example, we may consider the angle at the corner C and at the point F in the length of the cutting edge. The angle or front rake of the corner C is obviously that of the outer edge of the spiral C D, while that of the point F is denoted by the line F *f*, more nearly parallel to the drill axis, and it is seen that the front rake increases in proportion as the corner C is approached, and diminishes as the drill centre or point is approached.

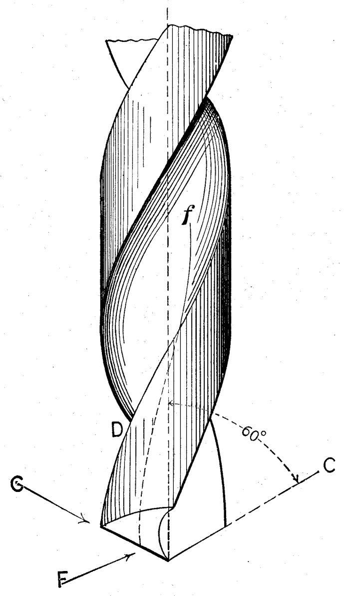

Fig. 1045.

It follows, then, that if the angle of the bottom face of the drill be the same from the centre to the corner of the drill, and we consider the cutting edge simply as a wedge and independent of its angle presentation to the work, we find that it has a varying degree of acuteness at every point in its length. This may be seen from Fig. 1046, in which the end face is ground at a constant angle from end to end to the centre line of the drill, and it is seen that the angle A represents the wedge at point C and the angle B the wedge at the point F in the length of the cutting edge, and it follows that the wedge becomes less acute as the centre of the drill is approached from the point C. If, then, we give to the end face a degree of clearance best suited for the corner C, it will be an improper one for the cutting edge near the drill point; or if we adopt an angle suitable for the point, it will be an improper one for the corner C.

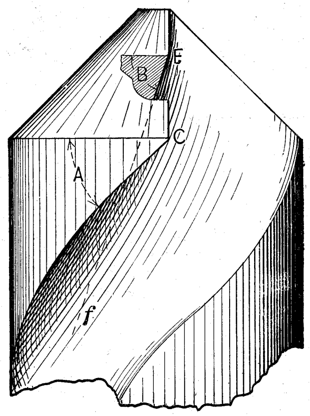

Fig. 1046.

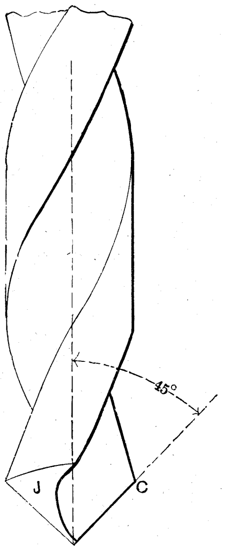

Fig. 1047.

This corner performs the most cutting duty, because its path of revolution is the longest, or rather of the greatest circumference, and it operates at the highest rate of cutting speed for the same reason, hence it naturally wears and gets dull the quickest.

As this wear proceeds the circumferential surface near this corner grinds against the walls of the hole, causing the drill to heat and finally to cease cutting altogether.

For these reasons it is desirable that the angle of the end face, or the angle of clearance, be made that most suitable to obtain endurance at this corner. It may be pointed out, however, that the angle of one cutting edge to the other, or, what is the same thing, its angle to the centre line of the drill, influences the keenness of this corner. In Fig. 1045, for example, each edge is at an angle of 60° to the drill axis, this being the angle given to drills by the manufacturers as most suitable for general use. In Fig. 1047, the angle is 45°, and it will be clearly seen that the corner C is much less acute; an angle of 45° is suitable for brass work or for any work in which the holes have been cored out and the drill is to be used to enlarge them.

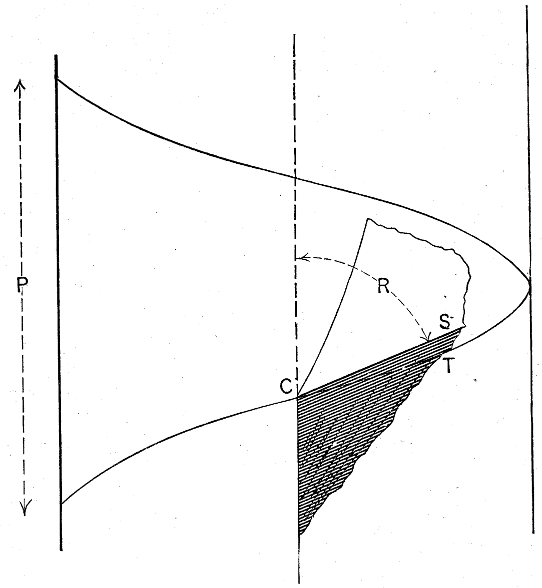

Fig. 1048.

Referring again to the angle of clearance of the end faces, it can be shown that in the usual manner of grinding twist drills the conditions compel the amount of clearance to be made suitable for the point of the drill, and therefore unsuitable for the corner C, giving to it too much clearance in order to obtain sufficient clearance for the remainder of the cutting edge. Suppose, for example, that we have in Fig. 1048 a spiral representing the path of corner C during one revolution, the rate of feed being shown magnified by the distance P, and the spiral will represent the inclination of that part of the bottom of the hole that is cut by corner C, and the angle of the end face of the drill to the drill axis will be angle R. The actual clearance will be represented by the angle between the end face S of the drill and the spiral beneath it, as denoted by T. But if we take the path of the point F, Fig. 1045, during the same revolution, which is represented by the spiral in Fig. 1049, we find that, in order to clear the end of the hole, it must have more angle to the centre line of the drill, as is clearly shown, in order to have the clearance necessary to enable the point F to cut, because of the increased spiral. It follows that, if the same degree of clearance is given throughout the full length of the cutting edge, it must be made suitable for the point of the drill, and will therefore be excessive for the corner C.

This fault is inseparable from the method of grinding drills in ordinary drill-grinding machines, which is shown in Fig. 1050, the line A A representing the axis of the motion given to the drill in these machines. It is obvious that the line A A being parallel to the face of the emery-wheel, the angle of clearance is made equal throughout the whole length of the cutting edge. This is, perhaps, made more clear in Fig. 1051, in which we have supposed the drill to take a full revolution upon the axis A A, and as a result it would be ground to the cylinder represented by the dotted lines. We may, however, place the axis on which the drill is moved to grind it at an angle to the emery-wheel face, as at B, Fig. 1052, and by this means we shall obtain two important results: (1) The angle of B may be made such that the clearance will be the same to the actual surface it cuts at every point in the length of the cutting edge, making every point in that length equally keen and equally strong, the clearance being such as it is determined is the most desirable. (2) The clearance may be made to increase as the heels of each end face are approached from the cutting edge. This is an advantage, inasmuch as it affords freer access to the oil or other lubricating or cooling material. If we were to prolong the point of the drill sufficiently, and give it a complete revolution on the axis B, we should grind it to a cone, as shown by the dotted lines in Fig. 1052.

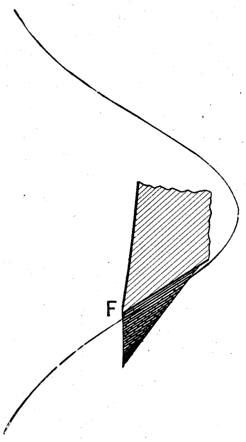

Fig. 1049.

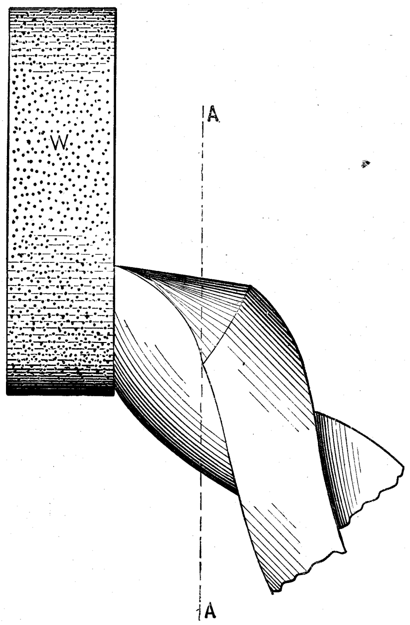

Fig. 1050.

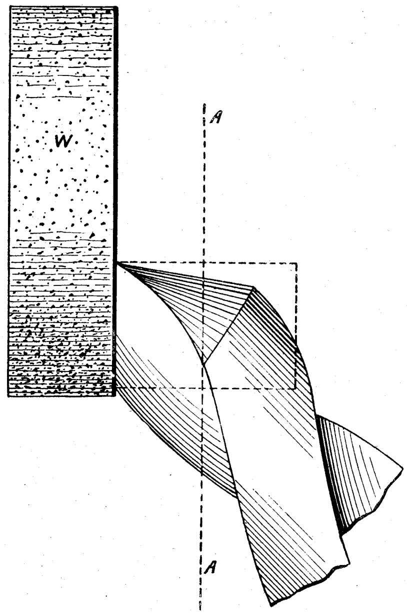

Fig. 1051.

In Fig. 1053 we have a top, and in Fig. 1054 a sectional, view of a conical recess cut by a drill, with a cylinder R lying in the same. P represents in both views the outer arc or circle which would be described by the outer corner, Fig. 1045, of the drill, and Q the path or arc described or moved through by the point at F, Fig. 1045, of the drill. At V and W are sectional views of the cylinder R, showing that the clearance is greater at V than at W. The cylinder obviously represents the end of a drill as usually ground.

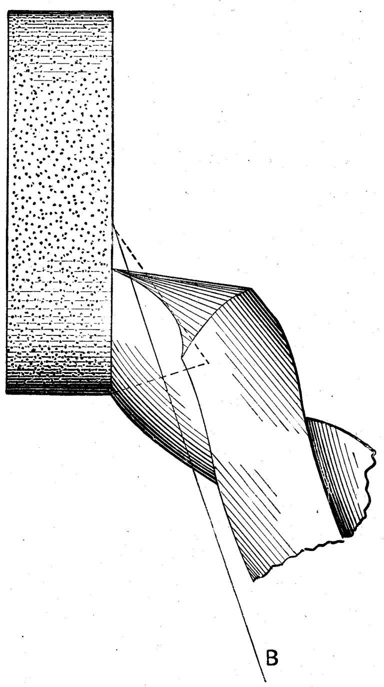

Fig. 1052.

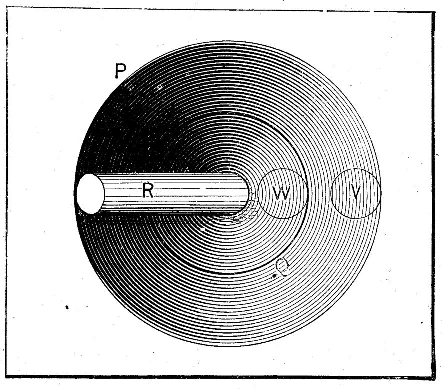

Fig. 1053. Top View.

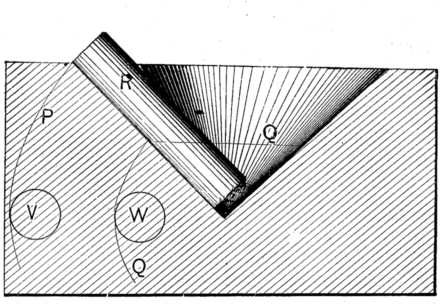

Fig. 1054. Sectional View.

In Figs. 1055 and 1056 we have two views of a cone lying in a recess cut by a drill, the arcs and circles P and Q corresponding to those shown in Fig. 1055, and it is seen that in this case the amount of clearance between V and P and between W and Q are equal, V representing a cross-section of the cone at its largest end, and W a cross-section at the point where the cone meets the circle Q. It follows, therefore, that drills ground upon this principle may be given an equal degree of clearance throughout the full length of each cutting edge, or may have the clearance increased or diminished towards the point at will, according to the angle of the line B in Fig. 1052.

In order that the greatest possible amount of duty may be obtained from a twist drill, it is essential that it be ground perfectly true, so that the point of the drill shall be central to the drill and in line with the axis on which it revolves. The cutting edges must be of exactly equal length and at an equal degree of angle from the drill axis. To obtain truth in these respects it is necessary to grind the drill in a grinding machine, as the eye will not form a sufficiently accurate guide if a maximum of duty is to be obtained. The cutting speeds and rates of feed recommended by the Morse Twist Drill and Machine Company are given in the following table.

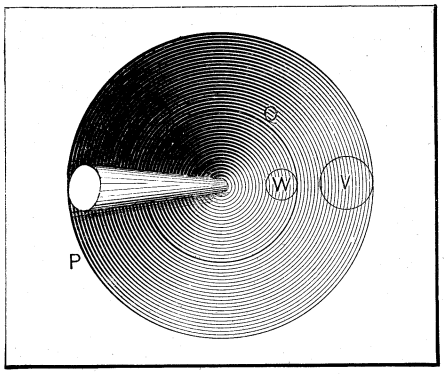

Fig. 1055. Top View.

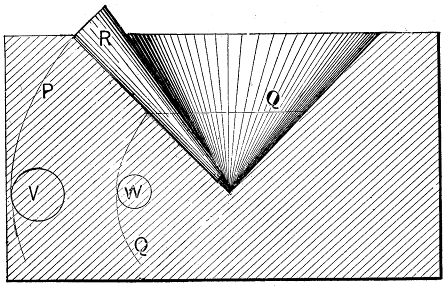

Fig. 1056. Sectional View.

The following table shows the revolutions per minute for drills from $\frac{1}{16}$ in. to 2 in. diameter, as usually applied :—

Diameter of Drills.	Speed for Steel.	Speed for Iron.	Speed for Brass.	Diameter of Drills.	Speed for Steel.	Speed for Iron.	Speed for Brass.
inch.				inch.			
$\frac{1}{16}$	940	1280	1560	$1\frac{1}{16}$	54	75	95
$\frac{1}{8}$	460	660	785	$1\frac{1}{8}$	52	70	90
$\frac{3}{16}$	310	420	540	$1\frac{3}{16}$	49	66	85
$\frac{1}{4}$	230	320	400	$1\frac{1}{4}$	46	62	80
$\frac{5}{16}$	190	260	320	$1\frac{5}{16}$	44	60	75
$\frac{3}{8}$	150	220	260	$1\frac{3}{8}$	42	58	72
$\frac{7}{16}$	130	185	230	$1\frac{7}{16}$	40	56	69
$\frac{1}{2}$	115	160	200	$1\frac{1}{2}$	39	54	66
$\frac{9}{16}$	100	140	180	$1\frac{9}{16}$	37	51	63
$\frac{5}{8}$	95	130	160	$1\frac{5}{8}$	36	49	60
$\frac{11}{16}$	85	115	145	$1\frac{11}{16}$	34	47	58
$\frac{3}{4}$	75	105	130	$1\frac{3}{4}$	33	45	56
$\frac{13}{16}$	70	100	120	$1\frac{13}{16}$	32	43	54
$\frac{7}{8}$	65	90	115	$1\frac{7}{8}$	31	41	52
$\frac{15}{16}$	62	85	110	$1\frac{15}{16}$	30	40	51
1	58	80	100	2	29	39	49

To drill one inch in soft cast iron will usually require: For $\frac{1}{4}$ in. drill, 125 revolutions; for $\frac{1}{2}$ in drill, 120 revolutions; for $\frac{3}{4}$ in. drill, 100 revolutions; for 1 in. drill, 95 revolutions.

The rates of feed for twist drills are thus given by the same Company :—

Diameter of drill.	Revolutions per inch depth of hole.
$\frac{1}{16}$ inch	125
$\frac{1}{4}$,, ...	,
$\frac{3}{8}$,, ...	120 to 140
$\frac{1}{2}$,, ...	,, ,,
$\frac{3}{4}$,, ...	1 inch feed per minute
1 ,, ...	,, ,, ,,
$1\frac{1}{2}$,, ...	,, ,, ,,

Taking an inch drill as an example, we find from this table that the rate of feed is for iron $\frac{1}{100}$th inch per drill revolution, and as the drill has two cutting edges it is obvious that the rate of feed for each edge is $\frac{1}{200}$th inch per revolution. But it can be shown that this will only be the case when the drill is ground perfectly true; or, in other words, when the drill is so ground that each edge will take a separate cut, or so that one edge only will cut, and that in either case the rate of feed will be diminished one-half.

