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No. 41

A Dollar's Worth of Condensed Information

Jigs and Fixtures

By EINAR MORIN

PART I

BUSHINGS, LOCATING POINTS AND CLAMPING DEVICES

SECOND EDITION

Price 25 Cents

CONTENTS

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JIGS AND FIXTURES—PART I

CHAPTER I

PRINCIPLES OF JIG AND FIXTURE DESIGN*

Jigs and fixtures may be defined as special devices made of cast iron, steel, or sometimes of wood, used in the manufacture of duplicate parts of machines, and intended to make possible interchangeable work at a reduced cost, as compared with the cost of producing each machine detail individually. The jigs and fixtures serve the purpose of holding and properly locating a piece of work while being machined, and are provided with necessary appliances for guiding, supporting, setting, and gaging the tools in such a manner that all the work produced in the same jig or fixture will be alike in all respects, even with the employment of more or less unskilled labor. When using the expression "alike," it implies, of course, simply that the pieces will be near enough alike for the purposes for which the work being machined is intended. Thus, for certain classes of work, wider limits of variation will be permissible without affecting the proper use of the piece being machined, while in other cases, the limits of variation will be so small as to make the expression "perfectly alike" literally true.

Objects of Jigs and Fixtures

The main object of using jigs and fixtures is, of course, the reduction of the cost of machines or machine details being built or made in great number. This reduction of cost is obtained in consequence of the increased rapidity with which the machines may be built, and on account of the employment of cheaper labor, which is possible when using tools for interchangeable manufacturing. Another purpose however, not less important, is the accuracy with which the work can be produced, making it possible to assemble the pieces produced in jigs without any great amount of work in the assembling department, thus also effecting a great saving in this respect.

The use of jigs and fixtures practically does away with the fitting, as this expression was understood in the old-time shop; it eliminates cut-and-try methods, and does away with the so-called patch work in the production of machinery. It makes it possible to have all the machines turned out in the shop according to the drawings, a thing which is rather difficult to accomplish if each individual machine in a large lot is built without reference to the other machines in the same lot.

The interchangeability obtained by the use of jigs and fixtures makes it also an easy matter to quickly replace broken or worn-out

* MACHINERY, April, 1908.

parts without great additional cost and trouble. When machines are built on the individual plan, it is necessary to send somebody from the shop where the machine was built to the place where it is installed, in order to fit the part replacing the broken or worn-out piece, in place, and this would, in a great many cases, involve considerable extra expense, not to mention the delay and the difficulties occasioned thereby.

As previously mentioned, jigs and fixtures permit the employment of practically unskilled labor. There are a great many operations in the building of a machine, which, if each machine were built individually, without the use of special tools, would require the work of expert machinists and toolmakers. Special tools, in the form of jigs and fixtures, permit equally good, or, in some cases, even better results to be obtained by a much cheaper class of labor, provided the jigs and fixtures are properly designed and correctly made. Another possibility for saving, particularly in the case of drill and boring jigs provided with guide bushings in the same plane, is met with in the fact that such jigs are particularly adapted to be used in multiple spindle drills, thereby still more increasing the rapidity with which the work may be produced, and, at the same time, making the machine extremely productive, so as to reduce the shop cost of this machine to a minimum. In shops where a great amount of duplicate parts are made, containing a number of drilled holes, multiple spindle drills of complicated design, which may be rather expensive as regards first cost, are really cheaper, by far, than ordinary simple drill presses.

Another point of advantage which has been gained by the use of jigs and fixtures, and which should not be lost sight of in the enumeration of the points in favor of building machinery by the use of special tools, is that the details of a machine that has been provided with a complete equipment of accurate and durable jigs and fixtures can all be finished simultaneously in different departments of a large factory, without inconvenience, thus making it possible to assemble the machine at once after receiving the parts from the different departments; and there is no need of waiting for the completion of one part into which another is required to fit, before making this latter part. This gain in time means a great deal to a manufacturing concern in cases where the orders are coming in with great rapidity, so as to require the utmost speed in production. This rapidity was entirely impossible under the old-time system of machinery building, when each part had to be made in the order in which it went on the finished machine, and each consecutive part had to be lined up with each one of the previously made and assembled details. Brackets, bearings, etc., had to be drilled in place, often with ratchet drills, which, of course, was a slow and always inconvenient operation.

Difference between Jigs and Fixtures

To exactly define the word "jig," as considered apart from the word "fixture," is rather difficult, as the difference between a jig and a fixture is oftentimes not very easy to decide. The word jig is frequently, although incorrectly, applied to any kind of a work-holding appliance used in the building of machinery, the same as, in some shops, the word fixture is applied to all kinds of special tools. As a general rule, however, we can say that a jig is a special tool, which, while it holds the work, or is held on the work, at the same time also contains guides for the respective tools to be used, whereas a fixture is only holding the work while the cutting tools are performing the operation on the piece, without containing any special arrangements for guiding these tools. The fixture, therefore, must, itself, be securely held or fixed to the machine on which the operation is performed, hence the name. A fixture, however, may sometimes be provided with a number of gages and stops, although it does not contain any special devices for the guiding of the tools.

The definition given, in a general way, would therefore define jigs as special tools used particularly in drilling and boring operations, while fixtures, in particular, would be those special tools used on milling machines, and in some cases, on planers, shapers, and slotting machines. Special tools used on the lathe may be either of the nature of jigs or fixtures, and sometimes the special tool is actually a combination of both, in which case the expression drilling fixture, boring fixture, etc., is in place.

Fundamental Principles of Jig Design

Before entering upon a discussion of the minor details of the design of jigs and fixtures, we will briefly outline the fundamental principles of jig and fixture design. Whenever a special tool is made up for a component part of a machine, it is almost always required that a corresponding jig be made up for the place on the machine, or other part, where the first-mentioned detail is placed. It is, of course, absolutely necessary that these two jigs be perfectly alike, as to the location of guides and gage points. In order to get the holes and guides in the two jigs in perfect alignment, it is advisable, and almost always cheaper and quicker, to transfer the holes or the gage points from the first jig made, to the other. In many instances, it is possible to use the same jig for both parts. Instances where the one or the other of these principles is applicable will be shown later in the detailed descriptions of drill and boring jigs. There are also cases where it is not advisable to make up two jigs, one for each of the two parts, which are to fit together. It may be that it is impossible to properly locate the jig on one of the parts to be drilled, or it may be that if the jig were made, it would be so complicated that it would not be economical. Under such conditions the component part, itself, may be used as a jig, and the respective holes or slots in this part used as guides for the tools when machining the machine details into which it fits. Guide bushings for the drills and boring bars may then be placed in the holes in the component part itself. In many cases, drilling and boring operations are also being done, to great advantage, by using the brackets and bearings already assembled and fastened onto the machine body as guides.

One of the most important questions to be decided before making a jig is the amount of money which can be expended on a special tool for the operation required. In many cases, it is possible to get a highly efficient tool by making it more complicated and more expensive, whereas a less efficient tool may be produced at very small expense. To decide which of these two types of jigs and fixtures should be designed in each individual case depends entirely on the circumstances. In any well-managed shop there should be a careful comparison of the present cost of carrying out a certain operation, the expected cost of carrying out the same operation with an efficient tool, and the cost of building that tool itself. Unless this is done, it is likely that the shop is burdened with a great number of special tools and fixtures which, while they may be very useful for the production of the parts for which they are intended, actually involve a loss. It is readily seen how foolish it is to make up an expensive jig and fixture for a machine or a part of a machine, that would only have to be duplicated a few times. In some cases, of course, there may be a gain in using special devices in order to get extremely good and accurate results.

Locating and Clamping Devices

Regarding the design of the jig, the most important requirements are that good facilities be provided for locating the work, and that the piece to be machined may be easily inserted and quickly taken out of the jig, so that no unnecessary time is wasted in placing the work in position on the machine performing the work. In some cases, a longer time is required for locating and binding in place, the piece to be worked upon, than is required for the actual machine operation itself. In all such cases the machine performing the work is actually idle the greater part of the time, and, added to the loss of the operator's time, is the increased expense for shop cost, incurred by such a condition. For this reason, the question of locating and binding the work in place quickly, and at the same time accurately, should be carefully studied by the designer before any attempt to design the tool is made. In choosing the locating surface or points of the piece or part, consideration must be given to the facilities for locating the corresponding part of the machine in a similar manner. It is, of course, highly important that this be done, as otherwise, although the jigs may be alike, as far as their guiding appliances are concerned, there may be no facility for locating the corresponding part in the same manner as the one already drilled, and while the holes drilled thus may coincide, other surfaces also required to coincide may be considerably out of line. For this reason, one of the main principles of location is that two component parts of the machine should be located from corresponding points and surfaces.

If possible, special arrangements should be made in the design of the jig so that it is impossible to insert the piece in any but the correct way. Mistakes are often made on this account in shops where a great deal of cheap help is used, pieces being placed in jigs upside down, or in some way other than the correct one, and work that has been previously machined at the expenditure of a great deal of time, is entirely spoiled. Therefore, whenever possible, a jig should be made "fool-proof."

When the work to be machined varies in shape and size, as, for instance, in the case of rough castings, it is necessary to have at least some of the locating points adjustable, and placed so that they can be easily reached for adjustment, but, at the same time, so fastened that they are, to a certain extent, positive. In the following chapters different kinds of adjustable locating points will be described in detail. The strapping or clamping arrangements should be as simple as possible, without sacrificing effectiveness, and the strength of the clamps should be such as to not only hold the piece firmly in place, but also to take the strain of the cutting tools without springing or "giving."

When designing the jig, the direction in which the strain of the tool or cutters acts upon the work should always be considered, and the clamps so placed that they will have the highest degree of strength to resist the pressure of the cut.

The main principles in the application of clamps to a jig or fixture are that they should be convenient for the operator, quickly operated, and, when detached from the work, still connected with the jig or fixture itself, so as to prevent the operator from losing them, or, at least, from losing time hunting for them. Many a time, looking for lost straps, clamps, screws, etc., causes more delay in shops than the extra cost sometimes incurred in designing a jig or fixture somewhat more complicated, in order to make the binding arrangement an integral part of the fixture itself. Great complication in the clamping arrangements, however, is not advisable. Usually clamping arrangements of this kind work very well when the fixture is new, but as the various parts become worn, complicated arrangements are more likely to get out of order, and the extra cost incurred in repairing often outweighs the temporary gain in quickness of operation.

Some of the principles mentioned may seem contradictory, and in fact they are. There is, therefore, all the more reason to refer to the fact that the judgment of the designer is, in every case, the most important point in the design of jigs and fixtures. Definite rules for all cases cannot be given. General principles can be studied, but the efficiency of the individual tool will depend entirely upon the judgment of the tool designer in applying the general principles of tool design to the case in hand.

When designing the jig or fixture, the locating and bearing points for the work, and the location of the clamps must also be so selected that there is as little liability as possible of springing the piece or jig, or both, out of shape, when applying the clamps. The springing of either the one or the other part will, of course, cause incorrect results when the piece is taken out of the jig, as the work surfaces will be out of alignment with the holes drilled or the faces milled. The clamps or straps, should therefore, as far as it is possible, be so placed that they are exactly opposite some bearing point or surface on the work.

The designer must use his judgment in regard to the amount of metal put into the jig or fixture. It is desirable to make these tools as light as possible in order that they may be easily handled, be of smaller size, and cost less in regard to the amount of material used for their making, but, at the same time, it is poor economy to sacrifice any of the rigidity and stiffness of the tool, as this is one of the main considerations for efficient results. On large-sized jigs and fixtures, it is possible to core out the metal in a number of places, without decreasing, in the least, the strength of the jig itself. The corners of jigs and fixtures should always be well rounded, and all burrs and sharp edges filed off, so as to make them convenient and pleasant for handling. Smaller jigs should also be made with handles in proper places, so that they may be held in position while working, if it be a drilling jig, and also for convenience in moving the jig about.

Jigs Provided with Feet

Ordinary drill jigs should always be provided with feet or legs on all sides which are opposite the holes for the bushings, or other provisions for guiding the tools, so that the jig can be placed square on the table of the machine. These feet also greatly facilitate the making of the jig, making it much easier to lay out and plane the different finished surfaces. On the sides of the jig, where no feet are required, if the body is made from a casting, it is of advantage to have small lugs projecting out, for bearing surfaces when laying out and planing. While jigs are most commonly provided with four feet on each side, in some cases it is sufficient to provide the tool with only three feet, but care should be taken in either case that all bushings and places where pressure will be applied to the tool are placed inside of the geometrical figure obtained by connecting, by lines, the points of location for the feet.

While it may seem that three feet are preferable to use, because the jig will then always obtain a bearing on all the three feet, which it would not with four feet, if the table of the machine were not absolutely plane, it is not quite safe to use the smaller number of supports, because a chip or some other object is liable to come under one foot, and throw the jig and the piece out of line, without this being noticed by the operator. If the same thing happens to a jig with four feet, it will rock, and invariably cause the operator to notice the defect. If the table is out of true, this defect, too, will be noticed for the same reason.

General Remarks on Jig Design

One mistake, quite frequently made, is giving too little clearance between the piece to be machined and the walls or sides of the jig used for it. Plenty of clearance should always be allowed, particularly when rough castings are being drilled or machined in the jigs; besides, those surfaces in the jig which do not actually bear upon the work, are likely to be made up with some slight variation from the dimensions on the drawing, particularly in a cast iron jig, and allowance ought to be made for such differences.

In regard to the locating points, it ought to be remarked that, in all instances, these should be visible to the operator when placing the work in position, so that he may be enabled to see that the work really is in its right place. At times the construction of the piece to be worked upon may prevent a full view of the locating points. In such a case a cored or drilled hole in the jig, near the locating seat, will enable a view of same, so that the operator may either see that the work rests upon the locating point, or, if the work be very particular, so that he can get a feeler or thickness gage between the work and the locating surface, to make sure that he has got the work in its correct position. Another point that should not be overlooked is that jigs and fixtures should be designed with a view of making them easily cleaned from the chips, and provision should also be made so that the chips, as far as possible, may fall out of the jig and not accumulate on or about the locating points, where they are liable to throw the work out of its correct position, and consequently spoil the piece.

The principles so far referred to have all been in relation to the holding of the work in the jig, and the general design of the jig for producing accurate work. Provisions, however, should also be made for clamping the jig or fixture to the table of the machine, in cases where it is necessary to have the tool fixed while in operation. Small drilling jigs, for instance, are not clamped to the table, but boring jigs, and milling and planing fixtures invariably have to be firmly secured to the machine on which they are employed. Usually plain lugs, projecting out in the same plane as the bottom of the jig, or lugs with a slot in them to fit the body of T-bolts, are the common means for clamping fixtures to the table. For boring jigs, it is unnecessary to provide more than three such clamping points, as a greater number is likely to cause some springing action in the fixture. A slight springing effect is almost unavoidable, no matter how strong and heavy the jig is, but, by properly applying the clamps, it is possible to limit this springing to so small a limit as to permit it to be commercially disregarded.

When jigs are made, before they are used, they should always be tested so as to make sure that the guiding provisions are placed in the right relation to the locating points and in proper relation to each other.

Summary of Principles of Jig Design

Summarizing the principles referred to in the previous discussion, we may state the following rules as being the main points to be considered in the designing of jigs and fixtures:

1. Before planning the design of a tool, compare the cost of production of the work with present tools with the expected cost of production, using the tool to be made, and see that the cost of building is not in excess of expected gain.

2. Before laying out the jig or fixture, decide upon the locating points and outline a clamping arrangement.

3. Make all clamping and binding devices as quick-acting as possible.

4. In selecting locating points, see that two component parts of a machine can be located from corresponding points and surfaces.

5. Make the jig "fool-proof," that is, arrange it so that the work cannot be inserted except in the correct way.

6. For rough castings, make some of the locating points adjustable.

7. Locate clamps so that they will be in the best position to resist the pressure of the cutting tool, when at work.

8. Make, if possible, all clamps integral parts of the jig or fixture.

9. Avoid complicated clamping arrangements, which are liable to wear or get out of order.

10. Place all clamps as nearly as possible opposite some bearing point of the work to avoid springing.

11. Cut out all unnecessary metal, making the tools as light as possible consistent with rigidity and stiffness.

12. Round all corners.

13. Provide handles wherever these will make the handling of the jig more convenient.

14. Provide feet, preferably four, opposite all surfaces containing guide bushings in drilling and boring jigs.

15. Place all bushings inside of the geometrical figure formed by connecting the points of location of the feet.

16. Provide abundant clearance, particularly for rough castings.

17. Make, if possible, all locating points visible to the operator when placing the work in position.

18. Provide holes or escapes for the chips.

19. Provide clamping lugs, located so as to prevent springing of the fixture, on all tools which must be held to the table of the machine while in use, and tongues for the slots in the tables in all milling and planing fixtures.

20. Before using in the shop, for commercial purposes, test all jigs as soon as made.

The two principal classes of jigs are drill jigs and boring jigs. Fixtures may be grouped as milling, planing, and splining fixtures, although there are a number of special fixtures which could not be classified under any special head.

CHAPTER II

BUSHINGS FOR DRILL JIGS*

Drill jigs are intended exclusively for drilling, reaming, tapping and facing. Whenever these four operations are required on a piece of work, it is, as a rule, possible to provide the necessary arrangements for performing all these operations in one and the same jig. Sometimes separate jigs are made for each one of those operations, but it is doubtless more convenient and cheaper to have one jig do for all, as the design of the jig will not be much more complicated. Although it may be possible to make a distinction between a number of different types of drill jigs, it is almost impossible to define and to get proper names for the various classes, owing to the great variety of shapes of

Fig. 1. Typical Open Drill Jig for Gear Guard

the work to be drilled. There are, however, two general types that are most commonly used, the difference between which is really very noticeable at sight. These types may be classified as open jigs and closed jigs, or box jigs. Sometimes the open jigs are called clamping jigs, although it is difficult to see a good reason for this name. The open jigs usually have all the drill bushings in the same plane, parallel with one another, and are not provided with loose or removable walls or leaves, thereby making it possible to insert the piece to be drilled without any manipulation of the parts of the jig. These jigs are often of such a construction that they are applied to the work to be drilled, the jig being placed on the work, rather than the work being placed in the jig. The work is held to the jig (or the jig to the work) by

* MACHINERY, April and May, 1908.

straps, hook bolts or clamps. Figs. 1 and 2 show types of open drill jigs.

The closed drill jigs, or box jigs, frequently resemble some form of a box, and are intended for pieces where the holes are to be drilled at

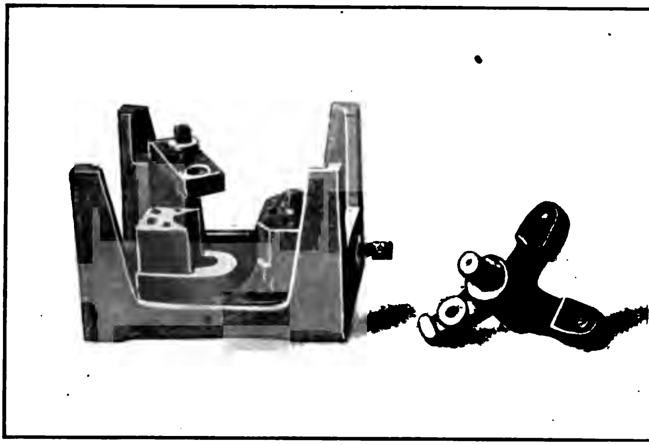


Fig. 2. Open Drill Jig, showing Commonly Used Design.

various angles to one another. As a rule, the walls are solid with the face of the jig, and the piece to be drilled can be inserted only after one or more leaves or covers have been swung out of the way. Sometimes it is necessary to remove a loose wall, which is held by screws

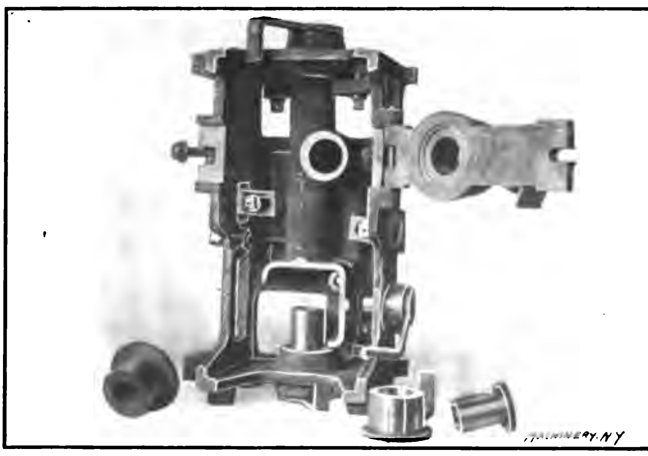


Fig. 3. Closed Drill Jig, showing Leaf opened

and dowel pins, in order to locate the piece in the jig. The work in the closed drill jig is generally held in place by set-screws and sometimes by screw bushings, as well as by straps and hook bolts. Fig. 3 shows an example of a typical closed jig. Another type of closed jig is exemplified in a combination of drill and boring jigs, designed to serve both for drilling and boring operations.

Before designing a combination drill and boring jig, the relation between, and number of, the drilled and bored holes must be taken into consideration, and also the size of the piece to be machined. In case there is a great number of holes, it may be of advantage to have two or even more jigs for the same piece, because it makes it easier to design and make the jig, and very likely will give a better result. The holes drilled or bored in the first jig may be used as a means for locating the piece in the jigs used later on. It is plain that combination drill and boring jigs are not very well adapted for pieces of large size. In Fig. 4 is shown a typical combination jig, where the bushings for guiding the drills are indicated in the bottom surface, the work upon

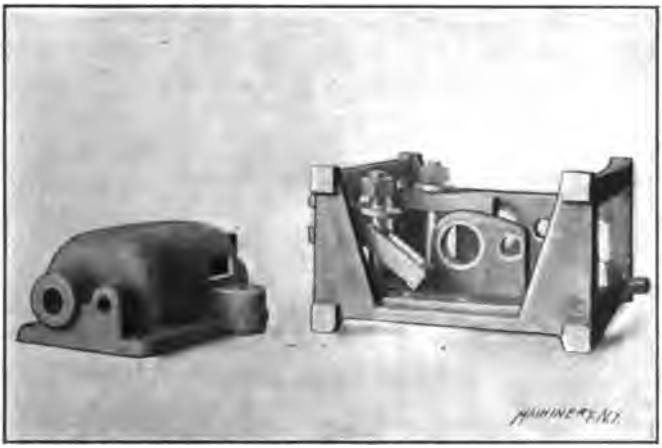


Fig. 4. Combination Drill and Boring Jig

which the operations are performed being shown at the left-hand side in the cut.

Guiding the Drill

The guides for the cutting tools in a drill jig take the form of concentric steel bushings, which are hardened and ground and placed in the jig body in proper positions. The bushings may be either stationary or removable; the latter, in the shop, are usually termed loose bushings. The most common, and the preferable form for the stationary bushing is shown in Fig. 5. This bushing is straight both on the inside and on the outside, excepting that the upper corners *A* on the inside are given a liberal radius, so as to allow the drill to enter the hole easily, while the corners *B* at the lower end of the outside are slightly rounded for the purpose of making it easier to drive the bushing into the hole, when making the jig, and also to prevent the sharp corner on the bushing from cutting the metal in the hole into which the bushing is driven.

When removable bushings are used, they should never be placed directly in the jig body unless the jig is to be used only a few times, but the jig should always be provided with a lining bushing. This lining bushing is always made of the form shown in Fig. 5. If the hole bored in the jig body receives the loose or removable bushing directly, the inserting and removing of the bushing, if the jig is frequently used, would soon wear the walls of the hole in the jig body, and after a while the jig would have to be replaced, or at least the hole would have to be bored out, and a new removable bushing made to fit the larger-sized hole resulting. In order to overcome this, the hole in the jig body is bored out large enough to receive the lining bushing referred to, which is driven in place. This lining bushing then, in turn, receives the loose bushing, the outside diameter of which closely fits the inside diameter of the lining bushing, as shown in Fig. 6, in which *A* is the jig body, *B* the lining bushing, and *C* the loose bushing. Both of these bushings are hardened and ground so that they will stand constant use and wear for some length of time. When no removable bushings

Fig. 5

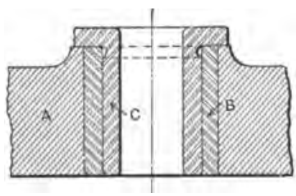
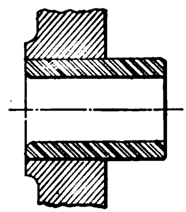


Fig. 6



Machinery,N.Y.

Fig. 7

Guide and Lining Bushings for Drill Jigs

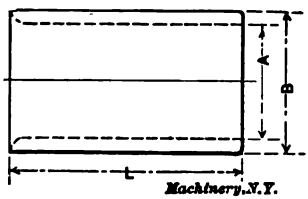
are required, the lining bushing itself becomes the drill bushing or reamer bushing, and the inside diameter of the lining bushing will then fit the cutting tool used. The bushing shown in Fig. 5 is cheaper to make, and will work fully as well when driven in place in the hole receiving it, as do bushings having a shoulder at the upper end, such as the loose bushing shown in Fig. 6. It was the practice some years ago to make all bushings with a shoulder, but this is entirely unnecessary, and simply increases the cost of making the bushing.

Dimensions of Jig Bushings

It is rather difficult to give any standard dimensions for jig bushings, as these depend, in most cases, on the different conditions of the various classes of jigs in which the bushings are inserted. As a rule the common practice is to make the length of the bushing twice the inside diameter of the hole in the bushing for stationary drill bushings. On very small bushings, however, say ¼ inch diameter hole and less, the length of the bushing will have to be made longer than twice the diameter, while on very large bushings the length may be made somewhat less than twice the diameter. The accompanying Table 1 gives proportions of stationary drill bushings. The dimensions, as here given, will be found suitable in all cases where no special conditions demand deviation from ordinary practice. If the jig wall is thin, the bushing may project out as shown in Fig. 7, so as to give the cutting tool the proper guiding and support as close to the work as possible. In Table II are given dimensions for lining bushings, not intended to directly guide the drill, but to hold removable bushings, which in turn, guide the cutting tools. The dimensions given in Tables I and II are for bushings made from tool steel or machine steel.

While it may be, in some cases, difficult to draw a distinct line between stationary drill bushings and lining bushings, it may be said in general, that the bushings in Table I are used for guiding the drills when drilling holes directly, either with a full-sized drill, when the hole is not required to be very smooth or accurate; or, if greater accuracy

TABLE I. DIMENSIONS OF STATIONARY DRILL BUSHINGS



A	B	L	A	B	L	A	B	L	A	B	L
1/16	3/16	3/8	9/16	13/16	1 1/8	1 1/16	1 7/16	2	1 9/16	1 15/16	2 3/4
1/8	1/4	1/2	5/8	7/8	1 1/4	1 1/8	1 1/2	2 1/8	1 5/8	2	2 7/8
3/16	5/16	1/2	11/16	15/16	1 3/8	1 3/16	1 9/16	2 1/8	1 11/16	2 1/8	2 7/8
1/4	3/8	5/8	3/4	1	1 1/2	1 1/4	1 5/8	2 1/4	1 3/4	2 1/4	3
5/16	1/2	5/8	13/16	1 1/8	1 1/2	1 5/16	1 11/16	2 1/4	1 13/16	2 5/16	3 1/8
3/8	9/16	3/4	7/8	1 3/16	1 5/8	1 3/8	1 3/4	2 3/8	1 7/8	2 3/8	3 1/4
7/16	5/8	7/8	15/16	1 1/4	1 3/4	1 7/16	1 13/16	2 1/2	1 15/16	2 7/16	3 3/8
1/2	11/16	1	1	1 3/8	1 7/8	1 1/2	1 7/8	2 5/8	2	2 5/8	3 1/2

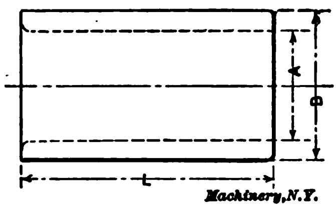
is required, for guiding a spotting drill which fits the bushings exactly, after which the hole is drilled out with a so-called reamer drill which is 0.010 inch or less under the size of the finished hole, and finally reamed out with a reamer fitting exactly the hole in the bushing. These bushings are thus, in general, used when no tapping or counterboring would be required. The lining bushing in Table II, again, may guide one of the tools for the holes to be finished directly, and then removable bushings are inserted to guide the other tools used.

Miscellaneous Types of Drill Bushings

As already mentioned, it was, some years ago, always the practice to provide even stationary bushings with a shoulder or head, as shown in bushing *C*, Fig. 6. This will prevent the bushing from being pushed through the jig by the cutting tool, but this seldom occurs if the bushings are made to fit the tool correctly. Sometimes the shoulder is used to take the thrust of a stop collar, which is clamped on the drill, to allow it to go down to a certain depth, as shown in Fig. 8, in which *C* is the stop collar, *D* the wall of the jig, *E* the stationary bushing, and *F*, the piece worked upon. In such a case, a shoulder on the bushing may be in place.

If the work to be drilled is located against a finished seat or boss on the wall of the jig, and the wall is not thick enough to take a bushing of standard length, it is common practice to make a bushing having a long head, as shown in Fig. 9. The length *A* of the head can be extended as far as necessary to get the proper bearing. As the bushing is driven in place, and the shoulder of the head bears against the finished surface of a boss on the jig, it will give the cutting tool almost as rigid a bearing as if the jig metal surrounded the bushing all the way up.

TABLE II. DIMENSIONS OF LINING BUSHINGS



A	B	L	A	B	L	A	B	L
5/16	1/2	1/2	1 1/8	1 1/2	1 1/2	2 1/8	2 5/8	2 5/8
3/8	9/16	1/2	1 1/4	1 5/8	1 5/8	2 3/16	2 11/16	2 3/4
7/16	5/8	1/2	1 5/16	1 11/16	1 3/4	2 1/4	2 3/4	2 7/8
9/16	13/16	5/8	1 3/8	1 3/4	1 7/8	2 5/16	2 7/8	2 7/8
5/8	7/8	3/4	1 7/16	1 13/16	2	2 3/8	3	3
11/16	15/16	7/8	1 9/16	1 15/16	2 1/8	2 9/16	3 3/16	3 1/8
3/4	1	1	1 5/8	2	2 1/8	2 5/8	3 1/4	3 1/4
13/16	1 1/8	1 1/8	1 3/4	2 1/4	2 1/4	2 11/16	3 5/16	3 3/8
15/16	1 1/4	1 1/4	1 13/16	2 5/16	2 1/4	2 3/4	3 3/8	3 1/2
1	1 3/8	1 3/8	1 7/8	2 3/8	2 3/8	...	...	..
1 1/16	1 7/16	1 1/2	1 15/16	2 7/16	2 1/2	...	...	..

Stationary or fixed drill bushings are almost invariably made from tool steel, but machine steel bushings, case-hardened and ground, give good service, and wherever it seems necessary to save in the expense of the jig, machine steel will serve the purpose well enough for any jig that is not in constant use. For large bushings in particular, the difference becomes quite considerable, and, therefore, a great many prominent firms have made it a rule to make all larger bushings and, in particular, all lining bushings of machine steel.

Removable bushings are frequently used for work which must be drilled, reamed and tapped, there then being one bushing for each of the cutting tools. They are also used when different parts of the same hole are to be drilled out to different diameters, or when the upper portion of the hole is counterbored, or when a lug has to be faced off. In this case, each tool, of course, has its own guiding bushing. The common design of removable bushings is shown in Fig. 10. The outside is made to fit the inside of the lining bushing with a nice, sliding fit, so that it can be gently pressed into the lining bushing by the hand. The distance *A* under the head of the bushing should be the same length or longer than the guiding bushing; in the latter case, for the purpose of getting close to the work. The thickness *B* of the head varies, of course, according to the size of the bushing. The diameter *C* of the head should be from ¼ to ½ inch larger than the diameter

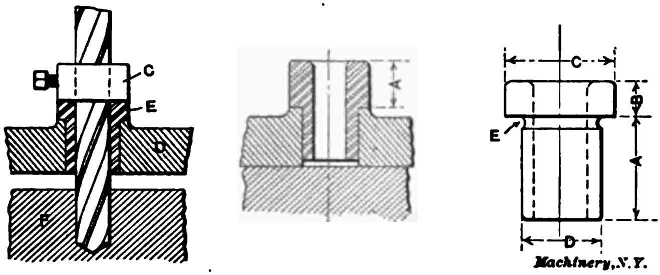


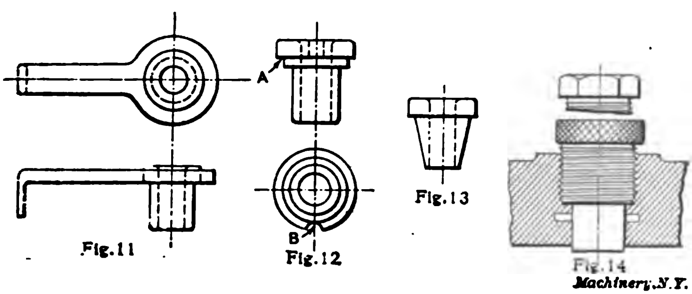
Fig. 8 Fig. 9 Fig. 10

Types of Drill Jig Bushings for Different Purposes

D of the bushing. A groove *E*, ⅛ to ¼ inch wide, is cut immediately under the head, so that the emery wheel can pass clear over the part being ground.

Means for Preventing Loose Bushings from Turning

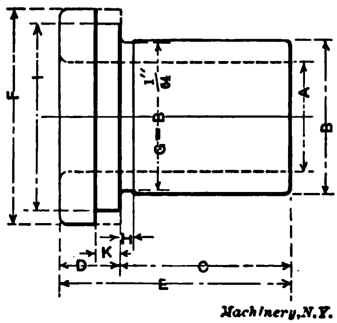
In order to prevent the bushings from turning, in some shops a collar, with a projecting tail, as shown in Fig. 11, is forced over the head of the bushing. This arrangement also makes it easy to remove



Means for Preventing Drill Bushings from Turning; Taper Bushing; and Screw Bushing

the bushing. The dog, as it is commonly called, is usually bent at the end of the tail, as shown in the cut, one end resting against some part of the jig, the proportions of which the dog must suit. Sometimes the bent end is left straight, if there is a possibility for the tail to strike against some lug in the same plane. The making of such dogs involves some extra expense, but it is very effective in avoiding troubles with the bushings turning and working their way out of the holes. In some cases simply a hole is drilled in the shoulder of the bushing at the edge, and a corresponding pin is driven into the jig body. This serves the same purpose as the dog. It is probably cheaper, but it does not furnish the convenient means for removing the

TABLE III. DIMENSIONS OF REMOVABLE DRILL BUSHINGS



A	B	C	D	E	F	H	I*	K*
1/8	5/16	1/2	1/8	5/8	5/8	1/8	1/2	1/32
3/16	3/8	1/2	1/8	5/8	5/8	1/8	1/2	1/32
1/4	7/16	5/8	1/8	3/4	3/4	1/8	5/8	1/32
5/16	9/16	5/8	1/8	3/4	7/8	1/8	3/4	1/32
3/8	5/8	3/4	1/8	7/8	7/8	1/8	3/4	1/32
7/16	11/16	7/8	1/8	1	1	1/8	7/8	1/32
1/2	3/4	1	1/8	1 1/8	1	1/8	7/8	1/32
9/16	13/16	1 1/8	1/8	1 1/4	1 1/8	1/8	1	1/32
5/8	15/16	1 1/4	3/16	1 7/16	1 1/4	1/8	1 1/8	1/16
11/16	1	1 3/8	3/16	1 9/16	1 1/4	1/8	1 1/8	1/16
3/4	1 1/16	1 1/2	3/16	1 11/16	1 3/8	1/8	1 1/4	1/16
13/16	1 1/8	1 1/2	3/16	1 11/16	1 3/8	1/8	1 1/4	1/16
7/8	1 1/4	1 5/8	3/16	1 13/16	1 1/2	1/8	1 3/8	1/16
15/16	1 5/16	1 3/4	3/16	1 15/16	1 5/8	1/8	1 1/2	1/16
1	1 3/8	1 7/8	1/4	2 1/8	1 3/4	3/16	1 5/8	3/32
1 1/16	1 7/16	2	1/4	2 1/4	1 7/8	3/16	1 3/4	3/32
1 1/8	1 9/16	2 1/8	1/4	2 3/8	2	3/16	1 13/16	3/32
1 3/16	1 5/8	2 1/8	1/4	2 3/8	2	3/16	1 13/16	1/8
1 1/4	1 3/4	2 1/4	5/16	2 9/16	2 1/8	3/16	1 15/16	1/8
1 5/16	1 13/16	2 1/4	5/16	2 9/16	2 1/4	3/16	2 1/16	1/8
1 3/8	1 7/8	2 3/8	5/16	2 11/16	2 1/4	3/16	2 1/16	1/8
1 7/16	1 15/16	2 1/2	5/16	2 13/16	2 3/8	3/16	2 3/16	1/8
1 1/2	2 1/8	2 5/8	3/8	3	2 1/2	3/16	2 5/16	1/8
1 9/16	2 3/16	2 3/4	3/8	3 1/8	2 5/8	3/16	2 7/16	1/8
1 5/8	2 1/4	2 7/8	3/8	3 1/4	2 5/8	3/16	2 7/16	1/8
1 11/16	2 5/16	2 7/8	3/8	3 1/4	2 3/4	3/16	2 9/16	1/8
1 3/4	2 3/8	3	3/8	3 3/8	2 3/4	3/16	2 9/16	1/8
1 13/16	2 9/16	3 1/8	1/2	3 5/8	3	1/4	2 13/16	5/32
1 7/8	2 5/8	3 1/4	1/2	3 3/4	3 1/8	1/4	2 13/16	5/32
1 15/16	2 11/16	3 3/8	1/2	3 7/8	3 1/8	1/4	2 15/16	5/32
2	2 3/4	3 1/2	1/2	4	3 1/4	1/4	3 1/16	5/32

* When using dogs as illustrated in Fig. 11, the dimensions in these columns are omitted.

bushing as does the dog. To make such a bushing more easily removable, the arrangement shown in Fig. 12 is probably the most common. A step *A* is turned down on the head, which, in this case, will have to be a trifle larger in diameter. This step permits some kind of a tool—a screw driver, for instance, to be put underneath, and with a jerk the bushing may be lifted enough to get a good hold on it. The half-round slot at *B* is milled or filed in the periphery of the head, and fits over a pin or screw which is fastened in the jig body, as mentioned before. There are, of course, a number of other devices for preventing drill bushings from turning, but the ones shown will serve the purpose of plainly exhibiting the principles.

