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NUMBER 94

OPERATION OF MACHINE TOOLS

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SECOND EDITION

DRILLING MACHINES

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CHAPTER I

UPRIGHT DRILLING MACHINES

In the construction of practically all machinery, a great many holes have to be drilled owing to the extensive use of bolts and studs for holding the various parts together. The drilling machines or "drill presses," as they are often called, which are used for drilling these holes, are made in many different types which are designed for handling different classes of work to the best advantage, and the various

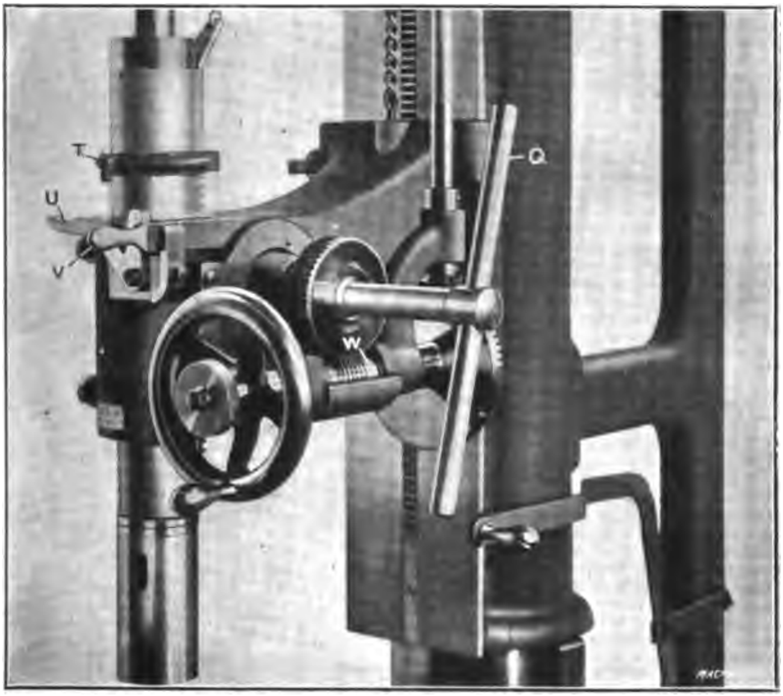

Fig. 1. Drill Spindle Feeding and Automatic Trip Mechanism

types are also built in a great variety of sizes, as the most efficient results can be obtained with a machine that is neither too small nor too large and unwieldly for the work which it performs.

An upright drill press of medium size is shown in Fig. 2. The drill itself is inserted in the end of spindle *S*, and when the machine is in use, this spindle is fed downward either by hand or power, thus causing the revolving drill to cut a hole into the work. The spindle is driven by a horizontal shaft *B* connecting with a cone pulley *P*, which is driven by belt from a lower cone pulley P_1. The shaft on which the lower cone pulley is mounted, is rotated by a belt from an overhead countershaft. The machine is started by shifting this driving belt

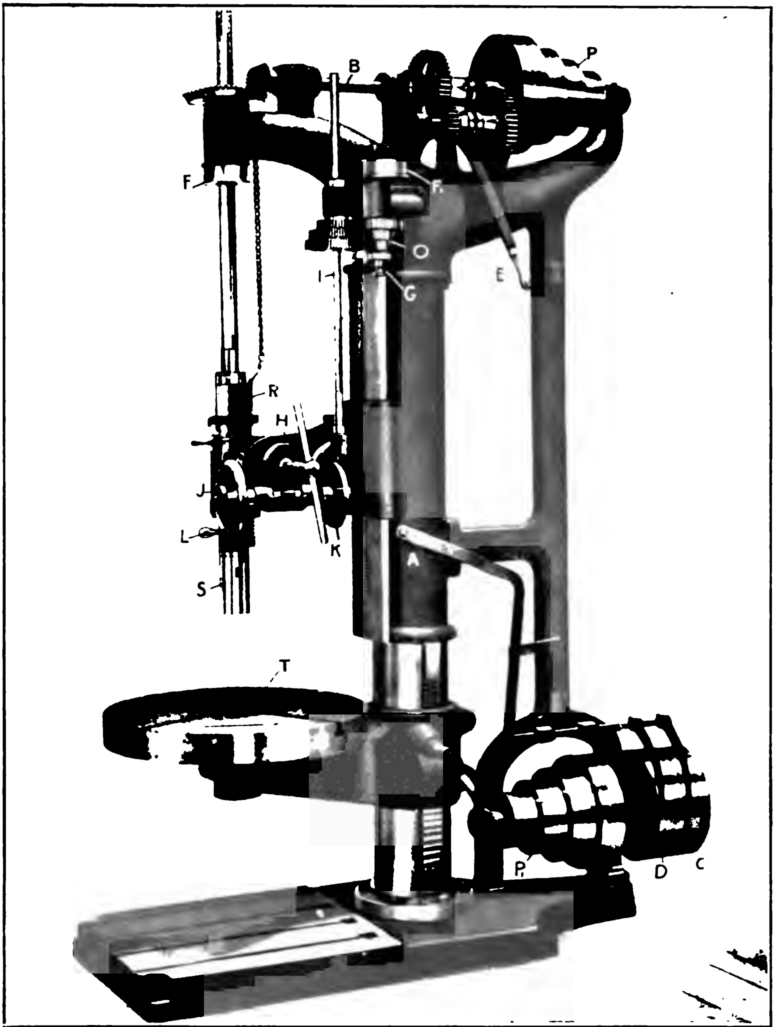

Fig. 2. Hamilton Upright Drilling Machine

from the loose pulley *C* to the "tight pulley" *D* which is keyed to the shaft, and the position of the belt is controlled by handle *A*. The speed of the spindle must be varied according to the diameter of the hole being drilled, the speed being increased as the diameter diminishes. To obtain these speed variations, the belt connecting pulleys *P* and P_1

is shifted to steps of different diameter. The range of speeds obtained in this way can be doubled, on this particular machine, by back-gears located just in front of the upper pulley. When these gears are not in use, shaft *B* is coupled direct to cone pulley *P* by means of a sliding clutch *N* (see the detail view Fig. 3), but when the back-gears are shifted into engagement by operating lever *E*, the clutch is disengaged and the cone pulley drives shaft *B* through train of gears *a*, *b*, *c* and *d*. The fastest speed obtained with the back-gears engaged, is slower than the slowest speed when driving direct, so that a gradually increasing range of eight speeds is available.

As the illustration shows, the connection between shaft *B* and the spindle is made by bevel gears. The spindle is free to move vertically

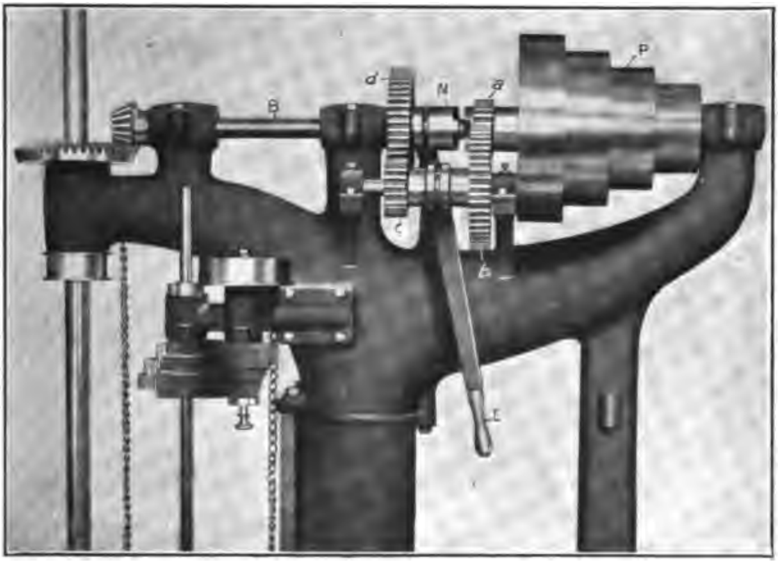

Fig. 3. Back-gearing and Feed Change-gears of Upright Drilling Machine

through the large bevel gear, and the lower end is steadied by the head *H*. (Fig. 2) which is clamped to the column and can be adjusted to different heights. The work-table *T* can also be adjusted vertically on the column to suit the height of the work, and it can be swung to one side when a large heavy part is to be supported directly on the base. After the work is clamped to the table, it can be adjusted for drilling at any point by swinging the table about the column and also by turning the table about its own center. When the table is properly adjusted, it can be clamped to the arm and the arm to the column by the bolts shown.

The power feed for the spindle is driven by a belt operating on pulleys *F* and F_1. Pulley F_1 is mounted on a shaft carrying a cone of gears *O* any one of which can be locked to the shaft by changing the position of "pull-pin" *G*. These gears are in mesh with corresponding gears on shaft *I*, which rotates, through bevel and worm-gearing, a pinion meshing with rack *R* attached to the quill in which the spindle revolves. As this pinion rotates, the quill and spindle are moved vertically and the amount of this movement for each revolution can be varied by shifting pull-pin *G*. For example, when a large gear in the cone *O* is locked and becomes the driving gear (by changing the position of the pull-pin), the feed or vertical movement of the spindle is more rapid than when the power is transmitted by one of the smaller gears. The driving gear is locked by a key attached to the pull-pin, and as this key can only engage one gear at a time, the others revolve idly on the shaft. The power feed is engaged or disengaged by tightening or loosening a knurled nut *J*, which controls a friction clutch that connects or disconnects bevel gear *K* with the worm-shaft. When the power feed is disengaged, the spindle can be moved up or down by turning handwheel *L*. On some drilling machines, the vertical feed shaft *I* is driven direct by a belt operating on cone pulleys and the feed changes are obtained by shifting this belt. The spindles of small drill presses usually have only the hand feed as the power feed is unnecessary when the holes to be drilled are small and not very deep; furthermore such holes can be drilled more rapidly when the spindle is fed by hand.

The machines equipped with power feed usually have some sort of trip mechanism which can be set to automatically disengage the feed when a hole has been drilled to the required depth. The automatic trip or stop on the machine illustrated in Fig. 2 is shown in detail in Fig. 1. This trip has an adjustable collar *T*, the position of which controls the depth of the hole drilled or the point at which the feed is disengaged. This disengagement is effected as follows: When collar *T* strikes the latch *U*, lever *V* is disengaged and worm *W* drops out of mesh with its wheel, thus stopping the feed. The spindle can then be raised quickly for drilling a new hole, by turning handle *Q* which is provided for that purpose. The automatic trip mechanism prevents drilling holes deeper than they should be, after it is properly set, and close attention on the part of the operator is not required.

These are the principal features of an upright drill press which, in many respects, is a typical design. Before referring to drilling machines of other types, some examples of drilling will be described.

CHAPTER II

DRILLING, REAMING, COUNTERBORING AND TAPPING

A simple example of drill-press work is shown in Fig. 5, which illustrates a steel link that is to have holes drilled in the ends. We shall assume that the location of these holes is indicated by circles previously drawn with dividers and dotted lightly to more clearly show their location. The centers of these circles should first be enlarged with a center-punch to form a starting point for the drill. When a part to be drilled is quite heavy and the holes are comparatively small, it is often unnecessary to clamp the work to the drill press table though, as a rule,

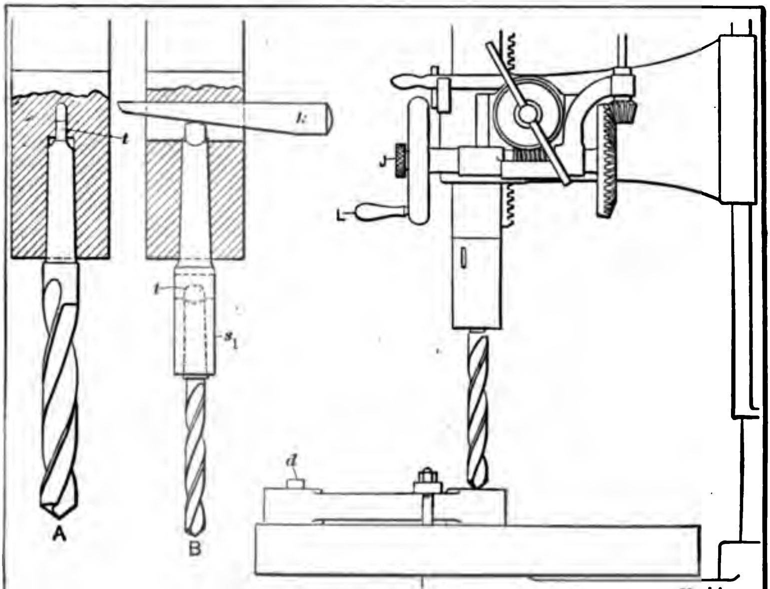

Fig. 4. Method of Holding and Driving Taper-shank Drills. Drilling-head of Upright Machine

it is better to use one or more clamps, depending on the shape and size of the work. A method of holding this particular part without using any special clamping appliances, is shown in Fig. 4. The end to be drilled is held by a clamp and a stop *d* is placed against one side of the work to prevent it from rotating with the drill.

