MODERN DRILLING PRACTICE

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A TREATISE ON THE USE OF VARIOUS TYPES OF SINGLE- AND MULTIPLE-SPINDLE DRILLING MACHINES, INCLUDING THEIR APPLICATION TO STANDARD AND SPECIAL OPERATIONS, THE RELATION OF SPEEDS AND FEEDS TO INTENSIVE PRODUCTION, AND THE DIFFERENT TYPES OF TOOLS AND FIXTURES UTILIZED IN PROGRESSIVE MACHINE SHOPS FOR INCREASING THE RANGE AND EFFICIENCY OF MACHINES OF THIS CLASS

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PREFACE

DURING recent years, a number of important changes have been made in methods of drilling holes in the parts of manufactured products. Noteworthy among these are the great increase in the speed at which twist drills are driven, the application of various types of universal or special multiple-spindle drilling machines or auxiliary drill heads, and the successful employment of semi-automatic drilling machines. All of these developments in drilling practice have been introduced with the view of increasing rates of production; and, in preparing the subject matter of this book, the author's object has been the same. The methods discussed are those which have been thoroughly tried out under actual manufacturing conditions, so that their practicability has been conclusively demonstrated. As a result, men who are responsible for the selection of methods of performing machining operations can decide upon the application of any of these suggestions for handling their own work with complete assurance that the resulting benefits are likely to be as great as in the case of other plants where substantial economies have been effected.

Probably it is safe to say that there is no class of cutting tool used in machine shops which receives as little consideration as the twist drill. This is largely due to the fact that drills can be bought ready for use in practically any size. As a result, the mechanic is likely to assume that the twist drill manufacturer has produced tools which are not only ready for use, but which are capable of remaining in good condition with very little attention. As a matter of fact, the proper grinding of a twist drill is of the utmost importance, and unless the drill is ground to the proper shape, its cutting efficiency is certain to be very seriously impaired. Realizing the importance of proper drill grinding, a comprehensive discussion has been presented of the theoretical considerations which must be fulfilled in order to grind a drill and maintain the point of such a shape that it will have the same cutting efficiency as a new drill of the same size. Drills may be ground on either a special drill grinding machine or on an ordinary tool grinder, and information is given concerning the proper method of procedure in both cases.

All mechanics are familiar with the various types of drilling machines which are extensively used in machine shops. Bearing this fact in mind, it was felt that nothing beyond a brief description of the essential features of each type of machine would be of practical value. After this preliminary discussion of machine design, examples of good practice in operating each type of machine are illustrated and described. In this connection, complete information is given concerning the material, the size of holes being drilled, the speed and feed at which the operation is performed, and the rate of production which is obtained. The examples selected show operations which are conducted under conditions approximating maximum output and, as a result, should prove of value in suggesting conditions under which a new job may be successfully handled. No attempt has been made to take up the subject of jigs and fixtures beyond explaining certain fundamental points in their design and the essential features of equipments used in performing the particular operations which are described. The reason is that this subject has been considered of sufficient importance to warrant its treatment in a separate volume in which a full discussion is presented of various principles of jig and fixture design.

THE AUTHOR

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CHAPTER I

GENERAL TYPES OF DRILLING MACHINES AND THEIR APPLICATION

In those shops where the most remarkable improvement has been made in rates of production secured on drilling machines, the increase has been largely due to constantly higher speeds and the rates of feed which are employed in the performance of drilling operations, but more particularly as a result of increasing the speed. There are many noteworthy advantages secured through drilling at high speed, and these will receive detailed consideration in Chapter IV on "Speeds and Feeds for Drilling." The remarkable increase in the speed at which drilling operations are performed has created a condition which was formerly unimportant, i.e., in regard to the relation between the time actually consumed in the performance of a drilling operation and the time required for setting up the work. Obviously, increasing the speed and rate of feed cuts down the time required to drill a hole, and, therefore, jigs and work-holding fixtures must be so constructed that the setting-up time does not become the limiting factor in performing the drilling operation. The steps which must be taken to secure this result will vary according to the depth of the hole, and consequently according to the time required to complete the drilling operation. In any case, the two chief points which require consideration are to design jigs and fixtures with clamping devices which may be quickly operated, so that the minimum amount of time is required to secure the work in place ready to be drilled, or to provide jigs or fixtures of the so-called indexing type, so that the operator may be setting up a piece in the fixture while the machine is engaged in drilling work held in other sections of the fixture. This point will receive detailed consideration in connection with a description of examples of drilling machine equipment which will be illustrated and described.

Types of Drilling Machines. — Drilling machines which find the most general application in American manufacturing plants may be roughly divided into three general classes, as follows:

1. Vertical drilling machines.
2. Radial drilling machines.
3. Multiple-spindle drilling machines.

Each of these general classes is capable of further subdivision, so that drilling machines are finally classified under the following headings:

1. Vertical or " upright " drilling machines.
2. Vertical sensitive drilling machines.
3. Vertical high-duty drilling machines.
4. Radial drilling machines.
5. Multiple-spindle drilling machines of straight-line type.
6. Multiple-spindle drilling machines of cluster type.
7. Automatic drilling machines.
8. Turret-type drilling machines.

In addition to the eight preceding types of machines, a great deal of useful work is done by special machines built to meet the requirements of individual cases. Such machines are generally of the multiple-spindle type, but they are especially designed for specific classes of work.

Vertical or Upright Drilling Machines. — The vertical or upright machine is the most commonly used type of " drill press " employed in the machine shop. It is usually equipped with power feed, and a tapping attachment is often provided, which may be engaged to provide for handling work in which holes have to be tapped.

The term " sensitive " is applied to those types of light drilling machines which are equipped with hand feed, so that the operator is able to judge the amount of feed pressure with which the drill is being driven into the work. These machines are usually adapted for drills from the smallest sizes up to from $\frac{3}{8}$ to $\frac{7}{8}$ inch in diameter. They are used on a great variety of work, and for handling small parts in quick-acting jigs or fixtures they are capable of giving very satisfactory results. One advantage of the hand feed is that an experienced operator may use his judgment in releasing the feed pressure, if he finds that the drill has struck a hard spot in the work. This is the means of saving the breaking of drills. Machines of this type are now being built for operation at speeds which were unheard of a few years ago. For instance, some types of sensitive drilling machines are built for operation at speeds ranging from 10,000 to 15,000 revolutions per minute.

Vertical High-duty Drilling Machines. — As their name implies, high-duty drilling machines are adapted for the performance of heavy work, and they are commonly employed for using a range of drill sizes running from the maximum capacity of sensitive drilling machines up to the largest sizes in which drills are made. In addition to the performance of drilling operations, high-duty drilling machines are used for a great variety of other classes of work, including such operations as hollow-milling, spot-facing, facing, counterboring, threading, tapping, etc. In general, machines of this character may be employed to advantage wherever it is desired to use a rotating tool on stationary work under conditions where heavy cuts are to be taken. To meet the requirements of such severe service, the high-duty drilling machine is equipped with power-driven feed, and the rates of feed are commonly much greater than that employed on sensitive drilling machines, while the speed at which the drill is operated is correspondingly reduced, owing to the greater diameter of the drill. There are various forms of mechanisms used on these machines, but in all cases provision is made for obtaining any of a range of speed and feed changes suitable for the work on which the machine is engaged.

Radial Drilling Machines. — On the familiar type of radial drilling machine the spindle head is carried on an arm, which may be swung around the column of the machine, and the spindle head may also be moved back and forth along the arm. This combination of movements makes it possible to locate the spindle of a radial drilling machine at any desired point over work which comes within this range of movement. Radial drilling machines are commonly classified according to the length of arm, i.e., a 6-foot radial drill has an arm 6 feet in length. Sizes in which these machines are generally built run from about 2½ to 6 feet. Obviously, the size of the work which can be handled with a machine of this type is governed by the length of arm and vertical adjustment of the arm on the machine column. Radial drilling machines are generally employed for handling those classes of work where there are a number of holes to be drilled and where the work is either too heavy or too large to be conveniently set up on multiple-spindle drilling machines.

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 spindles are often used when the work requires a number of successive operations. The advantage of the multiple spindle or " gang " type as applied to work of the class mentioned 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.

Drilling machines of the multiple-spindle type are also commonly 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.

Automatic Drilling Machines. — For drilling holes in small parts, and particularly in those cases where the diameter and depth of the holes are not great, profitable use may often be made of automatic drilling machines. These are built in various types, which will be illustrated and described, but in each case the aim is to provide means of keeping the drilling spindle or spindles constantly employed while the operator is removing drilled pieces from the work-holding fixtures and loading fresh blanks into these fixtures, so that the parts may be drilled when they have been carried around under the drilling spindles.

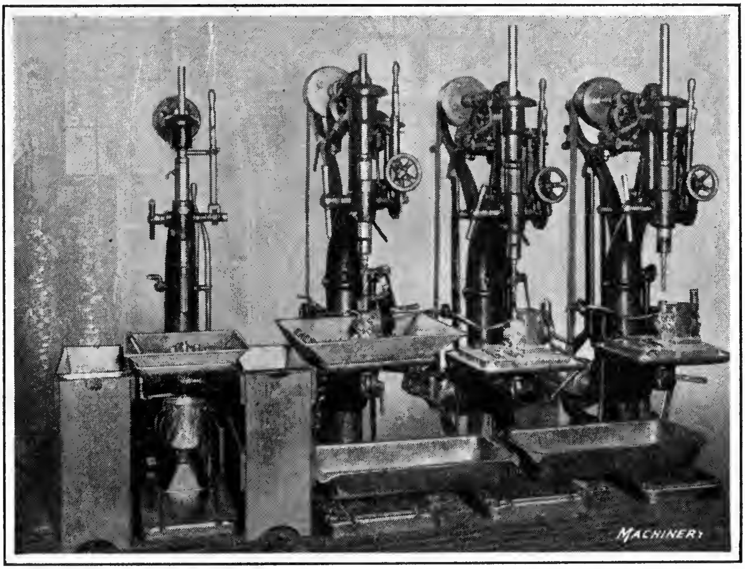


Fig. 1. Vertical Drilling Machines equipped with Indexing Fixtures for Drilling Universal Joint Rings

Exceptionally high rates of production can be obtained from machines of this type.

Turret Type of Drilling Machines. — Drilling machines of the turret type fill the same general place among drilling machines that is taken by the turret lathe among machines of that type. In other words, turret drilling machines are used in those cases where there is a sequence of such operations as drilling, counterboring, and tapping to be performed on a piece of work. Machines of this type are equipped with a turret carried on a horizontal axis about which the turret may be revolved to bring the sequence of tools into the operating position. In general, turret-type drilling machines are used as an alternate method of handling those classes of work which are commonly handled on multiple-spindle drilling machines of the straight-line type, where work is passed along from spindle to spindle.

Now that the different types of drilling machines and classes of work for which each is adapted have been considered, a detailed discussion of installations of the different types of machines, and examples of work for which each type is adapted will be discussed as well as the methods of setting up the work and rates of production that are obtained under favorable conditions. The same order will be followed in discussing the use of these machines as that which was followed in mentioning the different types.

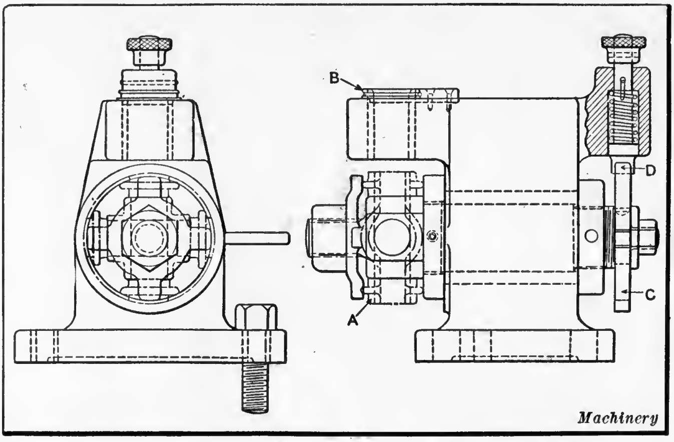


Fig. 2. Indexing Fixture used on Drilling Machine shown in Fig. 1 for Drilling Four Holes in Universal Joint Rings

Operation of Vertical or Upright Drilling Machines. — Fig. 1 shows a group of three upright drilling machines built by the Rockford Drilling Machine Co., engaged in drilling universal joint rings; and a fourth machine to the left is employed for reaming the holes. The three drilling machines are equipped with indexing jigs to provide for bringing the work into the required positions for successively drilling each of the four holes. A detailed view of the indexing jig is shown in Fig. 2. Referring to this illustration, it will be seen that work *A* is clamped in place under bushing *B* and that provision for locating the work in the four drilling positions is made by means of index plate *C* and spring plunger *D*. The work to be drilled is a drop-forging containing from 0.15 to 0.25 per cent of carbon, from 0.30 to 0.60 per cent of manganese, sulphur below 0.045 per cent, and phosphorus below 0.05 per cent. The holes to be drilled are 1 inch in diameter by $\frac{9}{16}$ inch in depth. The production is approximately 600 completed rings on the three right-hand drilling machines in a ten-hour working day, i.e., 2400 holes are drilled per day in these forgings.

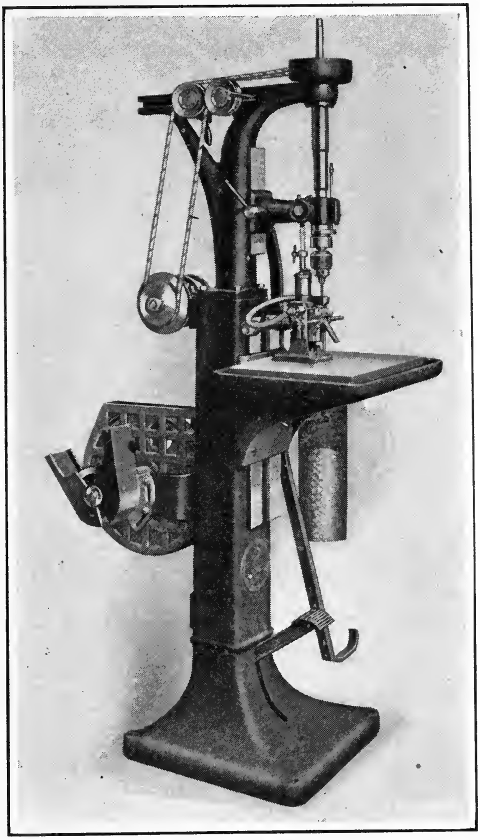


Fig. 3. Sensitive Drilling Machine with Special Jig for Drilling Cross-holes in Pins

High-speed Ball-bearing Sensitive Drilling Machines. — To take advantage of the benefits which are secured through the performance of drilling operations at high speed, the Leland-Gifford Co. builds a line of ball-bearing sensitive drilling machines which are adapted for operation at speeds ranging from 10,000 to 15,000 revolutions per minute. These machines are built in a bench type or with a pedestal base so that they may be set up on the floor. Fig. 3 shows one of the pedestal type machines equipped with a special drilling jig built by Caulkins & Carpenter, and a better idea of the way in which this outfit operates will be gathered from Fig. 4. This jig is especially suited for use in drilling cross-holes in pins and similar shaped parts, and, to meet the requirements of such work, it is furnished with a V-block *A* to hold the work and an end-stop *B* to locate the work in the desired position in the jig. End-stop *B* is connected to a piston in air cylinder *C*, and this cylinder is connected by a rubber hose with cylinder *D*. A rack, which meshes with the feed pinion on

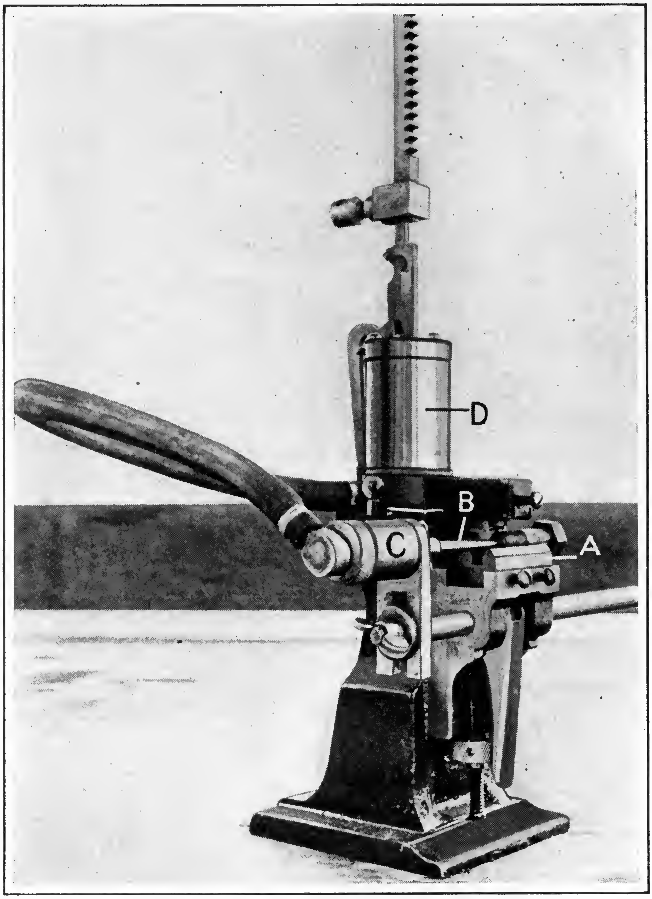


Fig. 4. Quick-acting Jig for Drilling Cross-holes in Pins

the machine, is carried at the upper end of a rod connected with the piston in cylinder *D*, and it will be apparent that, during the time the drill is being fed into the work, the rack carried at the back of the feed pinion is raised, thus raising the piston in cylinder *D*.

After the drilling operation has been completed and the drill spindle starts to rise, the reverse movement of the feed pinion drives down the piston in cylinder *D*, and this results in driving air through the flexible tube into cylinder *C*. The result is that end-stop *B* is driven forward and ejects the drilled piece from the V-block. During this time the operator has picked up another piece of work which he can immediately place in position ready to be drilled, so that the operation of the machine may be practically continuous. When the work has been placed in the V-block and the drill starts to feed down, raising of the piston in cylinder *D* results in actuating a link mechanism at the back of the jig, which is responsible for clamping the work in place.

As shown in the illustration, the V-block which supports the work is carried on a knee which may be adjusted vertically to provide for holding pieces of various diameters; the rod which carries end-stop *B* and cylinder *C* may also be adjusted in its bearing in the knee to provide for drilling pins of different lengths, and it is obviously an easy matter to substitute drill bushings of the correct size for handling different operations. In drilling holes through pins made of screw stock $\frac{3}{16}$ inch in diameter with a No. 51 drill, the machine was operated at 6700 revolutions per minute and produced 2200 pieces an hour. Such a high rate of production would not be possible were it not for the provision made in designing this jig for rapid handling.

Semi-automatic Sensitive Drilling Machine. — Fig. 5 shows a high-speed, ball-bearing sensitive drilling machine built by the Leland-Gifford Co. The spindles are mounted in ball bearings, so that the machine is adapted for running at speeds up to 3500 revolutions per minute. It is known as a " semi-automatic " machine, and in this respect deviates from what is generally understood to constitute a sensitive drilling machine, because the spindles are equipped with power feed. In operating the machine, one man attends to both spindles; he sets a piece of work up in one fixture and engages the power feed, then reaches over to the second fixture, removes the drilled piece of work, sets up a fresh piece in the fixture, and engages the power feed. By this time the drilling operation on the piece under the first spindle has been completed, at which time the feed is automatically tripped and the spindle returned to the starting point, so that the operator merely has to remove the drilled piece and substitute a fresh blank. In this way, both spindles of the drilling machine and the man employed to operate them are

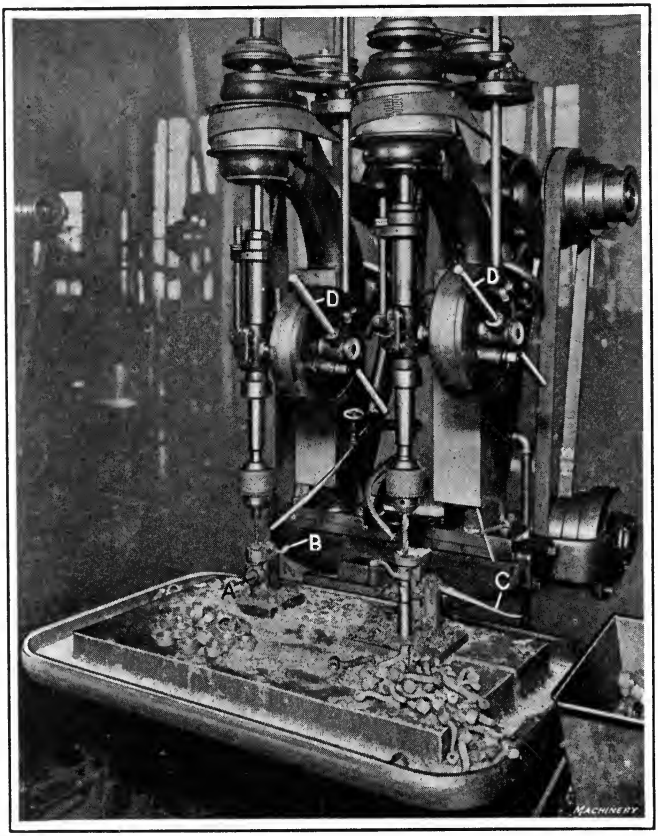


Fig. 5. Sensitive Drilling Machine equipped with Power Feed which enables One Operator to keep Two Spindles Constantly in Operation

kept busy almost all of the time, so that an unusually high rate of efficiency is secured. The lever which engages the power feed-clutch may also be used to feed the drill by hand; and by simply pushing up this lever, the power feed may be instantly disengaged in any position, without waiting for the full downward movement to be completed. This last-named feature is often of great convenience.

Particular attention is called to the design of the jigs used on this machine. In the case of the $\frac{7}{8}$-inch set-collar shown under the left-hand spindle, the operation consists of drilling a $\frac{1}{4}$-inch tap-hole which is $\frac{3}{8}$ inch deep in a malleable-iron part. The work is slipped over pilot *A* and secured by a bell-mouthed bushing operated by lever *B*. In the case of the malleable-iron cranks which are being drilled under the right-hand spindle, a bell-mouthed bushing is also employed to secure the work, this bushing being operated by lever *C*. In this case, a stronger spring is required to hold the work; therefore, a longer lever is necessary. The hole being drilled in these cranks is $\frac{3}{8}$ inch in diameter by $\frac{3}{4}$ inch deep. It will be apparent that in both cases work may be set up and removed with a minimum expenditure of time, which is important, because the operations are soon finished. In drilling the set-collars, the operation is performed at 1100 revolutions per minute with a feed of 0.005 inch per revolution, and the production is 4800 pieces per eight-hour day. In drilling the small cranks, the drill runs at the same speed and feed and 2400 pieces are produced in eight hours. The power feed used in this machine is so designed that, when the operator grasps either of the feed-levers *D* and pulls it forward, feed is engaged and the drill is advanced into the work by power until an automatic trip throws out the feed-clutch, at which time the spindle is automatically returned to the starting position. Graduated circles which are furnished on each of these feed-clutches provide for setting the feed to be tripped after a hole has been drilled to a predetermined depth.

Sensitive Machine arranged to Automatically Control Spindle Movements. — Fig. 6 shows a No. 2½ high-duty, ball-bearing sensitive drilling machine built by the Cincinnati Pulley Machinery Co. This machine is illustrated in use drilling steel bushings where it is required to drill a $\frac{17}{64}$-inch hole through a wall $\frac{9}{32}$ inch in thickness. These pieces are turned out by an unskilled operator at the rate of 1186 pieces per hour, or approximately 10,000 pieces in a ten-hour day. The daily figure allows time for changing drills and for further unavoidable losses. Machines of this type are built with either plain hand feed or with power feed, and means are provided for automatically reversing the travel of the spindle in one or both directions. The machine equipped with automatic feed mechanism is quite flexible, it being possible to operate it as a fully automatic or semi-automatic machine, or the automatic mechanism may be entirely disconnected and the machine fed by hand. In shops which have pieces that are manufactured in large quantities, and where the nature of the work is such that it may be rapidly set up and removed from fixtures, the fully automatic mechanism is usually employed. On the other hand, where the work is comparatively difficult to handle, more time will be required

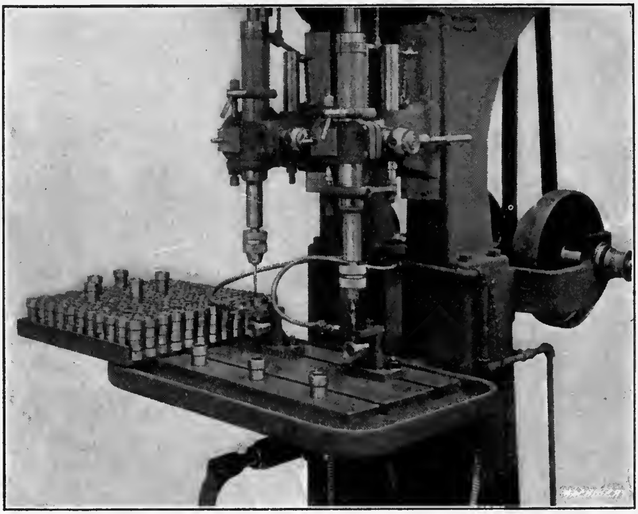


Fig. 6. Ball-bearing Sensitive Drilling Machine set up for Use in Drilling Steel Bushings. On this Operation the Production is 10,000 Bushings in a Ten-hour Day

between successive strokes of the drill, and for such work the automatic trip for the down-feed of the drill is thrown out. In this case, the return of the spindle is automatic, but the power feed-clutch must be engaged by hand. For still other classes of work, all of the automatic movements are disconnected. The trips for the automatic movements may be set so that the time between strokes is just enough to allow the operator to remove the drilled piece and substitute a fresh casting.

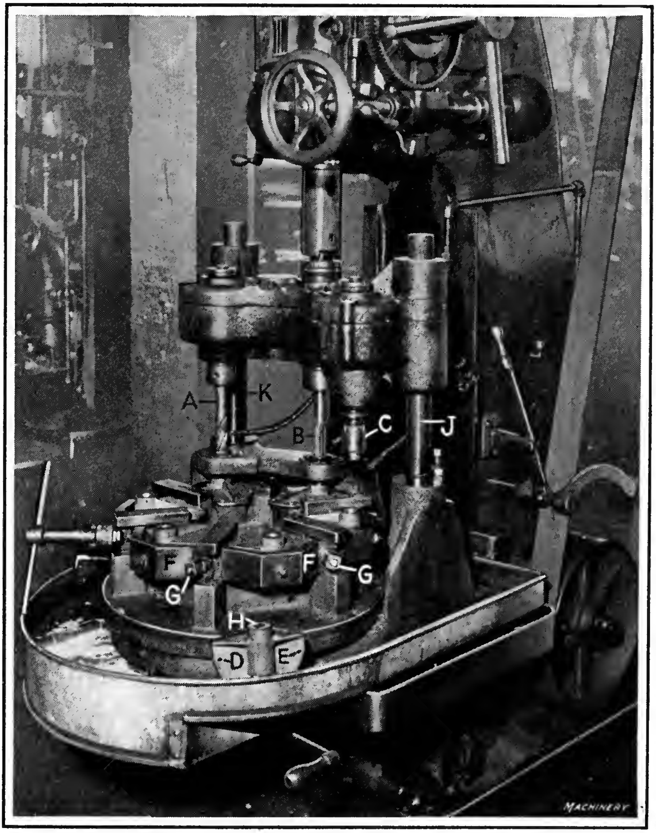


Fig. 7. High-duty Drilling Machine equipped with Indexing Fixture and Special Three-spindle Head for Drilling, Reaming, and Facing

Vertical High-duty Drilling Machines. — For drilling, reaming, and facing the 0.998-inch hole in rear spring center brackets used in the construction of automobiles of its manufacture, the Willys-Overland Co. employs high-duty drilling machines built by Baker Bros., one of these machines being shown in operation in Fig. 7. The nature of the work is such that a considerable amount of time must necessarily be employed in setting up the work in the fixture, but, as the depth of the hole to be drilled, reamed, and faced is also considerable, this need not constitute an unsurmountable barrier against the attainment of efficient production. The problem has been adequately solved through adoption of the use of an indexing work-holding fixture. The pieces have to be drilled, reamed, and faced, and these operations are performed by tools shown at *A*, *B*, and *C*, respectively. The drilling operation naturally consumes the greatest amount of time, and while the drill is in operation the workman has ample time to remove one drilled piece from the loading station at the front of the fixture and substitute a fresh blank; then, when the machine spindle lifts the multiple head which drives the three tools, the operator pushes the fixture around until the index-pin locates it at the next station. For each traverse of the drilling machine spindle, it will be apparent that one finished piece is produced, as the drilling, reaming, and spot-facing operations are performed simultaneously.

The work is malleable iron, and referring to the piece shown leaning against the fixture at the front, attention is called to the fact that two locating pins enter holes *D* and *E*, which were drilled in a previous operation. Swinging clamp *F* is then brought up against the front of the work and secured by nut *G* that is tightened with a wrench. The hole *H* to be drilled is 0.998 inch in diameter by $3\frac{1}{16}$ inches deep, and the rate of production is 600 pieces per eight-hour day. The operation is performed at a speed of 300 revolutions per minute with a feed of 0.024 inch per revolution. The machine is equipped with a three-spindle auxiliary head built in the Willys-Overland factory; pilots *J* and *K*, which extend up from the work-holding fixture into bushings in the drill head, assure permanent alignment.

Special Work on High-duty Machine. — In connection with the general discussion of high-duty drilling machines, mention was made of the fact that machines of this type are well adapted for the performance of many other operations besides drilling. In Fig. 8, one of the Baker high-duty drilling machines is shown set up to provide for simultaneously spot-facing three pads on a universal joint spider. The machine used for this purpose is equipped with a three-spindle multiple head, and this head is piloted from the fixture, as in the preceding case. The pads on these spiders have to be spot-faced on both sides, and to

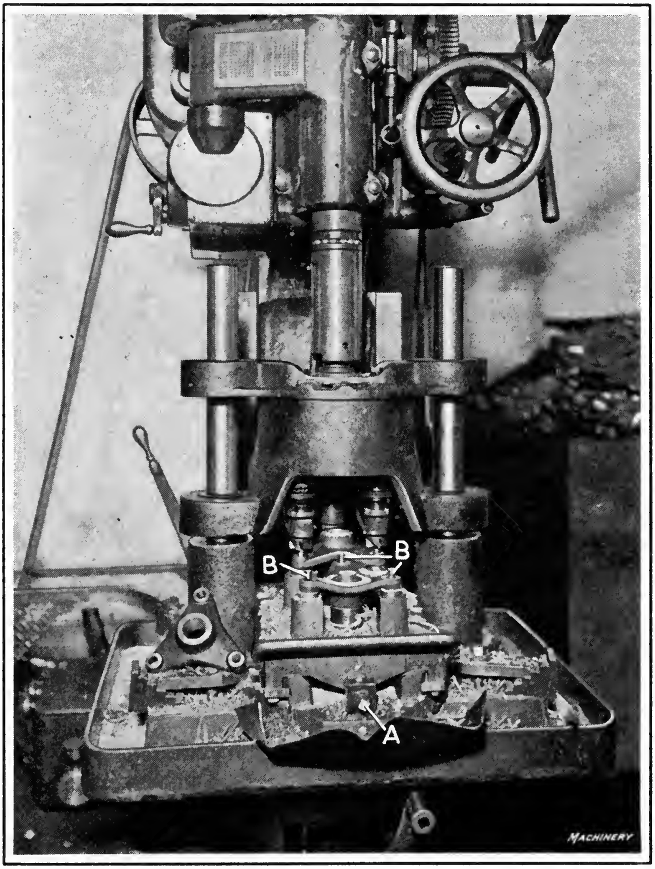


Fig. 8. High-duty Drilling Machine equipped with a Two-station Work-holding Fixture and Special Three-spindle Head for Spot-facing

provide for turning over the work or for removing a finished piece from the fixture and substituting a fresh malleable-iron casting, so that any idle time of the machine may be reduced as far as possible, use is made of a sliding fixture of the type shown.

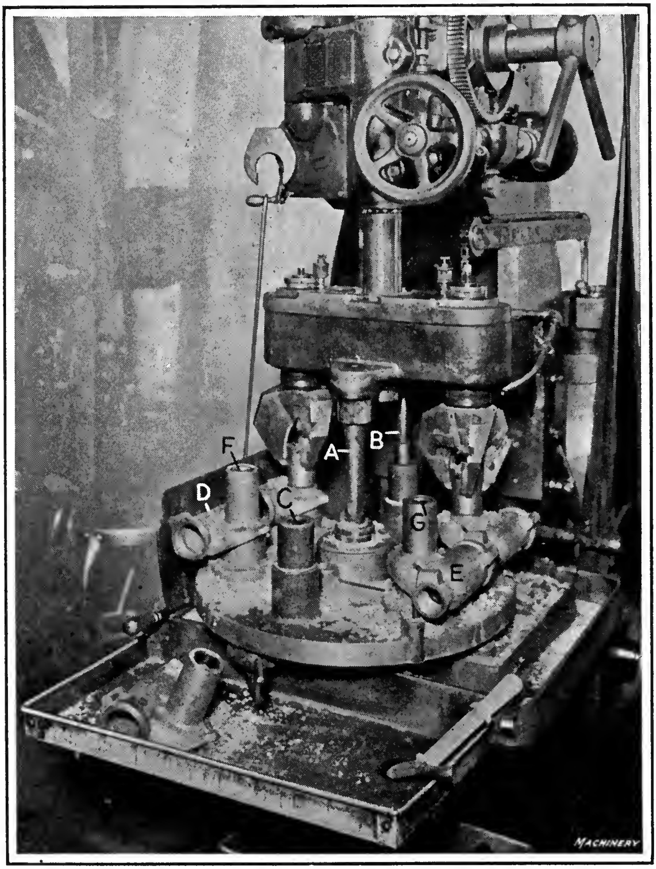


Fig. 9. High-duty Drilling Machine equipped with Indexing Fixture and Two-spindle Head for Hollow-milling Steering-gear Housings

This fixture is furnished with two stops, one of which is shown at *A*, which limit the travel of the fixture in either direction to provide for locating the work supported at one or the other of the two stations on the fixture under the spot-facing tools. The holes in these spiders have already been drilled, and these are employed as locating points; in addition, the pins *B* which locate the work from these holes extend up sufficiently through the work so that the spot-facing tools may be piloted over them to assure rigidity. Owing to the ingenious way in which the design of this fixture has been worked out and applied, these malleable-iron spiders may have three pads spot-faced on both sides with a production of 288 parts per eight-hour day from each machine. The machine is run at 200 revolutions per minute with hand feed.

Another example which tends to show the range of work that may be efficiently handled on high-duty drilling machines is illustrated in Fig. 9, which shows the operation of hollow-milling steering-gear housings for the Willys-Overland car. Here, again, use is made of an indexing work-holding fixture, and the machine is equipped with a special two-spindle auxiliary head. To provide the degree of rigidity that is required under severe service of this kind, however, the system of piloting is somewhat different from that shown on preceding machines of this type. In this case, two pilots are employed; the central pilot *A* is carried by the fixture and runs in a bushing in the drill head, while pilot *B* is carried by the head and runs in sockets carried by the fixture. This fixture is indexed through 180 degrees, and in this position pilot *B* will run in socket *C*.

In performing this hollow-milling operation, the two pieces of work, *D* and *E*, are dropped over pilots on the fixture, and the ends of these pieces simply bear against lugs on the fixture which prevent them from turning. Where this method of securing work can be employed, it is extremely satisfactory, because the length of time required to set up the work in place for machining is reduced very close to a minimum. The holes have been machined by a previous operation and are employed as the locating points. After setting up the work the fixture is indexed through 180 degrees, as previously mentioned, and this brings the blanks into the position shown in the illustration where two pieces may be milled simultaneously. The hollow-milling cutters used on this machine are provided with pilots which enter bushings *F* and *G* in the studs on which the work is carried, so that further provision is made to guard against vibration. The length of time consumed by this hollow-milling operation is ample to allow the finished pieces to be removed from the fixture and new blanks to be set up. The material is malleable iron; and the surface finished during this operation is 3¼ inches in length by 2¼ inches in diameter; the rate of production is 160 pieces per eight-hour working day. This operation is performed at 70 revolutions per minute with a feed of 0.010 inch per revolution.

By employing a carefully worked out design for tools and work-holding fixtures, there are many classes of work on which a considerable sequence of operations may be performed through the use of high-duty drilling machines, one of which is shown in Fig. 10 which illustrates one of the Baker high-duty drilling machines equipped with tools and an indexing fixture to provide for boring and reaming holes of three diameters in the Willys-Overland steering-gear housing, facing the surface at the top of this housing, facing off a seat for the ball bearing, and tapping one of the bored holes. As in the preceding case, a double system of pilots is employed, one of which is secured to the work-holding fixture and enters a bushing in the three-spindle auxiliary head provided on the machine, while the other pilot is carried by this special auxiliary head and runs in a sequence of bushings provided for that purpose in the work-holding fixture. Rough-boring of the holes of different diameters is performed by bits carried in bar *A*. Then, when the work is indexed to the next position, the combination reaming and facing tool *B* reams the three bored holes and faces both the top of the steering-gear housing and the ball bearing seat. After this has been accomplished, the work is indexed once more and the tap *C* cuts the thread in the large hole. To provide for this last operation, the tapping spindle is furnished with a hand-feed lever *D*, and after the tap has penetrated to the desired depth, it is reversed and backed out of the hole. This reversal of motion is through gearing operated by lever *E*.

In this connection, attention is called to the fact that all the auxiliary heads employed on these heavy-duty Baker Bros. drilling machines are counterweighted, the arrangement being clearly indicated at the right-hand side of the machine shown in Fig. 10. The fixture used to support the work for performing the preceding operations is interesting. The work is placed over a pilot that enters a hole bored by a preceding operation,

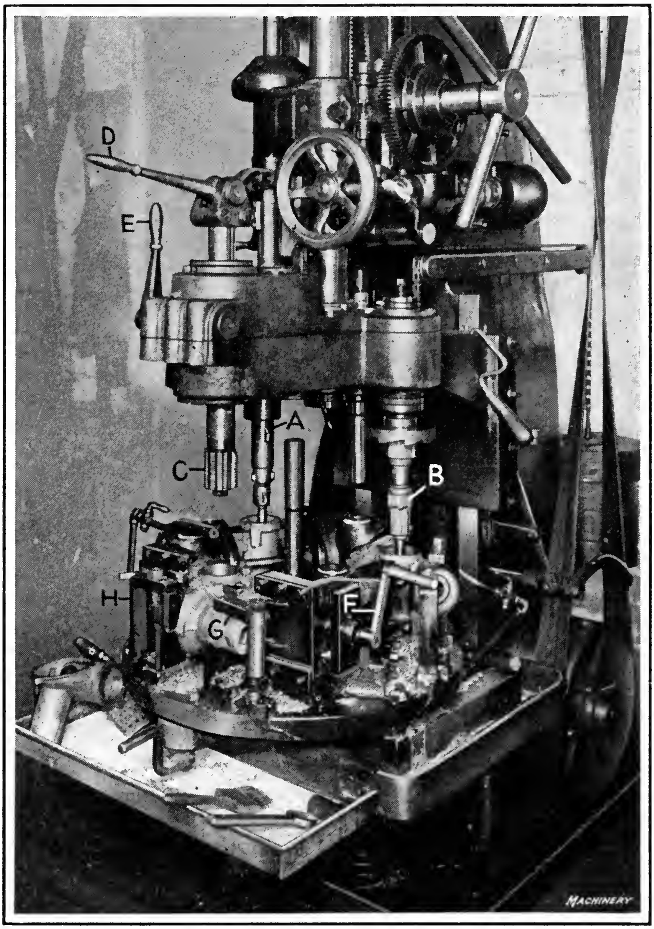


Fig. 10. High-duty Drilling Machine with Indexing Fixture and Three-spindle Head for Boring and Reaming Three Holes, Facing Two Surfaces, and Tapping One Hole

and is then clamped at either end by jaws actuated by a screw threaded right- and left-hand at opposite ends, which is turned by crank *F*. The work is further secured in place by clamp *G*, and in this connection attention is called to the second clamp *H*, which is not in use. The reason for this is interesting, as it shows an economy effected in the design of work-holding fixtures. Cars built for American use are generally equipped with the steering-wheel at the left, while those exported to Europe have the steering-wheel at the right. This makes it necessary to machine steering-gear housings for both types of design, but to avoid the necessity of an additional investment in jig and fixture equipment, or the loss of time and incidental expense which would be involved in changing from one type of work-holding fixture to another, the fixture shown in Fig. 10 is made "universal," in that it will hold either type of steering-gear housings. The only change is that, for holding a housing of the opposite hand, the piece will rest in the fixture in the opposite direction, and in that case clamp *H* will be employed and clamp *G* will remain idle. The holes bored and reamed during this series of operations are $2\frac{3}{8}$ by $\frac{13}{16}$, $2\frac{1}{16}$ by $\frac{11}{16}$, and $1\frac{1}{2}$ by $1\frac{3}{4}$ inch in diameter and depth, respectively; the first of these three holes is the one to be tapped. These pieces are made of malleable iron and the rate of production is 120 pieces per eight-hour day.

Radial Drilling Machines. — Where there are a number of holes to be drilled over the area of a piece of work that is too large or too heavy to enable all of the holes to be conveniently reached by a multiple-spindle drilling machine, use is generally made of a radial drilling machine on which the combined movement secured by swinging the radial arm and adjusting the position of the drill spindle head on this arm will enable all of the holes to be reached with a single setting of the work. Radial drilling machines are also employed in some cases where the size of the holes to be drilled and the material is such that the service would be too severe for many classes of multiple-spindle machines.

Fig. 11 shows a typical example of radial drilling machine work, which consists of drilling holes in the air-head of a blowing engine. The view shown is in the shops of the Mesta Machine Co., and the radial drilling machine is a product of the American Tool Works Co. In the Mesta Machine Co.'s shops, radial drilling machines are also used to a considerable extent for the performance of machining operations on castings of such size and weight that they sometimes exceed the maximum capacity of the 75-ton electric cranes in the shop, and in any case

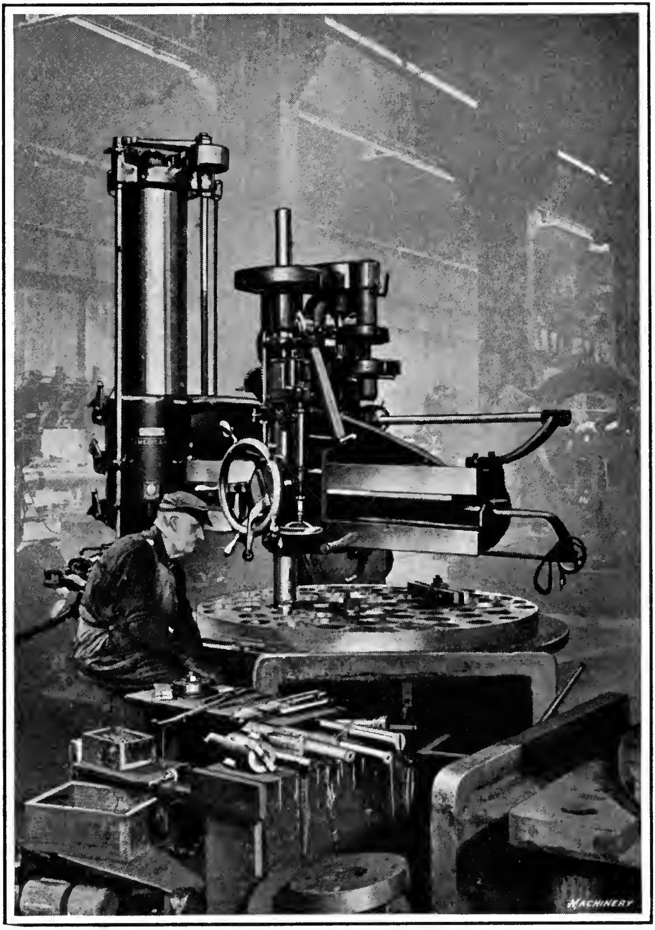


Fig. 11. Radial Drilling Machine engaged in machining Air-head of Blowing Engine

would be far too heavy to enable them to be set up on any drilling machine. For this class of work the radial drills are furnished with eyes so that they can be picked up by the crane hook and carried to the work instead of following the general practice of taking work to the machine. For handling these exceptionally large pieces which are constantly going through the Mesta shops, the use of portable machines is practically a matter of necessity; at the same time, their application has been found beneficial in that it is possible to have a number of machines working simultaneously on one of these large castings, so that the time required to complete the various machining operations is substantially reduced.

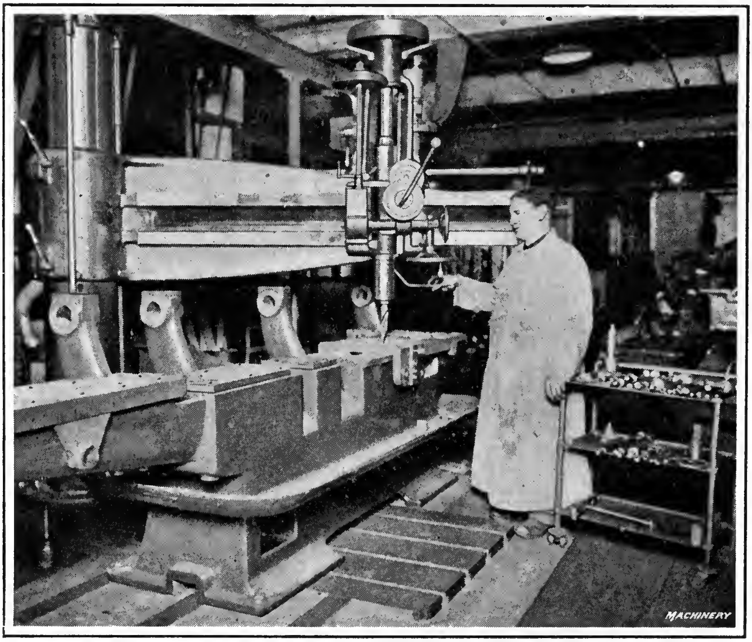


Fig. 12. Radial Drilling Machine engaged in drilling Bed of a Machine Tool

Fig. 12 shows a radial drilling machine built by the Cincinnati Bickford Tool Co. This machine is shown engaged on a typical radial drilling operation; namely, drilling all of the holes in a machine bed casting. This machine is used in the plant of the Cleveland Automatic Machine Co., where it is engaged in drilling fifty-two holes in the bed of a Cleveland automatic. The operations comprise drilling, reaming, counterboring, and tapping holes varying from $2\frac{1}{4}$ down to $\frac{1}{4}$ inch in diameter; the largest counterbore is 4 inches in diameter. The spindle of the machine is equipped with a quick-change chuck, and, located conveniently for the operator, there will be seen a portable

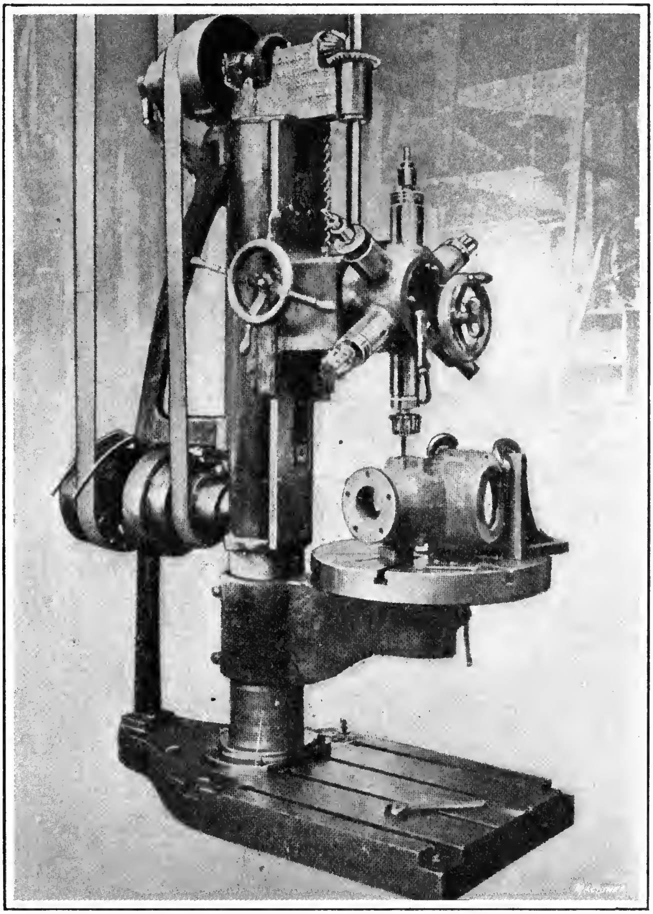


Fig. 13. Turret Type of Drilling Machine in which Turret revolves in Vertical Plane

stand on which are carried the different drills, counterbores, reamers, etc., which are required in carrying out the work.

Turret-type Drilling Machines. — Turret-type drilling machines fill the same place in the drilling machine group that is occupied by turret lathes in the lathe group. From this, it will be obvious that turret drilling machines are employed for the performance of a sequence of operations on a piece of work

Fig. 14. Turret Type of Drilling Machine in which Turret revolves in Horizontal Plane

without requiring the setting of the work to be changed. Fig.13 shows a machine, built by A. E. Quint, in which the required series of drills, counterbores, taps, etc., are mounted in spindles carried by a turret which can be revolved to bring the required spindles into successive operation. On this machine, the design has been so worked out that the only spindle which revolves is the one carrying the tool that is in the operating position. One of the chief claims made for this type of machine is that time is saved through avoiding the necessity of resetting the work for performing a sequence of operations, and by having the entire equipment for performing these operations contained in a single unit an economy is effected in both floor space and the required investment in machine tool equipment. Fig. 13 shows one of these machines in operation, and attention is called to the fact that different types and sizes of machines are provided for the performance of various classes of work.

In the turret-type drilling machines built by the Turner Machine Co., a different principle is employed for bringing the required sequence of tools into operation. Fig. 14 shows one of these machines in operation at the plant of the Greenfield Tap & Die Corporation, where it is engaged in the performance of a series of operations on threading dies. This machine is shown drilling one hole to two different diameters, and it is necessary to ream one section of the hole. The method of bringing the different tools into operation is different from that of the machine shown in the preceding illustration. Here the turret is carried on a vertical spindle, about which it revolves horizontally to index the different spindles into the working position. Only the spindle in the operating position revolves. Machines of this type are built in different sizes, so that a suitable size may be selected for handling work covering a considerable range. These machines are designed with a turret case that holds the turret rigidly against side play, and a detent and socket positively lock the turret against rotary movement. Different styles in which these machines are built provide for driving tools fitted with Nos. 2, 3, and 4 Morse taper shanks, so that machines of this type may be used for the performance of machining operations in a wide range of work.

Another equipment of somewhat the same general type is built by the Newman Mfg. Co.; the difference between this equipment and the two preceding types is that, in the present case, a turret head is provided for use on a single-spindle drilling machine. Fig. 15 shows a machine equipped in this way, from which it will be seen that the turret head is furnished with spindles for carrying the required sequence of tools. The drive is so designed that the only tool which rotates is the one in

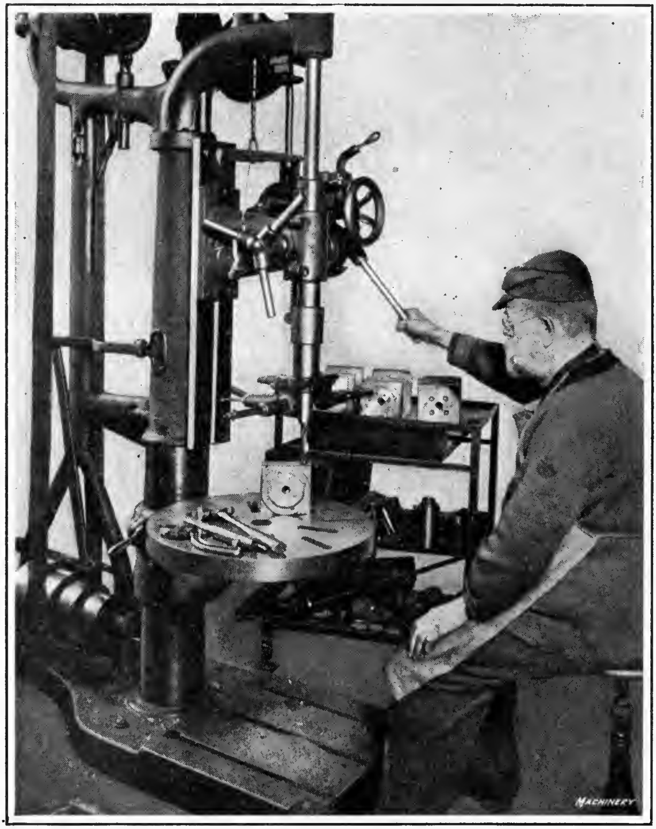


Fig. 15. Auxiliary Turret Head to adapt Single-spindle Drilling Machine for Rapid Performance of a Sequence of Operations

the operating position. The different spindles are held in place by a locking mechanism and may be quickly changed to bring successive tools into the operating position. A sleeve on the head is attached to the quill surrounding the drilling machine spindle, and provides for locking the head at the proper height. These drilling machine turret heads are made in two sizes for No. 2 and No. 4 Morse taper shanks; they are also made to hold straight shanks, if so desired.

CHAPTER II

MULTIPLE-SPINDLE DRILLING MACHINES OF STANDARD AND SPECIAL DESIGN

THE vertical drilling machine is commonly built with from one to six spindles, and the terms "multiple spindle" and "gang" are used somewhat indiscriminately in referring to machines of this type. Probably the best opinion favors the use of the term "gang" in cases where separate drilling machine units with individual drive are bolted to a common bed casting, while the term "multiple spindle" is understood to designate machines of this type on which all of the spindles are carried in a machine frame of unit construction and are driven by a common driving shaft. In any case, the use made of both gang and multiple-spindle machines covers two general classes of work. In one of these the machine is employed for the performance of a sequence of operations on a piece of work which is passed along from spindle to spindle. On work of this type one or more operators are employed, according to the length of time required to perform the various drilling, counterboring, and tapping operations. The other general class of work handled on straight-line multiple-spindle or gang drilling machines is where it is required to drill a number of holes in a piece, a case in point being where a line of holes is to be drilled in a pipe. For operations of this kind the machines are so equipped that all of the spindles feed down and return together.

To obtain efficient results in the performance of drilling operations, the keynote of success in securing a satisfactory rate of production is often found in a satisfactory solution of the problem of properly balancing the ratio of drilling time to setting-up time. If proper means are not provided to reduce setting-up time, this will often become so excessive that the production of the machine is far below the normal rate which ought to be secured. For work where there are a large number of holes to be drilled, profitable use may be made of multiple-spindle drilling machines. These are built with different numbers of spindles, arranged in a "cluster," and furnished with the necessary adjustment to enable the spindles to be set in the desired positions for drilling different groups of holes. The possibility of drilling a number of holes simultaneously, after setting up the work once, is obviously the means of greatly increasing the productivity of the machine.

Multiple Drilling Machines of Straight-line Type. — In connection with the introductory statement concerning the classes of work handled on multiple-spindle drilling machines of the straight-line type, mention was made of the fact that such machines are commonly employed for either simultaneously drilling a number of holes located in a straight line in a piece of work, or else that the machines are arranged to perform a sequence of operations on parts which are set up successively under the different spindles of the machine. In the latter case, the operator moves progressively from spindle to spindle, removing drilled pieces and substituting blanks in their place ready to be drilled.