In Table III are given dimensions for removable bushings of the type shown in Fig. 12. As will be seen in the engraving above the table, dotted lines have been shown, indicating a shoulder without any recess of the kind shown at *A*, Fig. 12. The dimensions for a shoulder such as would result if the heads of the bushings were made to the dotted lines, apply to such bushings as are used with a dog, as shown in Fig. 11. In this case the dimensions in columns *I* and *K* in the table are omitted.

Table IV gives dimensions for bushings for holes which are reamed with a rose chucking reamer, after having first been drilled with a drill 1/16 inch smaller than the diameter of the reamer with which the hole is finally reamed out. The bushing to the extreme right, over the table, is the lining bushing, which is made of machine steel, case-hardened and ground. The bushing to the extreme left is the bushing for the rose chucking reamer. It is made of cast iron and ground. The bushing in the center is the drill bushing which is made from tool steel, hardened and ground, or in cases where it does not seem warranted to make the bushing of tool steel, of machine steel, case-hardened and ground.

The tapered removable bushing shown in Fig. 13 is objectionable on account of being expensive to make, and also on account of its liability to be thrown out of true by chips, etc., getting in between the outside of the bushing and the hole.

Screw Bushings

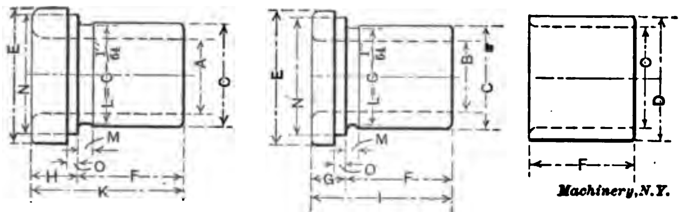
Sometimes removable bushings are threaded on the outside and made to fit a tapped hole in the jig, as shown in Fig. 14. The lower part of the bushing is usually turned straight, and ground, in order to center the bushing perfectly in the hole in the jig. The head of the bushing is either knurled, or milled hexagon for a wrench. When these bushings are used, they are, as a rule, not used for the single purpose of guiding the cutting tool, but they combine with this the purposes of locating and clamping the work. For such purposes they are quite frequently used. These bushings are not commonly used as removable bushings, as it would take considerable time to unscrew, and to again insert, a bushing of this type into the jig body.

Sometimes bushings for guiding the tools may be made of cast iron, but only in such cases when the cutting tool is of such a design that it does not have any cutting edges in the bushing itself, as, for instance, in the case of guiding the smooth surface of a boring-bar, or the shank of a reamer or a rose reamer, but hardened steel bushings must always be used when the cutting tool is liable to cut the bushing, as, for instance, in the case of drills and reamers, guided on their flutes, taps, etc.

Special Designs of Guide Bushings

When the guide bushings are very long, and consequently would cause unnecessary friction in their contact with the cutting tools,

TABLE IV. BUSHINGS FOR HOLES REAMED WITH ROSE CHUCKING REAMERS



A	B	C	D	E	F	G	H	I	K	M	N*	O*
3/4	11/16	1 1/4	1 5/8	1 1/2	1 1/4	3/16	1/4	1 7/16	1 1/2	1/8	1 3/8	1/16
13/16	3/4	1 5/16	1 11/16	1 5/8	1 5/16	3/16	1/4	1 1/2	1 9/16	1/8	1 1/2	1/16
7/8	13/16	1 3/8	1 3/4	1 5/8	1 3/8	3/16	1/4	1 9/16	1 5/8	1/8	1 1/2	1/16
15/16	7/8	1 7/16	1 13/16	1 3/4	1 7/16	3/16	1/4	1 5/8	1 11/16	1/8	1 5/8	1/16
1	15/16	1 1/2	1 7/8	1 3/4	1 1/2	1/4	5/16	1 3/4	1 13/16	3/16	1 5/8	1/8
1 1/16	1	1 9/16	1 15/16	1 7/8	1 5/8	1/4	5/16	1 7/8	1 15/16	3/16	1 3/4	1/8
1 1/8	1 1/16	1 5/8	2	1 7/8	1 11/16	1/4	5/16	1 15/16	2	3/16	1 3/4	1/8
1 3/16	1 1/8	1 11/16	2 1/8	2	1 3/4	1/4	5/16	2	2 1/16	3/16	1 7/8	1/8
1 1/4	1 3/16	1 13/16	2 5/16	2 1/8	1 7/8	5/16	3/8	2 3/16	2 1/4	3/16	2	1/8
1 5/16	1 1/4	1 15/16	2 7/16	2 1/4	2	5/16	3/8	2 5/16	2 3/8	3/16	2 1/8	1/8
1 3/8	1 5/16	2	2 1/2	2 1/4	2 1/8	5/16	3/8	2 7/16	2 1/2	3/16	2 1/8	1/8
1 7/16	1 3/8	2 1/16	2 9/16	2 3/8	2 1/4	5/16	3/8	2 9/16	2 5/8	3/16	2 1/4	1/8
1 1/2	1 7/16	2 1/8	2 5/8	2 3/8	2 3/8	5/16	3/8	2 11/16	2 3/4	3/16	2 1/4	1/8
1 9/16	1 1/2	2 3/16	2 11/16	2 1/2	2 1/2	3/8	7/16	2 7/8	2 15/16	3/16	2 3/8	1/8
1 5/8	1 9/16	2 3/8	3	2 5/8	2 5/8	3/8	7/16	3	3 1/16	3/16	2 1/2	1/8
1 11/16	1 5/8	2 7/16	3 1/16	2 3/4	2 3/4	3/8	7/16	3 1/8	3 3/16	3/16	2 5/8	1/8
1 3/4	1 11/16	2 1/2	3 1/8	2 7/8	2 7/8	3/8	7/16	3 1/4	3 5/16	3/16	2 3/4	1/8
1 13/16	1 3/4	2 9/16	3 3/16	3	3	7/16	1/2	3 7/16	3 1/2	1/4	2 13/16	3/16
1 7/8	1 13/16	2 5/8	3 1/4	3	3 1/8	7/16	1/2	3 9/16	3 5/8	1/4	2 13/16	3/16
1 15/16	1 7/8	2 11/16	3 5/16	3 1/8	3 1/4	7/16	1/2	3 11/16	3 3/4	1/4	2 15/16	3/16
2	1 15/16	2 3/4	3 3/8	3 1/8	3 3/8	7/16	1/2	3 13/16	3 7/8	1/4	2 15/16	3/16
2 1/16	2	2 15/16	3 9/16	3 1/2	3 1/2	1/2	5/8	4	4 1/8	1/4	3 1/4	3/16
2 1/8	2 1/16	3	3 5/8	3 1/2	3 1/2	1/2	5/8	4	4 1/8	1/4	3 1/4	3/16
2 3/16	2 1/8	3 1/16	3 13/16	3 5/8	3 5/8	1/2	5/8	4 1/8	4 1/4	1/4	3 3/8	3/16
2 1/4	2 3/16	3 1/8	3 7/8	3 5/8	3 3/4	1/2	5/8	4 1/4	4 3/8	1/4	3 3/8	3/16
2 3/8	2 5/16	3 3/8	4 1/8	3 7/8	3 7/8	1/2	5/8	4 3/8	4 1/2	1/4	3 5/8	3/16
2 1/2	2 7/16	3 1/2	4 1/4	4	4	1/2	5/8	4 1/2	4 5/8	1/4	3 3/4	3/16
2 5/8	2 9/16	3 5/8	4 3/8	4 1/8	4 1/8	1/2	5/8	4 5/8	4 3/4	1/4	3 7/8	3/16
2 3/4	2 11/16	3 3/4	4 1/2	4 1/4	4 1/4	1/2	5/8	4 3/4	4 7/8	1/4	4	3/16

* When dogs illustrated in Fig. 11 are used, dimensions in these columns are omitted.

they may be recessed, as shown in Fig. 15. The distance *A*, of the hole in the bushing, is recessed enough wider than the diameter of the tool, so as not to bear on it. The length *B*, being about twice the diameter of the hole, gives sufficiently long guiding surfaces for the cutting tool, to prevent its running out. If the outside diameter of the bushing is very large, as compared with the diameter of the cutting tool, as indicated in Fig. 16, the expense of making the bushings may be reduced by making the outside bushing of cast iron, inserting into this a hardened tool steel bushing, driven in place. The steel bushing is then given dimensions according to Table I for stationary bushings. The reason why there may be the necessity of a bushing having so large an outside diameter and so small a hole, may be that the bushing is required to be removed for counterboring part of the small hole being drilled, by a counterbore of large diameter, in which case the hole in the jig body has to be large enough to accommodate the large counterbore.

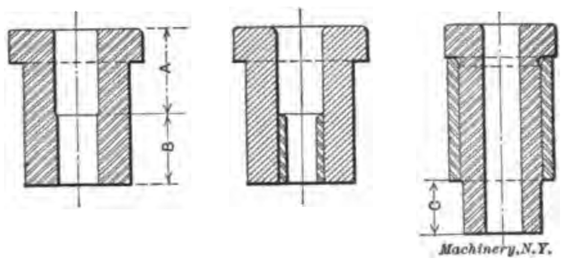


Fig. 15 Fig. 16 Fig. 17

Special Types of Drill Jig Bushings

If a loose or removable bushing is longer than the lining bushing, as illustrated in Fig. 17, it will prove advantageous to have the diameter of the projecting portion of the bushing about 1/32 inch smaller in diameter than the part of the loose bushing which fits the lining bushing. This lessens the amount of surface which has to be ground, and, at the same time, makes it easier to insert the bushing, giving it, so to say, a point, which will first enter the lining bushing, and it interferes in no way with the proper qualities of the bushing as a guide for the cutting tool.

In some cases, the holes in the piece to be drilled are so close to one another that it is impossible to find space for lining bushings in the jig. In such a case, it will be necessary to make a leaf, or a loose wall, or the whole jig, of machine steel or tool steel, hardening a portion or the whole jig thus made

CHAPTER III

LOCATING POINTS*

The locating points in a jig usually consist of finished pads, bosses, seats, or lugs, cast solid with the jig, as illustrated in Fig. 18. In this engraving the surfaces marked *f* are the locating points, which bring the piece to be machined in right relation to the bushings guiding the drills, or to the gages to which other cutting tools may be set. This way of locating the work is satisfactory when the work done is finished in a uniform way, and where there is very little variation in the parts inserted in the jig.

Another commonly used means for locating the work in jigs is by means of dowel pins, as shown at *A* and *B* in Fig. 19. The sides of the dowel pins which rest up against the work are usually flattened, as indicated, so as to give more bearing than a mere line contact with

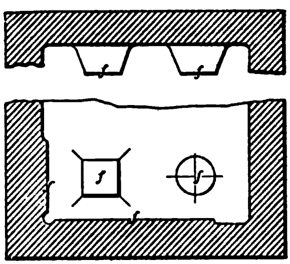
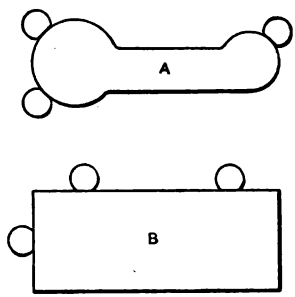


Fig. 18. Locating Pads in Jigs



Machinery,N.Y.

Fig 19. Pins Used for Locating Work

the pins could give, and, at the same time prevent too rapid wear on the locating pins, as would be the case if the work bear against the pins along a line only.

Sometimes pins or studs are inserted in jigs to act as locating points, instead of having lugs cast directly on the jig as shown in Fig. 18. A case where a pin is used for this purpose is shown in Fig. 20, where *B* is the body of the jig, *A* the pin inserted to act as a locating and resting point, and *C* the work located against this point. Locating pins of this character should always be provided with a shoulder or collar, so that they will firmly resist the pressure of the work they support, without possibility of moving in the hole in which they are inserted.

A common method of locating cylindrical pieces or surfaces is that of placing the cylindrical surface in a V-block, as shown in Fig. 21. This V-block as a rule is stationary, and is held in place by screws

* MACHINERY, June, 1908.

and dowel pins, as indicated in the engraving, but sometimes these V-blocks may also be made adjustable, in order to take up the variations of the pieces placed in them, and also in order to act as clamps. A V-block of this character is shown in Fig. 22. In this, *A* is the adjustable V-block, having an oblong hole *B* to allow for the adjustment. The block is held down in place by a collar-head screw *C*,

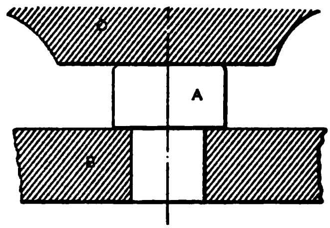


Fig. 20. Inserted Pin used for Locating and Supporting Work

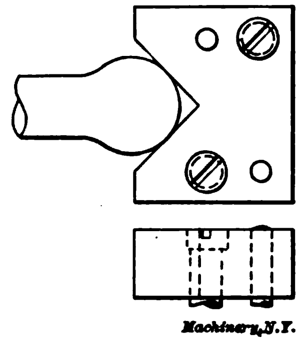


Fig. 21. V-block for Locating Round Work or Cylindrical Surfaces

which passes through the elongated hole. The under side of the block is provided with a tongue *D*, which enters into a slot in the jig body itself, the V-block being thereby prevented from turning sideways. The screw *E* passes through the wall of the jig, or through some lug, and prevents the V-block from sliding back when the work is inserted into the jig. It is also used for adjusting the V-block, and, in some cases, for clamping the work. The V-blocks are usually

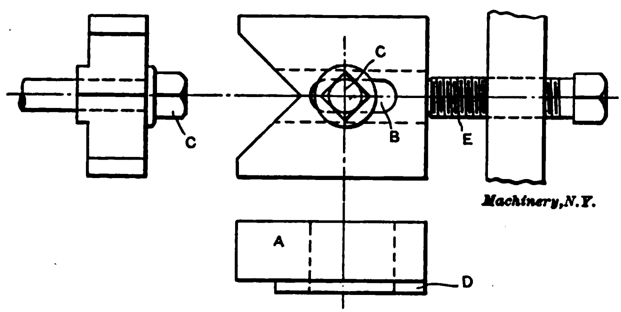


Fig. 22. Adjustable V-block used for Locating Purposes

made of machine steel, but when larger sizes are needed, they may be made out of cast iron. Little is gained, however, in making these blocks out of cast iron, as most of the surfaces have to be machined anyway, and the difference in the cost of material on such a comparatively small piece is very slight.

When it is essential that a cylindrical part of the work is located centrally either with the outside of a cylindrical surface, or with the center of a hole passing through the work, good locating means are provided by the designs shown in Figs. 23 and 24. In Fig. 23, the stud *A* is countersunk conically to receive the work. The stud *A* is made of machine or tool steel, and may, in many cases, serve as a bushing for guiding the tool. In Fig. 24, the stud is turned conically in order to enter into a hole in the work. These two locating appliances are always made stationary, and are only used for locating the work, never for binding or clamping.

Screw Bushings and Sliding Bushings Used as Locating Means

Screw bushings of the type which has already been shown in Fig. 14, may be used for locating and clamping purposes by making them

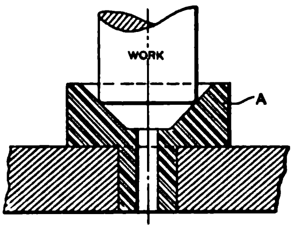


Fig. 23. Recessed Stud used for Locating Round Work

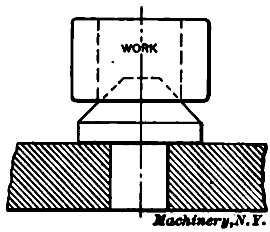


Fig 24. Conical Stud used for Locating Work in Relation to the Center of a Hole

long enough to project through the walls of the jig, and by turning a conical point on them, as shown in Fig. 25, or by countersinking them, as shown in Fig 26.

Another type of bushing which serves the same purpose as a screw bushing is illustrated in Fig. 27. This bushing, together with the forked lever *D*, and clamping bolt and wing nut shown, will serve not

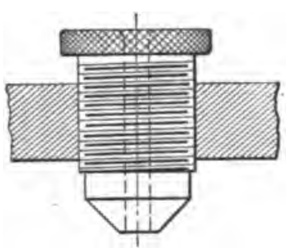


Fig. 25. Screw Bushing used for Locating Work Central with a Hole

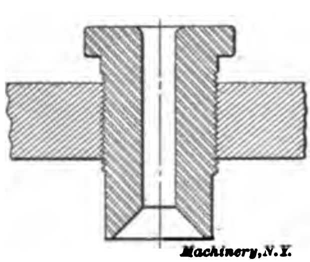


Fig. 26. Screw Bushing used for Locating Round Work by means of a Conical Recess

only to locate but also to clamp the work in place. This sliding bushing gives very good results and is preferable to the screw bushing in cases where accurate work is required, but, as a rule, where extreme accuracy would be required, this kind of bushing is not used.

In Fig. 27 the sliding bushing *A* has a close sliding fit in the lining bushing *B*. In the head of the bushing *A* there are two screws with hardened heads, which fit into elongated slots in the forked lever or yoke *D*, which, in turn, swivels around pin *E*. The eye-bolt *F* fits into a slot *G* in the yoke, and the wing nut tightens down the bushing against the work as clearly indicated in the engraving. A comparatively long bearing for the bushing is required in order to produce good results. On work that varies considerably in size, this arrangement works somewhat quicker than does a screw bushing, but it is clearly in evidence that it is a rather expensive appliance, and that the construction of the jig does not always permit of its application.

In some instances it is necessary to have the screw bushing movable sideways, for instance, when the piece of work to be made is located by some finished surfaces, and a cylindrical part is to be provided with a hole drilled exactly in the center of a lug or projection, the

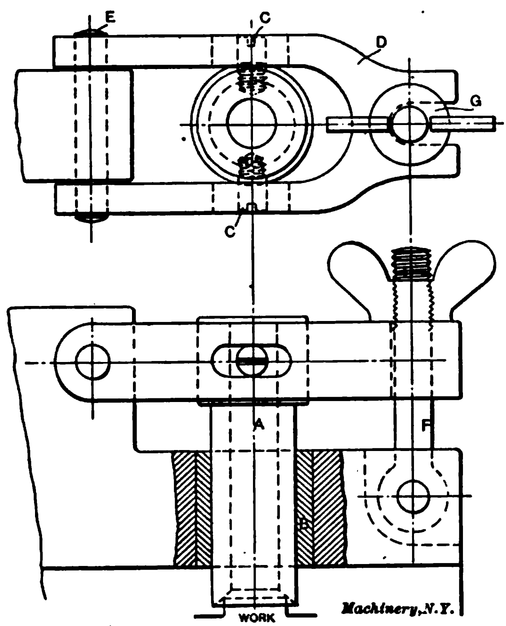


Fig. 27. Sliding Bushing for Locating and Clamping Work

relation of this hole to the finished surfaces used for locating being immaterial. The piece of work, being a casting, would naturally be liable to variations between the finished surfaces and the center of the lug, particularly if there be other surfaces and lugs to which the already finished surfaces must correspond, and in such a case, the fixed bushing for drilling a hole that ought to come in the center of the lug, might not always suit the casting. In such a case, so-called floating bushings, as shown in Fig. 28, are used. The screw bushing *A* is conically recessed, and locates from the projection on the casting. It is fitted into another cylindrical piece *B*, provided with a flange on one side. The piece *B*, again, sets into the hole *C* in the jig body *D*, this hole being large enough to permit the necessary adjustment of the jig bushing.

When the bushing has been located exactly concentric with the lug *E* on the work, the nut *F*, having a washer G under it, is tightened. It will be seen that the flange on piece *B* and the washer *G* necessarily must be large enough to cover the hole *C* even if *B* is brought over against the side of the hole. It is not often necessary, however, to use this floating bushing, because it is seldom that a drilled hole

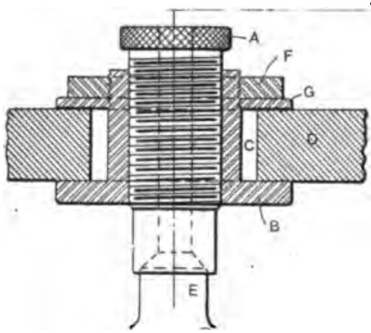


Fig 28. Floating Bushing

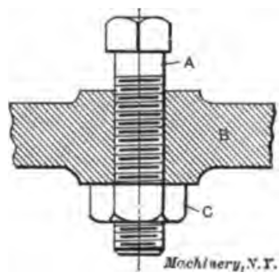


Fig. 29. Simplest Form of Adjustable Locating Point

in a piece of work can be put in without having any direct relation to other holes or surfaces.

Adjustable Locating Points

The most common form of adjustable locating points is the set-screw provided with a check nut, as shown in Fig. 29. The screw *A* is a

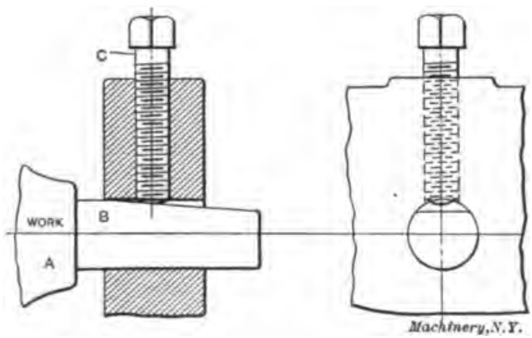


Fig. 30. Adjustable Locating Point consisting of a Flatted Stud Held in Place by a Set-screw

standard square head set-screws, or, in some cases, a headless screw—with a slot for a screw driver; this screw passes through a lug on the jig, or the jig wall itself, and is held stationary by a check nut *C* tightened up against the wall of the jig. Either end of this screw may be used as a locating point, and the check nut may be placed on either side. By using a square head screw, adjustment is very easily accomplished, but unless the operator is familiar with the intentions of the designer of the jig, locating points of this kind are often mistaken for binding or clamping devices, and the set-screws are tightened up and loosened to hold and release the work, when the intention is that these screws should be fixed when once adjusted. It is not even possible to depend upon the check nut stopping the operator from using the screw as a binding screw. A headless screw, therefore, is preferable, as it is less apt to be tampered with.

The sliding point, as illustrated in Figs. 30 and 31, is another adjustable locating point which is used to a great extent in jig work. A flat piece of work or a plate which is not perfectly level will always rock if put down on four stationary locating points, but the difficulty thus encountered is very easily overcome by making one of the locating points adjustable, and, as a rule, the sliding point is used for this purpose.

One design is shown in Fig. 30, where *A* represents the work to be located, *B* the sliding point itself, and *C* the set-screw, binding it in

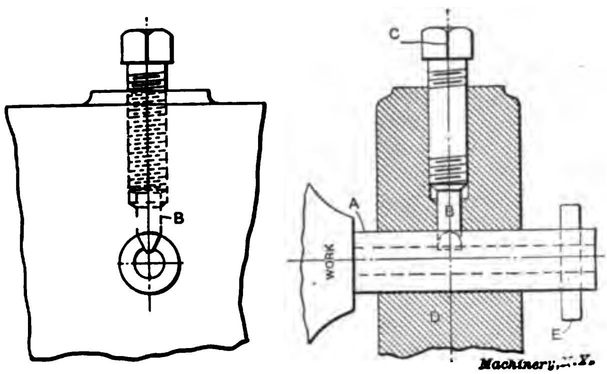
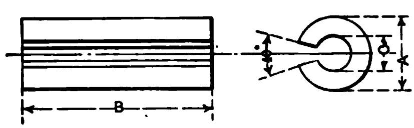


Fig. 31. Sliding Point used for Locating Work

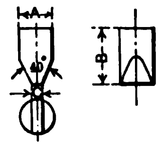
place when adjusted. The sliding point *B* fits a hole in the jig wall and is provided with a milled flat slightly tapered, as shown, to prevent its sliding back under the pressure of the work or the tool operating upon the work. This design of sliding point is frequently used, but it is not as efficient as the one illustrated in Fig. 31. In this design the sliding point *A* consists of a split cylindrical piece, with a hole drilled through it, as illustrated in the engraving, and a wedge or shoe *B* tapered on the end to fit the sides of the groove or split in the sliding point itself. This wedge *B* is forced in by a set-screw *C*, for the purpose of binding the sliding point in place. Evidently, when the screw and wedge are forced in, the sliding point is expanded, and the friction against the jig wall *D* is so great that it can withstand a very heavy pressure without moving. Pin *E* prevents the sliding point from slipping through the hole and into the jig, when loosened, and also makes it more convenient to get hold of. In Figs. 32 and 33 are given the dimensions most commonly used for sliding points and binding shoes and wedges.

If the work to be finished in the jig has some holes already finished, it is sometimes most satisfactory to locate the work by these holes, which may be done by means of studs or plugs similar to the one shown in Fig. 20, which then enter the holes; preferably, these studs should then be ground and hardened to the standard size of the hole. If the finished hole should be of a character that varies somewhat in size, expansion studs with bushings may be used. These studs may be of a great many different designs and styles, but, as a rule,



A	3/8	1/2	5/8	3/4
B	2¼ TO 3	2¼ TO 3	2¼ TO 3	2¼ TO 3
C	3/16	1/4	5/16	3/8

Fig. 32. Dimensions of Sliding Points



SCREWS	5/16	3/8
A	1/4	9/32
B	1/2	5/8
C	1/16	3/32

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Fig. 33. Dimensions of Shoes or Binders for Sliding Points

they always work on the same principle as the one shown in Fig. 34. In this, *A* is the bushing, fitting the finished hole in the work. This bushing is split in several different ways, either by having one slot cut entirely through it, and two more slots cut to within a short distance of the outside periphery, or by having several slots cut from the top and from the bottom, alternating, but not cut entirely through the full length of the bushing. The method of splitting,

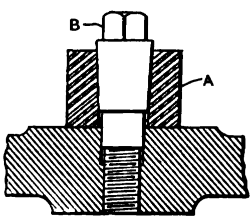
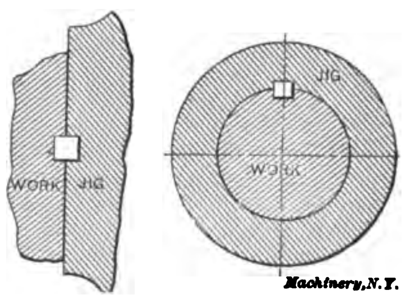


Fig. 34. Expansion Bushing used for Locating and Clamping Work



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Figs. 35 and 36. Locating Work by Keyways

however, in every case, accomplishes the same object, that of making the bushing capable of expansion, so that when the stud *B*, which is turned to fit the tapered hole in the bushing, is screwed down, the bushing is expanded.

Locating by Keyways in the Work

Sometimes the work to be finished in the jig is provided with a keyway or a slot, or with some other kind of a seat, by means of which it is located on its component part on the machine for which it is ultimately intended, and it is always essential that the work be located in the same way in the jig as it is to be located on the machine on which it is to go; thus, if the work has a keyway, suitable for locating, a corresponding keyway ought to be put into the jig, and the work located by means of a key, as shown in Figs. 35 and 36. Instead of a loose key, a tongue may be planed or milled solid with the jig, but, as a rule, it is more satisfactory to have the loose key, as, if it should happen to wear, it is possible to replace it; and if the width of the keyway should vary in different lots of the parts made, it is possible, with little expense, to make a new key to fit the variation, whereas, if the key is made solid with the jig, and found to be either too large or too small, the trouble of fixing this would be considerably greater.

There are, of course, a variety of different methods of locating the work in the jig, depending upon the nature and the shape of the work, but those mentioned above are the most common, the cheapest, and those that, as a rule, give sufficiently good results for ordinary work. The principles involved in the design of the means of locating the work described above, would all be the same in any kind of locating devices, so that it would simply be a difference in application of the principles, rather than a difference in the principles themselves.

CHAPTER IV

CLAMPING DEVICES*

In order to hold the work rigidly in the jig, so that it may be held up against the locating points, while the cutting tools operate upon the work, jigs and fixtures are provided with clamping devices. Sometimes a clamping device serves the purpose of holding the jig to the work, in a case where the work is a very large piece and the jig is attached to the work in some suitable way. The purpose of the clamping device, however, remains the same, namely, that of preventing any shifting of the guiding bushings while the operation on the work is being performed. As has been previously mentioned, at the time when the general principles of jig and fixture design were treated in Chapter I, the clamping device should always be an integral part of the jig body in order to prevent its getting lost.

The clamping device may either directly clamp the work to the jig or *vice versa*, but very frequently the clamps simply hold in place

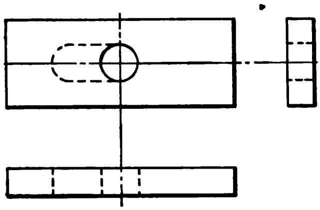


Fig. 37. Form of Clamps used in Jigs and Fixtures

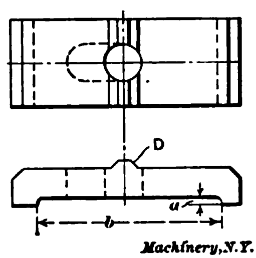


Fig. 38. Improved Form of Clamp

a loose or movable part in the jig, which can be swung out of the way to facilitate the removing and the inserting of the work in the jig. The work itself is in turn clamped by a set-screw or other means passing through the loose part, commonly called leaf. The simplest form of clamping device is the so-called clamp, of which a number of different forms are commonly used. Perhaps the most common and most reliable of all clamps is the one shown in Fig. 37. This kind of clamp is also commonly termed a strap. It is simple, cheap to make, and, for most purposes, it gives satisfactory service. The clamp shown in Fig. 38 is practically made on the same principle as the one shown in Fig. 37, but several improvements have been introduced. The clamp is recessed at the bottom for a distance *b*, to a depth equal to *a*, so as to give a bearing only on the two extreme ends of the clamp. Even if the strap should bend somewhat, on account of the pressure of the screw, it will be certain to bear at the ends, and exert

* MACHINERY, July and August, 1908.

the required pressure on the object being clamped. This strap is also provided with a ridge at *D*, located centrally with the hole for the screw, as shown in Fig. 38. This insures an even bearing of the screw head on the clamp, even if the two bearing points at each end of the clamp should vary in height, as illustrated in Fig. 39. The clamp in Fig. 37 would not bind very securely, under such circumstances, and the collar of the screw would be liable to break off, as the whole strain, when tightening the screw, would be put on one side.

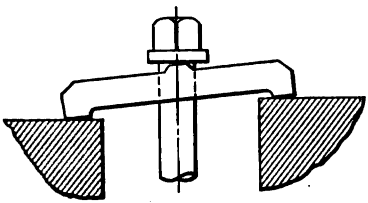


Fig. 39. Action of Clamp shown in Fig. 38 when used to Clamp Work which is not Level with the Clamping Surface

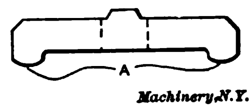
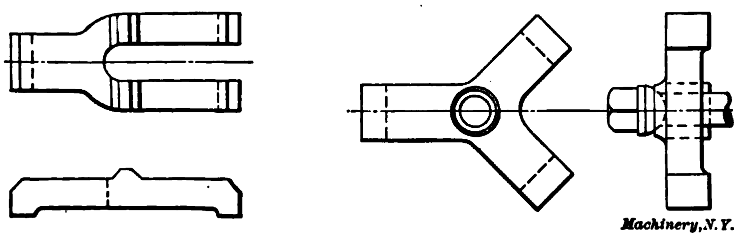


Fig. 40. Clamp shown in Fig. 38, further Improved

A still further improvement in the construction of this clamp may be had by rounding the under side of the clamping points *A*, as shown in Fig. 40. When a clamp with such rounded clamping points is placed in a position like that indicated in Fig. 39, it will practically bind the object to be held fully as firmly as if the two clamping surfaces were in the same plane.

The hole in these straps is very often elongated, as indicated by the dotted lines in Figs. 37 and 38. This allows the strap to be pulled

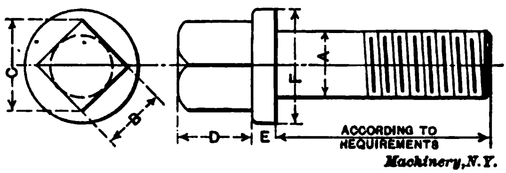


Figs. 41 and 42. Special Forms of Clamps

back far enough so as to clear the work, making it easier to insert and remove the piece to be held in the jig. In some cases, it is necessary to extend the elongated hole, as shown in Fig. 41, so that it becomes a slot, going clear through to the end of the clamp, instead of being simply an oblong hole. Aside from this difference, the clamp in Fig. 41 works on exactly the same principle as the clamps previously shown. It is evident that the clamps described may be given a number of different shapes to suit different conditions. The screws used for clamping these straps are either standard hexagonal screws or standard collar head screws, dimensions of which latter are given in Table V. In a case where it is not necessary to tighten the clamps very much, shoulder thumb screws, as shown in Table VI, may be employed.

Instead of having the strap or clamp bear on only two points, it is sometimes necessary to have it bear on three points, in which case it may be designed similar to the strap shown in Fig. 42. In order

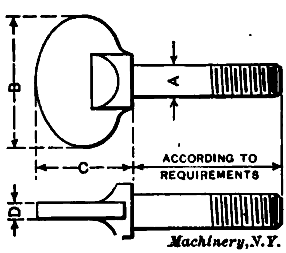
TABLE V. DIMENSIONS OF COLLAR-HEAD SCREWS



A	B	C	D	E	F	St'd No. of Threads per inch.
$\frac{3}{16}$	$\frac{3}{16}$	0.260	$\frac{1}{4}$	$\frac{3}{32}$	$\frac{3}{8}$	24
$\frac{1}{4}$	$\frac{1}{4}$	0.850	$\frac{5}{16}$	$\frac{1}{8}$	$\frac{1}{2}$	20
$\frac{5}{16}$	$\frac{5}{16}$	0.440	$\frac{3}{8}$	$\frac{1}{8}$	$\frac{9}{16}$	18
$\frac{3}{8}$	$\frac{3}{8}$	0.580	$\frac{7}{16}$	$\frac{5}{32}$	$\frac{11}{16}$	16
$\frac{7}{16}$	$\frac{7}{16}$	0.620	$\frac{1}{2}$	$\frac{5}{32}$	$\frac{3}{4}$	14
$\frac{1}{2}$	$\frac{1}{2}$	0.710	$\frac{9}{16}$	$\frac{3}{16}$	$\frac{7}{8}$	18
$\frac{9}{16}$	$\frac{9}{16}$	0.790	$\frac{5}{8}$	$\frac{3}{16}$	1	12
$\frac{5}{8}$	$\frac{5}{8}$	0.880	$\frac{11}{16}$	$\frac{7}{32}$	$1\frac{1}{16}$	11
$\frac{3}{4}$	$\frac{3}{4}$	1.060	$\frac{13}{16}$	$\frac{1}{4}$	$1\frac{1}{4}$	10

to get an equal pressure on all the three points, a special screw, with a half-spherical head like the one shown, may be used to advantage. The half-spherical head of this screw fits into a concave recess of the same shape in the strap. When the bearing for the screw head is made in this manner, the hole through the clamp must have plenty of clearance for the body part of the bolt.

TABLE VI. DIMENSIONS OF SHOULDER THUMB SCREWS



A	B	C	D
$\frac{3}{16}$	$\frac{9}{16}$	$\frac{1}{2}$	$\frac{3}{32}$
$\frac{1}{4}$	1	$\frac{11}{16}$	$\frac{1}{8}$
$\frac{5}{16}$	$1\frac{1}{8}$	$\frac{3}{4}$	$\frac{5}{32}$
$\frac{3}{8}$	$1\frac{1}{4}$	$\frac{13}{16}$	$\frac{5}{32}$
$\frac{7}{16}$	$1\frac{1}{2}$	$\frac{15}{16}$	$\frac{3}{16}$
$\frac{1}{2}$	$1\frac{5}{8}$	$1\frac{1}{8}$	$\frac{3}{16}$

When designing clamps or straps of the types shown, one of the most important things to take into consideration is to provide enough metal around the holes, so that the strap will stand the pressure of the screw without breaking at the weakest place, which naturally is in a line through the center of the hole. As a rule, these straps are made of machine steel, although large clamps may sometimes be made from cast iron.

The hook bolt shown in Fig. 43 is better adapted for some classes of work than any other clamping device. At the same time, it is very easy and cheap to make and easily applied. The bolt *A* passes through a hole in the jig, having a good sliding fit in this hole, and is pushed up until the hook or head *B* bears against the work, after

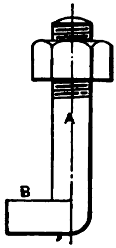


Fig. 43

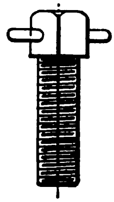


Fig. 44

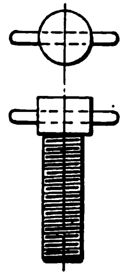
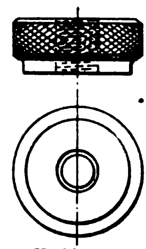


Fig. 45

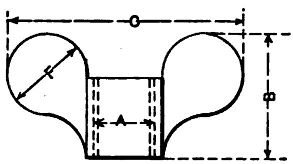


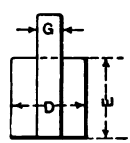
Machinery, N.Y.