The drill itself is inserted either directly in the spindle or in a socket, as will be explained later. The type of twist drill commonly used is shown at *A* in Fig. 6. It has two beveled cutting edges *e* at the end, formed by the two spiral grooves or flutes, and the part *s*. called the shank, is made to a standard taper. The size of the shank is the same on all drills up to a certain diameter, and then a larger shank is used for another range of sizes, and so on. In the Morse system of tapers, which is universally used for twist-drill shanks, the sizes are designated by numbers. For this particular operation, the drill would perhaps be large enough to permit inserting it directly in the spindle as shown at *A* in Fig. 4, though this would depend on the number or size of the taper hole in the spindle. On the other hand, if a comparatively small drill were to be used, it might be necessary to place a socket s_1 (see sketch *B*) in the spindle and insert the drill in the end of this socket. The drill is caused to rotate with the spindle or socket, principally by a flat end or tang *t* on the shank, which engages a cross-slot at the end of the taper hole, as shown. As the taper of the shank corresponds with the taper of the hole in the spindle or socket, the drill is also driven partly by friction.

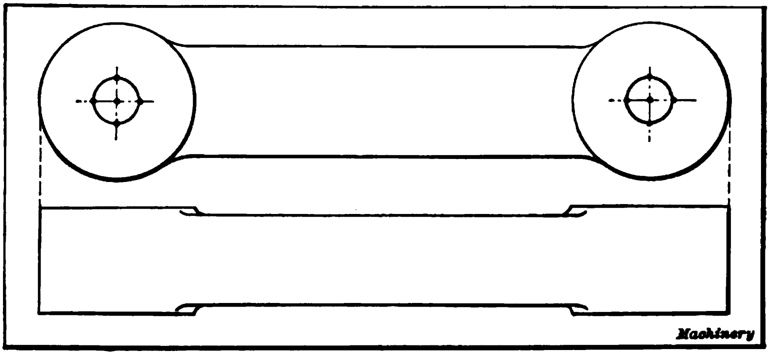

Fig. 5. Example of Drill-press Work

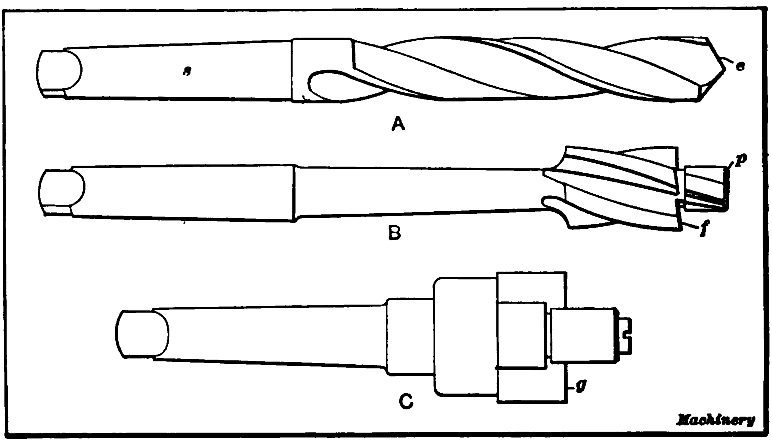

Fig. 6. (A) Twist Drill. (B) Solid Counterbore. (C) Counterbore with Inserted Blade

When the drill is in place, it is fed down by hand-wheel *L* for starting the hole. If the work is clamped in position, it is adjusted for drilling at the proper place, by turning the table about its own center and swinging the supporting arm about the column. When the drill begins to cut, the location of the hole with reference to the scribed circle should be noted. If the hole starts off center, as at *A*, Fig. 7, a groove should be cut down that side which is farthest from the circle (see sketch *B*) by using a gouge and hammer, the proper depth of this groove depending on the amount that the hole is off center. This operation is repeated, if necessary, so that the drill will be concentric with the circle (as at *C*) just before it begins to cut to the full diameter. The power feed is then engaged by tightening knob *J*. When the work rests directly on the table, as in this case, the end to be drilled should be set over a slot or hole, to prevent the drill from cutting the table when it comes through on the lower side. The table and arm should also be clamped after they are properly set. Drills or sockets are removed by a taper center-key or drift *k*, Fig. 4, which is

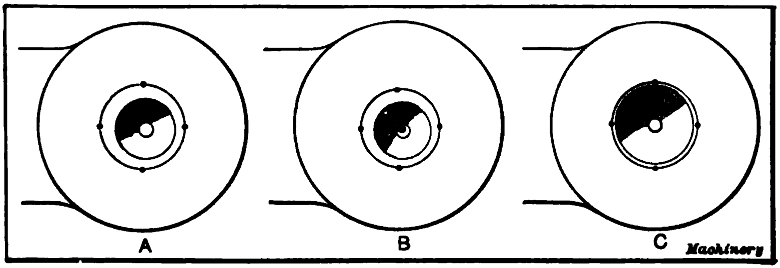

Fig. 7. Method of Starting Drill Concentric with Scribed Circle

driven in a cross-slot above the tang, as the illustration indicates. When drilling steel or wrought iron, the drill point should be kept lubricated. Sperm or lard oil may be used, and soda water, which is made by dissolving sal soda in water, is also extensively used for lubricating purposes. Cast iron and brass are drilled without a lubricant.

Finishing Holes by Reaming

Drilled holes are not always round or straight and the diameters vary to some extent, especially when the drill used is sharpened by hand, so that when accurate holes are required, the drilled hole is finished by reaming to secure smooth straight holes of uniform diameter. Holes for bolts that must fit accurately are often finished in this way, though on some classes of work, which does not need accurately fitting bolts, a drill slightly larger than the bolt body is used and the reaming operation is omitted.

Three different styles of reamers are shown in Fig. 8. The style of reamer shown at *A*, which is known as the fluted type, cuts along the edges *a*–*b* and it has a taper shank similar to a drill shank, which is inserted in the spindle. This reamer will produce a smooth accurate hole, but it is not adapted to removing much metal, and the diameter of the drilled hole should not be more than 0.010 or 0.015 inch under the finished size. The speed for reaming should be much slower than for drilling, and a fluted reamer should not be forced too hard, as both

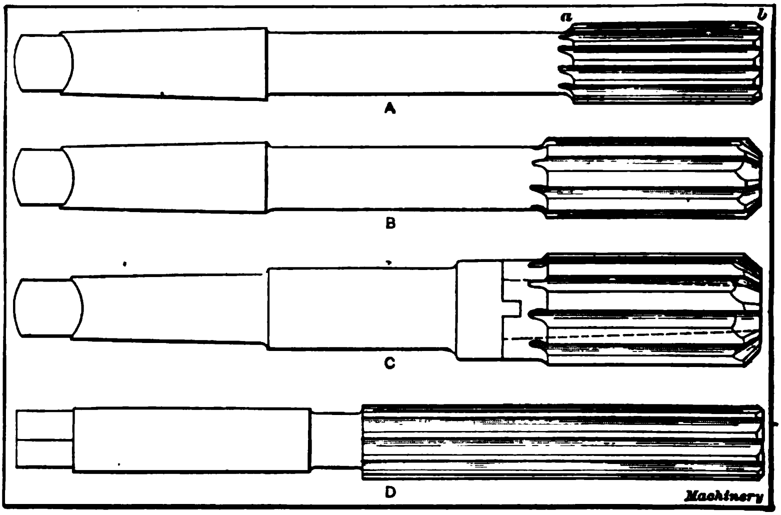

Fig. 8. Reamers of Different Styles

the tool and work may be injured. Another type of reamer is shown at *B*. This is called a rose reamer and it differs from the fluted type in that the cutting is all done by the beveled edges at the end. The fluted cylindrical body, back of the cutting edges, fits closely into the

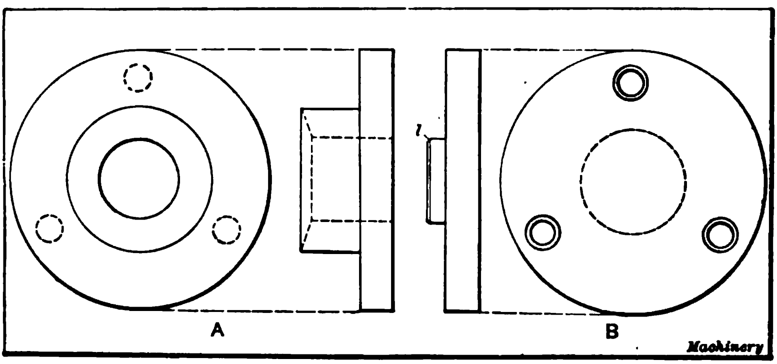

Fig. 9. (A) Packing Gland. (B) Drill Jig for Gland

reamed hole and guides the cutting end. This reamer will remove more metal than the fluted type and it is used for enlarging holes, as well as for truing drilled holes. When very accurate and smooth holes are necessary, the fluted reamer is ordinarily used, but for general purposes the rose reamer is preferable, especially for "machine reaming" when jigs are used. If a fluted reamer is guided by a hardened jig bushing, the cutting edges will be dulled more or less, depending on the alignment between the drilled hole and bushing and the resulting side thrust on the reamer. On the other hand, the rose reamer cannot be injured by the guide bushing as the cutting edges are on the end only. The shell type of rose reamer shown at *C* has an arbor on which the shell reamer is mounted. The advantage of this arrangement is that reamers of different sizes can be held on the same arbor.

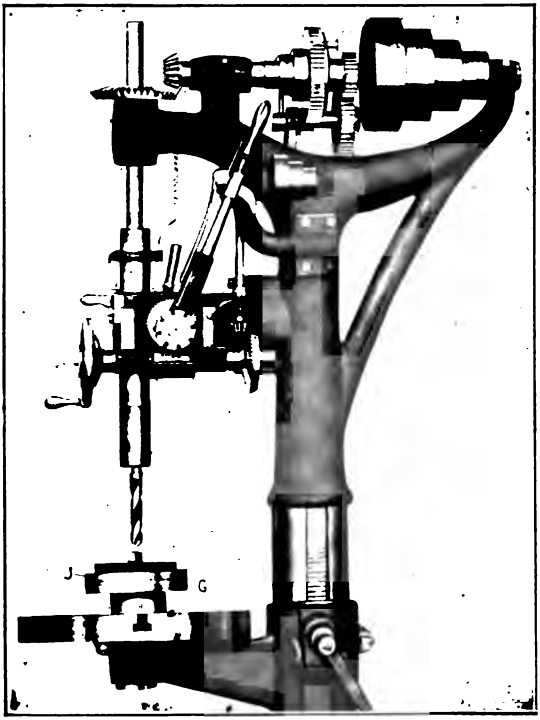

Fig. 10. Drill-press of the Wheel- and Lever-feed Type

When a very accurate hole is required, it is good practice to ream by hand. One method would be to first drill and rough ream the hole to within a few thousandths inch of the finished size, and then finish by using a hand reamer *D*. In order to keep the reamer in alignment with the hole, especially when starting, the upper end is sometimes supported by a conical center which is inserted in the spindle.

Drilling by the Use of Jigs

Another example of drill-press work is shown at *A*, Fig. 9, which illustrates an engine packing gland that is to have three holes drilled through the flange as indicated by the dotted lines. This work could be done by laying out the three holes and proceeding as described in the foregoing in connection with the link illustrated in Fig. 5, but if a large number of these glands were to be drilled, it would be much better to use a jig for properly locating the drill with reference to the work, without any preliminary laying out operation. A simple form of jig for drilling this flange is shown at *B*. This jig has three holes for guiding the drill, and one side is provided with a round projection *l* which fits closely the hole in the gland, in order to locate the jig in a central position. The method of using the jig is shown in Fig. 10. The gland *G* with the jig *J* placed on it, is clamped to the table (in this particular instance) by a single clamp and bolt in the center, and the holes are drilled by feeding the drill, successively, through the three holes in the jig. It will be seen that the use of a jig not only saves time, but also insures accurate and uniform work, for naturally if a number of these glands were drilled without a jig and by simply laying out the holes, more time would be required and there would also be some variation in the location of the holes. As the result of the uniformity obtained by the use of jigs, corresponding parts are drilled so near alike that they will interchange, which is a great aid in assembling a machine and also makes it possible to easily replace a broken member.