Fig. 1 shows a special multiple-spindle machine of the straight-line type built for the Willys-Overland Co. by the Foote-Burt Co., which is engaged in the performance of drilling operations on connecting-rods. Here the work is of such character that two spindles are required for drilling each piece, but the length of these operations is sufficient so that a four-spindle machine may be employed to allow the operator to busy himself setting up work under one pair of spindles, while the other pair is engaged on the drilling operation on another part. In this way the operator is kept constantly employed. The work-holding fixtures used on this machine employ two principles which are often used in jig and fixture design for locating and securing the work in place. The small end of the connecting-rod is pushed into a V-block, which locates it under the drill, and after this has been done, a bell-mouthed bushing, through which the other drill operates, is screwed down onto the large end of the connecting-rod, thus locating this end in place to be drilled and also clamping the work in the fixture. With an arrangement of this kind the time involved in setting up the work is reduced to a point where lost time becomes unimportant. The material to be drilled is drop-forgings, the large hole being 2.188 by 1.688 inch deep; and the small hole is 1.123 by $1\frac{5}{16}$ inch deep. The operation is performed at a speed of 325 revolutions per minute and a feed of 0.005 inch per revolution; the production is 720 crankshafts per eight-hour day from each machine.

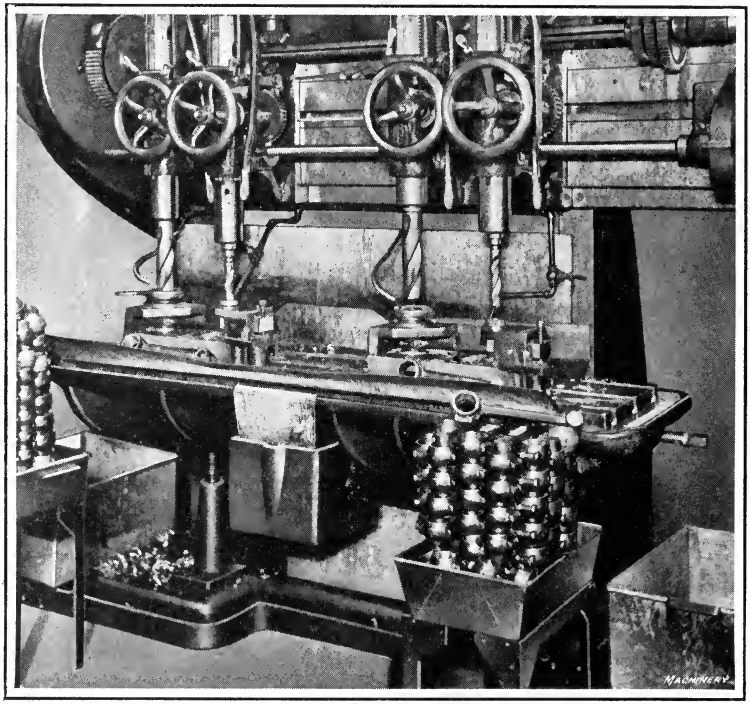


Fig. 1. Four-spindle Drilling Machine engaged in simultaneously drilling Both Holes in Two Connecting-rods

For use in drilling and tapping nose adapters for shrapnel cases, excellent results have been obtained with an equipment consisting of two four-spindle drilling machines built by the Washburn Shops. These machines are of the power-feed type and are placed back to back, as shown in Fig. 2, with metal covered shelves extending across the ends of the machines to provide for sliding jigs from one machine to the other. The work consists of drilling two holes, each of which must subsequently be tapped, the sizes being $\frac{3}{8}$- and $\frac{3}{16}$-inch tap holes. The interesting feature of this installation is the careful way in which plans were made to increase production as far as possible. About three dozen jigs were supplied and the " team " which operates this pair of machines consists of ten operatives, one at each of the spindles and one stationed at each end shelf, whose duty it is to remove finished pieces from the jigs and substitute fresh blanks. A piece is placed in a jig by one of the men stationed in the loading position, and this piece is passed along from spindle to spindle, so that the two holes are drilled and tapped by the four spindles of one machine unit. This piece is then removed from the jig and a fresh blank substituted, after which the jig is pushed across the shelf to the four men operating the machine at the opposite side of the group. In this way, each jig goes round and round in a continuous circuit, and there is practically no loss of time. The order in which the operations

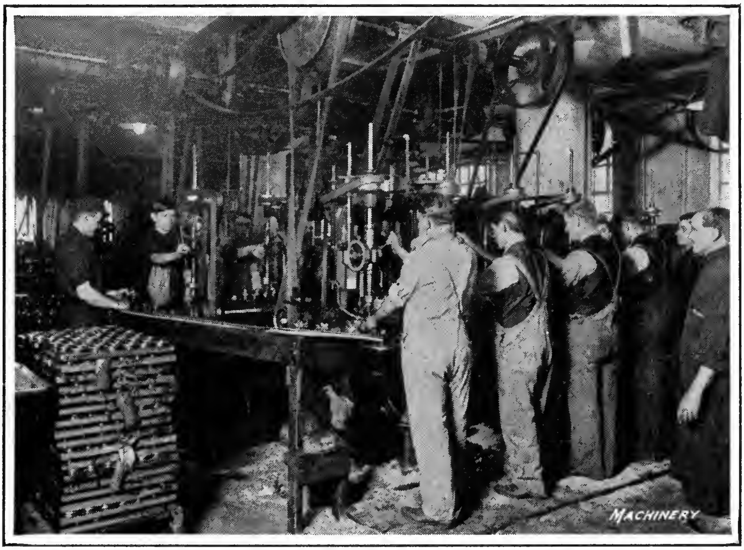


Fig. 2. Battery of Two Four-spindle Drilling Machines operated by " Team " of Ten Men for Drilling and Tapping Holes in Fuse Parts

are performed is as follows: Drill $\frac{3}{8}$-inch hole, drill $\frac{3}{16}$-inch hole; tap $\frac{3}{8}$-inch hole and tap $\frac{3}{16}$-inch hole. These men work ten hours a day on a piece-work basis, and the normal rate of production is about 5500 pieces per working day for each gang. At times the production was increased to a considerable extent, but this is regarded more in the light of a " spurt " than normal operating conditions.

Sliding Jigs for Multiple-spindle Operation. — In the plant of the Hupp Motor Car Co., heavy-duty drilling machines, built by the Colburn Machine Tool Co., are used for drilling and reaming connecting-rods. A gang of four machines is used equipped with a special combination table or track on which the jigs are slid along from one spindle to another, the arrangement being clearly shown in Fig. 3. Looking at the spindles from right to left, the first spindle at the right drills out the hole at the large end of the connecting-rod and the second spindle reams this hole; the third is a reserve spindle, the use of which will be explained later, and the fourth spindle drills the hole in the small end of the connecting-rod. One operator attends to the whole battery of machines, and after he has started a drill working on one hole, he goes along to the next jig and gets it ready for operation. The jigs are never lifted, it being merely necessary for the operator to remove the drilled connecting-rod and insert a new forging after each operation.

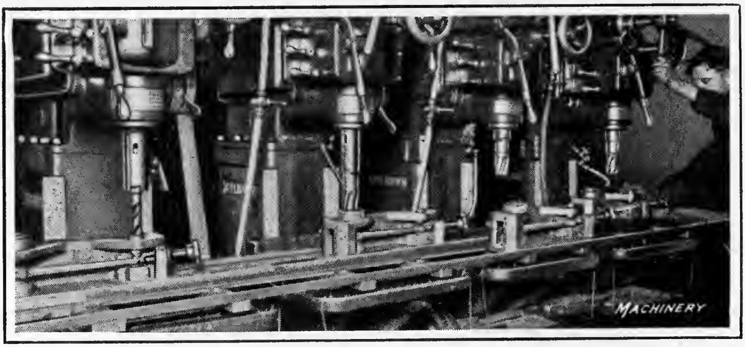


Fig. 3. Gang of Four High-duty Drilling Machines equipped with Sliding Jigs for Drilling Connecting-rods. One Spindle is held in Reserve to Substitute as required

By having the drilling machines independently belted, it is possible to obtain any speed for any particular requirement, and should a break-down occur on any spindle, the other three spindles are not affected, as would be the case with a multiple-spindle machine of the straight-line type. In case of emergency, the reserve spindle may be quickly changed over to either tool that requires this spindle, so that production is not held up. The way in which the connecting-rods are held in the jigs is apparent from the illustration. Both ends of the rod rest on finished pads in the jig, and, by tightening the clamping screw, the large end of the rod is forced between the ends of two converging studs that form the equivalent of a V-block. The clamping screw is inclined slightly downward so that it holds the work down on the supporting surfaces of the jig. The drop-forgings to be drilled contain from 0.035 to 0.045 per cent of carbon. The hole to be drilled in the large end of the rod is $2\frac{1}{16}$ inches in diameter by $1\frac{3}{8}$ inch deep; and the hole in the small end of the rod is 0.864 inch in diameter by $\frac{7}{8}$ inch deep.

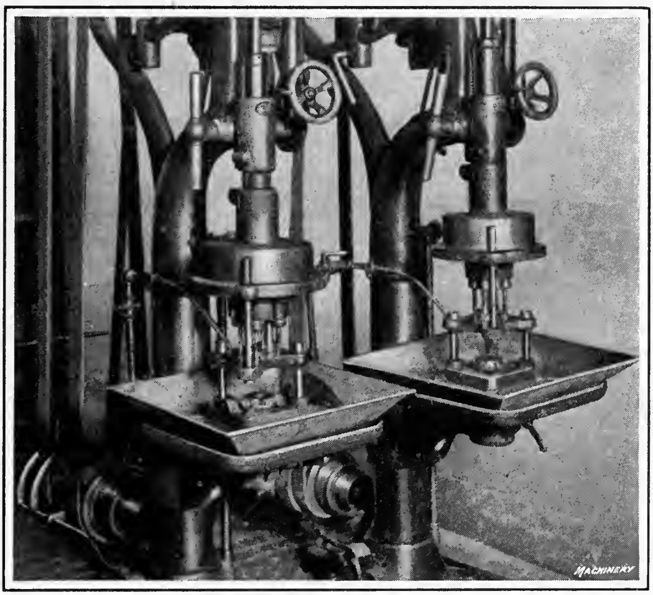


Fig. 4. Vertical Drilling Machines with Multiple Heads

The rate of production secured on this job is 400 connecting-rods in a nine-hour working day.

Vertical Machines equipped with Multiple-spindle Drill Heads. — Fig. 4 shows an installation of vertical drilling machines built by the Rockford Drilling Machine Co., and equipped with multiple-spindle drill heads. The feature of this equipment is the provision of a jig-plate carried by the drill head, as shown in detail in Fig. 5, which gives a view of the jig construction. This jig-plate comes down to the points of the drills, so that adequate support is provided during the intervals at which the drills are being started into the work; then the jig-plate remains on the work while the drills are fed in to the desired depth. While the drilling machine spindle is raised, the head carries the jig-plate up with it, so that there is no obstruction to hinder the operator in removing work from the fixture. The way in which this result is secured is as follows: When the drilling machine spindle is raised, heads at the lower ends of rods *A*, carried by the multiple head, lift the jig-plate. These arms are so adjusted that the jig-plate is held with its

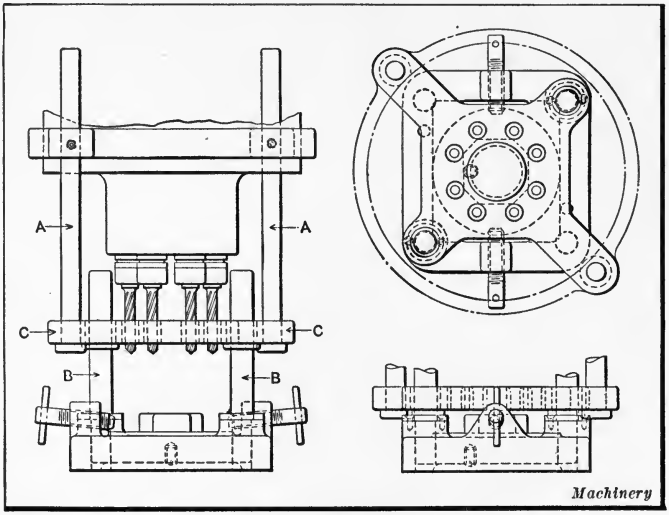


Fig. 5. Multiple-spindle Drill Head provided with Jig-plate that is Lifted with Head when Spindle of Drilling Machine Rises in Order to Facilitate Removal of Work from Fixture

lower surface just above the drill points, as shown in Fig. 4. When the drills are fed down to the work, the jig-plate drops until further movement is retarded by flanges on rods *B* carried by the work-holding fixture. In this position, the jig continues to support the drills, but the drills may be fed through to the desired depth. It will be apparent that jig-plate *C* is furnished with the usual arrangement of hardened steel bushings; and the work is held in the fixture by an arrangement of clamps as shown in the illustration. The drill heads shown on the machines in Fig. 4 are of four- and eight-spindle types, respectively, and the work to be drilled consists of two types of universal joint rings. The holes drilled by the four-spindle head are $\frac{5}{16}$ inch in diameter by $\frac{3}{8}$ inch deep, and the holes drilled by the eight-spindle head are $\frac{5}{16}$ inch in diameter by $\frac{1}{2}$ inch deep. The material is drop-forgings containing from 0.025 to 0.035 per cent of carbon. The rate of production is from 1400 to 1500 rings in a ten-hour working day.

Compressed Air for Ejecting Work from Fixtures. — Mention has already been made of the increased importance of designing fixtures to provide for the rapid handling of work on account of the reduction in drilling time which has been made possible through the design of high-speed machines. Fig. 6 shows the fixture used on a machine equipped with a two-spindle head which is used for drilling holes 0.107 inch in diameter in disks shown at *A*. A feature of this equipment is the provision for rapid handling of the work. A supply of disks is kept in feed-trough *B*, and as soon as one piece has been engaged by the drills, the operator lays his thumb on a second piece and starts to advance it to the drilling position. Location of the work is very simple, as it is merely necessary to slide the work into the notch *C*, which locates it under the drill spindles. When the drilling operation has been completed, the operator removes his thumb from the piece of work and reaches for another piece. As the spindle on the machine rises, a blast of compressed air through tube *D* blows the drilled work off the fixture and it drops through opening *E* into a receiver. At the back of the drill head is located a stud *F* that engages a trip which actuates air-valve *G* to provide for the admission of air into tube *D* at the proper time to eject the work. Such an apparatus may be worked very rapidly.

Multiple-spindle Drilling Machines of Cluster Type. — Machines which will be discussed under this heading may be roughly subdivided into standard and special equipments. Standard multiple-spindle drilling machines are built by several firms and are practically universal in their application, in so far as drilling holes over an area within their range is concerned. The only limitation in the use of these machines is in regard to the minimum distance between centers of different holes that must be drilled. As compared with this condition, there is the special-purpose multiple-spindle drilling machine which is adapted for the performance of one specific manufacturing operation; machines of this type are being used to good advantage in the performance of drilling operations on automobile crankcases, etc., but it necessarily follows that a plant that can afford to buy a single-purpose multiple-spindle drilling machine must

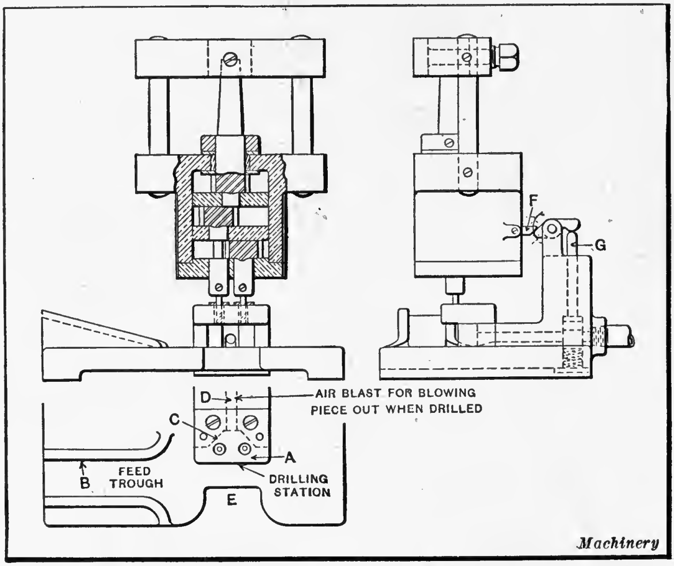


Fig. 6. Work-holding Fixture provided with Automatically-operated Air Ejector to Discharge Work through Chute into Receiver placed under Drilling Machine

have a large volume of work in order to be able to earn a fair return upon the investment. After reading the following description of operations performed on machines of each type,

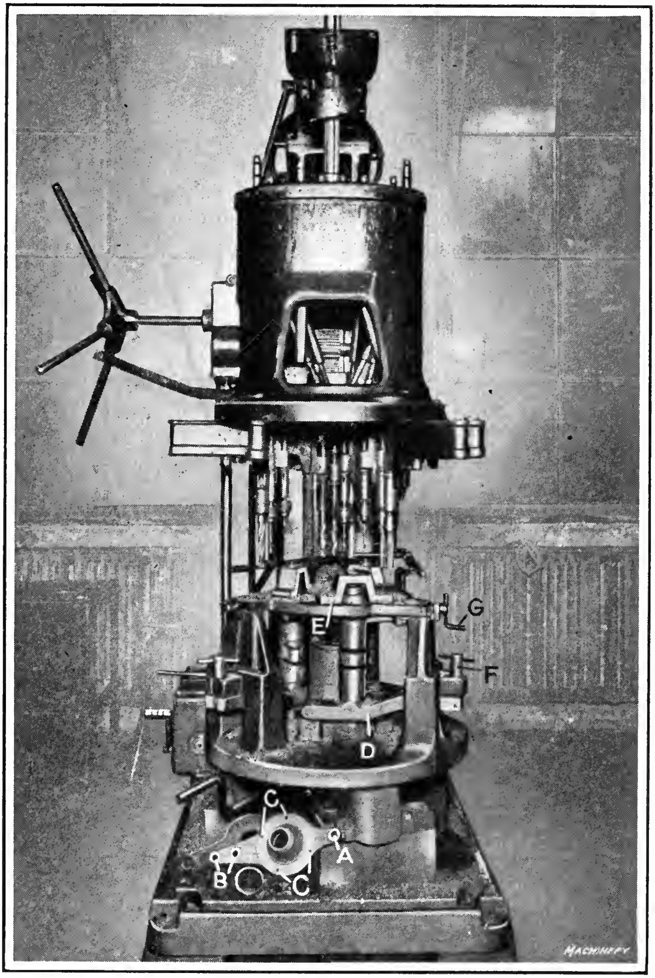


Fig. 7. Ten-spindle Drilling Machine engaged in drilling and reaming Rear Axle Spiders

the reader will have a good idea of the scope of work that comes within the province of the cluster-type multiple-spindle drilling machine.

Indexing Fixture on Machine of Cluster Type. — Fig. 7 shows one of the No. 14 "Natco" multiple-spindle drilling machines built by the National Automatic Tool Co.; this machine is used at the plant of the Willys-Overland Co. for drilling and reaming one hole $\frac{3}{4}$ inch in diameter by $1\frac{3}{8}$ inch deep and two holes $\frac{5}{8}$ inch in diameter by 1 inch deep; in addition, four $\frac{17}{64}$-inch holes, $\frac{7}{32}$ inch deep, are drilled in the flange of the rear axle spiders, but these holes are not reamed. This installation is somewhat exceptional in that it involves the use of an indexing fixture on a multiple-spindle drilling machine. This fixture is furnished with three stations, one of which is a loading station; at one station, the three large holes are drilled and two of the $\frac{17}{64}$-inch holes are also drilled, and at the third station, the three large holes are reamed while the other two $\frac{17}{64}$-inch holes are drilled. Evidently this calls for the use of a ten-spindle drilling machine with the spindles arranged in two groups of five spindles each. In the first group there are one $\frac{3}{4}$-inch drill, two $\frac{5}{8}$-inch drills, and two $\frac{17}{64}$-inch drills; in the second group, there are one $\frac{3}{4}$-inch reamer, two $\frac{5}{8}$-inch reamers, and two $\frac{17}{64}$-inch drills. The arrangement of these holes in the work will be apparent after studying the piece shown lying at the base of the machine just under the fixture. The $\frac{3}{4}$-inch hole is shown at *A*, the two $\frac{5}{8}$-inch holes at *B*, and the four $\frac{17}{64}$-inch holes at *C*.

The preceding description has explained the manner in which the indexing fixture carries the work under the two groups of spindles, in order to provide for drilling and reaming three holes and drilling four other small holes. The arrangement of this work-holding fixture is quite interesting. A pilot carried on pivoted bar *D* enters the hole in the lower end of the work and raises the work so that a pilot carried by frame *E* enters the upper end. After the pivoted bar *D* has been clamped by T-screw *F*, the work is secured in the fixture, as regards its vertical position. It is still necessary, however, to locate the work about its vertical axis so that all seven holes *A*, *B*, and *C* will be properly positioned in the spider. This is accomplished by a sliding V-block, which is pushed over the end of the work adjacent to the $\frac{3}{4}$-inch hole *A* by means of screw *G*.

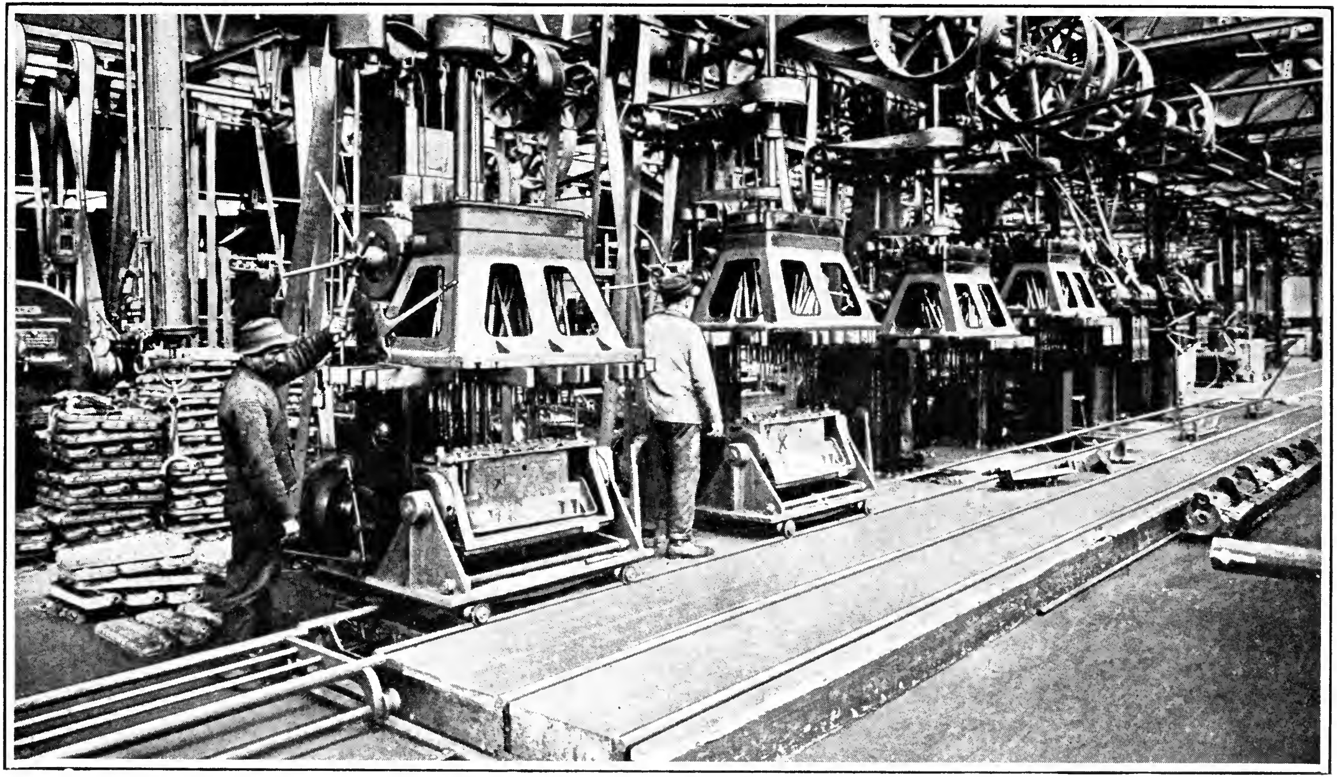


Fig. 8. Traveling Jigs used in Connection with Multiple-spindle Drilling Machines for Machining Automobile Engine Cylinder Blocks

There are three complete sets of mechanism corresponding to each of the three stations on the work-holding fixture, and for each traverse of the multiple-spindle drill head, one spider is finished, so that the operator may remove one piece at the loading station and substitute a fresh blank. These spiders are made of malleable iron and the rate of production is 960 pieces per eight-hour working day. Owing to the length of time required to load pieces into this fixture, the speed and feed at which the operation is performed are less than would ordinarily be employed for drills and reamers of these sizes. This loss is partially offset by the fact that more parts are obtained for each grinding of the tools.

Traveling Jigs used in Conjunction with Machines of the Cluster Type. — At the plant of the Continental Motors Co., there is an interesting equipment of multiple-spindle drilling machines built by the Baush Machine Tool Co. These machines are used for the performance of drilling operations on the engine cylinder blocks, and to facilitate handling of the work as far as possible an interesting arrangement of traveling jigs has been developed. Reference to Fig. 8 will show that each of these fixtures is carried on a truck running on tracks that pass along under the heads of the multiple-spindle drilling machines. The jigs are supported on trunnions in the truck frames, which make it possible to swing the work around to provide for the performance of drilling operations in different planes on the work. Each drilling machine is equipped with a cluster head in which the spindles are grouped to provide for simultaneously drilling all of the holes in one face of the cylinder block. After the groups of small holes have been drilled, the work goes on under straight-line multiple-spindle drilling machines which provide for drilling the valve-stem holes, valve push-rod holes, etc. The work is then removed from the jig and the empty truck is run onto a section of track, which, in turn, is supported on truck wheels so that the track may be moved over into alignment with the return track rails, which will be seen in the foreground of the picture. As the truck jig moves down this track a new casting is put in place, after which the jig is moved along onto a second transfer truck on which it is moved over to the rails which will carry it under the drilling machines for the performance of successive operations. With this arrangement, it is possible to employ a sufficient number of reserve jigs, so that work may be constantly available for the machines as fast as they complete operations on a given cylinder block. Conse-

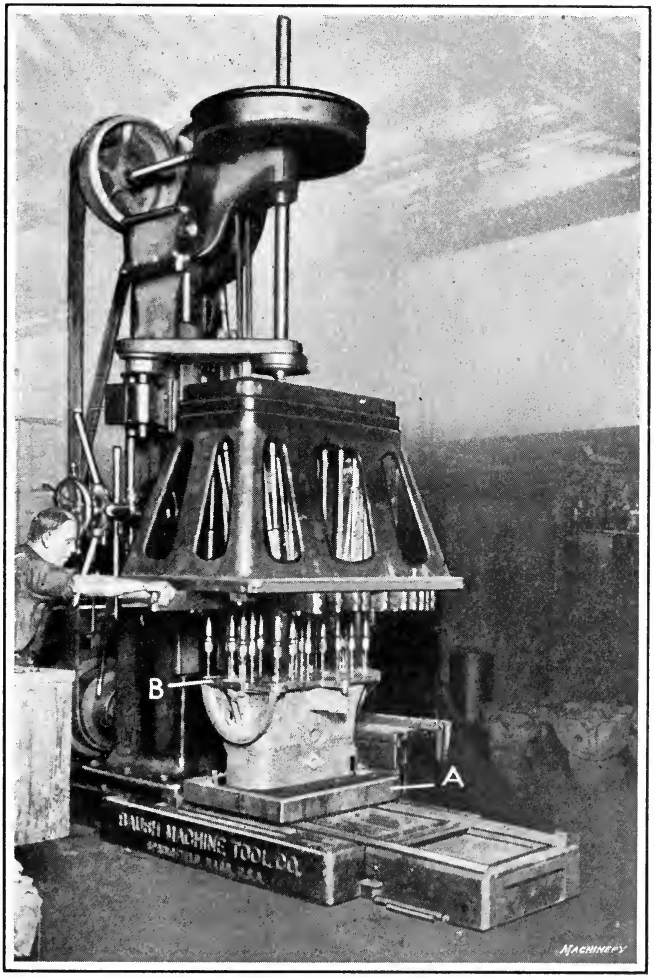


Fig. 9. Multiple-spindle Drilling Machine equipped with Sliding Fixture to Facilitate Loading Casting in Fixture and Removing Drilled Work

quently, idle time of the machines and operators is reduced very close to the absolute minimum.

Sliding Fixture applied to Machine of the Cluster Type. — Fig. 9 shows another application of a Baush multiple-spindle drilling machine on cylinder block work. In this case, the machine is employed in the plant of the Lozier Motor Co., and the arrangement of the work-holding fixture and the jig-plate brings out two principles which are of interest. In the first place, the base *A*, on which the work is supported, is mounted on ways which enable it to be slid out from under the multiple-spindle drill head to provide for the convenient removal of drilled work and the substitution of a fresh casting. The other point of interest in connection with this work is the use of a jig-plate *B*, which is secured to the work to provide for maintaining a posi-

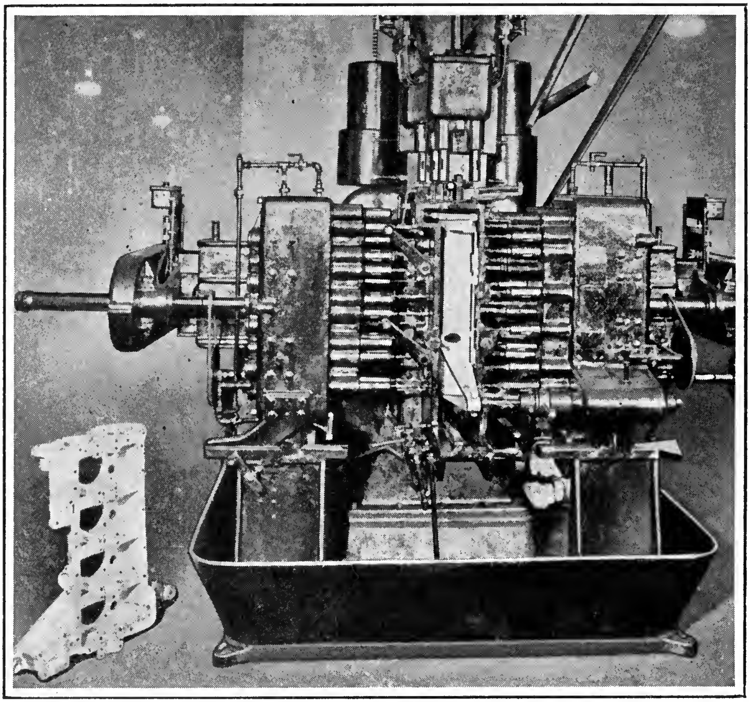


Fig. 10. Three-way Multiple-spindle Drilling Machine for Drilling Eighty-four Holes in Automobile Crankcase at One Setting

tive relation of the drills to one another. This idea of employing a jig-plate which is secured to the work, instead of having the jig part of a work-holding fixture which carries the piece to be drilled, may be employed in many cases with very satisfactory results.

Special Multiple-spindle Machines. — In addition to the universal multiple-spindle machines previously described, there is a very important group of cluster-type multiple-spindle drilling machines which are designed and built to meet the requirements of specific manufacturing operations. In these machines the spindles are not usually made adjustable, because they are intended for one given class of work, and each spindle is properly located to drill the particular hole in the work for which that spindle has been provided. Fig. 10 shows a three-way multiple-spindle drilling machine built by the Foote-Burt

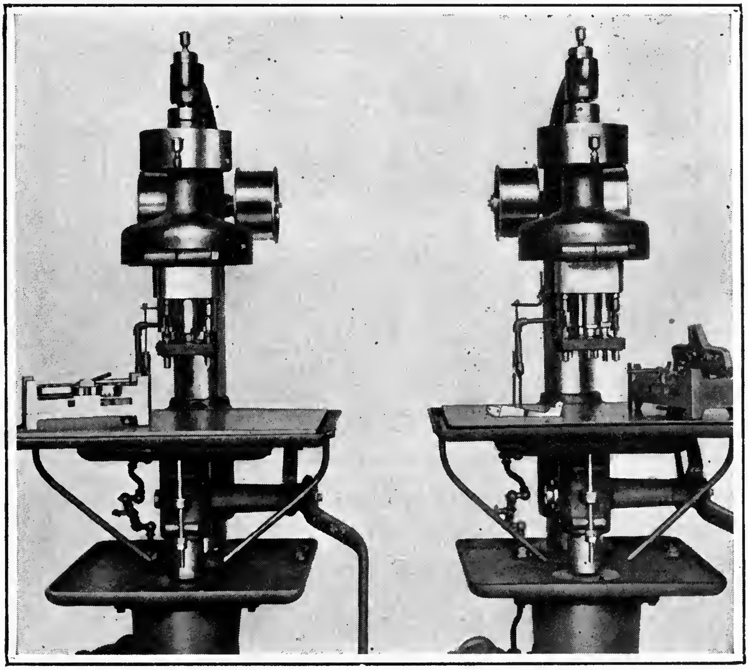


Fig. 11. Multiple Drilling Machines used in Couples for Drilling, Reaming, and Counterboring Holes in Floor-plate of Rifle Receivers

Co. for use in simultaneously drilling all of the screw holes in the upper half of a Willys-Overland crankcase. The material is aluminum, and this machine provides for drilling eighty-four holes at a single setting of the work. An idea of the remarkable rate of production secured through the possibility of simultaneously drilling such a large number of holes will be gathered from the fact that 480 crankcases are drilled in an eight-hour working day. This machine is so designed that the different sizes of drills are driven at approximately the correct speed and feed.

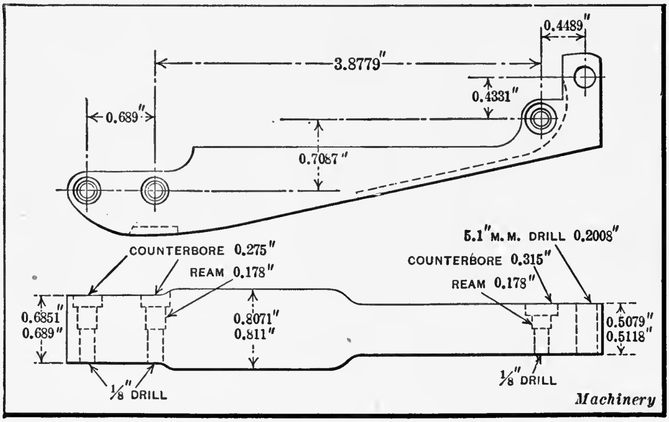


Fig. 12. Rifle Receiver Floor-plate which is drilled, reamed, and counterbored in Machines shown in Fig. 11

Special-purpose multiple-spindle drilling machines of the cluster type are built for a great variety of work, although the automobile industry represents the most important field in which these machines are employed. The reason for this is that it would not pay to invest in an expensive machine of this kind, unless the volume of work to be drilled were sufficiently great so that it would be found profitable to build special machines for handling the work. Among the parts which are frequently drilled on special-purpose multiple-spindle drilling machines, the following may be mentioned: cylinder blocks, transmission cases, flywheels, crankcases, crankshafts, differential frames, wheel hubs, cover plates, etc.

Drilling, Reaming, and Counterboring on Multiple-spindle Machines. — Fig. 11 shows two Langelier multiple drilling machines used in couples for drilling, reaming, and counterboring four holes in the floor-plate of a foreign rifle. The operations are performed without removing the work from the jig. The drilling is done with the machine at the left in two operations, and the reaming and counterboring with the machine at the right in two operations. Fig. 12 shows the floor-plate. Three of the holes are drilled, reamed, and counterbored; the fourth is only drilled. The holes are drilled half way through from each side, the meeting of holes not being important, as the floor-plate is afterward slotted as shown by the dotted lines. To produce the greatest possible output from these machines, an operator is required for each machine, while a third loads and unloads the jigs. A set of three jigs is used; thus the machines are continually at work. Fig. 13 shows the lay-out of spindles in the drilling head for the two drilling operations. This head is in the machine to the left in Fig. 11. The group of four spindles that carry the 5.1-millimeter and the three No. 17 drills is used for the first operation with the cover side of the jig down. The four that carry the 5.1-millimeter and the three $\frac{1}{8}$-inch drills are used for the second operation with the cover side up. The

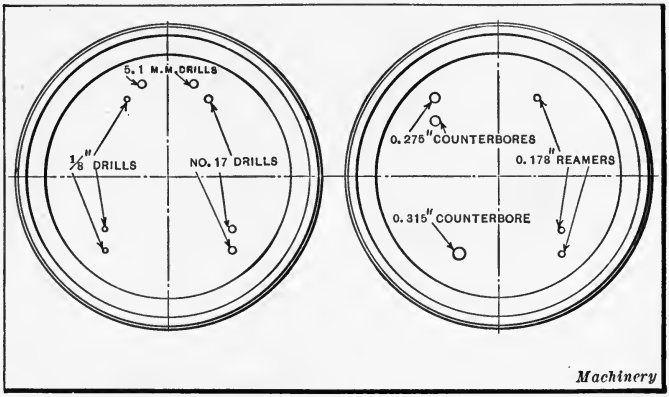


Fig. 13. Lay-out of Spindles in Drilling Head

Fig. 14. Lay-out of Spindles in Reaming and Counterboring Head

$\frac{1}{8}$-inch holes are not reamed. The jig is then carried to the second machine.

Fig. 14 shows the lay-out of spindles in the drilling head in the machine to the right in Fig. 11, which is used for reaming and counterboring. The group of three spindles carrying the 0.178-inch reamers does the reaming with the cover side of the jig down. The group of spindles carrying the two 0.275-inch and one 0.315-inch counterbores does the counterboring with the cover side of the jig down.

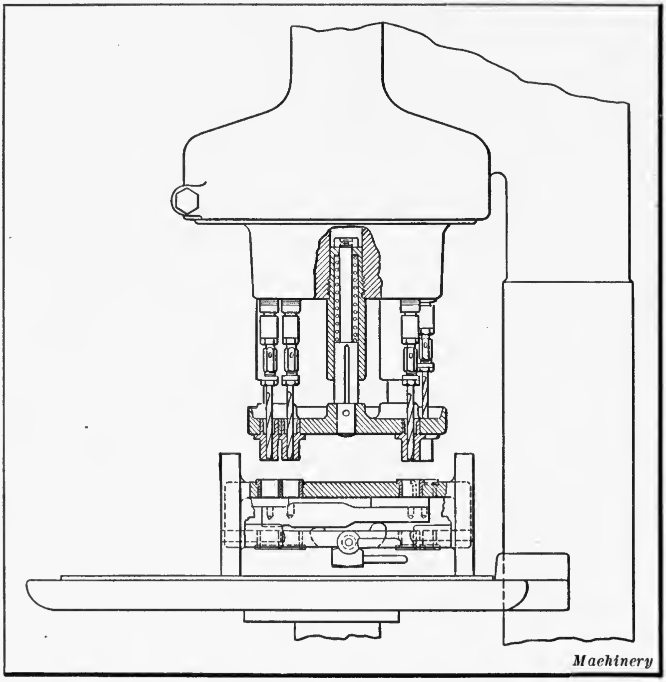


Fig. 15. Partial Side Elevation of Drill Head used on Machine at Left in Fig. 11, showing Sub-jig and Jig in Position for First Drilling Operation

Fig. 15 is a partial side elevation showing the drill head with its sub-jig attached and the jig on the table of the machine in position for the first drilling operation. The sub-jigs on the two machines are the same in principle. The bushings in the sub-jig guide the tools, and the bushings in the jig guide the sub-jig.

By this method, each of the drills, reamers, or counterbores has its own guide bushing, and the use of interchangeable slip bushings in the jig is avoided. The sub-jig is attached to the drill head under the compression of a spring. When the sub-jig comes in contact with the work jig, it is forced upward while the drilling, reaming, or counterboring takes place. The sub-jigs can be quickly removed by unscrewing two tapering thumb-pins so as to provide free access to the tools, if required. All of the spindles are provided with adjusting screw collets so as to compensate for the grinding of tools, also for individual adjustment for depth of holes. The jigs are of the swing cover type, compensating means and stops being incorporated for accurately locating and holding the work while it is operated upon. The machines are of the round column and base type. The table has a working surface of 21 by 14 inches, which is ample for the handling of the jigs. It is trunnioned into a supporting arm that is clamped to the column and can be adjusted to the required working position. The trunnion of the table has a rack which meshes with a pinion shaft having bearings in the supporting arm and to which is attached the long feed hand-lever. A single feed-stop is provided for the table for both operations.

Station-type Multiple-spindle Drilling Machines. — The battery of Baush multiple-spindle drilling machines shown in Fig. 8 is used in conjunction with a traveling jig as previously described, which carries the work from one machine to another in order that advantage may be taken of the possibility of performing a number of groups of operations without the necessity of resetting the work. When the importance of the savings that are possible through the use of such an arrangement has been fully appreciated, it will be apparent that a still further benefit would be secured by the combination of different groups of spindles in a single machine that would provide for saving time by avoiding the necessity of frequent resetting of the work, and at the same time economizing in floor space through having the entire outfit contained in a single unit. This is the idea that has been successfully accomplished through development of the " station type " of multiple-spindle drilling machines which are built by the Baush Machine Tool Co. Machines of this type were first constructed for the use of the Ford Motor Co. in drilling all of the holes that are required in flywheel castings. The complete machine for doing this work is shown in Fig. 16, and Figs. 17 to 19, inclusive, show, respectively, the loading station where

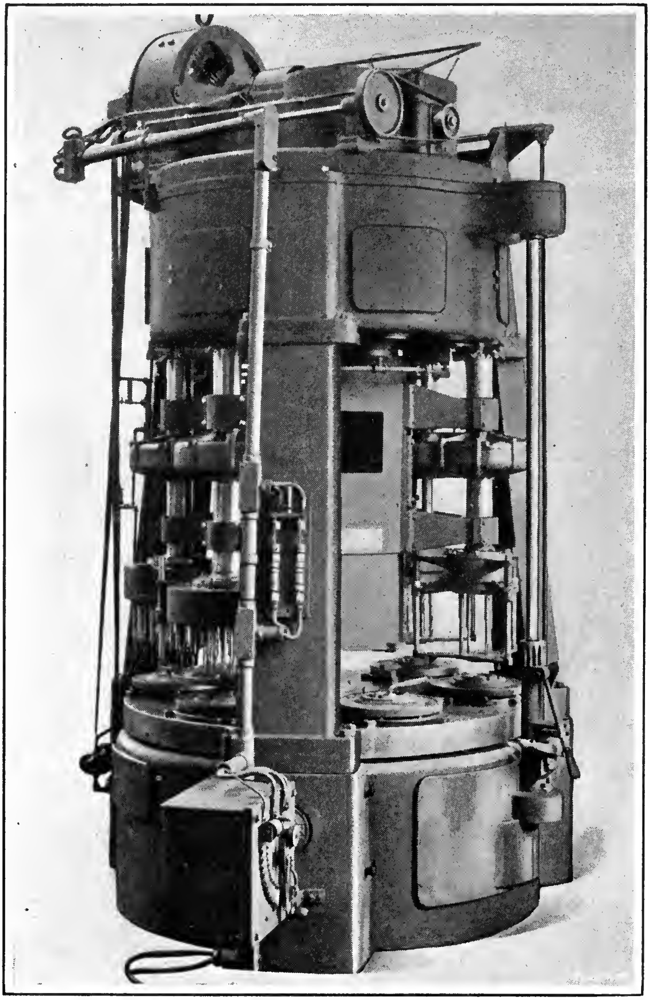


Fig. 16. Station-type Multiple-spindle Drilling Machine built for Performing Eighty-one Drilling, Counterboring, and Reaming Operations on Ford Flywheels

the work is set up on the machine, a view of two multiple-spindle drill heads, and a view of heads equipped with tools for the performance of drilling and reaming operations.

In operating the machine, each flywheel is placed on a supporting block and secured by means of an expanding center.

Fig. 17. View of Loading Station of Drilling Machine shown in Fig. 16

The loading station on the machine is illustrated in Fig. 17, and in this view the wrench used for expanding the center on which the flywheel is held will be clearly seen in position. The counterbore in the wheel is used to locate the work under each jig, this result being obtained by a tapered leader which enters the counterbore as the jig at each station on the machine comes down to the working position. In addition to this counterbore, there is a flat dowel in the supporting block that registers between two jaws on the extreme outside portion of the jig, thus securing the wheel against rotation. The feed is accomplished by means of a barrel cam which is of the correct form to give a quick approach and the desired rate of feed and return. By employing different cams, suitable rates of feed may be employed for the tools in different heads. The table is rotated by a mechanism which also lifts it, thus allowing the weight to be carried on a center pintle, while it is in motion, and the provision of ball bearings in this connection makes it possible for the table to be easily moved. A hardened steel locking bolt is

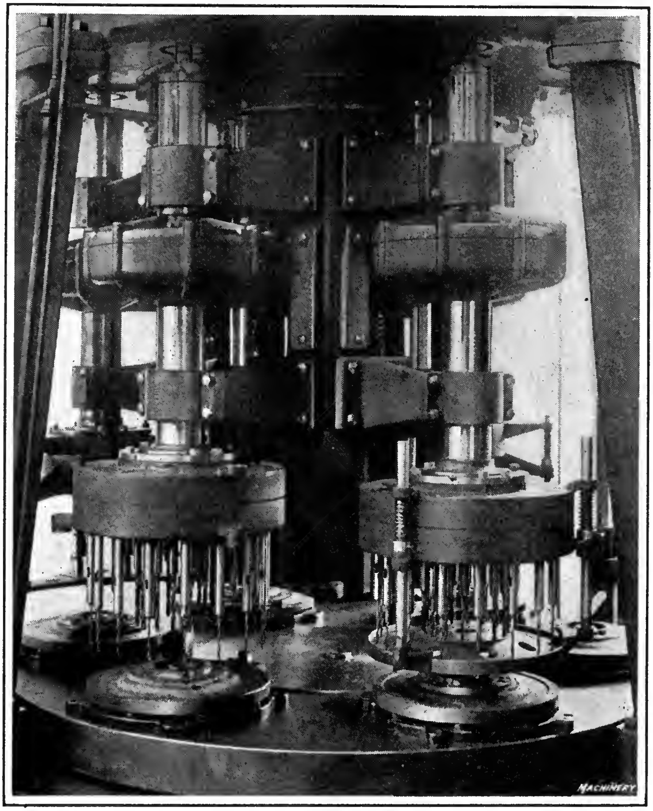


Fig. 18. Close View of Multiple-spindle Drill Heads

provided, which is actuated by a cam and comes into play just before the table is lowered to its working position, where the bolt locks the table in place.

When in the working position, the table rests on a circular rail which is slightly smaller than its outside diameter, this rail being carried up inside a flange at the periphery of the table to protect the bearing from chips. One central oiling system is provided which delivers lubricant to all bearings, the pump taking the oil from a tank in the base and circulating it through a system of piping provided with return connections. There are eighty-one drilling, counterboring, and reaming operations

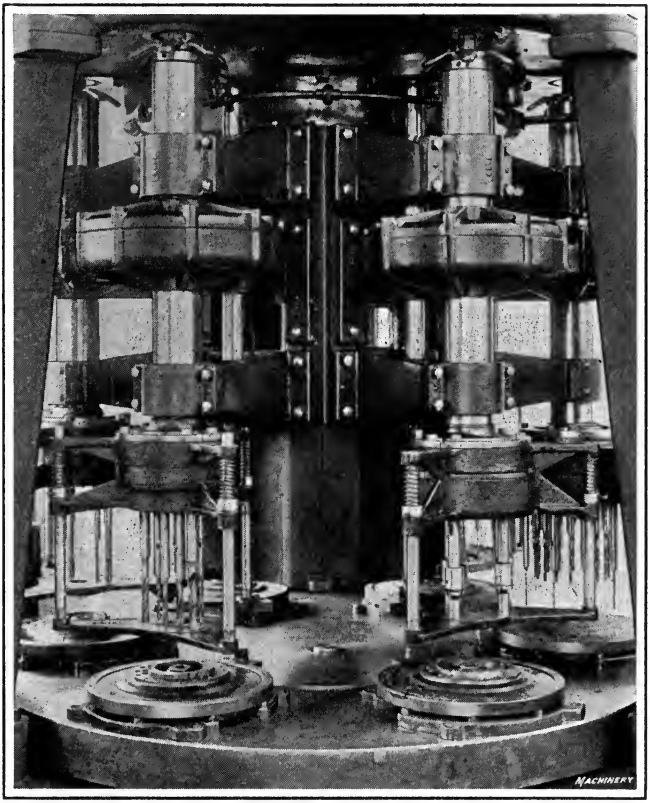


Fig. 19. Drill Heads equipped with Tools for Drilling and Reaming Operations

to be performed on the Ford flywheel, and with this machine it is found possible to perform all of these operations in fifty-four seconds. Each machine has a capacity for drilling 500 flywheels in an eight-hour working day, the actual rate of production being 510 flywheels in 450 minutes.

The operations consist of drilling sixteen $\frac{21}{64}$-inch holes in the inner circle through $1\frac{1}{8}$ inch of metal, and sixteen $\frac{1}{4}$-inch holes in the outer circle half way through the same thickness of metal; second, counterboring the sixteen holes in the inner circle to a diameter of 0.386 by $\frac{3}{16}$ inch deep, and drilling the holes in the outer circle through the remaining metal, a 0.204-inch drill being used for this purpose which cuts through $\frac{7}{16}$ inch; third, counterboring three half round faces 0.936 inch in diameter by $\frac{3}{8}$ inch deep in the hub of the wheel; fourth, drilling four holes 0.386 by $\frac{5}{8}$ inch deep, two holes $\frac{27}{64}$ by $\frac{5}{8}$ inch deep, and three holes $\frac{21}{32}$ by $\frac{7}{8}$ inch deep; fifth, reaming three holes 0.675 inch in diameter by $\frac{7}{8}$ inch deep and two holes 0.436 inch in diameter by $\frac{5}{8}$ inch deep.

While the discussion of the work of this machine is presented in connection with its application in machining the flywheels of Ford motor cars, it must not be thought that this is a single-purpose machine, because there are a great many classes of work that could be handled on an equipment of this type with beneficial results. Not only is the use of this machine responsible for saving a lot of space in the shop, but it will be apparent that its use also presents the possibility of drilling holes on centers that would be too close for an ordinary multiple-spindle drilling machine. Where the center distance is so close that it would be impossible to arrange spindles in a cluster head to provide for drilling them with a machine of this type, one hole may be drilled by one head and the next hole by a following head, so that the question of distance from center to center becomes relatively unimportant. The multiple-head feature also makes it possible for heavy and light drills to be grouped together in different heads, so that each size may be operated at suitable rates of cutting speed and feed. Different standard spindle clusters may be furnished to meet the requirements of different classes of work, and these heads may be readily removed to enable different ones to be substituted. The regular adjustable drill heads built by the Baush Machine Tool Co. can also be used to adapt the machine for more or less general classes of

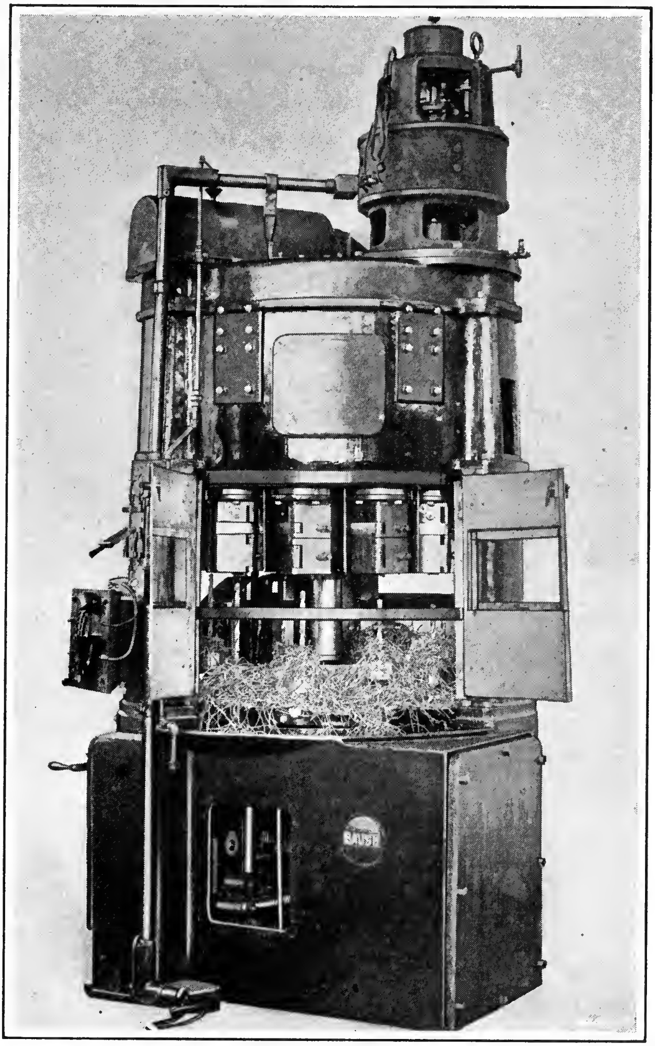


Fig. 20. Station-type Drilling Machine for Drilling Rifle Bolts and Receivers

multiple drilling. A switch and starter are located beside the loading station, which enable the operator to control the motor with his left hand, while the feed mechanism is governed by a small lever at the right-hand side of the operating position. By means of this lever, it is possible to stop all the feed motions of the machine instantly, including the indexing of the table.

Station-type Machine equipped with Inverted Drills. — The station-type drilling machine shown in Fig. 20 was designed and built by the Baush Machine Tool Co. for drilling the bolts and receivers of military rifles. At first sight, this machine may appear similar to the preceding type for drilling automobile flywheels, but as a matter of fact there are noteworthy points of difference. On the preceding type of machine the drills are carried in multiple heads and the work is mounted on an indexing table supported by the base of the machine. In the present case, the work is supported in fixtures carried by the spindles of an indexing turret, while the tools are carried on a fixed spider. In both cases, the drive is from above, but in the case of the present machine the work revolves and the tools remain stationary. Advantage is taken of the inverted drilling principle, which is beneficial in clearing chips from the work. Feeding the drills to the work is accomplished by raising the spider on which the drills are carried. The drills increase progressively in length in order to obtain the required depth of hole, and it will be evident that for each indexing of the work one finished part is produced. The use of various lengths of drills serves the same purpose as backing out the drill at the required intervals, which is the practice in deep-hole drilling operations where a single drill is employed. On this machine the drills used are of the oil-tube type, which provide for delivering oil direct tho te cutting point of the drill. Drive is provided by an electric motor at the top of the machine, from which power is transmitted to the spindles which carry the work-holding fixtures by means of a central gear meshing with pinions on each of the spindles. Feed motion is furnished by a barrel cam, which provides for raising or lowering the spider that carries the drills. Indexing is accomplished by rotating the turret that carries the work-spindles; and the release of the locking bolt that secures this turret in place, during the performance of each drilling operation, is accomplished by means of an edge cam carried at the bottom of the feed cam.