In Fig. 1057, for example, is shown a twist drill in which one cutting edge (*e*) is ground longer than the other, and the effect this would produce is as follows. First, suppose the drill to be fed automatically, the rate of feed being $\frac{1}{100}$th inch, and the whole of this feed would fall on cutting edge *e*, and, being double what it should be, would in the first place cause the corner *c* to dull very rapidly, and in the second place be liable to cause the drill to break when *c* became dull.

In the second place the drill would make a hole of larger diameter than itself, because the point of the drill will naturally be forced by the feed to be the axis or centre of cutting edge revolution, which would therefore be on the line *b b*. This would cause the diameter of hole drilled to be determined by the radius of the cutting edge *e* rather than by the diameter of the drill. Again, the side of the drill in line with corner *c* would bind against the side of the hole, tending to grind away the clearance at the corner *c*, which, it has been shown, it is of the utmost importance to keep sharp. But assuming $\frac{1}{200}$th inch to be the proper feed for each cutting edge, and the most it can carry without involving excessive grinding, then the duty of the drill can only be one-half what it would be were both cutting edges in action.

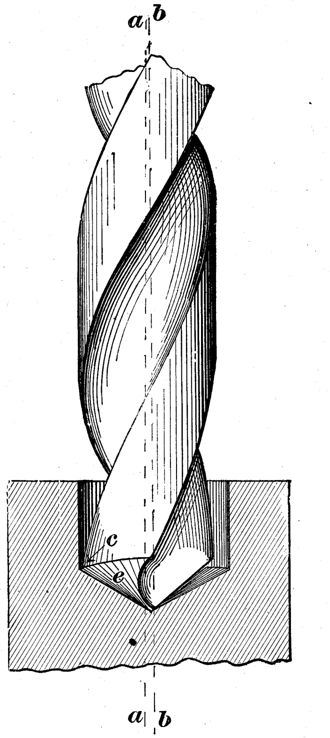

Fig. 1057.

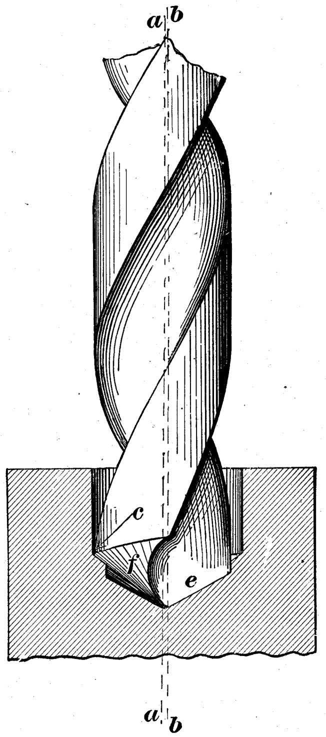

Fig. 1058.

In Fig. 1058 is shown a twist drill in which one cutting edge is ground longer than the other, and the two cutting edges are not at the same angle to the axis *a a* of the drill.

Here we find that the axis of drill rotation will be on the line *b* from the point of the drill as before, but both cutting edges will perform some duty. Thus edge *e* will drill a hole which the outer end of *f* will enlarge as shown. Thus the diameter of hole drilled will be determined by the radius of corner *c*, from the axis of drill revolution, and will still be larger than the drill. A drill thus ground would drill a more true and round hole than one ground as in Fig. 1057, because as both cutting edges perform duty the drill would be steadied.

The rate of feed, however, would require to be governed by that length of cutting edge on *f* that acts to enlarge the hole made by *e*, and therefore would be but one-half what would be practicable if the drill were ground true. Furthermore, the corner *c* would rapidly dull because of its performing an undue amount of duty, or in other words, because it performs double duty, since it is not assisted by the other corner as it should be. In both these examples the drill if rigidly held would be sprung or bent to the amount denoted by the distance between the line *a a*, representing the true axis of the drill, and line *b b*, representing the line on which the drill point being ground and one-sided compels the drill to revolve ; hence one side of the drill would continuously rub against the walls of the hole the drill produced, acting, as before observed, to grind away the clearance that was shown in figure and also to dull corner *c*.

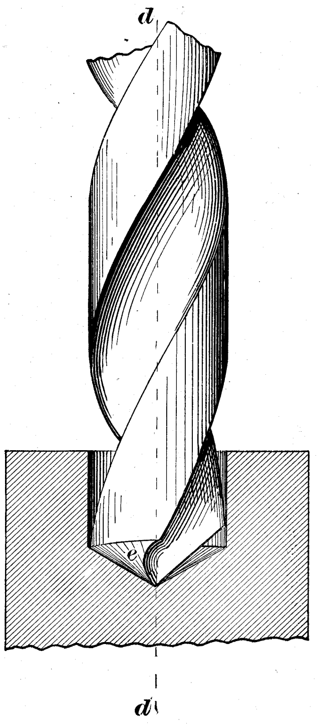

Fig. 1059.

Fig. 1059 shows a case in which the point of the drill is central to the drill axis *d d*, but the two cutting edges are not at the same angle. As a result all the duty falls on one cutting edge, and the hole drilled will still be larger in diameter than the drill is, because there is a tendency for the cutting edge *e* to push or crowd the drill over to the opposite side of the hole.

It will be obvious from these considerations that the more correctly the drill is ground, the longer it will last without regrinding, the greater its amount of feed may be to take an equal depth of cut, and the nearer the diameter of the hole drilled to that of the drill—the most correct results being obtained when the drill will closely fit into the hole it has drilled and will not fall through of its own gravity, a result it is somewhat difficult to attain.

Professor John E. Sweet advocates grinding twist drills as in Fig. 1060 (which is from *The American Machinist*), the object being to have a keener cutting edge at the extreme point of the drill.

In a paper on cutting tools read before the British Institution of Mechanical Engineers the following examples of the efficiency of the twist drill are given—

Referring to a $\frac{1}{2}$ inch twist drill, it is said :

" The time occupied from the starting of each hole in a hammered scrap-iron bar till the drill pierced through it varied from 1 minute 20 seconds to $1\frac{1}{2}$ minutes. The holes drilled were perfectly straight. The speed at which the drill was cutting was nearly 20 feet per minute in its periphery, and the feed was 100 revolutions per inch of depth drilled. The drill was lubricated with soap and water, and went clean through the $2\frac{3}{4}$ inches without being withdrawn, and after it had drilled each hole it felt quite cool to the hand, its temperature being about 75°. It is found that 120 to 130 such holes can be drilled before it is advisable to resharpen the twist drill. This ought to be done immediately the drill exhibits the slightest sign of distress. If carefully examined after this number of holes has been drilled, the prominent cutting parts of the lips which have removed the metal will be found very slightly blunted or rounded to the extent of about $\frac{1}{100}$th inch, and on this length being carefully ground by the machine off the end of the twist drill, the lips are brought up to perfectly sharp cutting edges again.

" The same sized holes, $\frac{1}{2}$ inch diameter and $2\frac{3}{4}$ inches deep, have been drilled through the same hammered scrap-iron at the extraordinary speed of $2\frac{3}{4}$ inches deep in 1 minute and 5 seconds, the number of revolutions per inch being 75. An average number of 70 holes can be drilled in this case before the drill requires resharpening. The writer considers this test to be rather too severe, and prefers the former speed.

" In London, upward of 3000 holes were drilled $\frac{5}{8}$ inch diameter and $\frac{3}{8}$ inch deep through steel bars by one drill without regrinding it. The cutting speed was in this instance too great for cutting steel, being from 18 to 20 feet per minute, and the result is extraordinary. Many thousands of holes were drilled $\frac{1}{8}$ inch diameter, through cast iron $\frac{7}{16}$ths inch deep with straight-shank twist drills gripped by an eccentric chuck in the end of the spindle of a quick-speed drilling machine. The time occupied for each hole was from 9 to 10 seconds only. Again, $\frac{1}{4}$-inch holes have been drilled through wrought copper $1\frac{3}{8}$ inches thick at the speed of one hole in 10 seconds. With special twist drills, made for piercing hard Bessemer steel, rail holes, $\frac{13}{16}$ths inch deep and $\frac{29}{32}$nds inch diameter, have been drilled at the rate of one hole in 1 minute and 20 seconds in an ordinary drilling machine. Had the machine been stiffer and more powerful, better results could have been obtained. A similar twist drill, $\frac{29}{32}$nds inch in diameter, drilled a hard steel rail $\frac{13}{16}$ths inch deep in 1 minute, and another in 1 minute 10 seconds. Another drill, $\frac{5}{8}$ inch diameter, drilled $\frac{3}{4}$ inch deep in 38 seconds, the cutting speed being 22 feet per minute. This speed of cutting rather distressed the drill; a speed of 16 feet per minute would have been better. The steel rail was specially selected as being one of the hardest of the lot."

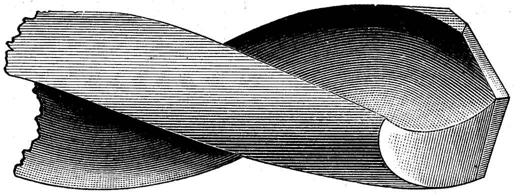

Fig. 1060.

Drills ground by hand may be tested for angle by a protractor, as in Fig. 1061, and for equal length of cutting edge by resting them upon a flat surface, as B in Fig. 1062, and applying a scale as at S in the figure. In the case of very small drills, it is difficult to apply either the protractor or the scale, as well as to determine the amount of clearance on the end face. This latter, however, may be known from the appearance of the cutting edge at the point A in Fig. 1063, for if the line A is at a right angle to E, there is no clearance, and as clearance is given this line inclines as shown at B in the figure, the inclination increasing with increased clearance, as is shown at C. When this part of the edge inclines in the opposite direction, as at D in the figure, the curved edges *e f* stand the highest, and the drill cannot cut. The circumferential surface of a drill should never be ground, nor should the front face or straight side of the flute be ground unless under unusual conditions, such as when it is essential, as in drilling very thin sheet metal, to somewhat flatten the corner (*c* in Fig. 1062), in order to reduce its tendency to run forward, in which case care must be taken not to grind the front face sufficiently to reduce the full diameter. In Fig. 1064, for example, that part of the circumference lying between A and B being left of full circle, the faces of the flutes might be ground away as denoted by the dotted lines C D without affecting the drill diameter.

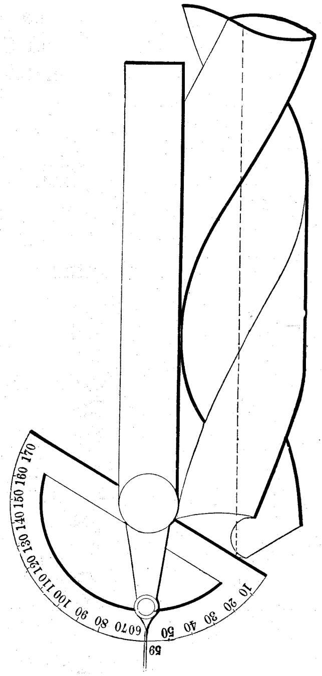

Fig. 1061.

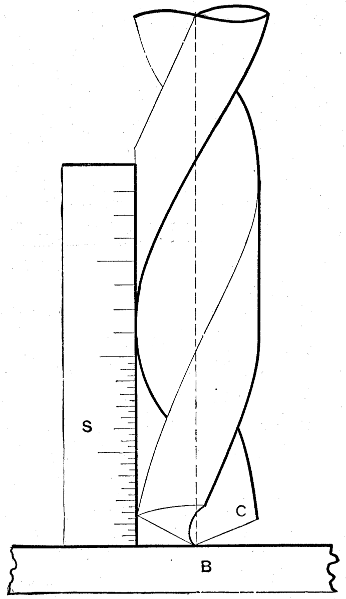

Fig. 1062.

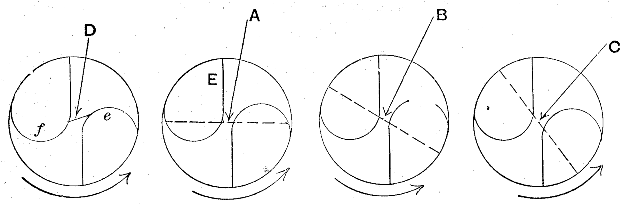

Fig. 1063.

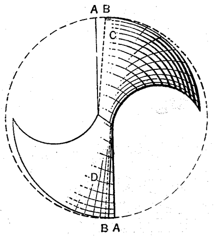

Fig. 1064.


Fig. 1065.

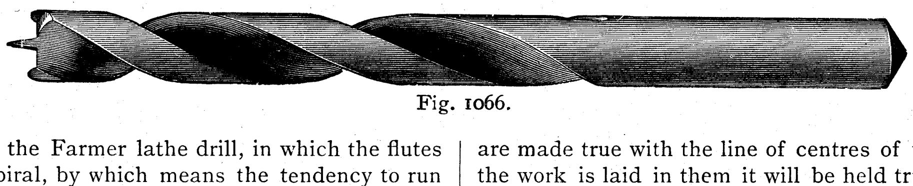
Fig. 1066.

Fig. 1065 represents the Farmer lathe drill, in which the flutes are straight and not spiral, by which means the tendency to run forward when emerging through the work is obviated.

When a twist drill is to be used for wood and is driven by a machine it is termed a bit, and is provided with a conical point to steady it, and two wings or spurs, as in Fig. 1066, which sever the fibres of the wood in advance of their meeting the main cutting edges and thus produce a smooth hole. The sharp conical point is used in place of the conical screw of the ordinary wood auger to avoid the necessity of revolving the drill or bit backwards to release the screw in cases in which the hole is not bored entirely through the work.

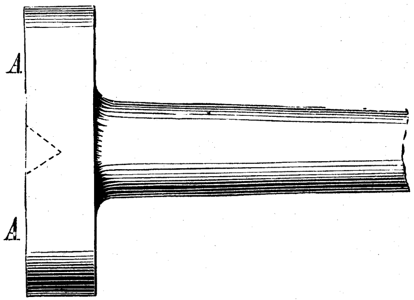

Fig. 1067.

When the drill revolves and the work is to be held in the hands a rest or table whereon to rest the work and hold it fair is shown in Fig. 1067, the taper shank fitting in the dead centre hole and the tailstock spindle being fed up by hand to feed the drill to its cut. The face A A of the chuck is at a right angle to the shank, and a coned recess is provided at the centre, as denoted by the dotted lines, to permit the drill point to pass through the work without cutting the chuck.

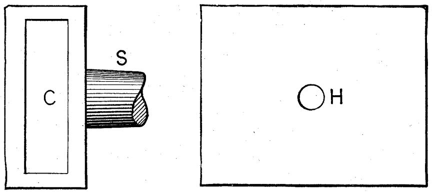

Fig. 1068.

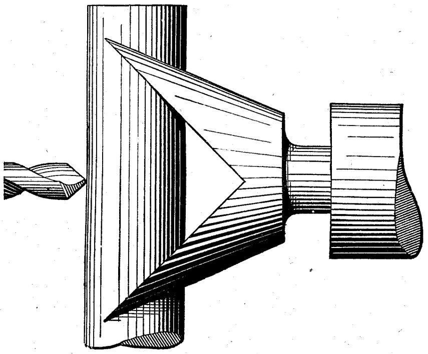
Fig. 1069.

For larger work a table, such as shown in Fig 1068, is used, the cavity C permitting the drilling tool to pass through the work, there being a hole H provided for that purpose. The stem S fits in place of the dead centre. For cylindrical work the rest or chuck shown in Figs. 1069 and 1070 may be employed. It consists of a piece fitted to the tail spindle in place of the dead centre, its end being provided with V-grooves. These grooves are made true with the line of centres of the lathe, so that when the work is laid in them it will be held true. It is obvious that one groove would be sufficient, but two are more convenient—one for large work and one for small work—so that the side of the shaft to be drilled shall not pass within the fork, but will protrude, so that the progress of the work can be clearly seen. In Fig. 1070 an end view of this chuck is shown It may be observed, however, that when starting the drill care must be taken to have it start true, or the drill may bend, and thus throw the work out of the true. For this reason the drills should be as short as possible when their diameters are small.

For square work this class of work table or chuck may be formed so as to envelop the work and prevent its revolving, thus relieving the fingers of that duty, and it may be so formed as to carry the work back or off the drill when the latter is retired after the drilling is performed.

Another and quite convenient method of holding work to be drilled by a revolving drill in the lathe is shown in Fig. 1071. It consists of simply a bracket, *a b*, fitted to the tool-box of the slide rest, carrying a spindle with one end screwed to receive any face plates or chucks that fit the lathe live spindle. The bracket is kept in position by two pins in the under side of it, fitting into holes in the bottom piece of tool-box. If it be required to drill a straight row of holes, the spindle is fixed by the set-screws in its bracket, and the work is bolted to the face plate at the proper level, and traversed across opposite the drill in the lathe mandrel, by the cross screw of the slide rest, while it is fed up to the drill by the upper screw or the rack and pinion.