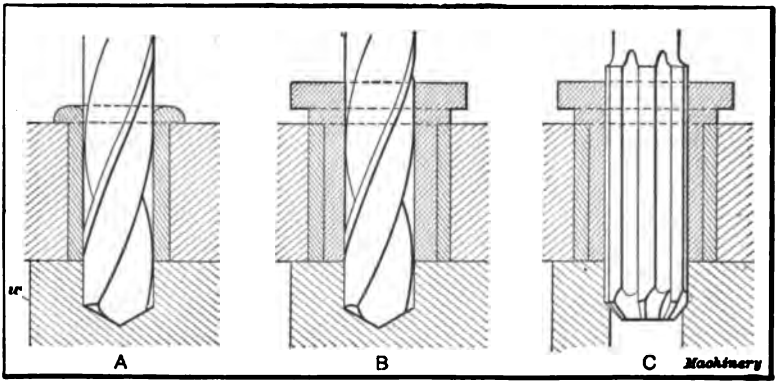

Fig. 11. Fixed and Removable Guide Bushings for Drill Jigs

The holes in jigs are ordinarily lined with hardened steel bushings to eliminate wear. These guide bushings fit the drill closely and keep it in the proper position. Some jigs have fixed guide bushings and others removable bushings. A fixed bushing is shown by the sectional view at *A*, Fig. 11, which also indicates how the drill is guided while it is drilling the work *w*. Jigs are equipped with removable bushings when drills of a different size are to be used, or when the drilled holes are to be finished by reaming. For example, if a hole is to be drilled and reamed, a removable bushing is used that fits the drill, as shown at *B*, and this is replaced by a bushing that fits the reamer, as shown at *C*. As previously intimated, a jig is only made when there are quite a number of parts to be drilled, as otherwise the saving effected by it would be more than offset by the expense of making it.

The ring-shaped jig shown at *A* in Fig. 12 is used for drilling the stud bolt holes in a cylinder flange and also for drilling the cylinder head, which is bolted to the cylinder. The position of the jig when the cylinder flange is being drilled, is shown at *B*. An annular projection on the jig fits closely in the cylinder counterbore, as the illustration shows, to locate the jig concentric with the bore. As the holes in the cylinder are to be tapped or threaded for studs, a "tap drill," which is smaller in diameter than the bolt body, is used and the drill is guided by a removable bushing *b* of the proper size. Jigs of this type are often held in position by inserting an acurately fitting plug through the jig and into the first hole drilled, which prevents the jig from turning with relation to the cylinder, when drilling the other holes. When the jig is used for drilling the head, the opposite side is placed next to the work as shown at *C*. This side has a circular recess or counterbore, which fits the projection on the head to properly locate the jig. As the holes in the head must be slightly larger in diameter than the studs, another size drill and a guide bushing of cor-

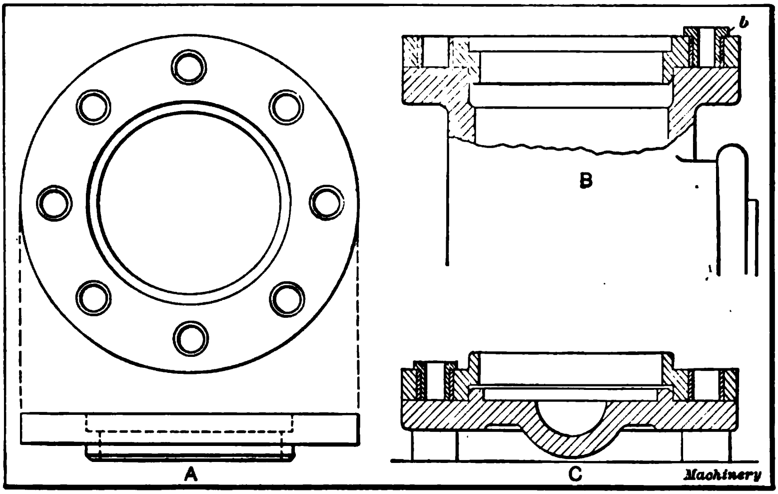

Fig. 12. Jig for Cylinder Flange and Head, and its Application

responding size is used. The cylinder is, of course, bored and the head turned before the drilling is done.

Jigs of the Box Type

As the use of drill jigs makes it possible to perform drilling operations quickly as well as accurately, jigs are used very extensively in all modern shops. Those shown in Figs. 9 and 12, represent a very simple type that is often used for drilling flanges, plates or similar parts. Jigs of this class, as well as those of other types, are made in a great variety of shapes, and, when in use, they are either applied to the work or the latter is placed in the jig. When the work is quite large, the jig is frequently placed on it, whereas small parts are more often held in the jig, which is so designed that the work can be clamped in the proper position. The form of any jig depends, to a great extent, on the shape of the work for which it is intended and also on the location of the holes to be drilled. As the number of differently shaped pieces which go to make up even a single machine, is often very great, and, as most parts require more or less drilling, jigs are made in an almost endless variety of sizes and forms. When all the holes to be drilled in a certain part are parallel, and especially if they are all in the same plane, a very simple form of jig can ordinarily be used; in fact, jigs for work of this class are often little more than flat plates having the necessary guide bushings and, perhaps, one or two clamps for holding the jig and work together. A great many parts, however, must be drilled on different sides and, frequently, the work is very irregular in shape, so that a jig which is made somewhat in the form of a box, and encloses the work, is very essential, as it enables the guide bushings to be placed on all sides and also makes it comparatively easy to locate and securely clamp the part in the proper position for drilling. This type of jig, which, because of its form, is known as a "box-jig," is used very extensively.

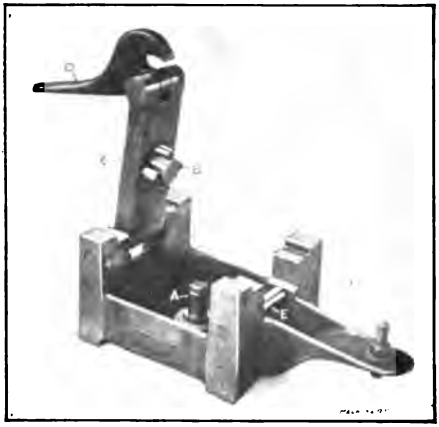

Fig. 13. Drill Jig of the Box Type

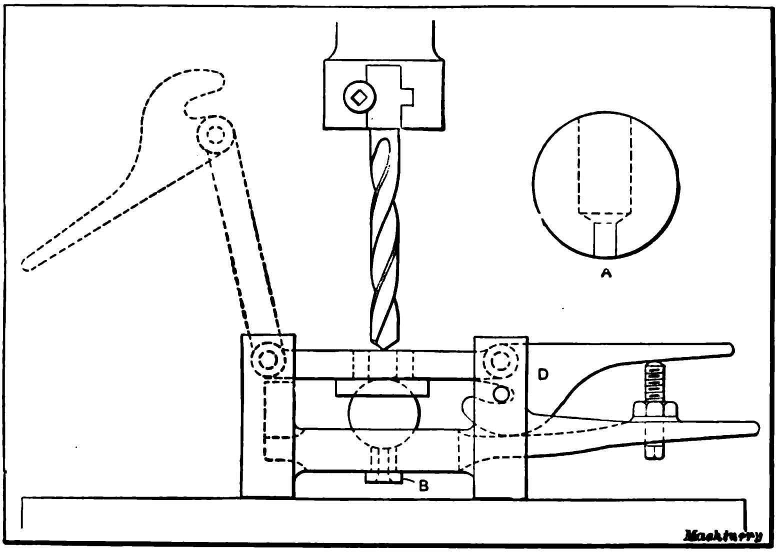

Fig. 14. Box Jig for Drilling Ball shown enlarged at A

A box jig of simple design is shown in Fig. 13. This particular jig is used for drilling four small holes in a part (not shown) which is located with reference to the guide bushings *B*, by a central pin *A* attached to the jig body. This pin enters a hole in the work, which is finished in another machine in connection with a previous operation. After the work is inserted in the jig, it is clamped by closing the cover *C*, which is hinged at one end and has a cam-shaped clamping latch *D* at the other, that engages a pin *E* in the jig body. The four holes are drilled by passing the drill through the guide bushings *B* in the cover.

Another jig of the same kind but designed for drilling a hole having two diameters, through the center of a steel ball, is shown in Fig. 14. The work, which is shown enlarged at *A*, is inserted while the cover

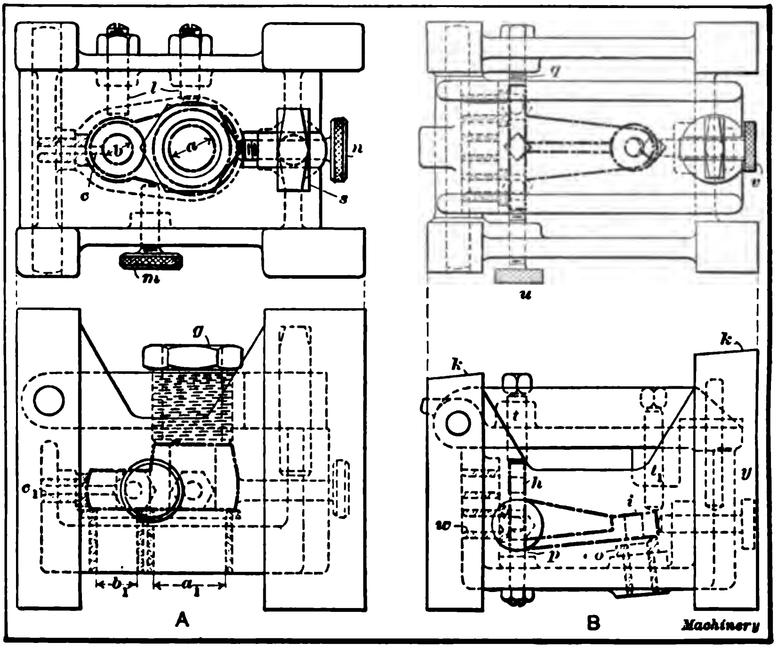

Fig. 15. Box Jigs for Drilling Parts shown by Heavy Dot-and-dash Lines

is thrown back as indicated by the dotted lines. The cover is then closed and tightened by the cam-latch *D*, and the large part of the hole is drilled with the jig in the position shown. The jig is then turned over and a smaller drill of the correct size is fed through guide bushing *B* on the opposite side. The depth of the large hole could be gaged for each ball drilled, by feeding the drill spindle down to a certain position as shown by graduation or other marks, but if the spindle has an adjustable stop, this should be used. The work is located in line with the two guide bushings by spherical seats formed in the jig body and in the upper bushing, as shown. As the work can be inserted and removed quickly, a large number of balls, which, practically speaking, are duplicates, can be drilled in a comparatively short time by using a jig of this type.

A box jig that differs somewhat in construction from the design just referred to, is illustrated at *A* in Fig. 15, which shows a side and top view. The work, in this case, is a small casting the form of which is indicated by the heavy dot-and-dash lines. This casting is drilled at *a*, *b* and *c*, and the two larger holes *a* and *b* are finished by reaming. The hinged cover of this jig is opened for inserting the work by unscrewing the T-shaped clamping screw *s* one-quarter of a turn, which brings the head in line with a slot in the cover. The casting is clamped by tightening this screw, which forces an adjustable screw bushing *G* down against the work. By having this bushing adjustable, it can be set to give the right pressure, and, if the height of the castings should vary, the position of the clamping bushing could easily be

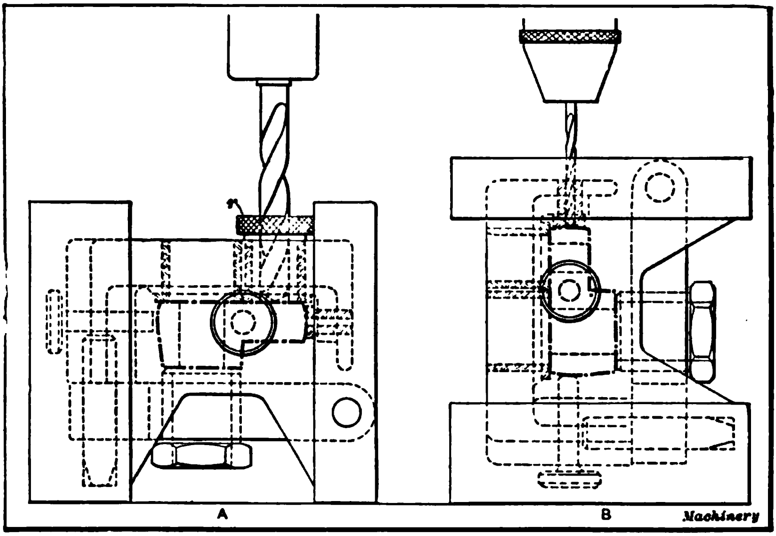

Fig. 16. Method of Using Jig

changed. The work is properly located by the inner ends of the three guide bushings a_1, b_1, and c_1, and also by the locating screws *l* against which the casting is held by knurled thumb-screws *m* and *n*. When the holes *a* and *b* are being drilled, the jig is placed with the cover side down as shown at *A* in Fig. 16, and the drill is guided by removable bushings, one of which is shown at *r*. When the drilling is completed, the drill bushings are replaced by reamer bushings and each hole is finished by reaming. The small hole *c* is drilled in the end of the casting by simply placing the jig on end as shown at *B*. Box jigs which have to be placed in more than one position for drilling the different holes, are usually provided with feet or extensions, as shown, which are accurately finished to properly align the guide bushings with the drill. These feet extend beyond any clamping screws, bolts, or bushings which may protrude from the sides of the jigs, and provide a solid support. When inserting work in a jig, care should be taken to remove all chips which might have fallen onto those surfaces against which the work is clamped and which determine its location.