Five-spindle Machine with Indexing Fixture. — In the operation of multiple-spindle drilling machines, where it is necessary to perform a sequence of operations in order to complete a piece of work, the development of means for attaining the highest rate of production from the machines involves taking into account the relative time required for the performance of the different operations necessary to complete drilling the work. For instance, if the piece to be machined has one short hole

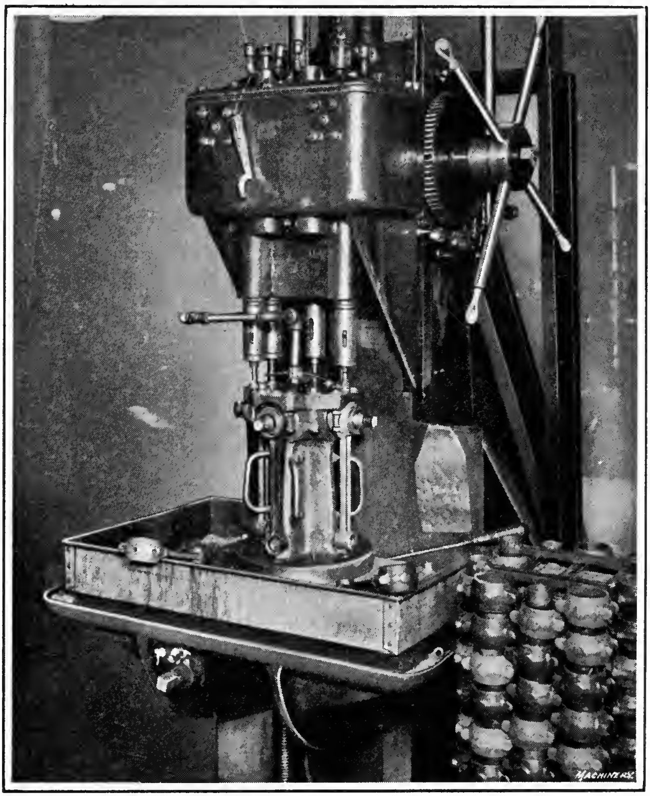


Fig. 21. Special Drilling Machine built for Drilling Bolt Holes and an Oil-hole in Connecting-rods

which can be rapidly completed and one deep hole which takes more time to drill, due consideration must often be paid to that fact in laying out the method of handling the work. If this is not done, the machine engaged in drilling the shallow hole will be idle for a substantial portion of the day, and hence will be earning only a part of the possible return on the money invested in it. An example of how provision has been made for taking care of a set of operations which vary considerably in length is shown in Fig. 21, which illustrates a special Foote-Burt multiple-spindle drilling machine built for the Willys-Overland Co. for use in drilling two bolt holes and an oil-hole in the large end of the connecting-rods. To arrange the work so that the time required for drilling the two deep bolt holes will not represent the limiting condition, the machine was designed with five spindles and an indexing work-holding fixture.

A connecting-rod forging is put in place at the loading station, after which the fixture is indexed to bring this piece under the first pair of drilling spindles. These spindles cut half way through the bolt holes, after which the work is indexed to a second pair of spindles which complete drilling these holes. The work is then indexed once more to bring it under a single spindle which drills the oil-hole, and the fourth indexing brings it back to the loading station, where the drilled piece is removed and a fresh forging substituted. For each indexing movement one finished piece is drilled, and by dividing the drilling of the deep bolt holes between two pairs of spindles, a balance is secured between the time involved in drilling these holes and that required for drilling the oil-hole, so that none of the spindles on the machine is kept idle for a substantial length of time. The work is located on this fixture by pilots fitting into the two bearing holes that were drilled by a preceding operation, and a C-washer at the upper end secures the work without making it necessary to do more than loosen the bolt sufficiently to slip this washer out so that the work may be lifted over the nut. The material consists of drop-forgings and the connecting-rods are drilled at the rate of 720 per eight-hour day from each machine. The two bolt holes are $\frac{25}{64}$ inch in diameter by $1\frac{11}{16}$ inch deep, and the oil-hole, which is for a $\frac{1}{8}$-inch pipe tap, is $\frac{23}{64}$ inch in diameter by $\frac{5}{16}$ inch deep. The drilling operation is performed at a speed of 325 revolutions per minute with a feed of 0.005 inch per revolution. The slow speed at which this operation is performed is due to the fact that it is necessary to hold the distance between each bolt hole center and a corresponding milled surface on the connecting-rod, and if the drills are forced, there will be danger of their "running out."

Auxiliary Multiple Drilling Heads and Drill Speeders. — There should be a clear understanding of the difference between the terms "auxiliary multiple drilling head" and "drill speeder." The former type of equipment is used in connection with a single-spindle drilling machine to provide for simultaneously drilling a number of holes, and the latter is employed for speeding up a small drill which is used for drilling oil-holes or small tap-holes in large castings that are being handled under a heavy drilling machine. The use of such a machine is necessary for drilling the large holes and also to provide for reaching these small holes in large pieces of work. As the spindle speeds provided on high-duty drilling machines are too slow for the efficient operation of small drills used for drilling tap-holes, oil-holes, etc., it is necessary to provide for the performance of such operations by making use of a drill speeder, which is simply an auxiliary drill head mounted on the drilling machine spindle and provided with gearing that gives the increase of speed necessary for driving small drills at the proper number of revolutions per minute.

As compared with these conditions, auxiliary multiple drilling heads may be provided with the necessary arrangement of gearing to increase the speed of the drills, to drive these drills at the same speed as the machine spindle, or to make a variation in the speeds of different sizes of drills carried in the head. The arrangement of gearing in any drilling head will depend entirely upon the particular conditions which must be met. The spindles of auxiliary multiple drilling heads used on sensitive high-speed machines usually run at the same speed as the drilling machine spindle.

Application of Multiple Drilling Heads. — The following instance is, perhaps, typical of the classes of work for which auxiliary multiple drilling heads are employed.

A certain firm engaged in machining clutch rings for several different automobile manufacturers often has orders for several thousand of each kind of ring, but it may only be possible to obtain a few thousand drop-forgings for these rings at one time. Experience has shown that it is economical to employ single-spindle drilling machines equipped with auxiliary multiple heads for each different type of ring to be drilled. These heads can be readily interchanged to adapt the same machines for drilling different types of rings. The increased production possible with machines equipped in this way, as compared

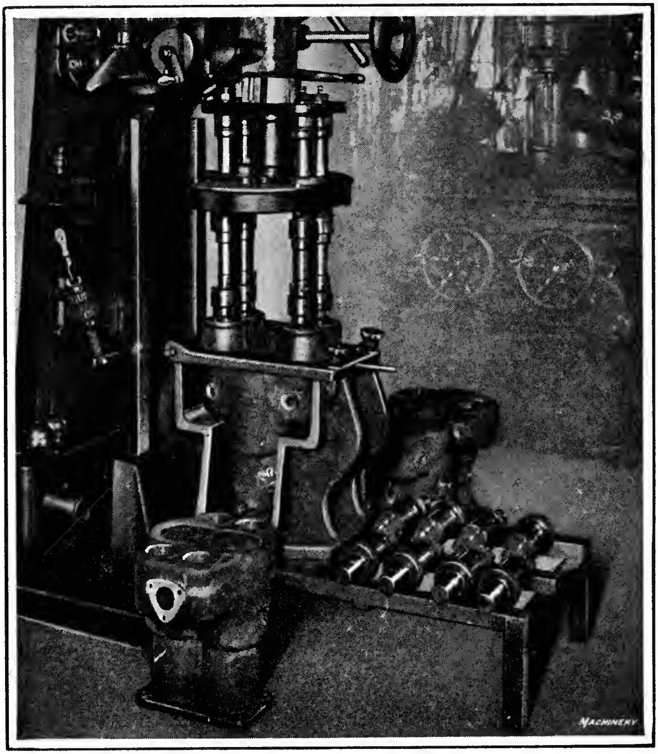


Fig. 22. Four-spindle Auxiliary Drill Head for Machining Motor Cylinder Blocks

with the use of single-spindle machines, will be readily understood when it is learned that the production was increased from 290 rings per day for one man on a single-spindle drilling machine to 2700 rings per day from a machine equipped with an auxiliary multiple head. The preceding instance is typical of the use which is made of auxiliary multiple heads; namely, to enable a single-spindle drilling machine of moderate cost to drill several holes simultaneously. In cases where holes of different sizes have to be drilled at the same setting, it is necessary to have special gearing to provide for driving different drills at the proper cutting speeds. Fig. 22 shows a four-spindle drilling head built by the Sellew Machine Tool Co., which is used in the plant of the Peerless Motor Car Co. for machining motor cylinder blocks. In this case, the drilling machine is rather heavy and the head is of correspondingly rugged construction.

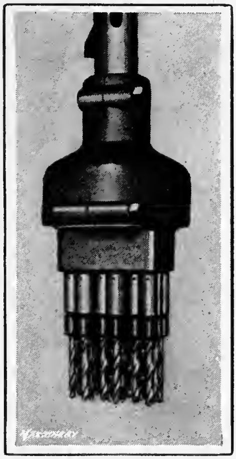


Fig. 23. Eighteen-spindle Auxiliary Drill Head

Fig. 23 shows an eighteen-spindle auxiliary head that was designed and built by the Langelier Mfg. Co., for drilling and countersinking in multiples the ninety-five holes of the center group in the radiator support shown in Fig. 24. The illustration shows a cold-rolled steel plate $\frac{1}{8}$ inch thick by $2\frac{9}{16}$ inches wide and $22\frac{1}{2}$ inches long. The six end holes in the plate are punched and the $\frac{17}{64}$-inch holes are drilled and countersunk with the multiple head. Fig. 24 also shows the arrangement of the spindles in the drilling head. These spindles are located to correspond with every other hole in the plate in a group of thirty holes; this staggering of the spindles was necessary in order to obtain a strong spindle construction. Each group of thirty holes in the plate is drilled and countersunk in two operations. The plate has ninety-five holes and the attachment drills them in groups of thirty holes, two operations being required to drill each group. There are three groups, and the remaining cross-row of five holes has to be drilled singly. Eighteen holes can be drilled and countersunk in five seconds. The plate is held and moved to its different drilling positions by an indexing fixture that is fastened to the table of the drilling machine. The lengthwise movement of the fixture corresponds to the shift between groups and the crosswise index to the $\frac{1}{2}$-inch movement required for the two operations in each group. For each of the two operations on a group of thirty holes, fifteen of the eighteen spindles in the head are in operation and the drills carried by the other three spindles hang over the side of the work.

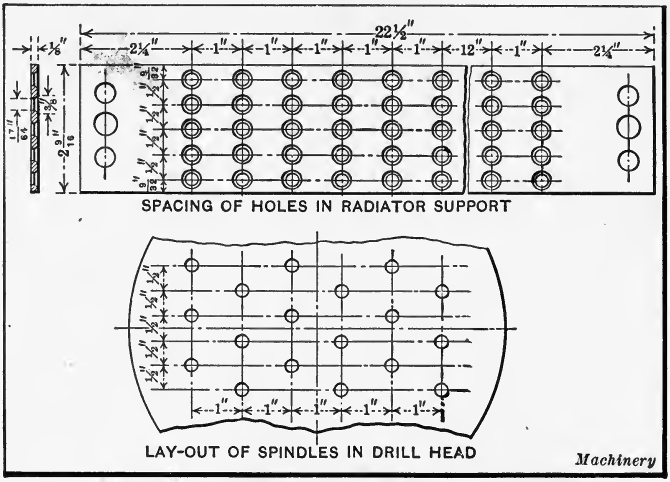


Fig. 24. Radiator Support in which Holes are drilled with Head shown in Fig. 23 by traversing Work Sidewise and Lengthwise between Successive Operations. Below is shown Layout of Spindles in Drill Head

The tools used are a combined drill and countersink. The shanks are squared and fit into a square socket in the spindle collets. Adjustment of the tools for producing uniform countersinking is obtained by an adjusting screw that is tapped into the squared end of the tool and butts against the bottom of the square socket in the collet. This requires the tool to be taken out and may seem a slow method of adjustment, but it has been proved that, after they have once been adjusted, it is a simple matter to keep them so. The ends of the collets are taper threaded and split, and the tools are held in the collets by pinch nuts. The pinch nuts are tightened or loosened by a sleeve T-wrench which telescopes the tools. The drilling head is adjustable rotatively and can be set in any position in the housing without affecting its running. The housing is attached to the feed sleeve of the drill press by a clamp nut.

Indexing Multiple Drilling Machine. — In a certain type of intercooler tube plate, it is required to drill eighty-four $\frac{3}{8}$-inch holes, and as the plates in which these holes must be drilled are only $4\frac{7}{8}$ inches in diameter by $\frac{3}{4}$ inch thick, it will be evident that the spacing of the holes is too close to make it possible for the work to be done on any standard type of multiple-spindle drilling machine. Fig. 25 shows a special multiple-head machine built by the Langelier Mfg. Co., which is equipped with an indexing work-holding fixture; the multiple head of this drilling machine has fourteen spindles, and, by indexing the work six times, provision is made for drilling all of the eighty-four holes without loss of time in removing and resetting the work or without the necessity of spending time in laying out the holes and drilling them in a

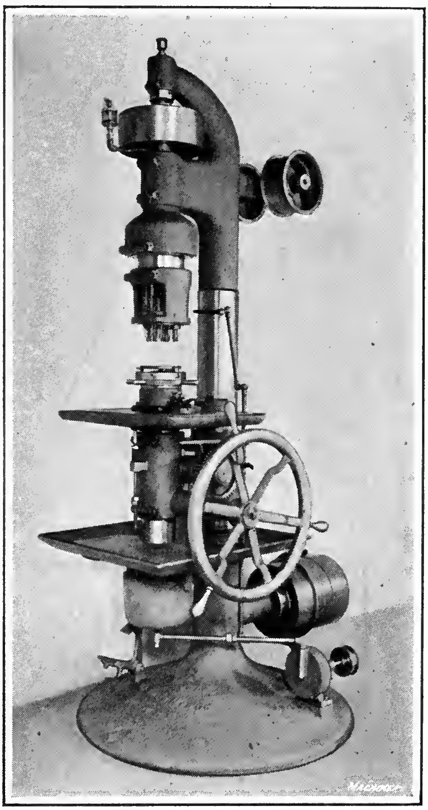


Fig. 25. Multiple Drilling Machine with Indexing Fixture to Locate Work for Six Successive Operations required to drill Eighty-four Holes, as shown in Fig. 26

single-spindle machine. Fig. 26 shows at *A*, *B*, *C*, *D*, and *E*, respectively, the condition of the work after the first, second, third, fifth, and sixth drilling operations. The piece of work after the fourth operation has been performed on it is not shown in this illustration. The distance between holes in the finished sheet is only 1¼ times the drill diameter, which shows how closely the drills have to be spaced. For holding and locating the work, the machine is provided with a three-jawed indexing fixture mounted on the table of the machine, and this fixture is laid out so that the work of indexing one-sixth revolution between each of the six successive operations may be accomplished rapidly. A machine of this kind could be built with a suitable drill head and work-holding fixture to provide for drilling other pieces where the spacing of the holes is too close to make it possible for the work to be done economically on machines of standard design.

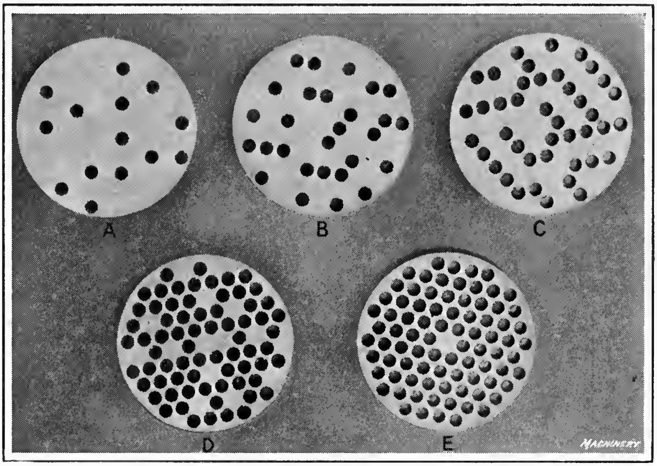


Fig. 26. Condition of Work done on Machine shown in Fig. 25, after First, Second, Third, Fifth, and Sixth Drilling Operations have been performed

CHAPTER III

AUTOMATICALLY CONTROLLED DRILLING MACHINES OF SPECIAL DESIGN

There are many classes of work where semi-automatic or fully automatic drilling machines may be used to extremely good advantage. As a general proposition, the work adapted for being drilled on machines of this class is of relatively small size, although this is not necessarily the case. With automatically controlled drilling machines, the high production secured is largely due to the possibility of effecting a great reduction in the idle time of the machine, as a result of means provided for continuous operation of the drilling machine spindle or spindles, and the possibility of having the operator constantly employed in removing drilled pieces from the work-holding fixture and substituting fresh blanks.

Five-spindle Semi-automatic Machine. — Fig. 1 shows a five-spindle semi-automatic drilling machine built by the Detroit Tool Co. The machine shown is used in the factory of the Willys-Overland Co. Two spindles are engaged in drilling a cross-hole in hood catch stems, while the other three spindles on the machine are employed for drilling a longitudinal hole in the end of torsion yoke pivot pins. In each case, the work is secured in a cam-operated V-block fixture which is tightened or loosened by a single movement of the binding lever. The five spindles on this machine are controlled by a cam-actuated feed mechanism arranged in such a way that the spindles are advanced to the work in consecutive order. This makes it possible for the operator to be constantly employed removing drilled pieces and substituting blanks in the work-holding fixtures, and by the time he has reached the fixture at the right-hand end of the machine, the piece in the fixture at the extreme left has been drilled and the spindle withdrawn; consequently the operator can start right in again removing drilled pieces and substituting blanks, this order being kept up continually.

On the hood catch stem the cross-hole is drilled with a No. 21 drill (0.159 inch in diameter) and the hole is $\frac{11}{32}$ inch deep. The drills are operated at 990 revolutions per minute with a feed of 0.002 inch per revolution; the use of this low speed is necessary on account of the larger sized drills used in the other three spindles of the machine. The production is 3600 pieces in an eight-hour working day. In drilling the longitudinal hole in the torsion yoke pivot pin, the hole is drilled to receive a $\frac{3}{8}$-inch tap and is $\frac{9}{16}$ inch in depth. The machine is operated at the same speed and feed employed for the previous operation, although the feed is really too light for this size of drill. The production is 3600 pieces per eight-hour working day.

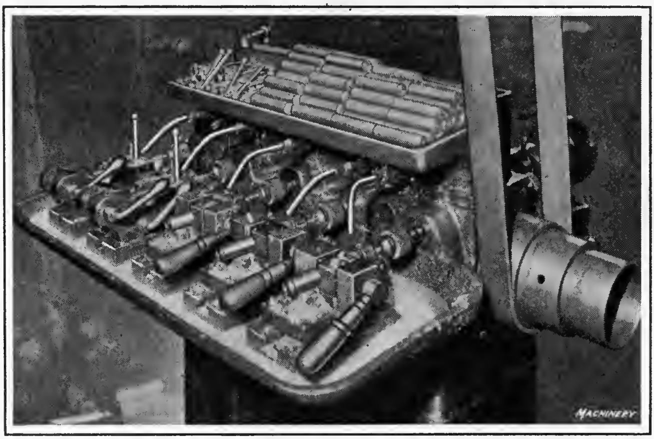


Fig. 1. Five-spindle Semi-automatic Drilling Machine

Fixture for Increasing Feed Range. — While the five-spindle semi-automatic drilling machine is shown in Fig. 1 engaged in the performance of drilling operations on two classes of pins, it must not be inferred that the scope of this machine is in any way restricted to the drilling of cylindrical shaped pieces. Where suitable work-holding fixtures are made, this machine is adapted for drilling pieces of a great variety of shapes and sizes, and in all cases advantage is taken of the ability of keeping the operator constantly employed in loading work into the fixtures while drilling operations are being performed on pieces held in other fixtures.

Where the pieces to be drilled are of such a character that the depth of hole required is in excess of the maximum feed movement provided by the throw of the cam, provision for drilling such pieces may be made by designing a special work-holding fixture of the general type shown in Fig. 2. This particular fixture was designed for drilling staybolts which are held in jaws *A*, these jaws being quickly opened or closed by means of lever *B*. The body of the fixture on which the work is supported is carried by a slide *C*, and provision is made for traversing this slide in a direction opposite to the feed movement of the drilling machine spindle by means of hand-lever *D*. In operating a drilling machine equipped with a fixture of this kind, the work is first held in the fixture with slide *C* in its position farthest away from the drilling machine spindle, and in this position the drill is fed into the work. After the hole has been drilled to the full depth in this position and the drill has been backed out of the work, slide *C* is advanced by manipulating hand-lever *D* and the fixture is secured in the forward position. Then the next time the spindle is fed forward by the cam, the drill completes cutting the hole to the required depth. Suitable fixtures

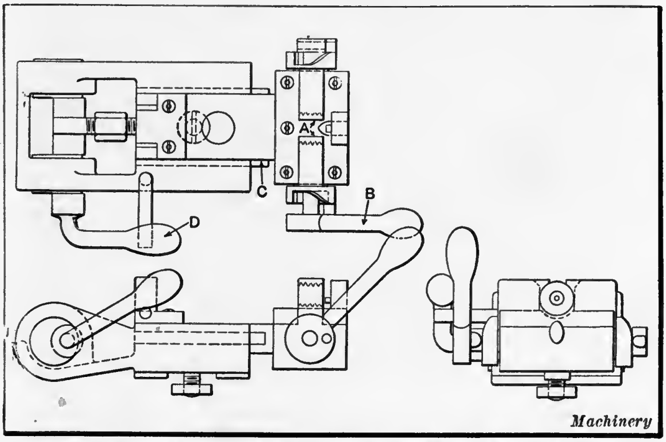


Fig. 2. Fixture for Use in Drilling Holes on Machine shown in Fig. 1

of this kind can be designed to meet the requirements of a variety of classes of work where deep holes have to be drilled.

Six-spindle Semi-automatic Machine. — A somewhat similar type of semi-automatic drilling machine to the one previously described is shown in Fig. 3, this machine being built by the National Acme Co. It will be seen that this is a six-spindle machine, and while in general appearance it resembles the one shown in the preceding illustration, the method of operation

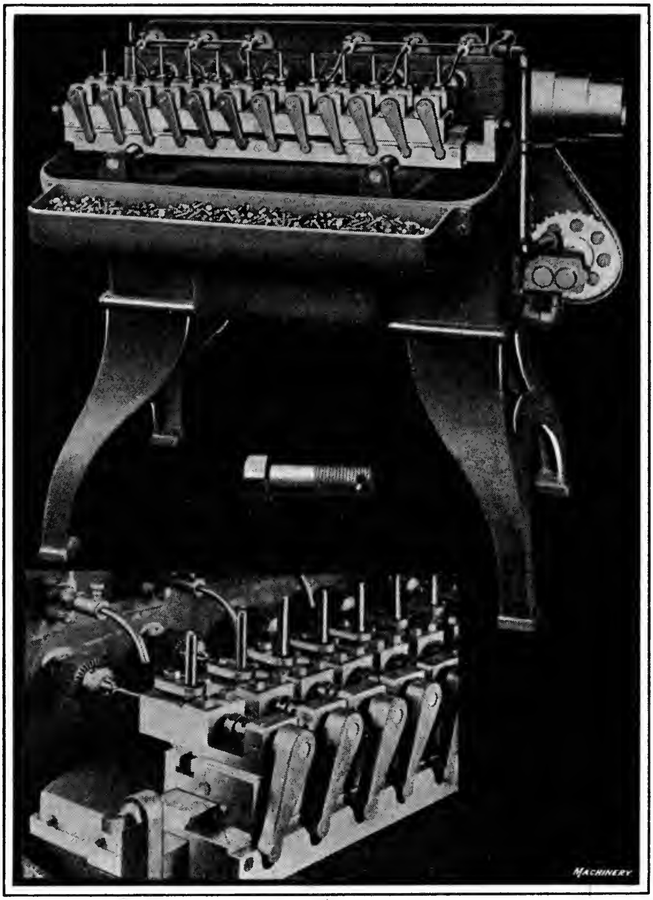


Fig. 3. Six-spindle Semi-automatic Drilling Machine with Double Work-holding Fixture which provides for Loading Six Sections of Fixture while Work is being drilled in Other Six Positions

differs considerably. On this machine, all of the spindles feed forward simultaneously, and to provide for reducing the idle time of both the machine and operator, the work-holding fixture is designed to carry twelve pieces. This fixture is arranged in such a way that while six pieces of work are being drilled, finished parts may be removed from the other six work-holding fixtures and fresh blanks substituted. When the drilling operation has been completed and the drills have been automatically withdrawn from the work, the operator rocks the work-holding fixture over on its oscillating support so that the fresh blanks are brought into the drilling position. He can then remove the drilled pieces and substitute blanks in the manner previously described. Some remarkably high rates of production are secured on these machines. For instance, at the plant of the Ford Motor Co. machines of this type are employed for drilling cross-holes in bolts of the form shown below the machine in Fig. 3. In drilling a $\frac{1}{8}$-inch hole through a $\frac{3}{8}$-inch bolt body, the machines are operated at 1500 revolutions per minute and the rate of production is 10,000 bolts per eight-hour working day. Another job performed on this machine consists of drilling a $\frac{1}{8}$-inch hole, $\frac{9}{16}$ inch deep, through the head of a bolt. Running the spindles at the same speed, the production is 6000 bolts per eight-hour day.

Semi-automatic Drilling Machine with Indexing Fixture. — In the two preceding types of drilling machines the spindles are advanced and withdrawn automatically, but the operator is required to manipulate the work-holding fixture by hand. In Figs. 4 and 5 there are shown two machines built by Baker Bros., which are equipped with an automatic indexing fixture. Near the top of the machine there is a cam-drum on which cams are mounted to provide for automatically feeding the drills into the work and withdrawing them, the amount of feed motion being regulated by the cams according to the work on which the machine is engaged. Extending down from this feed drum on the left-hand side of the machine, there will be seen a shaft which is driven by a pair of spur gears. This shaft transmits motion to an indexing mechanism located beneath the table and work-holding fixture, and by this means provision is made for continuously indexing the work-holding fixture to bring a fresh blank or blanks into the operating position to be drilled during the time that the drills are being raised ready to start the next downward stroke. With an equipment of this kind it is merely necessary for the operator to stand at the front of the machine so that he can remove finished pieces and substitute fresh blanks to be drilled.

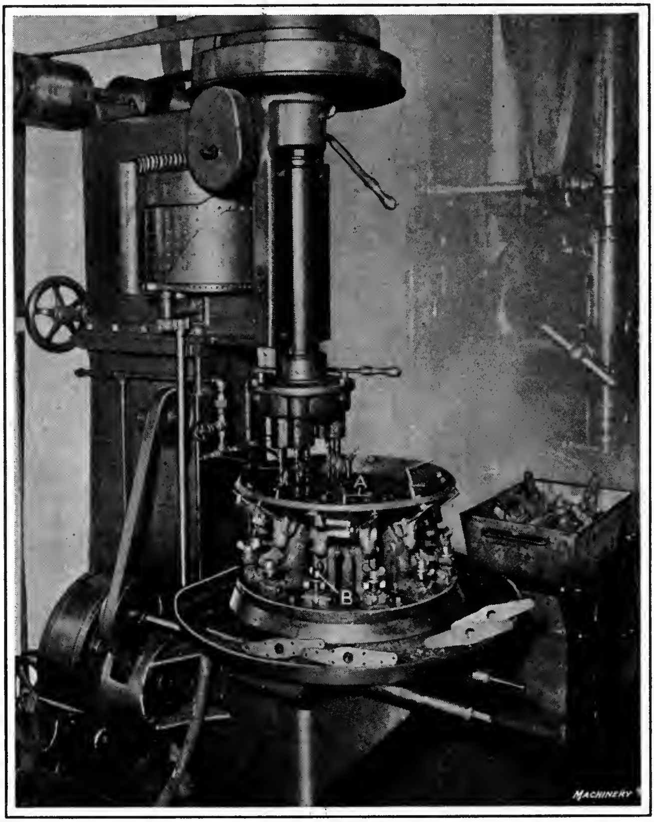


Fig. 4. Semi-automatic Drilling Machine with Station-type Work-holding Fixture which is automatically indexed

Fig. 4 shows a machine engaged in drilling external brake-band anchors in the plant of the Willys-Overland Co. The operation consists of drilling eight $\frac{13}{64}$-inch holes, which are approximately $\frac{3}{16}$ inch in depth. Four holes are drilled at one end, after which the piece is reversed end for end in the fixture, to provide for drilling the other four holes. In each case the work is located in the fixture by a pilot that enters the large central hole, but alternate stations on the fixture are designed to locate the work by different methods, according to whether the first four holes have or have not already been drilled. When the piece is first set up in the fixture, it is slipped over the pilot, entering the center hole, after which the lever *A* is turned to operate an " equalizer " that lines up the work properly; then wing-nut *B* is tightened, which results in raising a clamping

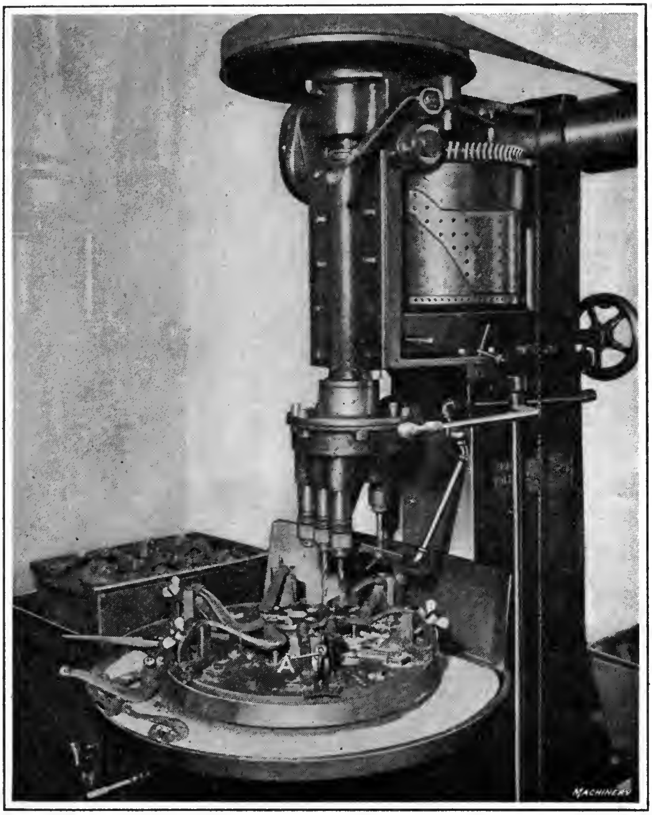


Fig. 5. Semi-automatic Drilling Machine drilling Holes in Ends of Levers

lever that secures the work in place on the under side of the jig-plate that forms the top of the work-holding fixture. In this position the first four holes are drilled, and when the piece has again come around to the front of the fixture, the operator releases the clamps, and after taking this piece out of the fixture, sets it up again in a work-holding fixture located on the next station. In this position, the work is located by a pilot entering the large center hole and by a small pin that enters one of the holes which have just been drilled. Then, by tightening the wing-nut *B*, the piece is clamped in place. At each downward movement of the spindle of the drilling machine eight holes are drilled — four in a piece which has already had the first four holes drilled and four in a fresh blank — so that one drilled piece is obtained for each traverse of the spindle. From this it will be apparent that the index mechanism is arranged so that the work-holding fixture is indexed through two stations on the fixture each time that the spindle of the drilling machine is raised. The machine is operated at such a speed that the drills run at 1100 revolutions per minute, with a feed of 0.002 inch per revolution; and operating under these conditions, 576 pieces are drilled in an eight-hour working day. The material is malleable iron.

Fig. 5 shows another application of the Baker Bros. semi-automatic drilling machines in the plant of the Willys-Overland Co. This illustration shows the operation of drilling two holes $\frac{3}{8}$ inch in diameter by 0.372 inch deep, and one hole $\frac{25}{64}$ inch in diameter by 1.120 inch deep, respectively, in the rear axle external brake-band lever. The material is malleable iron and the operation is performed at a speed of 650 revolutions per minute, with a feed of 0.003 inch per revolution. The production is 600 pieces per eight-hour working day. The drilling machine is equipped with a four-spindle auxiliary head, but only three of the spindles are provided with twist drills. This is not due to the fact that use is being made of a four-spindle head that happened to be available, but because of the necessity for drilling both right- and left-hand brake-band levers. In drilling levers of the opposite hand, the drill shown in the right-hand spindle is removed and set up on the spindle at the left hand of the central position. In the work-holding fixture used on this machine, the end of the work is located by means of a V-block, and clamping is effected by means of wing-nuts *A* which bind the outer V-block against the end of the work. Supporting pads on the fixture prevent the work from springing.

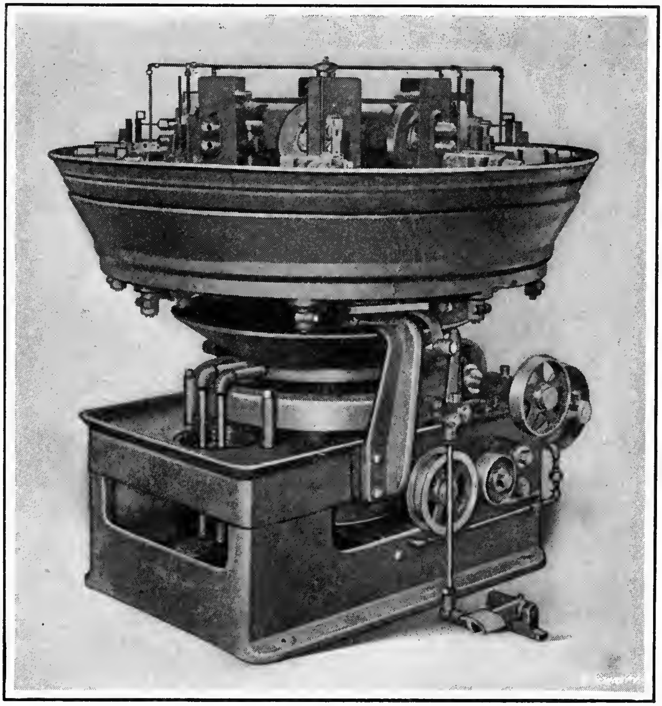


Fig. 6. Semi-automatic Continuous-feed Drilling Machine equipped for Drilling Cotter-pin Holes

Cotter-pin Hole Drilling Machine. — Fig. 6 shows a machine known as the No. 1 semi-automatic continuous-feed drilling machine, which is built by the Langelier Mfg. Co. This machine is particularly adapted for drilling small holes, such as cotter-pin holes in long pins, balls, screws, nuts, and work of a similar nature. It is built for various sizes of work, with any number of drilling heads up to and including ten. In the illustration, eight heads are shown, each head having two drilling spindles, located one above the other, making a total of sixteen drilling spindles. The piece drilled was a pin $\frac{5}{8}$ inch in diameter, having two $\frac{1}{8}$-inch cotter-pin holes crosswise through the ends, the distance between the holes being $1\frac{21}{32}$ inch. The drilling spindles feed outward as they travel around the center of the machine, the two spindles in each head drilling the two holes in the pins at the same time. Each of the drilling heads has a vise which opens and closes automatically as it passes the operator, or may be closed by the operator with a foot-pedal the instant he puts the work in the vise. Seven of the drilling heads are drilling continuously, while the eighth one is in the loading position, where the operator removes the finished piece and replaces a blank which is to be drilled. The drill is withdrawn as it passes the loading position and the corresponding vise opens automatically for the operator to remove the work and replace it with a blank. The operator can either sit or stand, as desired, while inserting fresh blanks in the vises. The vises are closed either automatically or by means of a foot-treadle.

All that the operator has to do is to remove the finished pieces and insert blanks in the vises, which can be made to hold pieces of various sizes and shapes. Either vertical or horizontal vises may be used, the style being determined by the class of work upon which the machine is to operate. When long pieces are to be drilled, the vises are made to hold the work in a vertical position, the work extending up any reasonable length that can be operated upon. On some classes of work an automatic ejecting device can be used to advantage, so that, when the jaws open automatically, the work will be forced out. With a machine equipped in this way, all that the operator has to do is to place fresh blanks in the vises. The maximum feed travel is $1\frac{1}{2}$ inch, and the chucks will take drills up to $\frac{1}{4}$ inch in diameter. The feed-cam that operates the spindles is easily removed, so that cams to give different ranges may readily be substituted. When deep holes are to be drilled, the cams are made to withdraw the drills frequently, thus breaking and clearing the chips from the holes. The feed of the drills can be changed to suit the depth of holes and the sizes of drills. Provision is made for ample lubrication of the drills, the lubricant being forced between the vise jaws and the work, thus keeping the work flooded at the point of drilling so that the highest possible feed and cutting speed may be employed. A circular pan surrounds the drilling heads, and holds the drilled work and chips. The oil flows into the base, and is pumped back to the work by a circulating pump.

An idea of the productive capacity of the machine will be obtained from the following example: Automobile chain pins $\frac{1}{2}$ inch in diameter are drilled with 0.121-inch drills running at 2200 revolutions per minute, the production being 12,000 pins per ten-hour day. The capacity of the machine for round pieces with two sets of vise jaws is from $\frac{1}{4}$ to 1 inch, the first set taking from $\frac{1}{4}$ to $\frac{5}{8}$ inch and the second set from $\frac{5}{8}$ to 1 inch. The jaws carry a drill guide bushing which centers the drill accurately. These jaws can be quickly changed when it is required to operate the machine on some other class of work.

Six-head Continuous-feed Drilling Machine. — Fig. 7 shows a six-head continuous-feed multiple drilling machine with which parts containing practically any number of holes may be drilled continuously, without any loss of time for the ejection of drilled pieces or inserting blank ones. This drilling machine is built by the Langelier Mfg. Co. The rate of production attained with this machine will be readily grasped upon noting that the work was drilled by an average unskilled operator at the rate of fourteen completely drilled pieces per minute, or a total of 8400 pieces or 42,000 holes in ten hours. The work is a forging $\frac{3}{16}$ inch thick, and there are two holes 0.199, two holes 0.261, and one hole 0.098 inch in diameter. The speeds for these three sizes of drills are 585, 455, and 1200 revolutions per minute, respectively, with a feed of 0.0018 inch per revolution. If it had been necessary that the pieces be drilled with more than five holes each, the total number of holes drilled in ten hours would have been still greater, because all of the holes in each piece, no matter how great the number, are drilled in practically the same time that it would take to drill a single hole. The machine works on six pieces simultaneously and continuously.

Each head is fitted with a " steady " jig for supporting and accurately starting the drill ends. The jig is adjustable vertically to compensate for the shortening of the drills by grinding, and is also under spring tension so as to exert pressure

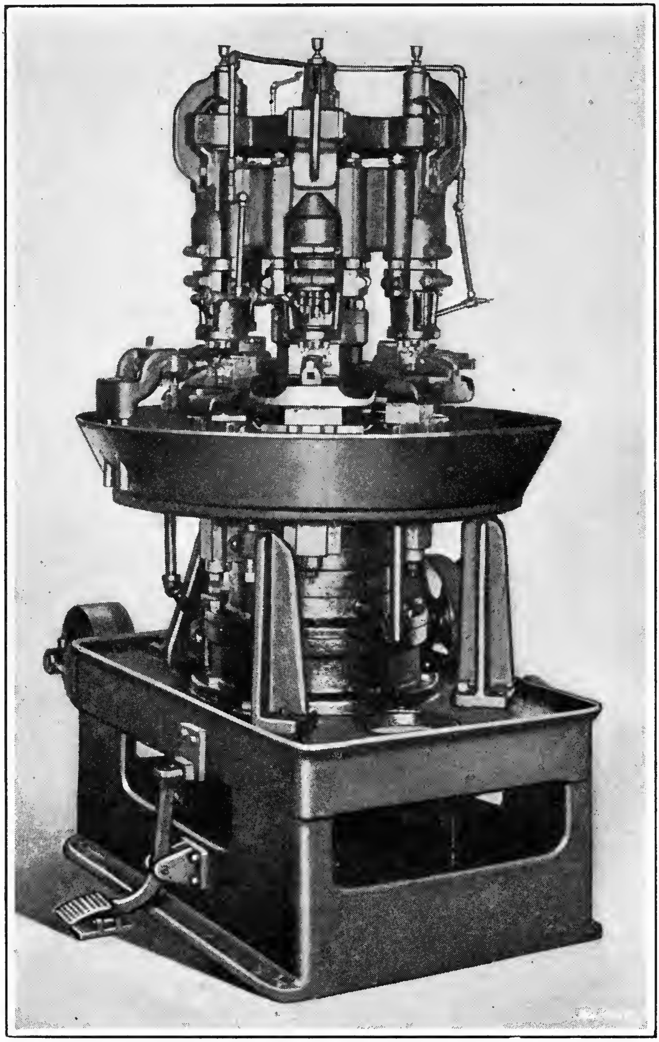


Fig. 7. Multiple-head Drilling Machine which provides for Drilling Parts containing practically any Number of Holes without Loss of Time for Ejection of Drilled Pieces or Setting up Undrilled Blanks

on the work while it is being drilled. The pieces to be drilled are located and held in position by a three-point supporting pressure lever fixture, the fixture body being screwed to the table permanently. Each type of work has a separate fixture seat of its own that can be quickly removed and replaced. The pieces to be drilled are gripped by a short fulcrumed lever under spring tension, the longest end being depressed to release the work by passing under a segment cam that is located directly in front of the operator and fastened to the rim of the oil-pan. The segment cam is stationary and is adjustable vertically so as to give just the proper amount of opening. The machine consists of a box base having a vertical stationary post at the center, around which revolves a member carrying the six drilling heads and tables upon which the work-holding fixtures are fastened. Each drilling head with its table revolves in unison. The drilling feed is accomplished by the upward movement of the tables; and at the lower extremity of each table slide there is a roller having contact with a circular feed-cam that is fastened to the base of the machine. The drilling is done against the tension of a spring, as a safeguard against very dull drills and incorrect chucking of work in fixtures by the operator. Tension springs pulling downward on the tables insure them having contact with the feeding edge of the cam at all times, especially on the return.

The revolving member carrying the drilling heads and tables is actuated by a Hindley worm and gear located inside of the central circular flange supporting the feed-cam. The work shaft, in turn, is belted to the clutch shaft, on one end of which is a pair of miter gears that receive motion from the main driving pulley inside the box base. The drilling heads are driven by a large central gear keyed to the vertical main driving pulley shaft extending up through the central post. The driven gears on the main spindles of the drilling heads are made of compressed cotton (Fabroil gears) so as to avoid unnecessary noise and to insure smooth running. A large stationary chip- and oil-pan, supported by the standards, is fastened to the base that surrounds the machine. On the outer end of the miter gear shaft is mounted a Johnson clutch that is operated by a foot-lever which is conveniently located for the operator. This clutch is used to make the circular feed of the machine independent of the driving of the drilling heads, so that it can be instantly stopped by simply unlocking the foot-lever by a side thrust of the foot.

The cutting lubricant is a special mixture that is pumped up through a tube passing through the main driving pulley shaft and then led to each drilling head by branch piping. After being used, it flows to the bottom of the circular oil-pan, where it is freed from the chips. It then passes to the top of the base, where it is filtered before entering the reservoir located in the bottom half of the base. This machine, with slight modification, can be used for drilling a large variety of pieces having one or more holes.

Semi-automatic Twelve-spindle Machine. — On a machine built by the Langelier Mfg. Co. for drilling the brass stems of pneumatic tire valves, a shaft to which six fixtures are fastened is mounted in a pan supported by legs at a convenient height for the operator. These fixtures are triangular in shape, having their apexes flattened sufficiently to receive split chucks for holding the valve stems. These chucks are kept closed by springs, and are opened by small levers of such shape that, when the chucks are opened by resting the palm of the hand on the levers, the work may be inserted or removed by the fingers of the same hand. The machine is shown in Fig. 8, and Fig. 9 shows the work to be drilled. The spindles, which are provided with chucks for holding the drills, run in bushed bearings in brackets attached to the outside of the pan, six on the back and six in front, and project through the pan at an angle of 30 degrees below the horizontal, thus being in line with the chucks that hold the work in the apexes of the triangular fixtures on the shaft above. There are also two larger brackets attached to the pan diagonally opposite each other, and extending out over drums at each end of the machine. These brackets support slides provided with rolls to engage with cam-plates secured to the faces of the drums. Long bars, which are attached to the slides, extend through the spindle brackets and carry a wedge for each spindle. When these bars are drawn forward by the revolving cams engaging with the rolls on the sides, the wedges come in contact with bushings on the spindles, and force the drills inward toward the work. The wedge bars are returned to their normal position by springs, and the wedges are separately adjustable, so that the points of the drills may be kept in line.

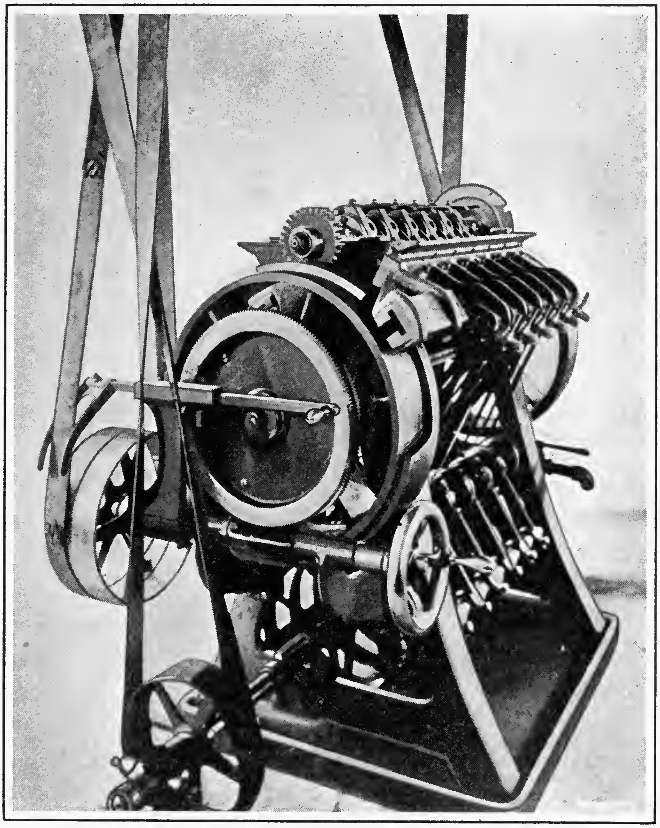


Fig. 8. Semi-automatic Machine on which Provision is made for Automatically Backing Out Drill at Specified Intervals to Provide for Clearing Chips from Hole

The two cam-drums are driven by a worm belted directly from the countershaft. At every revolution of the cam-drums, a wedge under the rim of the right drum withdraws a spring lock-pin from a notch in the index plate on the right end of the shaft, carrying the triangular fixtures, while a toothed sector on the left drum engages with a pinion on the left end of the shaft, turning it one-third revolution, where it is locked by the pin springing into the next notch in the index plate. A lever is provided for unlocking the fixture shaft by hand, and the cam-drums may be revolved by the handwheel on the worm shaft. When the machine is in operation, the pan into which the spindles project is filled with oil, so that the drills and work are completely submerged. The oil lubricates the spindles. A large pipe with a stop-cock is provided by which the oil may be quickly drawn off into a pail placed on the floor. The whole machine stands in a large pan, which insures cleanliness, although the drills never throw the oil and it could only be splashed out of the upper pan by the carelessness of the operator. The valve requires to have a hole 0.081 inch in diameter drilled to a depth of $\frac{7}{8}$ inch, and then a hole 0.0635 inch in diameter is drilled $\frac{1}{4}$ inch farther. The cam-plates on the faces of the drums are so made that the drills are fed into the work about $\frac{1}{8}$ inch, then entirely withdrawn, and after the oil has cooled, lubricated, and cleared the drills of chips, they are fed in $\frac{1}{8}$ inch farther, and so on until the required depth is reached. The large drills are in the spindles on the back of the machine, and the small ones in front. The triangular fixtures run from front to back.

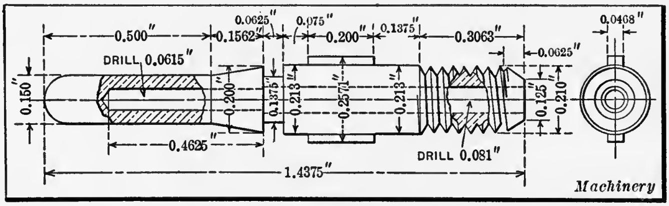


Fig. 9. Type of Brass Pneumatic Tire Valve Stem drilled on Machine shown in Fig. 8

The operation of the machine is as follows: A valve stem is placed in each of the six chucks in the upturned apexes of the fixtures, then the fixture shaft is turned one-third revolution toward the back, where it is locked by the spring-pin in position for drilling the large holes. While the large drills are operating, the six chucks, now upturned, are filled with stems, and when the large holes are completed on the first set of stems, the fixture shaft turns one-third revolution, presenting the first set of stems to the small drills, the second set to the large drills, and the third set of chucks to the operator to be filled with stems.

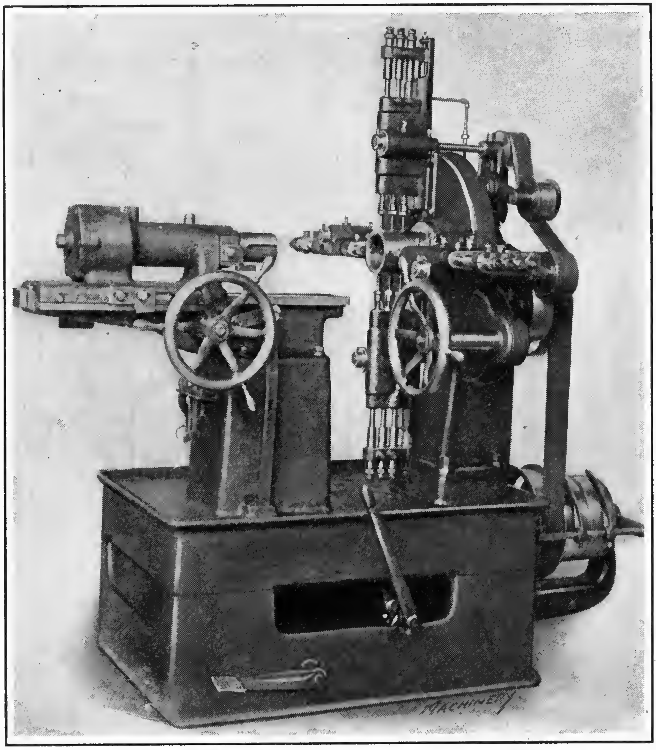


Fig. 10. Drilling Machine with Four Sets of Three Opposed Spindles for Drilling Twelve $\frac{1}{8}$-inch Oil-holes

The machine is now fairly under way, and need not be stopped, except for accident, until working hours are over, as the operator has only to remove finished stems from the chucks, and insert blanks, while the drills are operating on the other two sets of stems. The drills make 8000 revolutions per minute, and at this speed the machine drills six valve stems every minute, or

3600 in a day of ten hours. Although designed and built for a special purpose, this machine may be adapted for a great variety of work.

Motor Valve Sleeve Multiple Drilling Machine. — For use in drilling at one operation the twelve $\frac{1}{8}$-inch oil-holes in the outer sleeve of a Willys-Overland motor valve, the Langelier Mfg. Co. designed the multiple drilling machine illustrated in Fig. 10. A similar machine was built for use in drilling four $\frac{1}{8}$-inch holes in the inner sleeve, and the output of each machine is $3\frac{1}{2}$ sleeves per minute, or 2100 per day. The material is cast iron and the holes are approximately $\frac{3}{16}$ inch deep. The machines are of exactly the same design, except that one is equipped with twelve drill spindles, while the other has only four spindles.

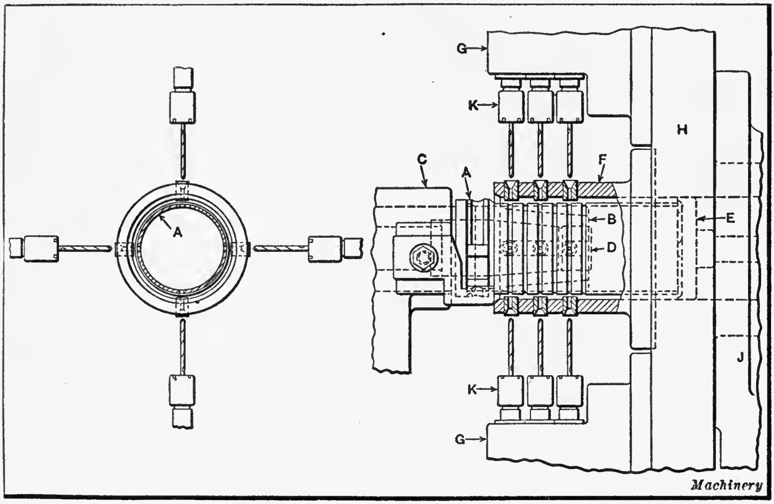


Fig. 11. Close View of Work-holding Fixture and Drilling Spindles of Machine shown in Fig. 10

Fig. 11 shows a cross-sectional view through the drill jig on the machine for drilling the outer sleeve, in which the work is shown in the drilling position. Referring to this illustration, the method of operating the machine will be clearly understood. Sleeve *A* is held and located in the drilling position by an internal expanding arbor *B* mounted on tailstock *C*, which slides upon ways in line with the axis of the machine. Expanding arbor *B* is opened or closed automatically by means of compressed air; the construction consists of a split sleeve that is attached directly to the piston in the compressed air cylinder; and inside this sleeve there is a fixed arbor *D* with a tapered end that is attached to the cylinder head. A slight travel of the sleeve on this tapered portion of the fixed arbor causes the sleeve to expand and hold the work securely, extra movement being avoided by a stop collar on the sleeve and tapered arbor.

Admission of air to the cylinder is controlled by a small piston valve that is attached to the tailstock *C* at the rear and operated by contract with a fixed stop attached to the tailstock slide. The tailstock is shown in its outer or loading position in Fig. 10, movement of the tailstock slide being secured by means of the handwheel at the front of the machine. The drilling position is obtained by the sleeve to be drilled coming into contact with a stop *E* located inside of drill jig *F*; this stop can be adjusted at the left-hand end of the machine. The tailstock is also automatically locked when in a drilling position, and is unlocked by the foot-treadle shown at the front of the bed; this lock is adjustable and can be set to suit the requirements of the work being drilled.

Drilling heads *G* are located radially 90 degrees apart upon a circular faceplate *H* that is mounted on column *J* attached to the bed of the machine. Drilling spindles *K* are driven by spiral gears, the drives extending to the rear and having pulleys on their ends. The thrust is taken up by ball thrust bearings. The feed of the drill spindles is operated by a handwheel at the right-hand side of the machine, which has a spur-gear connection to a rim gear located inside and concentrically with faceplate *H*. The rim gear carries a segment feed-cam for each head that has roller contact with the feed yoke of each drill head. These yokes have a clamp connection to the sleeve on the outer end of the drilling spindles, and this clamp connection provides ready means of adjusting the feeding position of the drill spindles.

CHAPTER IV

SPEEDS AND FEEDS FOR DRILLING

THERE are so many variables which enter into the performance of a drilling operation that it is extremely difficult to establish anything in the nature of hard and fast rules for the speed and feed that are correct for drilling a hole of specified size in a given class of material. It is quite general practice for an experienced mechanic to determine what appears to be the proper speed and feed for a given job by the use of " cut and try " methods. Experience will enable him to tell very closely what are the proper conditions of operation, and with this as a basis he will observe the operation of the drill, and from that judge whether he is working under conditions that yield the maximum production. The successful use of high-speed steel drills often depends more upon the conditions under which they are operated than upon the tools themselves, provided they are properly made from a suitable grade of steel.