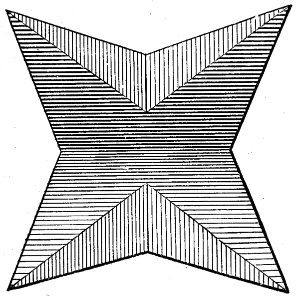

Fig. 1070.

For circular rows of holes the centre line of the spindle is adjusted parallel with and at a proper distance from that of the mandrel. For holes in the edge of the work, the whole top of slide rest is turned round till the spindle is at right angles with the mandrel.

Work merely requiring to be held fast for drilling is bolted on one side of the face plate, and can then be adjusted exactly to the drill by the combined motions of the cross screw and the face plate on its centre. Small round work, while drilled in the end, can be held in a scroll chuck screwed on the spindle the same as a face plate.

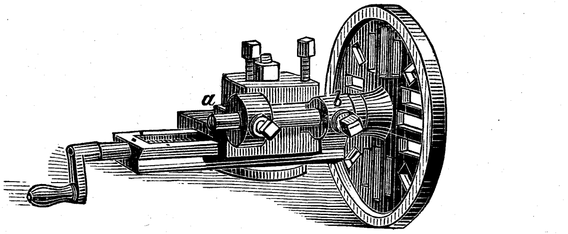

Fig. 1071.

The convenience of this device consists in this, that the work turned on the chuck may be drilled without moving it from the chuck, which may be so set as to cause the drilled holes to be at any required angle to the work surface, which is quite difficult of accomplishment by other ordinary means.

On account of the readiness with which a flat drill may be made to suit an odd size or employed to recess work with a flat or other required shape of recess, flat drills are not uncommonly used upon lathe work, and in this case they may be driven in the drill chucks already shown. A very convenient form of drill chuck for small drills is shown in Fig. 1072. It consists of a cylindrical chuck fitting from A to B into the coned hole in the live spindle so as to be driven thereby. At the protruding end C there is drilled a hole of the diameter of the wire forming the drill. At the end of this hole there is filed a slot D extending to the centre of the chuck. The end of the drill is filed half round and slightly taper, as shown in Fig. 1073 at D, so that the half-round end of the drill will pass into the slot of the chuck, therefore forming a driving piece which effectually prevents the drill from slipping, as is apt to occur with cylindrical stem or shank drills. If one size of wire be used for all drills, and the drill size be determined by the forging, the drill will run true, being held quite firmly, and may be very readily inserted in or removed from the chuck.

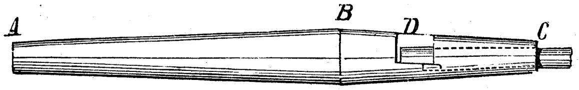

Fig. 1072.

But the flat drill possesses several disadvantages: thus, referring to figure, it must be enough smaller at A than at B to permit the cuttings to find egress, and this taper causes the diameter of the drill to be reduced at each drill grinding. The end B may, it is true, be made parallel for a short distance, but in this case the cuttings will be apt to clog in the hole unless the drill be frequently removed from deep holes to clear the cuttings. For these reasons the fluted drill or the twist drill is preferable, especially as their diameters are maintained without forging. For deep holes, as, say, those having a depth equal to more than twice the diameter, the flat drill, if of small diameter, as, say, an inch or less, is unsuitable because of the frequency with which it must be removed from the hole to clear it of cuttings.

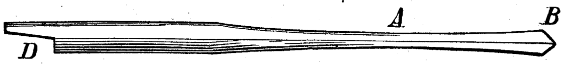

Fig. 1073.

For fluted or twist drills the lathe may run quicker than for a flat drill, which is again an advantage. It sometimes becomes convenient in the exigencies which occur in the work of a general machine shop to hold a drill in a dog or clamp and feed it into the work with the lathe dead centre. In this case the drill should be held very firmly against the dead centre, or otherwise the drill may, when emerging through the back of the hole, feed itself forward, slipping off the dead centre, and causing the drill to catch and break, or moving the work in the chuck, to avoid which the drill should have a deep and well countersunk centre.

A very effective drill for holes that are above two inches in diameter and require enlarging is shown in Fig. 1074. It consists of a piece of flat steel A, with the pieces of wood B fastened on the flat faces, the wood serving to steady the drill and prevent it from running to one side in the work. This drill is sometimes used to finish holes to standard size, in which case the hole to be bored or drilled should be trued out a close fit to the drill for a distance equal to about the diameter of the drill, and the face at the entrance of the hole should be true up. This is necessary to enable the drill to start true, which is indispensable to the proper operation of the drill.

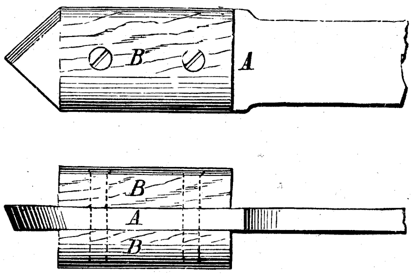

Fig. 1074.

This drill is made by being turned up in the lathe, and should have at the stock end a deep and somewhat large centre, so that when in use it may not be liable to slip off the dead centre of the lathe. The drill is held at the stock end by being placed in the lathe dead centre and is steadied, close to the entrance of the hole in the work, by means of a hook which at one end embraces the drill, as shown in Fig. 1075, in which A represents the hook and B the drill.

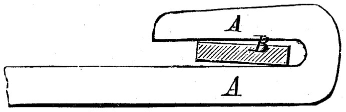

Fig. 1075.

This drill will bore a parallel hole, but if the same be a long or a deep one it is apt to bore gradually out of true unless the bore of the hole is first trued from end to end with a boring tool before using the drill. It is often employed to enlarge a hole so as to admit a stout boring tool, and to remove the hard surface skin from which the boring tool is apt to spring away.

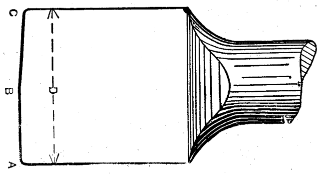

Fig. 1076.

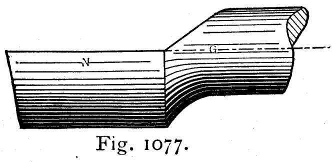

Fig. 1077.

HALF-ROUND BIT OR POD AUGER.—For drilling or enlarging holes of great depth (in which case it is difficult to drill straight holes with ordinary drills), the half-round bit—Figs. 1076 and 1077—is an excellent tool. Its diameter D is made that of the required hole, the cutting being done at the end only from A to B, from B to C being ground at a slight angle to permit the edge from A to B to enter the cut. When a half-round bit is to be used on iron or steel, and not upon brass, it may be made to cut more freely by giving the front face rake as at E F, Fig. 1078.

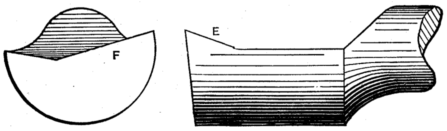

Fig. 1078.

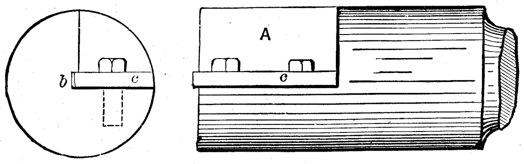

Fig. 1079.

To enable a bit of this kind to be adjusted to take up the wear, it may be formed as in Fig. 1079, in which a quarter of the circumference is cut away at A, and a cutter *c* is bolted in position projecting into a recess at *b* to secure the cutter in addition to the bolts. Pieces of paper may be inserted at *b* to set out the cutter.

An excellent form of boring bar and cutter is shown in Figs. 1080 and 1081.

Fig. 1082 shows a side view of the cutter removed from the bar; Fig. 1081 an end, and Fig. 1080 a side view of the bar and cutter. The cutter is turned at A and B to fit the bore of the bar. The cutting edge C extends to the centre of the bar, while that at D does not quite reach the centre. These edges are in a line as shown in the end view. On account of the thickness of the cutter not equaling the diameter of the bore through the bar there is room for a stream of water to be forced through the bar, thus keeping it cool and forcing out the cuttings which pass through the passages G and H in the bar. The cutter drives lightly into the bar. By reason of one cutting edge not extending clear to the centre of the cutter there is formed a slight projection at the centre of the hole bored which serves as a guide to keep the cutter true, causing it to bore the hole very true.

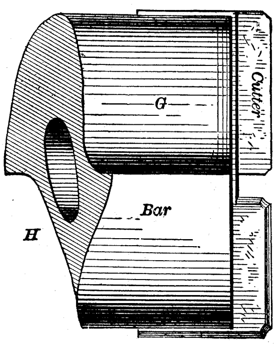

Fig. 1080.

For finishing the walls of holes more true, smooth, and straight, and of more uniform diameter than it is found possible to produce them with a drill, the reamer, or rymer, is employed. It consists of a hardened piece of steel having flutes, at the top of which are the cutting edges, the general form of solid reamer for lathe work being shown in Fig. 1083. The reamer is fed end-ways into the work at a cutting speed of about 15 to 18 feet per minute.

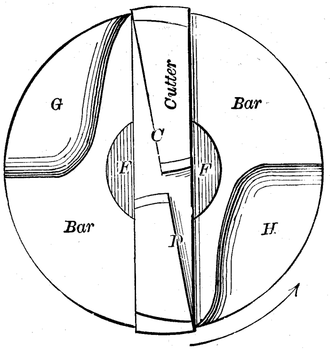

Fig. 1081.

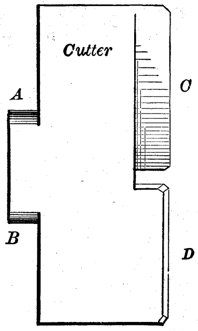

Fig. 1082.

The main considerations in determining the form of a reamer are as follows:—

1. The number of its cutting edges.
2. The spacing of the teeth.
3. The angles of the faces forming the cutting edges.
4. Its maintenance to standard diameter.

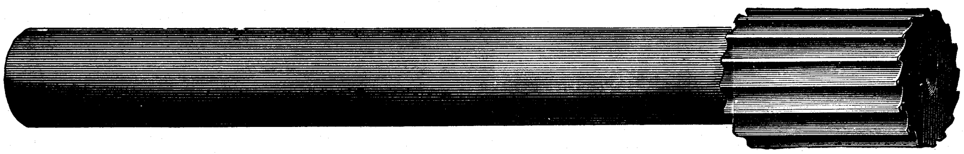

Fig. 1083.

As to the first, it is obvious that the greater the number of cutting edges the more lines of contact there are to steady it on the walls of the hole; but in any case there should be more than three teeth, for if three teeth are used, and one of them is either relieved of its cut or takes an excess of cut by reason of imperfections in the roundness of the hole, the other two are similarly affected and the hole is thus made out of round.

An even number of teeth will not work so steadily as an odd one, for the following reasons.

In Fig. 1084 is represented a reamer having 6 teeth and each of these teeth has a tooth opposite to it; hence, if the hole is out of round two teeth only will operate to enlarge its smallest diameter. In Fig. 1085 is a reamer having 7 teeth, and it will be seen that if any one tooth cuts there will be two teeth on the opposite side of the reamer that must also cut; hence, there are three lines of contact to steady the reamer instead of two only as in the case of the 6 teeth. An even number of teeth, however, may be made to operate more steadily by spacing the teeth irregularly, and thus causing three teeth to operate if the hole is out of round. Thus, in Fig. 1086 the teeth are spaced irregularly, and it will be seen that as no two teeth are exactly opposite, if a tooth on one side takes a cut there must be two on the opposite side that will also cut. The objection to irregular spacing is that the diameter of the reamer cannot be measured by calipers. Another method of obtaining steadiness, however, is to make the flutes and the cutting edges spiral instead of parallel to the axis, but in this case the spiral must be left-handed, as in Fig. 1087, or else the cutting edges acting on the principle of a screw thread will force the reamer forward, causing it to feed too rapidly to its cut. If, however, a reamer have considerable degree of taper, it may be given right-hand flutes, which will assist in feeding it.

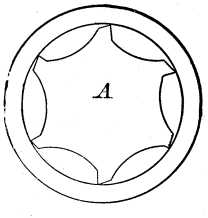

Fig. 1084.

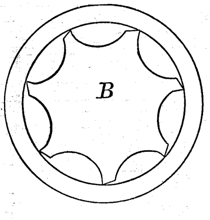

Fig. 1085.

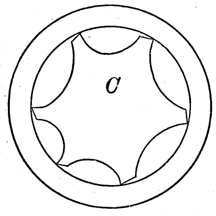

Fig. 1086.

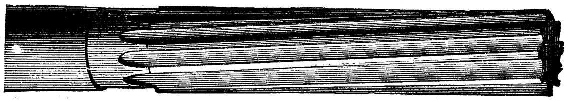

Fig. 1087.

Referring to the second, the spacing of the teeth must be determined to a great extent by the size of the reamer, and the facility afforded by that size to grind the cutting edges to sharpen them.

The method employed to grind a reamer is shown in Fig. 1088, in which is shown a rapidly-revolving emery-wheel, above the reamer, and also a gauge against which the front face of each tooth is held while its top or circumferential face is being sharpened. The reamer is held true to its axis and is pushed end-ways beneath the revolving emery-wheel. In order that the wheel may leave the right-hand or cutting edge the highest (as it must be to enable it to cut), the axis of the emery-wheel must be on the left hand of that of the reamer, and the spacing of the teeth must be such that the periphery of the emery-wheel will escape tooth B, for otherwise it would grind away its cutting edge. It is obvious, however, that the less the diameter of the emery-wheel the closer the teeth may be spaced; but there is an objection to this, inasmuch as that the top of the tooth is naturally ground to the curvature of the wheel, as is shown in Fig. 1089, in which two different-sized emery-wheels are represented operating on the same diameter of reamer. The cutting edge of A has the most clearance, and is therefore the weakest and least durable; hence it is desirable to employ as large a wheel as the spacing of the teeth will allow, there being at least four teeth, and preferably six, on small reamers, and their number increasing with the diameter of the reamer.

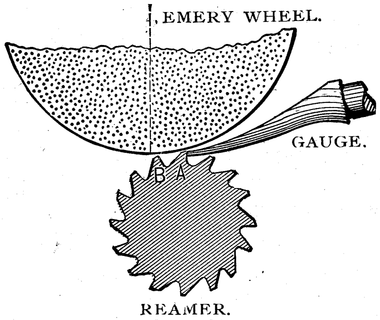

Fig. 1088.

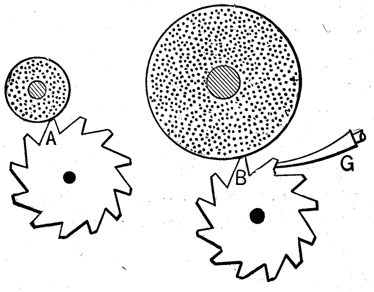

Fig. 1089.

It would appear that this defect might be remedied by placing the emery-wheel parallel to the teeth as in Fig. 1090; but if this were done, the wear of the emery-wheel would cause the formation of a shoulder at S in the figure, which would round off the cutting edge of the tooth. This, however, might be overcome by giving the emery-wheel enough end motion to cause it to cross and recross the width of the top facet; or the reamer R may be presented to the wheel W at an angle to the plane of wheel rotation, as in Fig. 1091, which would leave a straight instead of a curved facet, and, therefore, a stronger and more durable cutting edge.

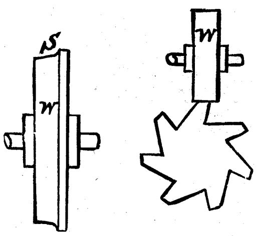

Fig. 1090.

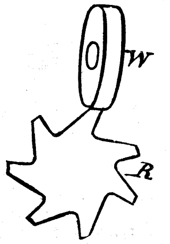

Fig. 1091.

Another method of accomplishing the same object would be to mount the emery-wheel as in Fig. 1092, using its side face, which might be recessed on the side, leaving an annular ring of sufficient diameter to pass clear across the tooth, and thus prevent a shoulder from forming on the side face of the wheel.

Yet another method is to use an emery-wheel bevelled on its edge, and mount it as in Fig. 1093, in which case it would be preferable to make the bevel face narrow enough that all parts would cross the facet of the tooth.