Still another jig of the box type, which is quite similar to the one shown at *A*, Fig. 15, but is arranged differently owing to the shape of the work and location of the holes, is shown at *B* in the same illustration. The work has three holes in the base *h*, and a hole at *i* which is at an angle of 5 degrees with the base. The three holes are drilled with the jig standing on the opposite end *y*, and the angular hole is drilled while the jig rests on the four feet *k*, the ends of which are at such an angle with the jig body that the guide

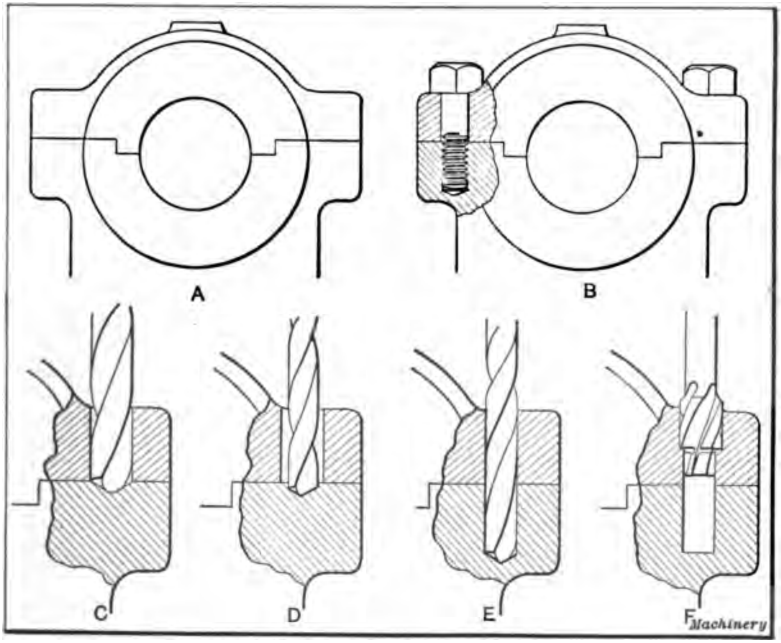

Fig. 17. Views indicating how Work can sometimes be used as a Jig

bushing for hole *i* is properly aligned with the drill. The casting is located in this jig by the inner ends of the two guide bushings *w* and the bushing *o* and also by two locating screws *p* and a side locating screw *q*. Adjustable screws *t* and t_1 in the cover, hold the casting down, and it is held laterally by the two knurled thumb-screws *u* and *v*. If an attempt were made to drill this particular part without a jig (as would be done if only a few castings were needed) it would have to be set with considerable care, provided the angle between hole *i* and those in the base had to be at all accurate, and it would be rather difficult to drill a number of these castings and have them all duplicates. By the use of a jig, however, designed for drilling this particular casting, the relative positions of the holes in any number of parts are practically the same and the work can be done much more quickly than would be possible if it were held to the drill-press table by ordinary clamping appliances.

These few jig designs have been referred to somewhat in detail to show, in a general way, how jigs are constructed and used. Those who would like to study other types of jigs and are interested in the principles of jig design, will find the subject fully covered in MACHINERY's Reference Books, Nos. 41 to 43, inclusive.

Using the Work as a Jig

When two separate parts must have holes drilled in line for bolts or studs, one part can often be used as a sort of jig. To illustrate, suppose a bearing cap and base (see sketch *A*, Fig. 17) are to be drilled for inserting bolts as shown in view *B* to the right. One

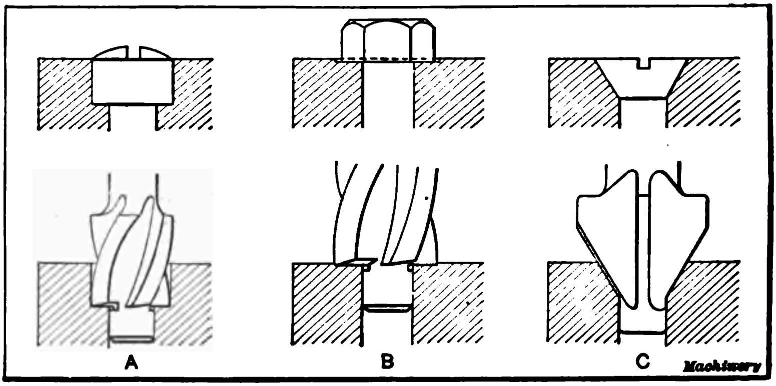

Fig. 18. Use of Counterbore and Countersink

method would be to first lay out and drill the bolt holes in the cap which we shall assume has been previously planed and fitted. The cap is then clamped in position and the same drill that was used for the bolt holes is fed down to cut a conical spot in the base as at *C*. This "spotting" operation forms a central starting point for the smaller "tap drill," which is then used as indicated at *D*. The drilling of holes which are to be tapped will be referred to later.

Another method of drilling this cap and base is shown at *E* and *F*. Both parts are clamped together and drilled with a tap drill as at *E*, after which the cap is removed and the holes are enlarged for the bolts by using a counterbore as indicated at *F*. This type of counterbore is shown in detail in Fig. 6. The cutting is done by the edges *f*, and the guide or pilot *p* fits closely into the hole which the counterbore is to follow, so that the enlarged part of the hole will be concentric. Another type of counterbore is shown at *C*. This style has a single blade or cutter, which cuts along the edges *g*. The blade can be removed by unscrewing the binding screw when it is desired to replace the blade with a different size. Guides and pilots of different diameters can also be attached to the end, as required.

Counterbores are also used frequently for enlarging holes to form seats for the heads of screws. A machine screw of the filister-head type, and a method of enlarging a hole which has been previously drilled for the body of the screw, is indicated at *A*, Fig. 18. The upper view shows the screw-head in position and the lower view the cutting end of a counterbore after it has been fed to the proper depth. Counterbores are often used for facing a spot around a hole, as indicated

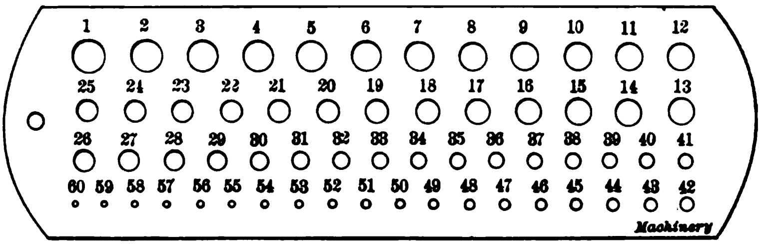

Fig. 19. Twist Drill and Steel Wire Gage

at *B*, to provide a true bearing surface for a bolt head. On some classes of work, screws having heads that are conical on the under side are used. Forming a conical seat for a head of this shape is known as countersinking. The operation is similar to counterboring except that a tool for forming a conical seat is used as indicated at *C*. The form of countersink shown is used after the hole for the screw-body has been drilled. Countersinks are also used which have a drill of

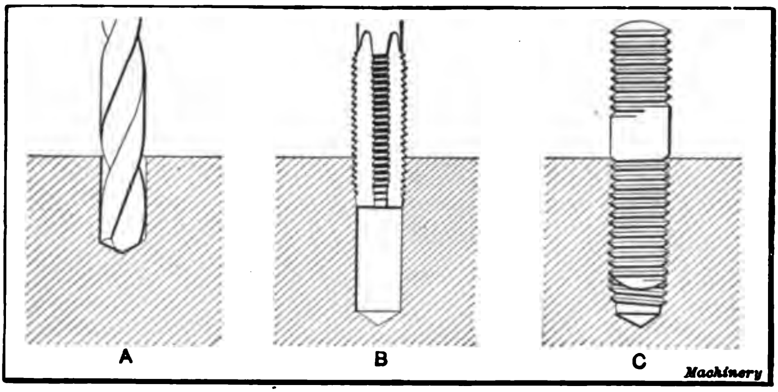

Fig. 20. (A) Tap Drill. (B) Tap for Threading Hole. (C) Stud inserted in Threaded Hole

the proper size at the end, instead of a pilot, so that the straight and conical parts of the hole are finished in one operation.

Drill Sizes

Regular taper shank drills may be obtained in a great variety of sizes. Many of the small drills used have straight shanks, and the sizes are designated by numbers or letters. A gage is shown in Fig. 19 for measuring drills with numbered sizes, the number of the drill being indicated by the number of the hole which it fits. The difference between the diameters of consecutive sizes represented by this gage only varies from 0.001 to 0.008 inch, so that almost any diameter between the smallest and largest size can be obtained. The decimal equivalents for each number are stamped on the back of the gage shown. Another common form of gage, known as the "jobbers' drill gage," has a series of holes which vary in diameter from 1/16 inch to 1/2 inch, the diameters increasing successively by sixty-fourths. The sizes of the different holes are expressed by common fractions which are stamped on the gage. The letter size drills are made in sets of twenty-six, or from

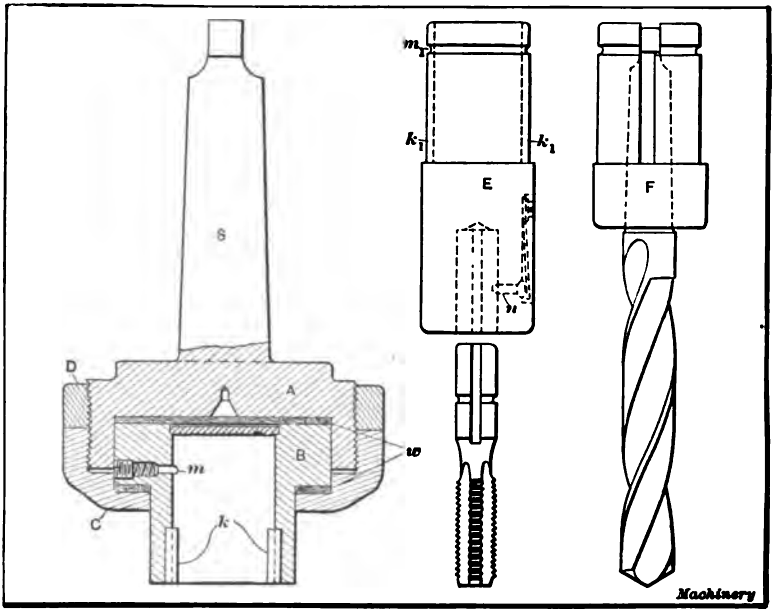

Fig. 21. Beaman & Smith Safety Drill- and Tap-holder

A to Z, and have a difference between consecutive sizes varying from 0.004 to 0.014 inch. Tables giving the corresponding sizes in decimals of an inch, for both lettered and numbered drills, are given in MACHINERY'S Reference Book, No. 35.

Drills having straight shanks are held, when in use, in chucks attached to the spindle. A common form of chuck is shown in Fig. 25. The drill is held between jaws in the chuck, which are tightened by turning the outer knurled sleeve by hand or with a spanner wrench.

Machine or Power Tapping

Holes which are drilled to receive studs or bolts are threaded by the use of taps. The hole is first drilled slightly larger than the "root diameter" of the thread, by using a "tap drill" as at *A*, Fig. 20. The hole is then threaded by screwing a tap into it, as indicated at *B*, after which a stud or bolt is inserted as at *C*. For example, if a hole were to be tapped for a ¾-inch stud having a U. S. standard thread, it would first be drilled to a diameter of ⅝ inch and a ¾-inch tap would then be used to cut the thread. The diameter of a tap drill—which is so called because it is followed by a tap—varies somewhat for U. S. standard and V-threads, and the proper size drill to use for any diameter of thread is usually determined by referring to a table. (Such tables are given in MACHINERY's Data Sheet Book, No. 2.) It is important to use a tap drill of the proper size, for if a hole is drilled too small, an excessive amount of power will be required for tapping and, on the other hand, a tap drill that is too large is equally objectionable as the threads will not have sufficient depth.