Advantages of Drilling at High Speed. — Recent years have witnessed great increases in the speed at which drilling operations are performed in many shops, and the advocates of high-speed drilling — both among builders of drilling machines and users of such equipment — claim that numerous advantages are secured by drilling at these high speeds. There is another body of mechanical men who treat with contempt the idea of benefits resulting from high-speed drilling, and state that this is a fad which has been carried to great excess. In any case, the proper speed at which a drilling operation should be performed is that speed at which the most desirable balance is obtained between cutting down of production through lowering the drilling speed and loss of time through the necessity of more frequently stopping the drilling machine to grind drills, where higher drilling speeds are employed. Owing to this diversity of opinion in regard to the most efficient speed at which drilling operations can be performed, the following recommendations made by different authorities should prove of interest and practical value.

H. M. Norris, chief engineer of the Cincinnati-Bickford Tool Co., has made a careful study of the question of drilling speeds, and the results of his investigations have led him to the conclusion that occasionally a drill is found which is capable of standing up satisfactorily at a cutting speed of 150 feet per minute in either cast iron or steel, but it is seldom desirable to drive anything but very small drills at speeds in excess of 100 feet per minute. Under average conditions of operation, the best results will be obtained with a cutting speed of 80 feet per minute in cast iron, while, for steel, a speed of $\frac{12}{d} + 76$ feet per minute will give satisfactory results. Where this rule is used, the cutting speed will be decreased from 100 feet per minute for a ½-inch drill to 80 feet per minute for a 3-inch drill. In explaining the rule, attention is called to the fact that, while cast iron is cut dry, a lubricant is required for drilling steel and a volume of lubricant sufficient to keep a ½-inch drill cool at 100 feet per minute will only be sufficient to cool a 3-inch drill at 80 feet per minute.

Speeds and Feeds Recommended. — Selection of the proper speed and feed for a given drilling operation is governed by the diameter of the drill and the kind of material being drilled. Exhaustive tests and close observation of the Cleveland Twist Drill Co. have led to the conclusion that, in establishing the best conditions of operation for a given job, it is well to start carbon steel twist drills under the following conditions of speed and feed until more definite data are available as to the maximum speed and feed which can properly be employed for the operation under consideration.

When drilling machine steel, use a peripheral speed of 30 feet per minute; for cast iron, use a speed of 35 feet per minute; and for brass, use a speed of 60 feet per minute. In each case, a feed of from 0.004 to 0.007 inch per revolution should be employed for drills up to ½ inch in diameter, while for larger sizes the feed should be from 0.005 to 0.015 inch per revolution. In the case of high-speed steel drills, the preceding rates of speed should be increased from 100 to 125 per cent, while the same rates of feed are employed. The Standard Tool Co. recommends starting high-speed steel drills at a peripheral speed of from 50 to 70 feet per minute for wrought iron or steel, and from 60 to 80 feet per minute for cast iron, or at 140 feet per minute for brass. The feeds recommended are 0.004 inch per revolution for a $\frac{1}{16}$-inch drill in wrought iron or steel, 0.005 inch per revolution for a $\frac{1}{4}$-inch drill, 0.008 inch per revolution for a $\frac{1}{2}$-inch drill, 0.010 inch per revolution for a 1-inch drill, and 0.015 inch per revolution for a $1\frac{1}{2}$-inch drill.

The Detroit Twist Drill Co. states that high-speed steel drills can often be run efficiently at over 100 feet per minute in cast iron, but that better results will usually be obtained at from 60 to 70 feet per minute. In establishing the proper conditions for a given drilling operation, a freshly ground drill of a given size should be tested at each of the two speeds provided by the machine above and below that which is necessary to give a cutting speed of 70 feet per minute, and then each successive feed provided on the machine should be tried until one is found at which the drill will run without slowing down the machine or injuring the drill during a period of one hour's operation, which is the standard shop interval during which a drill should operate without requiring grinding. It might be thought that this would require considerable time, but, as a matter of fact, the establishment of speeds and feeds by this method can be quickly accomplished and the saving will more than compensate for the time spent in determining the most efficient conditions of operation where there are a large number of parts to be drilled.

For drilling wrought iron or steel, the drill should be started at a peripheral speed of from 50 to 70 feet per minute, for cast iron the speed should be from 60 to 80 feet per minute, and for brass, from 100 to 150 feet per minute. Under favorable conditions, the feed should be 0.004 inch per revolution for a $\frac{1}{16}$-inch drill in wrought iron or steel; 0.005 inch per revolution for a

$\frac{1}{4}$-inch drill; 0.008 inch for a $\frac{1}{2}$-inch drill; 0.010 inch for a 1-inch drill; and 0.015 inch for a 2-inch drill. If the drill breaks or chips on the cutting edges, the rate of feed should be reduced.

Starting with any of the preceding speeds and feeds which have been recommended by different authorities, the operator carefully notes the condition of the drill after it has been working for some time. If the drill shows a tendency to wear away on the outside, it is running too fast, while if it breaks or chips on the cutting edges, the feed is probably too heavy for the work required. A little careful experimenting in this way, making changes gradually according to indications which are shown after working for some time, will usually result in securing a combination of speed and feed which will be the means of obtaining something approaching the maximum possible production. It will, of course, be obvious that, to obtain a given peripheral cutting speed, the number of revolutions per minute must differ according to the size of the drill which is being used. This is the reason for running very small drills at extremely high speeds in order to have them working under conditions which approximate the required cutting speed for the material that is being machined. For the convenience of users of twist drills and other rotary cutting tools, tables are available which show the number of revolutions per minute at which a given size of drill should be run in order to obtain the required cutting speed. In Tables 1 and 2 the diameters of drills are given in the left-hand column, while peripheral cutting speeds in feet per minute are noted at the top of the table. By finding the intersection of horizontal and vertical lines through the given drill diameter and the required cutting speed, the number of revolutions per minute at which the drill must be run in order to obtain this speed will be found. Table 3 gives the decimal equivalents of nominal sizes of drills, and will be found useful when calculating the peripheral cutting speed of drills of various sizes; this table also shows the relation of the different sizes of drills, which are designated by letters and numbers, as compared to the fractional sized drills.

Table 1. Cutting Speeds

Diam., Inches	Feet per Minute														
	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85
	Revolutions per Minute														
1/8	459.0	611.0	764.0	917.0	1070.0	1222.0	1375.0	1528.0	1681	1834	1986	2139	2292	2445	2598
1/4	229.0	306.0	382.0	458.0	535.0	611.0	688.0	764.0	851	917	994	1070	1147	1222	1300
3/8	153.0	204.0	255.0	306.0	357.0	408.0	458.0	509.0	560	611	662	713	764	815	865
1/2	115.0	153.0	191.0	229.0	268.0	306.0	344.0	382.0	420	459	497	535	573	611	649
5/8	91.8	123.0	153.0	184.0	214.0	245.0	276.0	306.0	337	367	398	428	459	489	520
11/16	83.3	111.0	138.0	167.0	194.0	222.0	249.0	273.0	300	333	360	389	416	444	472
3/4	76.3	102.0	127.0	153.0	178.0	203.0	229.0	254.0	279	306	330	357	381	408	432
13/16	71.1	94.8	119.0	142.0	166.0	190.0	213.0	237.0	261	284	308	332	356	379	403
7/8	65.5	87.3	109.0	131.0	153.0	175.0	196.0	219.0	241	262	285	306	329	349	372
15/16	61.0	81.4	101.0	122.0	142.0	163.0	183.0	204.0	224	244	265	285	305	326	346
1	57.3	76.4	95.5	115.0	134.0	153.0	172.0	191.0	210	229	258	267	287	306	325
1 1/16	53.9	71.8	89.8	108.0	126.0	144.0	162.0	180.0	197	215	233	251	269	287	305
1 1/8	51.0	68.0	85.0	102.0	119.0	136.0	153.0	170.0	187	204	221	238	255	272	289
1 3/16	48.3	64.4	80.5	96.6	113.0	129.0	145.0	161.0	177	193	209	225	242	258	274
1 1/4	45.8	61.2	76.3	91.8	107.0	123.0	137.0	153.0	168	183	199	214	230	245	260
1 5/16	43.6	58.2	72.8	87.3	102.0	116.0	131.0	146.0	160	175	189	204	218	233	247
1 3/8	41.7	55.6	69.5	83.3	97.2	111.0	125.0	139.0	153	167	180	195	208	222	236
1 7/16	39.8	53.0	66.3	79.5	92.8	106.0	119.0	133.0	146	159	172	186	199	212	225
1 1/2	38.2	50.8	63.7	76.3	89.2	102.0	115.0	127.0	140	153	165	178	191	204	216
1 9/16	36.6	48.8	61.0	73.2	85.4	97.6	110.0	122.0	134	146	159	171	183	195	207
1 5/8	35.0	47.0	58.8	70.5	82.2	93.9	106.0	117.0	129	141	152	165	176	188	199
1 11/16	33.9	45.2	56.5	67.8	79.1	90.4	102.0	113.0	124	136	147	158	170	181	192
1 3/4	32.7	43.6	54.5	65.5	76.4	87.3	98.2	109.0	120	131	142	153	164	175	185
1 13/16	31.7	42.2	52.8	63.3	73.9	84.4	95.0	106.0	116	127	137	148	158	169	179
1 7/8	30.6	40.7	50.9	61.1	71.3	81.5	91.9	102.0	112	122	133	143	153	163	173
1 15/16	29.6	39.4	49.3	59.1	69.0	78.8	88.7	98.5	108	118	128	138	148	158	167
2	28.7	38.2	47.8	57.3	66.9	76.4	86.0	95.5	105	115	124	134	143	153	162

Table 2. Cutting Speeds

Diam., Inches	Feet per minute														
	90	95	100	110	120	125	130	140	150	160	170	175	180	190	200
	Revolutions per Minute														
⅛	2750	2903	3056	3362	3667	3820	3973	4278	4584	4890	5195	5348	5501	5806	6112
¼	1376	1453	1528	1681	1734	1910	1986	2139	2292	2445	2598	2674	2750	2903	3056
⅜	916	967	1018	1121	1222	1273	1323	1425	1527	1629	1731	1782	1832	1934	2036
½	688	726	764	840	917	955	993	1070	1146	1222	1299	1337	1375	1452	1528
⅝	552	581	612	673	736	765	796	857	918	979	1040	1071	1102	1163	1224
11/16	500	527	555	611	666	692	722	770	833	888	944	971	999	1054	1110
¾	458	483	508	559	610	635	661	711	762	813	864	889	914	965	1016
13/16	427	450	474	521	569	593	616	664	711	758	806	830	853	901	948
⅞	392	416	438	482	526	548	569	613	657	701	745	767	788	832	876
15/16	366	387	407	448	488	509	529	570	611	651	692	712	733	773	814
1	344	363	382	420	458	478	497	535	573	611	649	669	688	726	764
1 1/16	323	341	359	395	431	449	467	503	539	579	610	628	646	682	718
1⅛	306	324	340	374	408	425	442	476	510	544	578	595	612	646	680
1 3/16	290	306	322	354	386	403	419	451	483	515	547	564	580	612	644
1¼	274	291	306	337	367	383	398	428	459	490	520	536	551	581	612
1 5/16	262	276	291	320	349	351	378	407	437	466	495	509	524	553	582
1⅜	250	264	278	306	334	348	361	389	417	445	472	487	500	528	556
1 7/16	239	272	265	292	318	331	345	371	398	424	451	464	477	504	530
1½	230	241	254	279	305	318	330	356	381	406	432	445	457	483	508
1 9/16	220	232	244	268	293	305	317	342	366	390	415	427	439	464	488
1⅝	212	222	234	257	281	293	304	328	351	374	398	410	421	445	468
1 11/16	203	215	226	249	271	283	294	316	339	362	384	396	407	429	452
1¾	196	207	218	240	262	273	283	305	327	349	371	382	392	414	436
1 13/16	190	200	211	232	253	264	274	295	317	338	359	369	380	401	422
1⅞	184	194	204	224	244	255	265	286	306	326	347	357	367	388	408
1 15/16	177	187	197	217	236	246	256	276	296	315	335	345	355	374	394
2	172	181	191	210	229	239	248	267	287	306	325	334	344	363	382

Table 3. Decimal Equivalents of Nominal Sizes of Drills

Inch	Wire Gage	Decimals of an Inch	Inch	Wire Gage	Decimals of an Inch	Inch	Letter Sizes	Decimals of an Inch	Inch	Decimals of an Inch
	80	0.0135		35	0.1100		G	0.2610	3/4	0.7500
	79	0.0145		34	0.1110	17/64		0.2656	49/64	0.7656
1/64		0.0156		33	0.1130		H	0.2660	25/32	0.7813
	78	0.0160		32	0.1160		I	0.2720	51/64	0.7969
	77	0.0180		31	0.1200		J	0.2770	13/16	0.8125
	76	0.0200	1/8		0.1250		K	0.2810	53/64	0.8281
	75	0.0210		30	0.1285	9/32		0.2813	27/32	0.8438
	74	0.0225		29	0.1360		L	0.2900	55/64	0.8594
	73	0.0240		28	0.1405		M	0.2950	7/8	0.8750
	72	0.0250	9/64		0.1406	19/64		0.2969	57/64	0.8906
	71	0.0260		27	0.1440		N	0.3020	29/32	0.9063
	70	0.0280		26	0.1470	5/16		0.3125	59/64	0.9219
	69	0.0293		25	0.1495		O	0.3160	15/16	0.9375
	68	0.0310		24	0.1520		P	0.3230	61/64	0.9531
1/32		0.0313		23	0.1540	21/64		0.3281	31/32	0.9688
	67	0.0320	5/32		0.1563		Q	0.3320	63/64	0.9844
	66	0.0330		22	0.1570		R	0.3390	1	1.0000
	65	0.0350		21	0.1590	11/32		0.3438	1 1/64	1.0156
	64	0.0360		20	0.1610		S	0.3480	1 1/32	1.0313
	63	0.0370		19	0.1660		T	0.3580	1 3/64	1.0469
	62	0.0380		18	0.1695	23/64		0.3594	1 1/16	1.0625
	61	0.0390	11/64		0.1719		U	0.3680	1 5/64	1.0781
	60	0.0400		17	0.1730	3/8		0.3750	1 3/32	1.0938
	59	0.0410		16	0.1770		V	0.3770	1 7/64	1.1094
	58	0.0420		15	0.1800			0.3819	1 1/8	1.1250
	57	0.0430		14	0.1820		W	0.3860	1 9/64	1.1406
	56	0.0465		13	0.1850	25/64		0.3906	1 5/32	1.1563
3/64		0.0469	3/16		0.1875		X	0.3970	1 11/64	1.1719
	55	0.0520		12	0.1890		Y	0.4040	1 3/16	1.1875
	54	0.0550		11	0.1910	13/32		0.4063	1 13/64	1.2031
	53	0.0595		10	0.1935		Z	0.4130	1 7/32	1.2188
1/16		0.0625		9	0.1960	27/64		0.4219	1 15/64	1.2344
	52	0.0635		8	0.1990	7/16		0.4375	1 1/4	1.2500
	51	0.0670		7	0.2010	29/64		0.4531	1 17/64	1.2656
	50	0.0700	13/64		0.2031	15/32		0.4688	1 9/32	1.2813
	49	0.0730		6	0.2040	31/64		0.4844	1 19/64	1.2969
	48	0.0760		5	0.2055	1/2		0.5000	1 5/16	1.3125
5/64		0.0781		4	0.2090	33/64		0.5156	1 21/64	1.3281
	47	0.0785		3	0.2130	17/32		0.5313	1 11/32	1.3438
	46	0.0810	7/32		0.2188	35/64		0.5469	1 23/64	1.3594
	45	0.0820		2	0.2210	9/16		0.5625	1 3/8	1.3750
	44	0.0860		1	0.2280	37/64		0.5781	1 25/64	1.3906
	43	0.0890				19/32		0.5938	1 13/32	1.4063
	42	0.0935		Letter Sizes		39/64		0.6094	1 27/64	1.4219
3/32		0.0938				5/8		0.6250	1 7/16	1.4375
	41	0.0960		A	0.2340	41/64		0.6406	1 29/64	1.4531
	40	0.0980	15/64		0.2344	21/32		0.6563	1 15/32	1.4688
	39	0.0995		B	0.2380	43/64		0.6719	1 31/64	1.4844
	38	0.1015		C	0.2420	11/16		0.6875	1 1/2	1.5000
	37	0.1040		D	0.2460	45/64		0.7031	1 33/64	1.5156
	36	0.1065	1/4	E	0.2500	23/32		0.7188	1 17/32	1.5313
7/64		0.1094		F	0.2570	47/64		0.7344	1 35/64	1.5469

Automatic Speed Adjustment for Drilling Machine. — Where quick-change chucks are used to facilitate changing tools for the performance of a sequence of operations on a piece of work, it is apparent that provision must be made for changing the spindle speed of the drilling machine for different sizes of tools, or else some of these tools will have to be driven below the most efficient speeds for such sizes of drills, counterbores, etc. In Fig. 1 is shown a radial drilling machine equipped with variable-speed motor drive and means of automatically changing the speed so that approximately the proper speed may be obtained

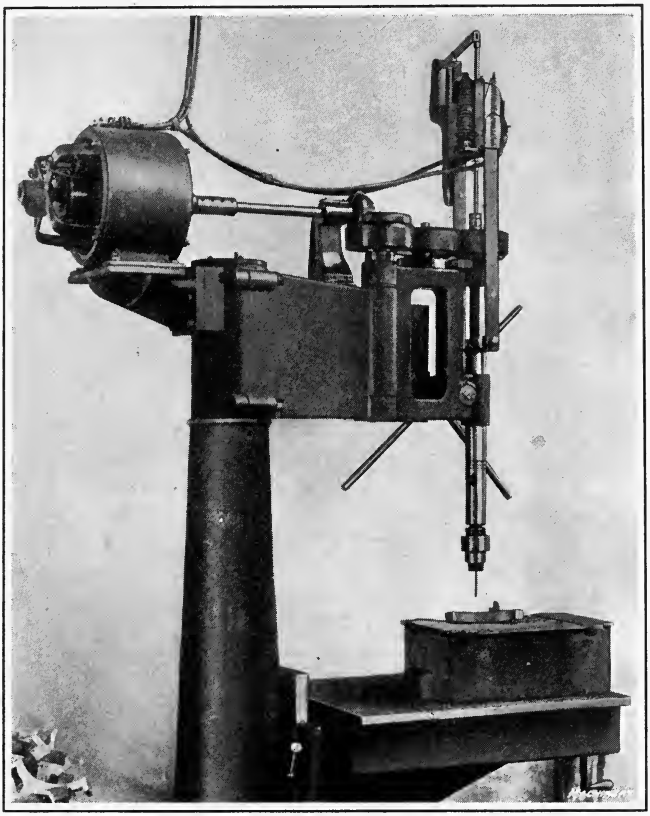


Fig. 1. Radial Drilling Machine equipped with Automatic Control for Variable-speed Motor Drive to assure Proper Cutting Speed for all Tools

for each size of tool that is used. The machine is shown at work in the shops of the Universal Motor Co., and the automatic speed-changing device was designed by L. J. Monahan, president of the firm. Referring to Fig. 2, it will be seen that the drilling machine is equipped with one of the "Magic" chucks *A* made by the Modern Tool Co., and the collets *B* which enter this chuck are each provided with a pin *C* which extends up through the chuck body and engages the bottom of pin *D*. These pins *C* are made of different lengths and automatically adjust a speed-controlling rheostat *E* to provide for regulating the speed of motor *F* to give the proper spindle speed for the particular size of drill or other tool being used. In this way there is an assurance of each tool being driven at its most efficient speed. By making the speed change automatically, no demand is made upon the operator, and, therefore, there is no loss of time in speed changing; also the "Magic" chuck enables tools to be changed without stopping the rotation of the drilling machine spindle.

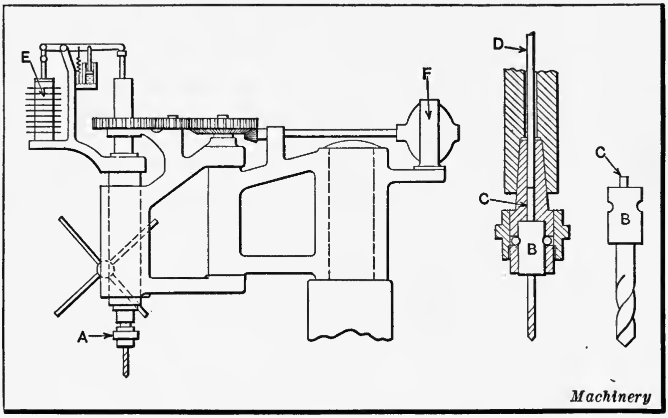


Fig. 2. Method of obtaining Automatic Control of Variable-speed Motor Drive

Critical Drilling Speeds. — In experimenting to determine the number of revolutions per minute at which a drill will have the greatest productive capacity, some interesting results are secured. Researches which were made at the plant of Baker

Bros., with the view of securing data required in connection with the design of their drilling machines, showed that there are certain critical speeds at which a twist drill will have a satisfactory rate of production, while there are other speeds — often lying between two rates of speed where the production is satisfactory — at which the drill will fail to give anything approaching satisfactory results. This condition is clearly shown by Fig. 3, which is plotted with data taken from original tests. These investigations were made several years ago, so that, while the condition shown by this set of curves is an established fact, the rates of speed and feed are lower than would be used

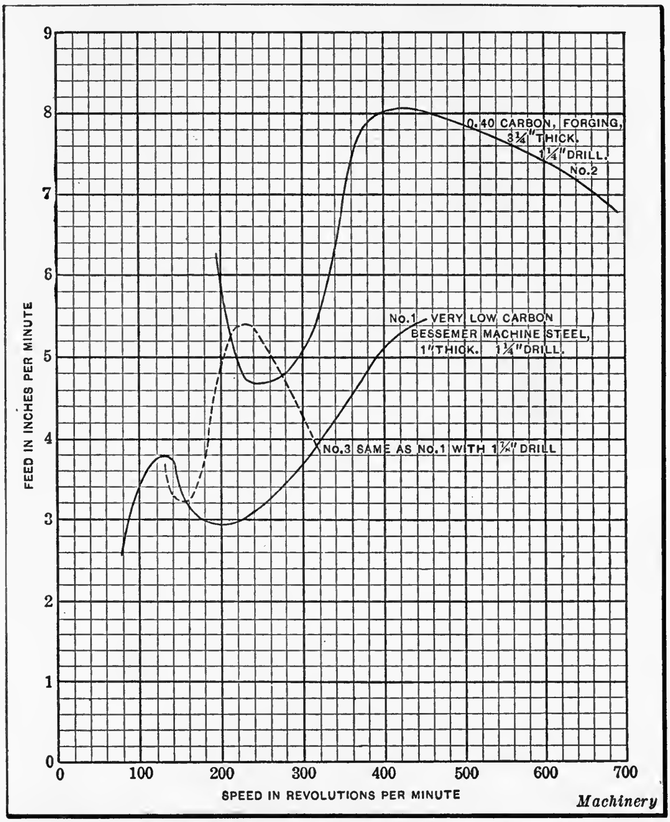


Fig. 3. Diagram showing Effect of Critical Speeds on Penetration-speed Curves

in conducting similar tests at the present time. The point brought out by this diagram is the remarkable increase in production which can be secured by increasing the speed. The curves are plotted for the maximum feed at which the stock was successfully drilled without destroying the drill; at the next higher feed the drill would be destroyed. Curve No. 2 shows that the drill would give a far greater production without failing at 200 revolutions per minute than it would at 250 revolutions per minute, and also that it would give a much greater production if the speed were still further increased to 400 revolutions per minute.

This is of particular interest in connection with the suggestions made for experimenting to determine the speed at which a given drilling operation may be performed to secure the greatest possible output. Should it happen that the drilling machine operator has reason to believe that the speed he is using is too low, but finds that a moderate increase in speed results in an even less satisfactory rate of production, he is justified in believing that, if the speed rate of penetration were plotted in the form of a curve shown in Fig. 3, the "speed-penetration" curve has taken one of those peculiar dips exhibited in this illustration, and that a still further increase in speed will probably result in determining a rate at which the desired production will be attained. If such is the case, it is obvious that correction of the original cause for the unsatisfactory rate of production will be made by a considerable increase in speed and not by making a reduction in speed, as might be inferred from the fact that advancing a little from the original speed at which production was unsatisfactory showed that even less desirable results were being obtained.

Recently a well-known manufacturing establishment had an investigating committee working for over two years on the development of a table of speeds and feeds for use in connection with different sizes of drills working in various materials. The result of this investigation is presented in Tables 4 and 5, and although it is not claimed that the data presented can be followed without modification, it is claimed that the

Table 4. Speeds and Feeds for High-speed Drills Working in Various Metals

Size of Drill, Inch	Feed per Rev., Inch	Bronze, Brass, 300 Feet, R.P.M.	Cast Iron, Annealed, 170Feet, R.P.M.	Hard Cast Iron, 80 Feet, R.P.M.	Mild Steel, 120Feet, R.P.M.	Drop-forging, 60 Feet, R.P.M.	Malleable Iron, 90 Feet, R.P.M.	Tool Steel, 60 Feet, R.P.M.	Cast Steel, 40 Feet, 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

Table 5. Speeds and Feeds for Carbon Steel Drills Working in Various Metals

Size of Drill, Inch	Feed per Rev., Inch	Bronze, Brass, 300 Feet, R.P.M.	Cast Iron, Annealed, 85 Feet, R.P.M.	Hard Cast Iron, 40 Feet, R.P.M.	Mild Steel, 60 Feet, R.P.M.	Drop-forging, 30 Feet, R.P.M.	Malleable Iron, 45 Feet, R.P.M.	Tool Steel, 30 Feet, R.P.M.	Cast Steel, 20 Feet, R.P.M.
1/16	0.003	....	5185	2440	3660	1830	2745	1830	1220
1/8	0.004	4575	2593	1220	1830	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	636	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	87	115	58	86	58	39

thousands of tests which were made during the period over which these data were secured have led to results which may safely be regarded as an average maximum of the rate of speed and feed under which a drilling machine may be operated. These tables are copyrighted by the Henry & Wright Mfg. Co., and the tests were made on a special drilling machine built by this company.

In starting to work on a new job the operator of the drilling machine will use the speed and feed shown in these tables, but should he find that the drill shows a tendency to wear around its periphery or that there is a considerable amount of chipping along the cutting edges of the drill, it indicates that the speed or feed is too heavy, and so the required adjustment of operating conditions must be made. In the plant where these data were obtained, the investigating committee reported that the installation of machines capable of operating under these conditions of speed and feed would represent a saving of $30,000 a year. The speeds recommended are rather high, and if twist drills are unable to stand them, the drill manufacturers should be notified, as it is claimed that any responsible maker can furnish suitable drills for use under these conditions if he is required to do so. The speeds are also too high for machines equipped with plain bearings, but properly constructed machines with ball bearings will easily stand up under such conditions of operations.

After reading the preceding suggestions concerning the most efficient speeds and feeds at which drilling operations can be performed, the reader will naturally be impressed by the difference in these recommendations, and noting that they are made by men who have equal opportunities of determining the required information, he will ask himself which conditions are likely to produce the best results in his own shop. The difference in these recommendations is probably due to the fact that there are so many variables which enter into the performance of drilling operations that different combinations of variable conditions enable the most satisfactory results to be obtained when using speeds and feeds which differ substantially. Regardless of the reason, it is a matter of fact that different men have found that the most satisfactory results are obtained when running their drilling machines under conditions of speed and feed which differ substantially when drilling a given size of hole in the same material. Such being the case, the best advice which can be given to the man who is trying to improve conditions in his drilling department is to adopt the method of experimenting with trial speeds and feeds — adopting those trial speeds and feeds recommended in the preceding discussion — until he has found the conditions of speed and feed which give the most satisfactory results on his work.

High Speeds of Modern Drilling Machines. — Machine tool builders are now making drilling machines fully equipped with ball bearings so that they are adapted for operation at speeds which would have been utterly impossible of attainment a few years ago. For instance, the Leland-Gifford Co. builds a machine which is adapted for operation at speeds of from 11,000 to 15,000 revolutions per minute, and the same speeds are recommended for use on a bench drilling machine recently brought out by the Fenn Mfg. Co. Other machinery builders are making high-speed drilling machines. Driving twist drills at such speeds means that the drilling operation is practically instantaneous; in fact, the speed at which holes may be drilled is often equal, if not in excess, of the speed at which the same work could be done on a power press. It is this constant increase in the speed of drilling, with the constant reduction of the ratio between "drilling time" and "setting-up time," which has emphasized the fact that, in order to approach the maximum rate of production, the user of high-speed drilling machines must design his work-holding fixtures in such a way that work may either be set up in indexing fixtures while the drilling operation is being performed, or, if this is not feasible, the clamping devices on fixtures must be so made that a minimum amount of time is consumed in securing the work in place ready to be drilled.

Several important advantages are secured through drilling at high speed, and this is particularly the case with small sized drills, which are likely to break, and also with high-speed steel drills. The reasons for this are as follows: In the case of small drills operated in sensitive drilling machines equipped with hand feed, running the drill at high speed makes it improbable that the operator will impose an excessive feed on the drill, because, in the case of a drill which is running at from 10,000 to 15,000 revolutions per minute, it would be necessary to pull the feed-lever down extremely fast in order that the feed for any one revolution of the drill would be sufficient to impose a stress in the steel which would be in excess of the maximum that the strength of the drill is capable of withstanding. A further explanation for the increased strength of a drill when running at high speed is that where an excessive amount of feed pressure tends to bend the drill slightly when running at high speed, the length of time that any set of fibers in the drill is subjected to stress is so short that the danger of breaking may be less than if the load remains on such fibers for a greater length of time. This is, of course, an unsettled question and is advanced in the form of a hypothesis rather than a statement of fact; in any case, the question is an interesting one.

Effect of High Speeds on High-speed Steel Drills. — With high-speed steel drills, there is an increase in strength and durability when running at high speed which can be explained in a more definite way. At a speed of, say, 10,000 revolutions per minute, the frictional resistance and tendency for the drill to become heated are far more pronounced than where the drill is being operated at, say, 350 revolutions per minute. It is a well-known fact that many classes of high-speed steel are tough and hard even at temperatures corresponding to a dull red heat; conversely, such steels are inclined to be quite brittle at low temperatures. As a result, the increase in frictional resistance resulting from the operation of a high-speed steel drill at the higher speed results in increasing its temperature, with a corresponding improvement in the toughness and hardness of the steel. Consequently, it is obvious that a high-speed steel drill should give better results when working at speeds which cause it to become heated slightly while in operation.

This naturally leads to two points which should be observed in caring for high-speed steel drills in order to enable them to give the best possible results. In cold weather it will be found advantageous to warm the drills slightly before they are placed in service. Such an increase in temperature will be the means of taking much of the brittleness out of the metal, thus avoiding danger of the drill breaking before it has had time to become warmed up through frictional resistance between the tool and work which is being drilled. Another point which is sufficiently important to merit careful consideration is that some makes of high-speed steel are likely to be damaged if suddenly quenched in cold water. In grinding a drill, some operators will plunge the point into water, and when this is done there is danger of introducing cracks in the cutting edge; these may not be of sufficient magnitude to show to the naked eye, but when the drill is put to work trouble is likely to be experienced at once through the chipping away of steel along the lips of the drill.

Feed Pressure required for Drilling. — In Fig. 4 there is shown a special drilling machine which was built for use in the laboratory of the Standard Tool Co. for conducting experimental work on twist drills. This machine is symmetrically designed on both sides of an axis corresponding to the axis of the twist drill which is being tested, this arrangement tending to equalize all stresses that are set up in the frame of the machine and to cause the thrust of the drill to be vertically downward. In the case of an ordinary drilling machine with the overhanging type of frame, there is a cantilever action which causes the thrust of the drill to be separated into two components. On this special drilling machine shown in Fig. 4, the bedplate which supports the work rests on a 12-inch piston, which is ground to a sliding fit in a cylinder filled with oil. Arms and counterweights attached to each side of the piston compensate for the total weight of the piston and bedplate, so that gages connected to the oil cylinder indicate the pressure actually applied by the drill, the gages being calibrated to indicate the total pressure on the 12-inch ram. Two gages are used, one of which reads up to 3000 pounds, while the other reads up to 15 tons.

The spindle and feed mechanisms are driven by two independent electric motors. For driving the spindle, the motor is mounted at the top of the machine with the armature shaft in a vertical position, so that it may be direct-connected to the spindle of the drilling machine. The feed mechanism is driven by a motor located at the right-hand side of the machine, and this motor is connected to the feed through a system of worm-gears and a rack and pinion. An indicating watt-

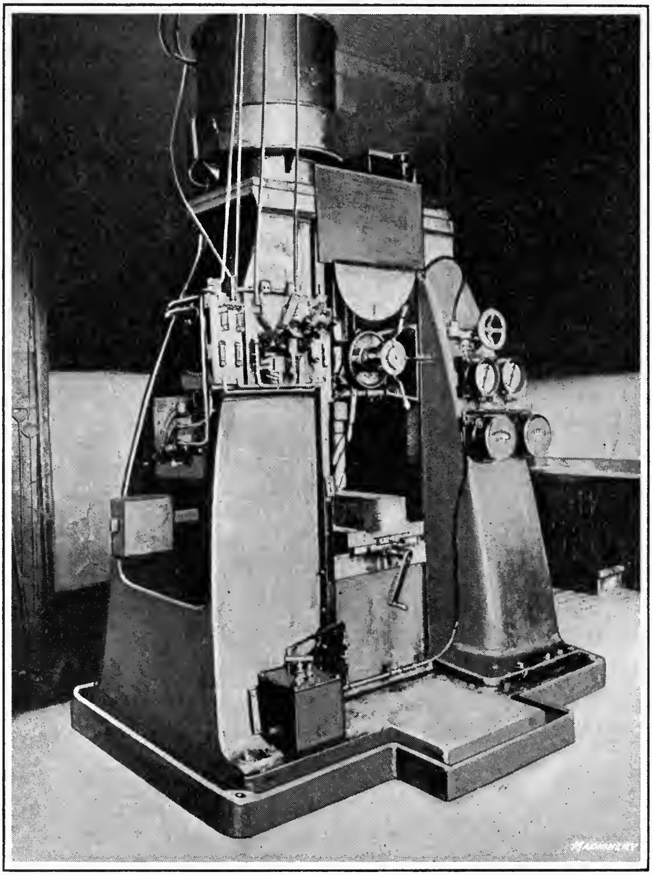


Fig. 4. Special Drilling Machine used in Laboratory of Standard Tool Co.

meter in each circuit shows the power consumption, and each motor is furnished with an independent rheostat by which variations in speed are effected. The speeds of the motors that drive the spindle and feed mechanism are indicated by two Warner tachometers, and a chart has been developed to give the rate of feed for different speeds of the motor that drives the feed mechanism.

A series of tests was conducted on this machine by Paul Bedell Starr and John Millard Marsh to secure data for a thesis presented at the time these men took the degree of Bachelor of Science in mechanical engineering at the Case School of Applied Science. The object of this investigation was principally to determine the feed pressure required to drive different sizes of drills under various conditions of speed and feed. That very little reliable data were available on this subject was shown by the fact that, when the special drilling machine was first built by a firm of wide experience in the design and construction of equipment of this type, a pressure gage reading up to 3000 pounds was provided. At the first test, using a 1-inch drill at a normal rate of feed, the range of this gage was shown to be entirely inadequate; therefore, a gage reading up to 15 tons was substituted, which proved suitable for the service required of it, this difference in gages showing conclusively that the knowledge concerning the magnitude of feed pressures was not at all definite.

Five series of tests were conducted under the following conditions: On the first series, the clearance angle of the drills used was less than the standard 12-degree clearance adopted by the Standard Tool Co., which furnished the twist drills used in making this investigation. On the second series, the clearance angle was greater than the standard 12 degrees. On the third series, the drills used were standard in every respect. On the fourth series, the web thickness of the drills was 10 per cent under standard, and thinned in accordance with the practice of the Standard Tool Co. On the fifth series, the web thickness was 10 per cent above standard. The first series of tests, with the clearance angle less than the standard of

12 degrees, showed that an excessive amount of feed pressure was required to operate a drill ground in this way, such a result being entirely expected, because the cutting edges are not given free play. In the second and third series of tests, where the clearance angle was greater than the standard of 12 degrees, and where all dimensions of the drills were standard, practically the same results were obtained as regards feed pressure, which indicated that no particular advantage was obtained by increasing the clearance angle beyond 12 degrees. It will also be recalled that such an increase results in weakening the cutting edges of the drill and introducing a tendency for them to be damaged by chipping.

In the fourth series of tests, where the web thickness was reduced 10 per cent, there was a noticeable decrease in feed pressure, which indicates that advantages are to be secured through thinning the point of the drill, provided this work is carefully done, so that there is no danger of weakening the drill sufficiently to cause it to split up the center. For the fifth series of tests, where the web thickness was greater than standard, the results obtained were not entirely satisfactory, but, under these conditions of operation, it is fairly safe to assume that an increase in feed pressure would be the result. The data secured from these tests must be regarded more in the light of indications of probable results from varying conditions of operation than as statements of fact concerning results actually discovered, because lack of time made it impossible for Mr. Starr and Mr. Marsh to carry their investigations far enough to secure average results; and average results are particularly important in the case of drilling tests, because of the numerous variations which may affect results.

Power required to Drive Drilling Machines. — The Detroit Twist Drill Co. states that the efficiency of most drilling machines is from 10 to 20 per cent, i.e., there is seldom over one-fifth of the power used to drive a drilling machine which is transmitted to the drill point. It frequently happens that very little care is taken to see that drilling machine bearings are properly aligned and lubricated, and this is especially true in the case of ball thrust bearings, which must be kept in good working condition in order to be effective in helping the machine to give the maximum possible service. Attention to the upkeep of machine bearings is exceptionally important in the case of drilling machines operated at excessively high speed.

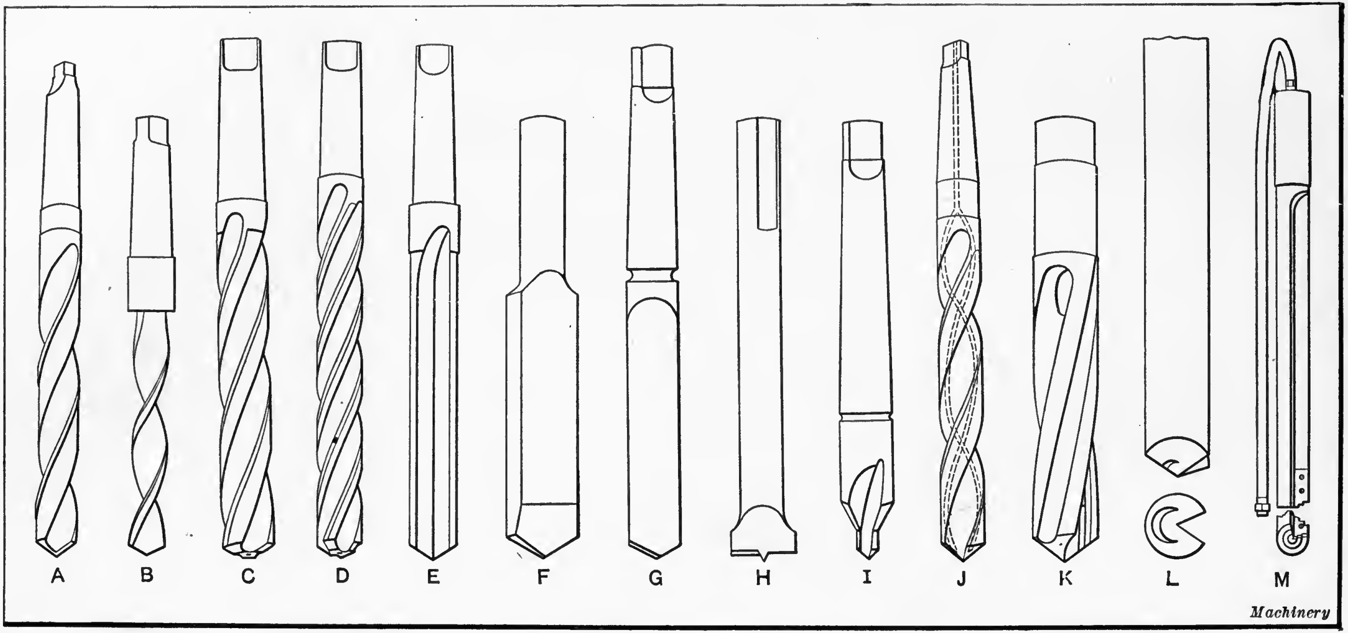
Coolants and Lubricants used for Drilling. — For drilling operations, satisfactory results can usually be obtained through the use of one of the soluble oil coolants, for all classes of work where the length of chips produced is not very great; but in cases where long chips are formed, there is a rubbing action produced by the chips sliding over the lips of the drill, which produces a condition analogous to that of a machine bearing, thus making it necessary to apply a fluid which serves the combined purpose of lubricant and coolant. The following is an outline of lubricants and coolants recommended for drilling operations in various classes of material, and the lubricants used are recommended in the order in which they are named. In this list "cutting compound" refers to any satisfactory brand of soluble oil mixed with water, in accordance with the manufacturer's instructions; and "mineral lard oil" is a mixture of lard oil and light petroleum oil. The proportions of this mixture vary according to the work, but one part of lard oil to two parts of petroleum gives a mixture that is well suited to the requirements of many average drilling operations. For drilling high-carbon or alloy steel, use mineral lard oil or turpentine; low-carbon steel, mineral lard oil or cutting compound; cast iron, dry or compressed air; wrought iron, cutting compound or mineral lard oil; malleable iron, cutting compound; brass, dry; bronze, cutting compound or dry; copper, mineral lard oil; aluminum, kerosene, beeswax, or tallow; monel metal, cutting compound; and glass, solution of camphor in turpentine.

CHAPTER V

TYPES OF DRILLS AND DRILL SOCKETS

When the purchasing agent of an industrial plant buys twist drills, he should bear in mind the fact that drills are merely the means to attain a desired end; in other words, he is really buying drilled holes for his company. Bearing this fact in mind, it should at once become obvious that the first cost of a drill is likely to be a very unimportant matter, as the ultimate criterion of the price of the tool is the number of holes which can be drilled before it is worn out. Such being the case, the wise purchasing agent will always decide upon the type of drill which the experience of men in the manufacturing departments of his company has shown to be capable of giving the greatest amount of service per unit cost.

Two-fluted Twist Drills. — In Fig. 1 are shown a number of different types of drills, some of which are commonly used, while others represent tools developed to meet the requirements of somewhat special classes of work. By far the majority of drilling operations are performed with either the milled twist drill shown at *A* or the so-called flat-twisted drill which is illustrated at *B*. Both of these types have certain features to commend them to the consideration of the average machine shop manager. It is generally conceded that greater accuracy is secured through drilling with the milled twist drill, but to offset this feature, the flat-twisted drill has about 60 per cent more chip clearance in the flutes. This reduces the amount of power required to drive the drill, and also makes it less liable that the drill will be broken. To offset the claim for greater accuracy of holes drilled with milled twist drills, the claim is made that, as most holes have to be reamed before their accuracy can be depended upon, it is economical to take advantage of the lower price of the flat-twisted drill. These drills are made by twisting a hot flat steel bar to the required form



Machinery

Fig. 1. Various Forms of Twisted and Flat Drills

Three- and Four-fluted Drills. — In drilling large holes, it will sometimes be found that owing to an insufficient amount of power in the drilling machine on which the operation is to be performed, or for some other reason, a hole of the required size cannot be drilled at one operation. In such cases, a small hole is drilled, after which this hole is drilled out to the required size at a second operation. For drilling out or enlarging the hole, use is generally made of either a three- or four-fluted twist drill of the forms shown at *C* and *D*, Fig. 1, respectively. These drills are not adapted for drilling holes from solid metal, but are used only for enlarging a hole already drilled.

Straight-fluted and Flat Drills. — While drilling brass and thin sheet metal, trouble is sometimes experienced through the rake of the cutting edges causing the drill to " catch " or " dig in." To overcome this trouble, profitable use may be made of a straight-fluted drill of the form shown at *E*, Fig. 1. By having two straight flutes in this type of drill, the rake angle of the cutting edges is eliminated, which is found advantageous for certain classes of drilling for the reasons just mentioned. At *F* and *G* there are shown two types of drills which are employed for the same general classes of service for which the straight-fluted drill is used, although the form of the two latter types is quite different from that of the drill with straight flutes. The type of drill illustrated at *F* is known as a flat " track drill " and has a shank of suitable form for use in a blacksmith's drilling machine; the flat drill shown at *G* is made by milling away from $\frac{1}{4}$ to $\frac{3}{8}$ of the material at opposite sides of a piece of round steel and providing two cutting edges in the manner shown. Such a drill may be employed for drilling brass or thin sheet metal, although it does not find very general application at the present time.

The Teat Drill. — The drill shown at *H*, Fig. 1, is generally known as a " teat " drill. This type of drill is employed for drilling shallow holes where it is required to have a flat bottom in the hole, or the teat drill may be used for drilling out the bottom of a hole produced with a regular twist drill in order to produce a flat bottom.

Center Drill and Countersink. — At *I*, Fig. 1, there is shown the familiar form of combination center drill and countersink which is used for producing centers in which twist drills may be started, for centering work ready to be set up on a lathe, etc. This tool finds such general application in the machine shop that it requires no further discussion.

Oil Tube Drills. — For drilling rather deep holes, it may be found that trouble will be experienced in getting the required quantity of oil or cutting compound to the point of the drill, due to tendency of the chips to carry the fluid back with them before it reaches the bottom of the hole. To overcome this difficulty, a practice is made of using what are known as " oil tube " drills which are provided with ducts through which the lubricant can be carried right to the cutting point, and after doing its work the lubricant and chips escape through the flutes of the drill in the usual manner. At *J*, Fig. 1, there is shown the most generally used type of oil tube drill which will be seen to have two oil ducts running through the metal between the two flutes in the drill.

Hollow and Rifle Barrel Drills. — At *K* and *L*, Fig. 1, there are shown types of drills which are intended for drilling deeper holes than could be handled with the type of drill shown at *J*. The drill point at *K* is known as a " hollow " drill and is generally used in a lathe where the work revolves and the drill remains stationary. There is a hole extending lengthwise through the shank to connect the grooves with a tubular shank of the required length for the depth of hole that is to be machined in the work. The drill point is threaded and fitted into this tube. Drill point *L* is part of what is known as a " rifle barrel " drill. This steel point will be seen to have a crescent-shaped duct through which oil is forced at a pressure of about 800 pounds per square inch in order that it may wash the chips back through the straight flute at the side of the drill. This steel drill point is secured to the end of a tube which is flattened at one side in order that oil may flow through the tube and escape through a channel outside the tube which corresponds in shape to the single flute in the drill point. It will be apparent that this type of drill has one cutting lip and that the clearance surface at the point of the drill is backed off to provide the necessary clearance for the cutting edge.

The Cannon Drill. — In general respects the deep-hole drill shown at *M* is of the same design as that shown at *L*, except that the cutting edge is "stepped" instead of straight, in order to provide for breaking up the chips into such a form that they will be more readily cleared from the hole. This is known as a "cannon" drill, and is adapted for the drilling of larger sized holes than are cut by the drill point shown at *L*. In the case of the last three types of drill points shown in this illustration, the work revolves and the drill remains stationary, a method that produces greater accuracy.

Spiral and Rake Angles of Twist Drills. — In addition to the standard dimensions of twist drills which have been given in connection with instructions for drill grinding, the following angles and dimensions are fairly standard: At the point of the drill, the spiral angle of the flute makes an angle of 25 degrees with the center line of the drill, and this angle is gradually decreased to 20 degrees at the end of the flute adjacent to the shank, the necessity for this change in angle being to increase the chip clearance to compensate for the thickening of the web of the drill. Drills are not made of the same diameter from end to end, but decrease from the point toward the shank by an amount varying from 0.00025 to 0.0015 inch per inch of length, according to the diameter of the drill. The body of the drill is not made exactly round, it being general practice to back off or relieve the land of the drill from a short distance behind the leading edge of each flute. The thickness of the web of the drill also increases from the point to the shank and the standard rake angle for the cutting edges is 3½ degrees. In a drill made by the Detroit Twist Drill Co., the rake angle is increased to 4½ degrees and the spiral angle of the flutes is 32 degrees at the point of the drill and 27 degrees at the ends of the flutes adjacent to the shank, thus representing an increase of 7 degrees in each case, from the angles which are recognized as representative of standard practice.

Drill Shanks. — Just as the milled twist drill and the flat-twisted drill are the two types with which a great majority of drilling operations are performed, so the taper shank or the straight shank are the two types of shanks that are most commonly used. At the same time, there are a number of different types of drill shanks which have certain points of merit in which the reader will be interested. In Figs. 2 and 3 are shown illustrations of a number of different types of drill shanks, and the advantages of these will be very briefly discussed. Starting with the taper shank, the reader's attention is called to the fact that drills are made in a great variety of sizes to meet the requirements of various classes of work, but to simplify the problems connected with drill manufacture, there is not the same diversity in the sizes of drill shanks. There are six sizes of drill shanks with Morse tapers running from Nos. 1 to 6, inclusive. The ranges of drill sizes for each of these shanks are shown in Table 1.

Next to the taper shank, as regards the extent to which it is used, comes the straight shank, and drills with shanks of this type are used in various types of drill chucks. One of the chief claims made for this type is that its use avoids the possibility of trouble through twisting off the tang at the end of a taper shank drill. At *C*, Fig. 2, there is shown what is known as the " double-grooved " or Graham shank which is machined with two parallel grooves of uniform depth and angle. These grooves correspond to the shape of jaws of the chuck in which the shank is held, thus preventing all possibility of the shank slipping. With this form of shank it is possible to hold with one chuck a complete range of sizes of drills or other tools, and to tighten or release the chuck without the use of wrenches, drifts, or other tools. A somewhat similar shank is shown at *D*, this being adapted for use in what is known as a " blacksmith's " drill press. Here it will be apparent that there is a flat milled on the shank of the drill to provide a positive drive. A flat-twisted drill of the type made by the Celfor Tool Co. is shown at *E* and this drill has a shank particularly adapted for use in connection with the drill chuck manufactured by this company. Used in connection with the Celfor chuck, this type of shank provides a positive drive and its form is exceptionally well adapted to requirements which arise in connection with manufacturing flat-twisted drills. A disadvantage of this type of shank, however, is that it must be used in connection with a special chuck. At *F* there is shown a drill with a square shank adapted for use in a ratchet. Both this type of shank and the shank for blacksmiths' drills shown at *D* are used to a very

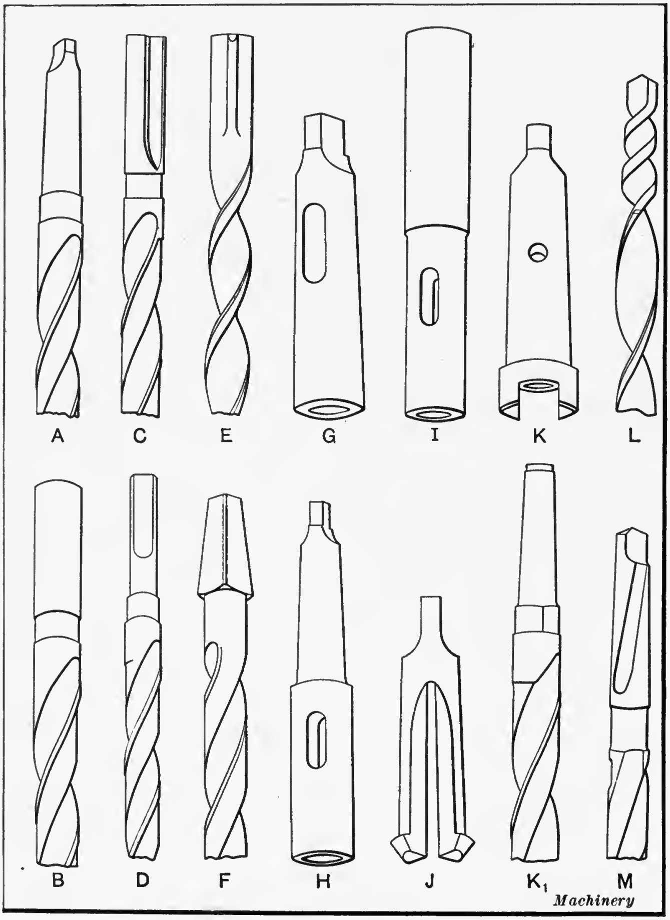


Fig. 2. Drill Shanks and Sockets

slight extent in manufacturing plants, their chief field being in the jobbing shop and on repair work, etc.

Drill Sockets. — Mention has already been made of the six different Morse taper drill shanks that are in general use. The spindle of a drilling machine is bored with a taper socket to fit the size of shank covering the range of drill sizes which will be most generally used upon the drilling machine in question. At the same time, the occasion will frequently arise for using a drill

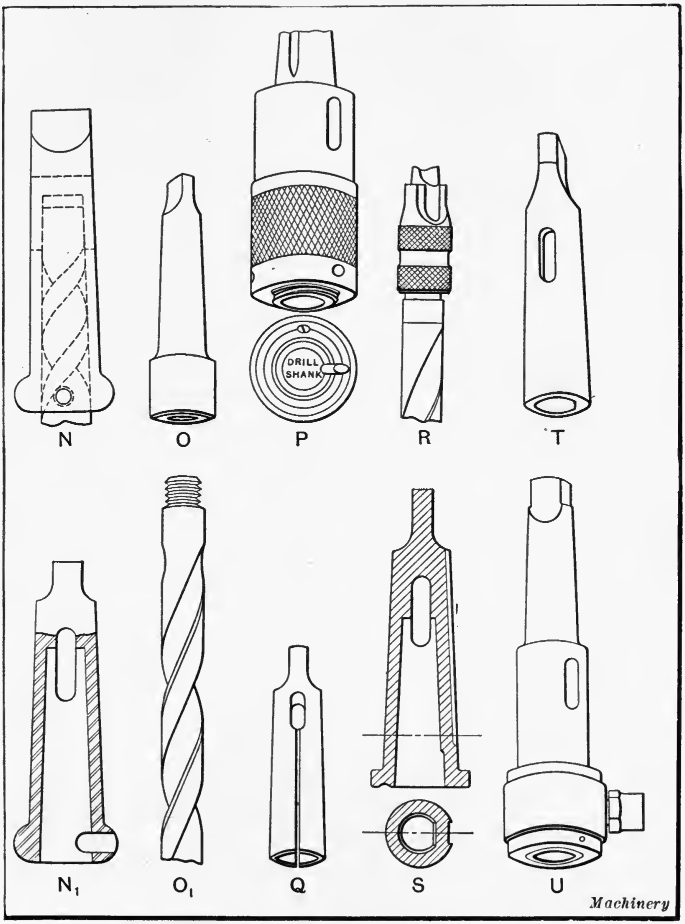


Fig. 3. Other Types of Drill Shanks and Sockets

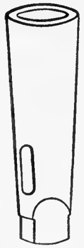
with a shank of some size other than the one corresponding to the taper socket in the drilling machine spindle. To meet the requirements of such cases, use is made of the familiar drill sockets which have an inside taper hole corresponding to the shank of the drill it is required to use, and a taper on the outside which corresponds to the socket bored in the drilling machine spindle. Examples of such sockets are shown at *G*, *H*, and *I*, Fig. 2, these being for what are known as " short " shank drills; and, in addition to these sockets, most manufacturers also make a series of sockets of the same types, but adapted for use in connection with " long " shank drills. The socket shown at *I* is provided with a shank which is left rough so that it may be machined to fit the spindle of the machine tool in which the socket will be used. Tables 2 and 3 give the ranges of combinations of inside and outside tapers in which sockets of the types shown at *G* and *H* are made. At *J* there is shown a special form of split socket or sleeve which provides for using a drill with a grooved shank of the form shown at *C* in a drilling machine equipped with the familiar Morse taper socket in the spindle. It will at once be apparent that the outside of this sleeve is of the usual taper shank form, while two jaws on the inside of the sleeve enter the grooves milled in the shank of the drill.