Referring to the third, viz., the angles of the faces forming the cutting edges, it is found that the front faces, as A and B in Fig. 1094, should be a radial line, for if given rake as at C, the tooth will spring off the fulcrum at point E in the direction of D, and cause the reamer to cut a hole of larger diameter than itself, an action that is found to occur to some extent even where the front face is a radial line. As this spring augments with any increase

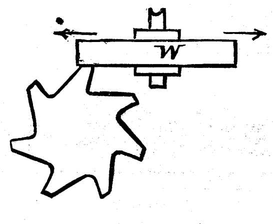

Fig. 1092.

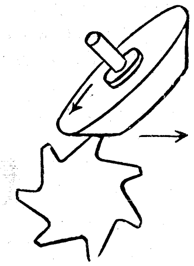

Fig. 1093.

of cut-pressure, it is obvious that if a number of holes are to be reamed to the same diameter it is essential that the reamer take the same depth of cut in each, so that the tooth spring may be equal in each case. This may be accomplished to a great extent by using two reamers, one for equalizing the diameters of the holes, and the other for the final finishing. The clearance at the top of the teeth is obviously governed by the position of the reamer with relation to the wheel, and the diameter of the wheel, being less in proportion as the reamer is placed farther beneath the wheel, and the wheel diameter is increased. In some forms of reamer the teeth are formed by circular flutes, such as at **H** in Fig. 1094, and but three flutes are used. This leaves the teeth so strong and broad at the base that the teeth are not so liable to spring; but, on the other hand, the clearance is much more difficult to produce and to grind in the resharpening.

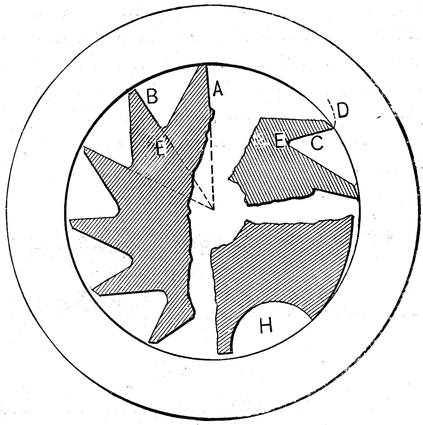

Fig. 1094.

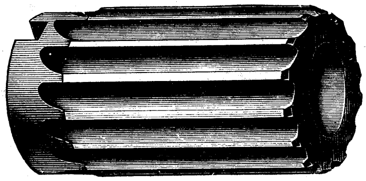

Fig. 1096.

As to the maintenance of the reamer to standard diameter, it is a matter of great importance, for the following reasons: The great advantage of the standard reamer is to enable holes to be made and pieces to be turned to fit in them without requiring any particular piece to be fitted to some particular hole, and in order to accomplish this it is necessary that all the holes and all the pieces be exactly alike in diameter. But the cutting edges of the reamer begin to wear—and the reamer diameter, therefore, to reduce—from the very first hole that it reams, and it is only a question of time when the holes will become too small for the turned pieces to enter or fit properly. In all pieces that are made a sliding or a working fit, as it is termed when one piece moves upon the other, there must be allowed a certain latitude of wear before the one piece must be renewed.

One course is to make the reamer when new enough larger than the proper size to bore the holes as much larger as this limit of wear, and to restore it to size when it has worn down so that the holes fit too tightly to the pieces that fit them. But this plan has the great disadvantage that the pieces generally require to have other cutting operations performed on them after the reaming, and to hold them for these operations it is necessary to insert in them tightly-fitting plugs, or arbors, as they are termed. If, therefore, the holes are not of equal diameter the arbor must be fitted to the holes, whereas the arbor should be to standard diameter to save the necessity of fitting, which would be almost as costly as fitting each turned piece to its own hole. It follows, therefore, that the holes and arbors should both be made to a certain standard, and the only way to do this is to so construct the reamer that it may be readily adjusted to size by moving its teeth.

It is obvious that a reamer must, to produce parallel holes, be held axially true with the holes, or else be given liberty to adjust itself true. Fig. 1095 shows a method of accomplishing this object. The reamer is made to have a slight freedom or play in the sleeve, being $\frac{1}{32}$ inch smaller, and the hole for the pin is also made large so that the reamer may adjust itself for alignment.

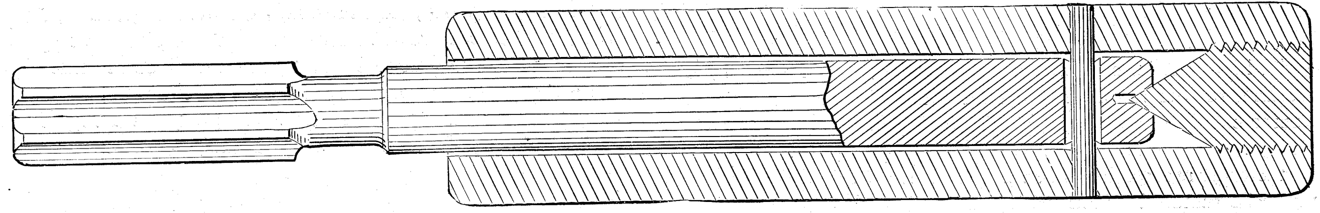

Fig. 1095.

For short holes the shell reamer shown in Fig. 1096 may be employed. Its bore is coned so that it will have sufficient friction upon its driving arbor to prevent its coming off; when it is to be withdrawn from the work it is provided with two slots into which fit corresponding lugs on the driving arbor. Fig. 1097 shows the the Morse Twist Drill and Machine Company's arbor.

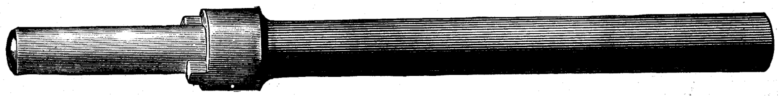

Fig. 1097.

The rose reamer, or rose bit, has its cutting edges on the end only, as shown in Fig. 1098, the grooves being to supply lubricating material (as oil or water) only, and, as a result, will bore a more parallel hole than the ordinary reamer in cases in which the reamer has liberty to move sideways, from looseness in the mechanism driving it. Furthermore, when the work is composed of two parts, the outer one, through which the reamer must pass before it meets the inner one, guides the reamer without becoming enlarged by reason of the reamer having cutting edges, which is especially advantageous when the inner hole requires to be made true with the outer one, or in cases where a piece has two holes with a

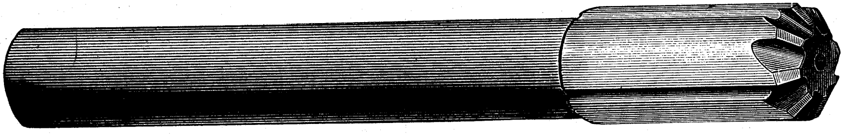

Fig. 1098.

space between them, and one hole requires to be made true with the other, and both require to be made to the same diameter as the reamer.

Fig. 1099 represents the Morse Twist Drill Company's shell rose reamer for short holes, corresponding in principle to the solid rose reamer, but fitting to an arbor for the same purposes as the shell reamer.

Instead of having upon a reamer a flat tooth top to provide clearance, very accurate and smooth work may be produced by letting the back of the tooth, as A in Fig. 1100, proceed in a straight line to B, leaving the reamer, when soft, too large, so that after hardening it may be ground by an emery-wheel to size; and the clearance may be given by simply oilstoning the top of each tooth lengthwise, the oilstone marks barely effacing the emery marks at the cutting edge and removing slightly more as the back of the tooth is approached from the cutting edge. This produces cutting edges that are very easily fed to the cut, which must obviously, however, be a light one, as should always be the case for finishing, so that the wear of the teeth may be a minimum, and the reamer may therefore maintain its standard diameter as long as possible.

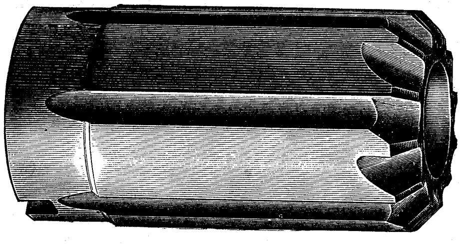
Fig. 1099.

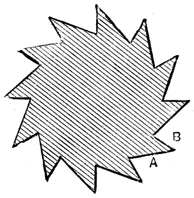

Fig. 1100.

When a solid reamer has worn below its required diameter, the same may be restored by upsetting the teeth with a set chisel, by driving it against the front face; and in determining the proper diameter for a reamer for work to be made to gauge under the interchangeable system the following considerations occur.

Obviously the diameter of a reamer reduces as it wears; hence there must be determined a limit to which the reamer may wear before being restored to its original diameter. Suppose that this limit be determined as $\frac{1}{1000}$ inch, then as the reamer wears less in diameter the bolts to fit the holes it reams must also be made less as the reamer wear proceeds, or otherwise they will not enter the reamed holes. But it is to be observed that while the reamer wears smaller, the standard gauges to which the pins or bolts are turned wear larger, and the wear is here again in a direction to prevent the work from fitting together. It is better then to make the reamer when new too large to the amount that has been determined upon as the limit of wear, so that when the work begins to go together too tight, the reamer requires resharpening and restoring.

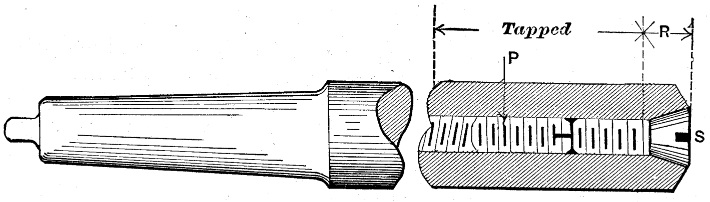

Fig. 1101.

A still better plan, however, is to use reamers adjustable for diameter, so that the wear may be taken up, and also the reamer sharpened, without being softened, which always deteriorates the quality of the steel.

Reamers that are too small to be made adjustable for size by a combination of parts may be constructed as in Fig. 1101, in which the reamer is drilled and threaded, and countersunk at the end to receive a taper-headed screw S, which may be screwed in to expand the reamer, which contains three longitudinal splits to allow it to open. To cause S to become locked in its adjusted position a plug screw P is inserted for the end of S to abut against. It is obvious that in this form the reamer is expanded most at the end.

Fig. 1102 represents a single-tooth adjustable reamer, in which the body A is ground to the standard diameter, and the wear of the cutter C is taken up by placing paper beneath the cutter. In this case the reamer cannot, by reason of the wear of the cutting edge, ream too small, because the body A forms a gauge of the smallest diameter to which the reamer will cut. The cutter may, however, be set up to the limit allowed for wear of cutting edge, which for work to fit should not be more than $\frac{1}{5000}$ inch.

An adjustable reamer designed and used by the author for holes not less than $1\frac{1}{2}$ inches in diameter, is shown in Fig. 1103, in which A represents the body of the reamer containing dovetail grooves tapered in depth with the least depth at the entering end. The grooves receive cutters B, having gib heads. C is a ring or washer interposed between the gib heads of the cutter and the face or shoulder of A, the cutters being locked against that face by a nut and a washer E. By varying the thickness of C, the cutters are locked in a different position in the length of the grooves, whose taper depth therefore causes the cutters to vary in diameter. Suppose, for example, that with a given thickness of washer C, the cutters are adjusted in diameter so as to produce a hole a tight working fit to a plug turned to a 2-inch standard gauge: a slightly thinner washer may be used, setting the cutters so as to bore a hole an easy working fit to the plug; or a slightly thicker washer may be employed so as to produce a hole a driving fit to the same plug. Three or more washers may thus be used for every standard size, their thickness varying to suit the nature of the fit required.

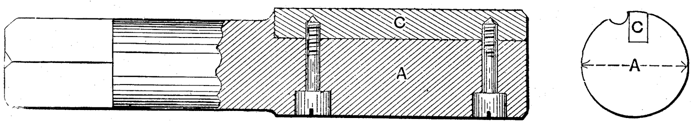

Fig. 1102.

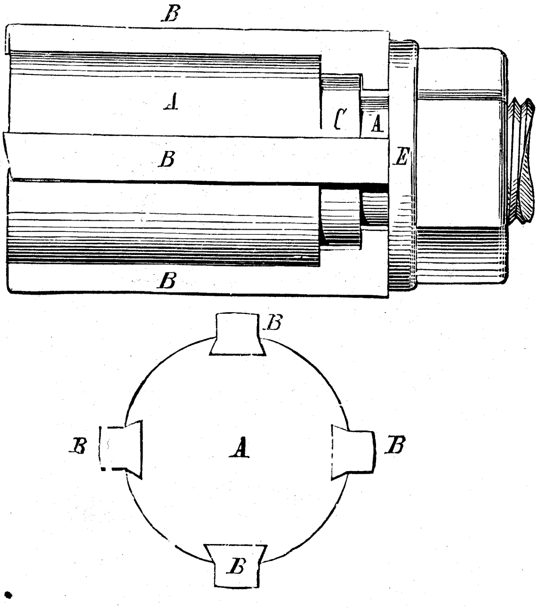

Fig. 1103.

It will be noted that it is mentioned that three *or more* washers may be used, and this occurs because a diameter of fit that would be a driving fit for a hole of one length would be too tight for a driving fit of a much longer hole, the friction of course increasing with the length of hole, because of the increase of bearing area.

For large sizes, a reamer of this description is an excellent tool, because if it be required to guide the reamer by means of a plain cylindrical shank, a washer, or sleeve, having a bore to fit the shank at the termination of the thread, may be used, but such a reamer is not suitable for small diameters, because of the reduction of shank necessary to provide for the nut and thread.

Reamers for roughing out taper holes may be made with steps, as in Fig. 1104, which is taken from *The American Machinist*, there being a cutting edge where each step meets a flute. Such a reamer may be used to enlarge parallel holes, or to rough out taper ones, and the flutes (if not to be used for brass work) may be spiral, as in the figure. The end step being guided by the hole serves as a guide to the first cutting edge; the second step serves as a guide for the cutting edge that follows it, and so on.

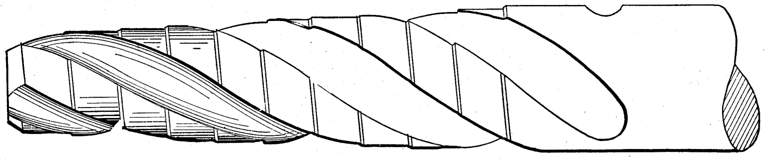
Fig. 1104.

The steps are best turned a trifle larger, say $\frac{1}{1000}$ inch larger, at the cutting end. Half-round taper reamers, such as shown in Fig. 1105, are used for finishing holes. The flat face is cut down, leaving rather more than a half circle; the clearance being filed or ground on the cutting side so as to enable the reamer to cut, and extending from the cutting edge to nearly half-way to the bottom of the reamer.

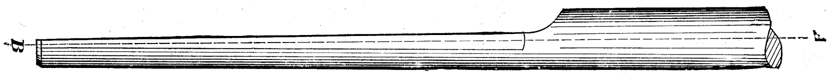

Fig. 1105.

For holes, however, that are large enough to admit a tool of sufficient strength, the single-pointed boring tool produces the most true work.

Brass finishers use square taper reamers, which produce upon brass more true work than the half-round reamer.

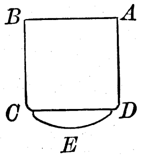

Fig. 1106.

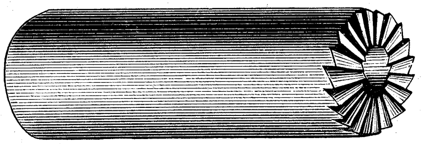
Fig. 1107.

For reaming the bores of rifles, a square reamer, such as shown in Fig. 1106, is employed; the edges A B are the cutting ones, the edges C D being rounded off; E is a piece of wood, beneath which slips of paper are placed to restore the size as the wear proceeds. The entering end of the reamer is slightly tapered. On account of the extreme length of this reamer in proportion to its diameter, it is fed to its cut by being pulled instead of pushed as is usually the case, the pull placing the rod of the reamer under tension and thus stiffening it; the line of pull is of course true with the axis of the rifle bore. The reamer is revolved at high speed and freely supplied with oil.

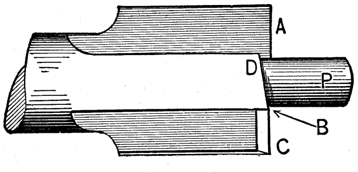

Fig. 1108.

By means of the slips of paper successive cuts and minute increases of diameter may be taken with the same reamer.

Fig. 1107 represents a class of rose bit employed to reduce pins to a uniform diameter, and face off the shoulder under the head, or it may be used to cut a recess round a pin, or to cut a recess and leave a pin.