Fig. 46

which the nut is tightened. When great pressure is not required, the thumb or wing nut, such as shown, together with its dimensions, in Table VII, permits the hook bolt to be applied more readily. The thumb or wing nut is preferable to the knurled nut, shown in Fig. 46, which sometimes is used. It is possible to get a better grip, and to tighten the bolt more firmly by a wing nut than it is with a knurled

TABLE VII. DIMENSIONS OF WING OR THUMB NUTS





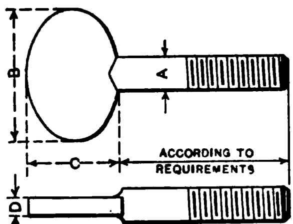
Machinery, N.Y.

A	B	C	D	E	F	G
3/16	5/8	1 1/8	5/16	3/8	7/16	1/8
1/4	3/4	1 3/8	15/32	1/2	17/32	5/32
5/16	3/4	1 3/8	15/32	1/2	17/32	5/32
3/8	13/16	1 11/16	17/32	9/16	5/8	5/32
7/16	7/8	2	21/32	5/8	11/16	3/16
1/2	1 1/16	2 1/4	3/4	13/16	7/8	3/16

nut. When the work is removed from the jig, using the hook bolt clamping device, the nut is loosened, and the head or hook of the bolt is turned away from the work, thus allowing it to be taken out, and another piece of work to be placed in position. The hook bolts are invariably made of machine steel.

In a box jig, or a jig where the work is entirely, or almost entirely, surrounded by the jig, the work is easily held in place by set-screws and sometimes by screw-bushings. The set-screws are of different kinds, the most common being the standard square head set-screw, which is used whenever great clamping pressure is required, the square head allowing the use of the wrench. Sometimes screws of this kind may be tightened enough for the purpose by hand if a pin is put through the head of the screw, as shown in Figs. 44 and 45.

TABLE VIII. DIMENSIONS OF REGULAR THUMB SCREWS

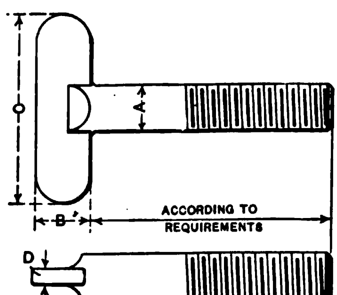


Machinery,N.Y.

A	B	C	D
3/16	3/4	5/8	3/32
1/4	15/16	3/4	1/8
5/16	1 1/8	7/8	5/32
3/8	1 1/4	1	5/32
7/16	1 1/2	1 1/16	3/16
1/2	1 5/8	1 3/16	3/16

This means is used not only when great pressure is not necessary, but also when the work is liable to spring if the screws are tightened too hard. In such a case, if a pin is inserted, it would be obvious that the screw head is not intended for a wrench, but that the pin is intended for getting a good grip by the hand for tightening the screw without resorting to any additional means. Usually it is not possible to use an ordinary machine wrench on such a screw, as it generally is rather thin, so that if applied to the top of the screw, it

TABLE IX. DIMENSIONS OF THUMB SCREWS WITH WIDE GRIP



Machinery,N.Y.

A	B	C	D
3/16	1/4	7/8	3/32
1/4	5/16	1	1/8
5/16	3/8	1 1/4	5/32
3/8	7/16	1 1/2	5/32
7/16	1/2	1 3/4	3/16
1/2	9/16	2	3/16
9/16	5/8	2 1/4	3/16
5/8	11/16	2 1/2	7/32

would not permit a very good grip. Of course, a monkey-wrench could be applied, but it ought to be stated in this connection that a monkey-wrench ought not to be employed in ordinary manufacturing shop work, as it is intended primarily for jobbing work. More screws probably have been tightened too hard and twisted off by the injudicious use of a money-wrench than in any other way. When a monkey-wrench is used, it should be used with discretion. This, of course, does not mean to imply that the monkey-wrench is not one of the handiest tools that a machinist ever had in his possession, but it is intended to impress the idea that unless the monkey-wrench is used in such a manner that, when it is applied to a small screw head, the power applied at the end of the handle is in proportion to the screw, it is a risky tool to have around.

While a screw with a round head, as shown in Fig. 45, and with a pin put through the head, is undoubtedly better and more convenient to use than the one shown in Fig. 44, the latter is cheaper to make, because standard screws can be taken right from stock, and a pin hole

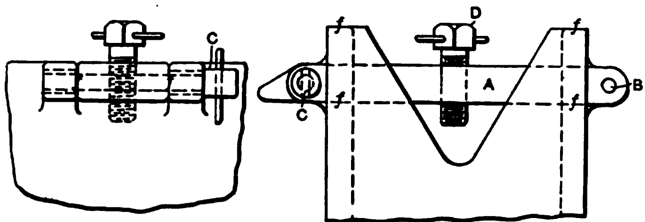


Fig. 47. Common Designs of Leaf in Drill Jigs. Screw D Clamps the Work

put through them, after the heads have been annealed. If thumb screws like the ones shown in Tables VIII and IX are available, they are preferable, as they give a good hold to the hand when they are tightened, and, besides, there is very little work required in finishing them. The use of a screw-bushing for clamping work has already been referred to. The clamping screws mentioned so far are generally applied directly onto the work, after having passed through the wall of the jig, or some projecting part serving as a seat for the screw.

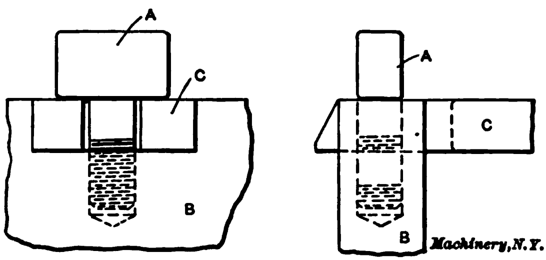


Fig. 48. Clamping Device for Leaf in Drill Jig

Loose leaves which swing out, in order to permit the work to be inserted and removed, are usually constructed in some manner similar to that shown in Fig. 47, in which *A* represents the leaf, being pivoted at *B* and held by a pin at *C*, which goes through the two lugs on the jig wall and passes through the leaf, thus binding the leaf and allowing the tightening of the set-screw *D*, which bears against the work. The holes in the lugs of the castings are lined with steel bushings in order to prevent the cast iron holes from being worn out too soon by the constant pulling out and putting in of the pin. This kind of leaf, when fitted in nicely, is rather expensive, but is used not only for binding purposes, but also for guiding purposes, making a convenient seat for the bushings. If the leaves are fitted well in place, the bushings will guide the cutting tools firmly.

Another way of holding down the leaf is shown in Fig. 48, in which *A* is a thumb screw, screwed directly into the wall *B* of the jig, and holding the leaf *C* down, as indicated. To swing the leaf out, the thumb screw is turned back about a quarter of the turn, so that the head of the thumb screw stands in line with the slot in the leaf, this slot being made wide and long enough to permit the leaf to clear the head of the thumb screw. This is a very rapid way of clamping, and is frequently used. The lower side of the head of the screw will wear a long time before the head finally comes in line with the slot when binding. It can then easily be fixed for binding the leaf again when standing in a position where the head of the thumb screw

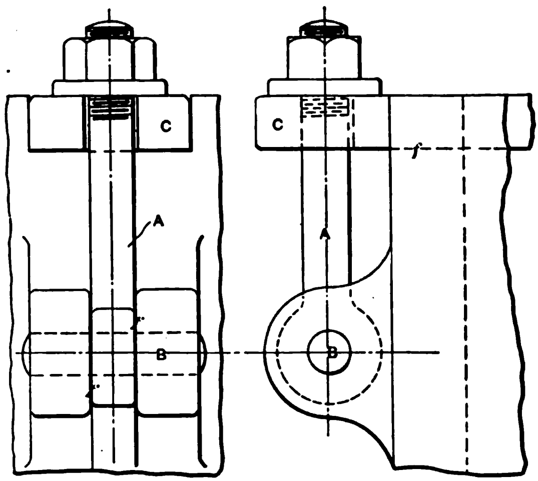


Fig. 49. Eye-bolt used for Clamping Drill Jig Leaf

is at right angles to the slot, by turning off a portion of the head on the under side. The size of these thumb screws is made according to the strain on the leaf and the size and design of the jig. No standard dimensions could be given for this kind of screw.

The hinged bolt, shown in Fig. 49, is also commonly used. Here *A* represents an eye-bolt, which is connected with the jig body by the pin *B*. The leaf or movable part *C* of the jig is provided with a slot in the end for the eye-bolt, this slot being a trifle wider than the diameter of the bolt. The threaded end of the eye-bolt is provided with a standard hexagon nut, a knurled head nut or a wing nut, according to how firmly it is necessary that the nut be tightened.

When the leaf is to be disengaged, the nut is loosened up enough to clear the point at the end of the leaf, and the bolt is swung out around the pin *B*, which is driven directly into lugs projecting out from the jig wall, a slot being provided between the two lugs, as shown, so that the eye-bolt can swing out with perfect freedom. At the opposite end, the leaves or loose parts of the jig swing around a pin the same as in Fig. 47, the detailed construction of this end being, most commonly, one of the three types shown in Fig. 50. It must be understood that to provide jigs with leaves of this character involves a great deal of work and expense, and they are used almost exclusively when one or more guide bushings can be held in the leaf.

When the jig leaf is simply intended to hold one or more set-screws by which the work is held down, it may be made and fastened as shown in Fig. 51. In this case, the name "leaf" is rather out of place, and this fastening device becomes merely a strap. Some improvements of this kind of clamping device are shown in Fig. 52, where the ends of the strap are slotted in various ways so as to

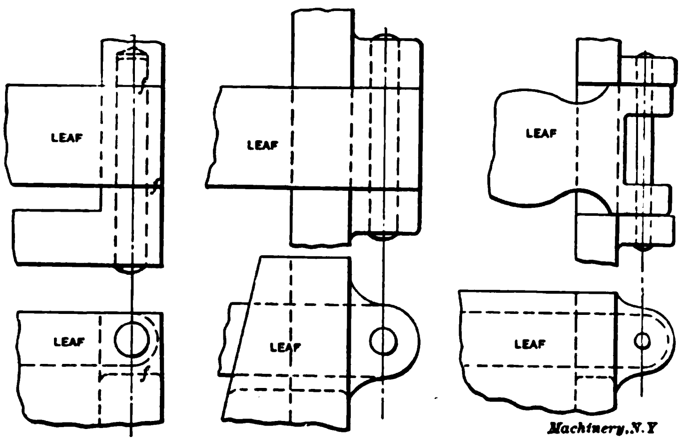


Fig. 50. Detail Designs of Joints between Leaf and Jig

permit getting the strap out of the way rapidly when the work is to be removed.

The ordinary jack-screw is employed quite commonly as a clamping device in drill jigs, but the objection to its use is that, not being an integral part of the jig, it is very apt to get lost. In Fig. 53 are shown two simple devices working on the same principle as the jack-screw, but having the advantage of being connected to the jig by the pin shown at *B*. At *A* in Fig. 53, a set-screw screws directly into the end of the eye-bolt, and at *C* a long square nut is threaded on the eye-bolt. These nuts must be made of special length, and be made up especially for this purpose. The eye-bolts are fastened, as shown, directly to the wall of the jig, and the set-screw or nut is tightened up against the work. The eye-bolt can be set at different angles to suit the work, thereby providing a clamping device which may be said to possess double adjustment. This device makes a very convenient clamping arrangement. It works satisfactorily, and has the advantage of being easily swung out of the way.

The principle of clamping work in the jig by means of a wedge or tapered gib is illustrated in Fig. 54. The work is located between the wedge *A* and the wall *B* of the jig and pressed up against the

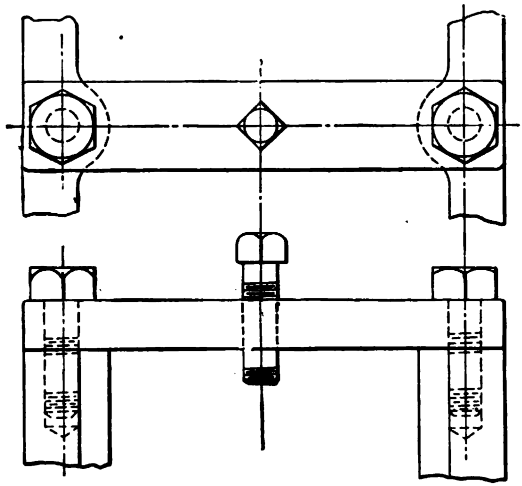


Fig. 51. Common Clamping Strap

wall by the wedge which can be driven in by a hammer, or screwed in place when the jig is constructed as shown. It is preferable to have the wedge screwed in place, as it is then less apt to be loosened by

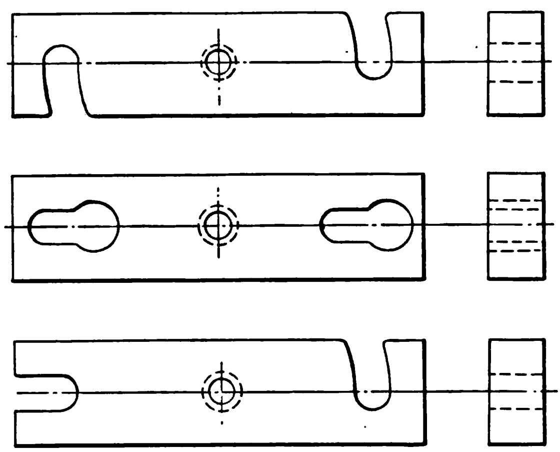


Fig. 52. Improved Designs of Clamping Straps

the constant vibrations to which it is subjected, and at the same time the wedge is less apt to get lost, being an integral part of the jig. The ear for the screw may be placed in any direction with regard to the gib, as indicated by the dotted lines in the end view of Fig. 54.

This tightening device is, in particular, adapted to work of dove-tail shape, as shown in Fig. 55. In this case the wedge is made similar to the common taper gib used for taking up the wear in dove-tail slides. It is sometimes of advantage to relieve the bearing surface opposite the wedge, as shown in dotted lines in Fig. 54, in order to

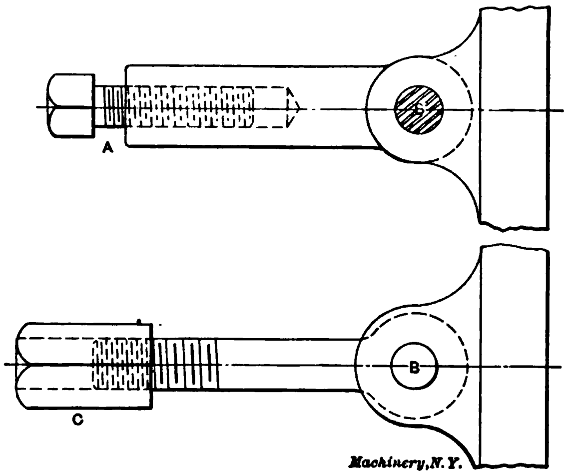


Fig. 53. Clamping Devices Working on the Jack-screw Principle

provide two distinct bearing points, which prevent the work from rocking. The hole in the ear of the gib through which the screw passes, must be oblong, so that when the screw is adjusted, and the gib moved in or out, there is ample allowance for the sidewise movement of the ear, due to the taper of the gib.

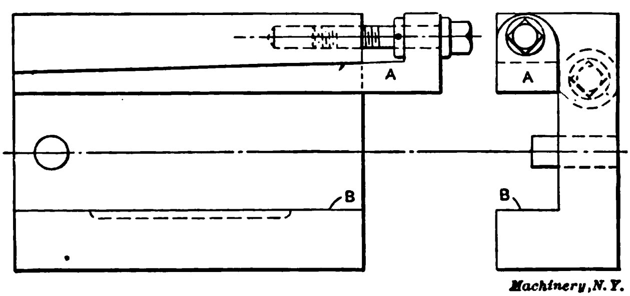


Fig. 54. Wedge or Taper Gib used for Clamping

If it is required to get a bearing on two points of a surface that is likely to vary in its dimensions, a yoke can be used, designed on the principle of that shown in Fig. 56. In the engraving, *A* is the work to be clamped, and *B* is the yoke which fits into a slot in the center of the strap or clamp *C*. The yoke is held by a pin *D*, around which it can swivel to adjust itself to the work. It is evident that the amount of pressure at the two points *E* and *F* will be equal, or at least near enough so for all practical purposes, even though the screws at the ends of the strap may not be equally tightened. In this device the pin *D* takes the full clamping strain, and should therefore be designed strong enough, and the strap which is weakened by the slot and the hole in the center, should be reinforced, as indicated, at this place.

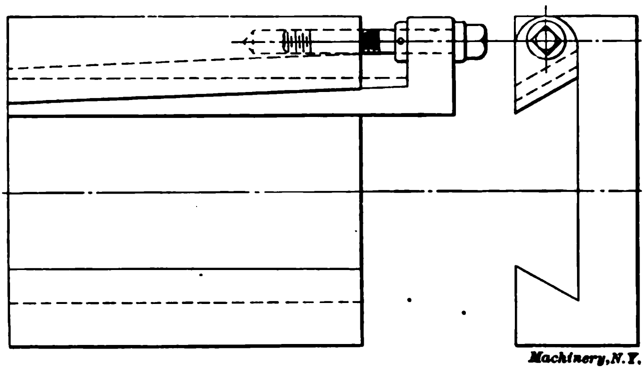


Fig. 55. Wedge used for Clamping Dove-tailed Work

It is preferable to have spiral springs at each end of the strap to prevent the strap from slipping down when the work is taken out. The strap may be made either of cast iron or machine steel, the yoke being made out of machine steel.

Eccentric clamps and shafts for binding purposes are often used. In Figs. 57 and 58 are shown two applications of the principle of the

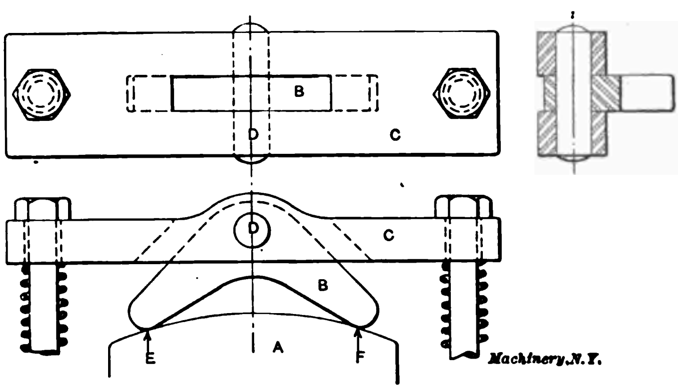


Fig. 56. Equalizing Clamp

eccentric shaft. In Fig. 57 the eccentric shaft *A* has a bearing at both ends, and the eye-bolt *B* is connected to it at the center and is forced down when the eccentric shaft is turned. This causes the two end points of the clamp *C* to bear on the work. This clamping arrangement has a very rapid action and gives good satisfaction. The throw of the eccentric shaft may vary from 1/16 inch to about

1/4 inch, depending upon the diameter of the shaft and the accuracy of the work. In cases where it is required that the clamp should bear in the center, an arrangement like the one shown in Fig. 58

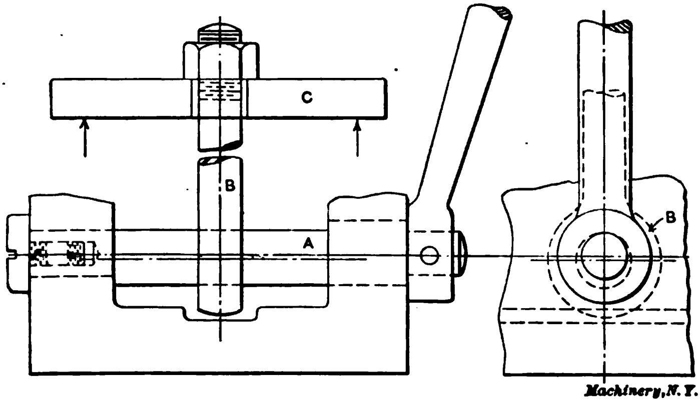


Fig. 57. Eccentric Clamping Bolt

may be used. Here the eccentric shaft *A* has a bearing in the center and eye-bolts *B* are connected to it at the ends. As the eccentricity is the same at both ends, the eye-bolts or connecting-rods will be pulled down evenly when the lever *C* is turned, and the strap *D* will get an

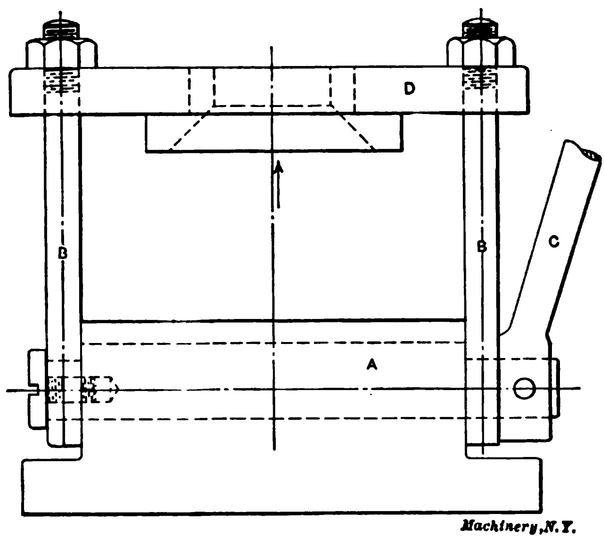
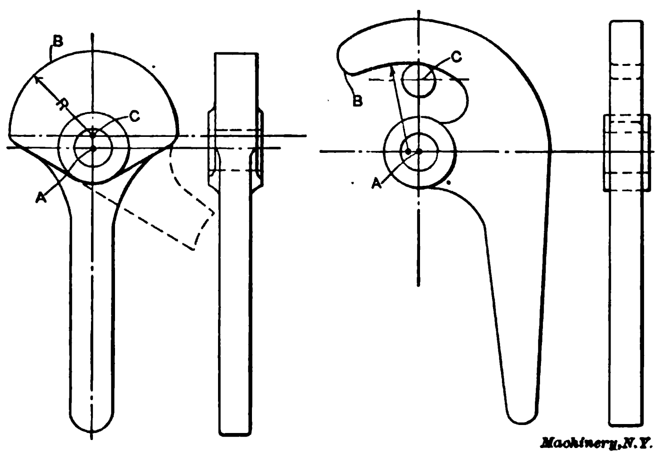


Fig. 58. Another Example of Eccentric Clamping Bolt

even bearing on the work in the center. If the force of the clamping stress is required to be distributed equally at different points on the work, a yoke like that shown in Fig. 56 may be used in combination with the eccentric clamping device in Fig. 58.

When it is essential that the strap *D* should also be used for locating purposes, necessary guides will be provided for the strap, so as to hold it in the required position. These guiding arrangements may consist of rigid rods, ground and fitted into drilled and reamed holes in the strap, or square bars held firmly in the jig, and fitted into square slots at the ends of the strap. The bars can also be round, and the slots at the ends of the strap half round, the principle in all cases remaining the same, excepting, of course, that the more rigid the guiding arrangement is, the more may the accuracy of the locating be depended upon.

The ordinary eccentric lever works on the same principle as the eccentric rods just described. There is a great variety of eccentric



Figs. 59 and 60. Cams or Eccentrics used for Clamping

clamping devices, but they are not as commonly used in present-day jig design as they used to be a few years ago. The eccentric clamping levers, however, provide good and rapid clamping action. In Fig. 59 is shown one especially intended for clamping finished work. It is not advisable to use this kind of lever on rough castings for the reason that the castings may vary so much that the cam or eccentric would require too great a throw to rigidly clamp them. The extreme throw of the eccentric lever in general should not exceed one-sixth of the length of the radius of the eccentric arc if the rise takes place during one-quarter of a complete turn of the lever. This would give an extreme throw of say ¼ inch for a lever having 1½ inch radius of the cam or eccentric. Even to one unfamiliar with this kind of work, it is plain that, as the eccentric cam swivels about the center *A*, the lever being connected to the jig with a stud or pin, the face *B* of the cam, which is struck with the radius *R* from the center *C*, recedes or approaches the side of the work, thereby releasing it from, or clamping it against, the bottom or wall of the jig. The lever for the eccentric may be placed in any direction, as indicated by the full and dotted lines in Fig. 59. In Fig. 60 is shown another eccentric lever, which is used frequently on small work for holding down straps or leaves, or for pulling together two sliding pieces, or one sliding and one stationary part, which in their turn hold the work. These sliding pieces may be V-blocks or some kind of jaws. The cam lever is attached to the jig body, the leaf, or the jaw, by a pin through hole *A*. The hook *B* engages the stud or pin *C* which is fastened in the opposite jaw or part, which is to be clamped to the part into which the pin through hole *A* is fastened.

The variety of design of eccentric cam levers is so great that it is impossible to show more than the principles, but the examples shown embody the underlying action of all the different designs.

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By EINAR MORIN

PART II

DRILL JIGS

SECOND EDITION

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JIGS AND FIXTURES—PART II

CHAPTER V

DESIGN OF OPEN DRILL JIGS*

To give any rational rules or methods for the design of drill jigs would be almost impossible, as almost every jig must be designed in a somewhat different way from every other jig, to suit and conform to the requirements of the work. All that can be done is to lay down the principles. The main principles for jigs as well as fixtures were treated at length in Chapter I. It is proposed in the following to dwell more in detail on the carrying out of the actual work of designing jigs.

Before making any attempt to put the lay-out of the jig on paper, the designer should carefully consider what the jig will be required to do, the limits of accuracy, etc., and to form, in his imagination, a certain idea of the kind of a jig that would be suitable for the purpose. In doing so, if a model or sample of the work to be made is at hand, it will be found to be a great help to study the actual model. If the drawing, as is most often the case, is the only thing that is at hand, then the outline of the work should be drawn in red ink on the drawing paper, on which the jig is subsequently to be laid out, and the jig built up, so to speak, around this outline. The designing of the jig will be greatly simplified by doing this, as the relation between the work and the jig will always be plainly before the eyes of the designer, and it will be more easily decided where the locating points and clamping arrangements may be properly placed. When drawing and projecting the different views of the jig on the paper, the red outline of the work will not in any way interfere, and when the jig is made from the drawing, the red lines are simply ignored, except to the extent to which the outline of the pieces may help the tool-maker to understand the drawing and the purpose of certain locating points and clamping devices.

If it is possible, the jig should be drawn full size, as it is a great deal easier to get the correct proportions, when so doing. Of course, in many cases, it will be impossible to draw the jigs full size. In such cases the only thing to do is to draw them to the largest possible regular scale. Every jig draftsman should be supplied with a set of blue-prints containing dimensions of standard screws, bolts, nuts, thumb-screws, washers, wing nuts, sliding points, drills, counterbores, reamers, bushings, etc.; in short, with blue-prints giving dimensions of all parts that are used in the construction of jigs, and

* MACHINERY, August and September, 1908.

which are, or can be, standardized. It should be required of every designer and draftsman that he use these standards to the largest possible extent, so as to bring the cost of jigs down to as low a figure as possible.

If it does not meet with objections from higher authorities, which it ought not to, it is highly advantageous for the obtaining of best results, that, before starting on the drawing, the draftsman who is to lay out the jig should converse with the foreman who is actually going to use the jig. Oftentimes this man will be able to supply the best idea for the making of the jig or tool. Not only is advantage taken of the combined experience of the draftsman and the foreman, but it is also a precaution of great importance for making all parties feel satisfied.

As a jig drawing, in most cases, is only used once, or at most only a very few times, it is not considered worth while to make a tracing or blue-print from the drawing, but, as a rule, the pencil drawing itself may be used to advantage. If, however, it is given out in the shop directly as it comes from the drawing-board, it is likely to get soiled, and to be used in such a manner that, after a while, it would be impossible to make out the meaning of the views shown on it. For this reason, in the first place, jig drawings should be made on heavy paper, preferably of brown color, which is not as quickly soiled as white paper. In order to prevent the drawing being torn, it should be mounted on strawboard, and held down along the edges by thin wooden strips, nailed to the board. It is also desirable to cover the drawings with a thin coat of shellac before they are sent out in the shop. When this is done, the dirt and black spots which will be always found on the drawing when it stays in the shop, if only for a few hours, may be washed off directly; and the shellac itself may be washed off by wood alcohol, when the drawing is returned to the drafting-room. The drawing, after having been cleaned, is then detached from the strawboard, which may be used over and over again. The drawing is, of course, filed away according to the drafting-room system. The most advantageous sizes for jig drawings for medium to heavy work are as follows:

Full size sheet, 40 × 27½ inches.

Half size sheet, 27½ × 20 inches.

Quarter size sheet, 20 × 13¾ inches.

Eighth size sheet, 13¾ × 10 inches.

Of course, these sizes will vary in different shops, and in many cases, particularly when the tool designing department and the regular drafting-room are combined as one drafting department, the jig drawings should be of the same regular sizes as the ordinary machine drawings.

It is common in a great many shops to make no detailed drawings of jigs, but simply to draw a sufficient number of different views and sections, and to dimension the different parts directly on the assembly drawings. In cases where the jig drawings are extremely complicated, and where they are covered with a large number of dimensions which make it hard to read the drawing and to see the outlines of the jig body itself, it has proved a great help to trace the outlines of the jig body, and of such portions as are made of cast iron, on tracing paper, omitting all loose parts, and simply putting on the necessary dimensions for making the patterns. A blue-print is then made from this paper tracing, and this is sent to the pattern-maker, who will find the drawing less of a puzzle, and who will need to spend far less time to understand how the pattern actually looks. A less skilled, and consequently a cheaper, man may also be used for making the pattern. It is, however, greatly to be doubted whether it is good policy not to detail jig drawings completely, the same as other machine details.

When jigs are made up for pieces of work which require a great many operations to be carried out with the same jig, and where a great number of different bushings, different sizes of drills, reamers, counterbores, etc., are used, a special operation sheet should be provided which should be delivered to the man using the jig, together with the jig itself. This enables him to use the jig to best advantage. On this sheet should be marked the order in which the various operations are to be performed, and the tools and bushings which are to be used. Of course, the bushings in such a case should be numbered or marked in some way so as to facilitate the selection of the correct bushing for the particular tool with which it is used. If this system is put in force and used for simpler classes of jigs also, the operator will need few or no instructions from his foreman, outside of this operation sheet.

The Designing of Open Jigs

The present chapter will be devoted to explaining and illustrating the application of the principles previously outlined, to the simplest and most common design of drill jig—the open jig. We will assume that the drill jig is to be designed for a piece of work, as shown in Fig. 61. Consideration must first be given to the size of the piece, to the finish given to the piece previous to the drilling operation, the accuracy required as regards the relation of one hole to the other, and in regard to the surfaces of the piece itself. The number of duplicate pieces to be drilled must also be considered, and, in some cases, the material.

The very simplest kind of drill jig that could be used for the case taken as an example would be the one illustrated in Fig. 62, which simply consists of a flat plate of uniform thickness of the same outline as the piece to be drilled, and provided with holes for guiding the drill. Such a jig would be termed a jig plate. For small pieces, the jig plate would be made of machine steel and case-hardened, or from tool steel and hardened. For larger work, a machine steel plate can also be used, but in order to avoid the difficulties which naturally would arise from hardening a large plate, the holes are simply bored larger than the required size of drill, and are provided with lining bushings to guide the drill, as shown in Fig. 63. It would not be necessary, however, to have the jig plate made out of steel for large work, as a cast-iron plate provided with tool steel or machine steel guiding bushings would answer the purpose just as well, and at the same time be much cheaper, and almost as durable. The thickness of the jig plate varies according to the size of the holes to be drilled and the size of the plate itself.

The holes in the jig in Fig. 62 and in the bushings in the jig in Fig. 63, are made the same size as the size of the hole to be drilled in the work, with proper clearance for the cutting tools. If the size and location of the holes to be drilled are not of great consequence, it is sufficient to simply drill through the work with a full size drill guided by the jig plate, but when a nice, smooth, standard size hole is required, the holes in the work must be reamed. The hole is first spotted by a spotting drill, which is of exactly the same size as the reamer used for finishing, and which fits the hole in the jig plate or bushing nicely. Then a so-called reamer drill, which is 0.010 inch, or less, smaller in diameter than the reamer, is put through, leaving only a slight amount of stock for the reamer to remove, thereby obtaining a very satisfactory hole. Sometimes a separate loose bushing is used for each one of these operations, but this is expensive and also unnecessary, as the method described gives equally good results.

By using the rose reaming method very good results will also be obtained. In this case two loose bushings besides the lining bushing will be used. These bushings were described and tabulated in Chapter II. The drill preceding the rose chucking reamer is 1/16 inch smaller than the size of the hole. This drill is first put through the work, a loose drill bushing made of steel being used for guiding the drill. Then the rose chucking reamer is employed, using, if the hole in the jig be large, a loose bushing made of cast iron.

When dimensioning the jig on the drawing, dimensions should always be given from two finished surfaces of the jig to the center of the holes, or at least to the more important ones. In regard to the holes, it is not sufficient to give only the right angle dimensions, *a*, *b*, *c*, and *d*, etc., Fig. 62, but the radii between the various holes must also be given. If there are more than two holes, the radii should always be given between the nearest holes and also between the holes standing in a certain relation to one another, as, for instance, between centers of shafts carrying meshing gears, sprockets, etc. This will prove a great help to the tool-maker. In the case under consideration, the dimensions ought to be given from two finished sides of the work to the centers of the holes, and also the dimension between the centers of the holes to be drilled.

When using a simple jig, made as outlined in Figs. 62 and 63, this jig is simply laid down flat on the work and held against it by a C-clamp, a wooden clamp, or, if convenient, held right on the drill press table by means of a strap or clamp, as shown in Fig. 64. Here two pieces of the work are shown beneath the jig plate, both being drilled at one time.

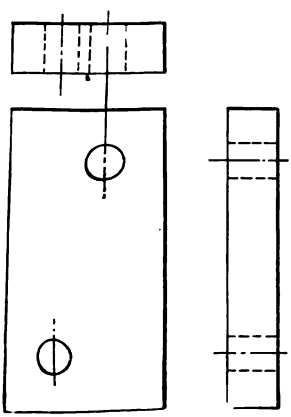


Fig. 61. Sketch of Plate to be Drilled

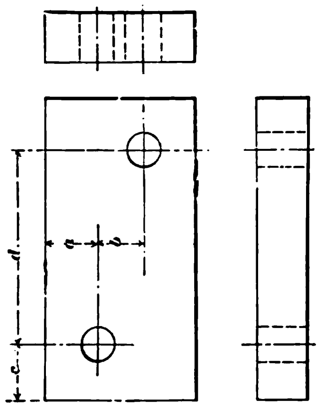


Fig. 62. Simplest Form of Jig for Piece shown in Fig. 61

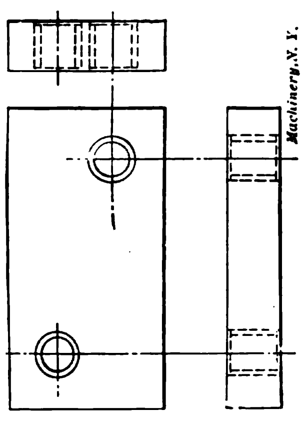


Fig. 63. Plate Jig with Inserted Guide Bushings

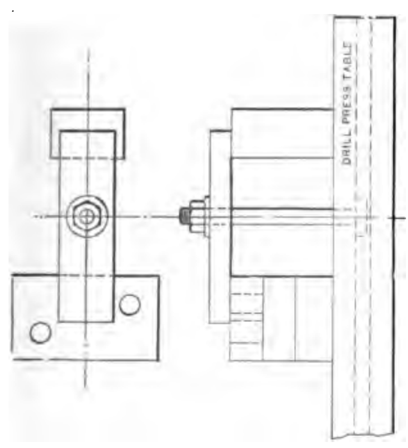


Fig. 64. Holding Jig and Work on Drill Press Table. Two Pieces Drilled at Once

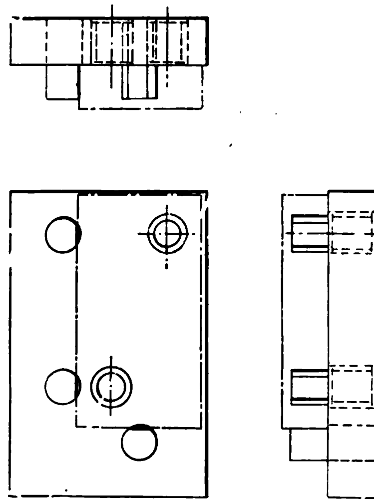


Fig. 65. First Improvement on Plate Jig: Locating Plug Inserted

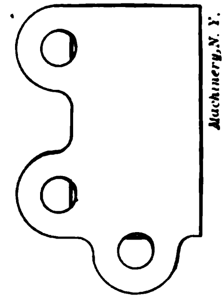


Fig. 66. Variation in Shape of Plate Jig

Improving the Simple Form of Jig Shown in Fig. 63

The first improvement that could be made on the jig shown in Fig. 63 would be the placing of locating points in the jig plate in the form of pins, as shown in Fig. 65, in which the dotted lines represent the outline of the work. The plate need not necessarily have the shape shown in Fig. 65, but may have the appearance shown in Fig. 66, according to the conditions. As previously mentioned in this chapter, exact rules could not be given for the form and shape of jigs, but common sense together with the judgment obtained by long practice must be relied upon in determining the minor points of design.