Table 1. Sizes of Drills used with Morse Taper Shanks

Morse Taper Number	Holds Drills Inclusive Diameter, Inches	Morse Taper Number	Holds Drills Inclusive Diameter, Inches
1	1/16 to 9/16	4	1 17/64 to 2
2	37/64 to 29/32	5	2 1/64 to 3
3	59/64 to 1 1/4	6	3 1/64 to 6

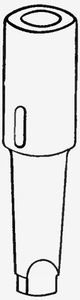
For use in connection with high-speed steel drills where a strong positive drive is required, the Morse Twist Drill & Machine Co. makes sockets of the form shown at *K*, Fig. 2, which have a clutch to engage a corresponding clutch member between the taper shank and the body of the drill which is shown below the socket at K_1. The drill shank has no tang; therefore, no dependence is placed upon this method of driving and there is no danger of trouble from broken tangs. Another method of overcoming trouble from this source is shown in the case of drill shanks *L* and *M*, Fig. 2, both of which are adapted for use in the type of socket shown at *N* and N_1, Fig. 3, drills and sockets of this type being made by the Pratt & Whitney Co. The socket is of the usual type, except that there is a steel stud that engages the side of the groove in the drill shank and forces the shank back into the socket. In this way, the socket is sure to seat itself properly, so that the maximum friction drive is secured, and this is supplemented by the positive driving furnished by the steel stud. As no reliance is placed upon a tang on the drill shank, there is no danger of the shank being twisted off under the most severe conditions of service for which high-speed steel drills are used. At *O*, Fig. 3, is shown a drill socket made by the Rich Tool Co., of Chicago, which is tapped to receive the threaded end of the drill shown at O_1. A socket which is made by the Morse Twist Drill & Machine Co., and known as the "Andrews" patent drill socket, is shown at *P*. This socket is fitted with a key sliding in a radial slot in the holding head. The key bears upon an inclined seat in the shank of the drill and is forced to its seat by a cap fitting over the holding head. Turning this cap by hand in one direction holds the drill firmly in place, while turning it in the opposite direction releases the grip so that the drill may be readily removed from the socket.

Table 2. Socket and Shank Combinations

	Socket, Morse Taper No.	Shank, Morse Taper No.	Socket, Morse Taper No.	Shank, Morse Taper No.	Socket, Morse Taper No.	Shank, Morse Taper No.
	2	1	3	2	5	3
	3	1	4	2	5	4
	4	1	5	2	6	4
	5	1	4	3	6	5

Methods of Utilizing Drills with Broken Tangs. — While going about among machine shops in which the management prides itself upon taking advantage of all possibilities of reducing production costs, it is not uncommon to see a considerable accumulation of twist drills lying in some corner of the tool-room waiting until such a time as they can be disposed of for their junk value. The " business end " of such drills will often be found in perfect condition, but they have been discarded because the tang has been twisted off the shank, making it impossible to drive the drill in the usual form of socket. The old saying that " prevention is better than cure " holds particularly true in this case, and a little care exercised by drilling machine operators would often be the means of saving the twisting of tangs off many drills. Despite a somewhat general opinion to the contrary, the tang on a taper shank is not responsible for furnishing anything like the entire driving power. Where a shank is properly seated in its socket, friction between the shank and socket will exert a very powerful influence in driving the drill. To take advantage of this friction drive, however, it is quite necessary for the socket to be perfectly clean before the drill shank is pushed into it. If a small chip is clinging to the inside of the socket when the drill shank is pushed into place, this chip will prevent the shank from coming into contact with the socket so that advantage may be taken of the friction drive, and, as a result, the entire strain will come upon the tang at the end of the shank with a consequent increase in the probability that this tang will be twisted off.

Table 3. Socket and Shank Combinations

	Socket, Morse Taper No.	Shank, Morse Taper No.	Socket, Morse Taper No.	Shank, Morse Taper No.	Socket, Morse Taper No.	Shank, Morse Taper No.
	2	1	5	2	4	4
	3	1	2	3	5	4
	4	1	3	3	6	4
	5	1	4	3	4	5
	3	2	5	3	5	5
	4	2	3	4	6	5

Several methods have been devised for the utilization of drills on which the tang has been twisted off from the shank. At *Q*, Fig. 3, there is shown a socket corresponding to the usual type of socket, except that it is split. Even where the tang has been twisted off a drill, a socket of this kind will provide a sufficiently tight grip on the drill shank to afford the necessary driving power. At *R* is shown what is known as a " tang gage." Where the tang has been twisted off a drill shank, this gage is used to mark the outline of a new tang after which the shank is ground down to the outline laid out with this gage, so that the drill can once more be driven in the usual manner. The " wear-ever " drill socket shown at *S* is made by Scully-Jones & Co. It has a flat on the inside of the socket to drive drills from which the tang has been twisted off, a corresponding flat being ground on the shank of the drill to engage this flat in the socket. The flange at the bottom of this socket furnishes additional strength and prevents the socket from spreading. The " use-em-up " drill socket shown at *T* is made by the American Specialty Co., and reference to this socket will make it apparent that provision is made for using a drill with a broken tang by simply grinding a flat on the side of the drill shank. The socket shown at *U* has nothing to do with the utilization of drills on which the tang has been twisted off from the shank. This type of socket is for use in connection with oil tube drills. The collar on the socket is held stationary by the supply pipe that connects with a nipple through which oil is delivered to the tubes in the drill that carry it direct to the cutting point.

CHAPTER VI

TYPES OF COMMONLY USED DRILL CHUCKS

There are three general methods of holding drills in the spindles of drilling machines and other machine tools. These are as follows: 1. By inserting the drill shank directly into a hole in the machine spindle. 2. By inserting the drill shank in a socket or sleeve which fits into the drill spindle. 3. By using some form of drill chuck. Although there are one or two types of drill chucks adapted for holding drills with the familiar form of tapered shank, by far the more general practice is to use drills with straight shanks in all cases where drill chucks are to be employed. Drill chucks are made in a variety of different designs, all of which are claimed to possess certain valuable features which adapt them for securely holding drills without marring the shanks and various other advantages. All drill chucks are provided with sufficient adjustment to adapt them for holding different sizes of drill shanks, and it is this capacity for handling a range of sizes, together with ability to secure a firm driving grip on the drill without marring the shank, and the possibility of rapidly changing from one size of drill to another, which are the chief advantages secured through the use of drill chucks over other methods of mounting drills in the spindles of drilling machines.

All types of drill chucks may be roughly subdivided into two general classes; namely, those types in which opening and closing of the jaws is controlled through the action of a geared sleeve, a screw, or some similar method; and the so-called " quick-acting " or " automatic " chucks, in which provision is made for rapidly operating the chuck jaws by hand, without requiring the use of a wrench or other tool, so that the tools may be rapidly changed in cases where a sequence of drilling, counterboring, and reaming operations, etc., have to be performed. In the following paragraphs, a brief description will be given of a number of types of drill chucks that find quite general application in American machine shops.

Use of Quick-change Collet Chucks. — Where there is a sequence of machining operations to be performed, for instance where it is necessary to drill, counterbore, and tap a hole, the planning department which decides the methods of performing machining operations has a choice between the use of a straight-line multiple-spindle drilling machine or a single-spindle machine equipped with a quick-change chuck. The use of multiple-spindle machines has been discussed in another section of this book and we are now concerned with the method of handling the work on a single-spindle machine. Quick-change chucks may be of the so-called " automatic " type, in which one tool may be instantly released from the chuck and another substituted, or they may be of the quick-change collet type, four examples of which are illustrated in Fig. 1. The difference between the automatic chuck and the collet chuck is that the former grips directly upon the shank of the drill, while the latter, as its name implies, grips a special collet in which the drill is held. The advantage of either type of chuck for use in performing a sequence of operations on a single-spindle machine is that practically no time is lost in changing tools. Not only are both the automatic and collet types of chucks rapid to operate, but they are so designed that it is unnecessary to stop the spindle of the machine in order to change tools.

At *A*, in Fig. 1, is shown the " magic " chuck made by the Modern Tool Co. This chuck consists of a cylindrical body with a taper shank and two steel balls that move in and out of races milled through the chuck body so that they can enter corresponding races in the locking ring which is mounted loosely on the chuck body. The body is bored out in the center to receive collets in which various types of tools are carried. These collets are made of tool steel with ball races to receive the balls carried in the chuck body, the way in which the collet is held in place in the body of the chuck being shown by dotted lines. When the locking ring is raised, centrifugal force pushes the balls out into the races cut in the locking ring, leaving a perfectly clear opening for the collet; and when the ring is released gravity draws it down, thus forcing the balls back through the walls of the chuck so that they enter the slots or races in the collet to hold it in place. Thus two natural forces are utilized to secure a quick release and positive grip. The body of the chuck is made of crucible steel and the collet of tool steel with the races hardened to provide the required durability.

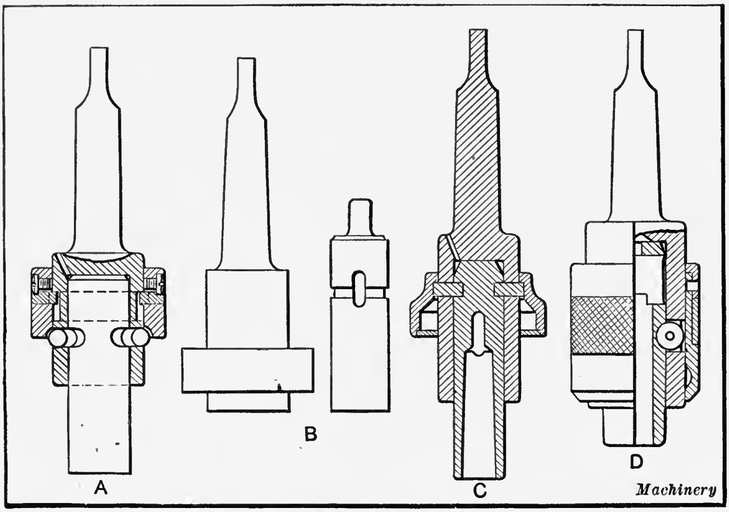


Fig. 1. Quick-change Collet Chucks

By using a special type of split collet in connection with one of the collets adapted for use in this chuck, it is possible to use taper shank drills from which the tangs have been twisted off. These chucks are made with Morse taper shanks from Nos. 1 to 6, inclusive, and collets for use in the chucks are made with sockets to fit Nos. 1 to 5 Morse taper shanks, inclusive; special collets are also made to meet the requirements of other tools.

At *B*, Fig. 1, there is illustrated the "Presto" drill chuck that is made by the Whitney Mfg. Co. Chucks of this type are furnished with shanks fitted to Nos. 2, 3, and 4 Morse taper sockets or with the shanks left blank, and collets are made to fit tools with Nos. 1, 2, and 3 Morse taper shanks; collets may also be furnished blank so that they may be machined to meet special requirements. To operate this collet chuck, it is merely necessary to lift the releasing ring which allows the collet in the chuck to be instantly removed and another collet carrying the next tool to be substituted in its place. The collet is driven by a tang entering a socket in the chuck. Dropping the ring locks the new collet in place.

At *C*, Fig. 1, there is shown a drill chuck made by the Quick Action Chuck Co., which is made in three different sizes with shanks ranging from Nos. 1 to 6 Morse taper, inclusive. Collets are made for use in this chuck which have a capacity for Morse taper shank drills from Nos. 1 to 5, inclusive, and special collets are made to hold tools with any size of shank up to 1½ inch in diameter. The collet in the chuck is released by simply raising the sliding sleeve and, after a fresh tool has been substituted, dropping the sleeve locks the collet carrying this tool firmly in the chuck.

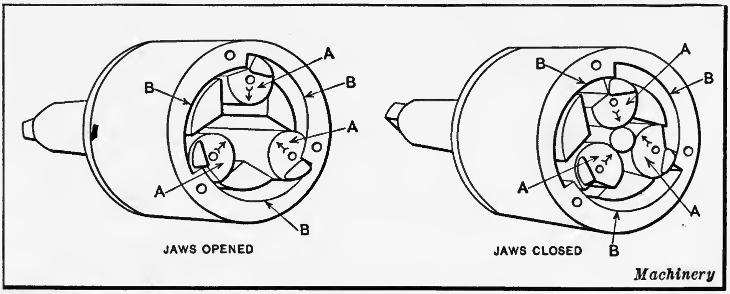


Fig. 2. Chuck having Eccentric Rollers which Grip Drill Shank

The Wiard chuck shown at *D*, Fig. 1, is made by the Eclipse Interchangeable Counterbore Co. These chucks are made in five different sizes with shanks ranging from Nos. 1 to 5 Morse taper, inclusive. The different sizes of chucks are adapted for drills up to $\frac{5}{16}$, $\frac{19}{32}$, $\frac{29}{32}$, $1\frac{1}{4}$, and 2 inches in diameter, respectively. The way in which this chuck operates will be apparent after referring to the illustration. Lifting the loose sleeve that surrounds the body of the chuck brings a groove in this sleeve into line with the corresponding groove in the chuck body. In this position, the steel disks which lock the collet in place in the chuck are allowed to roll back so that one collet may be withdrawn and another collet pushed up into place in the chuck. After this has been done, the sleeve is dropped, thus forcing the steel disks back so that they engage the collet and lock it firmly in place in the chuck. It will, of course, be apparent that, in the case of the chucks shown at *A*, *B*, *C*, and *D*, it is unnecessary to stop the machine while changing tools, because the sleeve or ring that operates the chuck may be held while the spindle rotates.

Automatic Drill Chucks. — Figs. 2 and 3 show two well-known types of quick-acting or automatic drill chucks which are operated by hand, making chucks of these types well adapted for use on drilling machines where it is required to perform a sequence of operations making necessary the frequent changing of tools. In the chuck shown in Fig. 2, which is made by the Wahlstrom Tool Co., the drill shank is gripped by three eccentric rollers *A*, which are so designed that, when in contact with the shank of the drill, the resistance offered by the drill to being driven into the work causes these rollers *A* to rock in such a way that they close in toward a common center and thus grip the drill shank, due to the eccentric form of the rollers. Owing to the way in which this chuck operates, the amount of gripping power applied by the chuck is in direct proportion to the resistance offered by the drill to being driven into the work. In other words, the power applied by the chuck is in direct proportion to the service required of it. Adjustment of the chuck for holding drills with shanks of various sizes is afforded by means of three cam surfaces *B* on the inside of the chuck shell. To open the chuck, the drilling machine operator grips the knurled surface on the outside of the chuck shell and holds this shell back against the rotation of the drilling machine spindle,

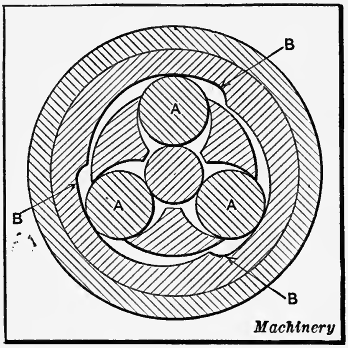


Fig. 3. Chuck equipped with Cams and Rollers

thus causing the chuck jaws to recede to their position of widest opening. The drill in the chuck then drops out and the machine operator simply pushes the next drill to be used up into the chuck and releases the shell, so that a spring in the chuck may rotate this shell sufficiently to cause cam surfaces *B* to bring eccentric jaws *A* into contact with the drill shank. The grip provided by the jaws through this spring action is sufficient to hold the drill in place in the chuck, but would not be sufficient to drive the drill when in contact with the work. When the machine spindle is fed downward so that the drill engages the work, the resistance offered by the drill to being driven causes eccentric jaws *A* to rock and secure a grip on the drill shank in the manner to which reference has already been made.

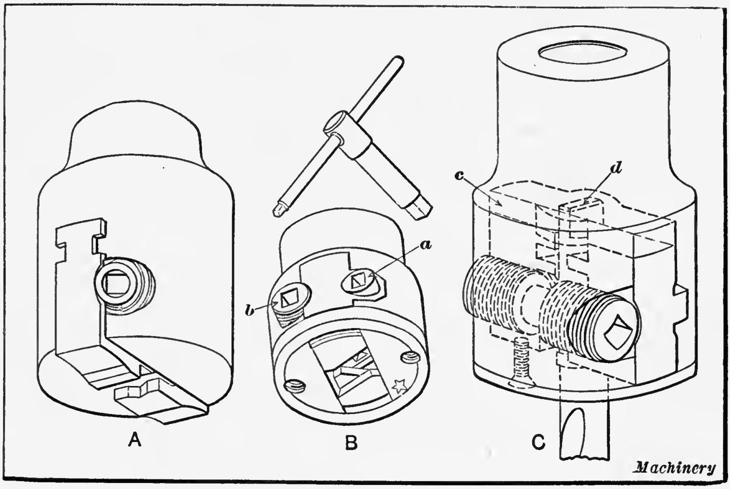


Fig. 4. Drill Chucks of the Screw Type

In the Gronkvist automatic drill chuck (SKF Ball Bearing Co., Hartford, Conn.) shown in Fig. 3, the method of operating the chuck and providing for securing a grip on the drill shank by the chuck jaws is somewhat similar to that of the chuck shown in the preceding illustration. Here it will be seen that the jaws *A* are cylindrical in form and three cam surfaces *B* provide for adjusting the position of these jaws for holding drills of different sizes. The chuck is operated by holding the knurled shell or sleeve back against the direction of rotation of the drilling machine spindle and, when jaws *A* secure a preliminary grip, the required grip for driving is secured through resistance offered by the drill against rotation causing the jaws *A* to roll sufficiently on cam surfaces *B*, so that the jaws are forced in against the drill shank.

Two-jaw Screw-type Drill Chuck. — There are a number of concerns making drill chucks of the general type shown in Fig. 4, which are furnished with two jaws operated by a screw and hand wrench. The chuck shown at *A* in this illustration is made by the Cushman Chuck Co. In these chucks, the jaws are threaded at the side to engage an operating screw which is threaded right hand at one end and left hand at the opposite end, so that turning of this operating screw with a hand wrench provides for tightening or loosening the two jaws simultaneously. The type of chuck shown at *B* is made by the Westcott Chuck Co., and the feature of its design consists of the provision of an auxiliary screw *a* that engages threaded sections of the chuck jaws at the opposite side from the main operating screw *b*, thus avoiding all tendency for the jaws to crowd away from the right- and left-hand sections of the operating screw. At *C*, there is shown a chuck made by the Pratt Chuck Co., in which the arrangement of jaws and method of operation is the same as that

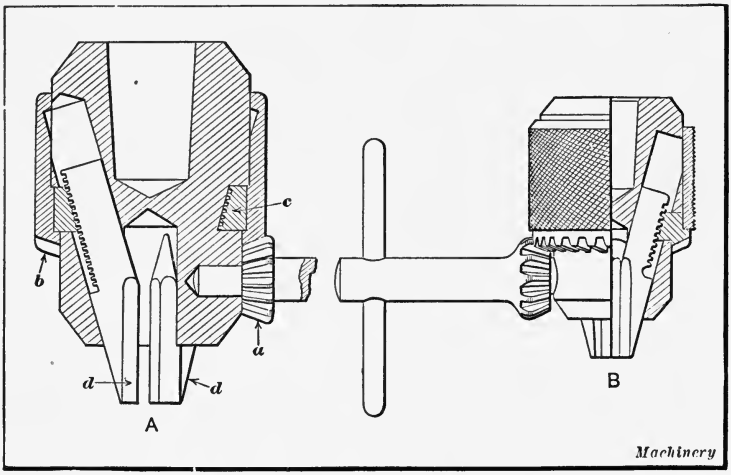


Fig. 5. Chucks of the Geared Type

of the chuck shown at *A*. The feature of this chuck consists of an equalizing driver *c* which is slotted to receive the drill tang *d*, thus providing a positive drive which is independent of the grip on the drill shank afforded by the chuck jaws. This driver is self-adjusting, permitting the jaws to center and line up the drill accurately in the chuck.

Geared Type of Chuck. — The chuck shown at *A*, in Fig. 5, is made by the Jacobs Mfg. Co., and tightening of the jaws is accomplished in the following manner: A hand wrench carrying pinion *a* is piloted to fit into bushings in the chuck body, and this pinion *a* meshes with gear teeth *b* cut in the bottom of a sleeve of which threaded ring *c* is an integral part. This threaded ring meshes with threads cut in the upper outside portion of each of the three chuck jaws *d*. Evidently, when the wrench is turned, pinion *a* turns sleeve *b* and threaded ring *c*, which is an integral part of the sleeve, thus either pushing down or lifting chuck jaws *d* according to the direction in which the wrench is turned. By having jaws *d* inclined to the axis of the drill, raising or lowering the jaws causes them to release their grip on the drill shank or to secure a firm grip.

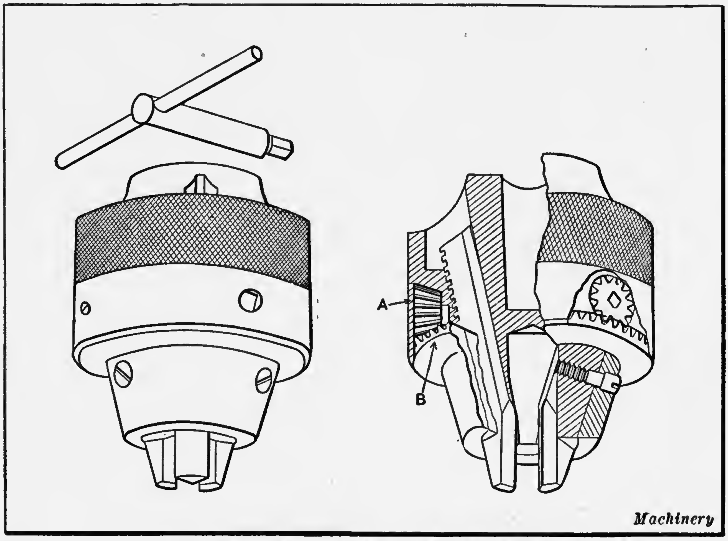


Fig. 6. Another Chuck of the Geared Type

At *B*, Fig. 5, there is shown a chuck operating on the same general principle, which is made by the J. R. Almond Mfg. Co. This illustration shows the outside of the chuck with the operating wrench in position, and in connection with the cross-sectional view of the Jacobs chuck shown at *A* it gives a very clear idea of the design and operation of this type of geared chuck. The chuck shown in Fig. 6, made by the Skinner Chuck Co., is so designed that it may be operated by hand except for obtaining the final grip of the jaws on the drill shank or for releasing these jaws after the drill has been in operation, a wrench being employed for this purpose which fits in the square hole in either of the pinions *A* which mesh with a gear *B* that governs the operation of the chuck jaws. This feature of hand adjustment is also common to the chucks shown in Fig. 5.

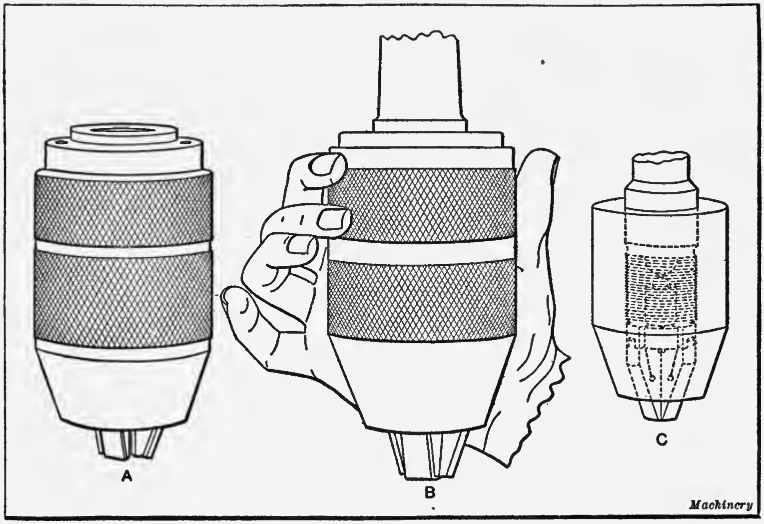


Fig. 7. Chucks of the Knurled-sleeve Type

Wrenchless Drill Chucks. — In some shops, an objection is made to the use of chucks which are operated by a wrench, because it is claimed that trouble is often experienced through having the wrench mislaid. The exponents of this theory have developed hand-operated drill chucks which are made with a knurled sleeve that may be gripped by hand and turned in either direction in order to tighten or loosen the grip of the jaws on the drill shank. The chuck shown at *A* in Fig. 7 is made by E. Horton & Son Co. This chuck is furnished with ball bearings so that its operation is made as easy as possible. A coarse pitch screw provides quick adjustment of the chuck jaws, while a fine pitch screw tightens up the jaws to afford the desired driving grip on the drill shank. At *B*, there is shown a drill chuck made by the Nielsen-Barton Chuck Co., and the chuck shown at *C* is a product of the Goodell Pratt Co. Both of these chucks are hand operated, so that they provide for quickly changing the tools and also avoid any possible complications through loss of the operating wrench.

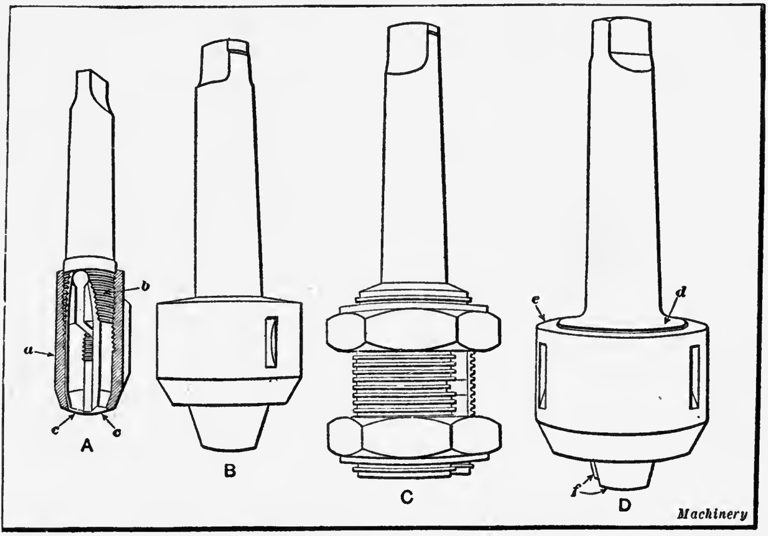


Fig. 8. Chucks for Drills having Shanks of Special Form

Chucks for Special Drill Shanks.—The preceding types of drill chucks are universal in their scope, being adapted for driving any standard straight shank drill which comes within their range. Reference to Figs. 2 and 3, Chapter V, will show that there are a number of special forms of drill shanks, and for driving drills with such shanks, the drill chucks must be especially designed for the purpose. For instance, at *C*, Fig. 2, there is shown what is known as the Graham grooved shank, drills of this type being made by the National Twist Drill & Tool Co. and also by the

Detroit Twist Drill Co. To provide for holding drills with this type of shank, both of these firms make chucks with a special form of jaw adapted to fit into the groove in the drill shanks. At *A*, in Fig. 8, there is shown one of these chucks which is a product of the Detroit Twist Drill Co. It will be evident from this illustration that when sleeve *a*, which is threaded internally to fit over the threaded section *b* of the chuck body, is screwed up, the taper on the inside of sleeve *a*, that engages a corresponding taper on jaws *c*, causes these jaws to be sprung inward to grip the grooves in the drill shank. At *E* in Fig. 2 (Chapter V) there is shown the type of shank provided on the flat-twisted drills made by the Celfor Tool Co., and to meet the requirements of holding drills with shanks of this type, this firm makes a special drill chuck as shown at *B* in Fig. 8. This chuck is provided with jaws which are grooved to receive the central beads on the drill shank. It will be apparent that the chuck is an extremely simple design and is strongly constructed to stand up under severe service. The Celfor drill shanks are made with the four corners of the shank beveled so that they are accurately located at an equal distance from the center line of the drill. At *C*, Fig. 8, there is shown a type of drill chuck which is designed to take advantage of this beveling of the corners of the Celfor drill shank by holding drills of this type by the beveled corners.

The Rich Tool Co. makes a type of drill in which the two spiral grooves of the drill are continued to the end of the drill shank, although these grooves change their direction to run parallel to the axis of the drill over the entire length of the shank. To provide for driving drills of this type, the Rich Tool Co. makes a drill chuck shown at *D* in Fig. 8. This chuck is simply constructed, consisting of only four parts; namely, the body *d*, operating nut *e*, and two jaws *f*. This chuck may be quickly adjusted and is said to be well suited for use where frequent changes of tools must be made. The jaws *f* clamp an inward taper in the grooves on the drill shank, which prevents the drill from being pulled out even where the grip of the jaws on the drill shank has not been made sufficiently tight.

CHAPTER VII

DRILL GRINDING

In order to give satisfactory service, a drill must be ground so that its point is of the correct form. Efficient results cannot be expected from a drill in which the material and original workmanship are of the required standard, unless the subsequent work of grinding to keep the point of the drill in working condition is handled in such a way that the proper form is maintained. It is very difficult to grind a drill by hand and secure the desired results without spending too much time on the work. Men employed in factories manufacturing drills learn to do this work very rapidly as the result of their special experience, but the drilling machine operator or tool-room attendant who attempts to grind a drill by hand is likely to fail to produce a point which comes even reasonably near to meeting all requirements. It is generally conceded that the form of a drill point exerts a powerful influence upon the rate of production, accuracy of drilled holes, and the number of holes which can be drilled between successive grindings. Granting this to be the case, it at once becomes apparent that steps should be taken to provide for grinding drills in such a way as to enable them to give the maximum amount of service.

Requirements in Drill Grinding. — For the average shop, the only way to be sure of attaining such a result is to have the drills ground on special drill grinding machines which are so designed that they assure producing drill points that meet all requirements. These requirements are as follows: (1) Both cutting lips of a drill must be inclined at the same angle with the axis of the drill. (2) Both cutting lips must be of exactly the same length. (3) The drill point must have the proper lip clearance or contour of the surface back of the cutting edges, and this clearance must be the same for each side of the drill. All of these factors are of the utmost importance in enabling a drill to give satisfactory service. The various undesirable conditions which it is possible to produce through improper drill grinding are shown in Fig. 1. If both lips of the drill are not inclined at the same angle α with the axis, one lip will fail to counteract the tendency of the other to spring away from the cut. Furthermore, this will result in having one lip of the drill do more work than the other, with the result that this lip will soon become dull, and an abnormal torsional strain will also be set up. When the cutting lips of the drill have the same inclination to the axis but are of different lengths, it means that the point of the drill is off center, and as a result the hole will be cut over size by an amount equal to twice the eccentricity of the drill point. It is also possible to have an error in both the angle of drill point and equality of length of the lips of the drill, and where such a condition exists there will be a combination of the undesirable results which have been mentioned.

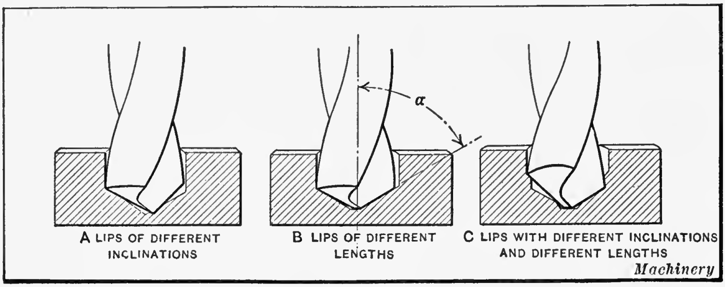


Fig. 1. Conditions under which a Twist Drill may be forced to Operate through Incorrect Drill Grinding

Concerning Angles of Drill Points. — An angle of 59 degrees has been adopted as the standard angle for the points of twist drills, and such a point is well suited for drills engaged on all average classes of work. There are certain cases, however, where a modification of the form of the drill point is considered advisable. For instance, where a drill is fed down onto the surface of a piece of work held at an angle to it, and where no guide bushing is provided to hold the drill in the desired position, it will be found desirable to make the drill point to an angle more acute than 59 degrees in order to facilitate penetration of the drill point without tendency for it to slide down on the surface of the work. Conversely, a drill which is used to make holes in fairly thin tubing will give better results where the point is made blunter than that of a standard drill. The reason for this is that the feed pressure of the drill tends to spring the tubing slightly until the point of the drill starts to break through; then the work springs back quickly to its original position and increases the rate of feed — the condition being similar to that explained in connection with Fig. 7, which shows the result of spring in the members of a drilling machine — and such a condition may cause the drill to be broken.

The two conditions which have been cited are typical of instances where it is necessary to reduce the standard angle when grinding drills. In general, if there is marked trouble through breakage of drills, and the other conditions which are likely to result in breakage are considered satisfactory, a slight modification of the drill point may produce a drill which gives the desired results without trouble from breaking. Another case where it is necessary to modify the standard form of twist drills is when drills are used for cutting brass. Here the standard angle of rake provided for use in drilling iron or steel is such that the drill would tend to hog into the work and produce an unsatisfactory condition of operation. To overcome this difficulty, it is the practice to grind the drill so that the rake angle is reduced practically to zero. Drills ground in this way will cut quite freely and give a satisfactory rate of production.

Clearance behind Cutting Edges. — In order that a drill may cut properly, there must be the correct amount of clearance behind each of the cutting edges so that these edges may be forced down into the work. Where there is insufficient clearance, a drill will not cut freely; and too much clearance results in weakening the tool at its cutting edges. Theoretically, the amount of clearance should be slightly in excess of that which is actually required for the rate of feed under which the drill is being operated, because any excess clearance results in a corresponding weakening of the cutting edge of the drill. As a matter of fact, drills are usually ground with an amount of clearance sufficient to take care of the maximum feed under which they are likely to be operated, and when so ground the amount that the cutting edges are weakened can safely be disregarded. In order to clearly understand the conditions which must be fulfilled in order to grind the desired amount of clearance on the point of a drill, it is necessary first to appreciate the fact that every point (as at *A* and *B*, Fig. 2) on each cutting edge is advanced on a spiral path as the drill is fed into the work. All of these spiral paths have the same lead *x* — which is equal to the rate of feed per revolution — but each spiral has a different diameter.

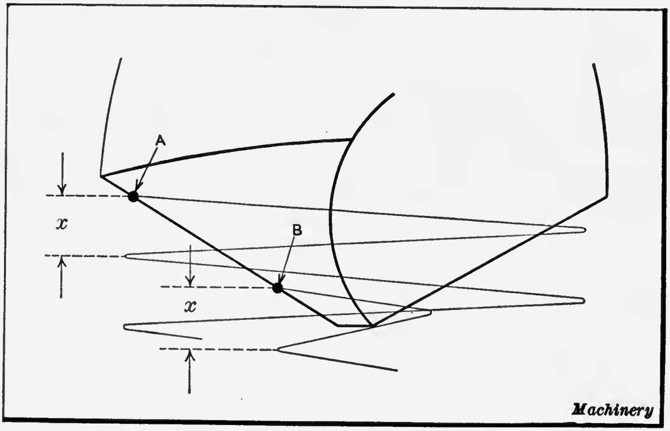


Fig. 2. Diagram showing why Clearance Angle should Increase Toward the Drill Point

The clearance angle is defined as the angle which a tangent to the spiral path followed by a point on the cutting edge at the periphery of the drill makes with the axis of the drill. This fact in regard to each point following its own spiral path will be readily understood by referring to Fig. 2. A study of this illustration will also show the requirements which must be fulfilled in order to grind the proper clearance on the point of a drill. It will be apparent that the clearance must increase from the periphery of the drill to the center. This is due to the fact that, while the spirals at all points along the lip of the drill have the same lead, the diameter of each spiral is constantly growing less as it passes from the periphery of the drill to the center. Consequently point *B* follows a steeper path than *A* which accounts for the increase in the clearance angle from the periphery toward the center. In drills made by the Cleveland Twist Drill Co., the clearance angle at the periphery is from 12 to 15 degrees, and this angle increases uniformly from the periphery to the center in such a way that the angle made by the chisel point with each cutting edge of the drill is from 125 to 135 degrees. This is the condition indicated in Fig. 3.

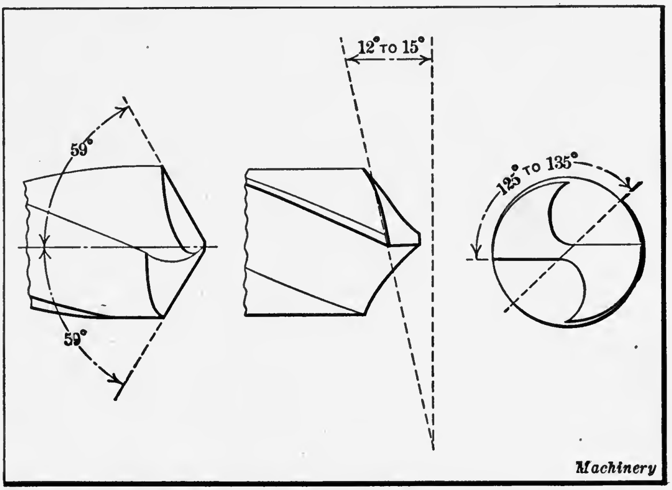


Fig. 3. Commercial Standards for Angle of Drill Point, Clearance, and Angle made by Chisel Point with Cutting Edges of Drill

In order to regulate the clearance so that it is correct for each lip of the drill all of the way from the periphery to the center, and to relieve each surface back of the cutting edges so that the proper degree of endurance and strength will be secured, it is necessary for the point of the drill to rock against the grinding wheel while it is being ground in a path similar to that which it follows while actually being fed into a piece of work. In order to secure this result, it is necessary to maintain the desired relation between the angle at which the drill is held against the grinding wheel and the axis about which it is rocked while in contact with the wheel.

In Fig. 4, let *AB* in each diagram represent the axis about which the drill is rocked while being ground, and let *C* and *D* represent the radii of arcs through which different portions of the drill lip will be swung during the grinding operation. In order to have the clearance increase from the periphery of the drill to the center, it is obvious that those portions near the center must travel on shorter paths and smaller circles than portions near the outer corner of the lip. In other words, radius *C* must be shorter than radius *D* in order to secure the desired clearance. In the upper two diagrams, this condition is attained,

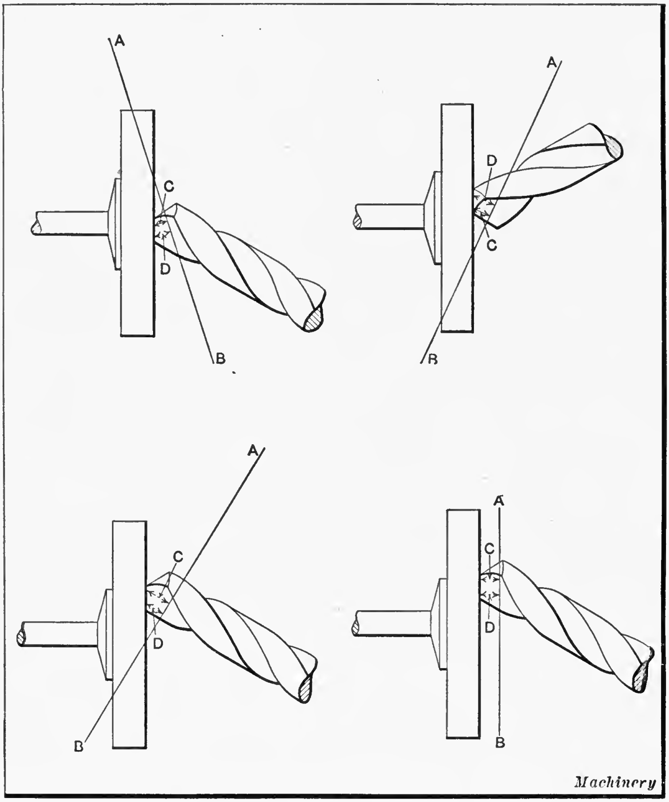


Fig. 4. Diagrams showing Correct and Incorrect Relations between Face of Grinding Wheel and Axis about which Drill is rocked while being ground

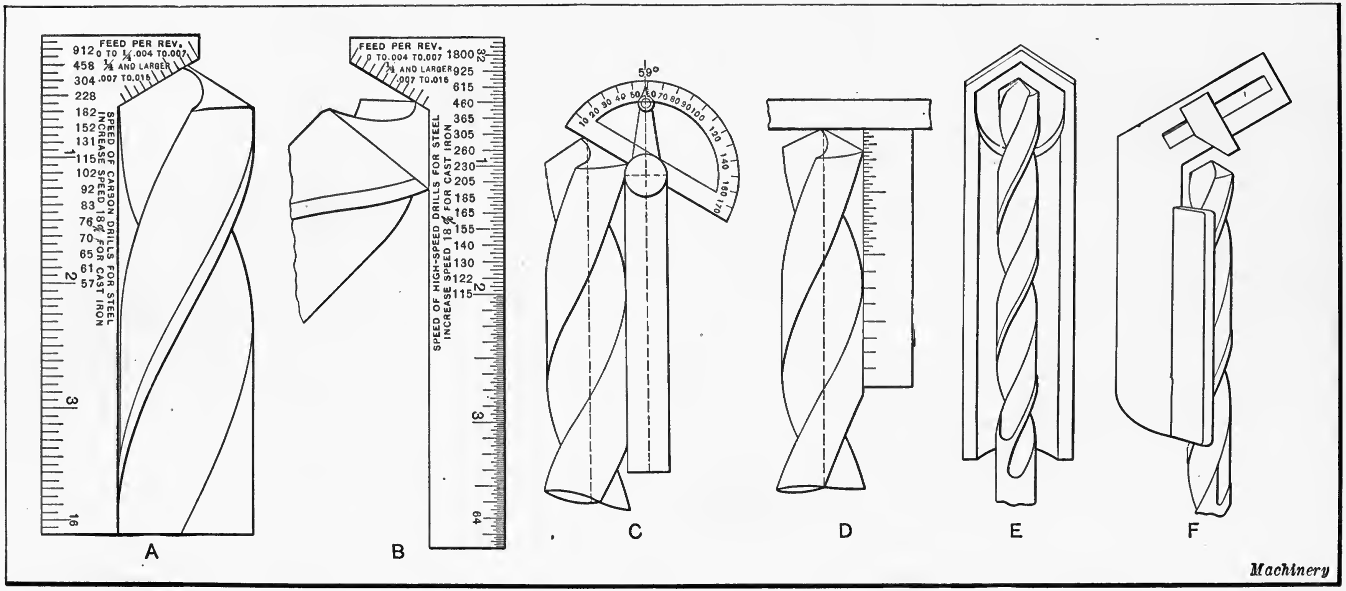


Fig. 5. Methods of Measuring Angle of Drill Point, Angle made by Chisel Point with Cutting Edges, and Clearance behind Cutting Edges

while in the lower two there is failure to secure the required condition.

Measuring or Gaging Drills after Grinding. — In Fig. 5 are shown various methods of gaging twist drills after grinding in order to determine the accuracy of the point angle, the clearance, etc. At *A* is shown a simple gage made by the Standard Tool Co. for measuring the accuracy of the 59-degree point angle; this gage is also graduated in such a way that it may be used to measure the length of the two cutting edges to see that these are equal. Used in the manner shown at *B*, this gage can also be employed to measure the center angle, i.e., the angle made by the chisel point with the cutting edges of the drill. Although the included angle of this gage is only 118 degrees and an angle of 130 degrees is required between the chisel point and the cutting edges of the drill, the use of the gage in this way enables a very close estimate to be made of the accuracy of the angle of the chisel point, and it will be recalled that this angle determines the clearance provided for the cutting edges.

At *C* is shown how a protractor may be used to measure the point angle, and this illustration is self-explanatory. Another method of measuring the angle of the drill point is shown at *D*, and this method also affords a means of obtaining an idea of the accuracy of the clearance provided behind the cutting edges. The length of each cutting edge is first measured with the scale to see that they are equal; and, if so, the drill is supported as shown and measurements are made at each side, as indicated in the illustration. If these measurements are equal, it shows that the point angle is the same at both sides of the drill. This method may also be used to measure the clearance provided for each cutting edge by placing the drill point beside the scale as shown, and then slowly revolving the drill. If the clearance at each side is not the same, it will be indicated by a difference in the relative positions of the drill and scale for corresponding positions of the drill. It must be borne in mind that this method indicates the clearance provided at the heel of the drill only, and while this clearance may be correct, there may still be a serious error in clearance near the drill point. At *E* and *F* are shown two types of gages made by the Morse Twist Drill & Machine Co. for testing the angle of drill point; these illustrations show clearly the method of using the gages without requiring a description.

Use of Drill Grinding Machines. — There are a number of drill grinding machines on the market which are properly designed to provide for accurately securing the required contour for the drill point. Drills ground on such machines ought to meet all of the requirements to which attention has been called. It should scarcely be necessary to call attention to the fact that it is very important for the drill grinding machine to be kept in proper adjustment in order to produce the expected results; but it was recently stated that a certain shop purchased its twist drills from a well-known manufacturing firm, and an investigation made to determine the cause of breakage of drills for which a replacement claim had been made revealed the fact that the drill grinding machine used in this shop was so badly out of adjustment that it failed to produce drill points of the required form. When attention was called to the fact that the broken drills had been improperly ground, the possibility of such a condition was promptly denied, as it was asserted that "they had been sharpened on a drill grinder." Subsequently this machine was properly adjusted and a responsible mechanic was employed to do all of the drill grinding, and since that time there has been a marked falling off in the number of drills broken in the shop. Several manufacturers of twist drills who have had a great deal of experience with troubles which may result through improper grinding state that, in shops using any considerable number of drills, the wages of an experienced mechanic, placed in charge of all drill grinding and held responsible for the results obtained, would be more than paid by the saving in broken drills.

How to Grind a Drill by Hand. — It is a difficult matter to grind a drill by hand and secure the desired results without taking altogether too much time in performing the grinding operation, as previously mentioned. Nevertheless, the mechanic who makes an intelligent study of the requirements of drill grinding can learn to grind a drill by hand after he has had enough experience to enable him to acquire the necessary degree of dexterity. One method of grinding drills by hand, which is capable of giving satisfactory results, is to hold first one lip of the drill and then the other against the grinding wheel so that a flat clearance surface is ground at the back of each cutting edge. In doing this work great care should be taken not to change the angle which the chisel point of the drill makes with the cutting edges, as it is the angle of the chisel point which determines the amount of clearance provided for the cutting edges. After these flat clearance surfaces have been ground, the mechanic very carefully swings the drill back and forth so that the flat ground surfaces are blended into the remainder of the surface back of each cutting edge. This method of grinding will not produce a drill point which appears to approximate closely the form produced on a drill grinding machine, but the results obtained with a drill ground in this way will often be far more satisfactory than those resulting from the use of a drill ground by hand, where the mechanic has attempted to secure a closer approximation of the original form of the drill point through swinging the drill back and forth on the surface of the grinding wheel.

If the mechanic attempts to grind a drill by hand and duplicate the movement secured through the use of a drill grinding machine, the proper method of procedure is as follows: The drill is held between the thumb and index finger of the left hand at a short distance back of the point, and the hand is steadied by the tool-rest of the tool grinder. The drill is held at such an angle to the grinding wheel that the surface of the drill point rests flat against the wheel, and great care must be taken to have the chisel point of the drill in a vertical position; in other words, the cutting edge of the drill is inclined upward. With the drill held in this position, the mechanic grips the shank between the thumb and index finger of his right hand and slowly oscillates the drill about an imaginary axis, between the thumb and index finger of his left hand, taking care to keep the chisel point vertical at all times. After grinding one side of the drill in this

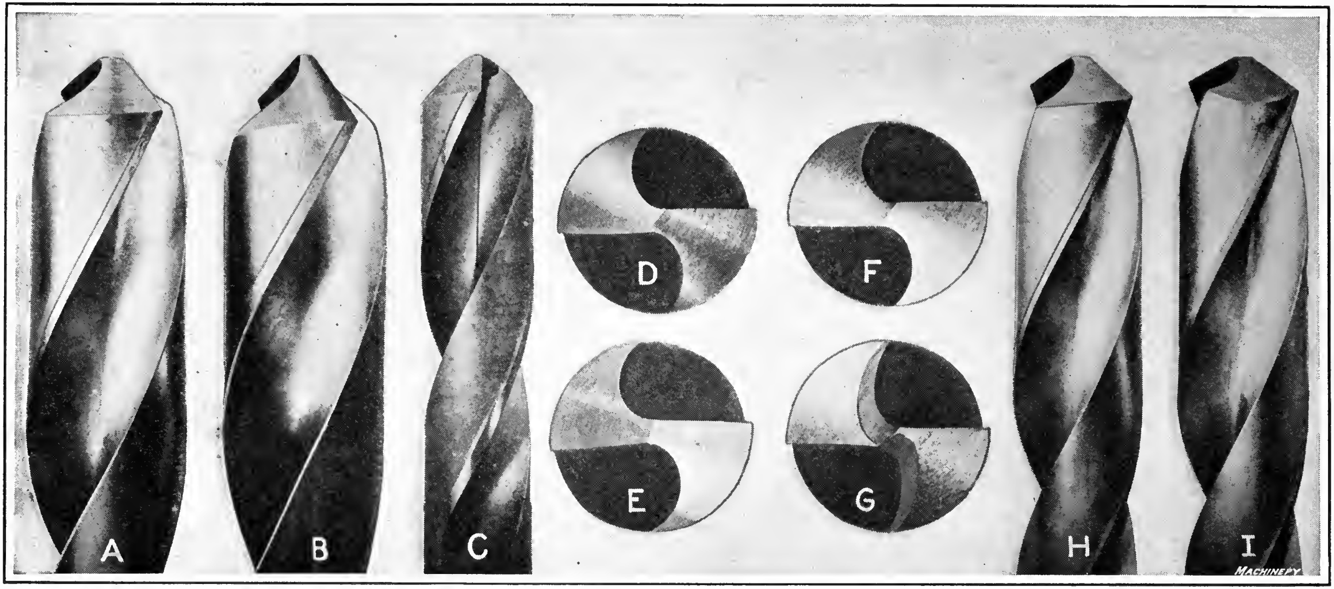


Fig. 6. (*A*) Drill with Proper Clearance. (*B*) Drill with Insufficient Clearance at Center. (*C*) Drill split because of Insufficient Clearance and Incorrect Angle between Chisel Point and Cutting Edges. (*D*) End of Drill with Chisel Point making Correct Angle with Cutting Edges. (*E*) End of Drill with Chisel Point making Incorrect Angle with Cutting Edges. (*F*) End of Drill where Web has been properly thinned. (*G*) End of Drill where Thinning has been carried to Excess. (*H*) Another Drill with Proper Clearance. (*I*) Drill with Insufficient Clearance

way, the drill is turned over so that the other side may be ground. This method can be used with extremely satisfactory results by men who have had a great deal of experience in drill grinding, but it is probable that the average mechanic will secure better results through the method of hand grinding referred to in the preceding paragraph. In any case, hand grinding is not recommended for the average shop, as the superior speed and quality of workmanship obtained through the use of drills ground on a drill grinding machine are quite sufficient to warrant the investment in an equipment of this kind.

Effect of Improper Drill Grinding. — A better idea of the actual effect of improper drill grinding will be gathered by reference to Fig. 6, which shows various conditions of the drill point which are made possible through correct or incorrect grinding. At *A* is shown a drill ground with the proper clearance for the cutting edges, and at *B* is shown a drill on which an insufficient amount of clearance has been furnished at the center, although there is plenty of clearance at the heel of each cutting edge. It will be recalled that the angle of the chisel point, i.e., the line separating the two faces of the drill point, indicates the amount of clearance provided for the cutting edges, and at *C* is shown what is likely to happen to a drill where the angle of the chisel point and clearance of the cutting edges are insufficient. This drill had plenty of clearance at the heel, but very little clearance at the center, with the result that it was split up the center. A better idea of the way in which the angle of the chisel point indicates the amount of clearance will be gathered by referring to the two end views of the drill shown at *D* and *E*. At *D* is shown a drill in which the chisel point has been ground to make an angle of 130 degrees to the cutting edges, which gives a sufficient amount of clearance, while at *E* the angle formed is only 100 degrees, and this drill has insufficient clearance.

Most twist drills are made in such a way that the web at the center increases in thickness as the length of the drill is gradually decreased in sharpening. On account of this increase in web thickness, mechanics have acquired the practice of grinding away the web at the drill point or " thinning " the web, as the process is commonly called. A great deal of trouble is likely to result from this practice of thinning the drill point, due to the excessive amount of metal which is often ground away. Where skilled mechanics do the work and are careful to grind away only a sufficient amount of metal to maintain the web thickness equal to the original thickness of the web at the point of the drill when it was new, this practice is not detrimental; but if an excessive amount of grinding is done, it is almost sure to produce undesirable results. At *F* is shown a drill point in which the web has been properly thinned to reduce it to the original dimension, while at *G* is shown a drill point on which thinning has been carried to excess. A drill ground in this way is extremely liable to break through splitting up the center, and such a drill will also require more power to drive it, due to trouble experienced in clearing the chips. While provision of the necessary amount of clearance for the cutting edges of a drill is highly important, it is equally important not to provide too much clearance, because in such cases an insufficient amount of metal is left behind the cutting edges and trouble is likely to be experienced through chipping the drill. At *H* is shown another drill which has the proper amount of clearance. Comparison with drill *I* shows that the latter has insufficient clearance, thus causing the heel to drag; consequently, the drill will give very unsatisfactory results in operation and may not cut at all.

Causes of Broken Drills. — The conditions of service under which a twist drill operates are more severe than those imposed upon almost any other type of cutting tool, because the drill must of necessity be of such size that it can enter the hole in which it works, while its cross-section has to be greatly reduced in order to provide the required clearance for the escape of chips. Despite this fact, it is quite probable that the average twist drill receives as little consideration as any tool used in the machine shop, there being a somewhat general impression among mechanics that a twist drill is sold ready for use and can properly be expected to continue to give satisfactory service regardless of the way in which it is handled. The fallacy of this idea is clearly shown by the tremendous wastage which occurs every year through breaking drills as a result of improper use. Reference has already been made to the conditions that must be fulfilled in order for a drill to give efficient service, and if the grinding operation is not conducted so that these conditions are fulfilled, an abnormal strain is likely to be placed upon the drill which may rapidly assume sufficient proportions to cause it to be broken.