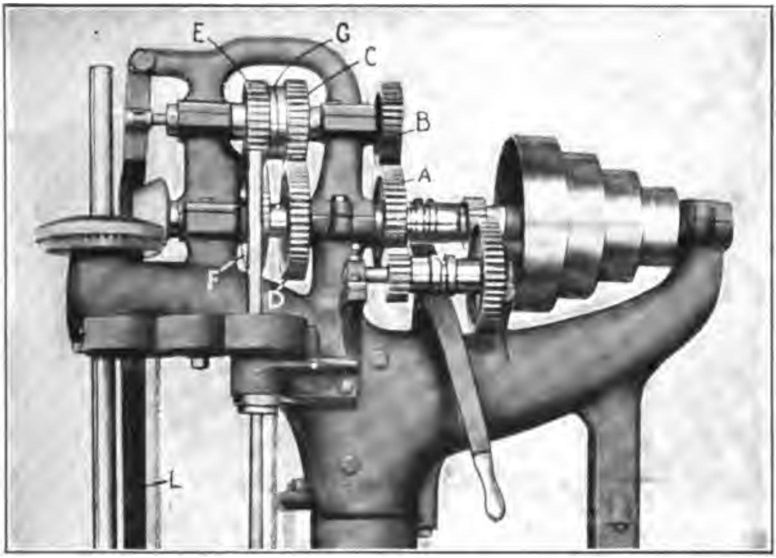

Fig. 22. Hamilton Tapping Attachment

When tapping a hole the tap can be turned with a hand wrench, but if tapping is done on an extensive scale, it is better to drive the tap by power. There are many appliances for machine or power tapping, which differ considerably in their construction, but most of them operate on practically the same principle. As most tapped holes do not extend clear through the work, but are "blind," provision should be made for allowing the tap to stop in case it should strike the bottom of the hole, as otherwise it might be broken. The tap's direction of rotation must also be reversed when it has been screwed down to the required depth, in order to back it out of the hole. One method of meeting the first requirement is to hold the tap in a friction chuck or holder, which will slip in case the tap strikes the bottom of the hole or meets with any other obstruction. A safety tap- and drill-holder which is extensively used, is shown in Fig. 21. This holder has a shank *S* which is inserted in the spindle of the drill press, and at the lower end of this shank there is an enlarged part *A*, which is recessed to receive the friction socket *B*. This socket is held in place by a cap *C*, which is screwed onto the enlarged part. Fiber washers *w* are placed on each side of the friction socket flange, and the cap *C* is tightened until the friction between parts *A* and *B* is sufficient to drive the tap. The check-nut *D* is then screwed against cap *C*, which locks the parts securely. The tap itself is held in a socket *E*, which is inserted in the friction socket *B*. This tap socket is driven by the dove-tailed keys *k*, which engage the keyways k_1, and it is kept from dropping out of the friction socket when there is no upward pressure, by a small spring-pin *m* which enters the groove m_1. The tap, which has a special shank, is also driven by side keys and it is retained by a spring-pin *n* which engages the annular groove shown. The tap is not held rigidly but is allowed a slight "floating" movement to secure better alignment with the hole and a more perfect thread. If a tap which is held in a holder of this type, strikes the bottom of the hole, the friction socket *B* will slip (provided the friction is properly adjusted) and the tap will stop turning while the shank *S* continues to revolve. In this way the breaking of taps is avoided. This form of holder is also used for drilling, the drill being held in a socket *F* having a standard taper hole for receiving the drill shank. These sockets are also inserted in the friction socket *B* and they are made in sets to receive drill shanks of different sizes. The power required to overcome the friction between the parts *A* and *B* and cause a slipping movement, should be less than that represented by the breaking strength of the drill or tap. On some drilling machines an adjustable friction is introduced in the spindle-driving mechanism to prevent the breaking of taps.

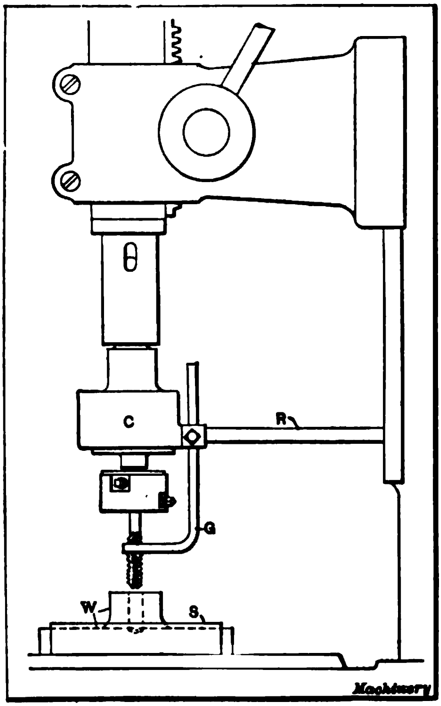

Fig. 28. Errington Automatic-reverse Tapping Chuck

The mechanism for reversing the spindle of a drill press, when the tap has reached the required depth, is known as a tapping attachment. One form of tapping attachment is illustrated in Fig. 22 which is a partial view of an upright drilling machine. When a hole is being tapped, power is transmitted to the spindle through gears *A*, *B*, *C* and *D*, until the tap has been fed to the required depth; the spindle rotation is then reversed by shifting lever *L* which, by means of a friction clutch at *G*, locks gear *E* with the upper shaft and releases gear *C*. The drive is then from gear *E* to *F* through an intermediate gear at the rear, which reverses the movement for backing the tap out of the hole. By placing lever *L* in a central or "neutral" position, the spindle can also be stopped, so that the machine is controlled by this single lever. Before beginning to tap, the feed-worm *W*, Fig. 1, is disengaged

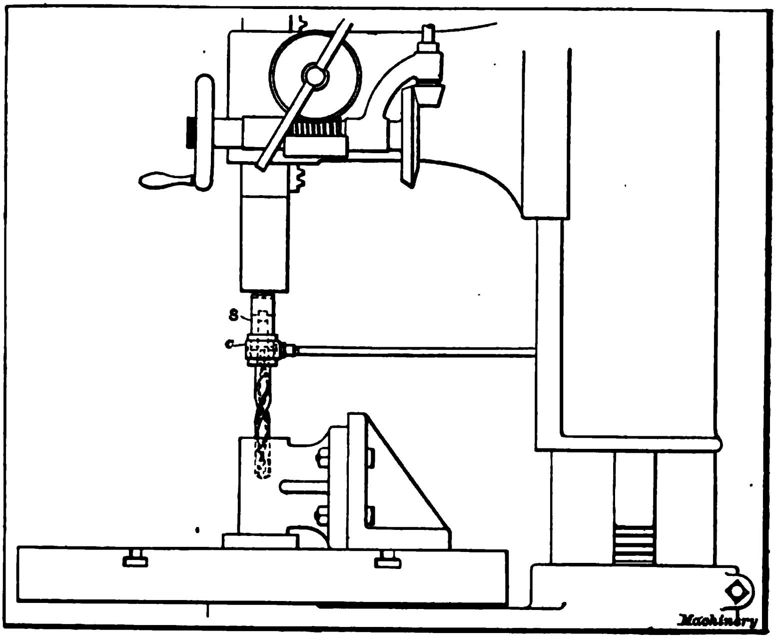

Fig. 24. Method of Applying Oil-tube Drill to Drill-press

and the tap is started in the hole by feeding it down with hand lever *Q*. As soon as a thread is started, the spindle, being free to move vertically, is fed down by the screwing action of the tap.

Errington Automatic-reverse Tapping Chuck

A tapping device is shown in Fig. 23, which is so arranged that the tap automatically stops when it strikes the bottom of the hole or when the adjustable depth gage *G* comes against the top of the work. The raising of the spindle then reverses the tap which backs out at an increased speed. This tapping chuck *C* is inserted in the spindle just like an ordinary drill chuck and as the tap is automatically reversed when the spindle is raised, no reversing gears or double belts are required to stop or change the rotation of the machine spindle. When this chuck is used in connection with light duplicate work which will center itself with the tap, very rapid production can be obtained by the following method: The work *W* to be tapped is prevented from rotating by passing it between two parallel pieces *S* clamped to the drill press table, just far enough apart to allow the work to be inserted easily. When a hole is being tapped, the spindle is raised and lowered

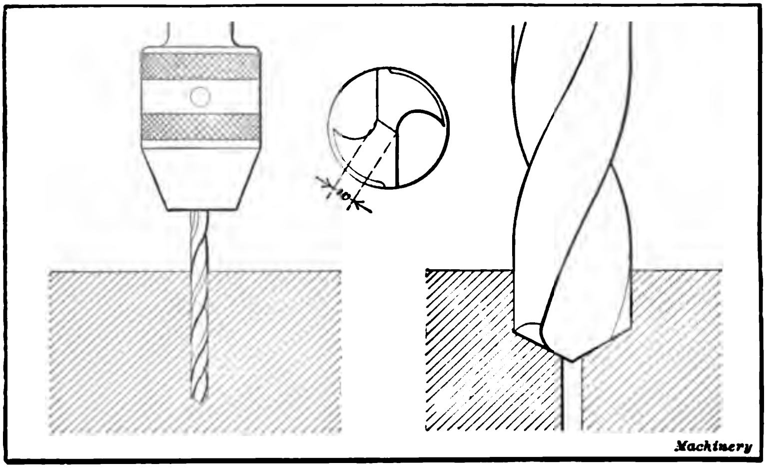

Fig. 25. Pressure for Feeding Large Drill can be reduced by Drilling Small "Lead Hole"

with the right hand while the work is inserted between the parallel pieces with the left hand, the operation being practically continuous. When this method is employed, the drilling is first completed and then the parts are re-handled for the tapping operation. Small round or irregularly shaped parts can often be held to advantage in a special holder which is passed between guides *S* attached to the table. This

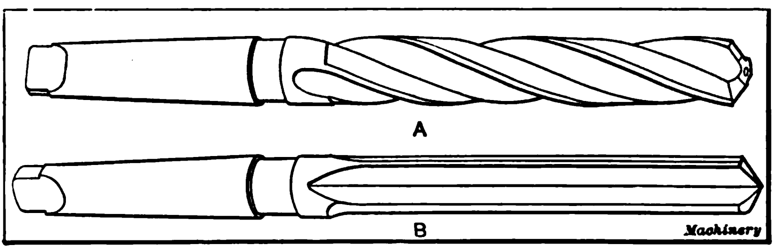

Fig. 26. (A) Three-groove Drill. (B) Straight-fluted Drill

type of chuck is made with a positive drive or with an adjustable friction drive that prevents the breaking of taps. Part of the chuck and gage *G* are prevented from rotating by a rod *R* which, in this case, rests against the left side of the machine column. This rod slides freely up and down as the spindle and tap are raised and lowered.

Numerous other attachments are used for tapping and when this class of work is done in large quantities, special machines are often employed. A lubricant such as sperm or lard oil should be used when tapping.

Oil Drills—Drilling Large Holes—Special Drills

As previously stated, a lubricant, such as oil or soda water should be applied to the drill point when drilling iron and steel, in order to secure efficient results. Ordinarily the lubricant is inserted in the hole and runs down the drill flutes to the cutting end, but when a deep hole is being drilled, this method is unsatisfactory as the chips which are carried upward to the surface by the spiral grooves, tend to prevent the lubricant from reaching the drill point. To overcome this difficulty, twist drills are made having internal oil holes as shown by

TABLE OF DRILL SPEEDS—MORSE TWIST DRILL & MACHINE CO.

Diameter of Drills, Inches	Speed for Wrought Iron and Steel	Speed for Cast Iron	Speed for Brass	Diameter of Drills, Inches	Speed for Wrought Iron and Steel	Speed for Cast Iron	Speed for Brass
1/16	1712	2383	3544	1 1/16	72	108	180
1/8	855	1191	1772	1 1/8	68	102	170
3/16	571	794	1181	1 3/16	64	97	161
1/4	397	565	855	1 1/4	58	89	150
5/16	318	452	684	1 5/16	55	84	143
3/8	265	377	570	1 3/8	53	81	136
7/16	227	323	489	1 7/16	50	77	130
1/2	183	267	412	1 1/2	46	74	122
9/16	163	238	367	1 9/16	44	71	117
5/8	147	214	330	1 5/8	40	66	113
11/16	133	194	300	1 11/16	38	63	109
3/4	112	168	265	1 3/4	37	61	105
13/16	103	155	244	1 13/16	36	59	101
7/8	96	144	227	1 7/8	33	55	98
15/16	89	134	212	1 15/16	32	53	95
1	76	115	191	2	31	51	92

the dotted lines, Fig. 24, which lead the lubricant directly to the cutting end. A special socket *S* is used for an oil drill, having a stationary collar *c* which is connected with a pipe and hose leading to the source of supply. This collar has an annular groove located opposite holes in the revolving socket, which permits the lubricant to enter holes in the drill shank. The lubricant is either supplied by a pump or it is fed by gravity from a bucket suspended above the drill.