The adding of the locating points will, of course, increase the cost of the jig somewhat, but the amount of time saved in using the jig will undoubtedly make up for the added expense of the jig, provided a fair number of pieces is to be drilled; besides, a great advantage is gained in that the holes can always be placed in the same relation

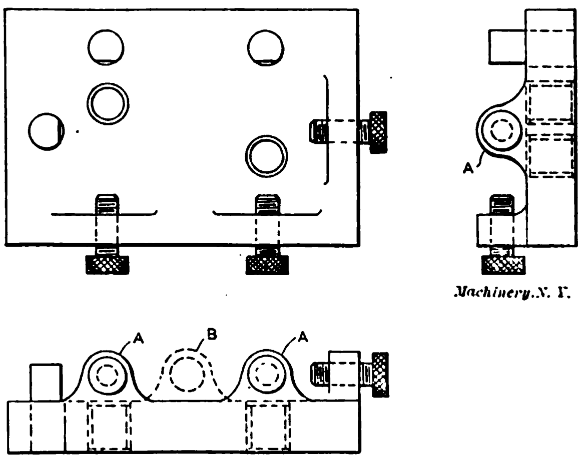


Fig. 67. Second Improvement: Locating Screws Holding Work in Place

to the two sides resting against the locating pins on all the pieces drilled. The locating pins are flattened off to a depth of 1/16 inch from the outside circumference, and dimensions should be given from the flat to the center of the pin holes and to the center of the nearest or the most important of the holes to be drilled in the jig. The same strapping or clamping arrangements for the jig and work, as mentioned for the simpler form of jig, may be employed.

Improving the Jig by Adding Locating Screws

The next step toward improving the jig under consideration would be to provide the jig with locating screws, as shown in Fig. 67. By the addition of these, the locating arrangements of the jig become complete, and the piece of work will be prevented from shifting or moving sideways. These locating screws should be placed in accordance with Rule 10 laid down in the summary of the principles of jig

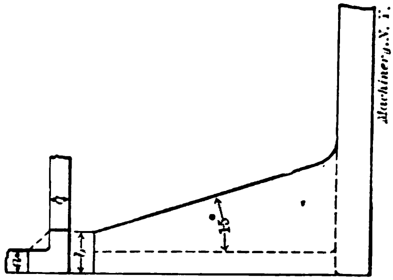


Fig. 69. Design of Legs for Cast-iron Jig Bodies

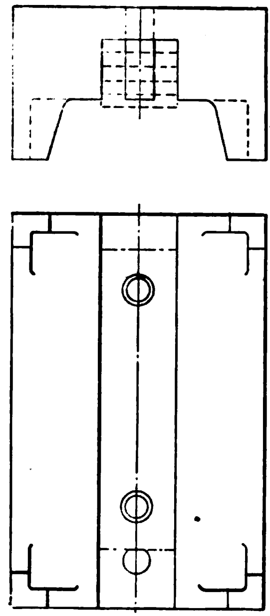
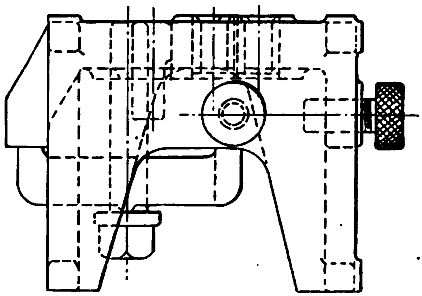


Fig. 70. Form of Jig which may be Used for Drilling a Number of Pieces Simultaneously



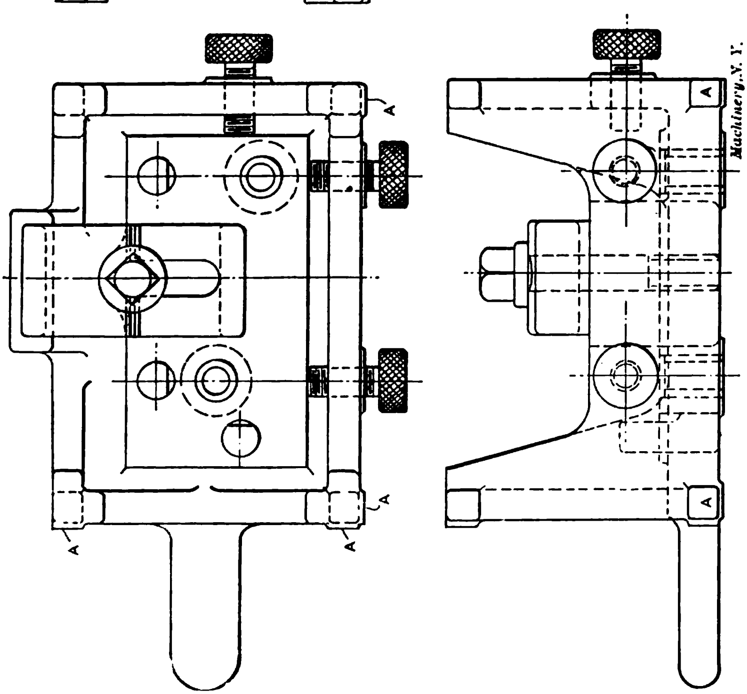


Fig. 68. Complete Jig for Rapid Duplicate Work

design in Chapter I, saying that all clamping points should be located as nearly opposite to some bearing points of the work as possible. In order to provide for locating set-screws in our present jig, three lugs or projections *A* are added which hold the set-screws. If possible the set-screw lugs should not reach above the surface of the piece of work, which should rest on the drill press table when drilling the holes.

The present case illustrates the difficulty of giving exact rules for jig design and indicates the necessity of individual judgment. It is perfectly proper to have two set-screws on the long side of the work, but in a case like this where the piece is comparatively short and stiff, one lug and set-screw, as indicated by the dotted lines at *B* in Fig. 67, would be fully sufficient. The strain of the set-screw placed right between the two locating pins will not be great enough to spring

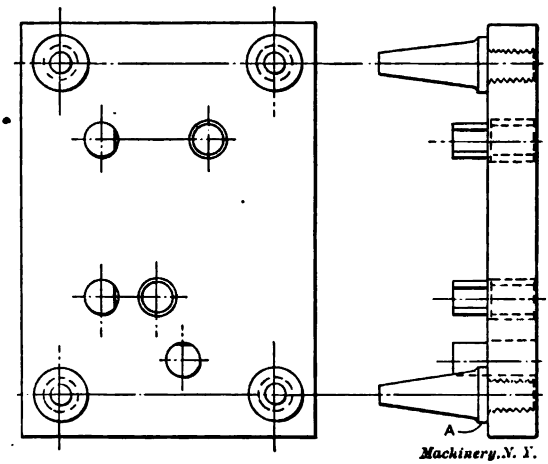


Fig. 71. Legs Screwed into Jig Body

the piece out of shape. When the work is long and narrow, two set-screws are required on the long side, but whenever a saving in cost can be obtained without sacrificing efficiency, as in the case illustrated, two lugs would be considered a wasteful design.

Providing Clamps and Feet for the Jig

The means by which we have so far clamped or strapped the work to the jig when drilling in the drill press (see Fig. 64) have not been integral parts of the jig. If we wish to add clamping arrangements that are integral parts of the jig, the next improvement would be to add four legs in order to raise the jig plate enough above the surface of the drill press table to get the required space for such clamping arrangements. The completed jig of the best design for rapid manipulation and duplicate work would then have the appearance shown in Fig. 68. The jig here is provided with a handle cast integral with the jig body, and with a clamping strap which can be pulled back for removing and inserting the work. Instead of having the legs solid with the jig, as shown in Fig. 68, loose legs, screwed in place, are sometimes used, as shown in Fig. 71.

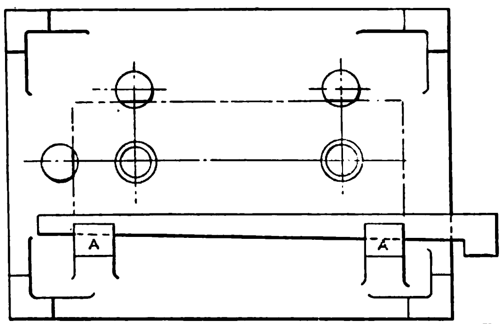
These legs are round, and provided with a shoulder *A*, preventing them from screwing into the jig plate. A headless screw or pin through the edge of the circumference of the threads at the top prevents the studs from becoming loose. These loose legs are usually made of machine steel or tool steel, the bottom end being hardened and then ground and lapped, so that all the four legs are of the same length. It is the practice of many tool-makers not to thread the legs into the jig body, but simply to provide a plain surface on the end of the leg, which enters into the jig plate, and is driven into place. This is much easier, and there is no reason why for almost all kinds of work, jigs provided with legs attached in this manner should not be equally durable.

Of course, when jigs are made of machine or tool steel, and legs are required, the only way to provide them is to insert loose legs. In the case of cast-iron jigs, however, solid legs cast in place are preferable. The solid legs cast in place generally have the appearance shown in Fig. 69. The two webs of the leg form a right angle, which, for all practical purposes, makes the leg fully as strong as if it were made solid, as indicated by the dotted line in the upper view. The side of the leg is tapered 15 degrees, as a rule, as shown in the engraving, but this may be varied according to conditions. The thickness of the leg varies according to the size of the jig, the weight of the work, and the pressure of the cutting tools, and depends also upon the length of the leg. The length *b* on top is generally made 1⅛ times *a*. As an indication of the size of the legs required, it may be said that for smaller jigs, up to jigs with a face area of 6 square inches, the dimension *a* may be made from 5/16 to 3/8 inch; for medium sized jigs, ½ to ⅝ inch; for larger sized jigs, ¾ to 1½ inch; but of course, these dimensions are simply indications of the required dimensions. As to the length of the legs, the governing condition, evidently, is that they must be long enough to reach below the lowest part of the work and the clamping arrangement.

If a drill is to be used in a multiple spindle drill, it should be designed a great deal stronger than it is ordinarily designed when used for drilling one hole at a time. This is especially true if there is a large number of holes to drill simultaneously. The writer has had sad experiences with drill jigs which would give excellent service in common drill presses for years, but which, when put on a multiple spindle drill, immediately broke to pieces as if subjected to a hammer-blow. It is evident that the pressure upon the jig in a multiple spindle drill is as many times greater than the pressure in a common drill press as the number of drills in operation at once.

Referring again to Fig. 68, attention should be called to the small lugs *A* on the sides of the jig body which are cast in place for laying out and planing purposes. The handle should be made about 4 inches long, which permits a fairly good grip by the hand. The design of the jig shown in Fig. 68 is simple, and fills all requirements necessary for producing work quickly and accurately. At the same time, it is strongly and rigidly designed. Locating points of a different kind from those shown can, of course, be used; and the requirements may be such that adjustable locating points, as described in Chapter III, may be required. A more quick acting, but at the same time, a far more complicated clamping arrangement might be used, but the question is whether the added increase in the rapidity of manipulation offsets the expense thus incurred.

Another improvement which should not be overlooked, and which in a case like this probably could be made, and which it is always wise to look into at any rate is: Can more than one piece be drilled at one time? In the present case, the locating pins can be made longer, or, if there is a locating wall, it can be made higher, the legs of the jig can be made longer, and the screw holding the clamp can also



Machinery,N.Y.

Fig. 72. Jig with Wedge for Holding the Work

be increased in length; if the pieces of work are thick enough, set-screws for holding the work against the locating pins can be placed in a vertical line, or if the pieces be narrow, they can be placed diagonally, so as to gain space. If the pieces are very thin, the locating might be a more difficult proposition. If they are made of a uniform width, they could simply be put in the slot in the bottom of the jig, as shown in Fig. 70, or if a jig on the principles of the one shown in Fig. 68, is used, they might be located sideways by a wedge, as shown in Fig. 72. A couple of lugs *A* would then be added to hold the wedge in place, and take the thrust. In both cases the pieces must be pushed up in place endways by hand. If the pieces are not of exactly uniform size, and it is desired to drill a number at a time, they must be pushed up against the locating pins by hand from two sides, and the clamping strap must be depended upon to clamp them down against the pressure of the cut, and at the same time prevent them from moving side or endwise. If the accuracy of the location of the holes is important, but one piece at a time should be drilled.

CHAPTER VI

EXAMPLES OF OPEN DRILL JIGS*

A typical example of an open drill jig, very similar to the one developed and explained in the previous chapter, is shown in Fig. 73. The work is located against the three locating pins *A*, and held in place against these pins by the three set-screws *B*. The three straps *C* hold the work securely against the finished pad, in the bottom of the jig. These clamps are so placed that when the work has been drilled and the clamp screws loosened, the clamps will swing around a quarter of a turn, allowing the work to be lifted directly from the jig and a new piece of work inserted; then the clamps are again turned around into the clamping position, and the screws tightened. These

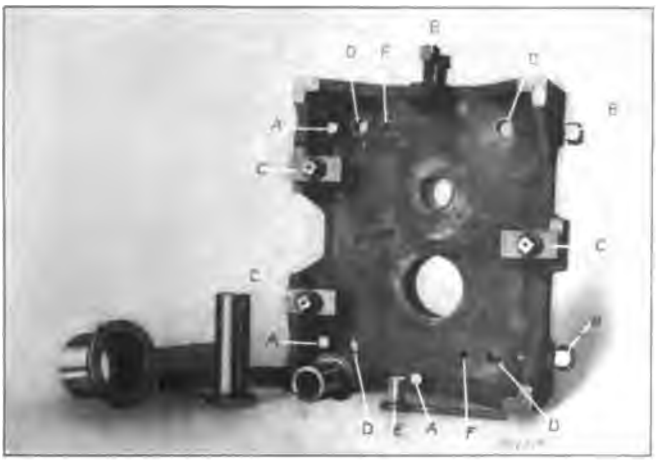


Fig. 73. Example of Open Drill Jig. View showing Front Side

straps are integral parts of the jig; at the same time, they are quickly and easily manipulated, and do not interfere with the rapid removal and insertion of the work. The strength and rigidity of the feet in proportion to the jig should be noted, this strength being obtained by giving proper shape to the feet, without using an unnecessary quantity of metal.

The jig in Fig. 73 is also designed to accommodate the component part of the work when it is being drilled. When this is done, the work is held on the back side of the jig, shown in Fig. 74. This side is also provided with feet, and has a finished pad against which the work is held. The locating pins extend clear through the central portion of the jig body, and, consequently, will locate the component

* MACHINERY, October. 1908.

part of the work in exactly the same position as the piece of work being drilled on the front side of the jig. The same clamping straps are used, the screws being simply put in from the opposite side into the same tapped holes as are used when clamping on the front side of the jig. The four holes *D* are guide holes for drilling the screw holes in the work, these being drilled the body size of the bolt in one part, and the tap drill size in the component part. The lining bushing in the holes *D* serves as a drill bushing for drilling the body size holes. The loose bushing *E*, Fig. 73, is used when drilling the tap holes in the component part, the inside diameter of this bushing being the tap drill size, and the outside diameter a good fit in the lining bushing. The two holes *F*, Fig. 74, are provided with drill bushings and serve as guides when drilling the dowel pin holes, which are drilled below size, leaving about 0.010 inch, and are reamed out

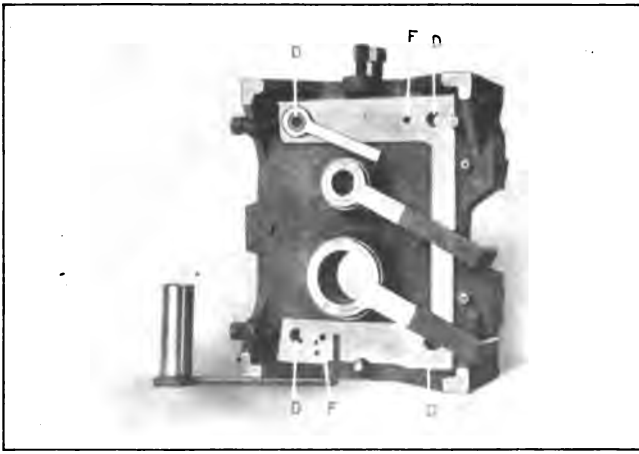


Fig. 74. Rear View of Drill Jig shown in Fig. 73

after the two component parts of the work are put together. The two holes shown in the middle of the jig in Fig. 73, and which are provided with lining bushings, and also with loose bushings, as shown inserted in Fig. 74, may be used for drilling and reaming the bearing holes for the shafts passing through the work. In this particular case, however, they are only used for rough-drilling the holes, to allow the boring-bars to pass through when finishing the work by boring in a special boring jig, after the two parts of the work have been screwed together.

The large bushings shown beside the jig in Fig. 73 are the loose bushings shown in place in Fig. 74. It will be noted that the bushings are provided with dogs for easy removal, as explained in Chapter II, and illustrated in Fig. 11. As the central portion of the jig body is rather thin, it will be noticed in Fig. 74 that the bosses for the central holes project outside of the jig body in order to give a long enough bearing to the bushings. This, of course, can be done only when such a projection does not interfere with the work. The bosses, in this particular case, also serve another purpose. They make the jig "fool-proof," because the pieces drilled on the side of the jig shown in Fig. 73 cannot be put on the side shown in Fig. 74, the bosses preventing the piece from being placed in position in the jig.

Attention should be called to the simplicity of the design of this jig. It simply consists of a cast-iron plate, with finished seats, and feet projecting far enough to reach below the work when drilling, three dowel pins, set-screws for bringing the work up against the dowel pins, three clamps, and the necessary bushings. The heads of all the set-screws and bolts should, if possible, be made the same size, so that the same wrench may be used for tightening and unscrewing all of them. It can also be plainly seen from the half-tones that there

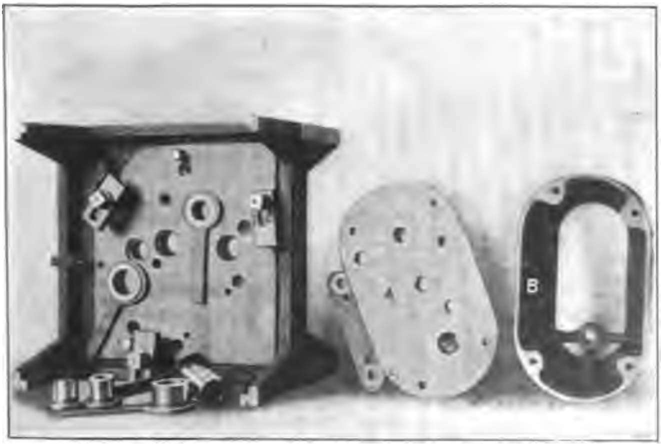


Fig. 75. Drill Jig Used for Drilling Work shown to the Right

are no unnecessarily finished surfaces on the jig, a matter which is highly important in economical production of tools.

Another example of an open drill jig, similar in design to the one just described, is shown in Fig. 75. The work to be drilled in this jig is shown at *A* and *B* at the right-hand side of the jig. In this case, the work is located from the half-circular ends. The pieces *A* and *B* are component parts, and when finished are screwed together. The piece *A* is located against three dowel pins, and pushed against them by set-screw *C*, and held in position by three clamping straps, as shown in Fig. 76. In this case, the straps are provided with oblong slots as indicated, and when the clamp screws are loosened, the clamps are simply pulled backward, permitting the insertion and removal of the work without interference. It would improve this clamping arrangement to place a stiff helical spring around the screws under each strap, so that the straps would be prevented from falling down to the bottom of the jig when the work is removed. At the same time this would prevent the straps from swiveling around the screws when not clamped.

In Fig. 77, the part *B* in Fig. 75 is shown clamped in position for drilling, the opposite side of the jig being used for this purpose. In

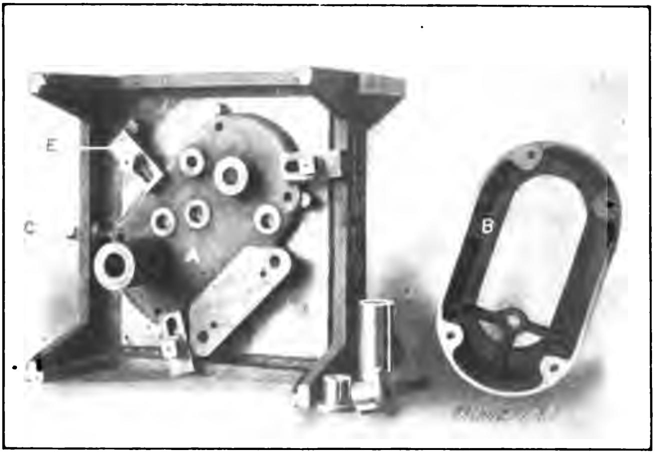


Fig. 76. Drill Jig shown in Fig. 75 with Work in Place

jig design of this kind it is necessary to provide some means so that the parts *A* and *B* will be placed each on the correct side of the jig, or, as said before, the jig should be made "fool-proof." In the present

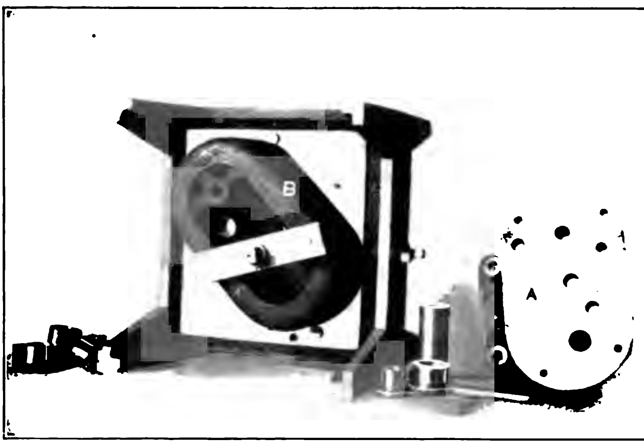


Fig. 77. Rear View of Drill Jig shown in Fig. 75, with Cover to be Drilled in Place

case, the parts cannot be exchanged and placed on the wrong side, because the cover or guard *B* cannot be held by the three straps in Fig. 76, because the screws for the straps are not long enough. On the other hand, the piece *A* could not be placed on the side shown in

Fig. 77, because the long bolt and strap used for clamping on this side would interfere with the work.

It may appear to be a fault in design that three straps are used to fasten the piece *A* in place, and only one is employed for holding piece *B*. This difference in clamping arrangement, however, is due to the different number and the different sizes of holes to be drilled in the different pieces. The holes in the piece *A* are larger and the number of holes is greater, and a heavier clamping arrangement is, therefore, required, inasmuch as the thrust on the former is correspondingly greater, the multiple spindle drill being used for drilling the holes. If each hole were drilled and reamed individually, the design of the jig could have been comparatively lighter.

In the design shown, the locating of each piece individually in any but the right way is also taken care of. The piece *A*, which is shown

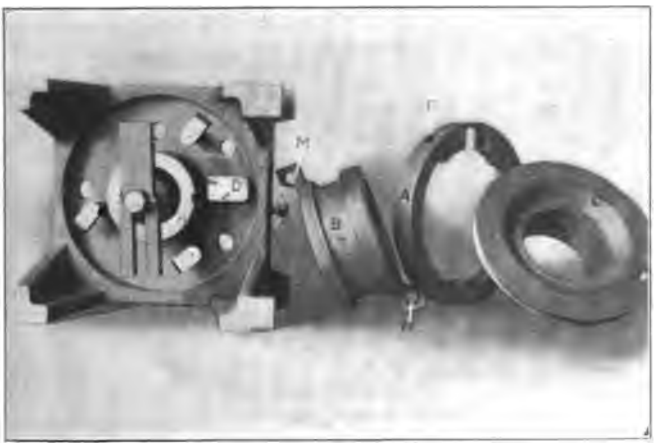


Fig. 78. Drill Jig for Parts of Friction Clutches shown at the Right

in place in the jig Fig. 76, could not be swung around into another position, because the strap and screw at *E* would interfere. For the same reason, the cover or guard *B* could not be located except in the right way. As shown in Fig. 77, the strap and screw would have to be detached from the jig in order to get the cover in place, if it were turned around. The locating pins for the work pass clear through the body of the jig, and are used for locating both pieces. The pieces are located diagonally in the jig, because, by doing so, it is possible to make the outside dimensions of the jig smaller. In this particular case the parts are located on the machine to which they belong, in a diagonal direction, so that the additional advantage is gained of being able to use the same dimensions for locating the jig holes as are used on the drawing for the machine details themselves. This tends to eliminate mistakes in making the jigs as well.

Sometimes, when more or less complicated mechanisms are composed of several parts fitted together and working in relation to each other, as, for instance, friction clutches, one jig may be made to serve for drilling all the individual parts, by the addition of a few extra parts applied to the jig when different details of the work are being drilled. In Figs. 78, 79, and 80, such a case is illustrated. The pieces *A*, *B*, and *C*, in Fig. 78, are component parts of a friction clutch, and the jig in which these parts are being drilled, is shown in the same figure, to the left. Suppose now that we wish to drill the friction expansion ring *A*. The jig is bored out to fit the ring before it is split, and when it is only rough-turned, leaving a certain number of thousandths of an inch for finishing. The piece is located, as shown in Fig. 79, against the steel block *D* entering into the groove in the ring, and is then held by three hook-bolts, which simply are swung around when the ring is inserted or removed: The hook-bolts are tightened by nuts on the back side of the jig. Three holes marked

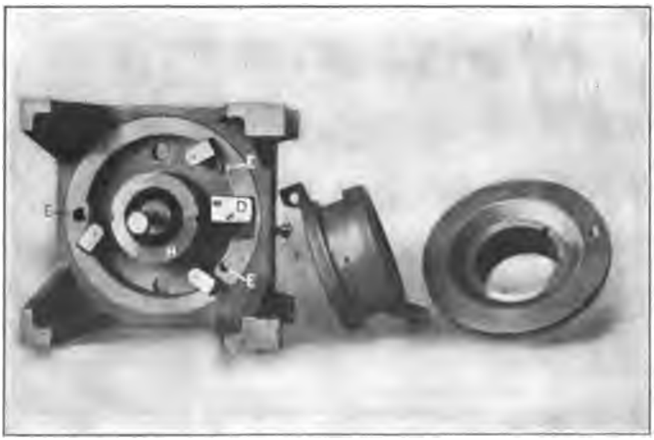


Fig. 79. Drill Jig shown in Fig. 78, with One of the Pieces in Place

E in Fig. 79, are drilled simultaneously in the multiple spindle drill, and the fourth hole *F* (see Fig. 78), is drilled by turning the jig on the side. The steel block *D*, Fig. 79, is hardened, and has a hole to guide the drill when passing through into the other side of the slot in the ring. The block is held in place by two screws and two dowel pins.

When drilling the holes in the lugs in the friction sleeve *B*, Fig. 78, the block *D* and the hook-bolts are removed. It may be mentioned here, although it is a small matter, that these parts should be tied together when removed, and there should be a specified place where all the parts belonging to a particular jig should be kept when not in use. The friction sleeve *B* fits over the collar *G*, Fig. 80. This collar is an extra piece, belonging to the jig, and used only when drilling the friction sleeve; it should be marked with instructions for what purpose it is used. The collar *G* fits over the projecting finished part *H* in the center of the jig, and is located in its right position by the keyways shown. The keyway in the friction sleeve *B*, which must be cut and placed in the right relation to the projecting lugs before the piece can be drilled, locates the sleeve on the collar *G*, which is provided with a corresponding keyway. A flange on the collar *G*, as shown more plainly at *L* in Fig. 80, locates the friction sleeve at the right distance from the bottom of the jig, so that the holes will have a proper location sideways. Two collars, *G* and *L*, are used for the same piece *B*, this being necessary because the holes *M* and *M* in the projecting lugs shown in Fig. 78 are not placed in the same relation to the sides of the friction sleeve. The collars are marked to avoid mistakes, and corresponding marks on the jig provided so as to assure proper location. The friction sleeve is clamped in place by a strap which in this case does not form an integral part of the jig. This arrangement, however, is cheaper than it would have been to carry up two small projections on two sides of the jig, and

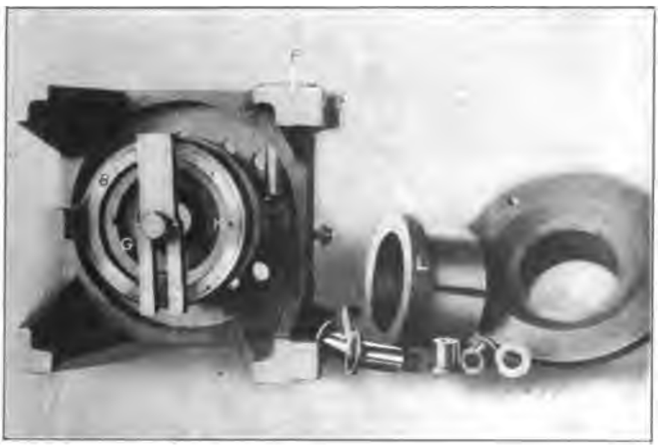


Fig. 80. Drill Jig shown in Fig. 78 used for Drilling Friction Sleeve

employ a swinging leaf and an eye-bolt, or some arrangement of this kind. Besides, the strap is rather large, and could not easily get lost. The jig necessarily has a number of loose parts, on account of being designed to accommodate different details of the friction clutch.

The friction disks *C*, in Fig. 78, when drilled, fit directly over the projecting finished part *H* of the jig, and are located on this projection by a square key. The work is brought up against the bottom of the jig and held in this position by the strap used in Fig. 80 for holding the friction sleeve. The bushings of different sizes shown in Fig. 80, are used for drilling the different sized holes in the different parts.

In all the various types of drill jigs described above, the thrust of the cutting tools is taken by the clamping arrangement. In many cases, however, no actual clamping arrangements are used, but the work itself takes the thrust of the cutting tools, and one depends entirely upon the locating means to hold the piece or jig in the right position when performing the drilling operation. It may be well to add that large bushings ought to be marked with the size and kind of cutting tool for which they are intended; and the corresponding place in the jig body where they are to be used should be marked so that the right bushing can easily be placed in the right position.

A few more examples of open drill jig designs of various types may prove instructive. In Fig. 81 are shown two views of a jig for drilling two holes through the rim of a hand-wheel. To the left is shown the jig itself and to the right the jig with the hand-wheel mounted in place, ready for drilling. As shown, the hand-wheel is located on a stud through its bore, and clamped to the jig by passing a bolt through the stud, this bolt being provided with a split washer on the end. The split washer permits the easy removal of the hand-wheel when drilled, and the putting in place of another hand-wheel without

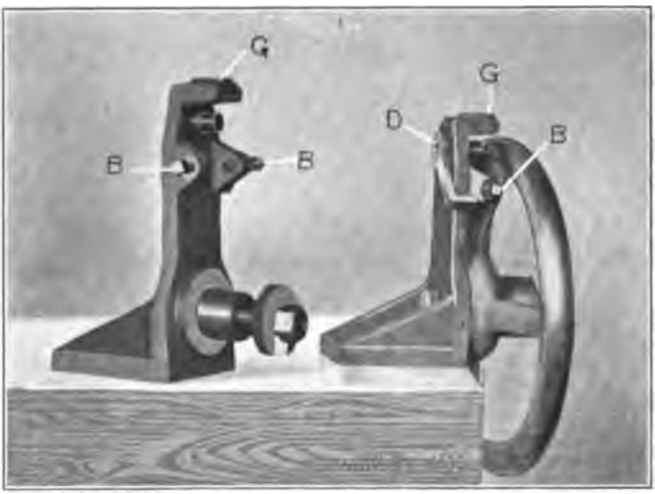


Fig. 81. Drill Jig for Holes in Rim of Hand-wheel

loss of time. The hand-wheel is located by two set-screws *B* passing through two lugs projecting on each side of a spoke in the hand-wheel, the set-screws *B* holding the hand-wheel in position while being drilled by clamping against the sides of the spoke. The jig is fastened on the edge of the drill press table, in a manner similar to that indicated in the half-tone, so that the table does not interfere with the wheel. The vertical hole, with the drill guided by bushing *G*, is now drilled in all the hand-wheels, this hole being drilled into a lug in the spoke held by the two set-screws *B*. When this hole is drilled, the jig is moved over to a horizontal drilling machine, and the hole *D* is drilled in all the hand-wheels, the jig being clamped to the table of this machine in a similar manner as on the drill press.

In Fig. 82, at *A*, an open drill jig of a type similar to those shown in Figs. 73 and 75, is shown. This jig, however, is provided with a V-block locating arrangement. An objectionable feature of this jig is that the one clamping strap is placed in the center of the piece to be drilled. Should this piece be slender, it may cause it to bend, as there is no bearing surface under the work at the place where the clamp is located, for taking the thrust of the clamping pressure.

At *B* and *C* in the same engraving are shown the front and back views of a drill jig, where the front side *B* is used for drilling a small piece located and held in the jig as usual; and the back side *C*, which

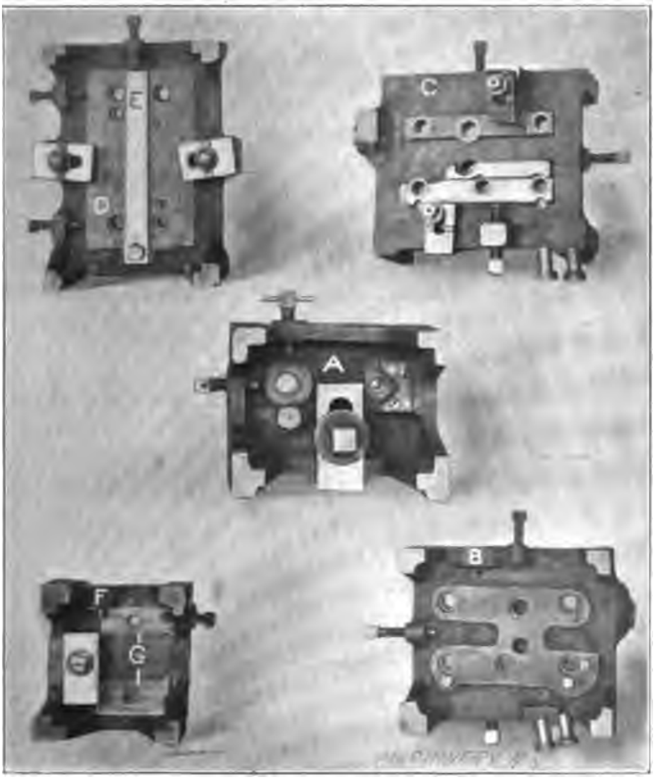


Fig. 82. Miscellaneous Examples of Open Drill Jigs

is not provided with feet, is located and applied directly on the work itself in the place where the loose piece is to be fastened, the work in this case being so large that it supports the jig, instead of the jig supporting the work.

At *D* in the same engraving is shown a jig for locating work by means of a tongue *E*. This tongue fits into a corresponding slot in the work. This means for locating the work was referred to more completely in connection with locating devices. Finally, at *F*, is shown a jig where the work is located by a slot *G* in the jig body, into which a corresponding tongue in the work fits.

CHAPTER VII

DESIGN OF CLOSED OR BOX JIGS*

In Chapters V and VI, the subject of the design of open drill jigs has been dealt with. In the present chapter it is proposed to outline the development of the design of closed or box jigs.

We will assume that the holes in a piece of work, as shown in Fig. 83, are to be drilled. Holes *A* are drilled straight through the work, while holes *B* and *C* are so-called "blind holes," drilled into the work from the opposite sides. As these holes must not be drilled through, it is evident that the work must be drilled from two sides, and the guiding bushings for the two blind holes must be put in opposite sides of the jig. The simplest form of jig for this work is shown in Fig. 84. The piece of work *D* is located between the two plates *E*, which form the jig, and which, if the jig be small, are made of machine steel and case-hardened. If the jig is large these plates

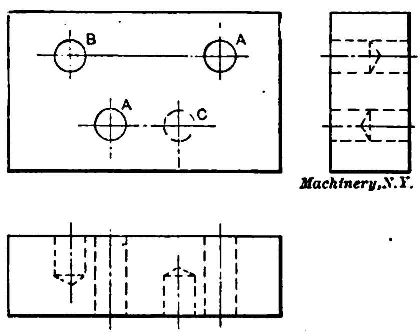


Fig. 83. Work to be Drilled

are made of cast iron. The work *D* is simply located by the outlines of the plates, which are made to the same dimensions, as regards width, as the work itself. The plates are held in position in relation to each other by the guiding dowel pins *F*. These pins are driven into the lower plate and have a sliding fit in the upper one. In some cases, blocks or lugs on one plate would be used to fit into a slot in the other plate instead of pins. These minor changes, of course, depend upon the nature of the work, the principle involved being that some means must be provided to prevent the two plates from shifting in relation to each other while drilling. The whole device is finally held together by clamps of suitable form. The holes *A* may be drilled from either side of the jig, as they pass clear through the work, and the guides for the drills for these holes may, therefore, be placed in either plate. Opposite the bushings in either plate a hole

* MACHINERY, November, 1908.

is drilled in the other plate for clearance for the drill when passing through, and for the escape of the chips.