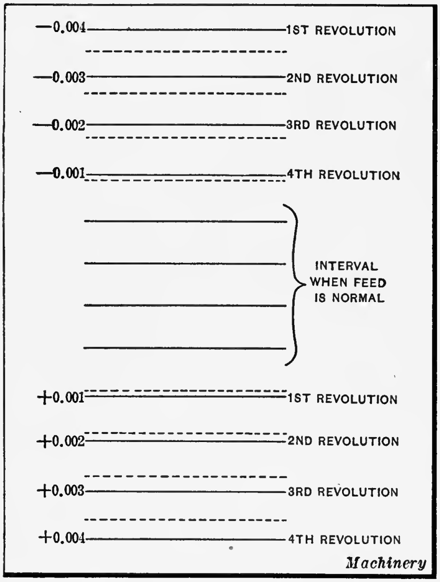


Fig. 7. Diagram showing how Spring in Drilling Machine causes Excessive Rate of Feed, which may break the Drill

There is another point which is likely to be responsible for breaking of drills; namely, the spring and lost motion in drilling machines due to improper design. The way in which this condition is likely to cause breakage of drills will be understood by reference to Fig. 7. Assuming that the members of a drilling machine can be sprung 0.010 inch as a result of back-pressure exerted by the drill while in operation, then, during the time that this spring is being imposed upon the machine members, the rate at which the drill point is fed into the work is represented by the normal feed per revolution *minus* the amount of spring imposed upon the members of the drilling machine per revolution.

When this lost motion has been taken up, the drill will continue to operate at the normal rate of feed until such a time as the drill point breaks through the work at the bottom of the hole. When this result takes place there will be a sudden reduction of back-pressure exerted by the drill, with the result that the strained members of the drilling machine will suddenly react; now, under these conditions, the rate of feed will be the normal rate provided by the gearing in the feed-box *plus* the increase due to a sudden release of the strain on members of the drilling machine. This sudden increase in the rate of feed as the drill breaks through is the reason why so many drills are broken at just this point, and not because there is any tendency for the bottom surface of the work to catch the cutting lips of the drill according to a somewhat general impression which exists among mechanics who have given very little thought to the situation.

Now, in the case of a drilling machine where the parts have not been designed in a way which assures the required degree of rigidity, it is obvious that one of two conditions must exist: either the rate of feed must be made the maximum safe rate for the drill *minus* the amount of additional feed imposed upon the drill during the time that it is breaking through the hole at the bottom of the work, or else the risk must be run of breaking a number of drills through this sudden increase in the rate of feed while the operation is being finished. Obviously, the decision of any experienced production manager will be that neither condition will meet his requirements. He will insist upon the purchase of drilling machines of sufficiently rigid construction so that the amount of back-pressure exerted by the drill point while penetrating the work will not be sufficient to cause an appreciable amount of spring.

Determination of Magnitude of Feed Pressure and Torsion. — In connection with research work conducted by engineers of the Cleveland Twist Drill Co. to determine the magnitude of strains imposed upon a twist drill due to feed pressure and torsional resistance, a special drilling machine was constructed in such a way that the table of the machine rests upon a piston-rod connected to a piston entering a cylinder filled with oil. When a drill mounted in the spindle of this machine is driven into a piece of work supported on the table, it will be obvious that pressure exerted by the drill results in introducing a corresponding amount of pressure on the piston, and hence on the oil contained in the cylinder. A recording pressure gage connected to this cylinder makes it possible to calculate the amount of pressure exerted by the drill while penetrating the work. To prevent rotation of the table of this special drilling machine, a radial arm is carried out from the table and provided with a piston-rod connecting with a piston in a second oil cylinder. A recording pressure gage is also connected to this cylinder, by means of which it is possible to measure the torsional stress upon the drill.

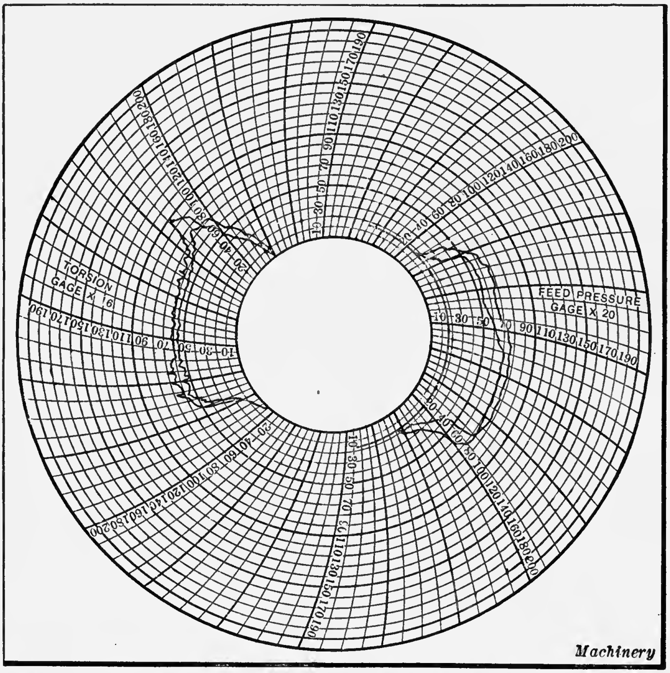


Fig. 8. Combined Torsion and Feed-pressure Chart for 1¼-inch Drill operated in Special Testing Machine which Registers Torsion and Feed Pressure on Recording Hydraulic Pressure Gages

Fig. 8 shows a combined feed-pressure and torsion chart for a 1¼-inch drill operated in this machine, and this chart illustrates very clearly another important consideration in preventing broken drills as a result of spring in the drilling machine members to which reference was made in a preceding paragraph. This is the provision of a proper amount of clearance on the drill surfaces behind the cutting edges. Reference to this pressure-torque chart will make it apparent that there is a pronounced difference in feed pressure and torsion for each of the pairs of curves recorded on this chart. These differences in feed pressure and torsion are due to the fact that the drill used in making one pair of curves, where the feed pressure and torsion are greater, was ground on a machine which provides less clearance for the drill point than is the case on the drill grinding machine which ground the drill used in drawing the pair of curves where feed pressure and torsion are less. Obviously, this lays emphasis upon the importance of grinding drills on a machine which will provide the required amount of clearance to enable satisfactory operation to be secured under the maximum amount of feed that will be used under the most severe conditions of operation, without unduly increasing the pressure and consequent spring in the drilling machine. In this connection, the reader's attention is directed to the paragraph on drill grinding which explains methods of measuring the amount of clearance provided on the drill point to make sure that this conforms with the recommendations of firms specializing in the manufacture of drills. In the case of the feed-pressure curves in the chart, it will be seen that the pressure first runs up rapidly and then takes a peculiar drop before assuming the normal condition. This drop is due to the fact that, near the center of the drill, the cutting edges have practically no rake; the pressure runs up while the point of the drill is entering the work, and when approaching the periphery, where there is a considerable amount of rake, this rake helps to pull the drill into the work, thus reducing the feed pressure and producing the peculiar dip seen in the feed-pressure curves.

CHAPTER VIII

DRILLING MACHINES APPLIED TO GENERAL MANUFACTURING OPERATIONS

THERE are many shop superintendents and men in charge of the planning of machining operations who do not realize the full scope of work which may be efficiently handled on drilling machines. In many shops gratifying results are obtained in the performance of such operations as drilling, counterboring, reaming, and tapping; but most factory executives have a well defined idea of what constitutes " drill press work," and the use which they make of their drilling machines is confined to those pieces which come under this arbitrary classification. Those in charge of the machine shops in some progressive manufacturing plants have recently broken away from this idea and have extended the use of drilling machines to provide for handling many operations for which turret lathes, engine lathes, and other types of machine tools were formerly employed. In so doing, the quality of workmanship has been kept up to the previous standards and in practically every case rates of production have been materially increased. There are few shops where a wider range of manufacturing operations are handled on heavy-duty drilling machines or where higher rates of production are obtained on this type of machine than at the plant of S. F. Bowser & Co., Inc., Fort Wayne, Ind. This concern operates a battery of twenty-eight of the No. 310 high-duty drilling machines built by Baker Bros., Toledo, Ohio, and the organization of systems for the expeditious handling of work and the development of jigs, fixtures, and special cutting tools for use on these machines has been carried to a high degree of perfection.

Range of Work done on Drilling Machine. — Many shop men who have formed their own opinions as to what constitutes the range of work that can be efficiently handled on drilling machines would be greatly surprised at the results obtained in the Bowser shops. Two points would doubtless be the first to attract attention; namely, the great variety of machining operations that are performed, and the extremely high rates of production which are secured with a relatively small labor cost for the operation of machines. In addition to the familiar operations of drilling, counterboring, reaming, tapping, etc., a variety of other operations, including turning, threading, facing, and boring are performed under conditions that give very satisfactory results from the standpoints of finish, accuracy, and rates of production.

Arrangement of Machines. — There are necessarily a number of details concerning the operation of this department which vary according to the character of the work, but the basic principles governing the handling of all classes of work are as follows: The machines are set up in one row and placed close enough together so that sheet-metal troughs extend from table to table of adjacent machines. As a result, when the operation on one machine has been completed, the work may be pushed across to the next machine with a minimum expenditure of time and exertion on the part of the operator. The parallel between this plan and the operation of turret lathes for handling the same work will be obvious. Instead of indexing a turret to bring successive tools into operation, the work is moved along under the spindles of machines carrying the required tools. Operations are conducted on the progressive system, but although many parts are handled which require a considerable number of operations to complete them ready for the assembling department — running as high as twelve operations in some cases — it is never found advisable to have so many machines working on the same piece at one time.

Number of Machines used Progressively. — Before giving the subject serious consideration, it would doubtless appear that the most efficient results would be obtained by setting up a sufficient number of machines to enable the work to be completed without the necessity of intermediate handling between the performance of different series of operations. Experience has shown, however, that on the average classes of work handled on these machines, one operator is able to take care of four machines. Accepting this as a basis of operation, and considering the case of a piece in which twelve operations are required to finish the machining, it at once becomes apparent that three operators and three groups of four machines would be necessary. So long as there is no interruption in the process of manufacture, the greatest efficiency would result through setting up twelve machines so that the work could be handed along progressively until the last operation was completed, after which the pieces would be transferred to the painting department preparatory to being assembled. As a matter of fact, the method of procedure would probably be to handle the first four operations as if their completion resulted in finishing the work. This set of four machines would then be dismantled and set up for the second set of four operations, and after these operations had been completed, the machines would again be dismantled and set up for the final operations. The reason for adopting this method is that experience has shown that, where more than four machines are operated at a time, delays resulting from the breakage of tools on any one machine or the temporary absence of one operator from his group of machines would result in a congestion of work and delay of one or more of the other operators, which would far more than offset the time saved by the avoidance of what might appear to be two unnecessary transfers of the work from machines to trucks, and vice versa. Another advantage of subdividing the total series of machining operations in this way is that the percentage of the total machine equipment used on a single piece at any one time is greatly reduced. As there are a large number of different parts constantly going through the shop, it would be poor practice to tie up as many as twelve machines out of twenty-eight on a single job.

No difficulty has been experienced in using four machines for a piece, regardless of the number of operations. Pieces with one operation would have four sets of tools and fixtures; pieces with two operations would have two sets of tools; and pieces with six or ten operations would have the tools doubled for the last two operations, which would enable the operator to do the last two operations on four machines, finishing two pieces at a time. With pieces requiring three, five, seven, or nine operations, etc., it is usually possible to combine two of the operations so as to fit an even number of machines, or else, in cases where there is one long operation, to set up two machines for this, the operator having time to perform the other two operations of this group on two pieces while either of the first two machines is performing one operation. An example of nine operations being performed on eight machines is shown on piece No. 15 of the accompanying lists of parts representing various examples of work done on drilling machines, an example of a piece with three operations being performed to advantage on four machines is shown on part No. 2; and an example of a piece with five operations being performed on four machines is shown on part No. 4. The detailed method of operations on this piece is as follows:

Order of Operations. — Referring to Fig. 1, it will be seen that four machines are used, the boring operation being performed on the first, turning on the second, tapping on the third, and threading on the fourth. The third operation is really a double one, because the piece is tapped with a taper pipe tap from each side. The machine for this operation has a sliding fixture with provisions for holding two pieces, one of these being inverted. The order followed by the operator of this group of machines in going about his work is as follows: (1) Remove bored piece from machine No. 1 and set up fresh blank. (2) Remove turned piece from machine No. 2 and set up bored piece from machine No. 1. (3) Remove piece from 3-B and place in position marked by a cross between 3-B and 4 in Fig. 1; remove piece from 3-A and place in position 3-B; take bored and turned piece from machine No. 2 and place in position 3-A; slide fixture until spindle is over 3-A and start machine No. 3. (4) Remove finished piece from machine No. 4 and set up piece which was set in position marked by cross between machines Nos. 3 and 4. (5) Go back to machine No. 3, hole at 3-A being tapped by this time, push fixture over and start spindle in piece in position 3-B. (6) Return to machine No. 1.

Another point which helps out the machining of pieces where it is necessary to perform a number of operations is the possibility of using portable machines, such as tappers, etc., to take a fifth and seventh operation. Piece No. 11 in the "List of Parts, Order of Machining Operations, and Rates of Production" is an example of this. With such highly systematized methods for the performance of a sequence of operations, it is believed by the management of the Bowser factory that the highest rate of production that is possible is obtained from each machine.

Organization of Department Management. — Reference has already been made to the fact that, in operating these machines, it is the practice never to have more than four machines working on the same piece; however, it occasionally happens that the length of operations on a group of machines is such that the operator can perform the first operation on the group of four machines next to his own in less time than the other operator can perform the remaining three, in which case the machines are divided up five and three between the two operators, although the parts being machined each require four machines. There is a set-up man in charge of the department who is under the jurisdiction of the general foreman, and it is the duty of this man to assist the operator in dismantling his machine at the completion of each job and in setting up the new jobs. He also sees that sharp tools are furnished to the operators at such times as they need them and can also substitute for any of the regular machine operators at such times as the latter are away,

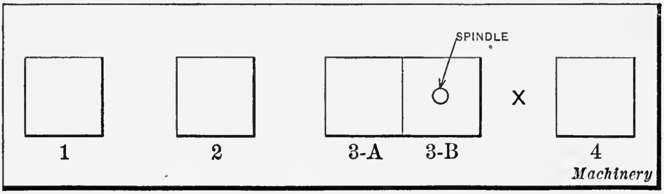
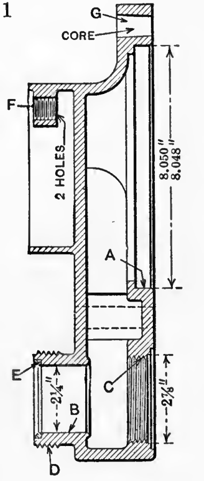
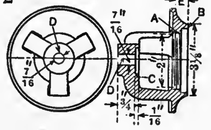
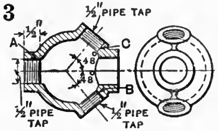
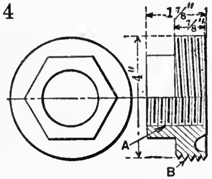
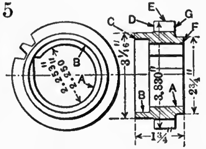


Fig. 1. Diagram illustrating Procedure in moving Work from Machine to Machine to keep all Machines in Group constantly in Operation

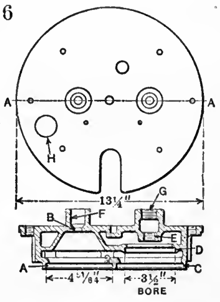
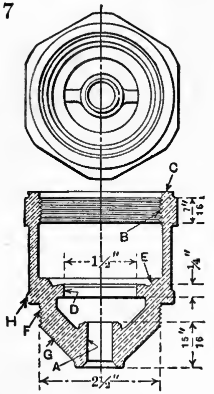
List of Parts, Order of Machining Operations, and Rates of Production — 1

	Oper. No.	Operation	Notes on Special Features of Tool Equipment	Material Production Time
1 	1	Grind top and bottom of work.	Besly double disk grinder.	Cast iron. 13 minutes.
	2	Bore hole *A*.	See Figs. 12 and 13.	
	3	Ream hole *A*.	See Figs. 12 and 14.	
	4	Rough-bore holes *B* and *C*, and chamfer top of hole *B*.	See Figs. 12 and 16.	
	5	Finish-bore and face top of hole *B*, counterbore and face top of hole *C*.	See Figs. 15 and 17.	
	6	Tap hole *C*.	See Figs. 12 and 18.	
	7	Finish valve-seat at top of hole *B*.	See Fig. 19.	
	8	Turn and face top of union *D*, bore seat for bronze bushing *E*.	See Figs. 20 and 21.	
	9	Ream seat for bushing *E*.	See Figs. 20 and 22.	
	10	Thread union *D*.	See Fig. 20.	
	11	Press in bushing *E*.	Portable arbor press.	
	12	Chamfer bushing *E*.	See Figs. 20 and 23.	
	13	Drill two holes *F*.	See Figs. 20 and 24.	
	14	Tap two holes *F*.	See Fig. 20.	
2 	1	Bore hole *A*, face flange *B*, and counterbore at *C*.	Combination boring, counterboring, and facing tool with provision for holding dimension *E*.	Cast iron. 1 minute.
	2	Drill holes *D* in two pieces.	Jig to hold two pieces and two-spindle head.	
	3	Tap hole *A* in two pieces.	Note: Two machines on Operation 1.	

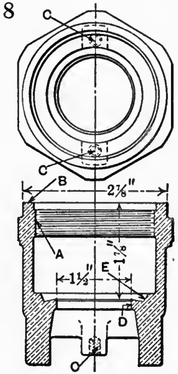
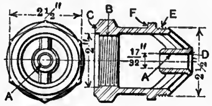
List of Parts, Order of Machining Operations, and Rates of Production — 2

	Oper. No.	Operation	Notes on Special Features of Tool Equipment	Material Production Time
3 	1 2 3 4 5 6	Drill hole *A*. Drill hole *B*. Tap hole *B*. Drill hole *C*. Tap hole *C*. Tap hole *A*.	Angle-plate jig with pilot in hole *A*. Angle-plate jig with pilot in hole *A*. Angle-plate jig with pilot in hole *A*. Angle-plate jig with pilot in hole *A*. Note: Operations 2 and 4 and Operations 3 and 5 performed on same machine.	Cast iron. 1 minute.
4 	1 2 3 4	Bore hole *A*. Turn boss *B*. Tap hole *A*. Thread boss *B*.	Piloted turning tool. Opening threading die. Note: Hole *A* is tapped from both sides with a 1½-inch taper pipe tap.	Cast iron. 1¼ minute.
5 	1 2	Bore holes *A* and *B*, face flange *C*, and clean up surface *D*. Turn diameter *E*, face flange *F*, and clean up face *G*.	Combination boring and facing tool for two holes and two faces. Combination turning and facing tool. Note: Two machines on Operations 1 and 2.	Cast iron. 2½ minutes.

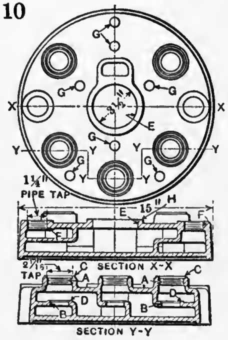
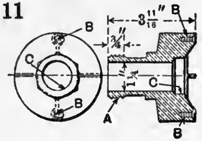
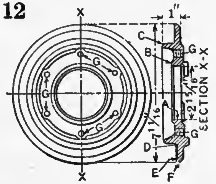
List of Parts, Order of Machining Operations, and Rates of Production — 3

	Oper. No.	Operation	Notes on Special Features of Tool Equipment	Material Production Time
6 	1	Rough-bore and chamfer hole *A* and face flange at top of hole	Combination boring, chamfering, and facing tool.	Cast iron. 5 minutes.
	2	Ream hole *A*.		
	3	Drill hole *B*.		
	4	Rough-bore holes *C*, *D*, and *E*.	Stepped boring tool.	
	5	Ream hole *C*.		
	6	Tap hole *E*.		
	7	Bore and turn gland *F*.	Piloted combination turning and boring tool.	
	8	Thread outside of gland *F*.		
	9	Bore hole *G*.		
	10	Tap hole *G*.		
	11	Bore hole *H*.		
	12	Tap hole *H*.	Note: All other holes drilled on multiple-spindle machine carrying two pieces.	
7 	1	Drill hole *A*, rough-bore hole *B*, face flange *C*, chamfer hole *A*.	Four-spindle drill head — work turned over twice.	Bronze. 2½ minutes.
	2	Finish-bore hole *B* and finish-face flange *C*; bore *D* and counterbore *E*.	Combination stepped boring, counterboring and facing tool which holds 1⅞ inch height.	
	3	Turn diameter *F*.	Piloted turning tool.	
	4	Thread diameter *F*.		
	5	Tap hole *B*.		
	6	Chamfer hole *D*.		
	7	True up face of flange *C*.		
	8	True up face *H*.		

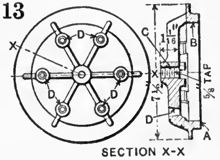
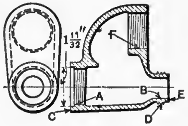
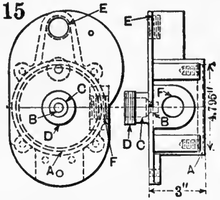
List of Parts, Order of Machining Operations, and Rates of Production—4

	Oper. No.	Operation	Notes on Special Features of Tool Equipment	Material Production Time
8 	1	Rough-bore hole *A* and face flange *B*, drill two holes *C*.	Four-spindle drill head. Work turned over once.	Bronze. 1½ minute.
	2	Finish-bore *A*, finish-face *B*, bore *D*, and counterbore *E*.	Combination stepped boring, counterboring and facing tool.	
	3	Tap hole *A*.		
	4	Chamfer hole ***D***.	Note: Holes *C* tapped on portable machine.	
9 	1	Drill hole *A*, bore and counterbore hole *B*, face flange *C*, chamfer hole *A* at *D*.	Three-spindle drill head—work turned over twice.	Malleable iron. 1½ minute.
	2	Turn diameter *E* and face flange *F*.	Combination piloted turning and facing tool.	
	3	Thread diameter *E*.		
	4	Tap hole *B*.		

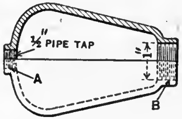
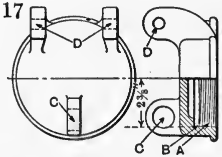
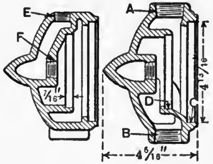
List of Parts, Order of Machining Operations, and Rates of Production — 5

	Oper. No.	Operation	Notes on Special Features of Tool Equipment	Material Production Time
10 	1	Bore holes *A* and *B*; index fixture five times for these holes.	Indexing fixture and stepped boring tool.	Cast iron. 15 minutes.
	2	Face flanges *C* and *D* and counterbore holes *A*.	Combination counterboring and facing tool that holds height between faces *C* and *D*.	
	3	Tap five holes *A*.	Indexing fixture.	
	4	Chamfer holes *B*.	Indexing fixture.	
	5	Bore hole *E* and face flange *H*.	Combination boring and facing tool.	
	6	Bore two holes *F*.	Sliding fixtures to locate second hole for boring or tapping.	
	7	Tap two holes *F*.		
	8	Drill out seven cored holes *G*.	Note: Fixture is indexed five times to machine holes *A* and *B*.	
11 	1	Turn diameter *A*.	Turning tool.	Cast iron. 1½ minute.
	2	Thread diameter *A*.		
	3	Drill and countersink two holes *B*.	Four-spindle drill head — work turned once.	
	4	Drill hole *C* to depth shown; holes *B* tapped on portable machine.	Note: Holes *B* tapped on portable machine.	
12 	1	Bore hole *A* and face flange *B*.	Combination boring and facing tool.	Cast iron. 4 minutes.
	2	Turn diameter *C*, face flanges *D* and *E*, and turn diameter *F*.	Combination turning and facing tool.	
	3	Drill two sets of three holes *G*.	Three-spindle drill head.	
	4	Chamfer hole *A* to 30 degrees.	Note: Holes *G* tapped on portable machine.	

List of Parts, Order of Machining Operations, and Rates of Production — 6

	Oper. No.	Operation	Notes on Special Features of Tool Equipment	Material Production Time
13 	1	Face flange *A* and bore hole *B*.	Combination boring and facing tool.	Cast iron. 3 minutes.
	2	Drill hole *C*.		
	3	Drill out six cored holes *D*.	Three-spindle drill head — two operations. Note: Two machines on Operation 1, hole *C* tapped on portable machine.	
14 	1	Bore and counterbore hole *A*, bore hole *B* and face *C*; turn diameter *D* and face *E*; bore hole *F*.	Three-position fixture and multiple-spindle head; stepped boring and facing tool; combination turning and facing tool. Work reset three times.	Malleable iron. 2 minutes.
	2	Thread diameter *D*.		
	3	Tap hole *A*.		
	4	Tap hole *F*.		
15 	1	Bore and chamfer hole *A*.	Boring and chamfering tool.	Cast iron. 4 minutes.
	2	Ream hole *A*.		
	3	Drill hole *B*.		
	4	Bore hole *C* and turn diameter *D*.	Piloted boring and turning tool.	
	5	Thread diameter *D*.		
	6	Bore hole *E*.		
	7	Tap hole *E*.		
	8	Bore hole *F*.		
	9	Tap hole *F*.	Note: Operations 7 and 9 performed on one machine with two-position fixture.	

List of Parts, Order of Machining Operations, and Rates of Production—7

	Oper. No.	Operation	Notes on Special Features of Tool Equipment	Material Production Time
16 	1	Drill hole *A*.		Malleable iron. 1 minute.
	2	Tap hole *A*.		
	3	Drill hole *B*.		
	4	Tap hole *B*.		
17 	1	Rough-bore hole *A*.		Malleable iron. 2 minutes.
	2	Under-cut hole *A* at *B*.	Cam-operated under-cutting tool.	
	3	Tap hole *A*.		
	4	Drill hole *C* and two holes *D*.	Angle-plate jig and two-spindle drill head.	
18 	1	Bore holes *A* and *B*.	Angle-plate jig; work turned over to drill and tap hole *B*.	Cast iron. 2½ minutes.
	2	Tap holes *A* and *B*.		
	3	Rough-bore holes *C* and *D*.	Stepped boring tool.	
	4	Ream hole *C*.		
	5	Drill hole *E*.		
	6	Tap hole *E*.		
	7	Drill hole *F*.		
	8	Tap hole *F*.		

MACHINERY

Note: The time of each operation does not include an allowance for setting up machines or grinding tools, but does allow for changing dull tools for sharp ones. The time of setting up machines varies from fifteen minutes to half an hour per machine, depending upon the nature of the tools and fixtures which are required.

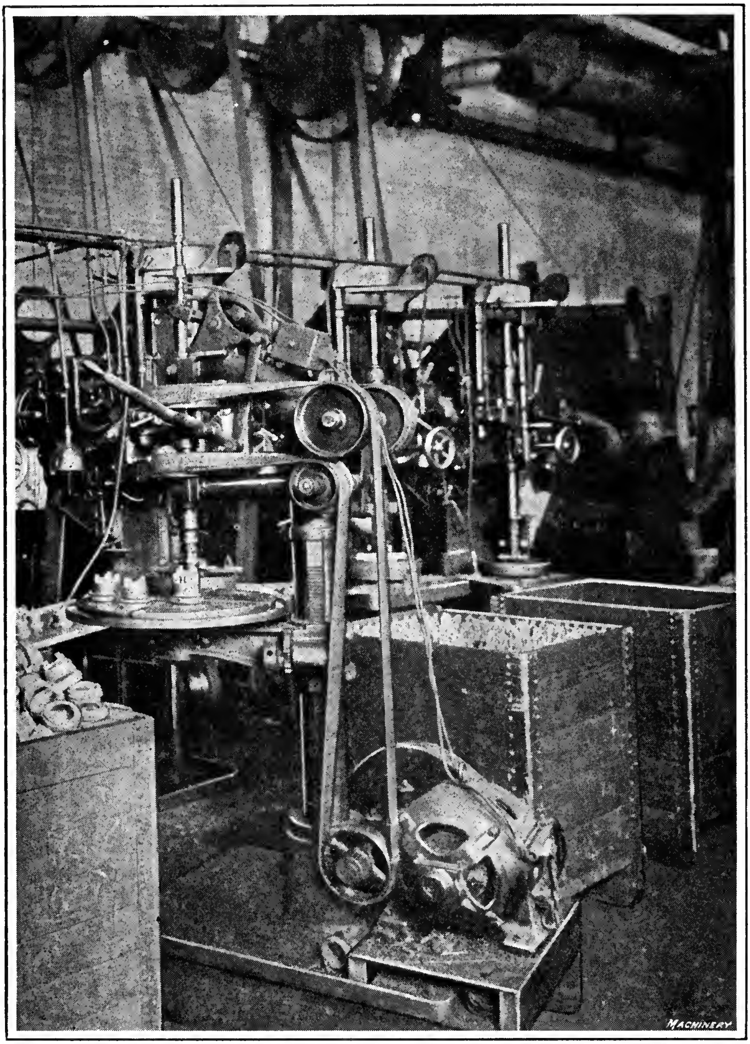


Fig. 2. Tapping Machine mounted on Skid to be handled by Elevating Truck, and equipped with Individual Motor Drive

in order to keep all the machines constantly employed during the working days. Figs. 2 and 3 show the application of portable machines for performing an extra operation for which a machine is not available.

Special Equipment for Machines. — Mention has already been made of the fact that the machines used in the plant referred to are the Baker No. 310 high-duty drilling machines. Standard machines were purchased, but in order to adapt them for the special requirements of this work it was found necessary to apply some additional equipment. Actual changes made in the machine details include the following: Provision of special gears in the feed train to allow for cutting threads of the desired pitches, including the 11½ pipe threads; provision of an automatically-operated air cylinder on each machine for shifting the double belt drive, to provide for reversing the direction of rotation for backing out taps and backing off threading dies; and the provision of a special feed-release mechanism which disengages the feed-clutch but allows the spindle to continue

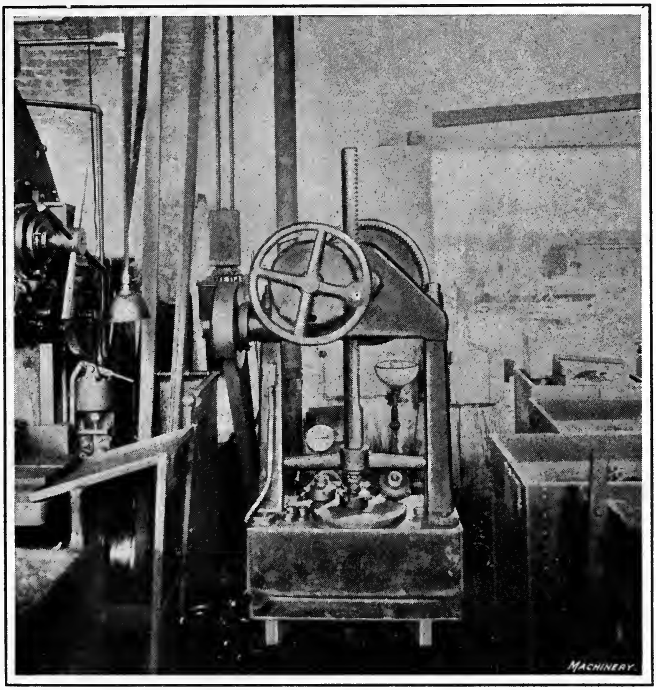


Fig. 3. Arbor Press mounted on Skid so that it can be set in Place to press in Bushings during Performance of a Sequence of Machining Operations

rotating for the necessary length of time to insure the removal of tool-marks when performing facing, chamfering, and counterboring operations.

In this connection, it might be mentioned that a special arrangement of counterweights is provided which are much lighter than the standard counterweights furnished on the machine. These weights are of the slotted disk type and the number of weights used can be such that the boring tool, tap, or die can either be just floated off the work or actually returned to the starting position automatically, so that all the operator has to do is to pull the spindle down and throw in his feed-lever. The capstan placed in the base of each machine under the counterweight provides for regulating the height to which the spindle is raised, so that the height of the spindle in its " up " position can be made to suit each job. It also prevents the spindle quill from striking the top of the machine in cases where heavy counterweights are used. This is accomplished by raising or lowering the capstan so that it stops the fall of the counterweight at just the required point.

Special Provision for Threading and Tapping. — On these machines, threading and tapping operations are performed on work where it is required to cut from eight to twenty threads per inch. On the Baker high-duty drilling machines, changes in feed are obtained by first placing lever *A*, Fig. 4, in one of the three positions controlled by inserting a pin into holes in the dial over which this lever rotates. Any of the rates of feed obtained in this way may be compounded through slip gears *B*, *C*, *D*, and *E*, which have 27, 33, 20, and 40 teeth, respectively. It will be apparent that both pairs of gears *BC* and *DE* have a total of 60 teeth, so that they may be placed on fixed centers, and by transposing gears *B* and *C* or transposing gears *D* and *E*, the three available rates of feed obtained for different settings of lever *A* are combined to give a total of 12 feed changes. The total range of feeds runs from 0.010 to 0.050 inch per revolution. This mechanism is standard for the Baker drilling machines with the exception of the fact that shafts *F* and *G* are made 5 inches longer than the standard dimension to provide for introducing special gears into the feed train in order to secure the desired rate of advance for the spindle when performing threading and tapping operations, which are the only operations for which these special gears are used.

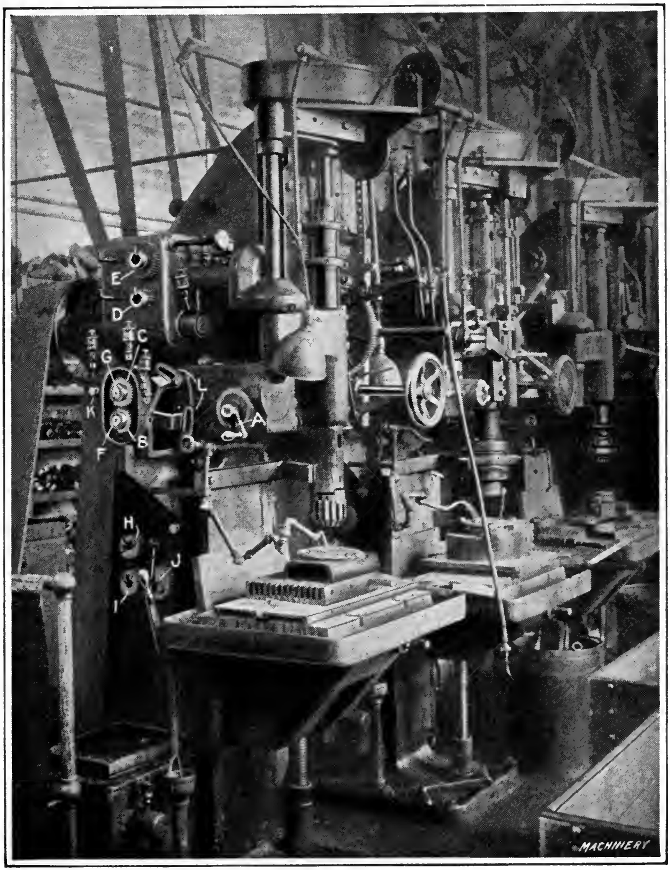


Fig. 4. Arrangement of Special Gears introduced into Feed Train to Provide for Performing Threading and Tapping Operations

When the machine is to be set up for threading or tapping, the first step is to remove the gears from shafts *F* and *G*. As a substitute for these two gears, one of the special change-gears *H*, *I*, or *J* is introduced into the feed train; this special gear has twice as many teeth as there are threads per inch on the work which is to be machined. For instance, a gear with 23 teeth is employed for threading or tapping work with the 11½ threads per inch commonly employed on pipe fittings. This gear is mounted on a pull-pin *K*, after which quadrant *L* is pulled up to readjust the position of the gears in the feed train so that this special " transposing " gear for threading and tapping operations is brought into mesh. Before starting the threading or tapping operation, it is necessary to remove the gears from shafts *F* and *G*, but, if so desired, the transposing gear may be left in place on the pull-pin *K* when the machine is used on other classes of work. When this is done, the gears are simply replaced on shafts *F* and *G* and quadrant *L* is dropped so that the transposing gear is no longer in mesh. Under such conditions, transmission is through the regular feed-gears on shafts *F* and *G*. Hooks are provided for the feed change-gears and for the special gears for threading and tapping, so that there is little danger of their being misplaced when not in use.

Automatic Compressed-air Reverse for Threading and Tapping. — Reversal of the direction of spindle rotation for the performance of threading and tapping operations is accomplished by the standard arrangement of forward and reverse belts furnished on the Baker high-duty drilling machines. A change in the method of operating these belts has been provided, however; instead of using a hand-lever, shifting of the belts is accomplished automatically by compressed air. At the right-hand side of two machines in each group of four, there will be seen a small air cylinder in which runs a piston that actuates the belt shifter.

A good idea of the way this mechanism operates will be obtained from Fig. 5 and the detail views of the control mechanism, Fig. 6. At the left-hand side of the machine, within convenient reach of the operator there will be seen a lever *A*, Fig. 5, which actuates the air valve. When this lever is thrown up it opens the valve to admit air to the under side of piston *B*, which forces this piston to the position at the top of the cylinder shown in Fig. 6. Connected to the piston-rod there is a rack *C* which meshes with a pinion on shaft *D*, by means of which the belt shifter is actuated to throw the "forward" driving belt onto its tight pulley, while the "reverse" driving belt is shifted onto its loose pulley. When it is desired to reverse the direction of rotation, lever *A*, Fig. 5, is thrown down to admit air into the cylinder above the piston, with the result that this piston is forced to the bottom of the cylinder. Through rack *C* and the meshing pinion carried on shaft *D*, the "reverse" belt is thrown onto its tight pulley and the "forward" belt is shifted to its loose pulley, which provides for backing out the tap or backing off the threading die.

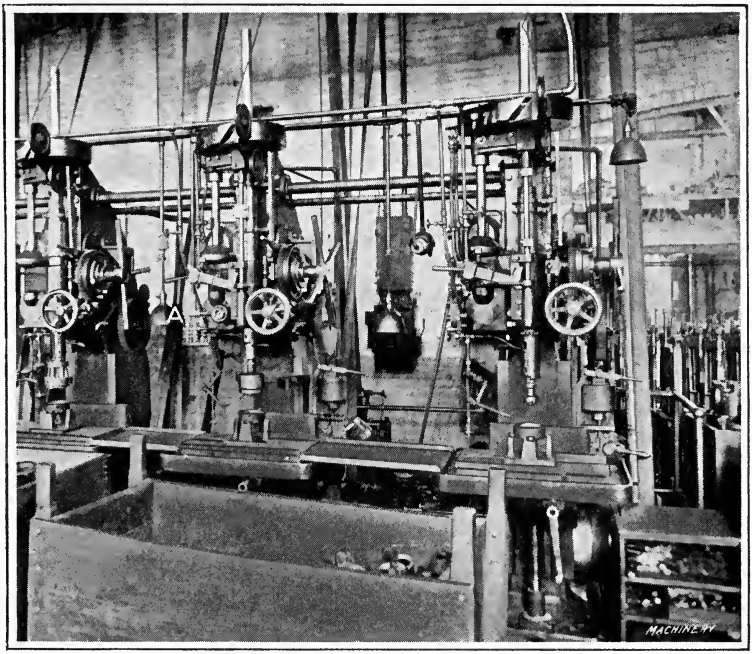
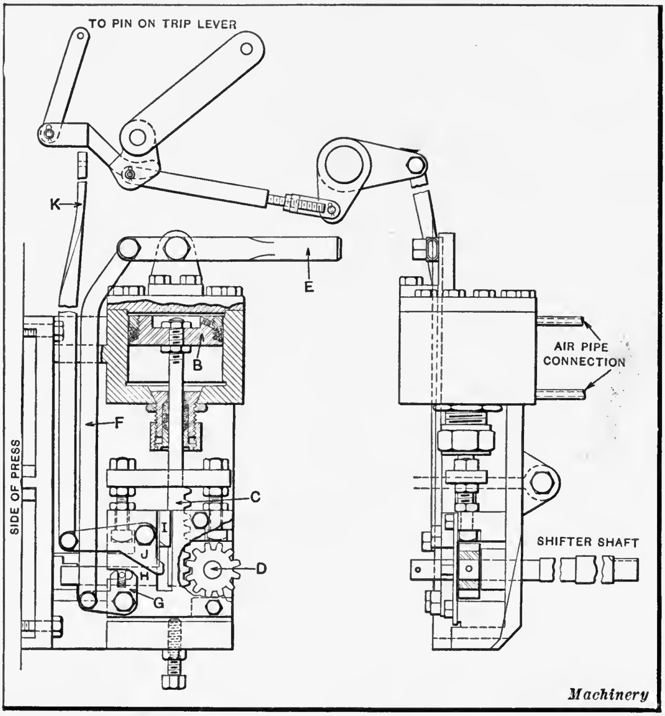


Fig. 5. Arrangement of Compressed-air Control for Spindle Reverse Mechanism for Threading and Tapping

Automatic Control of Mechanism. — So far the operation of this mechanism has been considered as if it were hand-operated, but, as a matter of fact, the operation is automatic. By making suitable adjustment of hand-lever *E*, Fig. 6, at the top of the air cylinder, provision may be made for either stopping the machine or automatically reversing the direction of rotation.

To stop the machine, lever *E* is thrown down, and the connection of this lever with link *F* and bellcrank *G* results in sliding bolt *H* to the right. In this position, cam *I*, attached to the back of rack *C*, comes down until the flat bottom of this cam engages bolt *H*. In this position, the forward belt has been shifted onto its loose pulley, but the reverse belt has not been shifted from its loose pulley to the tight pulley. As a result, both the forward and reverse belts are running on their loose pulleys, and thus the machine stops.



Machinery

Fig. 6. Mechanism of Compressed-air Control for Spindle Reverse, shown in Place on Machine in Fig. 5

If, on the other hand, it is desired to have the machine reverse automatically, lever *E* is pushed up so that bolt *H* is withdrawn. It is now possible for the piston to descend right to the bottom of the air cylinder, thus allowing the rack *C* to shift the " forward " belt to its loose pulley and the " reverse " belt to its tight pulley. This reverses the direction of rotation of the spindle to back out the tap. In this position of the mechanism, cam *I* descends and engages with a corresponding cam surface on bellcrank *J*, which results in rocking this lever and raising rod *K*. This rod is connected to a link mechanism, which drops the feed-worm out of engagement with the worm-wheel at the time that the reverse belt is shifted onto the backward driving pulley. Under these conditions the spindle is free, so that the tap or die can be backed off the work. A collar on the drilling machine spindle trips valve lever *A* to provide for reversing the machine at the bottom of the spindle travel, i.e., when the tap or threading die has reached the desired depth; and a second collar again reverses the machine ready for the next operation. To start the machine, it is merely necessary for the operator to throw the feed-worm into engagement with the worm-wheel in the usual way.

Air Hose for Blowing away Chips. — Connected with the same air line that supplies the cylinders for reversing the direction of rotation of the spindles for threading and tapping operations, connections are made at each machine with a flexible tube and metal nozzle, on which there is a push-button valve. This equipment is found convenient for blowing chips and cutting compound off the work after an operation has been completed. It will be seen that there is a second pipe line running along at the top of the machines, this being provided to carry cutting compound to the machine from a single distributing station. All bolts on the machine have standard heads to fit a single socket wrench. Each machine has its individual electric light with a shade which protects the operator's eyes and directs all light down to the work.

Electrical Connections for Portable Tools. — At each third machine, connection is made with a power circuit, the purpose of this being to provide for driving portable tools. The purpose of this is to allow a portable drilling or tapping machine to be brought into place for performing one or two operations in cases where the number of operations to be performed is such that they cannot be conveniently divided up among the machines.

When not required, the portable machine is carried away on an elevating truck; it is mounted on a skid for this purpose. At each machine a safety plug is provided which may be pulled out to stop the main driving motor in case of emergency.

Disengagement of Feed for Facing Operations. — There are a number of different parts that are machined on this battery of drilling machines on which it is required to perform facing operations. This work can readily be handled on drilling machines equipped with suitable facing tools, but where a fine, smooth finish is required — as in cases of couplings on gasoline pumps, etc. — trouble would be experienced through having tool-marks show on the work if the facing head were simply advanced to the work until the feed mechanism was tripped automatically and the spindle returned to its upper position. To overcome this trouble, a special equipment has been furnished on all machines, which provides for disengaging the clutch at the end of the feed-worm and still holding this worm in contact with the worm-wheel, so that the spindle continues to rotate with its position held stationary, as far as vertical feed movement is concerned. In this way, the facing operation is completed without any tool-marks being left. The same device is used to secure a smooth finish when performing chamfering and counterboring operations.

Two complete revolutions of the capstan wheel are necessary in order to obtain the full travel of the drill spindle. In working out the design of this mechanism for rotating a cutter without any feed movement, while completing a facing operation, provision had to be made for obtaining practically the full spindle travel to meet the requirement of those cases where it is necessary, before the feed is tripped. For this purpose the following means are employed, as shown in Figs. 7 and 8. A disk *A* is bolted to the feed worm-wheel, and this disk has a circular T-slot milled in it to carry an adjustable dog *B*. Pivoted freely on the face of this disk there is a second member *C* on which there is arranged a lever *D* that may be pulled to advance a catch *E* out of the edge of disk *C*. This catch *E* ultimately engages the upper end of a bellcrank lever (the lower end of which is shown at *F*) which results in causing the lower end of this lever to disengage the clutch at the end of the feed-worm shaft. Just how the mechanism operates will now be described.

In operation, the position of dog *B* is adjusted in the circular T-slot in disk *A*, so that this dog causes catch *E* to trip the feed-worm clutch when the spindle has reached the desired position. As two complete revolutions of the capstan wheel are required to secure the maximum feed motion for the spindle, it was necessary to employ the double arrangement of disks

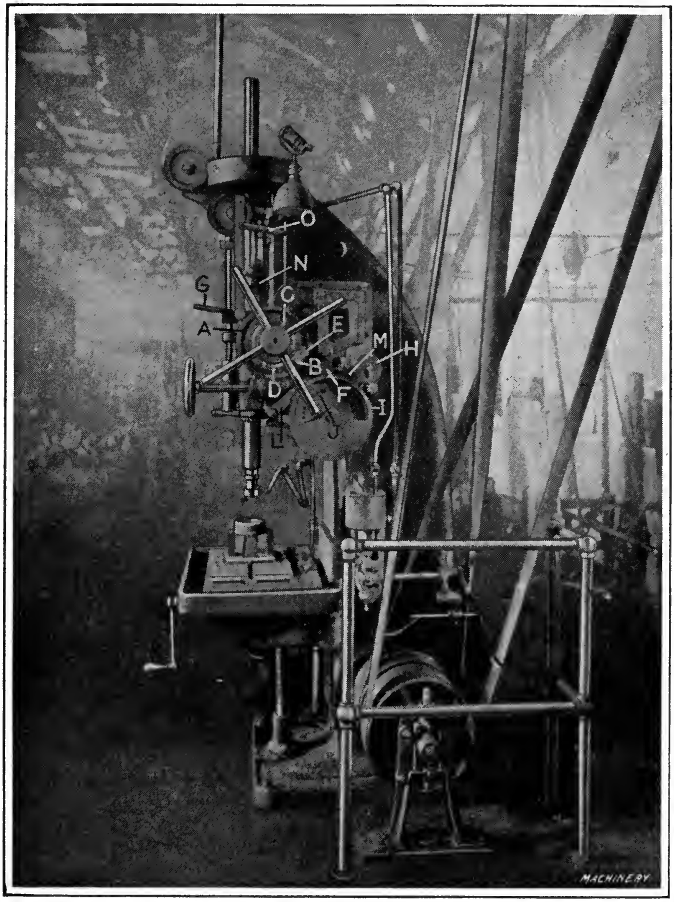


Fig. 7. Close View of Mechanism employed to Disengage Feed but hold Spindle Vertically while completing Facing Operations

shown at *A* and *C*, in order that disk *A* can make a complete revolution to bring dog *B* to the opposite side of the lug on disk *C*, after which continued revolution of disk *A* causes dog *B* to carry disk *C* around. When this revolution has been completed, catch *E* engages bellcrank lever *F* and trips the feed-worm. Of course, any portion of the maximum feed movement of the drill spindle may be obtained by making a proper setting of dog *B*.

When the clutch has been disengaged on the feed-worm shaft, it will be apparent that the worm is still in engagement with the worm-wheel, which prevents the counterweight from returning the spindle; at the same time, the spindle continues to rotate, thus completing the facing operation with a fixed vertical position of the cutter, so that the work is finished without showing any tool-marks. To complete the cycle of operations, it will be apparent that the feed-worm must be thrown out of engagement with the worm-wheel so that the spindle may be returned to the starting position. The mechanism provides means of doing this automatically, the operation being as follows: The preceding description has explained how catch *E* comes into contact with bellcrank *F* and results in disengaging the clutch on the feed-worm shaft. After this has been done, it is necessary for pinion *H* to be brought into mesh with gear *I* in order that a dog mounted in one of the holes *J* in gear *I* may engage with a link to throw the feed-worm out of engagement with the worm-wheel.

After catch *E* has engaged with bellcrank lever *F* and moved this lever sufficiently to disengage the clutch on the feed-worm shaft, catch *E* plays no further part in the operation. Carried by lever *G* there is a spring plunger with a roller at its end, which runs over the V-shaped block secured to the frame of the machine. At the same moment that catch *E* has disengaged the feed-clutch, this roller carried by the spring plunger on lever *G* has reached the position at the apex of the V-shaped block. The spring behind the plunger is now compressed so that its maximum tension is exerted, and as the roller passes over the top of the vee, the spring pressure becomes effective in causing the roller to run down the decline of the V-shaped block. In so doing, a further movement is imparted to lever *G* which has the following effect: Pinion *H* is carried on a quadrant, which has been gradually swung over during the time that catch *E* is in contact with bellcrank *F*. As the roller carried by the spring plunger on lever *G* runs down the decline of the V-block, movement imparted to lever *G* is transmitted through a link mechanism of which *M* is a part, which results in bringing pinion *H* into mesh with gear *I*.

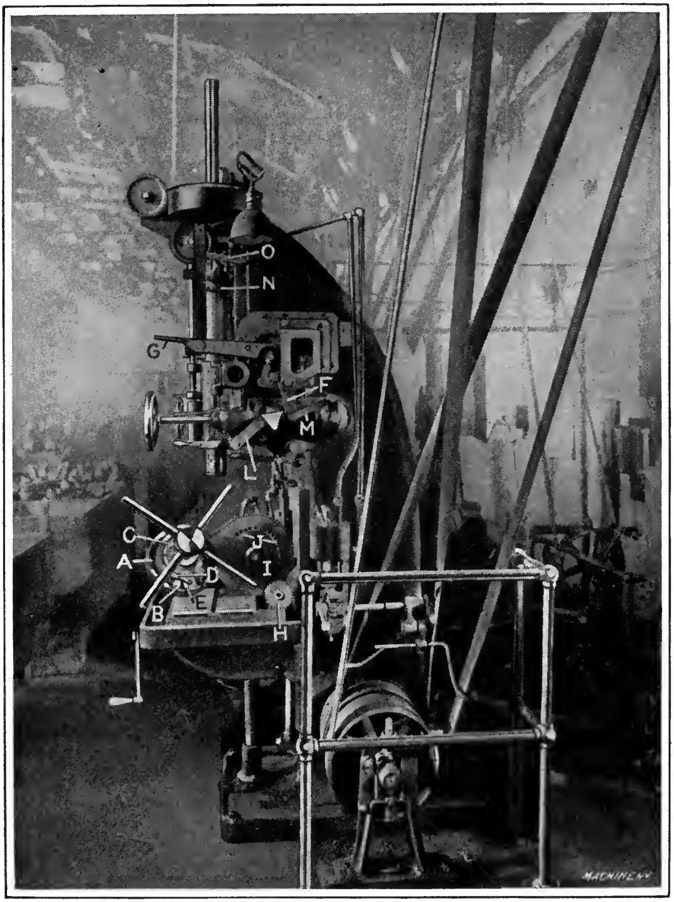


Fig. 8. Another View of Mechanism shown in Fig. 7

As previously mentioned, a pin carried in one of the holes in this gear trips the feed-worm out of engagement with the worm-wheel. The counterweight then returns the spindle to its upper position. At this point collar *N* carried by the spindle engages lever *O*, which imparts the reverse movement to the mechanism which has just been described. In the first place, the quadrant which carries pinion *H* is rocked back so that this pinion is disengaged from gear *I*. Gear *I* is made heavy at what is the lower side in the starting position, and this gear is free on its shaft, so that, when the pinion is disengaged, gear *I* is automatically returned to the starting position, where the heavy side of the gear is at the bottom. Bellcrank lever *F* and the extension *G* of this bellcrank are also returned to their starting positions ready for the next cycle of operations. When the operator has set up the next piece of work, he merely has to engage the feed-worm with the wheel, after which he goes on to the next machine.

Drilling Machine equipped for Milling Operation. — Improvements which have been made in the design of drilling machines, and a better understanding of the possibilities of these machines by shop superintendents and others who decide upon methods of performing machining operations, have led to a remarkable extension of the range of work handled on this type of machine tools.

In Fig. 9 is shown the way in which the Rockford Drilling Machine Co., Rockford, Ill., has equipped a high-duty drilling machine of its manufacture for use in milling universal joint rings. It will be apparent from this illustration that the work-holding fixture is so designed that the operation is conducted on what is commonly known as the "continuous" principle; that is, the fixture revolves so that forgings are constantly being fed under the milling cutter, and the operator has plenty of time to remove the milled universal joint rings from the fixture and substitute rough forgings. These forgings are made of 0.25 per cent carbon steel and are held in place on the fixture by means of T-clamps. The drilling machine used for this work is equipped with a special spindle of suitable design for driving the large inserted-tooth face milling cutter, which can just be seen projecting down below the guard that is furnished to protect the operator against injury.