The pressure required for feeding a large drill is considerable, but it can be greatly reduced and the drill be made to cut faster, by first drilling a small "lead hole," as shown in the view to the left, Fig. 25. The diameter of this lead hole should be as large, or a little larger, than the width *w* of the drill point, because this point does not have the keenness of the cutting edges and merely scrapes the metal, so that the pressure necessary to force it downward is comparatively great. The lead hole relieves this excessive pressure and permits all the thrust to come directly on the cutting edges of the drill, as indicated by the sectional view to the right.

HENRY & WRIGHT MANUFACTURING CO.'S STANDARD CHART OF SPEEDS AND FEEDS FOR DRILLING

Carbon Steel Drills

Size of Drill	Feed per Rev.	Bronze, Brass, 150 Feet	C. Iron Ann'ld, 85 Feet	Hard C. Iron, 40 Feet	Mild Steel, 60 Feet	Drop Forg., 30 Feet	Mal. Iron, 45 Feet	Tool Steel, 30 Feet	Cast Steel, 20 Feet
Inches	Inches	R.P.M.	R.P.M.	R.P.M.	R.P.M.	R.P.M.	R.P.M.	R.P.M.	R.P.M.
1/16	0.003	....	5185	2440	3660	1830	2745	1830	1220
1/8	0.004	4575	2593	1220	1840	915	1375	915	610
3/16	0.005	3050	1728	813	1220	610	915	610	407
1/4	0 006	2287	1296	610	915	458	686	458	305
5/16	0.007	1830	1037	488	732	366	569	366	245
3/8	0.008	1525	864	407	610	305	458	305	203
7/16	0.009	1307	741	349	523	261	392	261	174
1/2	0.010	1143	648	305	458	229	343	229	153
5/8	0.011	915	519	244	366	183	275	183	122
3/4	0.012	762	432	204	305	153	212	153	102
7/8	0.013	654	371	175	262	131	196	131	87
1	0.014	571	323	153	229	115	172	115	77
1 1/4	0.016	458	260	122	183	92	138	92	61
1 1/2	0.016	381	216	102	153	77	106	77	51
1 3/4	0.016	327	186	88	131	66	98	66	44
2	0.016	286	162	77	115	58	86	58	39

High-speed Steel Drills

Size of Drill	Feed per Rev.	Bronze, Brass, 300 Feet	C. Iron Ann'ld, 170 Feet	C. Iron Hard, 80 Feet	Mild Steel, 120 Feet	Drop Forg., 60 Feet	Mal. Iron, 90 Feet	Tool Steel, 60 Feet	Cast Steel, 40 Feet
Inches	Inches	R.P.M.	R.P.M.	R.P.M.	R.P.M.	R.P.M.	R.P.M.	R.P.M.	R.P.M.
1/16	0.003	....	....	4880	....	3660	....	3660	2440
1/8	0.004	....	5185	2440	3660	1830	2745	1830	1220
3/16	0.005	....	3456	1626	2440	1210	1830	1220	807
1/4	0.006	4575	2593	1220	1830	915	1375	915	610
5/16	0.007	3660	2074	976	1464	732	1138	732	490
3/8	0.008	3050	1728	813	1220	610	915	610	407
7/16	0.009	2614	1482	698	1046	522	784	522	348
1/2	0.010	2287	1296	610	915	458	636	458	305
5/8	0.011	1830	1037	488	732	366	569	366	245
3/4	0.012	1525	864	407	610	305	458	305	203
7/8	0.013	1307	741	349	523	261	392	261	174
1	0.014	1143	648	305	458	229	349	229	153
1 1/4	0.016	915	519	244	366	183	275	183	122
1 1/2	0.016	762	432	204	305	153	212	153	102
1 3/4	0.016	654	371	175	262	131	196	131	87
2	0.016	571	323	153	229	115	172	115	77

Large holes are sometimes drilled about one-half or two-thirds the required size by first using an ordinary two-groove drill, which is then followed by a three- or four-groove drill similar to the one shown at *A*,

Fig. 26. This type is only used for following smaller drills or for enlarging cored holes, and it is not adapted for drilling holes into solid stock.

A drill is shown at *B* in Fig. 26, having two straight flutes instead of the spiral form. This type is used to advantage for the drilling of brass or thin sheet metal. Ordinarily twist drills, owing to the acute angles of the cutting edges, tend to "dig in" or catch especially when coming through the lower side of a thin plate, but this is largely overcome by the straight-fluted type, as the cutting edges do not have the rake or slope common to twist drills. Sometimes the cutting edges of twist drills are ground flat at the front for drilling brass or thin sheet metal.

Speed of Drills

The proper speed for a drill depends on its diameter and the kind of material being drilled. The table on page 25 (which is recommended by the Morse Twist Drill & Machine Co.) gives the speeds in revolutions per minute, for drills ranging from 1/16 inch to 2 inches in diameter, when drilling wrought iron, steel, cast iron or brass. It may be necessary to vary these speeds somewhat in accordance with the hardness of the metal. Some castings, for example, are soft and others very hard, so that it is not possible to give speeds which will apply under all conditions. If the speed is too high, this will be shown by the action of the drill and the wear on the cutting edge. Oil drills can usually be run about 25 per cent faster than the speeds listed. Drills made from "high-speed" steel can also be run at much higher speeds than those made from ordinary carbon steel. An approximate idea of the feed to use for the various drill diameters can be obtained from the following figures: A ¼-inch drill should have a feed of about 0.005 inch, a ½-inch drill, 0.007 inch, and a ¾-inch size, 0.010 inch per evolution of the spindle.

The following suggestions regarding the use of high-speed steel drills, are given by the Cleveland Twist Drill Co. The drill should be started with a peripheral speed ranging between 50 and 60 feet per minute, and with a feed varying from 0.005 to 0.010 inch per revolution, for drills over ½ inch in diameter. The following points should also be carefully observed to obtain the best results. If the drill has a tendency to wear away on the outside, it is running too fast, and if it breaks or chips on the cutting edges, the feed is too coarse. When used in steel or wrought iron, the drill should be flooded with a good lubricant or cutting compound. Paraffine oil is recommended for brass and an air blast for cast iron.

The tables on page 26 give both speeds and feeds for various sizes of carbon and high-speed steel drills. These tables were compiled by a special committee and represent the results of tests covering a period of over two years, which were made to determine the most efficient feeds and speeds for drilling the different metals listed. The speeds given are comparatively high, and are only recommended for use with drilling machines of the high-speed type.

CHAPTER III

RADIAL, SENSITIVE, MULTIPLE-SPINDLE, AND HIGH-DUTY DRILLING MACHINES

What is known as a radial drilling machine is illustrated in Fig. 27. This type differs from the vertical machine illustrated in Fig. 2 in that the drilling head is so mounted that it can be moved to the required position for drilling, instead of adjusting the work or table each time a new hole is to be drilled. Because of this feature, the radial drill is

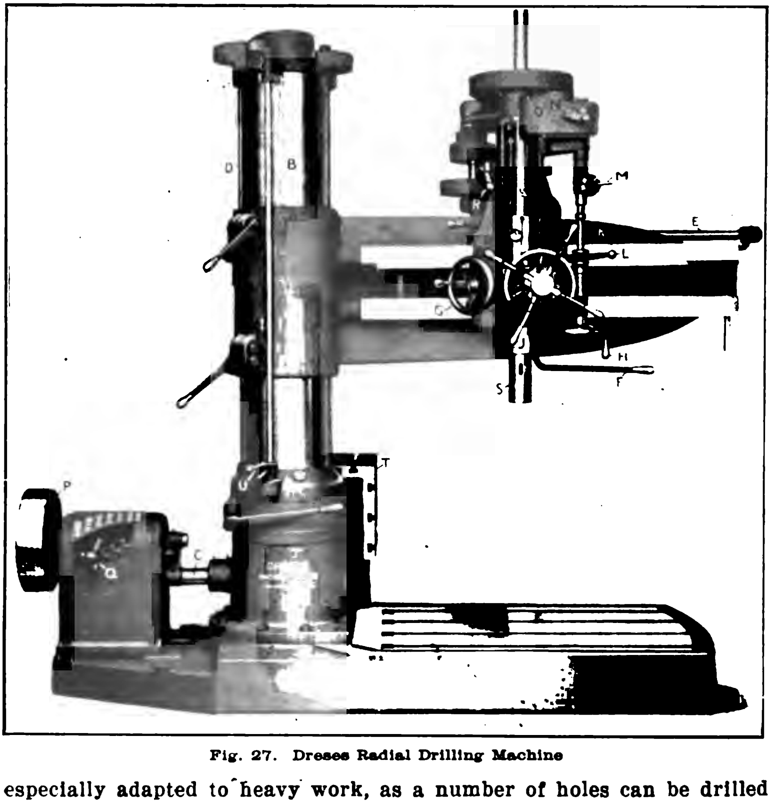

Fig. 27. Dresses Radial Drilling Machine

especially adapted to heavy work, as a number of holes can be drilled by simply adjusting the drill head to the proper position. This drill head, which contains the spindle *S*, is mounted on an arm *A* carried by an outer column *B*, which, with the arm, can be turned about a stationary inner column attached to the base. The head can also be traversed along the arm, and this radial adjustment, combined with the swinging movement of the arm about the column, makes it possible to set the drill spindle in any position within the range of the machine. The drill spindle is driven, indirectly, by a belt operating pulley *P*. The shaft carrying this pulley drives, through gearing, a lower shaft *C* which transmits the movement, by means of bevel gears, to a vertical internal shaft which extends to the top of the column. At this point connection is made by spur gears with an outer vertical shaft *D*, which drives shaft *E* mounted on the arm. Shaft *E*, in turn, rotates through bevel gears, a vertical shaft at the rear of the head which drives the drill spindle. The spindle can be started, stopped or reversed by lever *F*, which controls the connection between shaft *E* and the rear vertical shaft. The head is traversed along the arm by handwheel *G* and the spindle can be fed by handwheel *H* or by power. The spindle can also be traversed rapidly up or down by pilot wheel *J* after the feed has been disengaged.

The power feed is derived from the spindle through gears which drive shaft *K* which rotates, through worm-gearing, a pinion shaft meshing with a rack cut in the spindle quill. The feed is engaged or disengaged by handle *L*, and it can also be disengaged by an automatic stop mechanism, which is adjustable and can be set previously for tripping the feed when a hole has been drilled to the required depth. The amount of feed is varied by handles *M* and *N*, which change the combination of the feed gearing enclosed at *O*. The spindle speeds are changed by shifting lever *Q* of the geared speed-box, to different positions controlled by the notches shown, and the range of seven speeds obtained in this way can be tripled by back-gears in the spindle head, which are engaged or disengaged by handle *R*. The radial arm *A* can be adjusted vertically on column *B* by power, the adjustment being controlled by lever *U*. Both the arm and column can be clamped rigidly in any position by the levers shown. The work is placed either on table *T* or directly on the base, the position depending on its size.

The machine just described is known as a plain radial type and it can only be used for drilling holes at right angles to the base, whereas what is known as the universal type, is also adapted to drilling holes at an angle. The head and drill spindle of a "full universal" machine can be set at an angle with the radial arm, and the latter can also be rotated about its own center or axis, so that the drill spindle can be placed in almost any position. With the exception of the changes necessary to permit these adjustments, the construction of the universal radial is practically the same as that of the plain type. It should be remembered, however, that the construction of drilling machines, as well as of other types of machine tools, varies more or less with different makes.

Sensitive Drill-press

The type of machine illustrated in Fig. 28 is intended especially for drilling small holes in light work. The power is transmitted directly to the spindle by belts which operate on the pulleys shown. This particular design is driven direct by a motor *M* which is connected with the lower cone pulley. The speed changes are obtained by shifting the belt connecting the two cone pulleys to steps of different diameter, and the tension of the belts can be varied by the handwheels *W*. The spindle and drill have a hand-feeding movement only. This is effected by hand-lever *H*, which rotates a pinion meshing with a rack attached to the spindle quill. This simple method of feeding the drill has two distinct advantages when applied to the drilling of small holes: In the first place, it enables the workman to drill rapidly, because, ordinarily, little time is required for drilling small holes and the drill can be raised and lowered quickly when its movement is entirely controlled by hand. The hand-feed is also very sensitive, as the operator can tell by the sense of feeling about how much work the drill is doing, and by regulating the downward feeding pressure accordingly, the breaking of drills is largely avoided. For this reason, light machines of this class are called sensitive drills. The machine illustrated has two work-tables. The upper square table can be set at an angle with the spindle for angular drilling and for supporting work having an angular base. When this table is not in use it can be swung to one side. The round table beneath can be adjusted vertically on the column, and the position of the spindle head can also be varied as required. When necessary, the round table can be removed from its supporting bracket and be replaced with either the cone or crotch centers shown. These centers are used for supporting the ends of shafts, spherical and cylindrical parts, etc. This machine has a capacity for holes up to about 9/16 inch in diameter.