For making a recess round a hole, or, in other words, for cutting a flat-bottom countersink, a facing countersink, Fig. 1108, may be used, its cutting edges being at A, B, C, &c. The clearance is given at the ends of the teeth only, being shown from B to D. The pin P steadies the tool, and is made a working fit to the hole in the work. Or if too small, a ferrule may be placed upon it, thus increasing the capacity of the tool. When a tool of this kind is to be used on iron, steel, or copper, and not upon brass, the front face of the teeth may be given rake by cutting the grooves at an angle, as in Fig. 1109.

Boring Tools for Lathe Work.—The principal object in forming a boring tool to be held in a slide rest is to have the body of the tool as large as can be conveniently got into the size of the hole to be bored; hence the cutting edge should not stand above the level of the top of the steel. By this means the tool will be as stiff as possible, and less liable to spring away from its cut, as boring tools are apt to do, especially when the cut or hole is a long one.

It is so difficult a matter to bore a long hole parallel with a long boring tool that cutters of various forms are usually preferred, and these will be described hereafter.

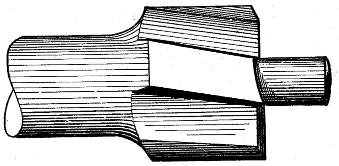
Fig. 1109.

The boring tool is, upon cast iron and brass, exceedingly liable to chatter, but this may always be avoided by making the angles forming the cutting edge less acute: thus, in Fig. 1110 are three boring tools, A, B, C, operating in a piece of work D. Now the lateral pressure of a cut is exerted upon the tool at a right angle to the length of the cutting edge; hence (in addition to the vertical pressure) the lateral pressure of the tool A will be in the direction of the dotted line and arrow A, that on B in the direction of dotted line and arrow B, and that on C in the direction of dotted line and arrow C; hence the pressure of the cut would tend to force A towards the centre of the hole and off or away from its cut, B back from its cut, and C deeper into its cut. Now as the cut proceeds, the tool edge dulls, hence it would appear that a compromise between C and B would be the most desirable, as giving to the tool enough of the tendency to deepen its cut to compensate for the tendency to spring away from its cut, as the cutting edge dulls (which it does from the moment the cut begins).

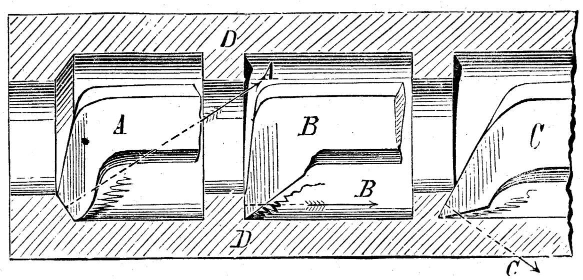

Fig. 1110.

This is quite practicable in tools to be used on wrought iron, as shown in Fig. 1111, which represents the most desirable form.

In this form the part of the cutting edge performing duty under a deep cut will be mainly in front of the tool, but in light cuts the cutting edge would be farther back, where it is more nearly parallel to the line of the work bore, and will hence cut smoother.

Where a boring tool is intended for light cuts only on wrought iron it may have all, or nearly all, its rake at the top, as shown in Fig. 1112, from *a* to B representing the cut, and C the tool.

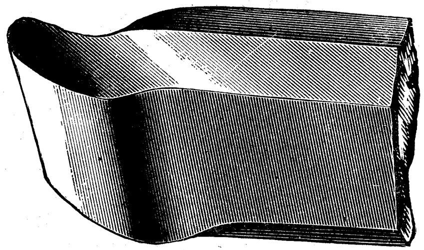
Fig. 1111.

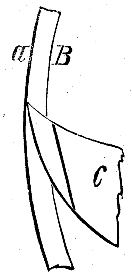

Fig. 1112.

Under ordinary conditions that in the form of tool shown in Fig. 1113* is best for brass work, the face A being horizontal or slightly depressed towards the point. Boring tools require very little bottom rake, and the cutting points should be as rounded as they can be made without chattering. On wrought iron the top rake may be as much as is consistent with strength, and water should be freely applied to the cut. For cast iron the best form of tool is that shown in Fig. 1114, the edge A being parallel with the bore of the hole, and the feed being a coarse one, taking a very light cut when finishing.

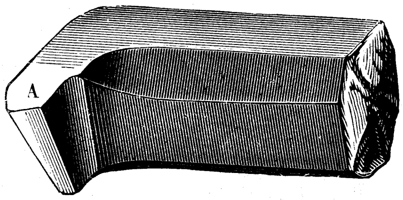

Fig. 1113.

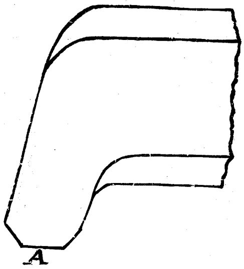

Fig. 1114.

In cases, however, where the tool point requires to cut up to a sharp corner, the form of tool shown in Fig. 1115 (which represents a top and end view) may be used. Its end face C is at an obtuse angle to the length of the tool, so that on passing up a bore and meeting a radial face the point only will meet that face. This angle, however, gives to the tool a keenness that will cause chattering on brass work unless the top face be bevelled to the tool body, as is A to B in the figure.

It frequently happens in boring cast iron that the skin or the surface of the metal is very hard, rapidly dulling the tool and forcing it away from its cut, unless the cut is deep enough to allow the point of the tool to cut beneath it, as shown in Fig. 1116, in which the hardness is supposed to extend from the bore to the dotted line.

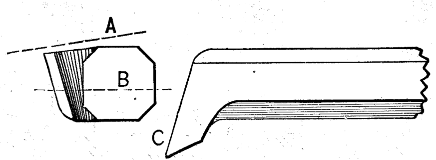

Fig. 1115

In this case a tool formed as at C is employed, the point cutting in advance of the rest of the tool, and entering the soft metal beneath the hard metal; the hard metal will then break away in lumps or pieces, without requiring to be absolutely cut into chips or turnings, because of being undercut, as shown at B.

The cross slider or tool rest of a lathe should be adjusted to closely fit the cross slide of the lathe if true and parallel work is to be bored, because any lost motion that may exist in the slide is multiplied by the length the tool stands out from the tool post. Thus the centre of motion of the rest if it has play, as at B, Fig. 1117, and the direction of motion at the tool point, will be an arc of a circle of which B is the centre, the bend of the tool from the pressure of the cut will have its point of least motion or fulcrum at A; hence, both tend to cause the tool point to dip and spring unequally under the varying cut pressure that may arise from hard or soft places in the metal, and from inequalities in the cut depth.

The pressure of the cut increases as the tool point loses its sharpness, and this makes sufficient difference for the amount of tool spring in light boring tools or in long holes to cause the tool to bore a larger hole at the beginning than it does at the end of its feed traverse; or, in other words, to bore a taper hole, whose largest end is that at which the cut was started. If, therefore, the cut is traversed from the front to the back of the hole the latter will be of the smallest diameter at the back, and conversely if the cut proceeds from the back to the front of the hole the front will be of smallest diameter. The amount of the taper so caused (or in other words the error from parallelism) will obviously increase with the length of the hole.

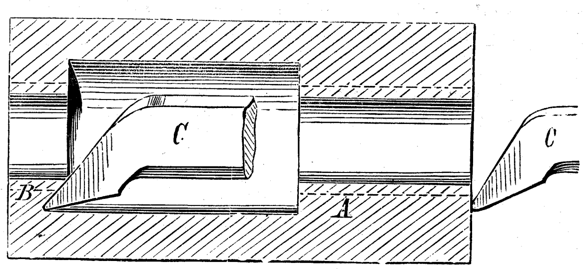

Fig. 1116.

To obviate this taper, the slide of the rest should for the finishing cut be set up firmly, and the tool after being sharpened should take a finishing cut through the hole, and then let traverse back, which can be done providing that care be taken not to bore the hole too large.

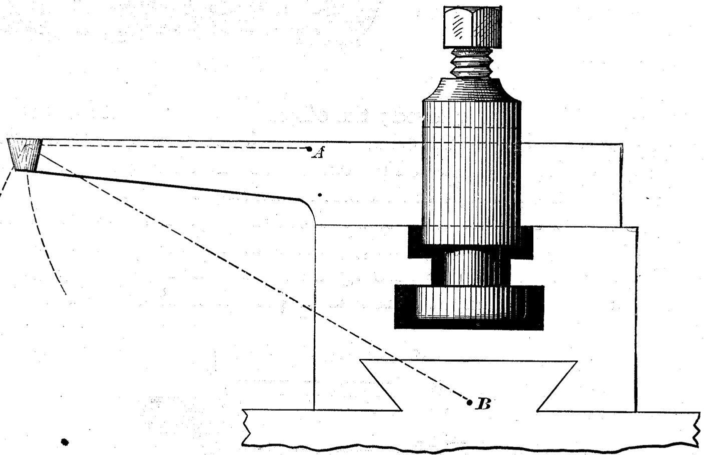

Fig. 1117.

A boring tool will take a smoother cut and chatter less if the final cut be from the back to the front of the hole, and for the following reasons: When the tool is fed in, the strain or pressure of the cut is in a direction to partly compress and partly bend the steel which is being pushed to its cut, but when it is fed in the opposite direction it is pulled to its cut and the strain is in a direction to stretch the steel, and this the tool is more capable of resisting, hence it does not so readily vibrate to cause chattering.

In consequence, however, of the liability of a boring tool to spring away from its cut, it is far preferable to finish holes with standard cutters, reamers, or bits, in which case the boring tool may be

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* From "The Complete Practical Machinist."

employed to rough out and true up the hole, leaving a *fine* cut for the finishing cutter or bit, so as to wear its cutting edge as little as possible. To further attain this latter object, the cutter or bit should be used at a slow cutting speed and with a coarse feed.

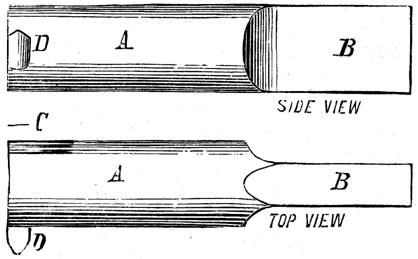


Fig. 1118.

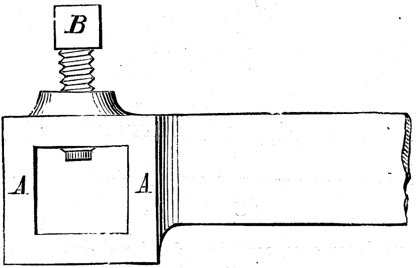
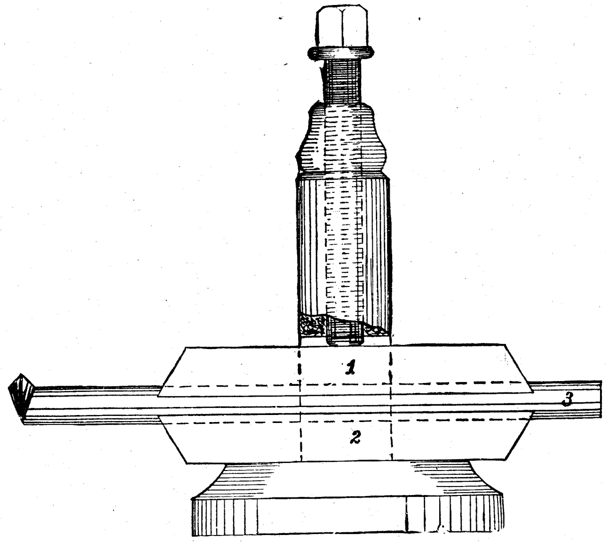


Fig. 1119.

If cutters or bits are not at hand, tool holders are desirable, and the forms of these depend upon the nature, or rather the diameter, of the hole to be bored. In all cases, however, the best results will be obtained when the diameter of the tool holder is as near that of the hole to be bored as will give it clearance. This occurs on account of the rigidity of the holder being greater than that of the tool.



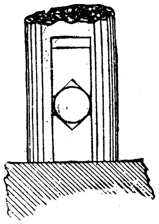


Fig. 1120.

For large work tool holders are desirable, in that the tools, being short, are easier to forge, to handle, and to grind.

For example, a tool holder of a cross section of two inches square may contain a tool whose cross section is 1 by $\frac{3}{4}$ inch, in which case it is necessary to forge, grind, &c., the small tool only, whereas in the absence of the holder the tool would require to be of a cross section equal to that of the holder to obtain an equal degree of rigidity.

A boring tool holder suitable for holes of from 2 to 4 or 5 inches is shown in Fig. 1118, in which A represents a round bar shaped at the end B to fit into the tool post of the slide rest, and having a groove across the diameter of the end C D to receive a short tool. The slot and tool may be either square or V-shaped, the tool being locked by a wedge. It is obvious that instead of shaping the end B as shown, the bar may be held (if the slide-rest head is provided with a clamp instead of a tool post) by two diametrically opposite flat faces.

For holes of a greater diameter a holder such as shown in Fig. 1119 should be used, the body being a square bar, and the tool being held in the box A A by two set screws B. For holes of small diameter, as, say, less than $1\frac{1}{2}$ inches, a tool holder is especially desirable, because when a boring tool is forged out of a piece of tool steel, its length is determined, and in order to have tools suitable for various depths of hole a number of tools of varying lengths are requisite. Suppose, for example, that a piece of steel be forged into a boring tool suitable for a hole of an inch diameter, and 4 inches deep, then the steel must be forged round for a distance of at least 4 inches from the cutting end, and if such a tool were applied to a hole, say, two inches deep, the cutting edge would stand out from the tool post at least two inches more than is necessary, which would cause the employment of a tool weaker than necessary for the work. To enable the use of one tool for various depths of work, and yet hold it in each case as close to the tool post as the work depth admits, tool-clamping devices, such as in Fig. 1120 (which are extracted from *The American Machinist*), are employed. 1 and 2 are pieces of steel fitting in the tool post and clamping the tool, which for very small holes is made of octagon or round forged steel. The tool may be passed to any required distance through the clamp, so as to project only to the amount necessary for the particular depth of hole requiring to be bored. These clamping pieces 1 and 2 should bed upon the tool fairly along their full length; or, what is better, they may bed the firmest at their extremities, which will insure that the tool is gripped firmly as near to the cutting edge as possible.

In place of a steel tool, a tool holder turned cylindrically true and parallel may be used to carry a short boring tool, as shown in Fig. 1121, in which A is the tool secured by the set-screw B into the holder C. The latter may be provided with a line running true longitudinally, and may have a fine groove similar to a thread, and having a pitch measuring some part of an inch, as $\frac{1}{8}$, $\frac{1}{4}$, $\frac{1}{2}$ inch, &c., so that the distance the tool projects from the holder may be known without measuring the same. But when a tool and holder of this description are used, the tool cannot be employed unless the hole passes entirely through the work, which occurs because of the presence of the set-screw B.

It is obvious that for a tool-holding bar such as this, a clamping device such as shown in Fig. 1120 is requisite, and that the position of the clamping device may be adjusted to suit the work by setting it more or less through the tool post.

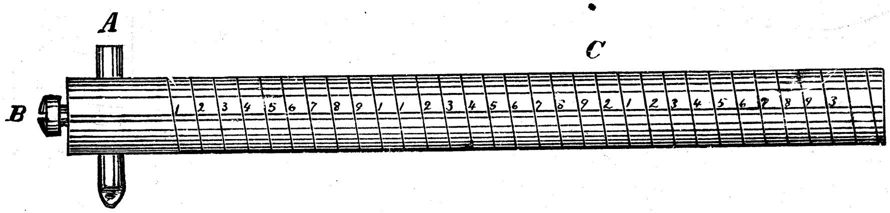


Fig. 1121.

The manner in which the deflection of a boring tool will affect the bore of the work depends upon the height of the boring tool in the work. If the tool is above the horizontal centre of the work, as in Fig. 1122, the spring vertically will cause it to leave the cut, and bore the hole to a corresponding amount smaller; and since the tool gets duller as the wear proceeds, it will spring more at the latter end of each tool traverse, leaving the end of the hole last cut of smallest diameter.

If, on the other hand, the tool be below the horizontal centre, as in Fig. 1123, the vertical spring will be in a direction to increase the amount of the cut, and thus offset the tapering effect of the increased tool spring due to the wear of the tool. Furthermore, the shaving will be easier bent if the tool be below than if above the horizontal centre, because the metal will be less supported by the metal behind it. It is always desirable therefore to have the cutting edge of a boring tool used on small work below rather than above the horizontal centre of the work. On large work, however, as say, having a bore of 6 inches and over, the curve of the bore in the length of the circumference affected by the cut or bending of the cut is so small, that the height of the tool is of less consequence.