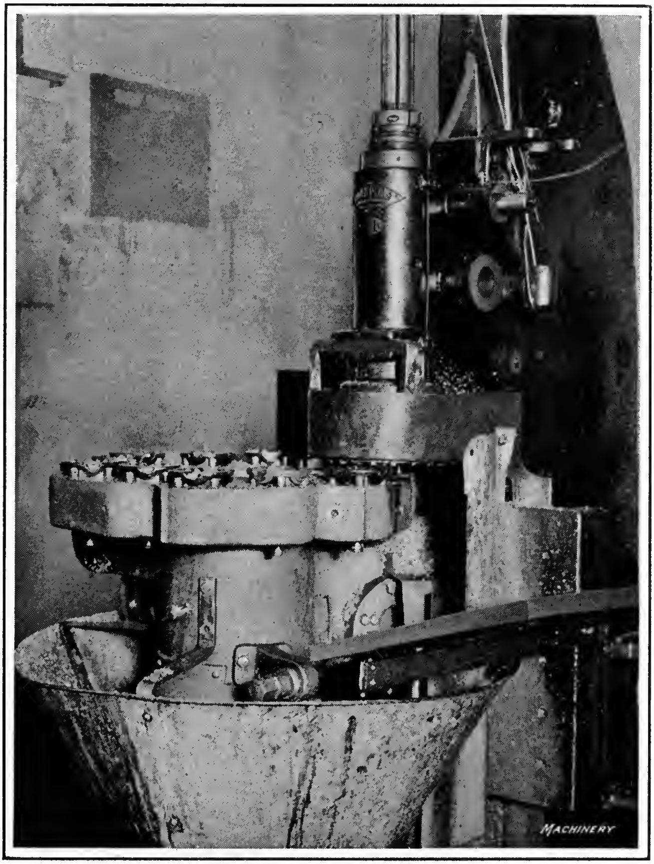


Fig. 9. Drilling Machine equipped with Continuous Milling Fixture for Milling Universal Joint Rings

Broaching Operation on Drilling Machine. — Regardless of the views held by any man who plans methods of performing machining operations concerning what constitutes drilling machine work, there are few of these men who will not concede that the use of a drilling machine for simultaneously broaching eight slots is somewhat unusual. Fig. 10 shows the way in which the Willys-Overland Co., of Toledo, Ohio, has equipped a 42-inch reversing type of drilling machine, built by the Cincinnati Machine Tool Co., Cincinnati, Ohio, for broaching eight slots in an aluminum crankcase to receive the push-rod guides,

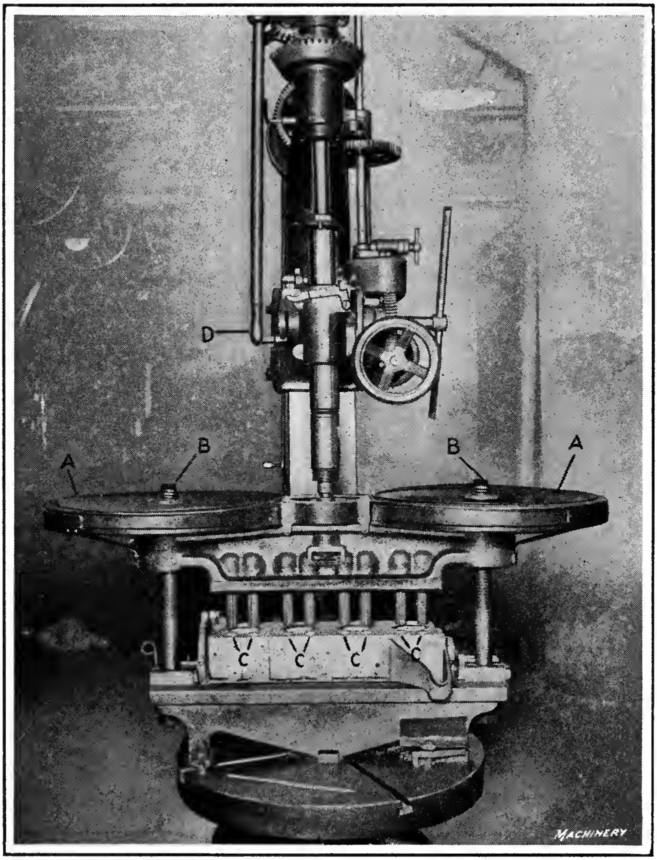


Fig. 10. Reversing Drilling Machine equipped for Broaching Push-rod Guide Slots in Crankcases

all of this work being finished by one feed movement of the drilling machine spindle. For the performance of this operation, the work is located by plugs on the fixture which enter the camshaft bearing holes at each end of the crankcase. Carried by the main spindle of the drilling machine there is a pinion which drives two gears carried in cases *A*. These gears are threaded onto screws *B*, the pitch of which is such that, as the gears are turned, they feed down the holder carrying the eight broaches *C* at the same rate that the drilling machine spindle carries down the driving pinion. When the broaches have reached the bottom of their downward stroke, lever *D* is manipulated to reverse the direction of rotation of the drilling machine spindle, which results in backing out the broaches. The broaches are fed into the work at the rate of 12 inches per minute, with a feed of 0.006 inch per tooth, and with this equipment 120 crankcases are broached per hour.

Driving Studs by Power. — The Errington Mechanical Laboratory, New York City, makes a stud setter of the type which opens automatically. It is equipped with two threaded jaws or half-nuts which are released and open, after the stud is set, in practically the same way that an automatic die opens at the end of a cut. The opening of the stud setter is controlled by a stop-collar which is placed around the stud. When the lower end of the stud setter engages this collar, the body of the stud setter is prevented from further downward movement, but, as it continues to revolve, the two jaws or half-nuts screw themselves onto the stud until a collar at the lower end moves down opposite a recess or counterbored part of the stud-setter body. As this collar normally supports the half-nuts, they are released when the supporting collar enters the enlarged part of the stud-setter body. The entire tool is then raised as it continues to revolve in the same direction as for driving in the stud. The half-nuts are reset for the next stud by sliding another collar upward. This collar is recessed on the inside and engages the projecting ends of pins connected with the jaws or half-nuts, and simply serves to move them upward so that the supporting collar will be caused to enter the smaller bore of the stud-setter body and once more close the jaws ready to engage the next stud. This tool may be rotated either in a drilling machine or by means of a portable pneumatic or electric drill. Flexible shafting is also used in some cases. The general method of setting studs is to start them by hand and then drive them in by power. If a stud is too tight and requires an unusual amount of power for driving it, the stud setter can be released at any time by simply raising the machine spindle, as this moves the outer shell of the stud-setter body upward and brings the half-nuts into the releasing position. Fig. 11 shows one of these Errington stud setters being driven by a drilling machine.

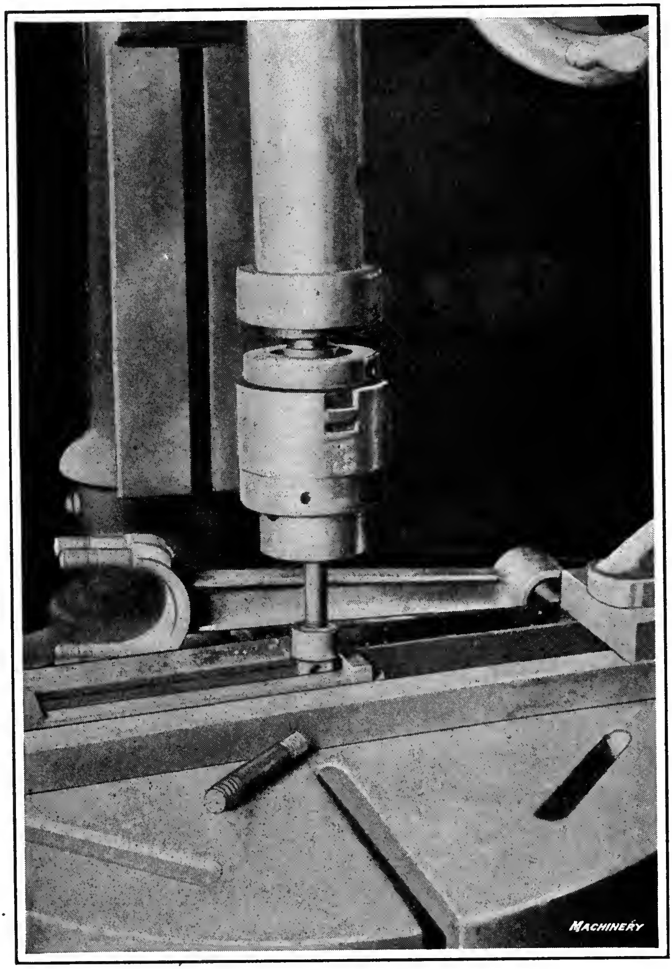


Fig. 11. Stud Setter operated by Vertical Drilling Machine

Assembling with Drilling Machine. — A large part of the labor of assembling machine parts that are held together by screws, bolts, and nuts is spent in the act of screwing the parts together with a wrench. When a nut is started on a screw thread, there is no reason why manual power should be employed to screw it in, provided there are a sufficient number of one size to warrant the use of power apparatus. In the manufacture of motor cars, special appliances are employed for assembling,

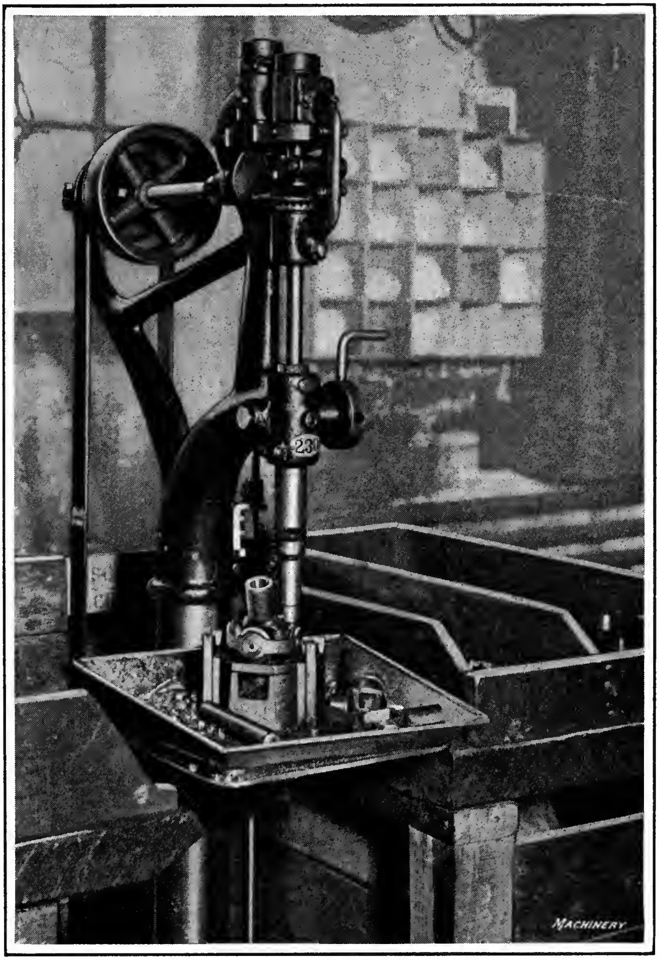


Fig. 12. Drilling Machine used for Assembling Universal Joints

especially for setting studs and screwing up nuts. In some cases, as many as sixteen nuts are driven in simultaneously by multiple-spindle drilling machine attachments. While it is necessary for the operator to test each nut with a wrench to see that it is screwed in firmly, the power apparatus saves a great deal of time and strength. However, the use of power apparatus for setting studs and screwing up nuts is not necessarily confined to the manufacture of machinery built in large quantities. It is quite feasible to employ an ordinary single-spindle drilling machine effectively for assembling simple parts that are made in quantities, especially if they have a number of nuts of the same size that may be screwed up consecutively during one operation. The drilling machine may be used as an assembling machine in many plants where the idea has never been employed or even suggested.

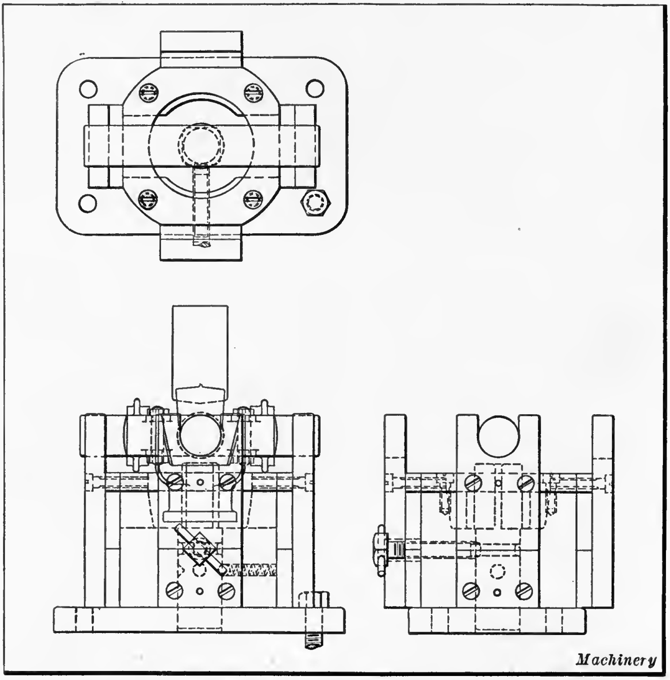


Fig. 13. Fixture for Assembling Universal Joint Rings on Drilling Machine as shown in Fig. 12

Fig. 12 shows a drilling machine built by the Rockford Drilling Machine Co., Rockford, Ill., which is used in this company's plant for tightening the four nuts on the bolts that hold together the parts of a motor car universal joint assembly. The universal joint is mounted in a fixture of the form shown in Fig. 13, which holds the ring level and thus presents the nuts to be tightened in a horizontal plane. The operator starts the nuts on the screws by hand, having all four nuts ready before

Fig. 14. Pneumatic Drill screwing in Cap-screws

placing the joint in the fixture for screwing them down. The wrench carried by the drilling machine spindle is then applied and the nut is screwed up as far as it will go or until the bolt slips. After this has been done, the fixture is indexed to the next position and the operation repeated. The fixture is essentially simple, consisting of a base that is bored and faced to receive the member on which the universal joints rest. A hardened steel ball and a coiled spring seated in a hole in the base constitute the indexing and locating plunger. It offers

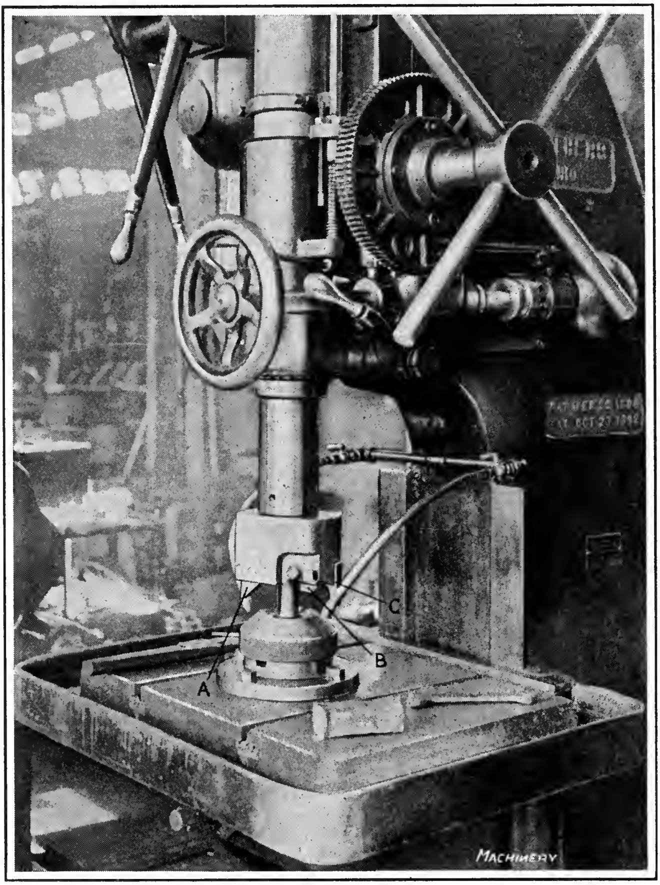


Fig. 15. Tools and Work-holding Fixture for Forming Bevel Gear Blanks on High-duty Drilling Machine

sufficient resistance to hold the fixture in place, but not enough to prevent the operator from easily turning the indexing member of the fixture around to the next station.

Fig. 14 shows another method of employing a power-driven machine to assist in the rapid assembling of machine parts. Here there is shown a No. 33 " Little David " portable pneumatic drilling machine made by the Ingersoll-Rand Co., New York City, which is used in the plant of the H. H. Franklin Mfg. Co., Syracuse, N. Y., for " running in " cap-screws. The pneumatic drill is suspended in such a way that the operator is relieved as far as possible from the work of lifting the tool. In this way, the fatigue factor is reduced to a minimum, enabling the operator's efficiency to remain as nearly normal as possible during the entire working day. The speed at which cap-screws may be run in by this method, as compared with the laborious method of driving them by hand, will be quite obvious.

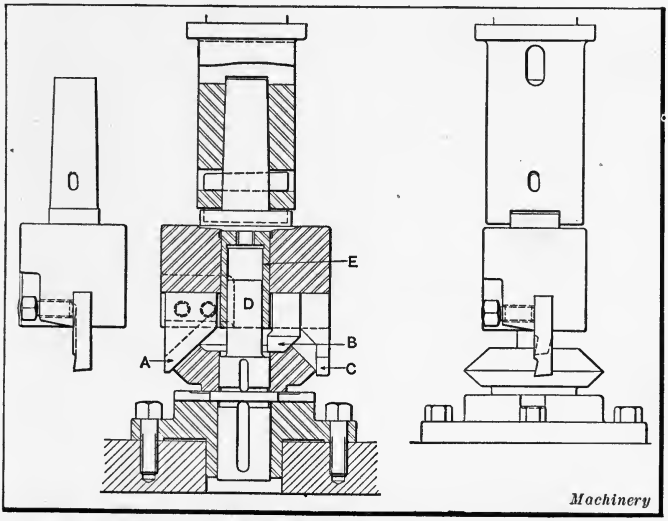


Fig. 16. Sectional View of Tool and Work-holding Fixture shown in Fig. 15

Forming Operation on a Drilling Machine. — A somewhat unusual way of performing a forming operation will be seen in Figs. 15 and 16, which show the tools and work-holding fixtures provided for turning up bevel gear blanks from steel forgings. For handling this work, the order of operations is as follows: First, drill a hole through the center of a blank; second, cut a keyseat in the blank; third, locate the work on the piloted fixture and form one side of the blank; fourth, turn the work over and form the opposite side of the blank. In the first forming operation, the face of the gear blank is formed by tool *A* (Fig. 15); tool *B* cuts the recess, and tool *C* cuts away the excess metal to reduce the gear blank to the required outside diameter. After this operation has been completed on all of the gear blanks, the tools are changed and the work is turned over so that the opposite side of the blank may be turned to the desired form, which is indicated by the cross-sectional view in Fig. 16. As the gear blanks are turned from steel forgings, evidently a high-duty machine is required to handle severe service of this kind. The pilot *D* on the work-holding fixture extends up into a bushing *E* in the tool to eliminate all chance of springing the tool away from the cut. The work is shown in the course of production on a No. 314 high-duty drilling machine built by Baker Bros., Toledo, Ohio, and the gear blanks being turned are for the bevel gear drive on these machines.

CHAPTER IX

JIGS, FIXTURES, AND SPECIAL TOOLS FOR DRILLING MACHINES

A JIG or work-holding fixture may be used on a drilling machine to provide for interchangeability of the drilled pieces, or it may be used for the sole purpose of holding the work and preventing it from turning while the drilling operation is being performed. By far, the most important object of using a jig or fixture for drilling parts that are to be assembled together is to eliminate laying out work and to provide for accurately locating holes in all duplicate parts produced on the drilling machine, so that bolts, screws, etc., will enter holes in all of these parts without the necessity of subsequent hand fitting. Obviously, the use of jigs and fixtures provides means of greatly reducing the ultimate cost of producing such parts. A further economy is secured through their use, owing to the fact that both the jig or fixture and the drilling machine can be made so simple to operate that unskilled labor may be employed with assurance that the work will possess the desired degree of accuracy. Aside from the actual saving in the cost of performing drilling operations, it is obvious that an even greater saving will usually be effected through the production of interchangeable parts which may be sent directly to the assembling department, where they are ready to be assembled into the finished product without requiring any hand work. Still another claim in favor of the use of jigs and fixtures is that the production of interchangeable parts makes it a very simple matter for broken pieces to be replaced, with perfect assurance that such pieces will fit properly when received by the customer.

In practically all up-to-date manufacturing establishments, interchangeable manufacture is now in use and one of the great advantages of this system is that, where a complete equipment of jigs and fixtures is employed for the performance of all machining operations, work may continue on the production of all different parts of the product which are machined in different departments of the factory with assurance that these parts will assemble together properly. This saves the necessity of waiting for one part to be finished so that other parts may be fitted to it, as was the case under the old method of " building " a machine, which stands out in strong contradistinction to the modern methods of " manufacturing " which are now employed. Necessarily, the attainment of this result calls for the use of a set of jigs and fixtures which have been very carefully designed so that the relation of all machined holes and surfaces is not only accurate in a given piece, but is also accurate in relation to each other.

The terms " jig " and " fixture " are often applied to the same class of equipment, although there is a distinction between these terms. Jigs and fixtures are made in such a great variety of types that it is hard to cover the subject comprehensively without going into a great deal of detail. Probably the best general distinction to make is that a jig is furnished with hardened steel bushings, through which the drills are guided into the work, while in the case of a fixture the desired location is secured through the provision of gage points on the fixture or by some other means. A combination of gage points and bushings is often employed in working out the design of a jig. In both jigs and fixtures, provision is commonly made for holding the work to prevent it from turning, although there are special cases where jigs are clamped to the work or dropped over a machined surface which affords the desired location for the jig. In the majority of cases, however, both jigs and fixtures are furnished with means of securing them to the table of the drilling machine, common methods of obtaining this result being to provide a tongue on the bottom of the fixture which enters a T-slot in the table, or to employ some similar method.

Essential Features of Jig Design. — In working out the design of either jigs or fixtures, there are a number of points which must receive careful consideration if the most satisfactory results are to be obtained. Among these there is none of greater importance than to be sure that the design of clamping devices which are furnished to secure the work in place and the form of the fixture are both such that the work may be put in and taken out after the drilling operation has been completed without entailing an unnecessary loss of time. This point has assumed exceptional importance on account of the steadily increasing rates of speed and feed employed in the performance of drilling operations, because the consequent reduction in drilling time means that the ratio of setting-up time to drilling time will become constantly less favorable unless great care is taken to eliminate all unnecessary loss in setting up the work. Generally speaking, it is necessary to provide a jig or fixture for use in drilling the hole in a part which is to be assembled with a second part that has been drilled with the use of similar equipment. There are certain cases, however, where this is not advisable, as it may be impossible to properly locate a jig on one of the parts to be drilled, or if the attempt were made to design a jig, it would be so complicated as to prove impractical. In such cases, the part drilled in a jig is used as the jig for drilling the second part on which it is to be assembled, and, where this method is followed, satisfactory results are secured, although the production time is likely to appear somewhat high.

One of the most important questions that should be decided before making a jig is the amount of money that can be profitably spent on special tools for the operation under consideration. In many cases greater efficiency could be secured by making a complicated and expensive tool, but this additional investment would not be warranted by the slight saving in production cost that would be effected through its use. In all cases where the question of jig and fixture design comes up, a careful comparison should be made of the cost of drilling under the present method and the estimated cost of performing the same operation in the new jig or fixture; and unless the saving is sufficient to warrant adoption of the new method, it is obvious that further work should be done by the tool designer to see if a greater reduction in production cost is not possible. While discussing the question of cost, attention is called to the fairly obvious fact that the number of parts to be machined will determine the expenditure that is warranted for jigs and fixtures, as it would be obviously impractical to spend a lot of money for special work-holding equipment — regardless of the efficient results that could be secured through its use — unless the number of parts to be drilled were great enough to return a satisfactory income on the tool investment.

Selection of Locating Points. — In choosing the locating surface of gage points on the work to be drilled, consideration must be given to the facilities for locating the corresponding part with which it is to be assembled. This is a highly important point, because, although jigs may be alike as far as their provision for locating the holes is concerned, there may be no facility for locating holes in the corresponding part in the same manner that was used in the one for which a satisfactory selection of locating points was made. In such cases, while the drilled holes may coincide, other surfaces which are required to come into coincidence may be considerably out of line. Therefore, one of the main principles of location is to have the two component parts located from corresponding points or surfaces on the castings. This naturally draws attention to the importance of designing patterns for use in the foundry with suitable provision for holding the castings while they are being drilled. It is sometimes apparent that lack of coöperation between the drafting-room and machine shop, which results in failure to provide efficient means for holding the work, is responsible for adding greatly to the cost of performing machining operations.

Wherever it is possible, special arrangements should be made in designing jigs and fixtures so that it is impossible to insert the piece in any but the correct way. This is especially important in developing tools for use in those shops where a great deal of unskilled labor is employed, as care taken by the tool designers will often be the means of saving a great deal of money which would be lost through spoiling work. The use of "fool-proof" jigs and fixtures in which it is impossible to insert the work upside down, etc., will also be the means of making important savings in plants where the labor is fairly well trained in the performance of the different classes of work, but where the use of a piece-work system may be responsible for some slight carelessness on the part of machine operators. Another important point is that where the work may vary in size, as in the case of rough castings, etc., it is necessary to have at least some of the locating points made adjustable and placed so that they can be easily reached to make the necessary adjustment, and then fastened so that they are reasonably positive in their function of locating the work.

Clamping Devices. — In designing clamping devices, care should be taken to arrange each clamp so that the direction in which the strain of the tool or cutter acts upon the work is such that the clamp will possess the maximum strength to resist the pressure of the cut. Another important point is to design the clamps so that they may not readily be detached from the fixture and require a lot of time to be spent in finding clamps which have been mislaid. In all cases, clamping devices should be made as simple as possible and they should be made to operate quickly for reasons that have already been mentioned. In addition to designing clamps so that they are strong enough to resist the pressure of the cut, it is highly important to see that such pressure will not result in springing the work out of place and cause inaccuracy in the location of holes and machined surfaces. This point can best be taken care of by paying attention to the selection of locating and bearing points for the work and clamps, respectively, so that the probability of springing the work is reduced as far as possible. One point to observe in providing for rigidity is to locate clamps or straps so that they are exactly opposite some bearing point on the surface of the work, whenever such a location is found feasible. Another point of importance, in so far as it may affect the accuracy of work produced in a jig or fixture, is to work out the design in such a way that chips may be readily cleared out of the fixture to avoid danger of inaccuracy resulting from chips accumulating on the locating points.

Jigs and fixtures should be made as light as possible in order that they may be easily handled. One way of securing this result is to design the castings with cored holes wherever metal may be eliminated without unduly affecting the strength of the tool. Where jigs are provided with feet, some designers favor the use of three feet, because with such an arrangement they are always sure of the jig taking a firm bearing on the machine table. As a matter of fact, this is an undesirable form of design, because there is nothing to show the presence of chips or other foreign matter under one of the feet of the jig or fixture, which would cause inaccuracy in the setting of the work. With a design in which four feet are provided, the presence of anything under one of the feet will immediately be shown by the fact that an improper bearing is provided and the jig will tend to rock in an unsteady manner until the trouble has been corrected.

Materials used in Making Jigs and Fixtures. — Opinion differs as to the relative merits of cast iron and steel for use in making the bodies of jigs and fixtures. In deciding this point, attention should be given to the use to which the tool is to be put and the character of the work which it is to handle. It is difficult to make a general statement, but the best opinion seems to be that for small and medium sized work, such as parts of sewing machines, typewriters, adding machines, cash registers, phonographs, guns, etc., the steel jig offers decided advantages; but in the case of large work of the kind that has to be machined in factories engaged in the manufacture of machine tools, engines, and automobiles, cast iron is undoubtedly the cheaper and more satisfactory material.

Summary of Important Points in Design of Jigs and Fixtures. — In presenting the following summary of the features which should be provided in designing jigs and fixtures, the idea is to furnish data which the tool designer may run over in checking up his design. Experienced men will not find it necessary to take such precautions, but in the case of designers who have not had an opportunity to gain the necessary experience to make their judgment absolutely reliable, checking over a design to see that it meets the following requirements will often be the means of saving costly mistakes. These requirements may be briefly summarized as follows:

(A) Does the estimated production cost of drilling work in the new jigs and fixtures show sufficient saving over the cost with existing tool equipment to warrant ordering new tools? (B) Were locating points selected and the method of clamping decided upon before laying out the jig or fixture? (C) Have all clamping devices been made as quick-acting as possible? (D) Were locating points for use in machining component parts selected on corresponding surfaces on these parts? (E) Has the jig or fixture been made fool-proof, i.e., is it arranged so that work cannot be inserted except in the correct way? (F) If the jig is used for holding rough castings, has adjustment been provided for the locating points to compensate for variations in the size of the castings? (G) Are all clamps located in the best position to resist pressure of cutting tool? (H) Have all clamps been made integral parts of the jig or fixture where possible? (I) Has the design of the clamping mechanism been simplified as far as possible? (J) Has provision to avoid springing the work been made by placing all clamps as nearly as possible opposite to bearing points on the work? (K) Has the jig or fixture been made as light as is consistent with rigidity and stiffness by coring out unnecessary metal? (L) Have all corners been made round? (M) Have handles been provided where these will make handling of the jig or fixture more easily accomplished? (N) Has adequate support been provided by placing feet, etc., directly beneath all points where the pressure of cut will come? (O) Has ample clearance been provided in jigs or fixtures used for drilling rough castings? (P) Have all locating points been made visible to the operator while placing work in position in the jig or fixture? (Q) Have holes been provided for the removal of chips from the jig or fixture? (R) Have clamping lugs been located in such a way as to prevent springing the fixture in cases where the fixture must be secured to the drilling machine table? (S) Have instructions been given for the jig or fixture to be tested before it is sent to the shop to be used?

Types of Jigs and Fixtures. — The variety of different jigs and fixtures which are in use at the present time is so great that the scope of an article of this kind does not include complete discussion. At the same time, the principles which have just been enunciated apply to all of these different types, and if carefully followed will be the means of greatly improving the efficiency of results secured with the auxiliary equipment designed for use on the drilling machines. Briefly stated, there are three different types of jigs and fixtures used on drilling machines, and mentioned in the order in which they are most generally employed, these are as follows: (1) Jigs or fixtures in which the work is held so that one or more holes may be drilled in its top face. (2) Indexing jigs or fixtures used to provide for the performance of a sequence of operations; such fixtures are furnished with a loading station at which finished pieces may be removed and new parts substituted while pieces held in other sections of the fixture are being drilled. (3) Box jigs in which the work is secured; such jigs are furnished with feet on two or more surfaces, so that the jig may be turned over to provide for drilling one or more holes in two or more surfaces on the work.

Design of Special Tools and Fixtures. — Various special forms of cutting tools, jigs, and work-holding fixtures are used on the drilling machines which are applied to special work, and in the following some of these tools will be described. The principles of tool design which have been responsible for making substantial increases in rates of production will also be considered.

It will be apparent when looking over the schedule of operations presented in Chapter VIII that advantage is frequently taken of the possibility of machining two or more surfaces on the work at a single operation. The form of each piece of work to be machined has been carefully studied, and after deciding the maximum number of surfaces that could be machined simultaneously, the tool designers have taken up the problem of working out the form of tool best adapted to meet the requirements of this particular operation. Another point which will attract the attention of experienced machine shop men while looking over the illustrations of typical parts machined in the Bowser factory will be the large number of parts which have several holes or holes and surfaces concentric with each other. In all cases, it is desirable to maintain this concentricity within a reasonable degree of accuracy, and there are many cases where a very high degree of precision is important to obtain the desired alignment when these parts are assembled together. Here advantage is taken of the concentric holes or holes and surfaces on the work to provide for the use of piloted tools which may be depended upon to maintain the concentricity of different surfaces on the work from some hole which has already been machined.

In many cases, it is also necessary to hold vertical dimensions on the work within close limits. Various means are provided on the tools for obtaining this result. In piece No. 2 in the table of operations (Chapter VIII), it is required to maintain the height *E* from finished face *B* to the upper side of the flange on the rough casting within $\frac{1}{64}$ inch. The automatic tripping point for the feed of the drilling machine spindle is set as closely as possible, but, to guard against lack of uniformity in the castings, a button *A* is provided on the facing tool which comes down into contact with the casting that is being machined. This tool is shown in Fig. 2. Normally the power feed is tripped at the same time that this button engages the work. The drilling machine on which this operation is performed is set up without having the automatic return for the drill spindle in operation; and after the power feed has been tripped the operator looks at the button on the tool to see that it is down in contact with the work. Should it happen that this engagement has not been obtained, he feeds the spindle by hand before returning it and setting up a fresh piece of work on the machine.

Accuracy in Tripping of Feed. — In starting to describe the special means provided in the design of tools to assure accuracy in tripping the feed mechanism, attention is called to the fact that Baker high-duty drilling machines are especially adapted for heavy work, and although the automatic trip for the feed mechanism may be safely relied upon to disengage the feed within $\frac{1}{64}$ inch of the desired point, it is not safe to rely upon a much closer limit. At the same time, there are many classes of work where the maximum error must not exceed 0.005 inch, and, in such cases, the tools are designed to make sure that the work is held to at least this degree of accuracy. As shown in Fig. 1, it will be seen that the arrangement employed calls for a combination of work-holding fixture and cutting tool which work in conjunction with each other. On the fixture there are placed four posts *A* that are engaged by a flange *B* on the cutting tool. This fixture and tool are used for machining the gear shown in the fifth position in the table of operations, Chapter VIII. It is necessary to have the thickness of this gear 1.750 ± 0.005 inch, and to provide for obtaining this result, the tools are so designed that collar *B* comes into engagement with the top of posts *A* when the cutters in the tool have reached the desired depth in the work.

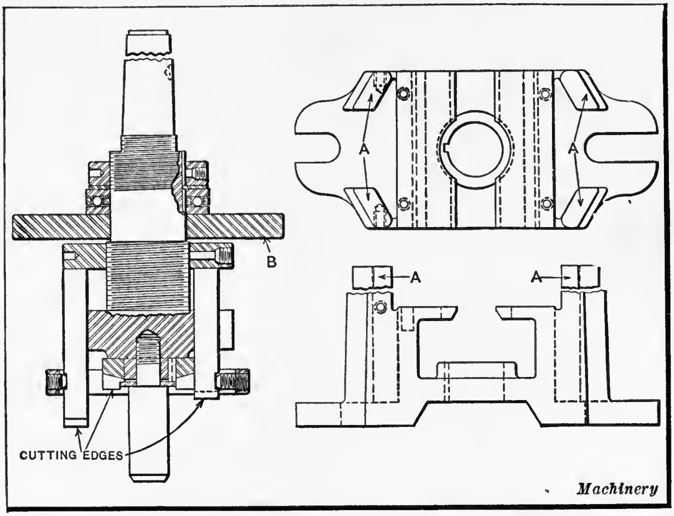
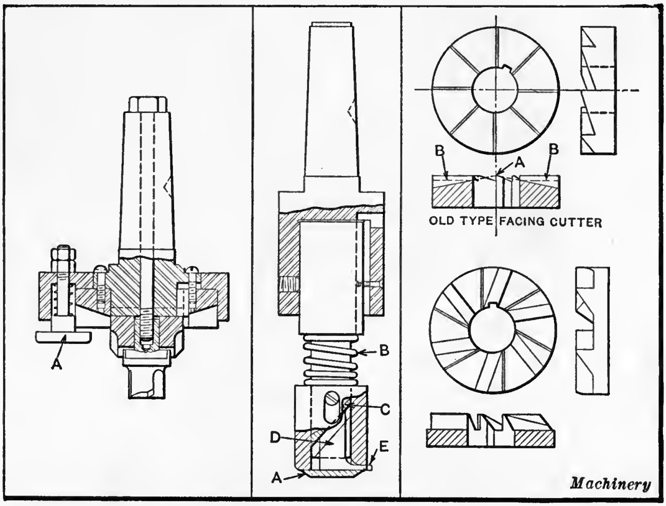


Fig. 1. Type of Tool and Work-holding Fixture used on Parts where Accuracy in Tripping Feed is of Great Importance

To prevent binding, a ball thrust bearing is provided on the tool above the collar. The regular trip mechanism on the machine is depended upon to disengage the feed-worm clutch at the desired point, but the arrangement of the tool and work-holding fixture makes it impossible for a slight lack of sensitiveness in the machine to prevent tripping to take place until the work has been machined beyond the minimum dimension which is called for. Those who have not experimented with the amount of spring which is possible to obtain in machine tools will naturally assume that the use of an arrangement of this kind would result in damage to the machine if the trip for the feed mechanism failed to operate at the same time that collar *B* came into engagement with posts *A*. Experiments have shown that it is quite practicable to obtain a spring of from 0.005 to 0.010 inch before any damage is done, and, as a result, the provision made in designing the tools makes it impossible for the bits to cut into the work beyond the desired point. If the trip for the feed mechanism fails to function when this point has been reached, the bits are prevented from cutting further, and springing of the machine members takes place until the feed is disengaged.



Figs. 2, 3, and 4. Tool which assures Accuracy in Tripping Feed — Design of Under-cutting Tool — Old and Improved Types of Facing Cutters

Design for Under-cutting Tool. — Where it is necessary to make an under-cut on the work, use may be profitably made of the type of tool shown in Fig. 3. This tool is used in making the under-cut in the " fill pipe cap " shown in the next to last position in the table of operations, Chapter VIII. The following is a brief explanation of the way in which this tool operates: Button *A* comes down into engagement with the side of the casting in which the under-cut is required. Further travel of the feed mechanism results in compressing spring *B* which, in turn, forces a cam *C* down into contact with the angular top of cutter *D*. When cam *C* engages cutter *D*, further movement of the feed mechanism of the drill press results in forcing out the cutting edge *E* which is thus fed into the work. This is a simple and convenient arrangement for machining under-cuts on the drill press. Of course, it is understood that, at the same time that cutting edge *E* is being fed into the work, the edge is rotating to machine the under-cut all the way around the piece.

Special Form of Facing Cutters. — To provide for the utilization of tool steel as far as possible, the tool designers have worked out a special form for facing cutters used on this battery of drilling machines. For the purpose of comparison, Fig. 4 shows the old type of facing cutter and the improved type of cutter which is now in use. Referring to this illustration, it will be seen that the teeth of the old type of cutter have all of the lines diverging from a common point *A* at the center of the top surface of the cutter. In sharpening a cutter of this type, grinding may proceed until the teeth of the cutter are worn down to a point indicated by dotted lines *B*. When this point has been reached, the cutter is considered worn out.

It will be apparent to anyone who gives this matter consideration that not over approximately 12½ per cent of the steel in the cutter has been used up when the teeth are ground down to line *B*. To overcome this obvious waste, an improved type of facing cutter was developed, in which it will be seen that the flutes are milled to a constant depth. This result was easily accomplished when the tool designer once decided to break away from established practice in grinding the teeth and flutes with all lines converging from a common point *A*, to which reference has already been made. In sharpening one of these improved cutters, the teeth can be ground right down to the bottom so that 50 per cent of the steel in the cutter is used up; i.e., four times as much service is obtained as from the old type of cutter. A further advantage of this improved facing cutter is that the cutting edges of the teeth are arranged tangent to a small circle surrounding the center of the cutter instead of having them converge to this center. As a result, a shearing action is obtained which enables the tool to cut more freely than is the case where the cutting edges of the teeth are radial. Also, additional clearance for the chips is provided by having the flutes milled to a constant depth.

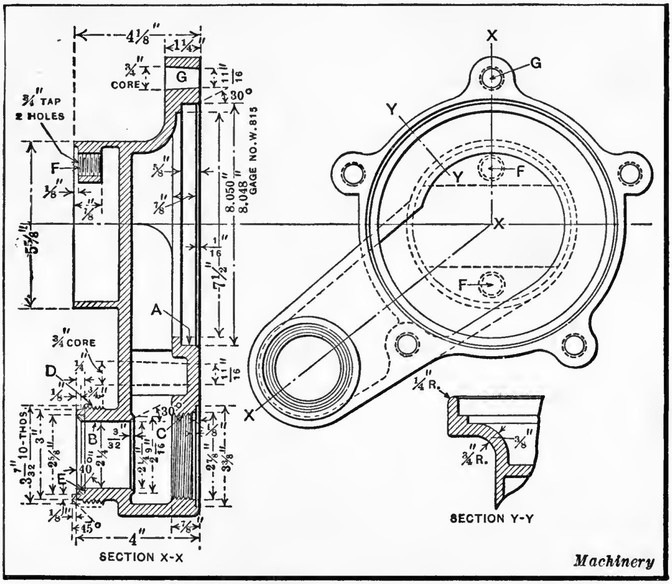


Fig. 5. Example of Work done on Drilling Machine

Special Features of Jigs and Fixtures. — It is not within the scope of this book to enter into an exhaustive discussion of the jigs, fixtures and similar equipment provided for use in machining the great variety of parts that are handled on Baker drilling machines. There are one or two points, however, which are of more or less general application, and these will be mentioned very briefly. For instance, there are many parts where simple drilling, boring, facing, and similar operations have to be performed. Here it is unnecessary to provide a jig or fixture for locating the work, but means must be provided for preventing the work from turning while the machining operation is in progress. For this purpose, considerable use is made of what are known as slotted fixtures, one of which is shown on the first machine illustrated in Fig. 4, in Chapter VIII. Suppose a square- or hexagon-shaped piece has to be machined; one of these slotted fixtures will be set up on the drill press table and then two rails will be slipped into slots in the fixture at such a distance apart that the work can just be dropped between them. This is only one of the many uses which is made of these slotted fixtures. In the illustration, the fixture is shown set up with a work-holding device made out of boiler plate that affords clearance for the tool after it has passed through the work.

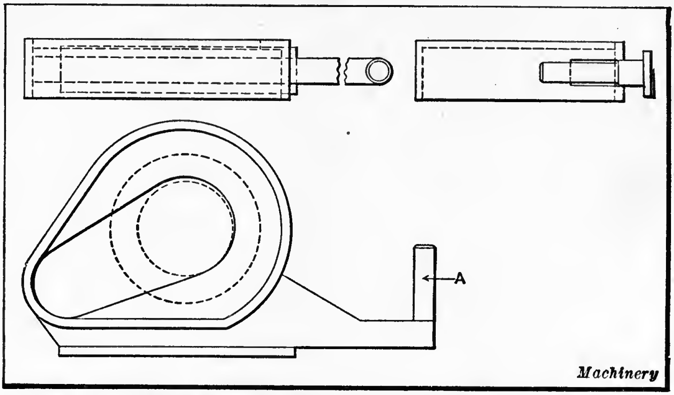


Fig. 6. Fixture used to Hold Work while performing Disk-grinding Operation on Double-spindle Machine

In most cases, the outstanding feature of the jig and fixture equipment is the extreme simplicity of its design. This is a point of cardinal importance where high production is aimed at, because the least unnecessary complication of equipment would result in a corresponding reduction in the speed of operation and rate at which parts could be set up and removed after machining. In many cases, it has been found feasible to use standard three-jaw chucks where circular parts have no projections to prevent them from turning around under the spindle. Another feature, which is a result of the war-time cost of copper and zinc, is the provision of special trays around the fixture holding brass and bronze parts that are being machined. These trays catch all of the chips as fast as they are produced and enable them to be collected without loss — an important saving at the present time.

Tools and Fixtures for Machining Cylinder Bottoms. — The tools and work-holding fixtures are unusually interesting, and with the view of giving a general idea of this practice, a complete description is given of all cutting tools, jigs and fixtures used for machining the cylinder bottom which is shown first in the tabulated information on machining operations (See Chapter VIII, page 147), and also in Fig. 5.

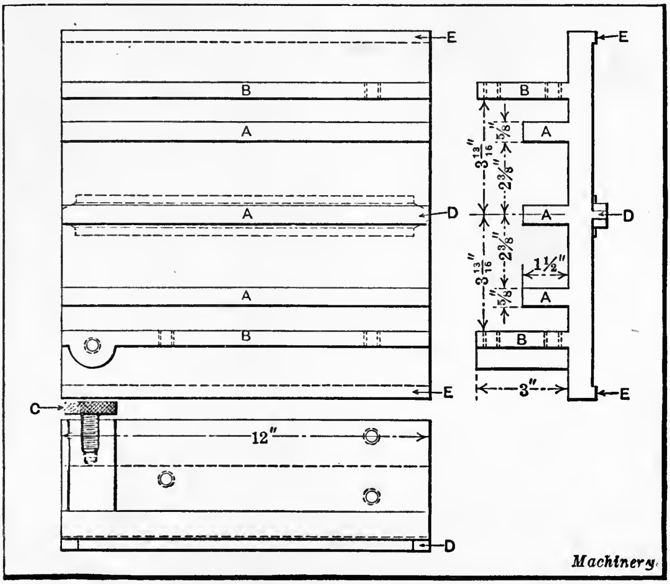
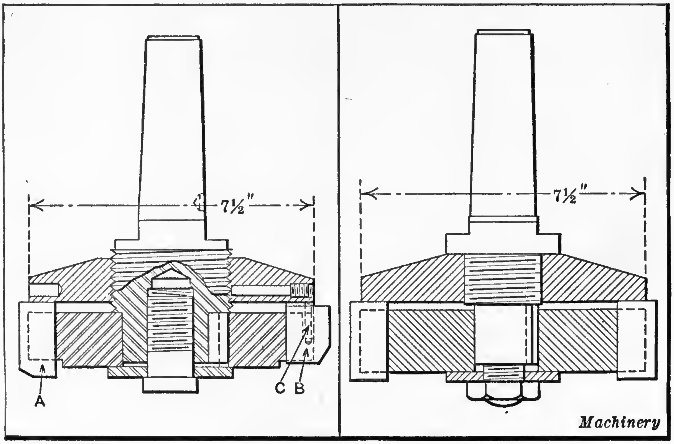


Fig. 7. Work-holding Fixture used on Drilling Machine

The first operation consists of disk-grinding the top and bottom of this piece of work, and a Besly double-spindle machine is used for the purpose. The work-holding fixture employed is shown in Fig. 6, and will be seen to consist of a socket in which the work is held in an edgewise position with the top and bottom extending out from the fixture so that they may be egaged by the two disk wheels. This fixture has a handle *A* by which it is pushed back and forth between the disk wheels on the machine, and these wheels are relied upon to hold the work in the fixture.

The second and third operations consist of rough-boring and reaming hole *A*. In both cases the work is held in the fixture shown in Fig. 7, and the cutting tools are shown in Figs. 8 and 9. For both boring and reaming, the speed is 25 revolutions per minute, and the feed is 0.018 inch per revolution. Referring to the tool shown in Fig. 8, it will be seen that the boring is done by bits *A*, while the function of bits *B* is merely to cut a 30-degree chamfer at the top of the hole. Fine-pitch screws *C* furnish means for making accurate adjustment of the position of the chamfering cutters. The tool for reaming this hole requires no special description.



Figs. 8 and 9. Tools used for Boring and Reaming Hole *A* in Work shown in Fig. 5

The work-holding fixture, Figs. 7 and 10, used for these two operations is of simple design, three rails *A* supporting the work while a rail *B* at each side of the fixture prevents the work from rotating. Very little time is required to slide work into such a fixture. It will be apparent from the dimensions that the flange on the work has considerable overhang at one end, and as this flange is at a higher level than the top of the side rails *B*, it would be unsupported. To overcome this difficulty, and at the same time to allow for slight variations in the castings, a knurled-headed screw *C* is provided on the fixture. When the operator sets a casting in place, he adjusts the position of this screw so that it comes up against the under side of the flange, thus supporting the work ready for the machining operation. Particular attention is called to the tongue *D* and strips *E* on the under side of the fixture. This is a standard construction on practically all work-holding fixtures, the purpose being to provide a " floating " fixture which is enabled to align itself properly with the drill spindle. All fixtures of this type rest on a standard baseplate (not shown in the illustration) which is not bolted down to the table of the machine. The upper side of this plate has a groove to receive tongue *D* and is machined to form bearing for strips *E*. On its under side, this plate has a tongue running at right angles to the groove in its upper surface, and this tongue fits into the T-slot on the drilling machine table. As a result, the fixture floats in so far as the spindle of the drilling machine is concerned, although it is held in such a way that rotation of the fixture is impossible.

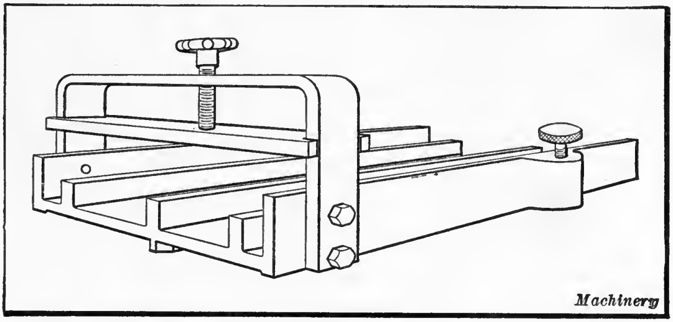


Fig. 10. Perspective View of Boring and Reaming Fixture showing Arrangement of Clamping Mechanism

The fourth operation consists of boring holes *B* and *C* (Fig. 5) and cutting a 30-degree chamfer at the top of hole *B*. For this purpose, the same work-holding fixture is employed that was used on the two preceding operations. The cutting tool is shown in Fig. 12, and will be seen to consist of cutters *A* and *B* for boring holes *B* and *C* (Fig. 5), respectively. The operation is performed at a speed of 100 revolutions per minute and a feed of 0.010 inch per revolution.

The fifth operation consists of finish-boring hole *B*, facing the surface at the top of the valve-seat in this hole, and chamfering and facing the top of hole *C*, for which the fixture used is shown in Fig. 11. The fixture is practically the same as that used for performing the preceding operations, except that the portion of the fixture under the part of the work that is being machined is furnished with solid metal surfaces shown at *A*, instead of simply having the work supported by a narrow rail. The reason for this construction is that, while the previous type of fixture is satisfactory for the performance of roughing operations, for taking the finishing cut it is possible for the work to be cocked sufficiently out of alignment to produce an appreciable error. It is to guard against the possibility of such a contingency that the present type of fixture is employed. This fixture is used for the performance of several other operations, and the openings at *B* and *C* with solid metal surfaces surrounding them have no special significance in connection with the present operation. The cutter used for taking this finishing cut is shown in Fig. 13. It will be seen that cutter *A* reams hole *B*, while cutter *B* faces the top of this hole. Chamfering

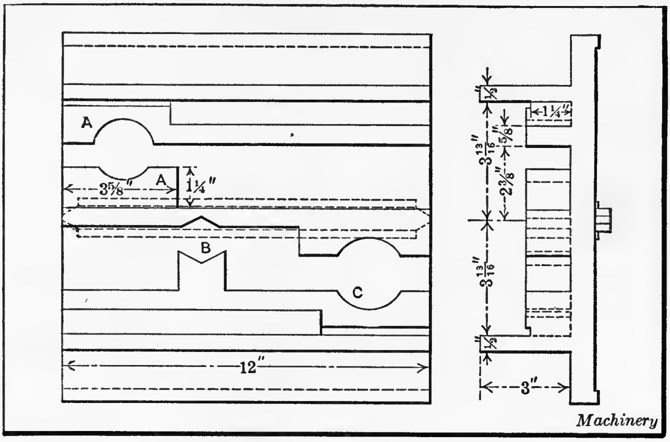
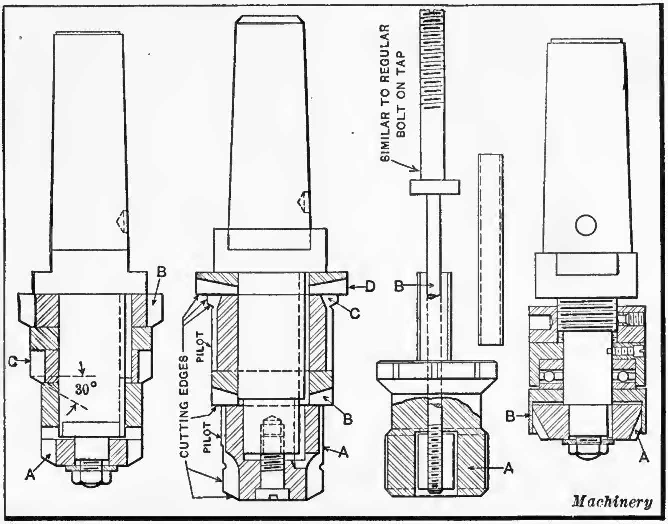


Fig. 11. Work-holding Fixture in which Casting is held for Finish-boring Holes *B* and *C*, Fig. 5

and counterboring the top of hole *C* is done by cutter *C*, while facing the top of this hole is done by cutter *D*. Cutters *C* and *D* are piloted in hole *C* to assure accurate alignment. This operation is performed at a speed of 100 revolutions per minute and a feed of 0.014 inch per revolution.

The sixth operation consists of tapping hole *C*, for which purpose a No. 9 tap, made by the Manufacturers' Equipment Co., of Chicago, is employed, this tap being furnished with a special pilot shown in Fig. 14, which runs in hole *B*. This pilot is shown at *A* in Fig. 14, and is held in place in the tap by a draw-bolt *B*. Above the collar on this draw-bolt the design is similar to the regular bolt used on the standard tap, but the thin extension *B* below the collar is provided to reach down and hold pilot *A* in place. The fixture used for performing this operation is the same as that used on the second, third, and fourth operations. The work is done at a speed of 25 revolutions per minute.



Figs. 12 to 15. Tools for Rough- and Finish-boring Holes *B* and *C* (Fig. 5), Special Tap Pilot for Hole *C*, and Valve-seating Tool for Top of Hole *B*

The seventh operation consists of finishing the valve-seat. The work is set on the bed of the machine without using a fixture, and the tool used is shown in Fig. 15. The valve-seat cutter is shown at *A* and collar *B* is provided on the tool which enables the seating tool to cut in to exactly the proper depth. This operation is performed at a speed of 100 revolutions per minute with hand feed.

After the valve has been seated, the eighth operation is to turn the outside of union *D*, face the top of this union, and counterbore for the brass insert *E*. The work-holding fixture used for this purpose is shown in Fig. 16; and it will be seen to be practically identical with the fixture used for performing the second, third, and fourth operations. It consists of three rails *A* to support the work and two side rails *B* to prevent the work from rotating. The cutting tool used for this purpose is shown in Fig. 17, from which it will be seen that three bits *A* provide for turning the outside of the union, three cutters *B* for counterboring for the brass insert *E*, and tool *C* for facing the top of the union. The design of this tool is worked out in such a way that two lock-nuts *D* support the bits *A* and *B* from the top and provide accurate means of adjusting them in the desired vertical position.

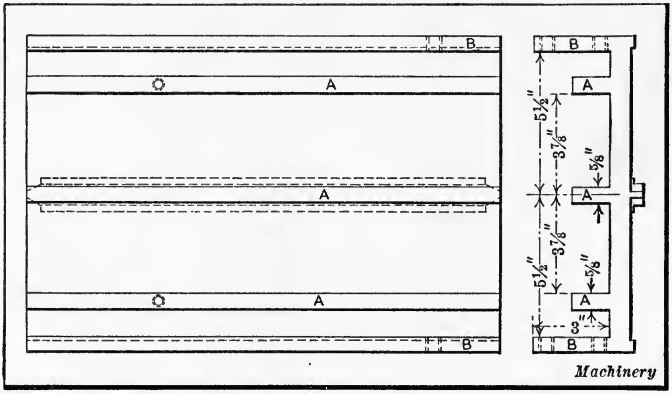
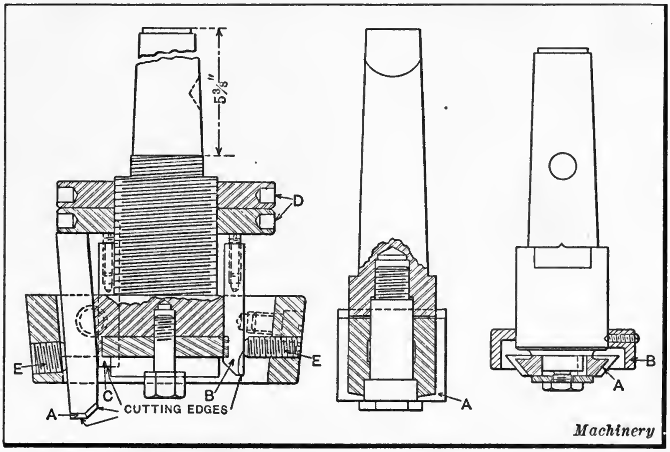


Fig. 16. Fixture used for Holding Work while Turning and Facing Union *D*, Fig. 5

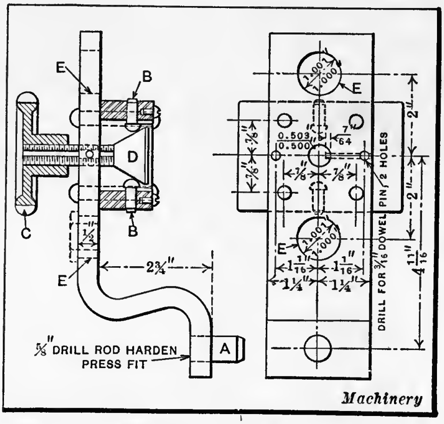
At the same time, the bits are furnished radial support by means of set-screws *E* carried in a collar surrounding the lower part of the tool. This is a somewhat old tool, and recently the design of this type of tool has been considerably modified to provide better radial support for the cutters. In designing tools of this type, it is now the practice to bring the collar down within about $\frac{1}{4}$ inch of the cutting edge of the bits, instead of having the bits overhang approximately $1\frac{1}{4}$ inch. In this way there is far better support and the possibility of their springing away from the work is very materially reduced. Some tool designers will be inclined to say that the amount of spring which could possibly occur in a tool of the type shown in Fig. 17 is so small that the change in design is scarcely worth while. Granting that this is the case, the Bowser tool designers did not feel satisfied with any form of construction that left the possibility for an error which there was any way to overcome. The speed at which this operation is conducted is 72 revolutions per minute with a feed of 0.012 inch per revolution.