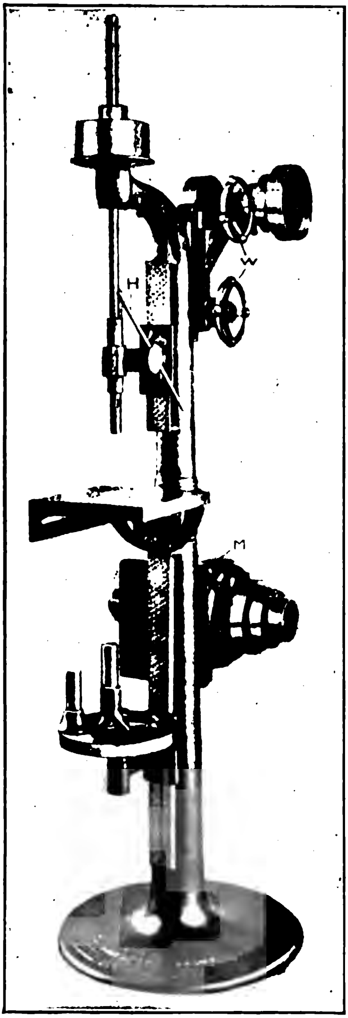

Fig. 28. Drill-press of the Sensitive Type

Multiple-spindle Drilling Machines

A great many parts that have to be drilled, require holes of different diameters, and other operations such as counterboring, reaming or countersinking are frequently necessary. When work of this class is done in a machine having one spindle, considerable time is wasted in removing one drill and replacing it with a different size or with some other kind of tool. For this reason, drilling machines having several

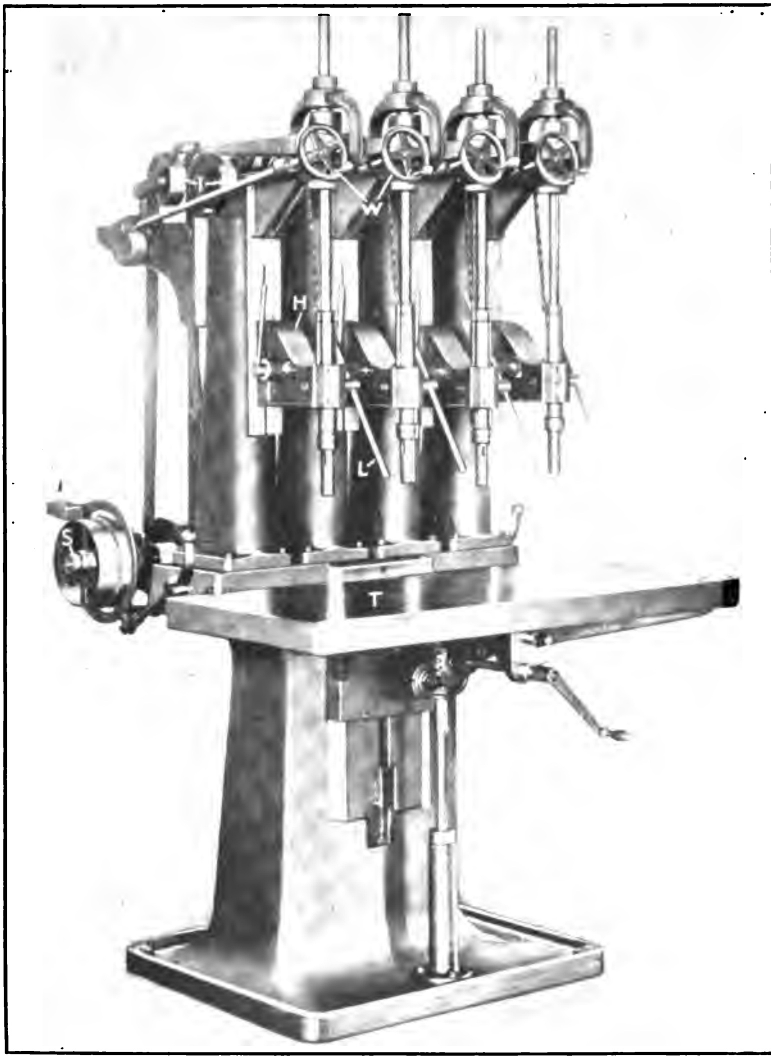

Fig. 29. Henry & Wright Multiple-spindle Drilling Machine

spindles are often used when the work requires a number of successive operations. The advantage of the multiple spindle or "gang" type is that all the different tools necessary can be inserted in the various spindles, and the drilling is done by passing the work from one spindle to the next. By this method, holes of different diameter can be drilled and counterboring or reaming operations be performed without changing any tools. Multiple-spindle machines can also be used to advantage for other purposes.

One type of multiple-spindle drilling machine is illustrated in Fig. 29. This particular design has four spindles, but the number of spindles in a machine of this type depends on the work for which it is intended. The spindles are all driven from a horizontal shaft *S* at the rear to which they are connected by belts as shown. The idler pulleys *I* over which the driving belts pass in making the quarter turn, can be ad-

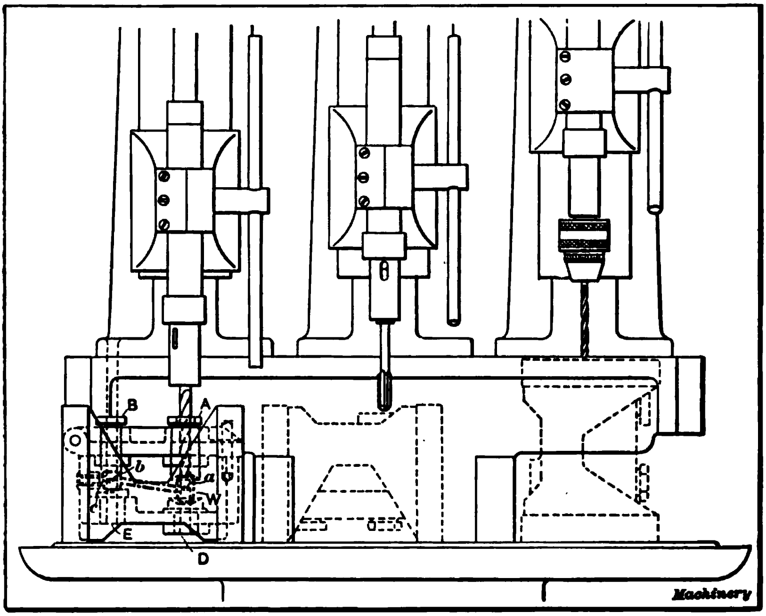

Fig. 30. Method of Using Multiple-spindle Machine for Successive Operations

justed for varying the tension of the belts by the handwheels *W*. The table *T* can be raised or lowered by the screw and crank shown, to suit the height of the work, and the spindle heads *H* also have vertical adjustment. The spindles are fed downward for drilling by the hand-levers *L*.

The method of using a multiple-spindle machine for performing successive operations on the same part is illustrated in Fig. 30. The work *W*, which is held in a box jig, is drilled and reamed at *a* and *b* and a small hole *c* is drilled in the end. The holes *a* and *b* are first drilled with the left-hand spindle by feeding the drill through guide bushings *A* and *B*. The jig is then turned over (as shown by the dotted lines) and moved to the next spindle containing a reamer of the proper size, which is guided by bushings *D* and *E* in the bottom of the jig, as it is fed through the work. The third and last hole *c* is drilled by the right-hand spindle, while the jig is standing on end as shown. The advantage of having all the tools at hand so that the work can be completed by simply moving it from one spindle to the next, is obvious.

Drilling machines of the multiple-spindle type are also commonly

Fig. 31. Pratt & Whitney Adjustable Multiple-spindle Drilling Machine

used for drilling a number of holes simultaneously. The arrangement of these machines is varied considerably to suit different kinds of work, but they may be divided into two general classes, namely, those having spindles which remain in the same plane but can be adjusted for varying the center-to-center distance, and those having spindles which can be grouped in a circular, square or irregular formation. The first class referred to is used for drilling rows of bolt or rivet holes in steel plates, etc., and the second type is adapted to the drilling of cylinder flanges, valve flanges or similar work. A machine of the latter type is illustrated in Fig. 31. This machine has sixteen spindles, all or part of which can be used, as required. These spindles are driven from a single pulley *P* to which they are connected by shafts *S* and spur gears. The connecting-shafts have universal joints which permit the spindles to be arranged in accordance with the work. When the machine is in operation, the table and work are fed upward against the revolving drills. The feeding mechanism is located at *F* and the power feed is derived from pulleys *A* and *B*, which are connected by a belt as shown. The table can also be fed by hand lever *L*, which is connected with the feed pinion shaft. By simply loosening a nut, this lever can be set to the most convenient position for the operator. The power feed is engaged or disengaged by a downward or upward movement of lever *C*. It can also be disengaged automatically at any point by an adjustable stop *D*. As practically all work done on this type of machine is "jig drilled," the spindles are set by aligning them with the holes in the jig. The position of the spindles is changed by adjusting the spindle arms *E* which are clamped to the under side of the housing. The spindles have an independent vertical adjustment so that drills of different lengths can be used. This feature also permits setting the spindles for drilling holes that are not in the same horizontal plane. The machine illustrated is set up for drilling lathe carriages. The work *W* is mounted in a jig *J* and the various holes are all drilled at the same time. A number of castings which have been drilled are shown on the floor to the right.

Multiple-spindle machines of this type are also built in much larger sizes and in designs which are adapted to different classes of work.

High-duty Drilling Machine

Two views of a powerful and rigid drilling machine which is especially adapted to rapid drilling, are shown in Fig. 32. This type was developed for driving modern high-speed drills, which are capable of much higher speeds than drills made of carbon steel. The frame of the machine is designed to avoid any deflection when subjected to heavy feeding pressures. Where there is any springing action, either in the frame or work table, the drill will bind in the hole (especially if it be a long one) and this greatly increases the amount of power required. The increased friction also expands the drill, thus causing it to bind more tightly, which may result in breaking the drill, owing to excessive torsional strain.

This machine is driven by a belt operating on tight and loose pulleys at *A*. From here the motion is transmitted through enclosed back-gears, to an intermediate pulley *B* on the other side of the machine, where connection is made by belt with speed-box *C*. There are eight speed changes obtained by sliding gears in this speed-box. Connection is made with the spindle through the bevel gears *D*, vertical shaft *E* and the spur gears shown. The illustration to the right shows the machine equipped with a plain work table, and the left-hand view shows a "compound" table having longitudinal and cross adjustments. These tables have vertical adjustment on the face of the frame or column. This adjustment is effected by turning shaft *G*

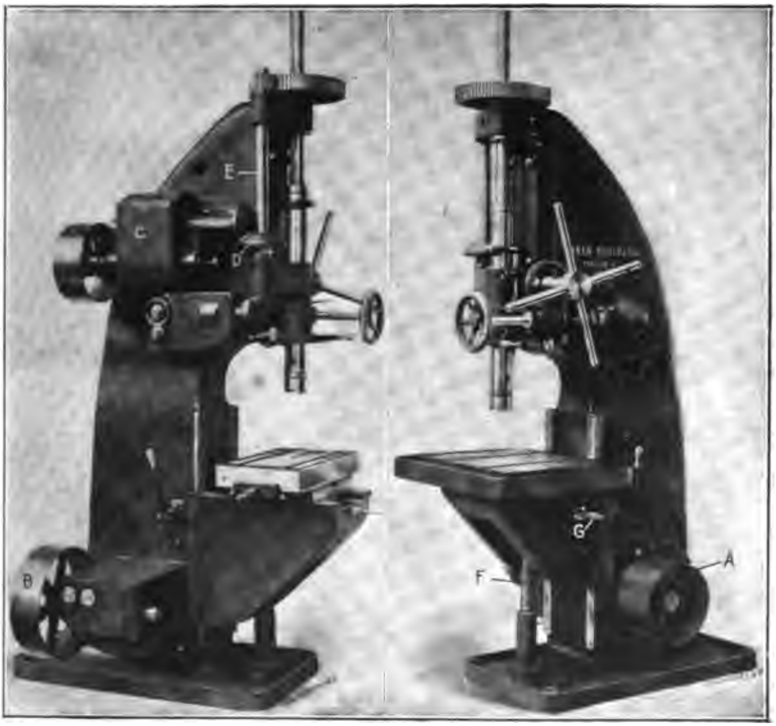

Fig. 32. Baker Bros. High-duty Type of Drilling Machine

which operates elevating screw *F*. The compound table permits work to be accurately centered under the drill, after it is clamped in place.