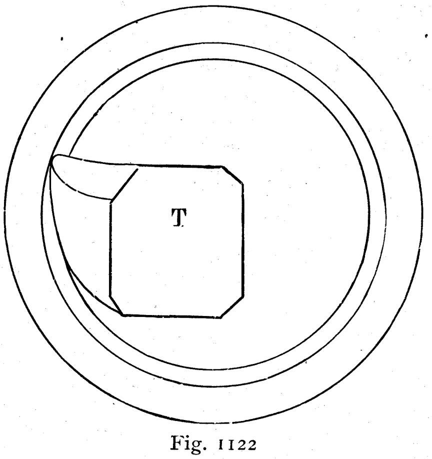


Fig. 1122

To enable the use of a stout-bodied boring tool, while keeping its cutting edge below the centre, the top face of the tool may be depressed, as shown in Fig. 1123.

An excellent attachment for boring parallel holes is shown in Figs. 1124 and 1125, in which there is fixed to the cross slide A the bracket B, which is bored to receive a number of bushes C, whose bores are made to suit varying diameters of boring-bars or reamers D. The hub of the bracket is split on one side to enable it to be closed (by the bolt *e*) upon the bush C and grip it firmly, the bush also being split at *f*. The bracket B is provided with a taper pin G, which brings it in position upon the slide so that the bushes C are true with the line of lathe centres. It is also provided with the screws H, which lock it firmly to the cross slide and prevent any spring or movement from play or looseness.

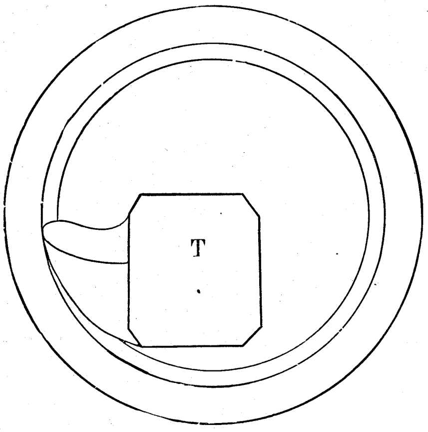


Fig. 1123.

When the bracket is adjusted and the bar fastened up (by screw *e*), the lathe-carriage feeds the boring tool to the cut in the usual manner. Now suppose that, as shown in our illustrations, a pulley P requires to be bored, and the boring tool or reamer may be set to have its cutting end stand out just as far as the length of the hub requires, and no farther, so that the bar will be held and supported as close to the pulley hub as is possible from the nature of the job. There need not be a separate bush for every size of reamer, because the bodies of several size bars may fit to one size of bush, especially if the set of reamers for every size of bush be made with its smallest size equal to the bore of the bush; because in that case the whole of the set may be adjusted to bore any required depth of hole by sliding the reamer through the bush to the required distance. If there are a number of lathes in a shop, each lathe may have its own bracket B, all these brackets being bored to receive the same bushes, and therefore the same boring-bars or reamers.

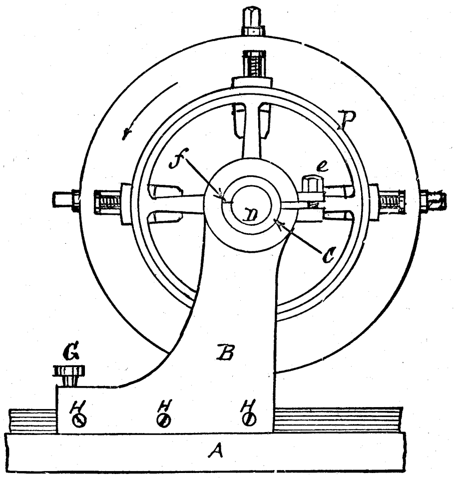


Fig. 1124.

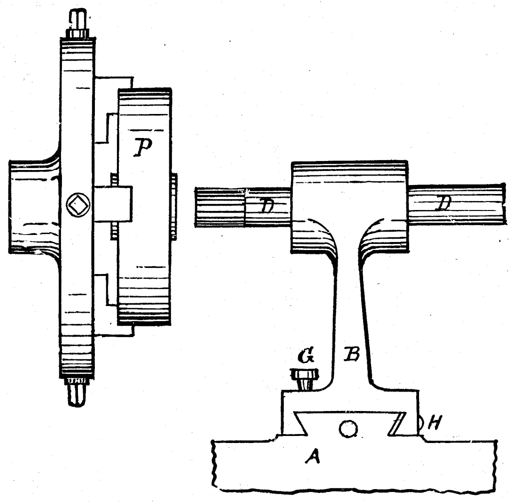


Fig. 1125.

A bracket or stand of this kind may obviously be used to carry a bar, having a head such as is shown in Fig. 1126, each dovetail groove carrying a cutting tool, and for wrought iron or steel work these grooves may be at an angle to the bar axis, as in the figure, to give each cutter front rake, and increase its keenness.

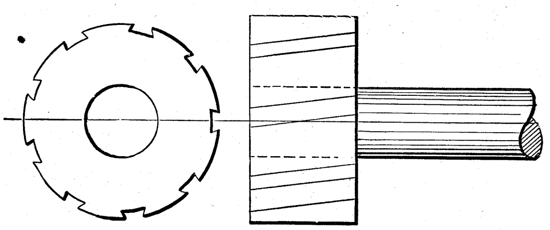


Fig. 1126.

BORING BARS FOR LATHE WORK.—Boring bars for lathe work are of two kinds, those in which the cutters are held in a fixed position in the length of the bar, and those in which the cutters are held in a head which traverses along the work. The former are the least desirable, because they require to be more than twice the length of the work, which must be on one side of the cutter at the commencement of the cut, and on the other at the termination of the same. But to traverse the head carrying the tools along the bar necessitates a feed screw either within the bar or outside of it. If within, the metal removed to give it place weakens the bar, while in small holes there is no room for it; hence solid bars with fixed cutting tools are used for small holes, and tools held in a traversing head for those sufficiently large to give room for a head without weakening the bar too much. A boring bar is best driven from both ends.

"The boring bar is one of the most important tools to be found in a machine shop, because the work it has to perform requires to be very accurately done; and since it is a somewhat expensive tool to make, and occupies a large amount of shop room, it is necessary to make one size of boring bar answer for as many sizes of hole as possible, which end can only be attained by making it thoroughly stiff and rigid. To this end a large amount of bearing and close fitting, using cast iron as the material, are necessary, because cast iron does not spring or deflect so easily as wrought iron; but the centres into which the lathe centres fit are, if of cast iron, very liable to cut and shift their position, thus throwing the bar out of true. It is, therefore, always preferable to bore and tap the ends of such bars, and to screw in a wrought-iron or steel plug, taking care to screw it in very tightly, so that it shall not at any time become loose. The centres should be well drilled and of a comparatively large size, so as to have surface enough to suffer little from wear, and to well sustain the weight of the bar. The end surface surrounding the centres should be turned off quite true to keep the latter from wearing away from the high side, as they would do were one side higher than the other."*

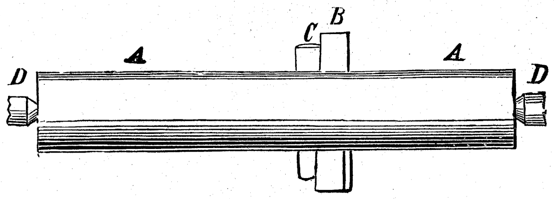


Fig. 1127.

The common form of the smaller sizes of boring bar is that shown in Fig. 1127. A A being the bar, D D the lathe centres, B the cutter passing through a slot or keyway in the bar, and C a key tapered (as is also the back edge of the cutter) to wedge or fasten the cutter to the bar. It is obvious that, if the cutter is turned up in the bar, and is of the exact size of the hole to be bored, it will require to stand true in the bar, and will therefore be able to cut on both ends, in which case the work may be fed up to it twice as fast as though only one edge were performing duty. To facilitate setting the cutter quite true, a flat and slightly taper surface should be filed on the bar at each end of the keyway, and the cutter should have a recess filed in it, as shown in Fig. 1128, the recess being shown at A, and the edges B B forming the diameter of the cutters. The backing off is shown at C, from which it will be observed that the cutting duty is performed by the edge C, and not along the edge B, further than is shown by the backing off. The recess must be made taper, and to fit closely to the flat places filed on the bar. Such a cutter, if required to be adjustable, must not be provided with the recess A, but must be left plain, so that it may be made to extend out on one side of the bar to cut any requisite size of bore; it is far preferable, however, to employ the recess and have a sufficient number of cutters to suit any size of hole, since, as already stated (there being in that case two cutting edges performing duty), the work may be fed up twice as fast as in the former case, in which only one cutting edge operates.

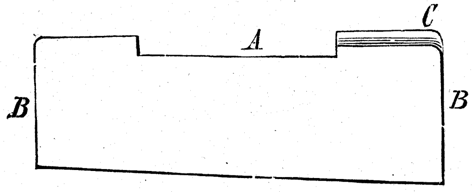


Fig. 1128.

Messrs. Wm. Sellers and Co. form the cutters for their celebrated car wheel boring bar machine as in Fig. 1129, the bottom or plain edge performing the cutting. By this means the recess to fit the bar is not reduced in depth from sharpening the tool. The tool is sharpened by grinding the ends of the lower face as shown by the unshaded parts, and the cutter is said to work better after the cutting part has begun to be oblique from grinding.

The cutter is hardened at the ends and left soft in the middle, so that the standard size of the cutter may be restored when necessary, by pening and stretching the soft metal in the middle. These cutters will bore from 50 to 250 car wheels, without appreciable reduction of size.

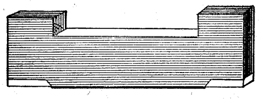


Fig. 1129.

The description of bar shown in Fig. 1127 may be provided with several slots or keyways in its length, to facilitate facing off the ends of work which requires it. Since the work is fed to the cutter, it is obvious that the bar must be at least twice the length of the work, because the work is all on one side of the cutter at the commencement, and all on the other side at the conclusion of the boring operation. The excessive length of bar, thus rendered necessary, is the principal objection to this form of boring bar, because of its liability to spring. There should always be a keyway, slot, or cutter way, near to the centre of the length of the bar, so as to enable it to bore a hole as long as possible in proportion to the length of the boring bar, and a keyway or cutter way at each end of the bar, for use in facing off the end faces of the work.

If a boring bar is to be used only for work that does not require facing at the ends, the cutter, slot, or keyway should be placed in such position in the length of the bar as will best suit the work (keeping in mind the desirability of having the bar as short as possible), and the bar should be tapering from the middle towards each end, as shown in Fig. 1130. This will make the bar stronger in proportion to its weight, and better able to resist the pressure of the cut and the tendency to deflect. The parallel part at A is to receive the driving clamp, but sometimes a lug cast on at that end is used instead of a clamp.

For bores too large to be bored by the bar alone, a tool-carrying head is provided, being sometimes fixed upon the bar by means of a locking key, and at others fed along the bar by a feed screw provided on the bar.

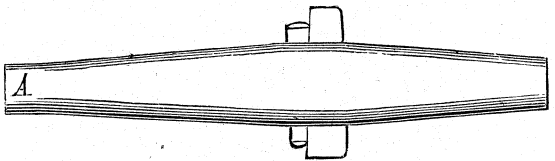


Fig. 1130.

When the head is fixed on the bar the latter must be twice as long as the bore of the work, as the work is on one side of the head at the beginning, and on the other at the end of a cut; hence it follows that the sliding or feeding head is preferable, being the shortest, and therefore the most rigid, unless the bar slides through bearings at each end of the head.

Fig. 1131 represents a bar with a fixed head in operation in a cylinder, and having three cutting tools, and it will be observed that if tool A meets a low spot and loses its cut, the pressure on tools B and C, both being on the opposite side of the head, would cause the bar to spring over towards A, producing a hole or bore out of round, and it follows that four tools are preferable.

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* From "The Complete Practical Machinist."

Fig. 1132 is a side view of a bar with four cutters, and Fig. 1133 an end view of the same shown within a cylinder, and it will be seen that should one of the cutters lose its cut, the two at right angles to it will steady the bar.

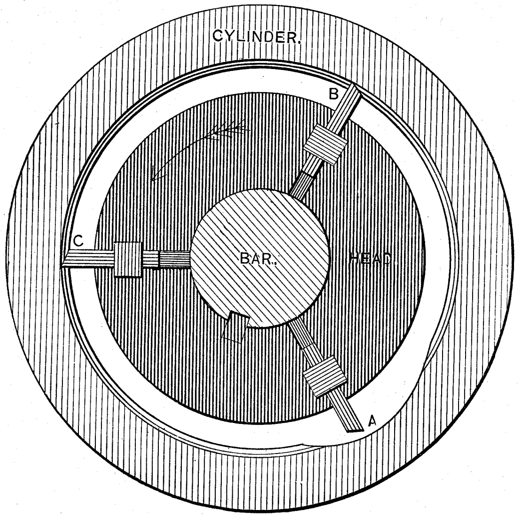

Fig. 1131.

When the cutters require to stand far out from the head, the bar will work more steadily if the cutters, instead of standing radially in the head, are placed as in Fig. 1134, so that they will be pulled rather than pushed to their cut.

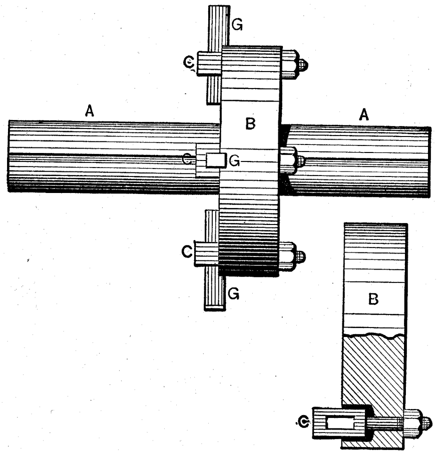

Fig. 1132.

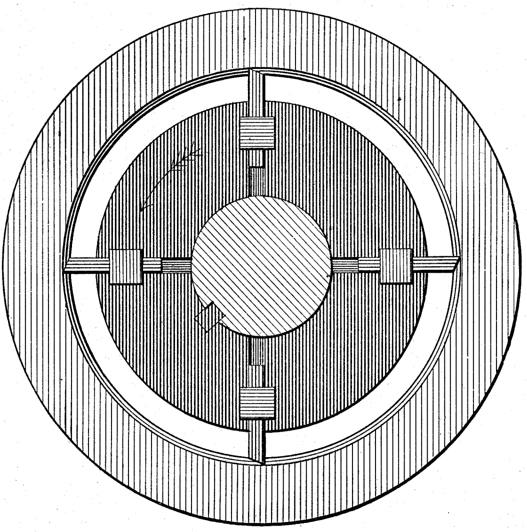

Fig. 1133.

An excellent form of boring bar fixed head, employed by Messrs. Wm. Sellers and Co. on their horizontal cylinder boring machine, is shown in Fig. 1135. The boring head is split at A, so that by means of the bolt B it may be gripped firmly to the bar D, or readily loosened and slid along it. The head is provided with cutters C (of which there are four in the latest design of bar), fitting into the radial slots E. These cutters are secured to the head by the clamps and nuts at G.

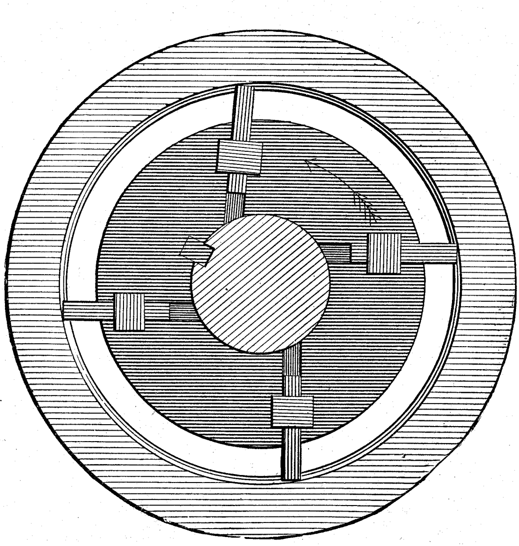

Fig. 1134.

Fig. 1136 represents a boring bar, with a sliding head fed by a feed screw running along the bar, and having at its end a pinion that meshes upon a gear or pinion upon the dead centre of the lathe.

The tools employed for the roughing cuts of boring bars should, for wrought iron, cast iron, steel, or copper, have a little front rake, the cutting corner being at A in Fig. 1137.