Figs. 17, 18, and 19. Tool for Turning, Facing, and Boring Union *D*, Tool for Reaming Seat for Bushing *E*, and Tool for Chamfering Bushing *E*

The ninth operation consists of reaming the bore for the brass insert *E*. The same fixture is used as for the preceding operation, and the tool employed is shown in Fig. 18, which consists of a simple reaming cutter *A* mounted on a suitable shank. The operation is performed at a speed of 100 revolutions per minute, with hand feed.

After reaming the hole for the brass insert, the tenth operation is to thread the outside of union *D*, which is done with a threading die. The same fixture is used as for the two preceding operations, and the work is done at a speed of 25 revolutions per minute. After threading, the work is ready for the eleventh operation, which consists of pressing the brass insert into place. This is done with a portable arbor press, which is brought up to the gang drills at such times as it is required for service. The arbor press is mounted on a skid, so that it can be carried on an elevating truck; it is motor-driven and connected to the power circuit arranged on this battery of drilling machines.



Machinery

Fig. 20. Jig used for Drilling Holes *F*, Fig. 5

The twelfth operation consists of cutting the valve-seat in brass insert *E* in the union. The work is held in the same fixture as for the preceding operation, and the tool used is shown in Fig. 19. It will be seen that this is a simple angular mill *A* mounted on a suitable shank. A guard *B* is placed around the cutter to provide for the operator's safety. The operation is performed at a speed of 180 revolutions per minute, and a feed of 0.010 inch per revolution.

The thirteenth operation consists of drilling two holes *F*. The same work-holding fixture is used as in the preceding operation, and the holes are located by means of a jig shown in Fig. 20. Pin *A* is dropped into the cored hole *G* on the work and locating pins *B* enter the rectangular shaped hole in the work, shown by dotted lines between the holes *F* which are to be drilled. When handwheel *C* is turned so that tapered block *D* is drawn up between the heads of pins *B*, these pins are forced outward, which results in clamping the jig firmly in place over the work.

Hardened steel bushings, through which the holes are drilled, are located in holes *E* in the jig. The drilling operation is performed at a speed of 280 revolutions per minute with a feed of 0.010 inch per revolution. After these holes have been drilled, the jig is removed from the work, which is left in position in the fixture ready for the performance of the fourteenth operation. This consists of tapping the holes *F*. This tapping operation is performed at a speed of 72 revolutions per minute.

Of these fourteen operations, it will be recalled that Operation 1 is done on a disk grinder, while Operation 11 consists of pressing a brass bushing into place in the work, a portable arbor press being used for this purpose. As a result, there are twelve operations that are performed on the Baker drilling machines, and these are divided up into three groups of four operations each. In order to have the relative amount of time taken by different operations work out to the best possible advantage, the following grouping was decided upon: Operations 2, 3, 13, and 14 are performed on a group of four machines; Operations 4, 5, 6, and 7 are next performed on this group of four machines at the second setting; and Operations 8, 9, 10, and 12 are performed at the third setting of these four machines.

It will be recalled that in Chapter VIII attention was directed to the fact that an endeavor is always made to select groups of four operations in such a way that all four machines of the group may be kept as constantly employed as possible. The grouping together of Operations 2, 3, 13, and 14 is a good example of this kind. Operation 13 calls for drilling two holes *F*, one at a time, and Operation 14 consists of tapping these holes one at a time. To provide for performing these two double operations without keeping other machines idle, they are grouped with Operations 2 and 3, which consist of boring and reaming the large hole *A*, and take as much time as the double operations of drilling and tapping two holes *F*, one at a time. In handling a battery of four machines, the operator goes from Operation 2 to Operation 3, then to Operation 13, where he starts drilling one hole, then to Operation 14, where he starts tapping one hole and waits until this operation is completed, the time being only a few seconds. He then starts the tap in the second hole for Operation 14, after which he starts the drill for the second hole in Operation 13. After this, he goes back to Operation 2 to start work on a fresh piece, and this order of procedure is followed continuously, with the result that all machines are kept constantly employed. In conclusion, it may be mentioned that only one group of four machines is working on the same piece at a time. After the first four operations have been performed on all pieces, this same group of four machines starts on the next four operations; and when these have been completed, the final group of four operations is performed on this set of machines. It would not do to have twelve machines out of a battery of twenty-eight working on one part.

Concerning Rates of Production. — As most of the work handled on this battery of high-duty drilling machines is of a character where an extremely high degree of accuracy is not required, the rates of production obtained in performing machining operations become a matter of unusual importance. A good idea of the actual output in machining various parts which could be handled with a shop equipment of this character will be gathered from a study of the machining operations and rates of production which are tabulated in a preceding chapter. It will at once be apparent to the experienced production engineer that these rates of output are very satisfactory, but a man who is considering the problem of selecting equipment for machining a given line of work which might be handled on drilling machines will naturally ask himself the question, "Is there no better way in which I could machine these parts?" An answer to this question is found in the experience of S. F. Bowser & Co. during the past two years. This firm's shops have been so rushed with work that a practice has been made of arranging with outside concerns to machine work on a contract basis. In many cases the figures submitted for machining parts which are ordinarily handled in the drilling machine department have been so far above the company's own production costs that a good deal of hesitation was felt about letting contracts to these bidders. Investigations which were conducted, however, went to show that the margin of profit made on the work by these outside concerns was not at all excessive, and as most of the bids obtained from outside machine shops were considerably above the cost of producing work on drilling machines — after deducting a reasonable margin of profit — it is fair to conclude that these shops based their bids upon the use of equipment which was unable to compete with the highly specialized tools and methods which have been described.

CHAPTER X

DEEP-HOLE DRILLING

A DEEP hole is usually defined as a hole the depth of which is equal to at least five times the diameter, although some authorities define it as one in which the depth is equal to four diameters. In deep-hole drilling, special precautions must be taken for two reasons: In the first place, trouble is likely to be experienced through breaking of the drill as a result of chips clogging the drill in the hole; and, secondly, further trouble may result through failure to obtain the desired cooling and lubricating action on account of having the chips prevent lubricant from reaching the cutting point of the drill. Numerous expedients are employed, to prevent trouble from chips clogging the drill in the hole. In drilling fairly deep holes with ordinary drilling equipment, it is quite general practice to back the drill out of the hole at frequent intervals in order that the chips may be cleared from the drill. This also guards against an accumulation of chips preventing lubricant from reaching the cutting point. A better way to assure efficient lubrication of drills used in deep holes is to use oil-tube tools which are furnished with ducts that carry the oil or cutting compound direct to the point of the drill where its action is required. Recently it has become quite general practice to adopt the use of inverted drills for deep-hole work, because it has been found that where an inverted drill operates from below the work, it is a much easier matter for the chips to clear themselves from the hole. Where this inverted drilling is employed, it is not often necessary to resort to the practice of backing the drill out of the hole at frequent intervals, in the manner which has just been mentioned.

When holes are very deep or long in proportion to their diameter, special drills and machines are required. The drilling of holes in rifle barrels is an example of the class of deep-hole work necessitating the use of special equipment. Some of the tools and methods employed for deep-hole drilling in connection with general manufacturing will first be described, and then the more special equipment required for rifle barrel drilling will be considered.

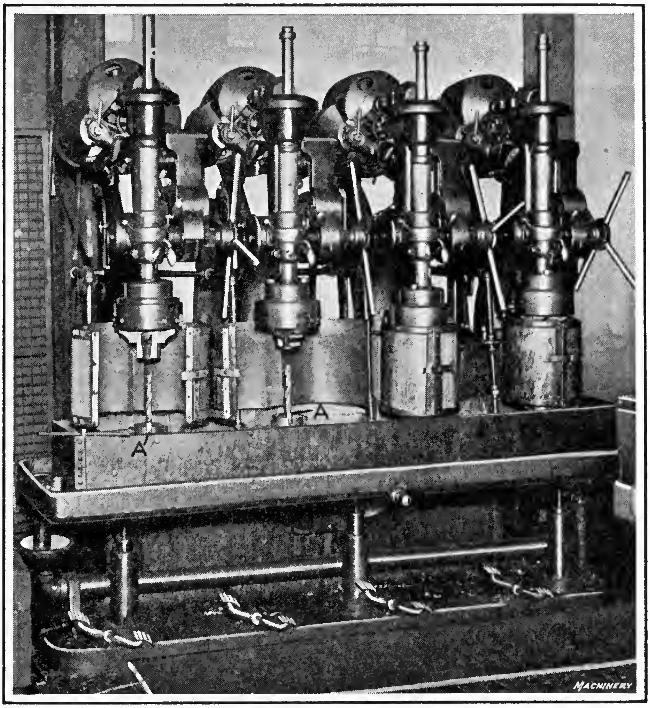


Fig. 1. Gang Drilling Machine arranged for Drilling by Inverted Method

Inverted Drilling for Deep-hole Work. — The inverted method of drilling consists in holding the drill stationary in an inverted position and revolving the part to be drilled. Fig. 1 shows a four-spindle gang drilling machine built by the Rockford Drilling Machine Co., which is equipped with two-jaw chucks mounted on the spindles so that work may be rotated by the spindles and fed down onto inverted drills which are held stationary on the table of the machine. The principle will be clearly understood by reference to the illustration. The advantage of this method of drilling is that the chips are cleared more easily from the deep holes than would be the case with the usual relation of the work and drill. The work consists of yoke forgings for universal joints, and these pieces are fed down over the drills so that, after the drilling operation has been completed, the end of the forging is faced by the stationary tool *A*, which will be seen in the holder at the base of each drill. The work to be drilled is a drop-forging containing from 0.15 to 0.25 per cent of carbon, from 0.30 to 0.60 per cent of manganese, phosphorus below 0.045 per cent, and sulphur below 0.05 per cent. The holes to be drilled are $\frac{7}{8}$ inch in diameter by $1\frac{3}{8}$ inch deep and approximately 1000 pieces are drilled on this four-spindle machine in a ten-hour working day. Fig. 2 shows a detailed view of the fixture provided for handling a

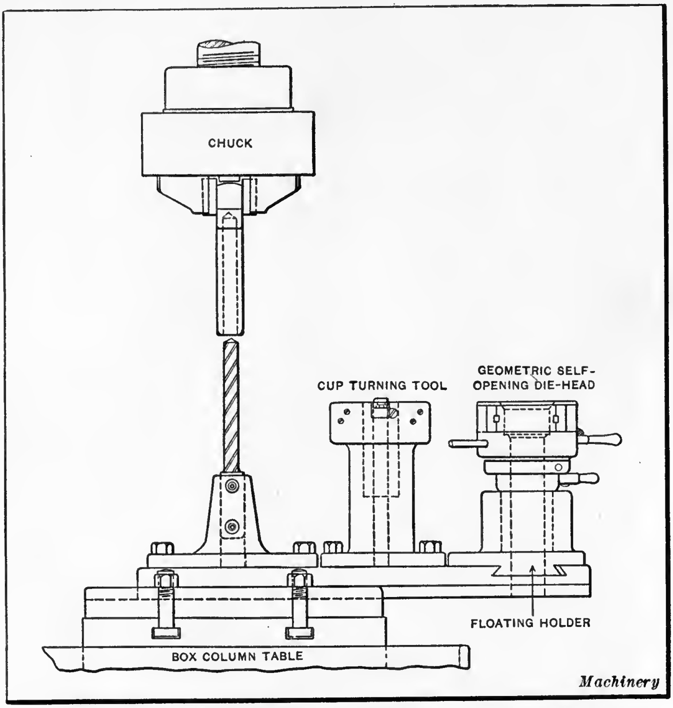


Fig. 2. Fixture for Drilling, Turning, and Threading Work

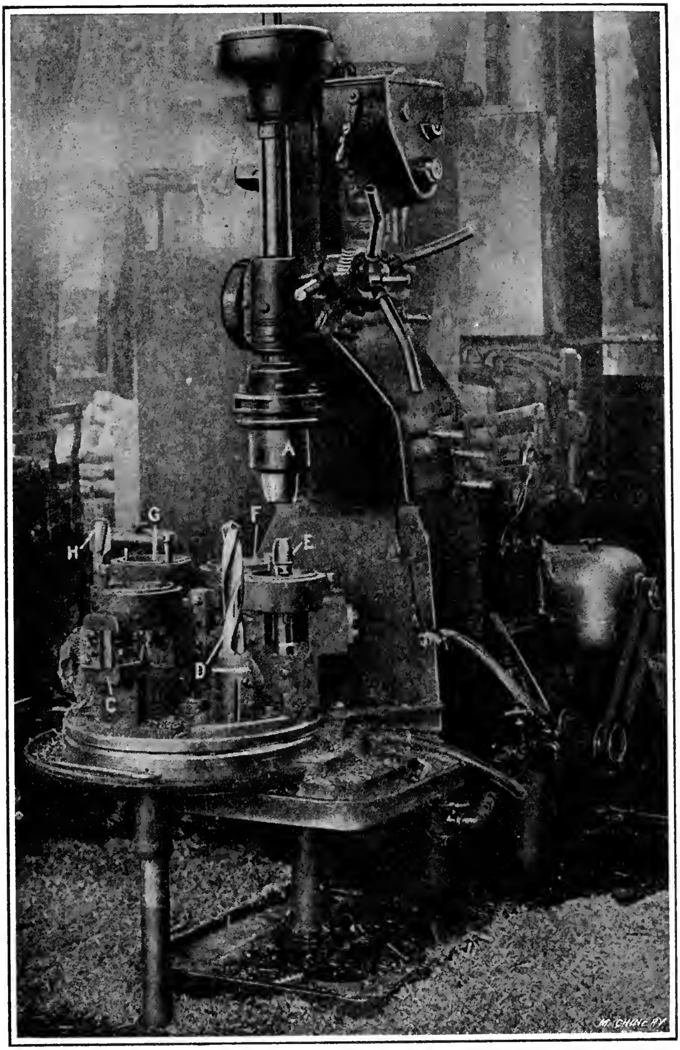


Fig. 3. Drilling Machine machining 18-pound High-explosive Shells

somewhat similar job, although in this case, after being drilled, the work is turned on the outside and then threaded. As in the previous case, the drill is held stationary on the machine table and a chuck carried on the drilling machine spindle provides for rotating the work and feeding it down onto the drill.

After the drilling operation has been completed, the fixture is indexed to bring the cup turning tool, or hollow-mill, into the operating position to provide for turning the outside of the work; and after this operation has been completed, the fixture is again indexed to bring the geometric self-opening threading die into position for threading.

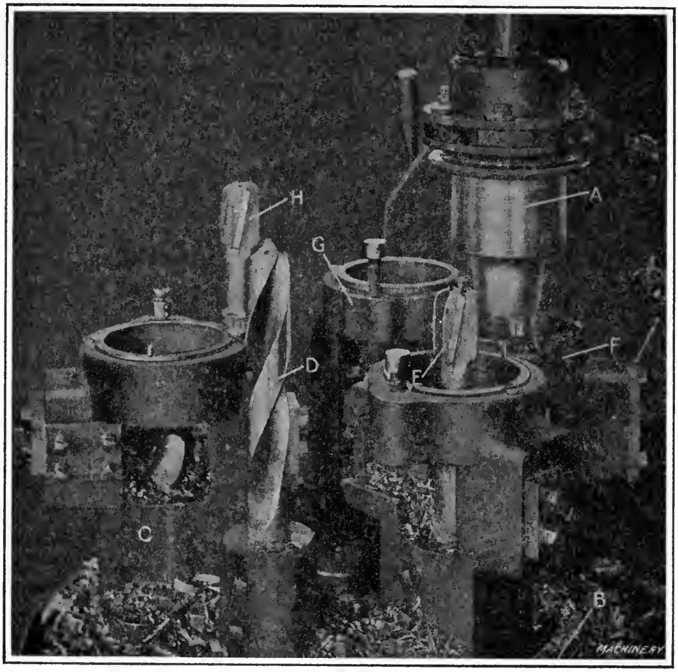


Fig. 4. Close View of Tool Equipment of Machine shown in Fig. 3

Inverted Tools held on Indexing Fixture. — Fig. 3 shows a drilling machine built by the Barnes Drill Co. for machining 18-pound high-explosive shells, and Fig. 4 shows a close view of the tool equipment on this machine. The selection of this type of equipment was decided upon at the factory where the machines are used, due to inability to secure reasonable deliveries on the types of machine tools that would ordinarily be selected for the performance of machining operations of this kind. A battery of eight of these self-oiling 22-inch machines was installed, and the results obtained have been entirely satisfactory. The shell to be machined is held in a fixture *A* secured to the drilling machine spindle, while the tools required for the performance of successive operations are carried on an indexing fixture mounted on the machine table. With this arrangement the work is revolved and fed down onto a stationary inverted tool, so that advantage may be taken of the greater ease with which chips clear themselves from an inverted hole of this kind. After each operation has been completed, the tool-holding fixture is indexed to bring the next tool into the operating position. The first operation is to spot-drill and rough-form the nose of the shell with tools held in holder *C*. A guiding ring is provided for the work so that it cannot spring away from the cut. The operation is performed at 92 revolutions per minute, with a feed of 0.013 inch per revolution. The spotting is done with a short twist drill, and rough-forming of the nose with three turning tools, which are stepped so that they cut to different depths, leaving an irregular surface.

The second operation is to drill the hole in the shell to the required depth; for this purpose, drill *D* is used, which is $1\frac{13}{16}$ inch in diameter. The drilling operation is performed at 145 revolutions per minute with a feed of 0.013 inch per revolution. The third operation is to rough-ream the hole with reamer *E*, which is formed at the end to finish the bottom of the shell cavity to the required shape. The operation is performed at 37 revolutions per minute with a feed of 0.093 inch per revolution. The fourth operation is to finish-form the nose with a form cutter located in holder *F*, which is bronze lined. The spindle runs at 45 revolutions per minute, and is fed down by hand. The fifth operation is to cut the step and bevel on the nose of the shell. For this operation, the tool is supported by a bronze-lined tool-holder *G* and the machine is operated at the same speed and feed as for the fourth operation. The sixth and final operation is to finish-ream the hole in the shell with reamer *H*. Great care is required in the performance of this operation, as specifications for the shells require that, when a light is dropped into the hole, the surface will show a uniform polish in all places. The finish-reaming operation is performed with the spindle rotating at 37 revolutions per minute with a down feed of 0.093 inch per revolution.

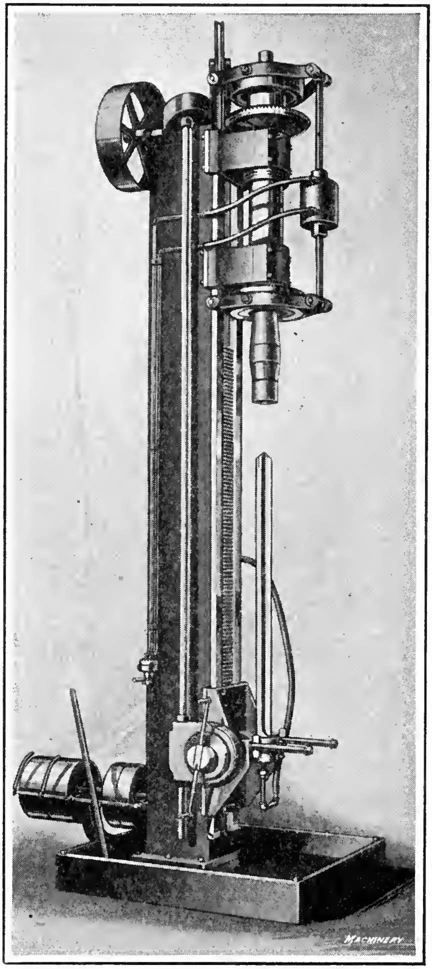


Fig. 5. Vertical Deep-hole Drilling Machine

Vertical Deep-hole Drilling Machine. — The deep-hole drilling machine shown in Fig. 5 was built originally by the Charles Stecher Co. for drilling holes in the solid forgings from which machine tool spindles are made, and the first machine was used for drilling the spindles of the Stecher screw machines. Several machines of this design were subsequently sold to other machine tool builders for the same service. Recently this machine has been enlarged and its design has been altered to adapt it for drilling recoil cylinders, axles for gun carriages, and gun barrels and jackets for the smaller guns. The largest machines built to date have a bore through the spindle 8 inches in diameter and a feed of 96 inches. These dimensions can easily be increased. This machine is used for roughing out the first hole from the solid forging and on finishing operations where wood-packed reamers are used. For roughing out holes from the solid, an ordinary drill point is used, inserted in a bar slightly smaller in diameter than the bore, and the bar is fluted for chip clearance. The vertical feature allows the chips to clear freely without the use of high pressure on the cutting compound, and it is not necessary to give special consideration to this problem, which is the chief source of trouble in drilling deep holes in a horizontal position. Drilling artillery axles in these machines with a drill point 3.185 inches in diameter, using 0.012 inch feed and driving the spindle at 48 revolutions per minute, the work is drilled to a depth of 57 inches without trouble from chips clogging, and, as the work revolves, the hole is straight and concentric to the bottom.

The spindle is equipped with an air chuck at each end, controlled by an operating valve which is conveniently reached from the floor. The work can be lowered through the spindle with an overhead tackle, but where head-room is limited the work can be placed on a carriage and raised through the spindle from below. An operator and helper can operate a number of these machines, depending upon the nature of the work accomplished. Where wood-packed reamers are used, the reamer is drawn down through the work by a draw-rod and is guided and held against turning by a rigid bushing above the spindle; or the work can be changed from the rougher to a special machine designed for reaming, which is constructed with the hollow spindle, in which the work is rotated, at the base end of the column and the drill carriage above, feeding the reamer down through the work and washing the chips ahead. By revolving the work, the best results are obtained, and the vertical lay-out permits the use of simple tooling, with consequent low tooling cost. The design of these machines permits of grouping the equipment, which is the ideal arrangement for handling four or five machines by one operator and helper without decreasing their production.

Horizontal Deep-hole Drilling Machine. — The machine shown in Fig. 6 was designed for the special purpose of drilling the long small hole through the length of the steel block shown in Fig. 7, which is a part of a machine gun. The making of this part is started in the block form and the hole is put in first, as it is the most difficult to locate accurately. All the subsequent machining is gaged from the finished hole. The drilling of this hole is difficult, on account of its small diameter as compared with its length. The test for straightness of hole was the free fit of a hard ground arbor sized to 0.0005 inch less than the low diameter limits given in Fig. 7. To pass inspection, the pin had to drop through the full length of the hole by its own weight.

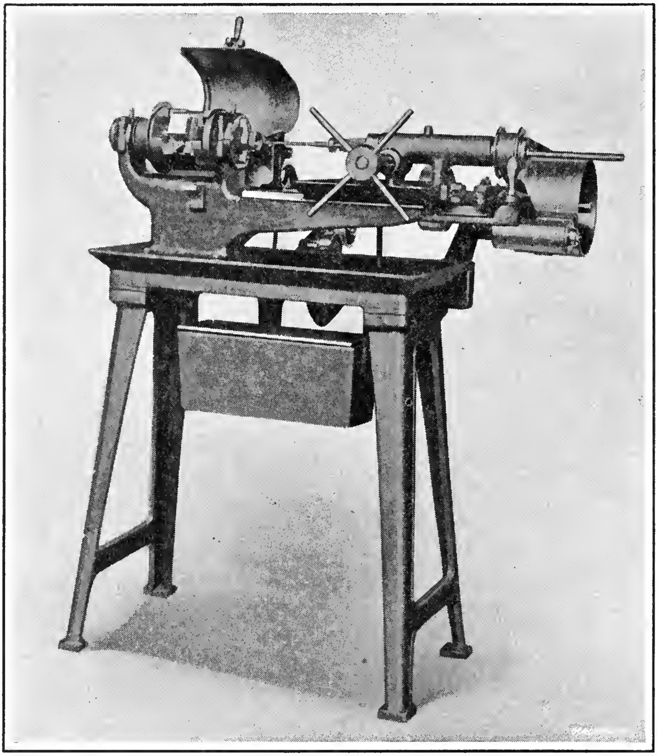


Fig. 6. Horizontal Deep-hole Drilling Machine

The limits for this hole diameter are 0.002 and 0.003 inch, and for depth, ±0.007 inch. The leading feature of this machine is that both the work and tools revolve, the proper speed for each being determined from experimental tests. A set of seven tools is used to produce the hole. The large portion of the hole requires a spotting tool, a twist drill, and a reamer, the reamer having a spotting tool on its end to start the middle hole. The middle hole requires a drill and reamer, the reamer also having a spotting tool on its end to start the small hole. The small hole is drilled and reamed. Each individual tool is fitted with a knurled taper socket lock shank that permits the tools to be quickly interchanged and locked firmly in place on the tailstock spindle.

The tailstock has two drilling positions, the outward position being used for the three operations on the large hole and the inner position for the operations on the middle and small holes. The tailstock is moved by a toggle lever motion that is self-locking in both positions. The tailstock spindle runs on ball bearings mounted in a feed sleeve that is actuated through a rack and pinion. The headstock has the work placed inside and the cover closed so as to lock it in place while revolving. To avoid any possible flying out of the block in case the cover should accidentally open, a guard is provided that surrounds the spindle on all sides. In Fig. 6 the guard is shown open, but when closed it is locked by a snap-catch. After a block has been completely drilled, it is necessary to bring the headstock spindle to a dead stop so as to permit the operator to open the swing cover, remove the block and put in a blank block. Rotation of the headstock and tailstock spindles is stopped by throwing the friction drive plates on the countershaft out of contact. This is done by the operator by means of a foot-pedal and long

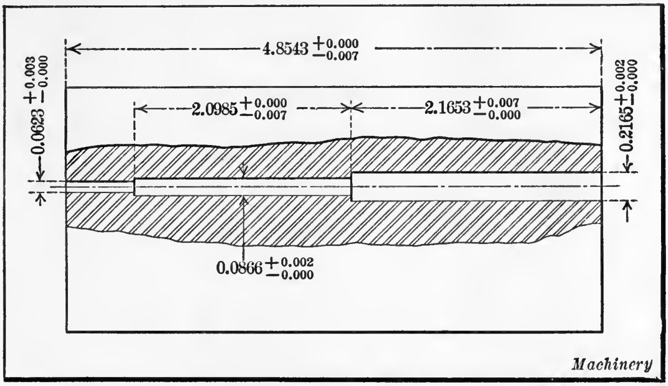
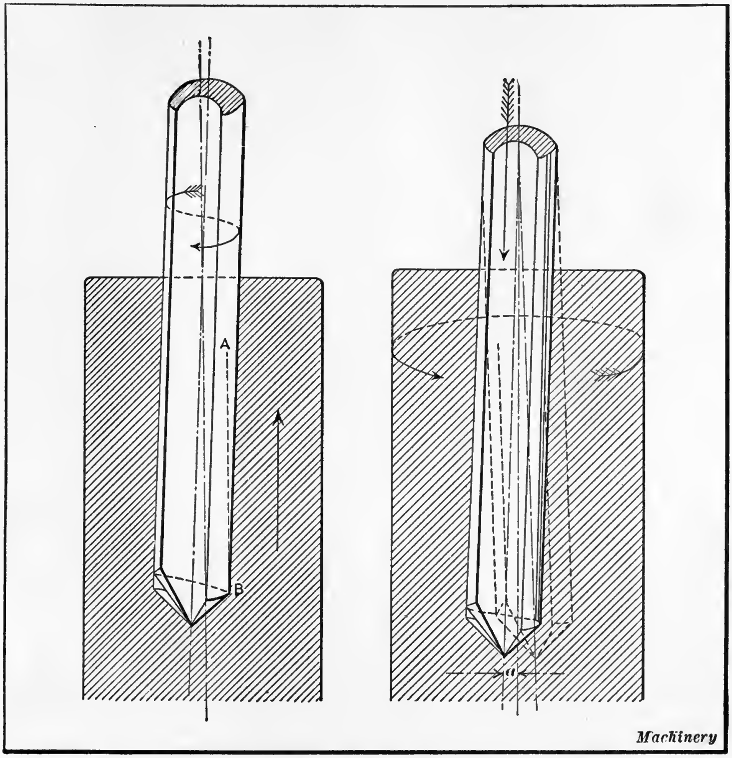


Fig. 7. Gun Part drilled in Machine shown in Fig. 6

link connection. To bring the headstock spindle to a quick stop, toggle-joint shoe brakes that act on a pulley on the jackshaft are automatically put into action when the guard is opened and released when it is shut. To the front end of the inner bearing of the headstock, there is screwed a stationary cover which supports the guide bushings required for the tools, and which also acts on a reservoir for forcing the cutting oil to the tools.

Why Work is revolved when Drilling Holes of Unusual Depth. — The principle involved in common drill presses where the drill is given a rotary motion simultaneously with the forward motion for feeding is the one least adapted to produce a straight and true hole, and this method cannot be employed for drilling very deep holes such, for example, as the holes in rifle barrels. Better results are obtained by giving only a rotary motion to the drill, and feeding the work toward it. It has been found, however, that, for drilling deep holes, the reversal of this, that is, imparting a rotary motion to the work, and the feed motion to the drill will answer the purpose still better. While a material difference between the latter two methods might not be apparent, an analysis of the conditions involved will show that there is a decided difference in the action of the drill. If the drill rotates and the work is fed forward, the drill, when deviating from its true course, will be caused to increase its deviation still more, by the wedge action of the part *B* (Fig. 8) which tends to move in the direction *BA* when the work is fed forward. In the case of the work rotating and the drill being fed forward, as shown to the right, the point of the drill when not running true will be carried around by the work in a circle with the radius *a*, thus tending to bend the drill in various directions. The drill is by this action forced back into the course of "least resistance," as it is evident that the bending action, being exerted on the drill in all directions, will tend to carry the point back to the axis of the work where no bending action will appear.

The difficulties to be overcome in producing deep drilled holes can be classified in three groups. In the first place, the drill, if applied in the ordinary manner, has a great tendency to run out, thus producing a hole that is neither straight nor uniform in diameter; in the second place, great difficulties are encountered in trying to remove the chips in a satisfactory manner; and, in the third place, the heating of the cutting tool is difficult to prevent. The first difficulty is overcome by adopting the method previously referred to, and the chips are carried off by forcing a fluid into the hole, which upon its return carries with it the chips. This fluid being oil will serve the double purpose of carrying away the chips and lubricating the cutting tool, keeping it at a normal temperature.



Machinery

Fig. 8. Comparison between Action of Cutting Tool when Drill and when Work revolves

Drill for Deep Holes. — A highly satisfactory drill for use in drilling deep holes is one brought out by the Pratt & Whitney

Co., principally for use in connection with their gun-barrel drilling machines. The tool in question is a development of the old D or hog-nose drill which has one cutting lip only. It is carefully ground on the outside, and is supplied with an oil-duct through which oil at high pressure may be brought directly to the cutting edge.

Referring to Fig. 9, *A* is the cutting edge, *B* the oil-duct, and *C* the chip groove. In milling the latter groove, the cutter is brought directly to the center line, so that, in this respect, the drill is very free cutting as compared with the ordinary two-lip twist drill which has a central web. In the end view, the shape of the chip groove is clearly indicated. The cutting edge *A* is radial. In sharpening the drill, the high point or part first entering the work is not ground in the center as is usually the case in drills, but to one side as shown by the cross-section *D* of the work being drilled, *E* being the high point of the drill. Grinding the drill in this manner makes possible its running true or straight, the teat *F* on the work acting as a support to the drill, which, owing to its periphery being partly

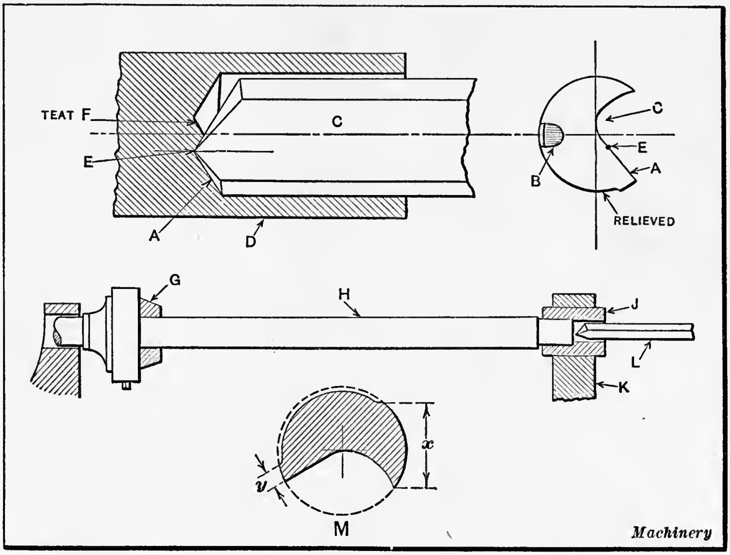


Fig. 9. Type of Deep-hole Drill adapted to Drilling Rifle Barrels

relieved, would have a tendency to travel in a curve away from its cutting side. The piece being drilled is run at very high speed, the periphery speed at the outer diameter of the hole being as high as 130 feet per minute on machine steel. The feed, however, is quite fine, on a 0.3-inch drill averaging 0.0004 inch per revolution, while on a 3-inch drill it is about 0.0008 inch. These figures, of course, are dependent to a great extent upon the material being drilled. The drills are made of high-grade steel and left very hard, so that the fine feed has little tendency to glaze the cutting edge.

The piece being drilled is held and revolved at one end by a suitable chuck on the live spindle of the machine, while the other end, which should be turned perfectly true, runs in a stationary bushing having at its outer end a hole the diameter of the drill. The drill enters the work through the bushing, and is thus started perfectly true. The arrangement is indicated in the middle view, in which *G* represents the chuck, *H* the work, *J* the bushing, *K* the support for holding the bushing, and *L* the drill. Through the oil-duct of the drill, oil is forced at a pressure varying from 150 to 200 pounds per square inch. After passing the cutting edge, the oil returns to the reservoir by the way of the chip groove, forcing the chips along in its travel. In drills of large diameter, especially when working on tough, stringy material, the cutting edge is usually ground so as to produce a number of shavings instead of one the full width of the cutting lip, so that no trouble is experienced in getting chips out of the way. The oil, of course, is used over and over again, and with a large reservoir will be kept quite cool.

The drill is made up of the drill tip and shank, the tip varying in length from 4 to 8 inches, while the length of the shank is determined by the depth of hole that is to be drilled. The shanks on small drills are made from steel tubing, rolled to special cross-sectional form. The tip is carefully fitted and soldered to the shank, which, it should be noted, is a little smaller in diameter than the tip.

The relief or clearance of the cutting edge of the drill, the amount the "high point" of the drill should be off center,

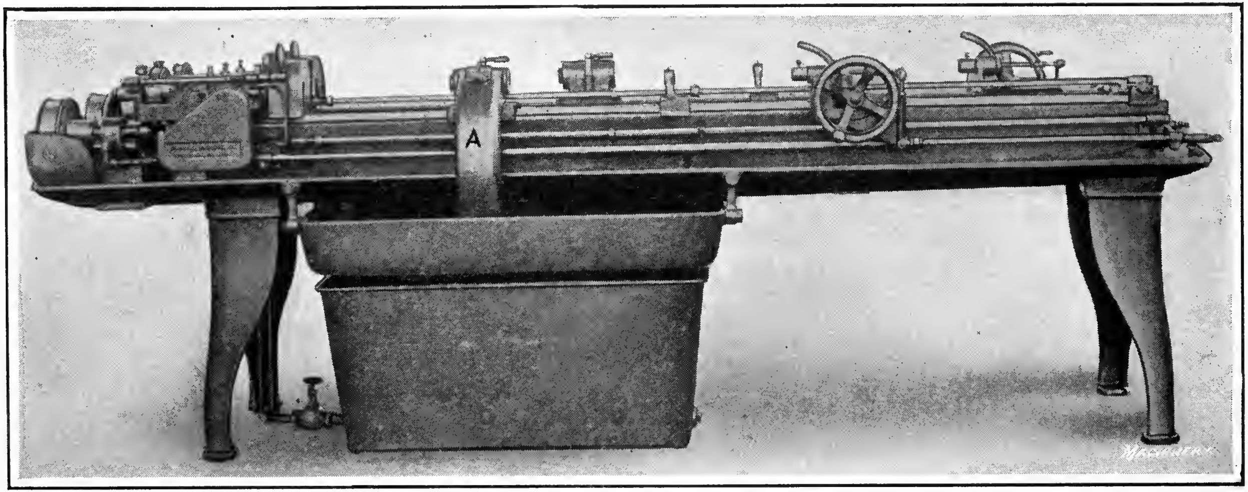


Fig. 10. Rifle Barrel Drilling Machine

and the number of rings on the end of the drill, when provided with notches for breaking up the chips, depend entirely upon the material that is to be drilled. For instance, on very soft stock, the supporting teat should be more substantial than on hard spindle or gun steel; it is, therefore, evident that on soft stock the high point should be more off center, or nearer to the outer diameter, than on hard stock.

The present practice in relieving the large drills is shown at *M*. The straight, or radial, edge is the cutting edge of the drill and the distance *y* is about $\frac{1}{8}$ inch on a one-inch drill. The surface *x* is left of the full radius of the drill, and makes a good back-rest. When the drill is ground on its periphery, it is made very slightly tapering toward the shank in order to free itself. As previously stated, in milling the chip groove, the cutter is brought exactly to the center of the drill. When hardening and grinding, however, the location frequently changes slightly so that the groove does not come to the center of the drill. In such cases, it is necessary to grind out the lip at the point.

Rifle Barrel Drilling Machine. — The rifle barrel drilling machine illustrated in Fig. 10 (made by the Diamond Machine Co.) operates on the general principle previously referred to, the work being revolved while the drill remains stationary, except for the slow feeding movement. Any machinist who has had experience in the drilling of deep holes will appreciate the difficulties encountered in drilling a hole through steel rifle barrels 30 inches in length and maintaining an extremely high degree of accuracy in the work. The most noteworthy feature of the operation to the mechanic who has had experience in drilling deep holes with ordinary drills, where it is necessary to back the drill out at frequent intervals in order to clear the chips, is the fact that the operation is continuous when the proper equipment is used. This has been made possible, in part, by using special drills of the general type previously referred to. As these drills are made hollow, a copious flow of cutting compound may be delivered right to the point of the drill where it is most effective in dissipating the heat of the cut. The oil escapes through the flute extending along one side of the drill which also provides means of washing away the chips as fast as they are produced.

The drill is made of sufficient length to extend entirely through the rifle barrel. The body of the drill is made of steel tubing which is rolled in at one side in order to produce the groove which provides for the escape of oil and chips from the work. The point of the drill is made of drill rod. A groove is ground down the side of the drill in order to continue the groove which has been rolled in the steel tube, and the drill point is soldered to the end of the tube. The description will be better understood by referring to Fig. 11 which shows one of the drills.

The drilling machine provides for working on two rifle barrels at a time. The barrel forging is supported in a chuck in the headstock spindle, this chuck consisting of a tapered socket which is serrated so that a firm grip is secured on the work when the end of the forging is driven into place by tapping the opposite end of the barrel with a lead hammer. The outer end of the work is supported by a bushing at the left-hand side of rest *A*, Fig. 10, and at the right-hand side of this rest there is a guide bushing which is a close fit around the point of the drill. As the work rotates, the drill is fed to the work by traversing the tailstock in which the shank of the drill is supported. As the drills are long and thin, it will be evident that some intermediate support is necessary, and this support is afforded by means of a steadyrest. This description and that which follows apply to one side of the machine, but it will be evident that the entire machine is composed of two sets of mechanism like that described.

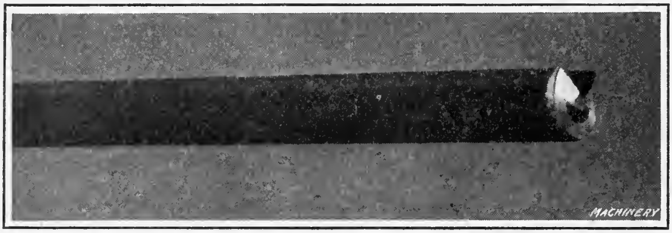


Fig. 11. Cutting End of a Rifle Barrel Drill

Driving Mechanism of Rifle Barrel Drilling Machine. — The arrangement of the drive will be best understood by referring to Fig. 12 which shows the mechanism quite clearly, but in connection with this description it should be understood that guards are provided over all gearing on the machine. The drill at the front of the machine is driven by pulley *A* which is mounted at the back of the spindle, and the power is transmitted through a friction clutch *B* which is held in engagement by the pointed end of lever *C* that engages a shoulder at the end of the horizontal rod *D*. When the tailstock has been traversed far enough along the bed of the machine so that the hole has been drilled entirely through the rifle barrel, a dog on the tailstock engages an adjustable stop carried by rod *D*, with the result that this rod is rocked down so that the shoulder disengages the end of lever *C*. As a result, compression spring *E* becomes effective and throws clutch *B* out of engagement, thus stopping both the rotation of the spindle and the feeding of the drill to the work. The feed motion for the tailstock is transmitted from the spindle through a worm and wheel, change-gears *F*, and a second worm and wheel to a lead-screw located inside the bed of the machine. This lead-screw traverses the tailstock in the same way that the lead-screw of an ordinary engine lathe moves the carriage along the bed of the machine.

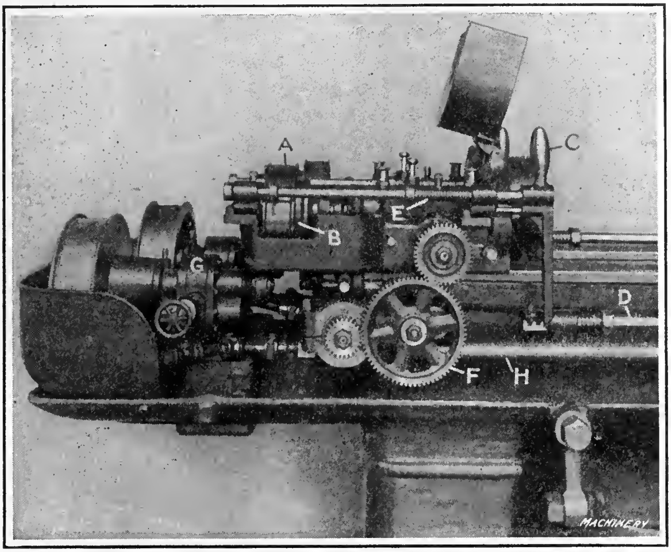


Fig. 12. Close View of Driving Mechanism with Gear Guard removed

Oil Supply for Rifle Barrel Drilling Machine. — In connection with the description of the drill it was mentioned that means are provided for clearing the chips from the hole by delivering a flow of oil through a tube in the drill and allowing it to escape by way of a groove at the side. The oil employed for this purpose is contained in a reservoir located beneath the machine, and the pump which is connected with this reservoir is shown at *G*, this pump being driven by a large pulley at the left-hand end of the machine. In order to provide for supplying the hollow drill with oil as the tailstock is traversed along the bed of the machine, connection is made with the tailstock and end of the hollow drill by means of a telescopic tube *H* through which oil is pumped from the reservoir. In order to secure satisfactory results in clearing the chips from the hole, it is necessary to have the oil at a pressure of not less than 800 pounds per square inch, and under actual working conditions this pressure is generally quite close to 1000 pounds per square inch. This pressure resists the action of the lead-screw in traversing the tailstock along the bed, and results in a tendency for the tailstock to move over toward the right-hand end of the bed.

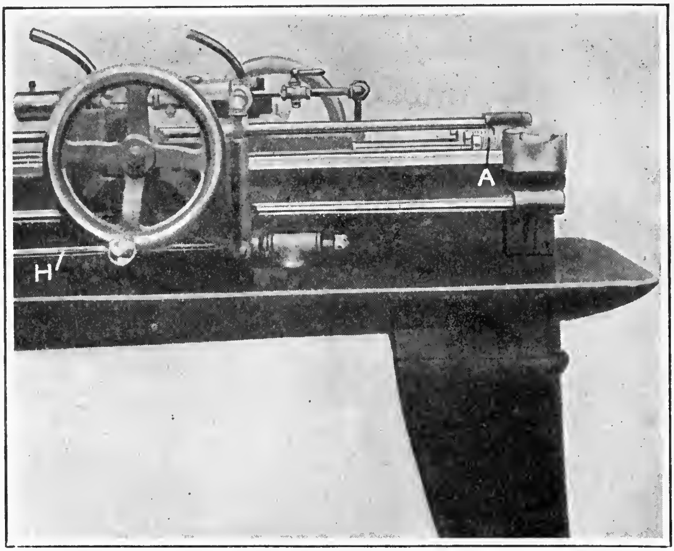


Fig. 13. End View of Machine, showing Tailstock Buffer Springs

After the drilling operation has been completed, the split nut by which connection is made between the lead-screw and tailstock is released in order to move the tailstock back to the starting position. Evidently when the split nut is released in this way there is a possibility of the residual pressure in the oil-tube causing the tailstock to be thrown back with considerable force, and cases are on record where a machine has actually been wrecked in this way. To obviate trouble from this source, a buffer spring is provided as shown at *A*, Fig. 13, which will absorb the shock in case the tailstock is thrown back in this way. It will be evident that, with oil at a pressure exceeding 800 pounds per square inch, it is necessary to provide an effective form of guard to prevent it from being thrown from the point at which it escapes from the end of the hole in the work. These means are provided by guard *A*, Fig. 10, which carries the bushing that supports the outer end of the rifle barrel; the oil and chips escape into this guard from which they drop down into the pan under the machine. This pan is provided with a strainer which holds back the chips, but allows the oil to flow through into the reservoir where it is ready to once more be pumped to the work.

When working on military rifles, these machines are ordinarily driven at a speed of 1500 revolutions per minute, and the drill is fed to the work at rates of feed which cover a range of from 0.2 to 1.0 inch per minute. The rate of production is about three barrels per hour from each two-spindle machine, i.e., a barrel forging can be set up in the machine, and drilled and removed in approximately forty minutes.

Twelve-spindle Rifle Barrel Drilling Machine. — A radical departure from the conventional method of drilling and reaming rifle barrels has been made in the machines shown in Figs. 14 and 15, designed by the New England Westinghouse Co. These machines differ from standard rifle barrel drilling and reaming machines in several important respects: First, they are designed to handle the barrels vertically instead of horizontally; second, twelve instead of two barrels are handled by each machine; third, each spindle on the barrel drilling machine is driven by a separate variable-speed motor; fourth, one machine occupies exactly the same floor space as the standard machine, which has a capacity for only two instead of twelve barrels;

fifth, on the drilling machine an automatic electric switch instead of a mechanically-operated clutch is provided for stopping the machine should a drill stick or become dull; and sixth, on the barrel reaming machine, the feed is by counterweights instead of a positive screw, thus automatically adjusting the rate of feed to suit varying conditions in the size of bore and hardness of metal.

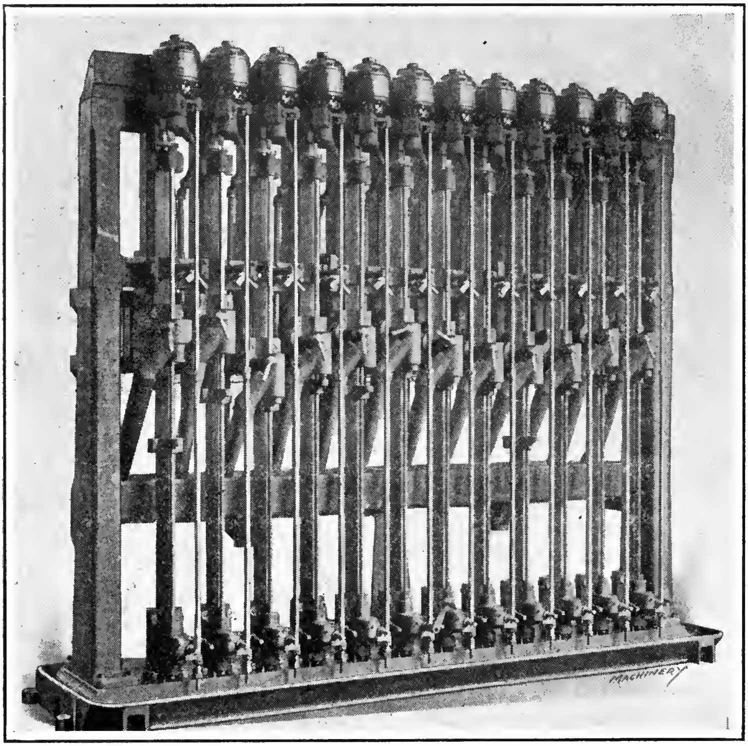


Fig. 14. Westinghouse Rifle Barrel Drilling Machine that Works on Twelve Barrels simultaneously

The machine consists of an upright frame standing on a base of rectangular section and carrying twelve individual units, comprising a variable-speed motor, headstock, tailstock, drill guide, carriage, and controller, the controller being located at the rear of the machine. All these members, with the exception of the motor and headstock, are carried on twelve uprights.

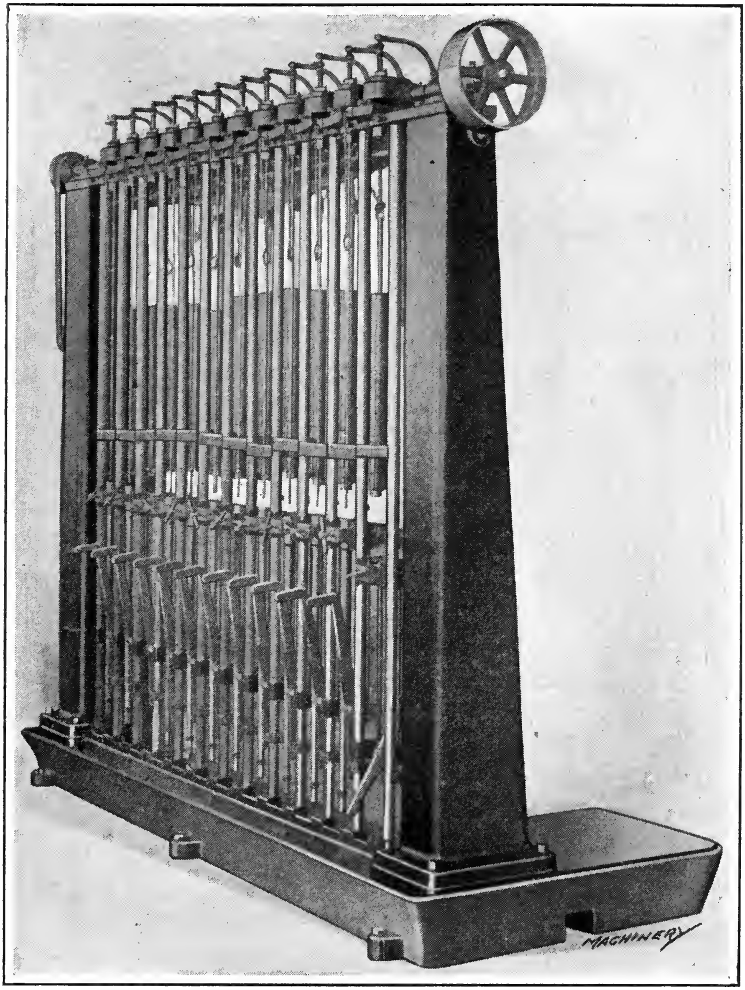


Fig. 15. Westinghouse Twelve-spindle Rifle Barrel Reaming Machine

In operation, the rifle barrel to be drilled is held in and rotated by the headstock, a female driving chuck or center with sharp projections contacting with the machined taper on the muzzle end of the barrel. This chuck is connected directly to the motor shaft. The lower center in the tailstock is held upward by a stiff spring, thus insuring that the barrel is always held up in the chuck with the same pressure, and at the same time providing for linear expansion of the barrel due to heating while it is being drilled. The carriage is furnished with the standard type of oil-tube barrel drill and is fed upward by a lead-screw that receives power from the motor through a train of gears, worms, and worm-wheels.

The oil is pumped up through the drill from an oil " line " in which the pressure registers about 800 pounds per square inch. The oil and chips pass down through the exterior flute in the drill and shank, and are carried off through a " by-pass " pipe which is part of the tailstock casting. This pipe extends to the rear of the machine and empties into a trough in which the chips are separated from the oil, which returns to the pump.

Each spindle is automatically stopped when the drill breaks through at the muzzle end of the barrel by a dog which operates the starting and stopping handle. An interesting feature in connection with this machine, which eliminates the splashing of oil when the drill breaks through, is a " by-pass " arrangement consisting of angular holes in the lower section of the headstock casting. This " by-pass " conveys oil from the drill to a pipe which, in turn, carries it to a trough behind the machine. In this way, the machine is kept clean and free from oil.

Another feature, which relates more particularly to the electrical equipment, is the provision made for stopping the machine automatically, should the drill become dull or stick and thus consume more power than would ordinarily be required. This consists of an electric switch, comprising an overload coil which is connected in series with the armature, and is so arranged that any excess current passing through the armature will operate the coil and through it the switch, thus automatically stopping the machine. This overload coil can be very accurately adjusted to suit conditions of steel, etc. A starting rheostat is also provided which enables work speeds varying from 1200 to 2400 revolutions per minute to be obtained.

Rifle Barrel Reaming Machine. — In the rifle barrel reaming machine shown in Fig. 15, advantage is taken of the vertical principle of handling the work. Reaming on vertical machines comprises several important advantages over the horizontal method. In the first place, twelve spindles occupy exactly the same floor space as two spindles of a horizontal machine, and present the spindles in compact form, so that they can be attended to by one operator. In the second place, lubrication of the reamer is more easily accomplished, resulting in the production of holes free from rings and other defects.

There are several other advantages incorporated in this machine, among which are the following: First, the barrels are swung from universal joints, enabling the reamers to follow the drilled holes accurately. Second, the feed is by counterweights — not positive — so that it automatically adjusts itself to agree with the amount of work being done by the reamers. For instance, if there is more material to be reamed out of a hole than is normally the case, the machine will feed more slowly; and if the reamer strikes a hard spot in the barrel, the feed will slow up to accomodate itself to this condition. Third, the machine can be used either for push or pull reaming. This is accomplished by changing the direction of driving rotation of the belt on the cone pulley at the left-hand end of the machine, and by changing the location of the counterweights.

The feed for the reamers, as previously mentioned, is obtained by means of counterweights which are placed on crossheads or at opposite ends of the cables, depending upon whether the push or pull method is being used. These cables run over pulleys that are mounted on friction clutches so arranged that they can be made to work in either direction. The weights can also be adjusted to give any rate of feed that is found most satisfactory for the steel being machined and the amount of material being removed. All twelve spindles are driven from one longitudinal shaft running the entire length of the machine, which, in turn, is operated from a countershaft located on the floor.

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