The two plates should be marked with necessary general information regarding the tools to be used, the position of the plates, etc., to prevent mistakes by the operator. It is also an advantage, not to

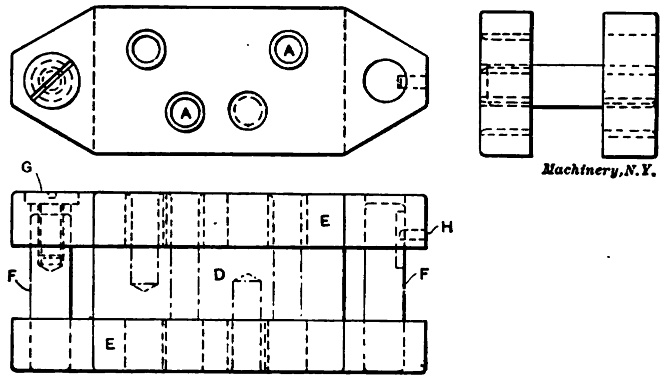


Fig. 84. Simplest Form of Closed Jig for Drilling Work in Fig. 83

say a necessity, to use some kind of connection between the plates in order to avoid such mistakes, as for instance, the placing of the upper plate in a reversed position, the wrong pins entering into the dowel pin holes. This, of course, would locate the holes in a faulty position. Besides, if the upper plate be entirely loose from the lower, it may

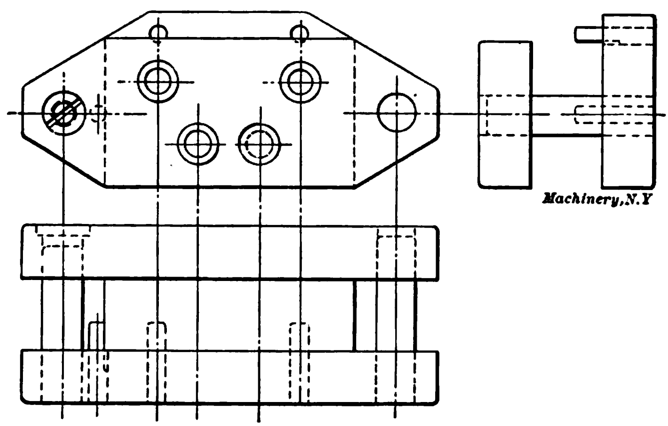


Fig. 85. Jig in Fig. 84 Improved by adding Locating Pins

drop off when the jig is stored, and get mixed up with other tools. Some means of holding the two parts together, even when not in use, or when not clamped down on the work, should therefore be provided. Such a means is employed in Fig. 84, where the screw *G* enters into the guiding dowel pin at the left, and holds the upper plate in place. A pin *H*, fitting into an elongated slot in the dowel pin as shown at the left, could also be used instead of the screw. The design shown presents the very simplest form of box jig, consisting, as it does, of only two plates for holding the necessary guiding arrangements, and two pins or other means for locating the plates in relation to each other.

In manufacturing, where a great number of duplicate parts would be encountered, a jig designed in the simple manner shown in Fig. 84 would, however, be wholly inadequate. The simplest form of a jig that may be used in such a case would be one in which some kind of locating means is employed, as indicated in Fig. 85, where three pins are provided, two along the side of the work, and one for the end of the work, against which the work may be pushed, prior to the clamping together of the two jig plates. In this figure the jig bushings are not shown in the elevation and end view, in order to avoid confusion of lines. The next improvement to which this jig would be subject would be the adding of walls at the end of the jig and the screwing

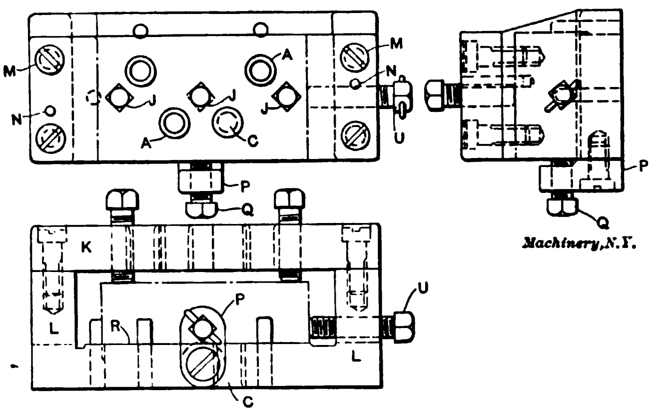


Fig. 86. Further Improvements in Jig, suiting it to Manufacturing Purposes

together of the upper and lower plate, the result being a jig as shown in Fig. 86. This design presents a more advanced style of closed jig—a type which could be recommended for manufacturing purposes. While the same fundamental principles are still in evidence, we have here a jig embodying most of the requirements necessary for rapid work. This design provides for integral clamping means within the jig itself, this being provided in this case by the screws *J*. The upper plate *K* is fastened to the walls of the lower plate *L* by four or more screws *M*, and two dowel pins *N*. The cover *K* could also be put on, as shown in Fig. 87, by making the two parts a good fit at *O*, one piece being tongued into the other. This gives greater rigidity to the jig. In this jig, also, solid locating lugs *F* are used instead of pins.

Referring again to Fig. 86, by providing a swinging arm *P* with a set-screw *Q*, the work can be taken out and can be inserted from the side of the jig, which will save making any provisions for taking off or putting on the top cover for every piece being drilled. If there is enough clearance between the top cover and the piece being drilled, the screw *Q* could, of course, be mounted in a solid lug, but it would not be advantageous to have so large a space between the top plate and the work, as the drill would have to extend unguided for some distance before it would reach the work. The set-screws *Q*

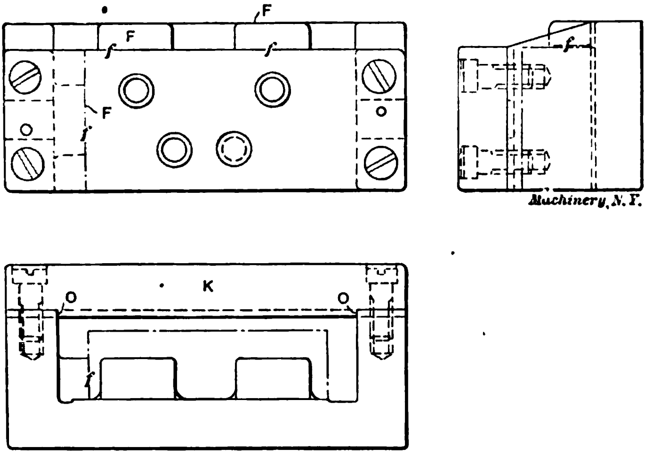


Fig. 87. Alternative Design of Jig shown in Fig. 86

and *U* hold the work against the locating points, and the set-screws *J* on the top of the jig, previously referred to, hold the work down on the finished pad *R* on the bottom plate. These screws also take the thrust when the hole *C* is drilled from the bottom side. It is rather immaterial on which side the bushings for guiding the drills for the

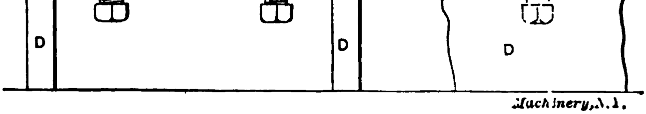


Fig. 88. Showing Use of Jig in Fig. 86 in Combination with Two Parallels

two holes *A* are placed, but by placing them in the cover rather than in the bottom plate, three out of the four bushings will be located in the top part, and when using a multiple spindle drill, the face *R* will take the greater thrust, which is better than to place the thrust on the binding screws *J*. In the designs in Figs. 86 and 87 the whole top and bottom face of the jig must be finished, or a strip marked *f* in

Fig. 88, at both ends of the top and bottom surfaces, must be provided, so that it can be finished, and the jig placed on parallels *D* as illustrated.

While the jig itself, developed so far, possesses most of the necessary points for rapid production and accurate work, the use of parallels, as indicated in Fig. 88, for supporting the jig when turned over so that the screw heads of the clamping screws point downward, is rather unhandy. Therefore, by adding feet to the jig, as shown in Fig. 89, the handling of the jig will be a great deal more convenient. The adding of the protruding handle *S* will still further increase the convenience of using the jig. The design in Fig. 89 also presents an improvement over that in Fig. 86 in that besides the adding of feet and handle, the leaf or strap *E* is used for holding screw *Q* instead of the arm *P*. This latter is more apt to bend if not very heavy, and would then bring the set-screw in an angle upwards, which would

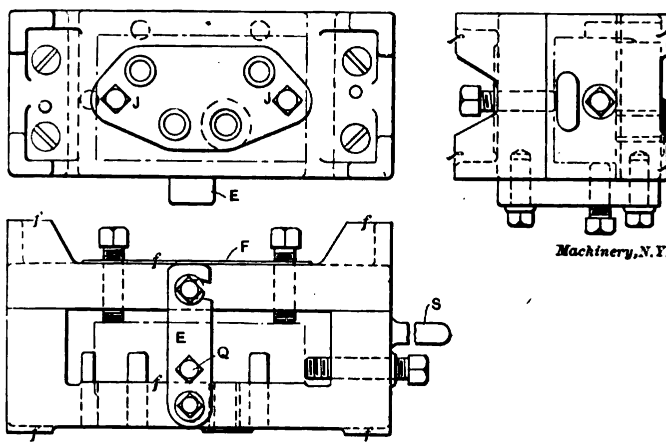


Fig. 89. Jig Improved by adding Feet opposite Faces containing Drill Bushings

have a tendency to tilt the work. The strap can be more safely relied upon to clamp the work squarely. To set-screws *J* are shown for holding the work in place. The number of these set-screws, of course, depends entirely upon the size of the work, and the size of the holes to be drilled. Sometimes one set-screw is quite sufficient, which, in this case, would be placed in the center, as indicated by the dotted lines in Fig. 86.

The type of jig shown in Fig. 89 now possesses all the features generally required for a good jig, and presents a type which is largely used in manufacturing plants, particularly for fairly heavy work. The jig shown in Fig. 90, however, represents another type, somewhat different from the jig in Fig. 89. The jig in Fig. 89 is composed of two large separate pieces, which, for large jigs, means two separate castings, involving some extra expense in the pattern-shop and foundry. The reason for making the jig in two parts, instead of casting it in one, is because it makes it more convenient when machining the jig. The locating points, however, are somewhat hidden from view when the piece is inserted. The jig shown in Fig. 90 consists of only one casting *L*, provided with feet, and resembles an open drill jig. The work is located in a manner similar to that already described, and the leaf *D*, wide enough to take in all the bushings except the one for the hole that must be drilled from the opposite side, is fitted across the jig and given a good bearing between the lugs in the jig wall. It swings around the pin *E*, and is held down by the eye-bolt *F* with a nut and washer. Sometimes a wing-nut is handier than a hexagon nut. Care should be taken that the feet reach below the top of the nut and screw. The set-screw *G* holds the work down, and takes the thrust when the hole from the bottom side is drilled. The three holes *AA* and *B* are drilled from the top so that the thrust of

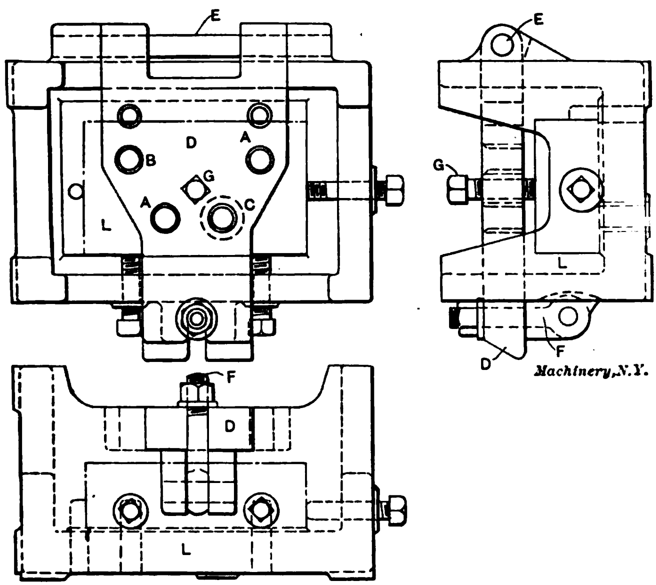


Fig. 90. Alternative Design of Jig in Fig. 89

the drilling these three holes will be taken by the bottom of the jig body *L*. If one set-screw *G* is not sufficient for holding the work in place, the leaf may be made wider so as to accommodate more binding screws.

It should be mentioned here, however, that it is an objectionable feature to place the clamping screws in the bushing plate. If the leaf has not a perfect fit in its seats and on the swiveling pin, the screws will tilt the leaf one way or another, and thus cause the bushings to stand at an angle with the work, producing faulty results. In order to avoid this objectionable feature, a further improvement on the jig, indicated in Fig. 91, is proposed. In the jig body, the locating points and the set-screws which hold the work against the locating pins are placed so that they will not interfere with two straps *G*, which are provided with elongated slots, and hold the work securely in place, also sustaining the thrust from the cutting tools. These straps should be heavily designed, in order to be able to take the thrust of the multiple spindle drill, because in this case all the bushings except the one for hole *B* are placed in the bottom of the jig body. The leaf is made narrower and is not as heavy as the one shown in Fig. 90, because it does not, in this case, take any thrust when drilling, and simply serves the purpose of holding the bushing for hole *B*. The leaves and loose bushing plates for jigs of this kind are generally made of machine steel, but for larger sized jigs they may be made of cast iron. The leaf in Fig. 91 is simply held down by the thumb-screw *H* of a type as shown in Fig. 48 in Chapter IV.

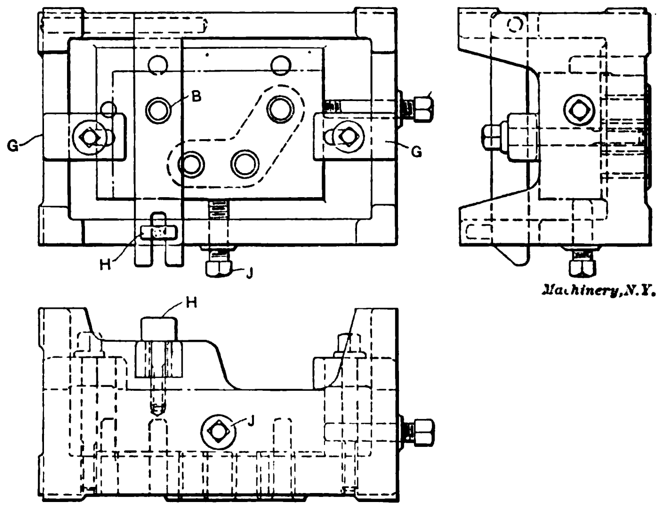


Fig. 91. Jig where Thrust of Drilling Operation is taken by Clamps

If the hole *B* should be near to one wall of the jig, it may not be necessary to have a leaf, but the jig casting may be made with a projecting lug *D*, as shown in Fig. 92, the jig otherwise being of the same type as the one illustrated in Fig. 91. The projecting part *D*, Fig. 92, is strengthened, when necessary, by a rib *E*, as indicated. Care must be taken that there is sufficient clearance for the piece to be inserted and removed. Once in a while it happens, even with fairly good jig designers, that an otherwise well-designed jig with good locating, clamping, and guiding arrangements, is rendered useless for the simple reason that there is not enough clearance to allow the insertion of the work. The jig shown in Fig. 92 resembles, in reality, an open jig more than a closed jig.

Fig. 93 shows the same jig as before, but with the additional feature of permitting a hole in the work to be drilled from the end and side as indicated, the bushings *E* and *F* being added for this purpose. It will be noticed that the bushings in this case extend through the jig wall for some distance, in order to guide the drill closely to the work. Bosses may also be cast on the jig body, as indicated by the dotted lines, to give a longer bearing for the bushings.

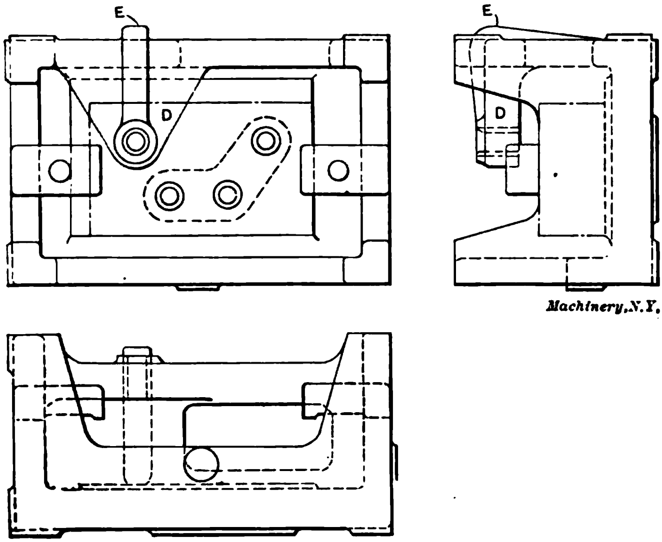


Fig. 92. Modification of Jig in Fig. 91, which practically brings it into the Class of Open Drill Jigs

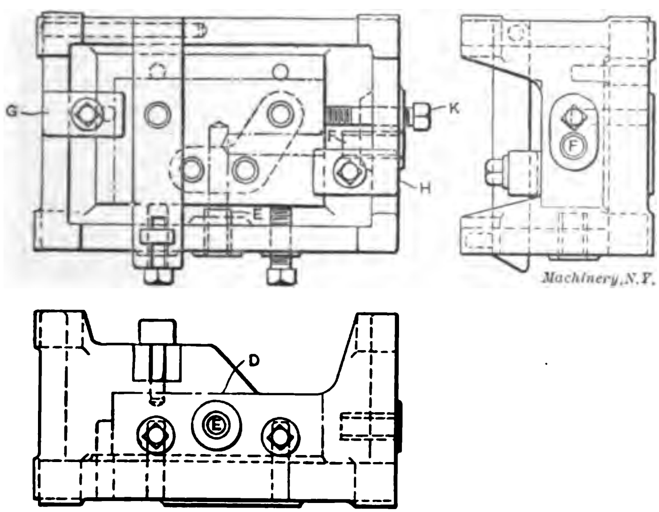


Fig. 93. Jig for Drilling Holes from Two Directions

Feet or lugs are cast and finished on the sides of the jig opposite the bushings, so that the jig can be placed conveniently on the drill press table for drilling in any direction. It will be noticed that when drilling the holes from the bushings *E* and *F*, the thrust is taken by the stationary locating pins. It is objectionable to use set-screws to take the thrust, although in some cases it is necessary to do so. When designing a jig of this type, care must be taken that strapping arrangements and locating points are placed so that they, in no way, will interfere with the cutting tools or guiding means. In this case the strap *H* is moved over to one side in order to give room for the bushings *F* and the set-screw *K*. Strap *G* should then be moved also, because moving the two straps in opposite directions still gives them a balanced clamping action on the work. If the strap *G* had been left in place, with the strap *H* moved sideways, there would have been some tendency to tilt the work.

Sometimes one hole in the work comes at an angle with the faces of the work. In such a case the jig must be made along the lines

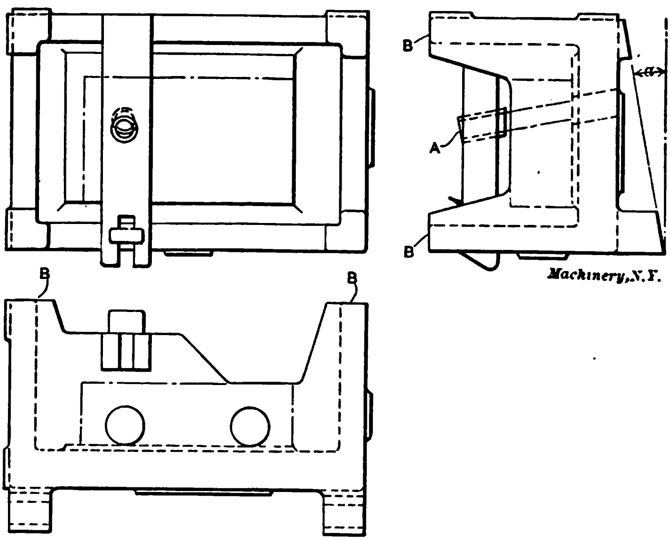


Fig. 94. Jig for Drilling Holes at an Angle

indicated in Fig. 94, the feet on the sides opposite to where the drill bushings are placed being planed so that their faces will be perpendicular to the axis through the hole *A*. This will, in no way, interfere with the drilling of holes which are perpendicular to the faces of the work, as these can be drilled from the opposite side of the work, the jig then resting on the feet *B*. Should it, however, be necessary to drill one hole at an angle, and other holes perpendicular to the face of the work from the same side, an arrangement as shown in Fig. 95 would be used. The jig here is made in the same manner as the jig shown in Fig. 93, with the difference that a bushing *A* is placed at the required angle. It will be seen, however, that as the other holes drilled from the same side must be drilled perpendicularly to the faces of the work, it would not be of advantage to plane the feet so that the hole *A* could be drilled in the manner previously shown in Fig. 94. Therefore the feet are left to suit the perpendicular holes, and the separate base bracket *B*, Fig. 95, is used to hold the jig in the desired inclined position when the hole *A* is drilled.

Stand *B* in Fig. 95 is very suitable for this special work. It will be noticed that it is made up as light as possible, being cored at the center,

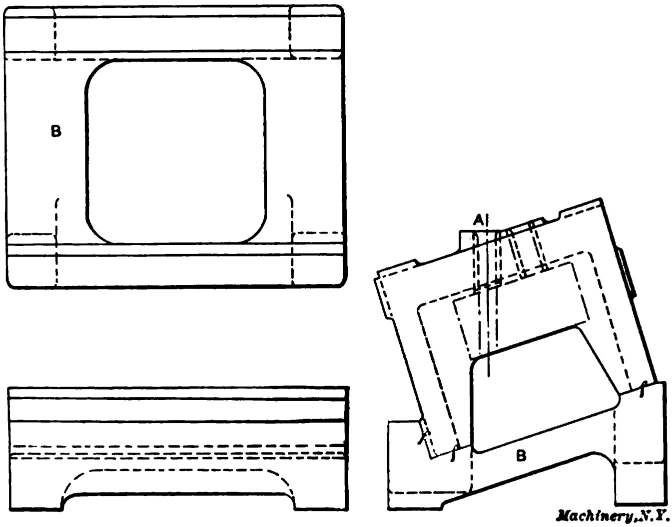


Fig. 95. Jig and Stand for Drilling Holes at an Angle

so as to remove superfluous metal. These stands are sometimes provided with a clamping device for holding the jig to the stand. Special stands are not only used for drilling holes at angles with the remaining holes to be drilled, but sometimes special stands are made to

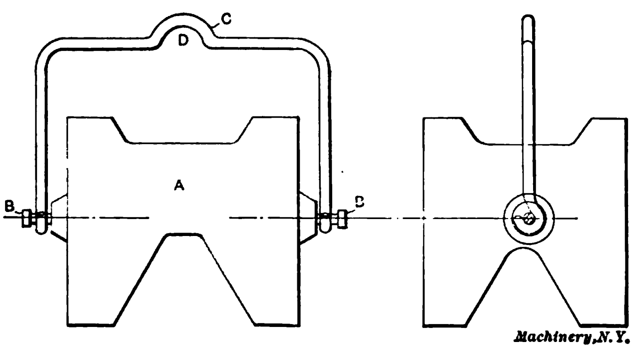


Fig. 96. Device for Turning over and Handling Heavy Jigs

suit the jig in cases where it would be inconvenient to provide the jig with feet, finished bosses or lugs, for resting directly on the drill press table.

When a jig of large dimensions is to be turned over, either for the insertion or removal of the work, or for drilling holes from opposite sides, a helper will have to be called upon to assist the operator. The disadvantage of this is readily seen. In cases where the use of a crane or hoist can be obtained, it is very satisfactory to have a special device attached to the jig for turning it over. Fig. 96 shows such an arrangement. In this engraving, *A* represents the jig which is to be turned over. The two studs *B* are driven into the jig in convenient places, as near as possible in line with a gravity axis. These studs then rest in the yoke *C*, which is lifted by the crane hook placed at *D*. The jig, when lifted off the table, can then easily be swung around. The yoke is made simply out of round machine steel.

Comparing what has been said above with the outline of the development of open jigs in Chapter V, it will be seen that the principles involved are exactly the same, and that the development of jigs for various purposes is simply the application of these principles to the work in hand, with an appropriate amount of common sense. The previous statements may be considered the A, B, C of jig making, and contain, of necessity, only the main principles on which the jig design is based.

CHAPTER VIII

EXAMPLES OF CLOSED OR BOX JIGS*

In the previous chapter, the development of a closed or box jig was treated. In the present chapter a number of examples of closed jig designs will be shown and described. There is, however, no distinct division line between open and closed drill jigs, so that in many cases it is rather inconsistent to attempt to make any such distinction.

In Fig. 97, for instance, is shown a box jig which looks like a typical open jig. The jig body *A* is made in one solid piece, cored out as shown, in order to make it lighter. The piece to be drilled, *B*, shown inserted in the jig, has all its holes drilled in this jig, the

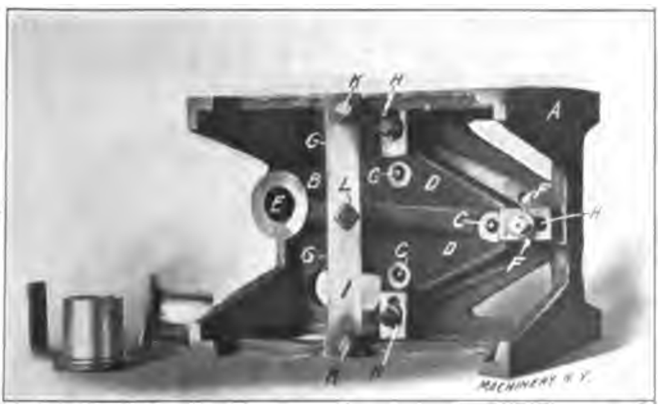


Fig. 97. Box Jig which Resembles the Open Type

holes being the screw holes *C*, the dowel pin holes *D*, and the large bearing hole *E*. The bosses of the three screw holes *C* are also faced on the top, and the bearing is faced on both sides while the work is held in the jig. The work is located against two dowel pins driven into the holes *F*, and against two lugs at *G*, not visible in the engraving, located on either side of the work. In these lugs are placed set-screws or adjustable sliding points such as described in Chapter III. It may seem incorrect not to locate the bracket in regard to the hole *E* for the bearing, so as to be sure to bring the hole concentric with the outside of the boss. This ordinarily is a good rule to follow, but in this particular case it is essential that the screw holes be placed in a certain relation to the outline of the bracket in order to permit this to match up with the pad on the machine on which the bracket is used. Brackets of this shape may be cast very

* MACHINERY, December, 1908.

uniformly, so that locating them in the manner described will not seriously interfere with drilling the hole *E* approximately in the center of its boss. The work is firmly held in the jig by the three straps *H*, care being taken in designing the jig that these straps are placed so they will not interfere with the facing tools.

The swinging strap *I*, which really is the only thing that makes this jig a closed jig, serves the sole purpose of taking the thrust of the heavy cutting tools when drilling the hole *E* and of steadying the work when facing off the two ends of the hub. The two collar-head screws *K* hold the strap to the jig body and the set-screw *L* bears against the work. This strap is easily swung out of the way

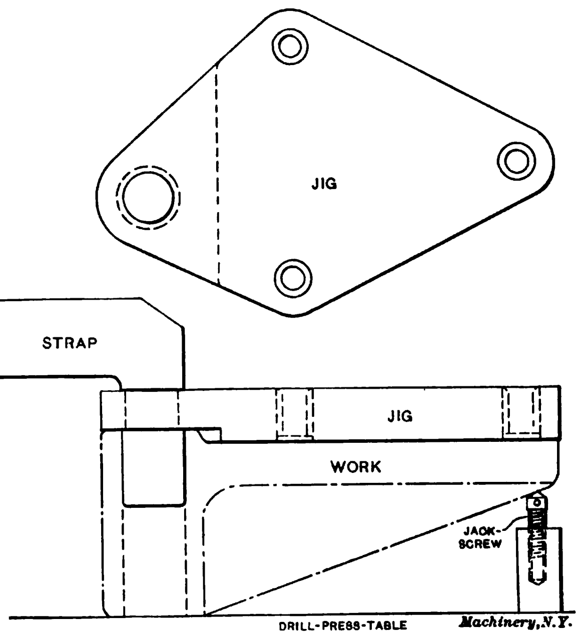


Fig. 98. Simple Form of Plate Jig for Drilling Bracket shown in Fig. 97, after Hole E has been bored in the Lathe

simply by loosening one of the collar-head screws, a slot being milled at one end of the strap to permit this. Stationary bushings are used for the screw hole and dowel holes, but for the bearing hole *E* three loose bushings and a lining bushing are employed. The hole *E* is first opened up by a small twist drill, which makes the work considerably easier for the so-called rose-bit drill. The latter drill leaves 1/16 inch of stock for the rose reamer to remove, which produces a very smooth, straight and concentric hole. The last operation is the facing of the holes. The holes just drilled are now used to guide the pilots of the facing tools, and as the operation is performed while the work is held in the jig, it is important that the locating or strapping arrangements should not be in the way.

In connection with the opening up of a hole with a smaller drill, it may be mentioned that it is not only for large holes that this method of procedure will save time, but the method is a time-saving one also for smaller holes, down to ¼ inch in diameter when drilled in steel.

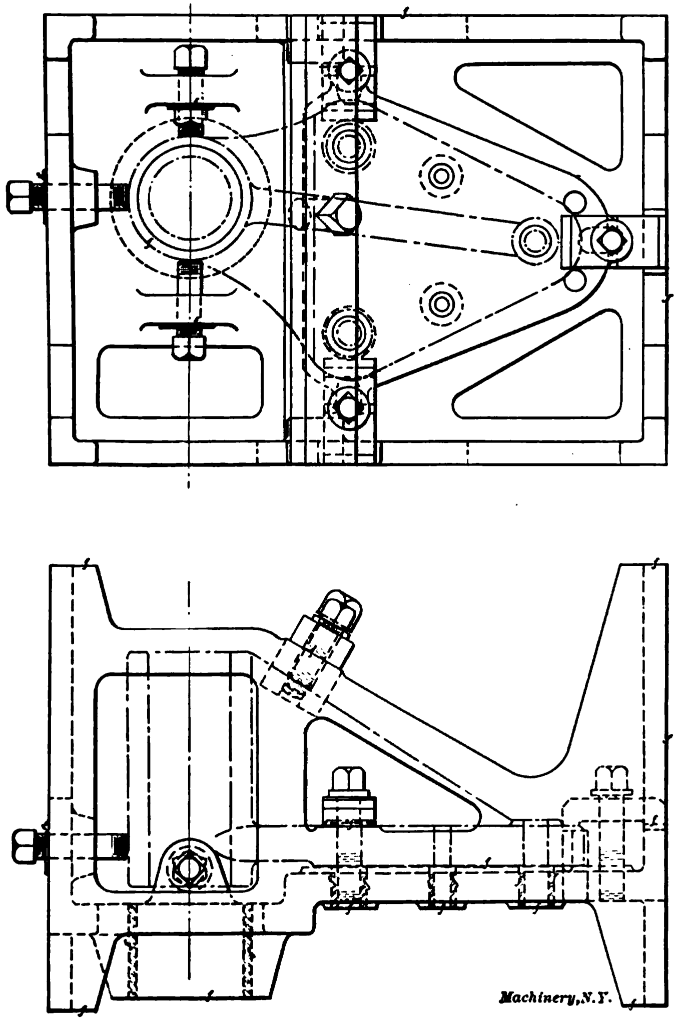


Fig. 99. Plan and Elevation of the Jig shown in Fig. 97

The use of lubrication in jigs is a very important item, the most common lubricant being oil or vaseline, but also soap solution is used. The objection to the latter is that unless the machine and tools are carefully cleaned, it is likely to cause rusting. Using a lubricant freely will save the guiding arrangements, such as the drill bushings, the pilots on counterbores, etc., to a great extent.

The jig in Fig. 97 is shown in Fig. 99, and a clear idea of the design of the jig will be had by studying this line engraving. The bracket *B*, in Fig. 97, could have been drilled in a different way than described, which will sometimes be an advantage. It could be held in a chuck, and the hole *E* reamed and faced in a lathe, which would insure that the hole would be perfectly central with the outside of the boss. Then a jig could be designed, locating the work by a stud entering in hole *E*, as indicated in Fig. 98, additional dowel pins and set-screws being used for locating the piece sidewise. The whole arrangement could be held down to the table by a strap and bolt, a jack-screw supporting it at the overhanging end.

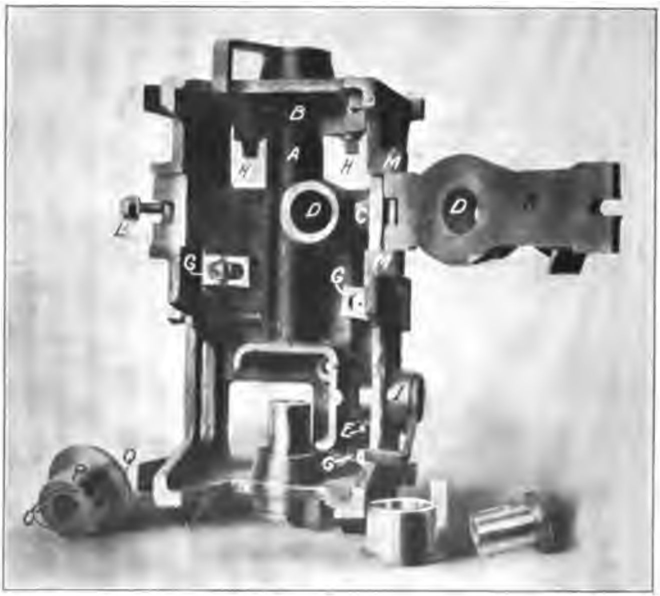


Fig. 100. Box Jig for Casing drilled from Five Directions

Fig. 100 shows another jig of the closed type, with the work inserted. The piece *A* is a casing, and the holes to be drilled vary greatly in size. The casing rests on the flat, finished bottom surface of the jig and is brought up squarely against a finished pad at *B*. It further locates against the finished lug *C* in order to insure getting the proper amount of metal around the hole *D*. At the bottom it is located against the sliding point *E*, the latter being adjustable because the location of the work is determined by the other locating points and surfaces. The work is held against the locating points by the long set-screws shown to the left. This clamping arrangement, however, is not to be recommended because this screw must be screwed back a considerable distance in order to permit insertion and removal of the work. An eye-bolt used in the manner previously described in Chapter IV of Part I would have given better service. The three straps *G* hold the work against the bottom surface, and the two straps *H* hold it against the finished surface at *B*. There is not a long finished hole through the casting, as would be assumed from its appearance, but simply a short bearing at each end, the remaining part of the hole being cored out. For this reason the hole is drilled and reamed instead of being bored out, as the latter operation would be a slower one. Although the two short bearings are somewhat far apart, the guiding bushings come so close to these bearings that the alignment can be made very good. The screw holes and dowel pin holes at

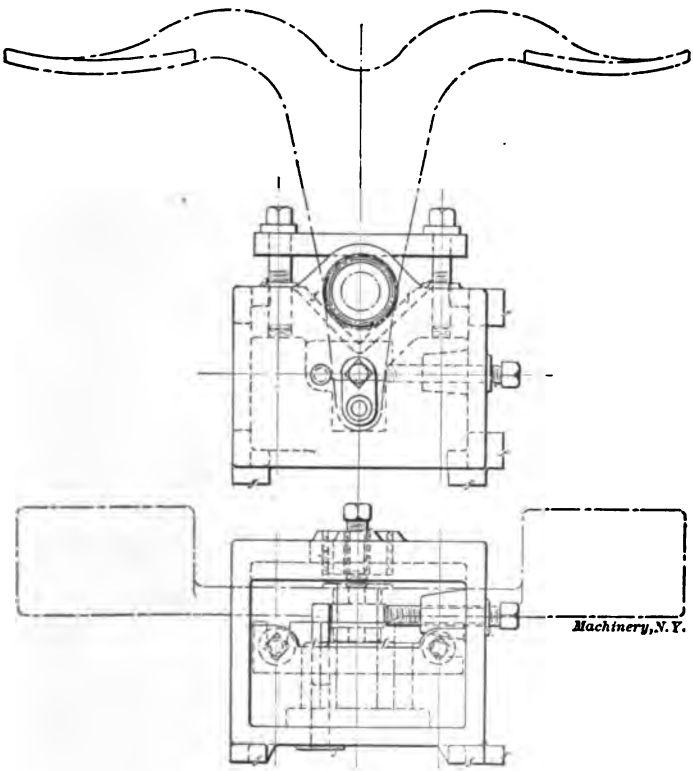


Fig. 101. Box Jig for Drilling Work shown in Dash-dotted Lines

the bottom of the casing are not shown in the half-tone, as the inserted casing is not yet drilled. The hole drilled from bushing *I* is a rather important hole, and the bushing requires a long bearing in order to guide the drills straight when drilling. When this jig was made, the projecting lug which was provided solid with the jig body, to give a bearing to the jig bushing, came so much out of the way in the rough casting for the jig that half of the lining bushing would have been exposed. It was therefore planed off and a bushing of the type shown in Fig. 9, Chapter II, inserted instead, in order to provide for a long bearing.