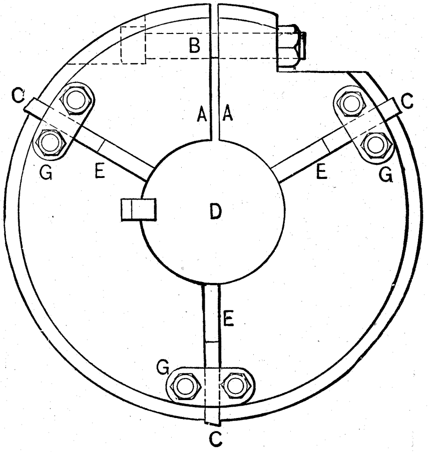

Fig. 1135.

If the cutters are to be used for one diameter of bore only, they will work more steadily if but little or no clearance is given them on the end B, Fig. 1138, but it is obvious that if they are to be used on different diameters of bores they must have clearance on these ends. The same tool may be used both for roughing and finishing cuts.

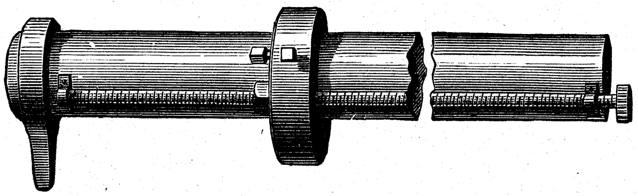

Fig. 1136.

The lip or top rake must, in case the bar should tremble during the finishing cut, be ground off, leaving the face level; and if, from the bar being too slight for its duty, it should still either chatter or jar, it will pay best to reduce the revolutions per minute of the bar, keeping the feed as coarse as possible, which will give the best results in a given time. In cases where, from the excessive length and smallness of the bar, it is difficult to prevent it from springing, the cutters must be made as in Fig. 1139, having no lip, and but a small amount of cutting surface; and the corner A should be bevelled off as shown. Under these conditions, the tool is the least likely to chatter or spring into the cut.

The shape of the cutting corner of a cutter depends entirely upon the position of its clearance or rake. If the edge forming the diameter has no clearance upon it, the cutting being performed by the end edges, the cutter may be left with a square, slightly rounded, or bevelled corner; but if the cutter have clearance on its outside or diametrical edge, as shown on the cutters in Fig. 1137, the cutting corner should be bevelled or rounded off, otherwise it will jar in taking a roughing cut, and chatter in taking a moderate cut. The principle is that bevelling off the front edge of the cutter, as shown in Fig. 1139, tends greatly to counteract a disposition to either jarring or chattering, especially as applied to brass work.

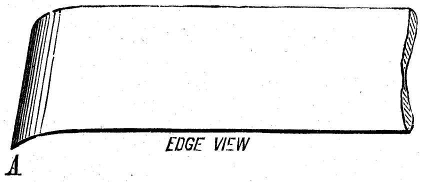

Fig. 1137.

The only other precaution which can be taken to prevent, in exceptional cases, the spring of a boring bar is to provide a bearing at each end of the work, as, for instance, by bolting to the end of the work four iron plates, the ends being hollowed to fit the bar, and being so adjusted as to barely touch it; so that, while the bar will not be sprung by the plates, yet, if it tends to spring out of true, it will be prevented from doing so by contact with the hollow ends of the plates, which latter should have a wide bearing, and be kept well lubricated.

It sometimes happens that, from play in the journals of the machine, or from other causes, a boring bar will jar or chatter at the commencement of a bore, and will gradually cease to do so as the cut proceeds and the cutter gets a broader bearing upon the work. Especially is this liable to occur in using cutters having no clearance on the diametrical edge; because, so soon as such a cutter has entered the bore for a short distance, the diametrical edge (fitting closely to the bore) acts as a guide to steady the cutter. If, however, the cutter has such clearance, the only perceptible reason is that the chattering ceases as soon as the cutting edge of the tool or cutter has lost its fibrous edges. The natural remedy for this would appear to be to apply the oil-stone; this, however, will either have no effect or make matters worse. It is, indeed, a far better plan to take the tool (after grinding) and rub the cutting edge into a piece of soft wood, and to apply oil to the tool during its first two or three cutting revolutions. The application of oil will often remedy a slight existing chattering of a boring bar, but it is an expedient to be avoided, if possible, since the diameter or bore cut with oil will vary from that cut dry, the latter being a trifle the larger.

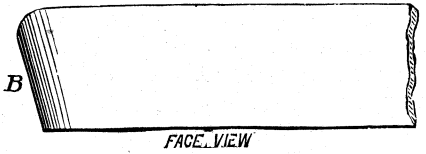

Fig. 1138.

The considerations, therefore, which determine the shape of a cutter to be employed are as follows: Cutters for use on a certain and unvarying size of bore should have no clearance on the diametrical edges, the cutting being performed by the end edge only. Cutters intended to be adjusted to suit bores of varying diameter should have clearance on the end and on the diametrical edges. For use on brass work the cutting corner should be rounded off, and there should be no lip given to the cutting edge. For wrought iron the cutter should be lipped, and oil or soapy water should be supplied to it during the operation. A slight lip should be given to cutters for use on cast iron, unless, from slightness in the bar or other cause, there is a tendency to jarring, in which case no lip or front rake should be given.

"In boring work chucked and revolved in the lathe, such, for instance, as axle boxes for locomotives, the bar shown in Fig. 1140 is an excellent tool. A represents a cutter head, which slides along, at a close working fit, upon the bar D D, and is provided with the cutters B, B, B, which are fastened into slots provided in the head A by the keys shown. The bar D D has a thread cut upon part of its length, the remainder being plain, to fit the sliding head. One end is squared to receive a wrench, which resting against the bed of the lathe, prevents the bar from revolving upon the lathe centres F, F, by which the bar is held in the lathe. G, G, G are plain washers, provided to make up the distance between the thread and plain part of the bar in cases where the sliding head A requires considerable lateral movement, there being more or less washers employed according to the distance along which the sliding head is required to move. The edges of these washers are chamfered off to prevent them from burring easily. To feed the cutters, the nut H is screwed up with a wrench.

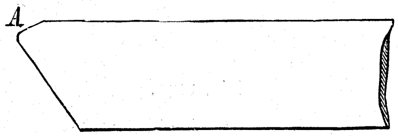

Fig. 1139.

"The cutter head A is provided in its bore with two feathers, which slide in grooves provided in the bar D D, thus preventing the head from revolving upon the bar. It is obvious that this bar will, in consequence of its rigidity, take out a much heavier cut than would be possible with any boring tool, and furthermore that, there being four cutters, they can be fed up four times as fast as would be possible with a single tool or cutter. Care must, however, be exercised to so set the cutters that they will all project true radially, so that the depth of cut taken by each will be equal, or practically so; otherwise the feeding cannot progress any faster than if one cutter only were employed." *

For use on bores of a standard size, the cutters may be made with a projecting feather, fitting into a groove provided in the head to receive it, as shown in Fig. 1141, which shows the boring bar and head, the nuts and washers being removed. A, A represent cutters, B the bar, C the sliding head, and D, D keys which fasten the cutters in the head. The cutters should be fitted to their places, and each marked to its place; so that, if the keyways should vary a little in their radius from their centre of the bar, they will nevertheless be true when in use, if always placed in the slot in which they were turned up when made. By fitting in several sets of cutters and turning them up to standard sizes, correctness in the size of bore may be at all times insured, and the feeding may be performed very fast indeed.

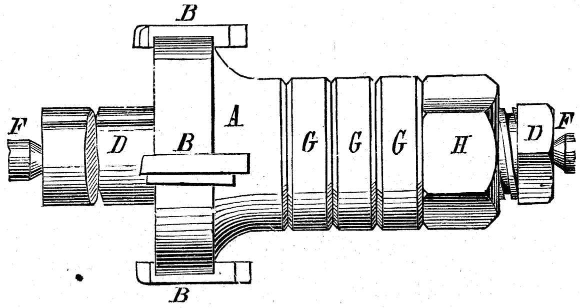

Fig. 1140.

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* From Rose's "Complete Practical Machinist."

For boring cannon the form of bar shown in Fig. 1142 is employed. The cannon is attached to the carriage or saddle of the lathe and fed to the boring bar. The working end only of the bar is shown in the figure, the shank stem or body of the bar being reduced in diameter to afford easy access to the cuttings. The cutters occupy the positions indicated by the letters A,A,A, being carefully adjusted as to distance from the axis of the bar by packing them at the back with very thin paper. As may be observed they are arranged in two sets of three each, of which the first set performs almost the whole of the work, the second being chiefly added as a safeguard against error in the size of the bore on account of wear of the cutting edges, which takes place to a small but an appreciable extent in the course of even a single boring. Following the cutters is a series of six guide-bars (B B B), arranged spirally, which are made exactly to fit the bore. Provided that the length of these is sufficient, and their fit perfect, it is evident that the cutters cannot advance except in a straight line. The spiral arrangement of the cutters is employed to steady the bar and to give it front rake.

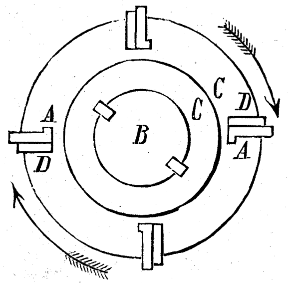

Fig. 1141.

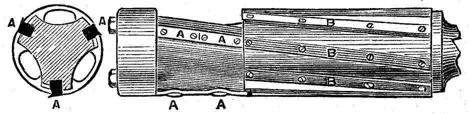

Fig. 1142.

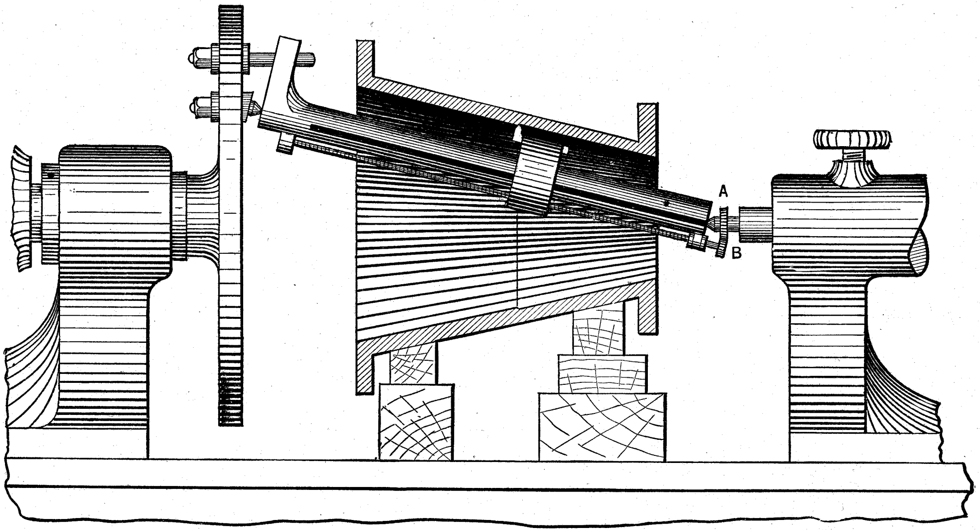

Fig. 1143.

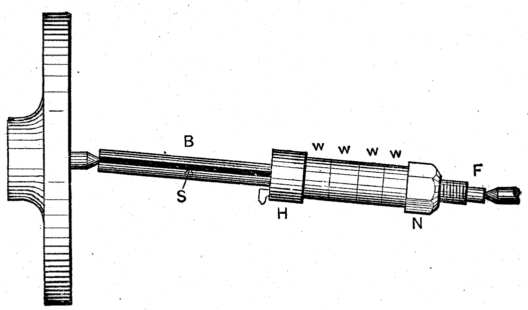

Fig. 1144.

Boring Tapers with a Boring Bar or Attachment.—In cases where the degree of taper is very great a live centre may be bolted to a chuck plate, as in Fig. 1143, by which means any degree of taper may be bored. Instead of a star feed, a gear feed may be provided by fastening one gear, as A, on the dead centre, and another, as B, on the feed-screw. The cutting tool must stand on the side of the sliding-head—that is, farthest from the line of lathe centres.

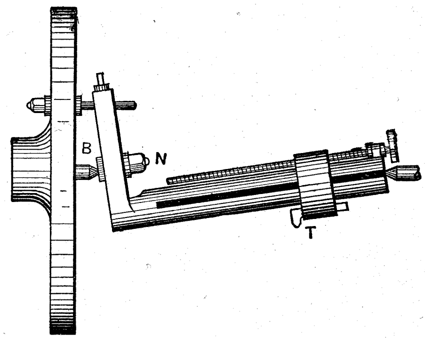

Fig. 1145.

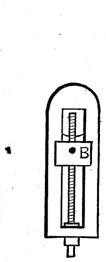

Fig. 1146.

Small holes may readily be bored taper with a bar set over as in Fig. 1144, the work being carried by a chuck. The head H carries the cutting tool, having a feather which projects into the spline S to prevent the head from rotating on the bar. To prevent the bar from rotating, it is squared on the end F to receive a wrench. The head is fed by the nut N, which is screwed upon the bar. W, W, W, W, are merely washers used to bring the nut N at the end of the thread when the head is near the mouth of the work, their number, therefore, depending upon the depth of the work. A bar of this kind is more rigid than a tool held in the tool post.

Instead of setting the dead centre of the lathe over, the bar may be set over, as in Fig. 1145, in which the boring tool is carried in the sliding head at T, and is fed by a screw having a star feed on its end. At B is a block sliding in the end of the bar and capable of movement along the same, to adjust the degree of taper by means of the screw shown in the end view, Fig. 1146. N is a nut to secure B in its adjusted position.

In this case the work must be bolted to the lathe carriage, and the tool feeds to the cut, and the largest end of the hole bored will be at the live spindle end of the lathe.

But we may turn the bar around, as in Fig. 1147, driving the work in a chuck, and holding the dead centre end of the bar stationary, feeding the sliding head to the cut by the feed screw F.

To increase the steadiness of the sliding head it may with advantage, be made long, as in Fig. 1148, in which S is a long sleeve fitting to the bar B at the head end H, and recessed as denoted by the dotted lines. The short cutting tool C may be fastened to H by a set-screw in the end of H, or by a wedge, as may be most desirable. The bar may obviously set over to bore tapers as in the cut, and the sliding head may be prevented from turning by a driver resting on the top of the tool rest, and pushed by a tool secured to the tool post, the self-acting carriage feed being put in operation.

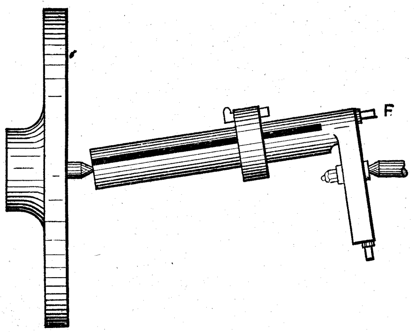

Fig. 1147.

It is obvious that when a boring bar is set over to bore a taper, the lathe centres do not bed fair in the work centres, hence the latter are subject to excessive wear and liable to wear to one side more than to another, thus throwing the bar out of true and altering the taper it will bore. This, however, may be prevented by fitting to the bar at each end a ball-and-socket centre, such as shown in section in Fig. 1149. A spherical recess is cut in the bar, a spherical piece is fitted to this recess and secured therein by a cap as shown, the device having been designed by Mr. George B. Foote.

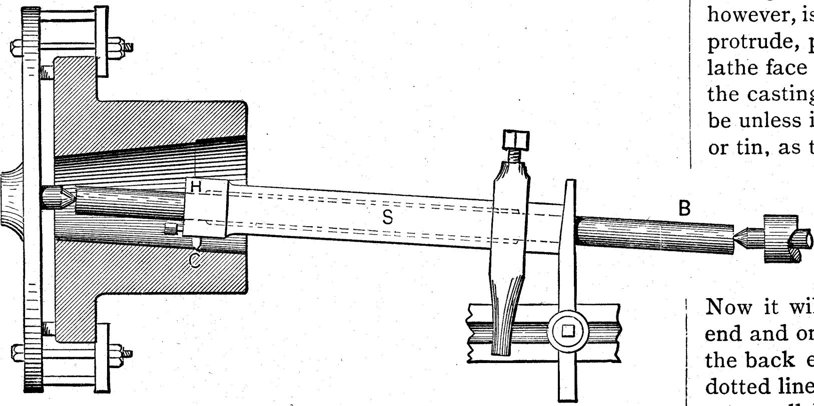

Fig. 1148.