The following figures will give a general idea of this machine's capacity for rapid drilling. Several 1⅛-inch holes were drilled through 4 1/4-inch cast iron blocks at the rate of 8 2/3 seconds per hole, and a number of 15/16 inch holes were drilled through 3/4 inch machine steel plate at the rate of 3½ seconds per hole.

CHAPTER IV

GRINDING TWIST DRILLS

The point or cutting end of a drill should be carefully ground because a poorly formed drill effects the quality and quantity of the work produced. It is difficult to grind drills theoretically correct by hand, at least in a reasonable length of time, and special grinders are often used for this purpose. Many shops, however, do not have such grinders, but if the requirements of a correctly formed drill point are known, it is possible, with practice, to grind a drill satisfactorily by hand. The requirements briefly stated are as follows: The two cutting edges

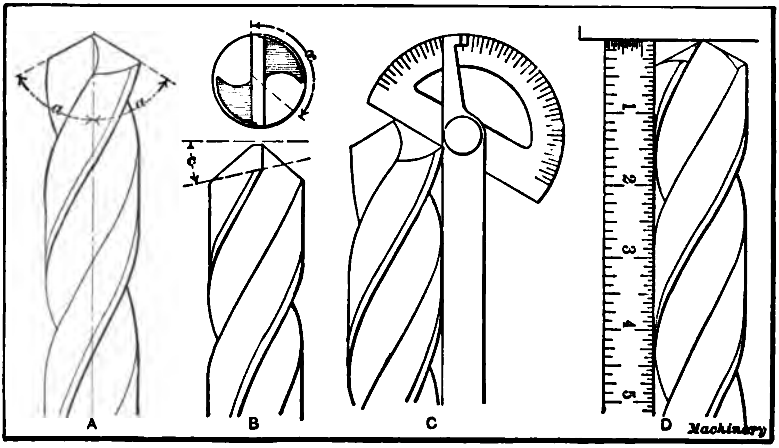

Fig. 33. Views showing Angles to be Considered when Grinding Drills, and Methods of Measuring Lip Angle and Clearance

should incline at the proper angle *a* with the axis, as shown at *A* in Fig. 33; each edge should have the same inclination and be of the same length; the angle of clearance *c* (see sketch *B*) should be sufficient to permit the drill to cut freely; the clearance should be the same on both sides, and increase toward the point of the drill.

At *A* in Fig. 34 is shown the relation between a drill point and a hole when the cutting edges are not at the same angle with the axis. When both cutting edges are ground to the same angle, one edge counteracts the tendency of the other to spring away from the cut (provided the clearance is also correct), but when these angles are different, as shown, one edge will do more work than the other, thus subjecting the drill to an unbalanced twisting or torsional strain. The drill will also be forced sidewise, which will result in an enlargement of the hole.

The effect produced when the lengths of the cutting edges are unequal, is illustrated at *B*. As the drill revolves about the center or point *p*, when it is fed into the metal, the horizontal distance *x* from this point to the side furthest away, will equal the radius of the hole which will, of course, be larger than the drill diameter if the point is not central; therefore, each cutting edge should have the same length, as otherwise the drill will cut a hole larger than its diameter. At *C* a drill point is shown having cutting edges inclined at different angles to the axis and of different lengths, thus combining the disadvantages mentioned in the foregoing.

Each cutting edge should be ground to an angle of about 59 degrees with the axis. When grinding, support the drill on the tool-rest of the grinder, and move it slowly back and forth, in order that any unevenness in the wheel-face will not affect the straightness of the cutting edge. Use preferably the face of the grinding wheel in order to derive benefit from the cooling water, and grind slowly so that the

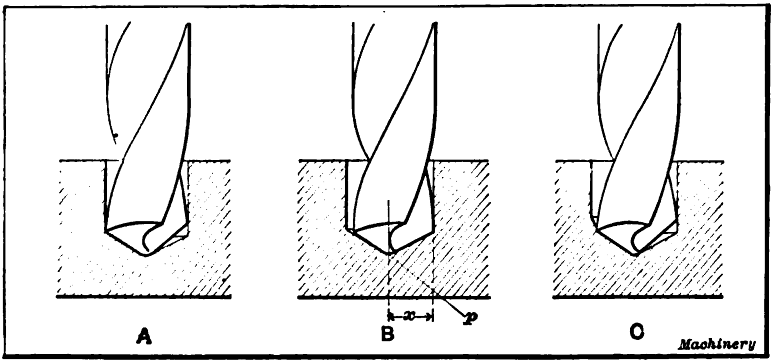

Fig. 34. Three Examples of Incorrect Drill Grinding

temper of the drill will not be affected. The position of the drill in relation to the face of the wheel, should be such that the angle *a* (Fig. 33) which the cutting edges make with the axis, and the angle of clearance *c*, will be ground as nearly correct as can be judged. The angle *a* can be tested by using a protractor as indicated at *C*. The length of each edge should also be measured with a scale and corrected by grinding if unequal, care being taken not to change the angle of the cutting edge, if this is found correct. It should be mentioned that there is a difference of opinion as to the best angle *a* for the cutting edges. As this angle is decreased, the pressure required for feeding a drill downward through the metal, becomes less, but the length of each cutting edge is increased, with the result that more power is required to turn the drill. An included angle of 118 degrees (59 degrees between the cutting edge and axis) is thought by some to equalize the thrust and torsion to the best advantage, while others advocate much more acute angles.

After each side or edge has been ground, the end of the drill will appear somewhat as shown in the upper view at *B*, the unshaded portion representing the ground surface. That part indicated by the shaded lines should then be ground away so that it will not interfere with the downward movement of the cutting edge when the drill is in use. When grinding this part, support the inner end of the drill on the tool-rest, and move the outer end so as to produce a surface which is approximately conical in form. The grinding should be continued until the conical surface is blended into the flat (unshaded) part, previously ground.

The clearance for each cutting edge may be tested by placing the drill point against a flat surface and then slowly revolving it close to a scale held in the position shown at *D*. If the clearances are not alike, this will be indicated by their relative positions to the graduation marks on the scale, as the drill is turned. The clearance is a very important feature in drill grinding, and the splitting of drills through the web is usually an indication either of incorrect clearance or excessive feed. If the end of a drill conforms exactly to the conical shape of the bottom of a hole, evidently it will not cut because the lack of clearance would make it impossible to sink the cutting edges into the metal; therefore, when there is insufficient clearance for a given feed, the drill binds back of the cutting edges, and is subjected to an excessive twisting strain. Theoretically, the clearance should be just enough to permit the drill to cut freely, because excessive clearance weakens the cutting edges. The Cleveland Twist Drill Co. advocates a clearance angle *c* of 12 degrees at the periphery of the drill, with a gradual increase towards the center, until the line joining the two cutting edges makes an angle *x* somewhere between 125 and 135 degrees, as shown in the plan view at *B*. When soft metal is to be drilled and heavier feeds are possible the angle of clearance may be increased to 15 degrees, whereas for hard material such as tool steel, for example, the amount of clearance is diminished, as a fine feed must necessarily be used and a strong cutting edge is required.

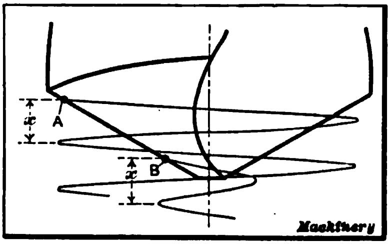

Fig. 35. The Angles of the Helical Paths described by Points A and B show why Angle of Clearance should increase toward Drill Point.

As previously stated, clearance should gradually increase toward the drill point. The reason for this will be apparent by considering the movement of two points *A* and *B* (Fig. 35) on the cutting edge, as the drill is fed downward, one point being much nearer the center than the other. Assuming that the feed is constant, the path described by each of these points will correspond to that indicated by the helical lines shown. As the vertical distance *x*, that each point moves per revolution of the drill, will be the same, the angle of the smaller helix or spiral will be greater than that of the larger one. The angle in each case indicates the minimum clearance necessary at that particular point for a feed per revolution equivalent to the distance *x*. The amount of feed indicated has been greatly exaggerated in order to make the comparison clear.

Worcester Drill-grinding Machine

As the correct grinding of drills by hand requires considerable time, even by an experienced workman, special grinders are often employed for this purpose. A type which has been used extensively is illustrated in Fig. 36. This grinder so controls the movement of the drill with relation to the grinding wheel, that the end is given the correct

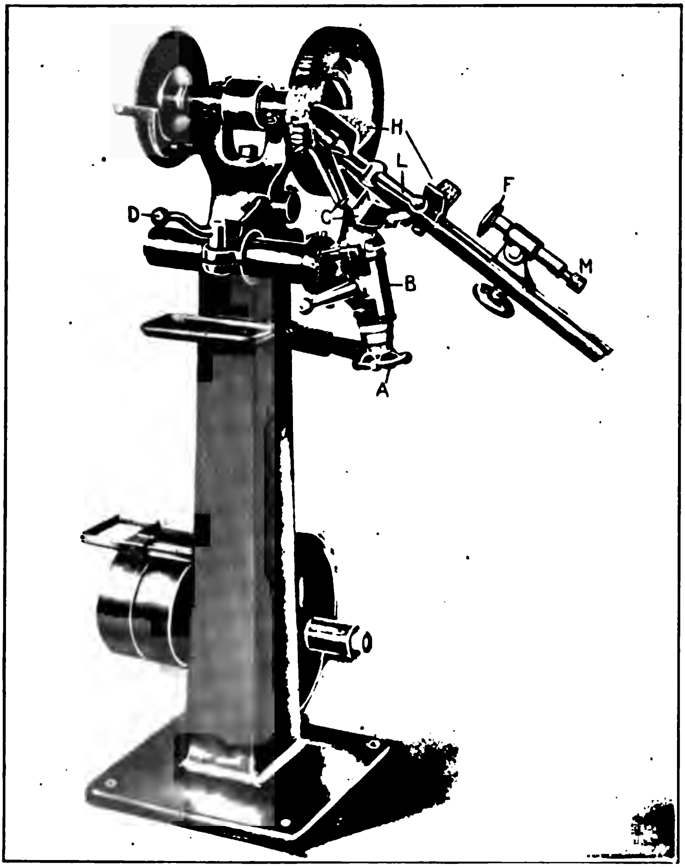

Fig. 36. Grinder for Sharpening Drills

form. The drill to be ground is first placed between the caliper jaws *C* which are adjusted to the diameter of the drill. This adjustment is effected by loosening lever *L* and shifting the sliding jaw the required amount. The drill is then placed in V-shaped holders *H* and it is turned to bring the lower lip against a hardened stop at the grinding end. In this way the drill is properly centered and located with reference to the face of the wheel. The point of the drill should project about 1/16 inch beyond the lip-rest, and the shank end is placed against an adjustable foot-stop *F*. The entire drill-holding device should be clamped in such a position that the drill will nearly touch the grinding wheel when the holder is swung at right angles to the wheel face. The grinding is done by oscillating the drill-holder in bearing *B* which is inclined to the face of the grinding wheel, as shown. After one lip is ground, the drill is turned over for grinding the opposite side. As the grinding proceeds, the drill is gradually fed against the wheel by turning micrometer screw *M* which pushes the foot-stop *F* forward. This screw should be turned to the same graduation for grinding each side of the drill, in order to secure cutting edges of equal length. When reversing or removing the drill, the holder should be swung to the extreme left.

The adjustment of the caliper jaws *C*, previously referred to, is done to give drills of different diameter a standard clearance. As these jaws are opened to fit a drill of given size, the lip rest and end of the drill is advanced with relation to the axis of bearing *B*, about which the holder rotates. If the opening between the jaws is made greater than the diameter of the drill, the clearance will be less than the standard, and, inversely, a smaller opening will increase the clearance. The proper way, however, to vary the angle of clearance, is by loosening hand wheel *A* and turning an eccentric bushing in which the holder rotates, thus moving the axis of rotation toward or away from the grinding wheel. This adjustment is indicated by suitable graduations, and it is not changed unless it is desired to vary the standard clearance. The entire holder can be adjusted in or out by loosening clamping lever *D*, in case this is necessary to compensate for the wear of the wheel face or to set the holder in correct relation to a new wheel.

When a drill has been shortened considerably by repeated grinding, the point or web becomes thicker because the grooves of twist drills gradually decrease in depth toward the shank. (The grooves are milled in this way in order to strengthen the drill). As the width of the point increases, more pressure is required for feeding the drill, and to overcome this, the point should be made thinner by grinding. The grinder shown in Fig. 36 has a thin elastic emery wheel on the left end of the spindle, which is provided for the thinning of drill points. Care should be taken to grind away an equal amount of stock on each side of the point in order to keep it central.

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