Leaf *K*, which carries the bushings for drilling the hole *D*, fits into a slot planed out in the jig body and is held down by the eye-bolt *L*. Two lugs *M* are provided on the main casting for holding the pin on which the leaf swivels, the construction being of the same type as illustrated in Fig. 50, Chapter IV. Around the hole *D* there are three small tap holes *O* which are drilled by the guiding afforded by the bushing *P*, which is made of cast iron and provided with small steel bushings placed inside as illustrated in Fig. 16, Chapter II. In the bushing *P* is another hole *Q* which fits over a pin located in the top of the leaf and which insures that the three screw holes will come in the right position. It should be noted that large portions of the jig body are cored out at top and bottom in order to

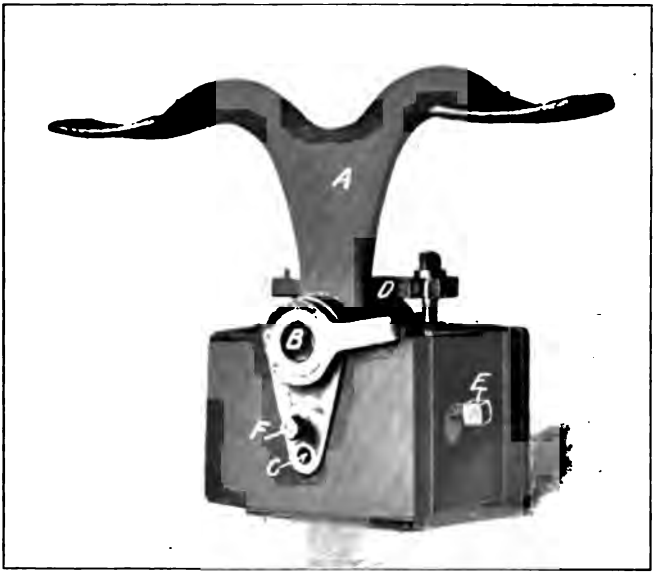


Fig. 102. Jig shown in Detail in Fig. 101

make it light and easy to handle. Of course some metal is also saved by the construction of jigs in this manner, but comparing the price of cast iron with the total price of a finished jig of this type, the saving in this respect is so insignificant that it is not worth while mentioning. The leaf *K* is also made of cast iron, being of particularly large size, and it is planed at the places where it has a bearing on the jig body.

Fig. 102 shows a closed jig about which there can be no doubt but that it should be classified as a box jig. The piece of work drilled, the foot trip *A*, has two holes *B* and *C* which are drilled in this jig. The cylindrical hub of the work is located against V-blocks and held in place by a swinging strap *D*. The work is further located against a stop pin placed opposite the set-screw *E*. The trip is located sidewise by being brought against another stop by the set-screw *F*. One-quarter of a turn of the collar-head screw on the top of the jig releases the swinging strap which is then turned out of the way; this permits the trip to be removed and another to be inserted. Half a turn or less of the set-screws is enough to release and clamp the work against the stops mentioned. A line engraving of this jig is shown

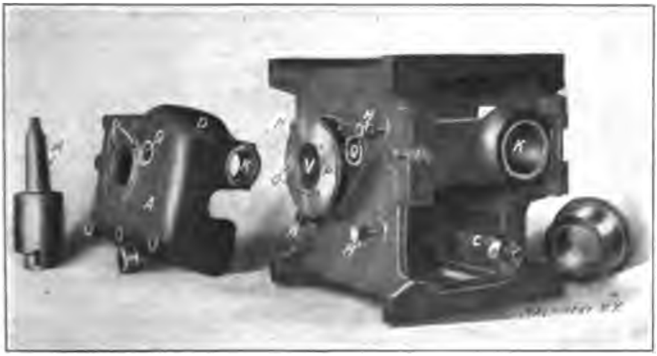


Fig. 103. Jig of Typical Design, and Work for which it is Used

in Fig. 101 which gives a better idea of some of the details of the construction.

In Figs. 103 and 104 are shown two views of another type of closed drill jig. The work *A*, to be drilled, is shown at the left in both illustrations, and consists of a special lathe apron with large bearing holes, screw holes, and dowel pin holes to be drilled. The apron is located

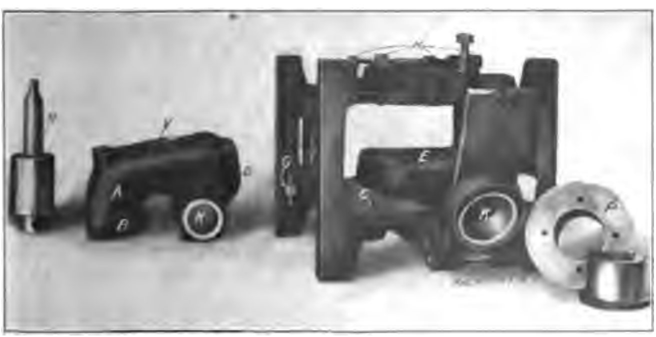
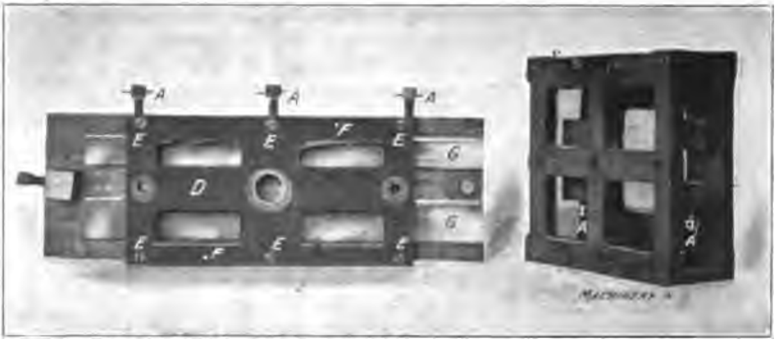


Fig. 104. Another View of the Jig in Fig. 103

in the jig body in the same manner as it is located on the lathe carriage, in this case by a tongue which may be seen at *B* in Fig. 104. This tongue fits into the slot *C* in the jig, care being taken in the construction of the jig that the slot is made deep enough to prevent the tongue from bearing in the bottom of the slot. A good solid bearing should be provided, however, for the finished surface on both sides of the tongue. The surface *D* should also have a solid bearing on the surface E in the jig, the difference in height between the two bearing surfaces in the jig being exactly the same as between the two bearing surfaces on the lathe carriage where the lathe apron is to be fitted. The work is brought up against, and further located by, a dowel pin at the further end of the slot, by the set-screw in the block F, Fig. 103. As



Figs. 105 and 106. Jigs in which the Work is Located by Means of Beveled Surfaces

it is rather difficult to get the tongues on all the pieces exactly the correct width for a good fit in the slot, the latter is sometimes planed a little wider and the tongue is brought up against one side of the slot by set-screws. In the case in hand, a few thousandths inch clearance is provided in the slot and the set-screw G in Fig. 104 is used

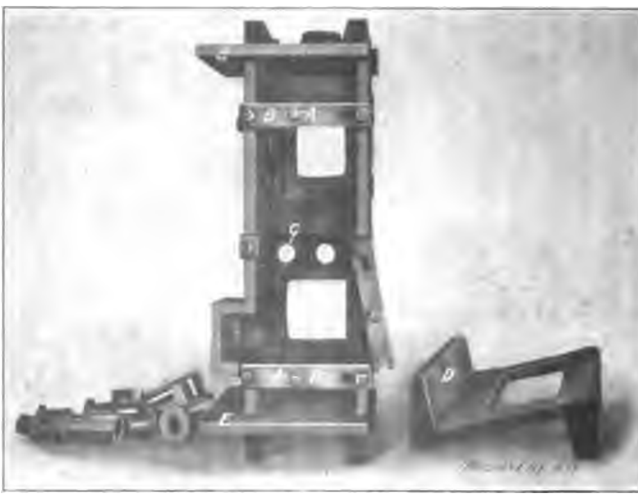


Fig. 107. Jig for Drilling Holes at other than 90-degree Angles

for bringing the work against the further edge which stands in correct relation to the holes to be drilled. The apron is held down against the bottom surface of the jig by four heavy set-screws H.

It will be noticed that the jig is open right through the sides in order to facilitate the finishing of the pads at the ends of the work, and a swinging leaf like the one previously described, reaches across one side for holding the lining and loose bushings for the hole *K* which is drilled and rose-reamed in the usual way. The large hole *V*, Fig. 103, is bored out with a special boring tool *M*, as there are no standard drills obtainable for this large size of hole. This special boring tool is guided by a cast iron bushing which fits into the lining bushing; it is provided with two cutters, one for roughing and one for finishing. The small screw holes *O* around the large hole *V* are drilled from the bushing *P*. For drilling the rest of the holes, except the hole *Q*, stationary bushings are used. The screw holes ought to be drilled simultaneously in a multiple spindle drill. The jig is provided with feet and cored out in convenient places in order to make it as light as possible to handle. Lugs project wherever necessary to give ample

Fig. 108. Jig in Fig. 107 in Position for Drilling Holes at an Oblique Angle with Jig Base

bearings to the lining bushings and, in turn, to the loose guiding bushings.

Figs. 105 and 106 show two closed jigs made up of two main parts which are planed and assembled by screws and dowels as indicated, the reason for making the jigs in this way being the ease of planing the bottom section. The work drilled in these jigs, some special slides, is located by the dove-tail and held up against one dove-tail side by set-screws *A*, as shown in both illustrations. In Fig. 105 the work is located endwise against a dowel pin and is held up against this stop by a set-screw through the block shown to the left. This block must be taken out when the slide is inserted, this being the reason why a lug cast directly in place, through which the set-screw could pass, is not used. The top plate *D* is held down on the main body by six fillister-head screws *E*, and two dowel pins *F* prevent it from shifting. No clamping arrangements, except the set-screws *A*, are necessary. The holes being drilled from the top, the main body of the jig takes the thrust. These jigs are also used in multiple spindle drills.

One objectionable feature of the jig in Fig. 106 is that set-screws *A* are difficult of access. There are, therefore, holes piercing the heads of the set-screws in two directions in order to allow a pin to be used when tightening the screws. A better idea, however, is to have the screw heads extend out through the wall, and if this is solid, to have cored or drilled holes through which the heads of the screws may pass.

In Fig. 107 is another closed drill jig in which the work is located against the finished seats and held down by the set-screws *A* in the straps *B*. All the holes, except the holes marked *C*, are drilled in the usual manner, the jig standing on its own feet, but when drilling the holes *C*, which come on an angle, the special stand *D* is employed which brings the holes in the right position for drilling, as illustrated in Fig. 108. If only the holes *C* were to be drilled, the feet on the side opposite the guiding bushing for these holes could have been planed off, so that they would have been in a plan perpendicular to the axis of the holes. This last jig has a peculiar appearance on account of the end walls coming up square, as shown in the illustrations, but this design was adopted only to simplify matters for the patternmaker, it being easier to make the pattern this way.

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JIGS AND FIXTURES—PART III

CHAPTER IX

PRINCIPLES OF BORING JIGS*

Boring jigs are as commonly used as drill jigs, in interchangeable manufacturing, and the requirements placed on drill jigs apply in most respects to boring jigs. Boring jigs are generally used for machining holes where accuracy of alignment and size are particularly essential, and also for holes of large sizes where drilling would be out of the question. Two or more holes in the same line are also, as a rule, finished with the aid of boring jigs.

The boring operation is performed by boring bars having inserted cutters of various kinds, and boring jigs are almost always used in connection with this kind of boring tool, although boring operations may be satisfactorily accomplished with three or four lipped drills and reamers. The reamers may be made solid, although most frequently shell reamers mounted on a bar and guided by bushings are used. The majority of holes produced in boring jigs, whether drilled or bored out, are required to be of such accuracy that they are reamed out in the last operation.

The boring bars are usually guided by two bushings, one on each side of the bored hole, and located as close as possible to each end of the hole being bored. The bar is rotated and simultaneously fed through the work, or the work with its jig is fed over the rotating bar. Boring jigs may be used either in regular boring lathes, in horizontal boring and drilling machines, or in radial drills.

The jig body is made either in one solid piece or composed of several members, the same as in drill jigs. The strain on boring jigs is usually heavy, which necessitates a very rigidly designed body with ribbed and braced walls and members, so as to allow the least possible spring. As boring jigs when in operation must be securely fastened to the machine table, means must also be provided in convenient and accessible places for clamping the jig without appreciably springing it.

The places in the jig where the bushings are located should be provided with plenty of metal so as to give the bushings a substantial bearing in the jig body. Smaller jigs should be provided with a tongue or lip on the surface which is clamped to the machine table; this permits the operator to quickly locate the jig in the right position. As an alternative, finished lugs locating against a parallel or square may be provided. It is frequently advantageous to have small sized boring jigs provided with feet so that they can be used on a

* MACHINERY, January, 1909.

regular drill press table in cases where holes to be bored out are to be opened up with a drill piercing the solid metal. It is both easier and cheaper to do this rough drilling in a drill press.

The guide bushings, of the same type as the bushings for drill jigs, are made either of cast iron or steel and ground to fit the boring bar, which is also ground. The bars are made of machine steel and should be made as heavy as possible, in order to prevent them from bending or springing too much should there be a heavier cut on one side than on the other. The bushings should be made rather long to insure good bearing.

The most common type of boring jig for small and medium size work is shown in Fig. 109. In this engraving, *A* represents the work which is held down by straps or clamps. In many instances when the work is provided with bolt and screw holes before being bored, these holes are used for clamping the work to the jig. In some cases

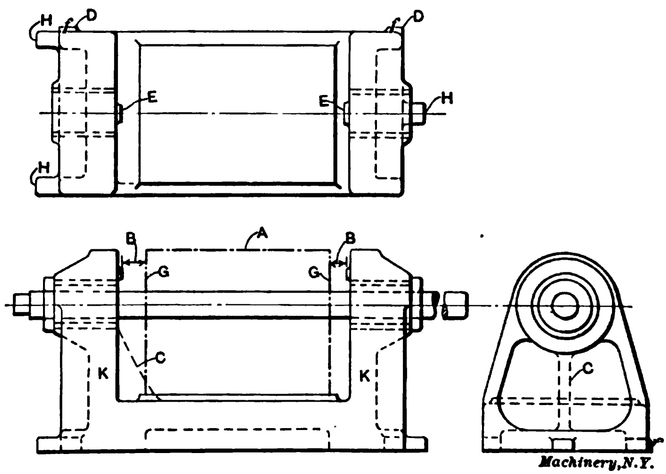


Fig. 109. General Outline of Simple Boring Jig

it is important that the work be attached to the jig in the same way as it is fastened to its component part in the machine for which it is made, and also that it be located in a similar way. If the work is located by V-slides when in use on the machine, it is preferable to locate it by V's in the jig. In other cases the locating arrangement for the work in the machine where it is to be used may be a tongue, a key, a dowel pin, a finished pad, etc. The same arrangement would then be used for locating it in the jig. In Fig. 109 enough clearance is left at *B*, at both ends, to allow for variations in the casting and to provide space for the chips; also, if the hole is to be reamed out, and the reamer be too large to go through the lining bushing, then the space left provides room for inserting the reamer and mounting it on the bar. In nearly all cases of boring, a facing operation of the bosses in the work has also to be carried out and provisions must be made in the jig to permit the insertion of facing tools.

A great deal of metal may be saved in designing heavy jigs by removing superfluous metal from those parts where it does not materially add to the strength of the jig. In Fig. 109, for instance, the jig can be cored out in the bottom and in the side standards as indicated without weakening the jig to any appreciable extent. The rib *C* may be added when necessary, and when it does not interfere with the work to be finished in the jig. It will be seen that extended bosses are carried out to provide long bearings for the bushings. The bosses may be made tapering, as shown, providing practically the same stiffness as a cylindrical boss containing considerable more metal. They must be given a rather liberal diameter, as they may not always be placed exactly correct on the pattern, and consequently be a little out of center in the casting. Finished bosses should be located at suitable places to facilitate the laying out and the making of the jig,

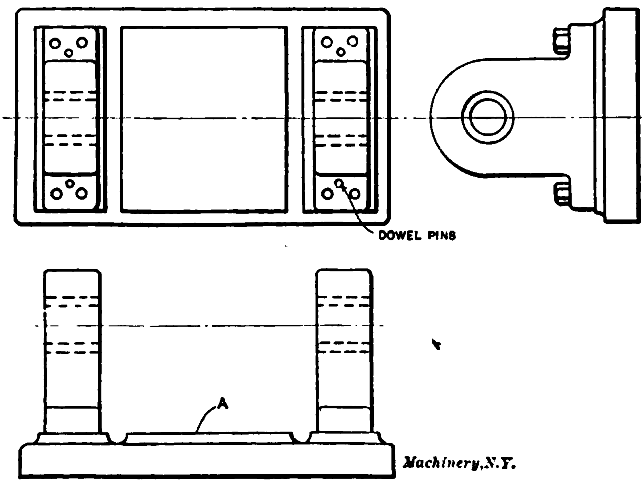


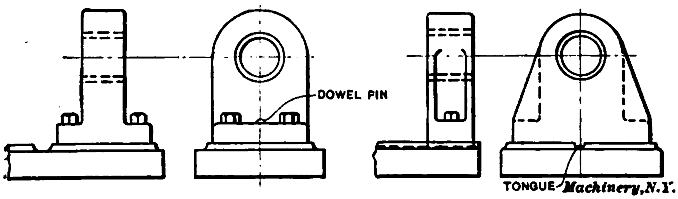
Fig. 110. Boring Jig with Base Separate from Side Standards

as shown at *D* in Fig. 109. The finished faces of these bosses are also of advantage when locating the jig against a parallel, when it is not provided with a tongue for locating purposes.

In some cases bosses are placed where measurements may be taken from the finished face to certain faces of the work, in which case the finished bosses, of course, must stand in a certain relation to the locating point; such bosses are indicated at *E*, from which measurements *B* can be taken to surfaces *G* on the work. The three lugs *H* are provided for clamping purposes, the jig being clamped in three places only to avoid unnecessary springing action. If the jig is in constant use, it would be advisable to have special clamping arrangements as component parts of the jig for clamping it to the table, thereby avoiding loss of time in finding suitable clamps.

The walls or standards *K* of large jigs of this type are frequently made in loose pieces and secured and dowelled in place as shown in

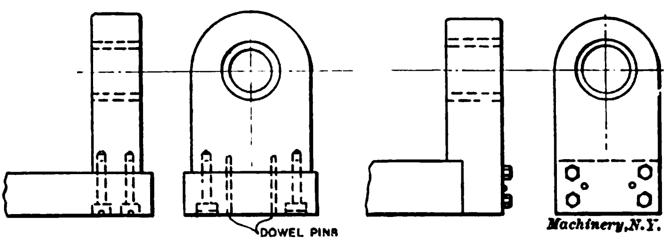
Figs. 110 to 114. In such a case the most important thing is to fasten these members firmly to the base, preventing shifting by tongues, keys, or dowels. It is evident that when the standards are made loose, as in Fig. 110, it is easier to finish the pad *A* of the base, and this is of importance, particularly when difficult locating arrangements are planed or milled in the base; the pattern-maker's and the molder's work is also simplified. As a rule the standards are screwed to the base permanently and then the bushing holes are bored. In some cases, however, it may be easier to first bore the hole in a loose part.



Figs. 111 and 112. Different Methods for Securing and Locating the Uprights on Base-plate of Boring Jig

and then attach it to the main body. Such an instance is shown in Fig. 115. It is easier to locate the bracket with the bushing *B* by working from the finished hole in connection with other important holes or locating means, than it would be to first screw the bracket in place and then expect to be able to locate the hole to be bored exactly in the center of the hub of the bracket.

When boring jigs are designed for machine parts of a similar design but of different dimensions, arrangements are often made to make one jig take various sizes. In such a case one or both standards may have



Figs. 113 and 114. Alternative Methods of Fastening Uprights to Jig Base

to be moved, and extra pads are provided on the face as illustrated in Fig. 116. This shifting of the standards will take care of different lengths of work. Should the work differ in height, a blocking piece *B* may be made as indicated in the same illustration. Sometimes special loose brackets may be more suitable for replacing the regular standards for shorter work. If there is a long distance between two bearings of the work, a third standard may be placed in between the two outside ones, if the design of the bored work permits, as shown in Fig. 117; this may then be used for shorter work together with one of the end standards. In Fig. 118 is shown another adjustable boring jig. Here the jig consists of two parts *A* mounted on a common base-plate or large table provided with T-slots. The work *B* is located between the standards. A number of different standards suitable for different pieces of work may be used on the same base-

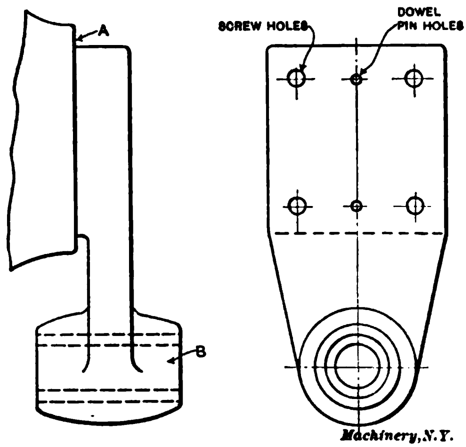


Fig. 115. A Case where the Bushing Hole is Bored Previous to Locating and Fastening Bracket on Jig Body

plate. The jigs or standards are held down on the base-plate by screws or bolts, and generally located by a tongue entering the upper part of the T-slots.

In the examples thus far given the work has been located on the jig, but it is apparent that boring jigs are frequently made which are

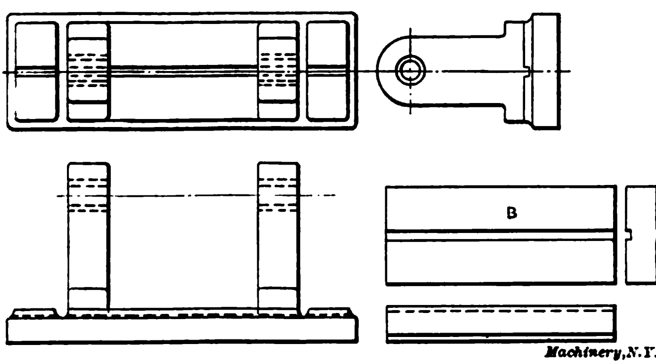


Fig. 116. Jig Adjustable for Different Sizes of the Same Class of Work

located and supported on the work. Fig. 119 shows such a jig. The work *A*, which in this case represents some kind of a machine bed, has two holes bored through the walls *B* and *C*. This jig may guide the bar properly if there be but one guide bushing at *E*, but it is better if it can be arranged to carry down the jig member *D* as indicated to give support for the bar near the wall *B*. It may sometimes be more convenient to have two separate jigs located from the same surfaces on the top or sides. In other cases it may be better to have the members *D* and *E* screwed in place instead of being solid with *F*,

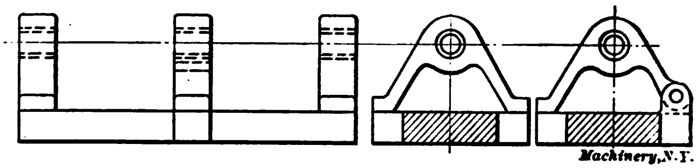


Fig. 117. Boring Jig with Removable Bearing in the Center, Adapting it to Different Sizes of Work of Similar Character

and in some cases adjustable. Of course, these variations in design depend on the conditions involved, but the principles remain the same. The jig or jigs are held to the machine on which they are used by clamping arrangements of suitable type.

The type of boring jigs described above supports the bar in two or

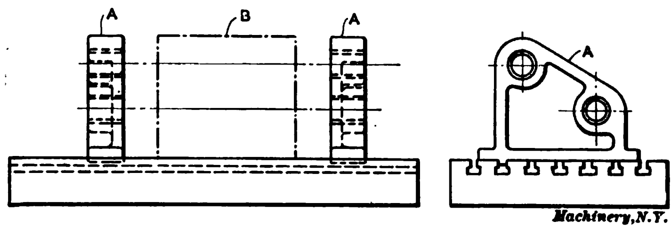


Fig. 118. Universal Base-plate for Standards of Various Descriptions for Different Classes of Work

more places, and the cutting tools are placed at certain predetermined distances from the ends of the bars, depending on the shape and size of the work. Sometimes it may prove necessary, however, to have a cutting tool inserted just at the end of the bar. For example, a boring jig may consist of simply one bracket as shown in Fig. 120. A very

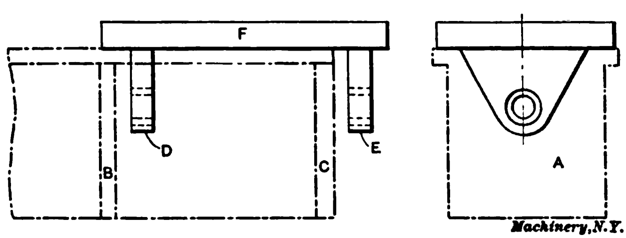
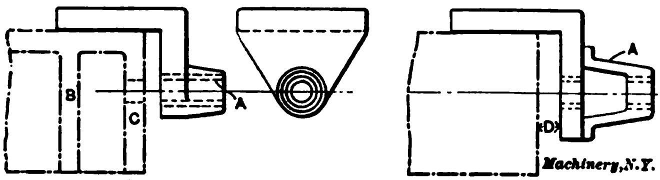


Fig. 119. A Case where the Jig is Located on and Supported by the Work

long bearing *A* is then provided so as to guide the bar true. The arrangement shown in Fig. 121 is sometimes used to insure a long bearing for the bar. A special bracket *A* is mounted on the jig and bored out at the same time as the jig proper is machined. This provides, in effect, two bearings. In these cases bars with a cutting tool at the end are used. The reasons for using the kind of boring jig illustrated in Figs. 120 and 121 are several; in Fig. 120, for instance, there is a wall *B* immediately back of the wall *C* in which the hole is to be



Figs. 120 and 121. Examples of Guiding Arrangements where no Support is Obtainable on One Side of Hole to be Bored

bored. Other obstacles may be in the way to prevent placing a bearing on one side of the hole to be finished. Instead of having a space *D* between the jig and the work, as shown in Fig. 121, the jig can oftentimes be brought up close to the work and clamped to it from the bushing side. A combination between this latter type of jig with

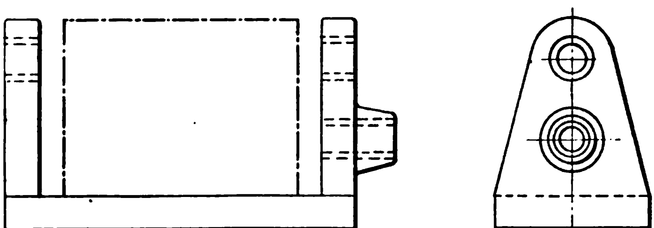


Fig. 122. Boring Jig in which One Bar has Single and One Double Bearing

but one bearing for the bar, and the type previously described with two bearings, is shown in Fig. 122.

Each of the different holes in boring jigs has, of course, its own outfit of boring bars, reamers, and facing tools. In making the jig it must be considered whether it will be used continuously and what

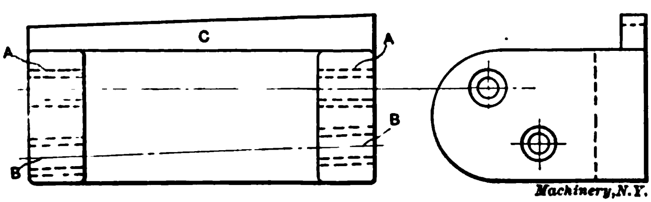


Fig. 123. Boring Jig for Boring Holes Placed at an Angle to Each Other

degree of accuracy will be required. When extreme accuracy is required there should be a bar provided with cutting tools for each operation to be performed. It is cheaper, of course, to use the same bar as far as possible for different operations and, ordinarily, satisfactory results are obtained in this way. It is desirable to have bushings fitting each bar, but often this expense can be reduced by using the same bushings for bars having the same diameter.

It sometimes happens that one or more holes form an angle with the axis of other holes in the work to be bored. In the jig shown in Fig. 123 the bushings *A* guide one bar for boring one hole and the bushings *B* the bar for boring another hole, the axis of which is at

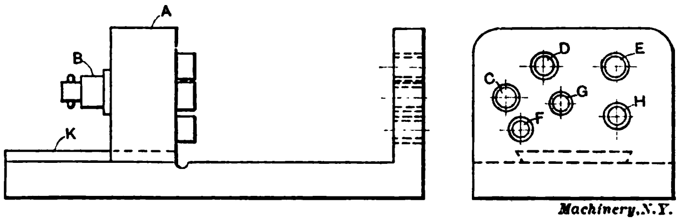


Fig. 124. Principle of Multiple Bar Boring Jig

an angle with the axis of the first hole in the horizontal plane. Then an angle plate *C* can be made in such a manner that if the jig is placed with the tapered side of plate *C* against a parallel, the hole *B* will be parallel with the spindle. This arrangement may not be necessary when universal joints are used between the spindle and the bar. If a hole is out of line in the vertical plane, a similar arrangement as

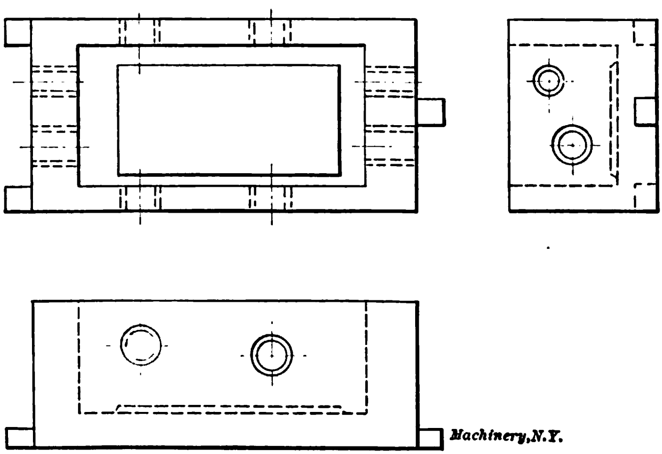


Fig. 125. Jig for Boring Holes through Work both from Sides and Ends

that used for drill jigs, and previously described in Part II, can be used.

As a rule but one hole is bored out at a time owing to the fact that machines for boring generally have but one spindle. Several holes, however, could be bored out in a large size multiple spindle drill, in which case the jigs naturally ought to be designed somewhat stronger. Another method of designing jigs for boring two or more holes at the same time is illustrated in Fig. 124, the outlines only being shown in this illustration. *A* is a gear box containing the main driving gear which is mounted on a shaft *B* which in turn is driven by the spindle of the machine. The gear on shaft *B* drives the gears and shafts connected with the boring bars passing through the bushings *C*, *D*, *E*, *F*, *G*, and *H*. The gears are proportioned according to the speed required for each bar, which in turn is determined by the sizes of the holes. The housing or gear box *A* slides on a dove-tail slide *K*. A particularly good fit is provided, and the gear box can be fed along in relation to the work either by table or spindle feed. If boring operations are to be performed in two directions, a jig on the lines indicated in Fig. 125 is designed. This jig may be mounted on a special revolving table permitting the work and the jig to be turned and indexed so as to save resetting and readjusting the work and jig when once placed in position on the machine.

The outline given above of boring jigs illustrates only the fundamental principles involved, it being considered more important to state the fundamental principles in this connection than to describe complicated designs of tools in which the application of such principles may be more or less obscure or hidden.

CHAPTER X

BORING JIG DESIGNS*

In the previous chapter the fundamental principles of boring jigs were outlined. In the present chapter a number of applications of these principles to boring jigs that have been designed for shop use will be shown.

In Fig. 126 are shown two views of a small jig supported directly on the work to be bored. This jig is used for boring out a cross-slide carriage, and is located on the work by the dove-tail slide and held in place by the two set-screws *A*. The two bushings *B* are driven into the solid part of the jig and the two corresponding bushings *C* are placed in the loose leaf *D* which is removed when the jig is placed in position on, or removed from, the work. The two set-screws *A* do not

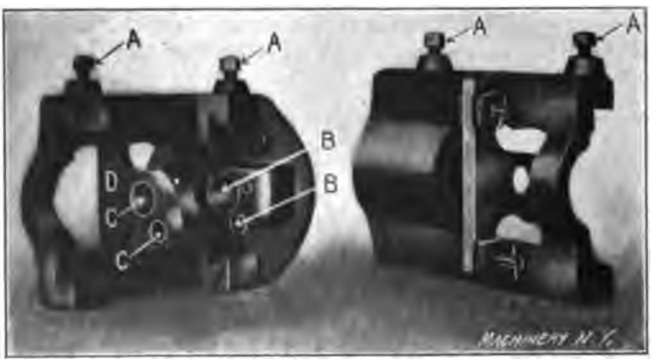


Fig. 126. Example of Small Boring Jig, with Removable Leaf for Holding Guide Bushings

bear directly on the side of the carriage, but are provided with brass or steel shoes as shown in Fig. 127, where *E* is the shoe. The leaf *D* cannot be attached permanently to the jig and simply swung out of the way when the jig is located on the work, because it could not be swung in place after the jig is applied on account of the small clearance in the cross-slide carriage. The leaf is therefore made loose, which is an objectionable feature, but lugs have been carried up on the casting on both sides of the leaf as shown, to give good support; these lugs are carefully finished to fit the leaf, and the latter is located and held in place by ground plugs.

In Fig. 128 is shown a boring jig which receives the work *A* between two uprights. The work in this case is the tail-stock of a lathe where two holes *B* and *C* are to be bored out. The bottom surface of the tail-stock is finished before boring, and is located on the finished

* MACHINERY, February, 1909.

bottom of the jig by means of a key and keyway. The keyway is cut in the jig and is a little wider than the key in the work. and the set-screws *D* bring the key against one side of the keyway, that side being in accurate relation to the hole *B* to be bored in the tail-stock. Longitudinally the work is located by a stop pin, against which it is brought

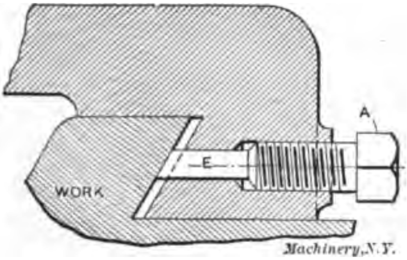


Fig. 127. Means for Holding Work against Locating Side of Dove-tail Slide of Boring Jig in Fig. 126

up by a set-screw from the opposite side. The tail-stock is held to the jig by bolts *E* exactly as it is held on the lathe bed.

The placing of the set-screws *D* at different heights is one of the features of the jig; this makes it possible for the jig to take tail-stocks of various heights for different sizes of lathes, raising blocks being used for the smaller sizes. The raising blocks are located exactly as the tail-stock itself, so that the work placed on them will come in the same relative position to the uprights of the jig whether

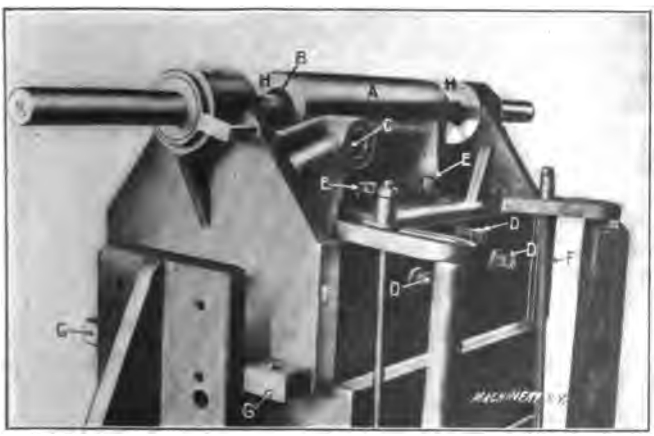


Fig. 128. Common Type of Medium Size Boring Jig

the work rests directly on the jig bottom or on the raising pieces. The two finished strips *F* are provided for facilitating the making of the jig, and the lugs *G* for the clamping down of the jig to the boring machine. The jig, however, can also be clamped to the boring machine table as shown in the illustration. At *H* is a liberal clearance between the work and jig, allowing ample room for the inserting of facing cutters, reamers, and boring tools. Ribs are provided for strengthening the jig, as shown.

The half-tone Fig. 129 shows a large size boring jig made from a solid casting. In this case the work to be bored out is the head of a lathe. It is located and clamped to the jig in a way similar to that mentioned in the case of the tail-stock; clamping it to the jig in the same way that it is fastened to the lathe bed insures that the effects of possible spring will be less noticeable. Opinions differ as to whether it is good practice to make up a jig of the size shown in one piece, the distance between the standards *A* and *B* being from four to five feet, or whether it would be better to make loose members located on a base-plate as shown in Fig. 130. The writer advocates the making of one piece jigs of as large sizes as possible, because, with loose members as shown in Fig. 130, there is no assurance that the standards are located

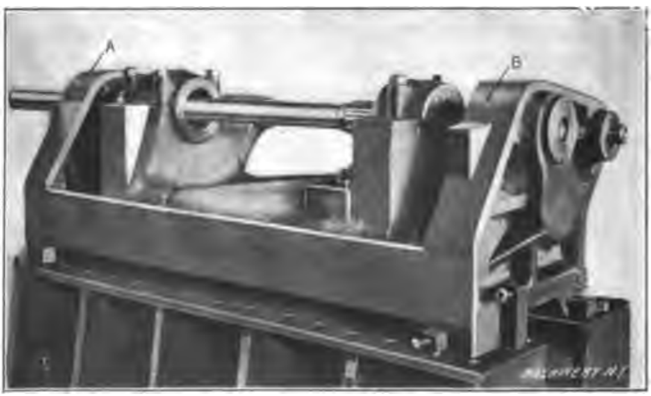


Fig. 129. Large Size Boring Jig made from a Solid Casting

correctly in relation to each other or to the work to be bored, and it involves more or less work to get the jig in order. The jig in Fig. 129 does not need to be as heavy as would be inferred from the illustration, because a large portion of the bottom can be cored out.