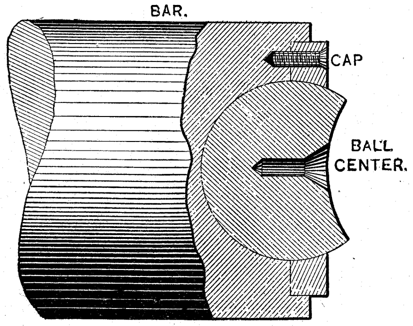

Fig. 1149.

Boring Double Tapers.—To prevent end play in journal bearings where it is essential to do so, the form of journal shown in Fig. 1150 is sometimes employed, hence the journal bearing requires to be bored to fit.

Fig. 1151 represents a bearing box for such a journal, the brasses A, B having flanges fitting outside the box as shown. The ordinary method of doing such a job would be to chuck the box on the face plate of the lathe, setting it true by the circle (marked for the purpose of setting) upon the face of the brasses, and by placing a scribing point tool in the lathe tool post and revolving the box, making the circle run true to the point, which would set the box one way, and then setting the flanges of the box parallel with the face plate of the lathe to set the box true the other way; to then bore the box half way through from one side and then turn it round upon the face plate, reset it and bore the other half; thus the taper of the slide rest would not require altering. This plan, however, is a tedious and troublesome one, because, as the flanges protrude, parallel pieces have to be placed between them and the lathe face plate to keep them from touching; and as the face of the casting may not be parallel with the slide ways, and will not be unless it has been planed parallel, pieces of packing, of paper or tin, as the case may be, must be placed to true the ways with the face plate, and the setting becomes tedious and difficult. But the two tapers may be bored at one chucking, as shown in Fig. 1152, in which A represents the lathe chuck, and B is a sectional view of the bearing chucked thereon, C, C being the parallel pieces. Now it will be observed that the plane of the cone on the front end and on one side stands parallel with the plane of the cone on the back end at an exactly opposite diameter, as shown by the dotted lines D and E. If then the top slide of the lathe rest be set parallel with those lines, we may bore the front end by feeding the tool from the front of the bore to the middle as marked from F to G, and then, by turning the turning tool upside down, we may traverse or feed it along the line from H to J, and bore out the back half of the double cone without either shifting the set of the lathe rest or chucking the box after it is once set.

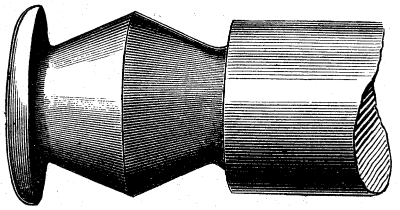

Fig. 1150.

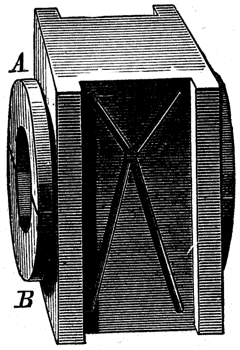

Fig. 1151.

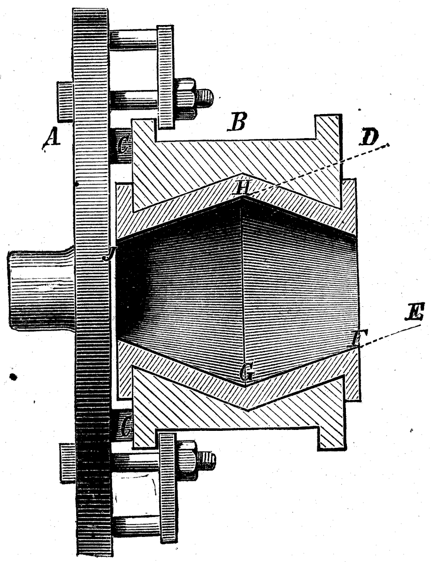

Fig. 1152.

In considering the most desirable speed and feed for the cutting tools of lathes, it may be remarked that the speeds for boring tools are always less than those for tools used on external diameters, and that when the tool rotates and the work is stationary, the cutting speed is a minimum, rarely exceeding 18 feet per minute, while the feed, especially upon cast iron, is a maximum.

The number of machines or lathes attended by one man may render it desirable to use a less cutting speed and feed then is attainable, so as to give the attendant time to attend to more than one, or a greater number of lathes. In the following remarks outside work and a man to one lathe is referred to.

The most desirable cutting speeds for lathe tools varies with the rigidity with which the tool is held, the rigidity of the work, the purpose of the cut, as whether to remove metal or to produce finish and parallelism, the hardness of the metal and stoutness of the tool, the kind of metal to be cut, and the length the tool may be required to carry the cut without being reground. The more rigid the tool and the work the coarser the feed may be, and the more true and smooth the work requires to be the finer the feed. In a roughing cut the object is to remove the surplus metal as quickly as possible, and prepare the work for the finishing cut, hence there is no objection to removing the tool to regrind it, providing time is saved. Suppose, for example, that at a given speed and feed the tool will carry a cut 12 inches along the work in 20 minutes, and that the tool would then require regrinding, which would occupy four minutes, then the duty obtained will be 12 inches turned in 24 minutes; suppose, however, that by reducing the speed of rotation, say, one-half, the tool would carry a cut 24 inches before requiring to be reground, then the rate of tool traverse remaining the same per lathe revolution, it would take twice as long (in actual cutting time) to turn a foot in length of the work. If we take the comparison upon two feet of work length, we shall have for the fast speed 24 inches turned in 40 minutes of actual cutting time, and 10 minutes for twice grinding the tool, or 24 inches in 50 minutes; for the slow speed of rotation we shall have 24 inches turned in 80 minutes.

In this case therefore, it would pay to run the lathe so fast that the tool would require to be ground after every foot of traverse. But in the case of the finishing cut, it is essential that the tool carry the cut its full length without regrinding, because of the difficulty of resetting the tool to cut to the exact diameter. It does not follow from this that finishing cuts in all cases require to be taken at a slower rate of cutting speed, because, as a rule, the opposite is the case, because of the lightness of the cut; but in cases where the work is long, the rate of cutting speed for the finishing cut should be sufficiently slow to enable the tool to take a cut the whole work length without grinding, if this can be done without an undue loss of time, which is a matter in which the workman must exercise his judgment, according to the circumstances. In tools designed for special purposes, and especially upon cast iron the work being rigid the tool may be carried so rigidly that very coarse feeds may be used to great advantage, because the time that the cutting edge is under cutting duty is diminished, and the cutting speed may be reduced and still obtain a maximum of duty; but the surfaces produced are not, strictly speaking, smooth ones, although they may be made to correct diameter measured at the tops of the tool marks, or as far as that goes at the bottom of the tool marks also, if it be practicable.

In the following table of cutting feeds and speeds, it is assumed that the metals are of the ordinary degree of hardness, that the conditions are such that neither the tool nor the work is unduly subject to spring or deflection, and that the tool is required to carry a cut of at least 12 inches without being reground; but it may be observed that the 12 inches is considered continuous, because on account of the tool having time to cool, it would carry more than the equivalent in shorter cuts, thus if the work was 2 inches long and the tool had time to cool while one piece of work was taken out and another put in the lathe, it would probably turn up a dozen such pieces without suffering more in sharpness than it would in carrying a continuous cut of 12 inches long. The rates of feed here given are for work held between the lathe centres in the usual manner.

CUTTING SPEEDS AND FEEDS.

For Wrought Iron.

Work diameter. Inches.	~~Roughing cuts.~~ Feet per minute.	Roughing cuts. Lathe revolutions per minute.	Roug cuts ~~Feed or~~ lathe revolutions per inch of tool travel.	Finishing cuts. Lathe revolutions per minute.	Finishing cuts. Lathe revolutions per inch tool travel.
½	40	305	30	305	60
1	35	133	30	133	60
1½	30	76	30	76	60
2	28	53	25	53	60
2½	28	42	25	42	50
3	28	35	25	35	50
3½	26	28	25	30	50
4	26	24	20	26	50
5	25	18	20	21	50
6	25	15	20	16	50
Cast Iron.					
1	45	163	30	163	40
1½	45	135	25	135	30
2	40	76	25	76	25
2½	40	61	20	61	20
3	35	44	20	50	16
3½	35	38	18	43	16
4	35	33	18	38	16
4½	30	25	16	28	14
5	30	22	16	26	14
5½	30	20	14	24	12
6	30	19	14	22	12
Brass.					
½	120	910	25	910	40
¾	110	556	25	556	40
1	100	382	25	382	40
1¼	90	275	25	275	40
1½	80	203	25	203	40
1¾	80	174	25	174	40
2	75	143	25	143	40
2½	75	114	25	114	40
3	70	89	25	89	40
3½	70	76	25	76	40
4	70	66	25	66	40
4½	65	55	25	55	40
5	65	50	25	50	40
5½	65	45	25	45	40
6	65	41	25	41	40
Tool Steel.					
⅜	24	245	60	245	60
½	24	184	60	184	60
⅝	24	147	50	147	60
¾	24	122	40	122	60
⅞	20	87	30	87	60
1	20	76	30	76	60
1¼	20	61	25	61	50
1½	18	45	25	45	50
2	18	34	25	34	50
2½	18	27	25	27	50
3	18	22	25	22	40
3½	18	19	25	19	40
4	18	17	25	17	40
4½	18	15	25	15	40

These cutting speeds and feeds are not given as the very highest that can be attained under average conditions, but those that can be readily obtained, and that are to be found used by skilful workmen. It will be observed that the speeds are higher as the work is smaller, which is practicable not only on account of the less amount of work surface in a given length as the diameter decreases, but also because with an equal depth of cut the tool endures less strain in small work, because there is less power required to bend the cutting, as has been already explained.

When it is required to remove metal it is better to take it off at a single cut, even though this may render it necessary to reduce the cutting speed to enable the tool to stand an increase of feed better than excessive speed. Suppose, for example, that a pulley requires ¼ inch taken off its face, whose circumference is 5 feet and width 8 inches. Now the tool will carry across a cut reducing the diameter ⅛ inch, at a cutting speed of 40 feet per minute, or 10 lathe revolutions per minute; but if the speed be reduced to about 35 feet per minute, the tool would be able to stand the full depth of cut required, that is, ⅛ inch deep, reducing the diameter of the pulley $\frac{1}{4}$ inch. Now with the fast speed two cuts would be required, while with the slow one a single cut would serve; the difference is therefore two to one in favor of the deep cut, so far as depth of cut is concerned.

The loss of time due to the reduced rotative speed of work would of course be in proportion to that reduction, or in the ratio of 35 to 50. It is apparent then that the tool should, for roughing cuts, be set to take off all the surplus metal at one cut, whenever the lathe has power enough to drive the cut, and that the cutting speed should be as fast as the depth of cut will allow.

Concerning the rate of feed, it is advisable in all cases, both for roughing and finishing cuts, to let it be as coarse as the conditions will permit, the rates given in the table being in close approximation of those employed in the practice of expert lathe hands.

It is to be observed, however, that under equal conditions, so far as the lathe and the work is concerned, it is not unusual to find as much difference as 30 per cent. in the rate of cutting speed or lathe rotation, and on small work 50 per cent. in the rate of tool traverse employed by different workmen, and here it is that the difference is between an indifferent and a very expert workman.

An English authority (Mr. Wilson Hartnell), who made some observations (in different workshops and with different workmen) on this subject, stated that taking the square feet of work surface *tooled* over in a given time, he had often found as much as from 100 to 200 per cent. difference, and that he had found the rate of *tooling* small fly-wheels vary from 2 to 8 square feet per hour without any sufficient reason. The author has himself observed a difference of as much as 20 feet of work rotation per minute on work of 18 and less inches in diameter, and as much as 50 per cent. in the rate of tool traverse per lathe revolution.

It is only by keeping the speed rotation at the greatest consistent with the depth of cut, and by exercising a fine discretion in regulating the rotations of feed and cutting speed, that a maximum of duty can under any given conditions be obtained.

It has hitherto been assumed that the workman's attention is confined to running one lathe, but cases are found in practice where the lathes, having automatic feed and stop motions, one man can attend to several lathes, and in this case the feeds and speeds may be considerably reduced, so as to give the operator time to attend to a greater number of lathes. As an example, in the use of automatic lathes, several of which are run by one man, the following details of the practice in the Pratt and Whitney Company's tap and die department are given.

Lathe Number 1.—Lathe turning tool steel $\frac{5}{8}$ inch in diameter and $1\frac{1}{4}$ long, reducing the diameter of the work $\frac{1}{8}$ inch. Revolutions of work per minute 125. Feed one inch of tool travel to 200 lathe revolutions.

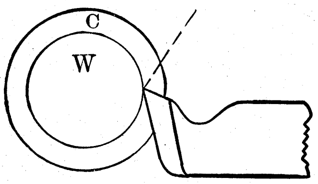

Fig. 1153.

Lathe Number 2.—Turning tool steel 2 inches long and $\frac{1}{2}$ inch diameter, reducing diameter $\frac{1}{8}$ inch. Revolutions of work 100 per minute. Feed 200 lathe revolutions per inch of tool travel.

Lathe Number 3.—Turning tool steel 4 inches long and $\frac{7}{8}$ inch in diameter, reducing the diameter $\frac{1}{8}$ inch. Revolutions of work 40 per minute. Feed 200 lathe revolutions per inch of tool travel.

Lathe Number 4.—Turning tool steel 6 to 8 inches long and $1\frac{3}{16}$ diameter, reducing work $\frac{1}{8}$ inch in diameter. Revolutions of work 35 per minute. Feed 200 lathe revolutions per inch of tool travel.

Lathe Number 5.—Turning tool steel 8 to 10 inches long, and 2 inches in diameter, reducing diameter $\frac{1}{8}$ inch. Lathe revolutions 30 per minute. Feed 200 lathe revolutions per inch of tool travel.

Lathe Number 6.—Turning tool steel 5 inches long and $3\frac{1}{2}$ inches diameter, reducing diameter $\frac{3}{16}$. Lathe revolutions 19 per minute. Feed 200 lathe revolutions per inch of tool travel.

The power required to drive the work under a given depth of cut varies greatly with the following elements :—

1st. The diameter of the work, all other conditions being equal.

2nd. The degree of hardness of the metal, all other conditions being equal.

3rd. Upon the shape of the cutting tool; and—

4th. Upon the quality of the steel composing the cutting tool, and the degree of its hardness.

That the diameter of the work is an important element in small work may be shown as follows :—

In Fig. 1153 let W represent a piece of work having a cut taken off it, and the line of detachment of the metal from the body of the work will be represented by the part of the dotted line passing through the depth of the cut (denoted by C). Let Fig. 1154 represent a similar tool with the same depth of cut on a piece of work of larger diameter, and it will be observed that the dotted line of severance is much longer, involving the expenditure of more power.

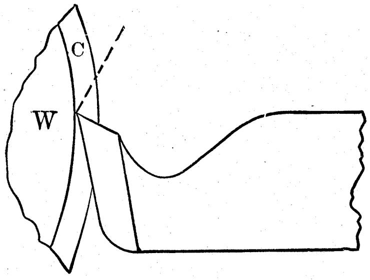

Fig. 1154.

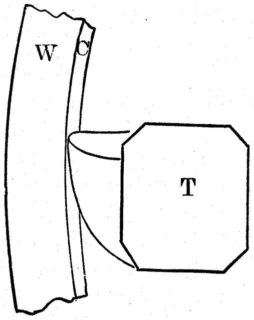

Fig. 1155.

In boring these effects are magnified: thus in Fig. 1155 let W represent a washer to be bored with the tool T, and let the same depth of cut be taken by the tool, the diameter of the work being simply increased. It is manifest that the cutting would require to be bent considerably more in the case of the small diameter of work than in that of the large, and would thus require more power for an equal depth of cut.

Again, from a reference to Figs. 950 and 952, it will be observed that the height of the tool will make a difference in the power required to drive a given depth of cut, the shaving being bent more when the tool is above the centre in the case of boring tools, and below the centre in the case of outside tools. But when the diameter of the work exceeds about 6 inches, it has little effect in the respects here enumerated.

The following, however, are the general rules applicable when considering the power required for the cutting of metal with lathe or planer tools. The harder the metal, the more power required to cut off a given weight of metal. The deeper the cut the less power required to cut off a given weight of metal. The quicker the feed the less power required to cut off a given weight of metal. The smaller the diameter of outside work, and the larger the diameter of inside or bored work, the less power required.

Copper requires less power than brass; yellow, and other brass containing zinc, less than brass containing a greater proportion of tin. Brass containing lead requires less power than that not containing it. Cast iron requires more power than brass, but less than wrought iron; steel requires more power than wrought iron.