The boring jig illustrated in Fig. 130 consists of four parts; the upright members *A*, *B*, and *C*, and the base-plate *D*, which latter may be used for all jigs of similar construction. This type of boring jig is used only for very large work. In the case illustrated large lathe heads are to be bored. The work is located on the base-plate between the two members *A* and *C*. The member *B* is only used when the distance between *A* and *C* is very long, so that an auxiliary support for the boring bar is required, or when some obstacle prevents the bar from passing through the work from one of the outside members to the other. As a rule these members are located on the base-plate by a tongue fitting into one of the slots as shown at *E*. The members are brought as close as possible to the work, sufficient space, of course, being permitted for the cutting tools to be inserted. The standards are cored out and ribbed and lugs provided so as to give the bearing bushings long and substantial support. Good results will be obtained with this type of jigs provided they are carefully set up on the base-plate. At *F* in the member *B* is shown a boss; this is provided with a tapped hole for a hook or eye-bolt for facilitating the moving of the jig

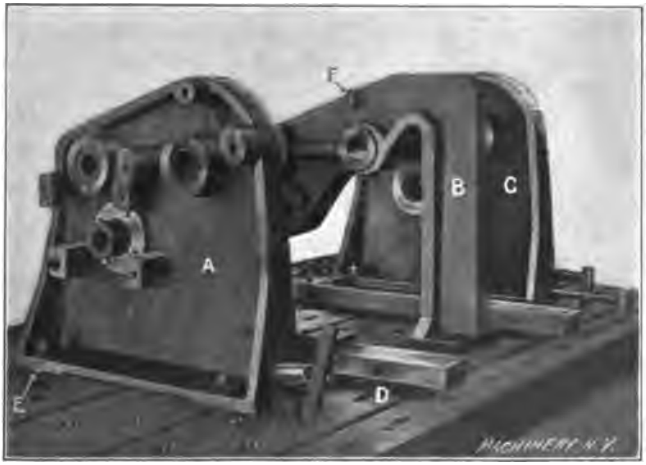


Fig. 130. Boring Jig Consisting of Base-plate and Separate Removable Uprights carrying the Guide Bushings

member by an overhead crane. The other members have tapped holes on the top for the same purpose.

The jigs in Figs. 126, 128, and 129 are ordinarily used on boring lathes, but the one shown in Fig. 130 may also be used in combination

Fig. 131. Boring Jig with Portable Drive

with a portable driving and feeding arrangement, one type of which is shown in Fig. 132. The lugs and finished bosses on the side of jig member *A*, which do not carry bushings, are used for connection to this drive and feed mechanism.

Fig. 131 shows a boring jig of the loose member type provided with motor drive for the boring bars. The members are mounted on the base *A*, located by the tongue *B*, and clamped down by T-bolts. The work *C*, a lathe head, is placed on the extension piece *D*. The boring bar is driven from the motor by means of a worm and worm-wheel, the bar being fed along as shown in Fig. 132. In this engraving, *A* represents the work, *B* and *C* the jig members, *D* the motor which is belt-connected to the pulley *E*, which, in turn, through a worm-shaft *F* and the worm-wheel *W*, drives the boring bar *G*; this latter is keyed to, but at the same time is a sliding fit in, the worm-wheel. The bar is fed forward by the feed-screw *H* which passes through the stationary nut *J* fastened to the base-plate. The motion of the screw is actuated from the bar itself through a train of gears. The gear *K* is keyed to the screw and driven by the gear *L* which is mounted on the same stud as the star-wheel *M* which is turned by the pin *N* attached to the connecting head *O*; this latter rotates with the boring bar, but the

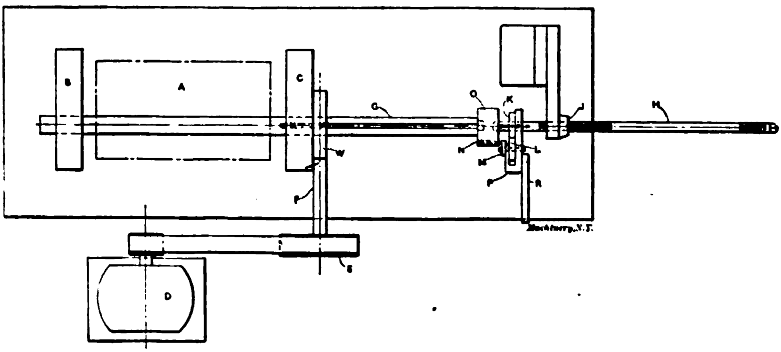


Fig. 132. Outline of Arrangement of the Drive and Feed of the Boring Bar of the Jig in Fig. 131

screw *H* is a free-running fit in *O*, and simply has a thrust washer at its end to take the feed thrust. More or less feed can be arranged for by using more than one pin in the connecting head. The pin or pins can be pulled back when the feed is not required. The gears and star-wheel are mounted in the bracket *P* which follows the bar and which is prevented from turning by the rod *R* fastened to the bracket. The bar can be pushed back by using a wrench or crank at the end of the feed-screw.

The feed arrangement shown has proved very serviceable and reliable. A separate and portable drive, of the type indicated, is quite necessary for large boring jigs as there are few machines large enough in the ordinary shop to handle such heavy work.

In Fig. 133 is shown a boring jig for boring out the top frame *A* of radial drills. The design of the jig is simple but effective; the hole *B* is parallel with the finished side *C* of the jig and is bored out after the jig has been brought up square against a parallel and strapped to the machine table. The hole *D* is bored at an angle with the hole *B*. and the setting of the jig for the boring out of this hole is facilitated by providing a wedge-shaped piece *E* of such an angle that the jig will be set in the proper position when moved up against the wedge. If universal joints are used for connecting the boring bar with the driving spindle, the setting of the work at an angle could be omitted, although it is preferable even when using universal joints to have the boring

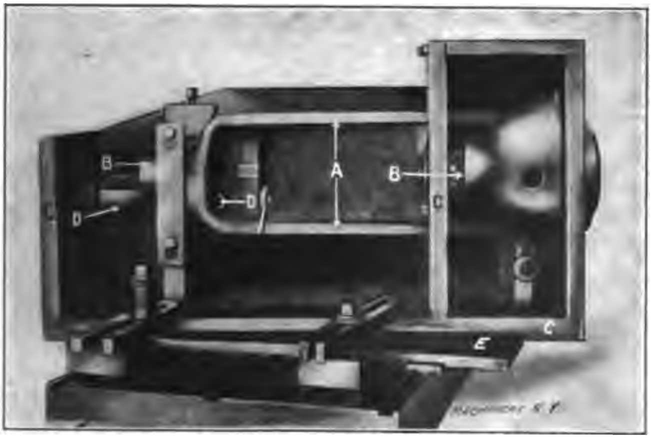


Fig. 133. Wedge-piece for Aligning Work for Boring Holes with the Axes at an Angle

bars as nearly as possible in line with the spindle. This eliminates a great deal of the eccentric stress, especially when taking a heavy cut with coarse feed.

Boring operations are sometimes carried out using parts of the machine itself as guiding means for the boring bars, and in some

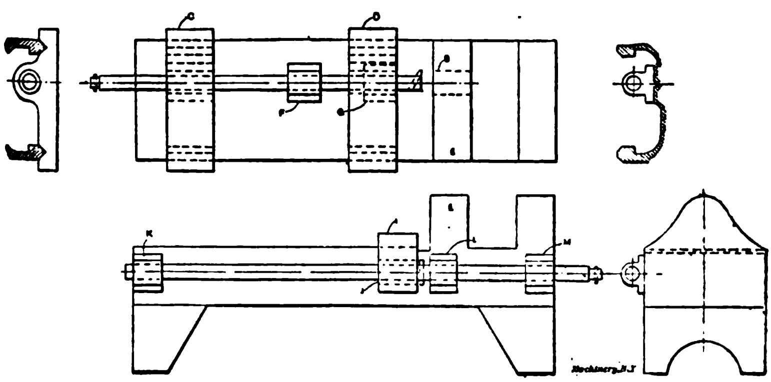


Fig. 134. Examples of Boring where Parts of the Machine being Built are Used as Guiding Means

instances it is very essential that boring operations be performed in this way in order to obtain perfect alignment. In Fig. 134 is shown a line engraving of a machine bed with the head-stock solid with the bed. In the top view is shown a method for boring out a hole at *B* by the use of two jigs *C* and *D* which are located on the V's of the machine and held down by hook bolts. If the hole *B* only passes through the part *E* of the head this would be the preferable way of boring it. In some instances, however, the hole *B* may be required to be in alignment with the holes in a carriage or in a bracket as at *F* and *G*. These holes, of course, can then be used to great advantage as guiding means. Should the holes be too large to fit the boring bar, cast-iron bushings can be made to fit the holes and the bar. In the elevation and end view of Fig. 134 is shown how a cross-slide carriage and apron *I*, which has a hole *J* in line with the holes in bearings *K*, *L*, and *M*, and travels between *K* and *L*, can be bored out by using the brackets *K*, *L*, and *M* to guide the boring bar. By keying the traveling part *I* close to the bracket during the boring operation, as illustrated, accurate results will be obtained. It is evident that two of the bearings could be bored out by using the finished bearing and the traveling part *I* as guiding

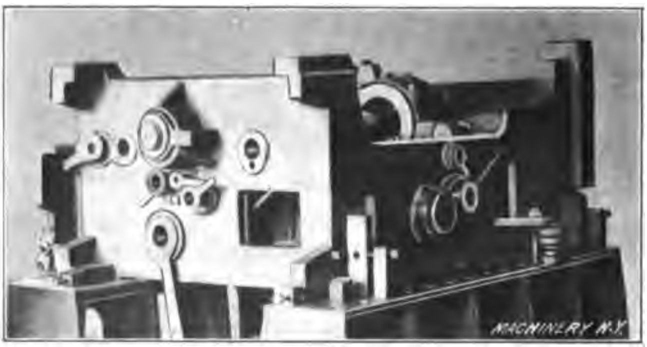


Fig. 135. Combined Drilling and Boring Jig Used with a Horizontal Drilling and Boring Machine

means. Arrangements of this kind usually save expensive tools, and often give better results.

Combination Drill and Boring Jig

Jigs for performing both drilling and boring operations are frequently used to great advantage. In designing such jigs, however, judgment must be shown so that combination jigs will not be employed when the operations can be more easily performed in two separate jigs. Sometimes it is advisable to have a jig for the boring alone, and then to use the bored holes for locating the work in a separate drill jig. In other cases it may be better to do the drilling first and locate the work for the boring operations from the drilled holes. The designer should decide which method would be preferable, considering, in the first place, the factors of the time required and the accuracy of the work. To give any definite rules for this work is not possible; but it may be said that combination jigs should be used only when the drilled and bored holes have nearly the same diameters. When the holes are of widely different diameters two jigs are preferable. If a few screw-holes of small diameter for holding a collar or bracket, for instance, located around a large bored hole, were to be drilled with the same jig used for the large hole, the jig, when used on a small drill press, would be entirely too heavy to manipulate. It is likely that in such a case a small separate drill jig could be attached directly to the work. In other cases, however, it will prove a distinct saving to combine the boring and drilling jig in one.

In Figs. 135 and 136 is shown a combination drill and boring jig of large size. The work *A* in Fig. 136 is a head-stock for a lathe with a

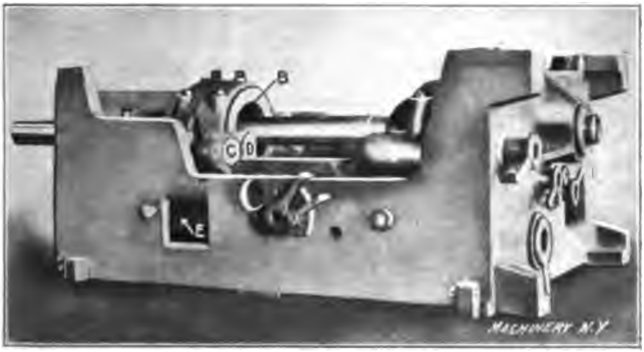


Fig. 136. Another View of the Jig in Fig. 135. Note that Holes are Drilled or Bored from All Sides

number of holes to be drilled. The large holes *B* at both ends of the head-stock are cored as usual, and allow the boring bar to enter for taking the roughing cut. The holes at *C* and *D* are opened up by drills previous to the boring operation. As there is considerable distance between the end of the head-stock and the uprights of the jig, long bushings are used to give the tools a good bearing close to the work. Both the drilling and boring operations may be performed on a horizontal boring and drilling machine. As the horizontal boring and drilling machines usually have adjustments in all directions, the only moving of the jig necessary is to turn it around for drilling the holes on the opposite sides.

CHAPTER XI

BORING, REAMING AND FACING TOOLS*

More or less elaborate tools or sets of tools are required for the various boring operations performed with or without boring jigs. These tools comprise boring, reaming and facing bars, boring and facing cutters, solid or shell reamers, boring and facing heads, bushings, stops, drills, collets, and knuckle or universal joints.

Boring Bars

The general requirements of a boring bar are that it must be as heavy and rigid as possible, straight, and ground concentric, and a good running fit in the bushings. When the bar has been turned and once ground to the right size, it should never be put in a lathe and filed, or emery cloth used on it. Boring bars are made from machine steel and are not hardened. Sometimes small bars are made from tool steel and hardened, in order to give them additional stiffness. Shanks for reamers, and facing bars, should be made in the same way as boring bars, but if possible, should be even stiffer.

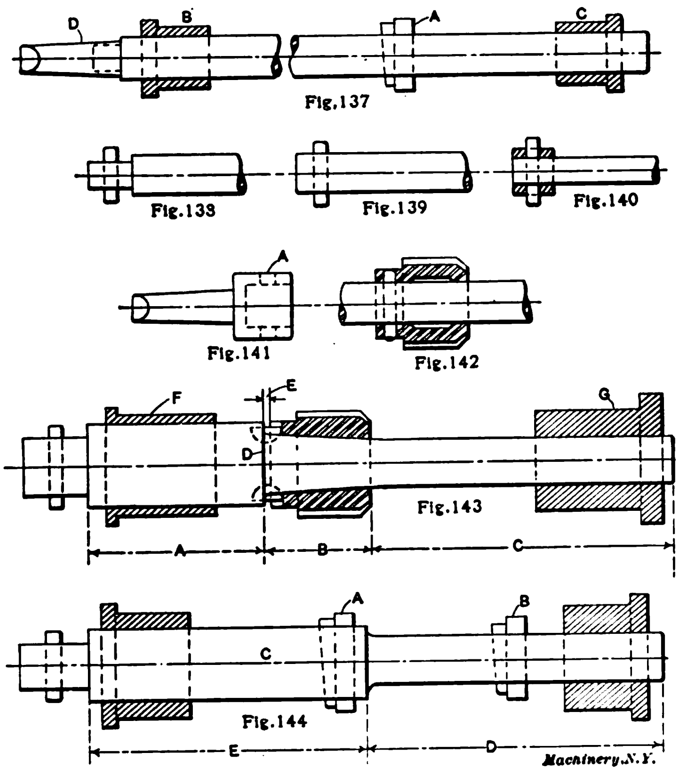
The most common type of boring bar is shown in Fig. 137, the cutter *A* being located about at the middle of the bar, and the bar being guided at both ends by bushings *B* and *C*. The bar is provided with a taper shank at *D*, fitting the spindle of the machine or a collet connected with a knuckle joint. It is quite common practice to turn down the end of the bar, as shown in Fig. 138, to fit a knuckle joint or the collet shown in Fig. 141. Sometimes, of course, the bar can be left full size, as shown in Fig. 139, and sometimes the end is even made larger than the bar, by forcing on a collar, as shown in Fig. 140, in order that the end may fit the driving collet. A key is passed through the end of the bar for driving it; this key fits in the slot *A* in the collet shown in Fig. 141.

The bar shown in Fig. 137 can also be used for facing purposes, the cutter *A* being taken out, and a facing cutter inserted. The same bar can also be used for a special shell reamer, when this has a straight hole, the reamer being held to the bar by a taper pin, as shown in Fig. 142. Standard shell reamers have a taper hole, and for these, the bar must be turned with a taper part, as shown in Fig. 143, where the part *A* is turned up to the largest size possible (generally 1/32 or 1/16 inch under the diameter of the reamer); part *B*, being turned to fit the taper hole in the shell reamer, is left long enough to permit the reamer being pressed up tight without touching the shoulder *D*. As a rule, the taper part is so dimensioned that ⅛ inch will be left at *E*, between the shoulder of the bar and the back of the shell reamer, when this is forced up as far as possible. The reamer is driven by keys or pins entering in a slot cut across the end of the reamer. The

* MACHINERY, March, 1909.

part *C* of the bar is turned down to some standard size, just below the size of the small end of the taper hole in the reamer. The bushings *F* and *G* may be made with the same outside diameter, fitting the same size lining bushings in the jig, their inside bearings being made to fit the large and small diameters of the bar.

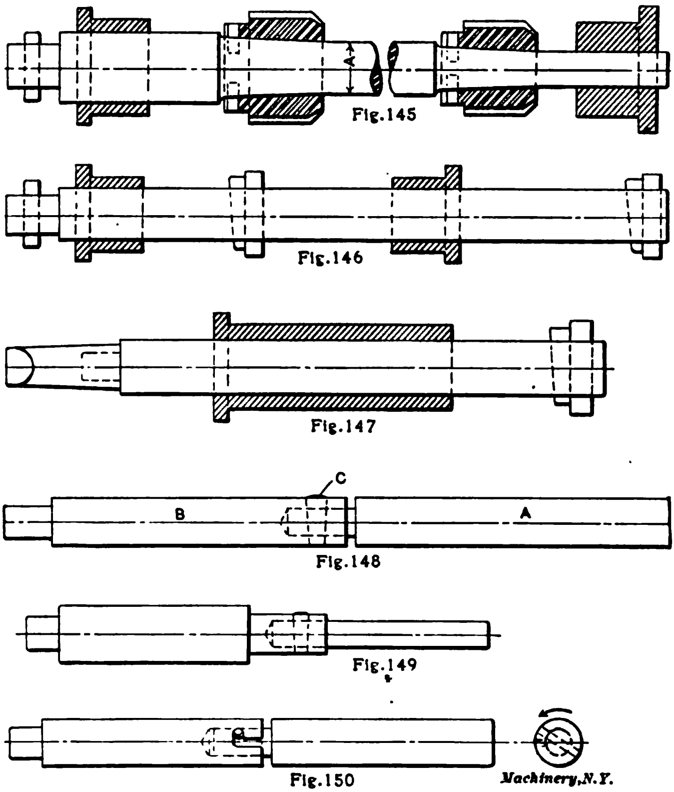
A boring bar used for boring out two holes of different sizes may be made as shown in Fig. 144; *A* and *B* are the cutters for the two holes, and part of the bar *C* is turned down for a length *D*, to fit the small hole. The part *E* can then be made of as large diameter as



Figs. 137 to 144. Boring Bars of Different Types

permissible for boring out the hole for which tool *A* is used. By making the bar in this way, a more rigid construction is possible than if the part *E* were turned down to the smaller diameter required by the hole bored by cutter *B*. There may be more than two holes of different sizes in succession,and then the bars may have a greater number of steps; if there is but a slight difference in the sizes of the holes to be bored out, it hardly pays to turn down steps on the bar. The stepped bar may also be used for facing bars. While these small matters may seem unimportant and elementary, they must be taken into consideration when designing a set of expensive tools for boring jigs which are to be in constant use.

Reamer bars used for reaming out two or more holes simultaneously may be made as shown in Fig. 145, providing the diameter *A* is large enough for turning the taper portion for another shell reamer of smaller size. Should the diameter be too small to permit this, an extension can be provided, or a separate bar used for the smaller reamer. The principle of stepped bars can be applied also in cases



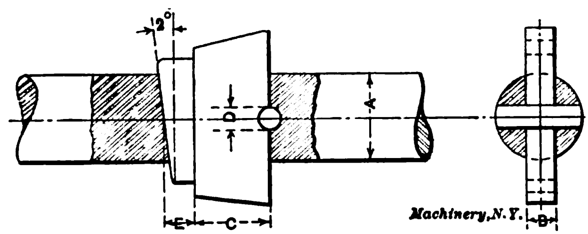
Figs. 145 to 150. Other Designs of Boring Bars

where the cutters are placed as illustrated in Fig. 146. Here one boring cutter or facing tool is placed at one end, the bar still being guided by two bushings.

A boring, facing, and reamer bar used almost as commonly as the one already described, is illustrated in Fig. 147. The principal features of this bar are that the cutting tool is always located at the end of the bar, opposite where it is driven, and that there is but one bushing for guiding. This bushing should be as long as possible to give a good bearing and prevent the bar from wabbling. Sometimes, as illustrated in Fig. 121, the jig is made with two bearings which, however, are on the same side of the cutter, and a comparatively short distance apart.

Sometimes a bar must be made in two parts. The reason may be that one solid bar would be too long to permit its being pushed into the jig from one side. Another reason may be that the cutting tools are too large to pass through some intermediate hole. The two parts of the bar may be connected with a taper pin, as shown in Fig. 148, the end of bar *A* being a sliding or driving fit in the hole in section *B*. This bar should be ground after the two parts are assembled, so that they will run exactly true with each other. A stepped bar made up of two sections is shown in Fig. 149. In Fig. 150, another method of connecting the two sections is shown; when this method is used the two bars can be put together and taken apart very rapidly.

TABLE X. BORING AND FACING CUTTERS

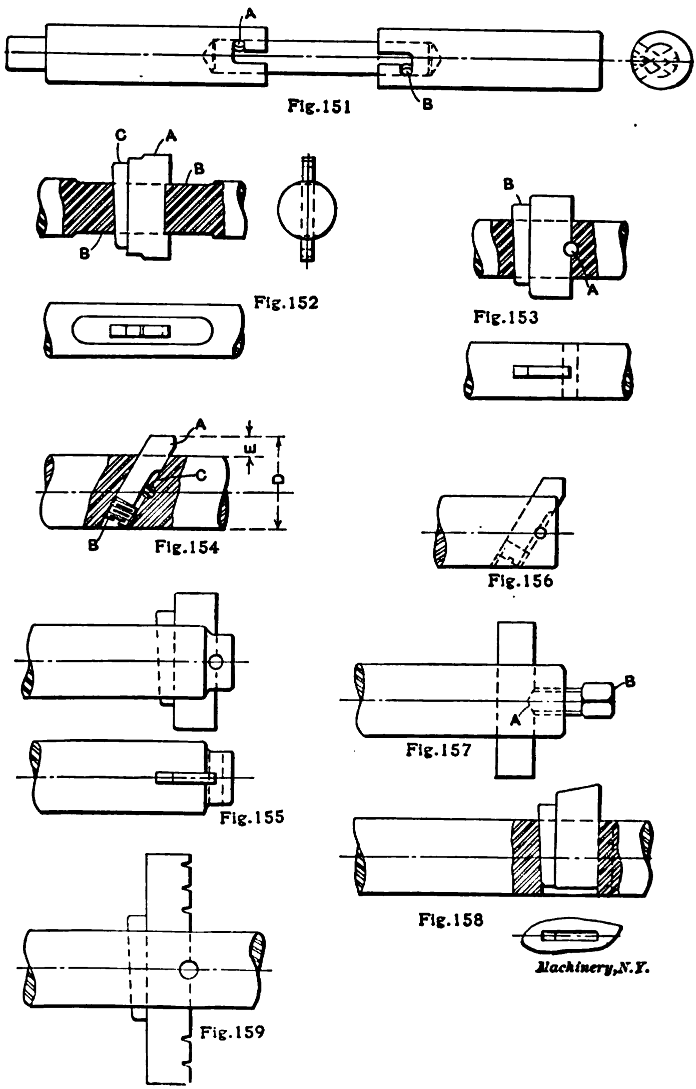


A	B	C	D	E
3/4 to 15/16	1/4	3/4	3/16	1/4
1 to 1 3/8	5/16	3/4	3/16	1/4
1 1/2 to 2 3/8	3/8	3/4	1/4	1/4
2 1/2 to 3	1/2	1	1/4	5/16
3 1/8 and larger	5/8	1 1/4	5/16	3/8

This method can also be used to connect two bars by a separate piece, as shown in Fig. 151, the two sections being bored out to fit the intermediate piece, which has two pins *A* and *B* driven into it, and transmitting the motion from one section of the bar to the other, as indicated. It is evident that two bearings would hardly be sufficient for this class of boring bars. When these bars are used, three or more bearings should be provided. This type of bar, however, is not used to a very great extent.

Cutters for Boring Bars

The cutters used in boring bars vary widely. The cutter *A*, Fig. 152, is commonly used. It cuts with both ends, and is centered by the two flats *B*, milled or filed on the bar; a slot is provided in the cutter, which fits these flats of the bar. After the cutter has been put in place, it is tightened by the key *C*, and is turned to the correct diameter required, and then hardened. A more modern arrangement is shown in Fig. 153. The cutter here is a plain rectangular piece of steel, cutting with both ends. It is centered by the pin *A*, which is driven into a hole drilled so that one-half of it passes through the slot in the cutter. As in the former case, the cutter is turned down to the



Figs. 151 to 159. Different Types of Cutters and Methods of Fastening

right diameter when in place. It is tightened down by the key *B*. This way of locating the cutter centrally has proved very satisfactory. In Table X are given dimensions of cutters for different bar diameters.

Facing cutters may be located and held in place in the same way.

They are longer than boring cutters, being intended to finish a boss or seat around a hole, but otherwise they are made to about the same dimensions.

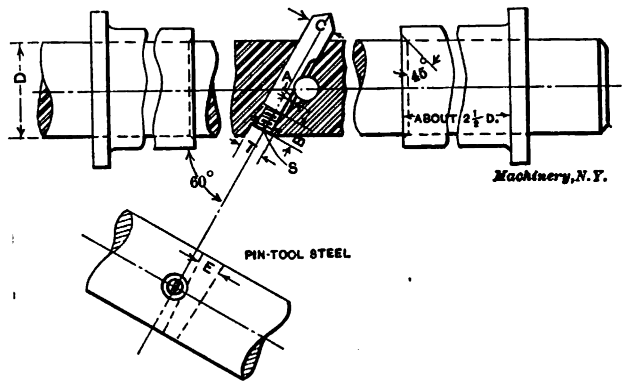
Single-ended boring cutters, as shown in Fig. 154, are used to a great extent, and it is claimed that they give a more perfect hole. The illustration shows a common way of securing the tool; the cutter *A*, which is made of drill rod or other round tool steel stock, fits a hole bored at an angle of sixty degrees with the axis of the bar, and is adjusted by the headless set-screw *B*. When adjusted, the cutter is held rigidly in place by the pin *C* provided on one side with a flat tapering portion, which fits against the flatted side of the cutter, as shown in the engraving. This cutter is very easily set by taking a measurement *D* with a micrometer. Subtract from the dimension *D* the diameter of the bar, thereby obtaining dimension *E*. Now add *E* to *D*, thereby obtaining the diameter of the hole which will be cut. The screw may have to be adjusted a few times, to obtain the desired result. Table XI gives dimensions for this kind of cutters, and also for screws and pins used with them. The two kinds of cutters referred to may also be used on the ends of the bars, as shown in Figs. 155 and 156. The cutter of the type shown in Fig. 153 may be held in either of the two ways shown in Fig. 155 and Fig. 157. In the latter case, the cutter is spotted at *A*, and held by a pointed screw *B*. This method, however, does not always insure very accurate results. The simplest kind of single-ended cutter, and the manner in which it is held is shown in Fig. 158. It may be used in any kind of bar, and with ordinary care, good results may be obtained even with this simple tool. The variations possible are many, and the examples shown simply indicate the most common practice.

Facing cutters may be made similar to boring tools, or they may be made with teeth, like end milling cutters, as illustrated in Fig. 161. In this engraving, one of the cutters *A* cuts with both sides, while the cutter *B* cuts with one side only. The bar is provided with a slot and with notches for locating and holding in place the various cutters, as shown at *C*. A pin *D* is driven into the cutter, and enters the notch, thus driving the tool. The cutters can also be held on the bar by taper pins, but the putting in place and the removal of the cutters would then be much slower.

Different cutters are commonly used for roughing and finishing. To make it easier to remove the metal with the roughing cutter, it may be made with every other tooth beveled in opposite directions, as shown in Fig. 160, where *A* is one tooth beveled toward the center, and *B* the next tooth beveled outward. Using a cutter of this kind will produce a surface as indicated at *C*, which must be faced square by a finishing cutter.

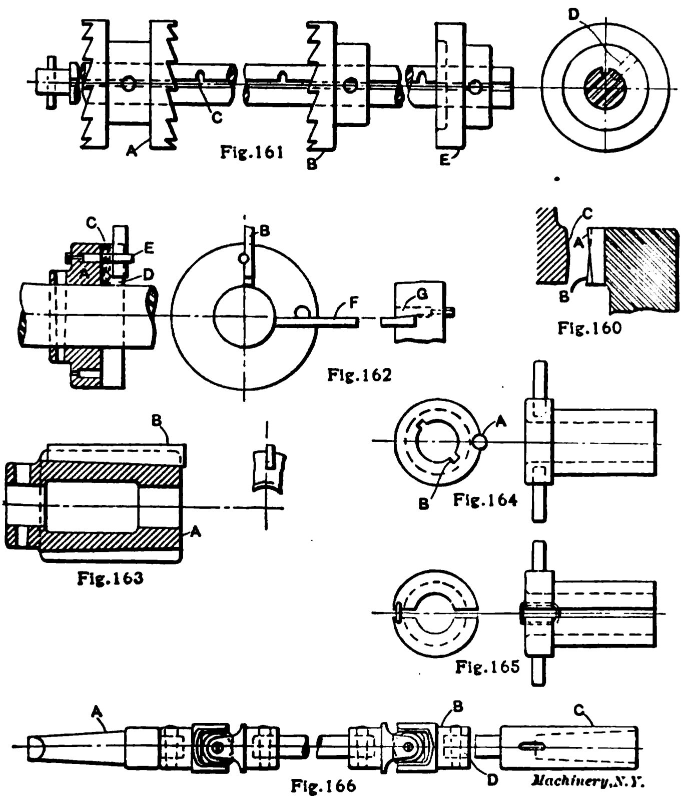
In order to face the work to correct dimensions, stops are sometimes provided which strike against some finished surface on the jig which stands in a given relation to the finished surface on the work and the cutting edge of the facing cutter. Such a stop may be made as shown at *E* in Fig. 161, and be held and located in the same way

TABLE XI. BORING-BAR CUTTERS



D	C	E	A	S	T	B
Diameter of Bar.	Diameter of Cutter.	Diameter of Pin.	Depth of Milled Down Part.	Diameter of Screw.	Diameter of Counter-bore.	Length of Thread.
3/8	1/8	1/16	1/64	1/16	1/8	5/64
7/16	1/8	3/32	1/64	1/16	1/8	5/64
1/2	1/8	3/32	1/64	1/16	1/8	5/64
9/16	1/8	1/8	1/32	1/8	5/32	1/8
5/8	3/16	1/8	1/32	1/8	5/32	1/8
11/16	3/16	5/32	1/32	1/8	3/16	5/32
3/4	3/16	5/32	1/32	1/8	3/16	5/32
13/16	1/4	5/32	1/32	3/16	1/4	3/16
7/8	1/4	5/32	1/32	3/16	1/4	3/16
15/16	1/4	3/16	1/32	3/16	1/4	1/4
1	1/4	3/16	1/32	3/16	1/4	1/4
1 1/8	5/16	7/32	1/32	1/4	5/16	5/16
1 1/4	5/16	1/4	3/64	1/4	5/16	5/16
1 3/8	3/8	1/4	3/64	1/4	5/16	5/16
1 1/2	3/8	9/32	3/64	5/16	3/8	3/8
1 5/8	7/16	5/16	3/64	5/16	3/8	3/8
1 3/4	7/16	5/16	3/64	3/8	7/16	1/2
1 7/8	1/2	11/32	1/16	3/8	7/16	1/2
2	1/2	3/8	1/16	7/16	1/2	9/16
2 1/8	9/16	13/32	1/16	7/16	1/2	9/16
2 1/4	9/16	13/32	1/16	1/2	9/16	5/8
2 3/8	5/8	7/16	5/64	1/2	9/16	5/8
2 1/2	5/8	15/32	5/64	9/16	5/8	11/16
2 5/8	11/16	1/2	5/64	9/16	5/8	11/16
2 3/4	11/16	1/2	5/64	5/8	11/16	3/4
2 7/8	3/4	17/32	3/32	5/8	3/4	7/8
3	3/4	9/16	3/32	5/8	3/4	7/8

as the facing cutter. The stops are made of machine steel, case-hardened, and ground on the bearing surface. When facing up a wide surface with an inserted blade facing tool, it is often the practice to cut small notches in the blade, as shown in Fig. 159, the cutting edges on the one end overlapping the notches on the other. Very often the holes to be bored are too large to permit cutters, such as previously described, being used, and then it is necessary to provide the boring bars with a boring head. A simple boring head is illustrated in Fig. 162, in which *A* is the head held on the bar by a taper pin; *B* is a boring tool which fits in a slot in the head, and which can be adjusted out and in by the screw *C*, passing through the shoe *D* which, in turn, fits the slot, and against which the cutter is located, as illustrated. The cutter and shoe are held by the bolt *E*. The bolt is milled flat on one side so that a hook is formed for binding the cutter

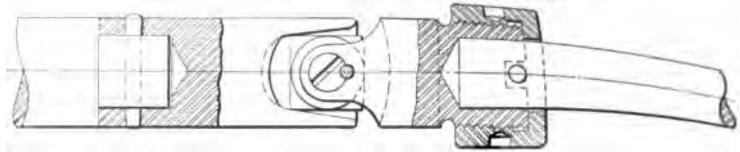


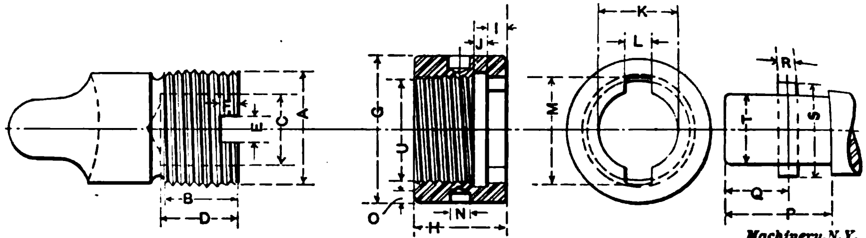
Figs. 160 to 166. Facing Tools, Boring Heads, Boring Jig Bushings, and Universal Joints for Driving Boring Bars

and shoe. Two or more cutters may be used in these boring heads. At *F*, in Fig. 162, is shown a facing tool used in the same head as the boring tool. No adjusting shoe is necessary in this case, as the facing cutter bears directly against the bottom of the slot in the head, and against the boring bar, and is held by a bolt *G*, milled with a tapering flat on one side, which wedges the cutter into its seat. More complicated boring heads are provided with a small slide for adjusting the tools; some are made similar to the box tools used in turret lathes.

The reamers most commonly used in connection with boring jigs

TABLE XII. BORING-BAR COUPLINGS





A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U, Bore.	Threads per inch.	Used for Bars
3/4	1/2	1/2	7/16	3/16	5/32	1	5/8	1/8	3/32	17/32	3/16	11/16	9/64	1/8	3/4	3/8	1/8	21/32	0.499	0.6610	16	3/8 to 1/2
1	1/2	5/8	9/16	1/4	7/32	1 3/8	5/8	5/32	3/32	21/32	1/4	15/16	11/64	5/32	7/8	15/32	3/16	7/8	0.624	0.9110	16	1/2 to 3/4
1 1/4	5/8	3/4	5/8	5/16	9/32	1 5/8	13/16	3/16	1/8	25/32	5/16	1 5/32	13/64	5/32	1 1/8	1/2	1/4	1 1/16	0.749	1.1615	12	3/4 to 1
1 1/2	13/16	1	7/8	7/16	13/32	2	1 1/16	1/4	1/8	1 1/32	7/16	1 13/32	15/64	7/32	1 3/8	11/16	3/8	1 5/16	0.999	1.4115	12	1 to 1 1/2
2 1/4	7/8	1 1/2	1 3/8	9/16	17/32	3	1 1/8	1/4	1/8	1 17/32	9/16	2 3/8	19/64	7/32	1 7/8	1 1/8	1/2	2 1/4	1.4985	2.4115	12	1 1/2 to 2
3	7/8	1 7/8	1 3/4	11/16	21/32	3 1/2	1 1/4	1/4	1/8	1 29/32	11/16	2 7/8	21/64	7/32	2 5/16	1 7/16	5/8	2 3/4	1.8735	2.9115	12	2 and over

are shell reamers of standard make. Many concerns have been in the habit of making their own shell reamers with inserted blades, designed about as shown in Fig. 163; *A* is a machine steel body, and *B* a tool steel blade, which is made tapered as shown, and driven into place. When the blades are inserted in the body, the reamer is ground. The reamer can be re-ground when dull, and kept to standard size, by forcing up the blades along the taper. The bodies of very large inserted blade reamers are made of cast iron.

Bushings for Boring Jigs

Lining bushings for boring jigs are made of machine steel, casehardened and ground, and the loose bushings also are often made of machine steel. They may, however, be made with equal success from cast iron, which wears well, and has less tendency to stick to the steel bar. The bushings for boring jigs may be made with facilities for removal, similar to those previously described in Chapter II, of Part I. In Fig. 164 is shown a bushing having two pins driven into the head, to facilitate removal, and the pin *A* over which the half-round slot in the edge of the head fits, prevents the bushing from turning. Slots, as shown at *B*, are sometimes provided to permit cutting tools to pass through.

In places where it is impossible to put in bushings before the bar is put in, or over the end of the bar after it is put in, a bushing made in two halves can be used, as illustrated in Fig. 165. The writer has seen this kind of bushing in use in the Pratt & Whitney Co.'s shops, where it probably was originated, and it worked very well. The two halves are held together by a wire passing through the head flanges at one side as indicated. A bushing of this type can be put right over the bar at any place, and pushed into the lining bushing.

Knuckle Joints

When boring bars are provided with a standard taper shank, this may be put directly into the spindle of the machine, but in that case the jig must be lined up very accurately with the spindle, and this sometimes takes more time than is permissible. It is better to use knuckle or universal joints for connecting the live spindle with the boring bar. These are constructed as indicated in Fig. 166, and are made in different sizes, for the different sized bars for which they are used. The shank *A* fits into the machine spindle. The end of the knuckle joint *B* is provided with a hole *D* into which fits the end of the collet *C*, which in turn, takes the shank of the boring bar. The hole *D* may also take the end of the boring bars directly. The method of driving the bar from the knuckle joint may be either by a taper pin as shown in Fig. 166, or by the means shown in the engraving in Table XII, where dimensions are given for a coupling of good construction, connecting boring bar and knuckle joint.

CHAPTER XII

PLANING AND MILLING FIXTURES*

Fixtures for planing and milling are as essential for interchangeable manufacturing as are drilling and boring jigs. Fixtures of this kind serve primarily the purpose of locating and holding the work, but they are often provided with setting pieces or templets which are made either in one part with the fixture or separate; the cutting tools are set to these setting pieces so that the work is always machined in a certain relation to the locating means on the fixture itself.

When more than one milling operation is to be performed on the same piece, it is often possible to use the same fixture for the various operations, but it may be, in some cases, of advantage to make up a fixture for each different operation. The designer must in this case be guided by the number of pieces that are to be machined, and the advantages as regards rapidity of handling and operation that may be gained by having special fixtures for every operation, even though the operations may be such as to permit the same fixture to be used, with or without slight changes.

The strength of fixtures should be governed by the kind of operation to be carried out on the work while in the fixture, whether planing, milling, slotting, etc., and how much stock is to be removed. A milling fixture, as a rule, must be made stronger than a planing fixture, because a milling cutter, as a rule, takes a heavier cut than a planing tool.

The principles which have been previously explained in this treatise for drill jigs govern the locating means of milling fixtures, and clamping devices of the same general type are described and illustrated in Chapter IV, are used, except that they are usually made heavier than when used for drill jigs and planing fixtures. On account of the irregular form of the work and the necessity for clearing the cutting tools, the clamps of milling and planing fixtures must often have irregular shapes.

An important factor, on which too much stress cannot be placed, is the necessity of having sufficient clearance for the cutting tools so that they will not interfere with some part of the fixture and clamping devices, and also that the fixtures, when located on the platen or machine table, will not interfere with any part of the machine, when the table is fed one way or another. As a rule, milling and planing fixtures are provided with a tongue or key in the base, for locating them on the machine table. Suitable lugs should also be provided for clamping the fixture to the platen.

One of the very simplest types of fixture is illustrated in Fig. 167; work being planed is very commonly located and held by the means indicated, and for taking light cuts in the milling machine such an

* MACHINERY, April, 1909.

appliance may also be used. In this case, the planer platen *A* forms part of the fixture, and the work *B*, located on the platen, is held up against the bar *C*, which is held down by bolts, and located by a tongue as shown. The lugs and lug-screws shown with the spurs *D* hold the work up against the bar, and press it flat against the table. Instead of using the loose spurs *D* between the screws and the work, it is sometimes possible to let the screws bear directly on the work, in which case the screws should pass through the lugs at an angle with the top of the table, as shown in Fig. 173. The arrangement in Fig. 167 may or may not properly be considered a fixture, but it illustrates the

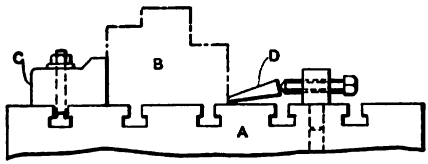


Fig.167

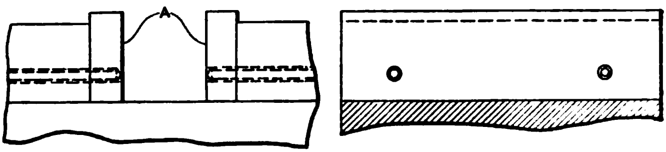


Fig.168

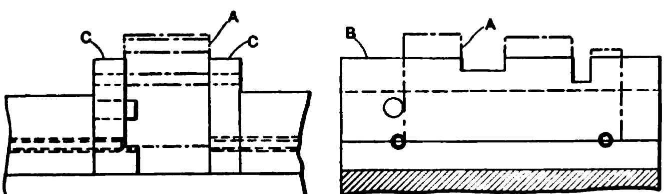


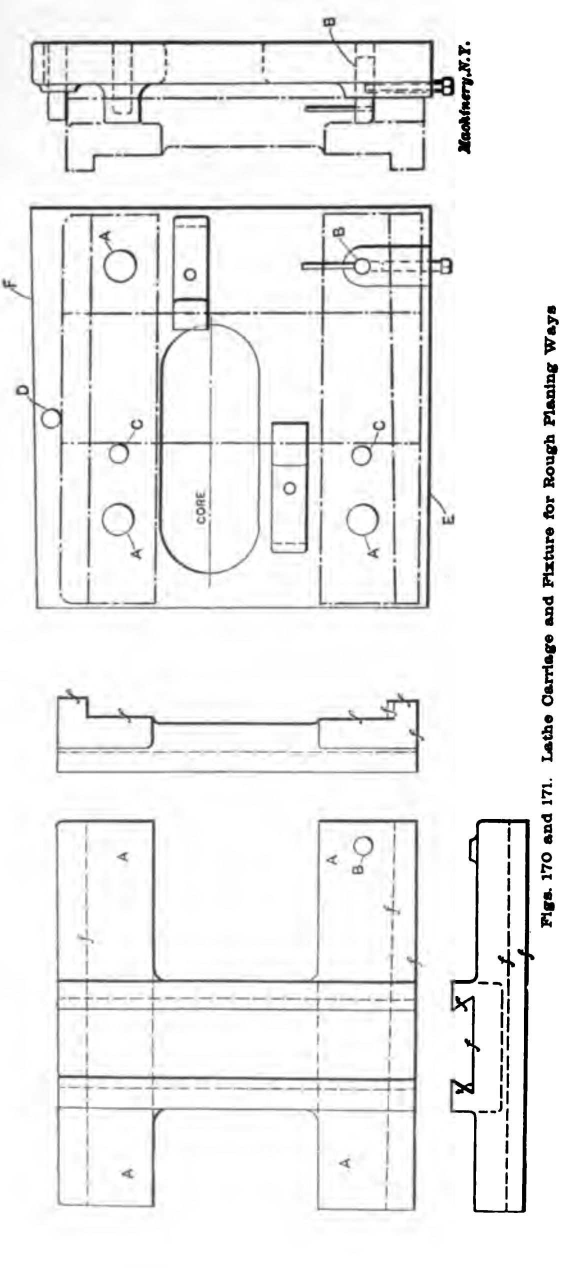
Fig.169

Machinery,N.Y.

Fig. 167. Principles of Fixtures as shown by Common Method of Clamping Work on the Planer. Fig. 168. The Common Milling Machine Vise, an Example of Adjustable Fixture of Wide Range. Fig. 169. Vise with False Jaws shaped to the Form of the Work by the Cutting Tools themselves

principles of a fixture, as it locates and clamps the work in the simplest manner.

The most commonly used fixture for planing, shaping and milling is the vise. Standard vises are indispensable in planer or milling machine work, and by slight changes they can be used for a large variety of smaller pieces. In Fig. 168 are shown the regular vise jaws *A* of a standard vise. These jaws are often replaced by false jaws, which may be fitted with locating pins and seats, and held to the vise the same as the regular jaws. They are usually left soft, and often the milling cutter is permitted to cut out the jaw to the same shape as required for the work, as shown in Fig. 169. Vises with false vise jaws are especially adapted for milling operations, but vises are not usually employed for long work, special fixtures then being commonly



Figs. 170 and 171. Lathe Carriage and Fixture for Rough Planing Ways

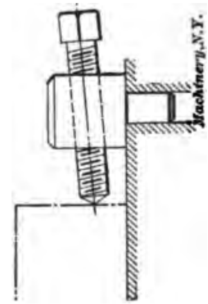


Fig. 173. Clamping Work by Means of Pointed Screw

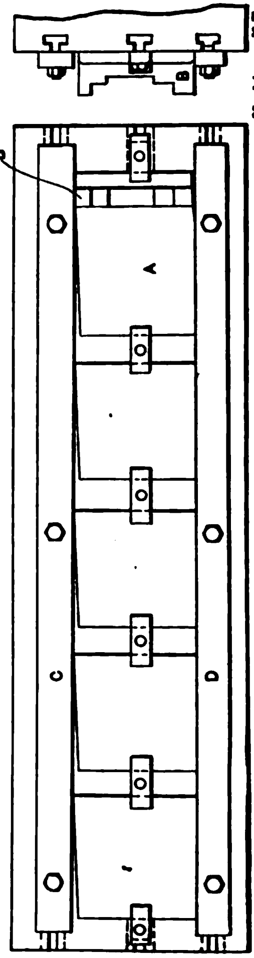


Fig. 172. "String" of Fixtures on the Platen of a Planer

made. While it is difficult to lay down specific principles for the designing of milling and planing fixtures, it may be said that for most kinds of plain work, finished in the planer, the fixture shown in Fig. 167 is quite satisfactory. When pieces of a more complicated nature are to be machined, particularly in the milling machine, more complicated fixtures will be required.

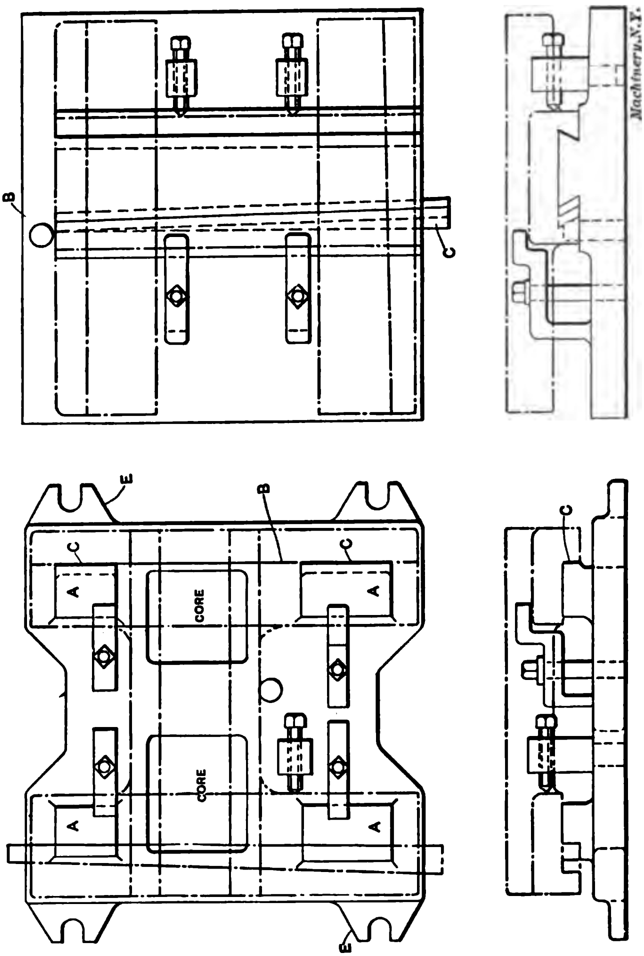
Assume that a set of planing fixtures for the piece shown in Fig. 170 is required. The work is a slide or carriage for a lathe. The finishing marks given on a number of the surfaces indicate where the work is to be finished. The piece comes from the foundry. In the first place, it must be considered from which sides to locate, and how to locate and hold the work without springing it, and in what order the operations should be performed to best advantage. Fig. 171 shows a fixture for roughing out the ways on the bottom. The slide is located on three fixed locating points *A* and the sliding point *B*. This latter is adjustable in order to enable cutting the metal in the slide as nearly as possible to uniform thickness. Sometimes, if the parts *A*, Fig. 170, bevel toward the ends, lugs *B* may be added; these can then be finished and used for locating purposes. The carriage, as shown in Fig. 171, is further located against the pins *C* in order to insure that the cross-slide of the carriage will be square with the bottom ways. The slide is brought up sidewise against the pin *D*, and then clamped down in convenient places, the clamps being placed as near the bearing points as possible to avoid springing. The reason for not having the locating point *D* on the opposite side, is that this side must be finished at the same setting; this side, being the front side of the carriage, is finished for receiving an apron.

The sides *E* and *F* of the fixture may be finished in a certain relation to the locating points and each other, and the side *E* may be made perfectly square with the locating points, so that when it is brought up against a parallel on the machine table, the ways of the machined piece will be square with the ends. The side *F* may be finished on the same taper as required in one way of the work for a taper gib.

The fixture for the next operation is shown in Fig. 174. This fixture is made to receive the carriage and locate it by the now rough-finished ways; in this fixture the cross-slide dove-tail in the work is planed. The slide rests on four finished pads *A*, and the straight side *B* of the ways in the slide is brought up against the finished surfaces *C*. If no other part is available for clamping the fixture on the machine table, lugs *E* are added. If there are no tapering surfaces, the fixture can be located on the machine table by a tongue, as already mentioned, or by placing a finished side against a parallel. The slide or dove-tail is now roughed out and it is usually sufficiently accurate practice to finish it in the same setting, especially as slides must always be scraped and fitted to suit the machine on which they are to be used.

The next operation would be performed in the fixture illustrated in Fig. 175. The carriage is here located by the dove-tail and by the pin *B*, and held by a gib *C*, or by straps and screws, as shown. It will be noticed that with the given design, the straps and screws must be removed each time a new piece is inserted, which is an undesirable feature of the fixture. If parts *A* in Fig. 170 project out too far, so that a light finishing cut would cause springing, they are supported by sliding points or other adjustable locating means.

If the dove-tail in the slide had simply been rough-finished in the fixture Fig. 174, the finishing operation of the bottom ways could

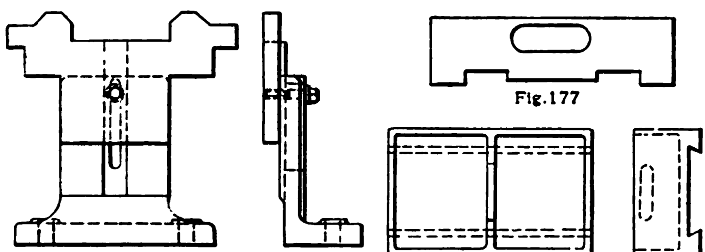


Figs. 174 and 175. Fixtures for Planing the Dove-tail Slide and for Finish Planing the Ways of Carriage in Fig. 170

have been done as just described in the fixture in Fig. 175, and then, after having finished the bottom ways in this fixture, the work could again have been located in the fixture Fig. 174, and the dove-tail finished; this procedure might insure more accurate work in some cases.

In the case just described, the work requires three different fixtures to be completed. The number of fixtures to use in each case is entirely dependent upon the nature of the work. When there is a large amount of work of the same kind to be done, several fixtures of the same type are made up for the same piece, and when in use these fixtures are placed in a "string" on the table of the machine, as shown in Fig. 172. Each strap holds down two of the jigs, one on each side of the bolt through the strap. The first one of the fixtures, *A*, is provided with a templet *B*, to which the tool may be set. The fixtures are located against the bars *C* and *D*, alternately, depending upon whether the straight or tapered side of the slide planed in these fixtures is being finished.

Templets are often made up separately and are used to determine the machining of both larger and smaller work. A templet may even be made adjustable, as shown in Fig. 176. This templet may be fastened to the machine table either in front or behind the work and the tool set to it, and is used when planing machine beds. Other templets or gages are made for testing the planing. They may not properly be considered as parts of the fixtures, but are usually designed and made at the same time as the fixtures are completed. These



Figs. 176 to 178. Gages for Setting Tools and Testing Work

gages are made from sheet iron, and the profile or cross-section of the work to be planed or milled is cut into the templet, as shown in Fig. 177. Other testing pieces may be made up more elaborately, as shown in Fig. 178. These latter are also used for testing when scraping and fitting the work. One templet may be made for rough planing or milling and one for the finishing cut.

A milling fixture of a type commonly used is illustrated in Fig. 179. The work *A* is supposed to be milled on both sides simultaneously. It is located on the fixture base *B*, and is held up against the half V-shaped piece *C*, which is stationary and held to the base by screws; the clamping is done by a clamp *D*, which is guided at *E* as indicated, so that it has a tendency to hold the work down well. Both the clamp and the corresponding piece *C* are thinner than the work, so as to allow the straddle milling cutters to pass over the fixture without interference.

In Fig. 180 is illustrated a simple fixture which may be used for both milling and planing. Two pieces are machined at the same setting in this fixture, and are located against the finished seats *A* and *B*. which latter acts both as a seat and as a stop. Another seat like *B* on the opposite side is not visible in the illustration. As the work to be done is of a rough character, sliding points provided at *C* give an adjustable support. The work is clamped by the pointed screws *D*. The tool is set by the lug *E*, which is cast solid with the fixture and which has its top finished to the required height.

It is often advantageous to perform milling operations after the boring and drilling has been done on the work, and then some fin-

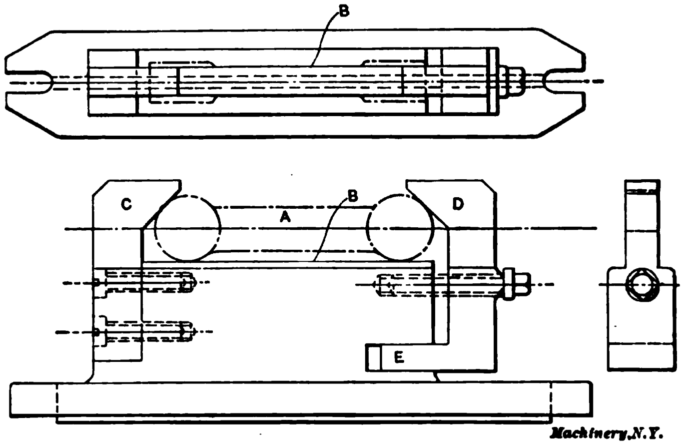


Fig. 179. A Typical Milling Fixture

ished hole may be used for locating the work. An example of this is shown in Fig. 181 where the work *A* is located by an arbor *B* passing through the finish-bored hole in the work, and resting on two V-blocks planed out in the fixture as shown. Two straps *C* hold the arbor down in the V-blocks. The work is further located against the screws *D*.

Fig. 180. Simple Type of Milling Fixture

which are adjustable so that the work may be held level. The clamping screw *E* holds the work against the screws *D*.

It is sometimes advantageous to make fixtures for holding work in the lathe. Suppose that a piece to be finished has the appearance shown in Fig. 182. The dove-tail *A* is finished, and the circular seat *B* is to be turned afterward so that the center of the seat will come in a certain relation to the dove-tail and a certain distance from the end. This operation can be carried out as shown in Fig. 183, by placing parallels *A* on the face-plate *B* of the lathe. These parallels will serve as locating means, and straps *C* hold down the work. If it is required that the seat be in exact relation to the dove-tail, two rollers *D* may be used against which the slide is located; the angle of the dove-tail and the diameter of the rollers are calculated so that the work can be very carefully located.

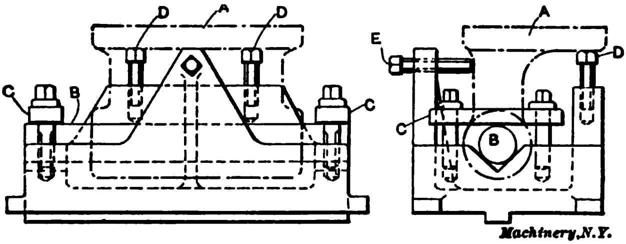
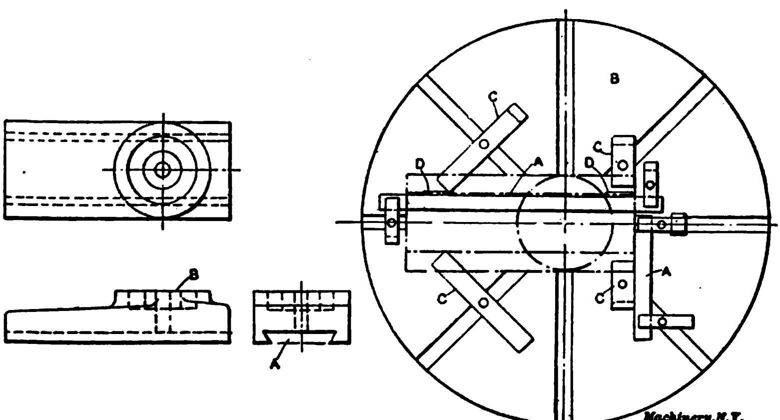


Fig. 181. Milling Fixture in which Work is Located from a Previously Bored Hole

The work may be turned out properly by this means by a careful man, but there are always chances of moving the parallels and it is a slow operation. If a simple fixture like the one illustrated in Fig. 184 is used, an apprentice can do the work correctly, provided he knows how to run a lathe. The work *A* is located by a dove-tail in a manner similar to that in which it will later be located on the machine on which it is to be used. It is held against the dove-tail in the fixture



Figs. 182 and 183. Work to be Recessed and Faced, and Method of Doing it in a Lathe

by screws *B* and clamped down on its seat by straps *C*. The pin *D* locates the work in the other direction, and the fixture itself is located on the face-plate by the boss *E*; as this boss has a perfect fit in a recess turned out in the face-plate, it must, by necessity, run true. Slots may be provided for locating the fixture on the face-plate and driving keys inserted at *F*. A sufficiently large lug *G* may be provided for counter-balancing.

It is always of advantage to try to locate work in fixtures in the same manner as it is located on the machine in which it is to be used

Indexing Fixtures

A number of fixtures for performing various operations are fitted with indexing devices, so that accurate machining at predetermined places in the work may be carried out in the shortest possible time. A simple indexing fixture is shown in Fig. 185. The work is mounted on a disk *A*, which turns in the bearing hole *B* bored out in the knee or angle iron *C*, which is located and fastened on the machine table. The disk *A* is indexed, and held in the right position by a pin *D*, which fits into a finished hole in the angle iron and also into one of the holes in the disk. The disk *A* is clamped against the knee *C* by a screw and washer *E* while taking the cut. When the main parts of this fixture are made of cast iron it is sometimes the practice to put lining

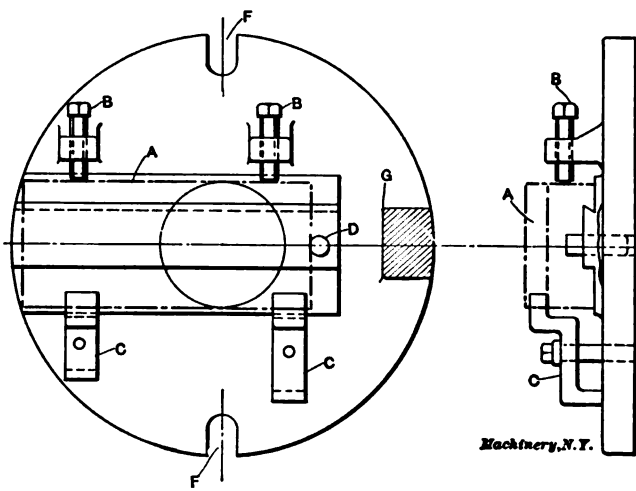


Fig. 184. Fixture for Recessing Work shown in Fig. 182

bushings of tool steel in the indexing holes to prevent them from being worn out too rapidly by the continual removal and insertion of plug *D*. This is a very simple indexing fixture, but a great deal of work can be finished without more elaborate arrangements. By adding a plate *F*, screwed to the top of the knee, and fitted with a drill bushing as indicated, radial drilling operations may be performed in the same device.

In Fig. 186 is shown a similar indexing fixture somewhat modified. The work is located and held on the rotating disk *A*, which is fitted in place in the bracket or body *C*, so as to have no play. The round plunger *B* is beveled on the end, and fits the slots in the circumference of the disk. A spiral spring pushes the plunger into place. The plunger is guided by a pin in an oblong slot, so as not to turn around. Sometimes the plunger may be made square or with a rectangular section, and fit a slot which may be shaped to this form. This latter method is more expensive and does not give better satisfaction than the plunger with the round body.

A large variation of methods for indexing are in use, employing pawls, levers, springs and safety-locking devices, which sometimes may be necessary. Indexing fixtures, however, designed according to the

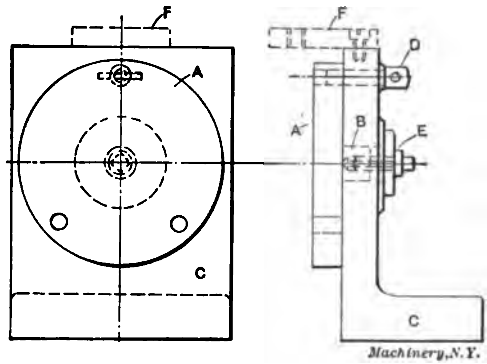


Fig. 185. Simple Type of Indexing Fixture

simple principles laid down above, will give as good service as many complicated arrangements. These indexing devices are used in cases where the standard indexing heads would not be suitable, and for many classes of work are equally efficient.

Conclusion

In a large shop with a great number of jigs and fixtures, it is quite difficult to keep them in proper order, and to have them so indexed

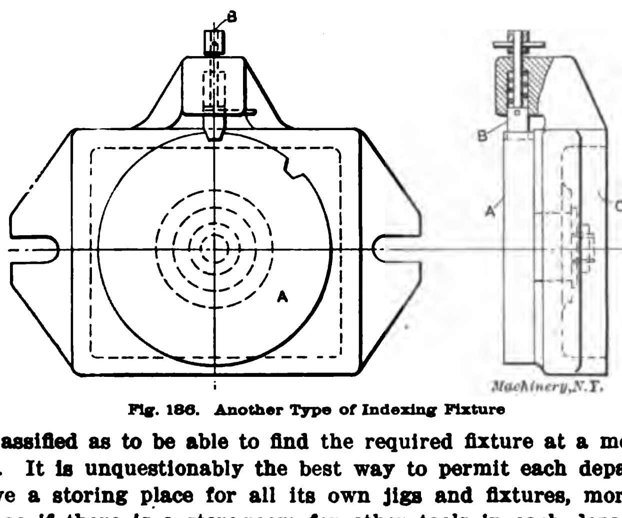


Fig. 186. Another Type of Indexing Fixture

and classified as to be able to find the required fixture at a moment's notice. It is unquestionably the best way to permit each department to have a storing place for all its own jigs and fixtures, more especially so if there is a store-room for other tools in each department. The jigs or fixtures are given out to the operators in exchange for checks, and before they are returned they should be carefully cleaned and the finished surfaces greased to prevent rusting. Before returning the check to the workman, the tool-room clerk should look over the fixture to see that no loose parts are missing, and no parts broken, and also that all loose pieces are tied together and attached to the jig body. The tools are placed on shelves partitioned off and numbered and an index is kept, showing at a glance the location of the tools for different operations. A copy of the index should be in the possession of the foreman, and also of the tool-room clerk, and should give the piece number of the work to be done in the jig, the number of the jig itself, and its place in the racks.

When arranging and storing the jigs, the lighter jigs are placed on the top shelves and the heavier further down. This not only permits a lighter construction of the storing shelves, but also makes it more convenient for the attendant to put the jigs and fixtures in place. If possible, jigs used for the same machine, or the same type of machines, should be in the same section of the rack, as this, to a certain extent, facilitates getting out jigs for the same work. When a jig or fixture needs repairing, it should be sent at once to the tool-making department, even if it is not to be used immediately.

In some trade journals there has been a great deal of paper wasted discussing what position a tool and jig designer really occupies,—whether he should be considered a designer with a designer's salary, or simply a draftsman, and of other topics of similar nature. The fact remains, however, that a progressive manufacturing plant, in order to have suitable and efficient tools devised, requires a man who possesses in the first place, good shop experience, in the second place, sound practical judgment, and in the third place, a fundamental knowledge of theoretical mechanical principles.

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NUMBER 45

DROP FORGING

SECOND EDITION

CONTENTS

49-55 Lafayette Street, New York City

CHAPTER I

THE DROP FORGING PLANT*

The design and equipment of the drop forge and hardening departments—adjuncts most important to the modern manufacturing plant—are subjects frequently entirely neglected in preliminary design, and almost invariably slighted in erection. While this fact is due, without doubt, to conservatism, it is not to be denied that in few places will careful design or small investment show greater beneficial results in finished product, or quicker returns from the amount of money expended. To install an elaborately equipped tool shop, and a hardening department consisting only of a few coal and gas fires and tubs of fresh water, indicates, to the writer's mind, lack of proper thought, and is, to say the least, inconsistent. It is the object of the present chapter to illustrate and describe a type of each department, indicative of what constitutes best modern practice, together with discussion bearing on such departments in general.

The drop forge and hardening departments being of the same general type, should preferably be combined under one roof. In a building for this purpose, ventilation is of greater importance than light. A good form of building is from 60 to 70 feet wide by about 20 feet high under the trusses, with roof pitched not less than 30 degrees, and a ventilating monitor at least 15 feet wide extending the entire length of the building. Windows throughout should be of the American type, with sliding sashes.

In the hardening room, all windows should be protected from excessive light by slat shutters or louvres, the slats being set at 45 degrees and about 3 inches apart, adjustable for about 1 foot at the top. This arrangement gives a subdued light, enabling the hardener to distinguish his color with a greater degree of accuracy. The slight adjustment at the top is sufficient to keep the interior light even, regardless of the outside conditions. Cne 16 candlepower light hung 7 feet from the floor should be provided for every 150 square feet of floor space in this department. Fig. 1 shows the plan of a building as primarily laid out as a part of a large manufacturing plant.

Location of Die-sinking Department

The die-sinking and inspecting departments are situated in the end of the building, both to insure better light, and to be further away from the jar of the larger drop-hammers. The jar in a department so located is insufficient to materially affect the quality of the work, provided the partitions are of brick and extend well below the floor line. The rough stock for dies is to be brought in at the door near the end of the building, planed up and dovetailed in 10-foot lengths, and rough sawed to size desired in a Thompson hacksaw. The finished

* MACHINERY, April, 1907.

dies are to be stored in a fireproof vault assigned to them, on racks with shelves 8 inches wide, the dies being stored face out, one half above the other. Thirty-inch passageways, being sufficiently wide to admit single trucks, are allowed between the racks.

Board and Steam Drop-hammers—Helve and Trip Hammers

In a moderate sized shop at least, it is good policy to install comparatively large drop-hammers on account of their broader range of utility. General practice is to install board drops with no size smaller than 400 pounds, and to install steam drops where the work requires sizes larger than 1,000 pounds. The steam drop in large sizes has the advantage of being able to break down its own work, but on small parts many forgings are spoiled by catching in the quick stroke.

In Fig. 1 the larger board drops have been set in conjunction with a helve hammer, so arranged that it may break down for two of them. This result may be obtained equally well by setting the helve hammer between two drops and faced the same way, but with the anvil block set about 3 feet in front of the base line of the drop hammers, thus permitting the blacksmith to swing his stock directly from one to the other.

The large hammers are set nearest the main cross passageways to lessen the travel for the larger stock and finished product. The forgings are, of course, hot trimmed in the trimming presses set in conjunction with each hammer, but before going to the machine shop, they are accurately trimmed to the size required for their reception into their various jigs and fixtures, in the presses of the cold trimming department.

The two trip hammers are used in conjunction with tool dressing and general work. The two blacksmith forges near the die-sinking department are used for general work during the day, and for night and overtime work when the main shop is not running. They are blown from an overhead blower, motor-driven, and are hung from the trusses, their exhausts being taken out through the roof. With the exception of these two fires, the use of fuel oil is universal throughout the entire shop. This subject will be further discussed later. Both the forge and hardening departments should be in general charge of one man whose office is centrally located between them, but each should have a separate sub-foreman.

Layout of the Hardening Department

The general layout of the hardening department is self-explanatory, but the details may require explanation. In front of the small open fires, lead pots, etc., with 45 inches clear space, is set a row of brine and whale-oil tanks, alternating, one of each kind being sufficient for two fires.

These regular brine tanks are built of 2½-inch Southern pine, and elliptical in shape, being 30 inches wide, 4 feet long, and 30 inches deep, with a capacity of 120 gallons. The brine is circulated through

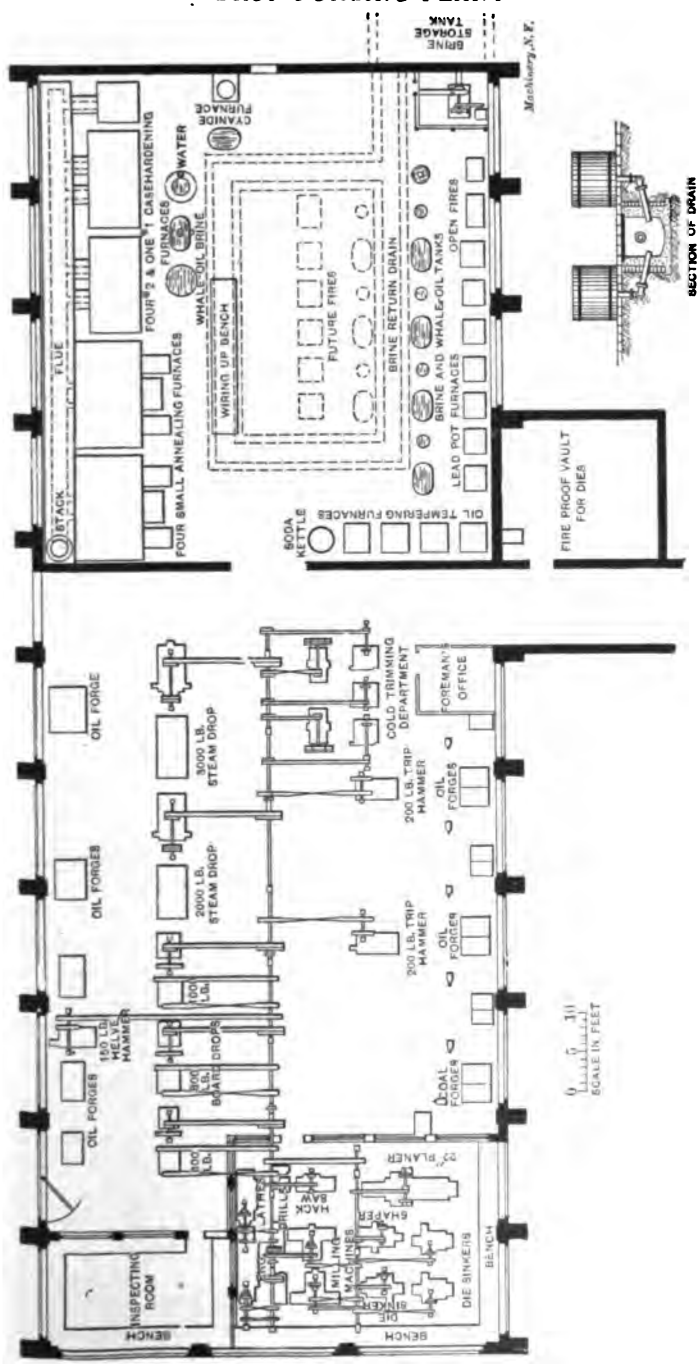


Fig. 1. Layout of Drop-forge and Hardening Shop

these tanks, entering at the bottom through a 1¼-inch brass pipe controlled by a gate valve, and overflowing at the top through a 4-inch cast-iron soil pipe. The required rate of circulation for each tank to keep the brine sufficiently cool for best results in hardening, is 50 gallons per minute.

Centrally located in front of the No. 2 casehardening furnaces is a brine tank of the same size as described above, a vertical section of which is shown in Fig. 2. Brine is admitted through the 4-inch brass pipe in the center of the tank. This pipe extends within 6 inches of the brine level, and is readily removable by hand, being loosely screwed into the coupling at the bottom. The brine entering through this pipe under pressure, forms a dome above the main level, which is used for the purpose of dipping the face of the drop-hammer dies, after which the dies are reheated slightly and completely immersed. By using this method of dipping the face, every corner and crevice of the die is struck at once, thereby preventing unequal cooling

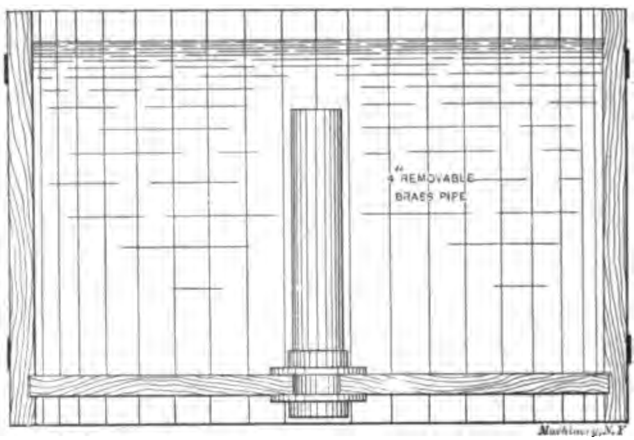


Fig. 2. Section of Brine Tank

and cracking. As the inlet pipe is readily removable, the utility of the tank as applied to general hardening is in no way limited. One hundred and fifty gallons per minute should be temporarily available for this tank. A 5-inch cast-iron soil pipe takes care of the overflow.

A 4-foot diameter whale-oil tank, one regular brine tank, and a portable fresh water tank complete the equipment required for the casehardening furnaces. These tanks are served by a crane. The portable fresh water tank is 30 inches in diameter by 30 inches deep, and when not elsewhere in use, is set in a concrete depression in the floor, 4 feet in diameter by 6 inches deep, which is drained through a screen by a 4-inch tile drain. The chief use of this tank is for water-marking screws and other small parts. The tank is drained at the bottom through a 2-inch spigot. A large part of the black bone used is caught by the screen in the depression, from which it may readily be shoveled out. Even with this precaution, however, it is desirable that the drain run with as steep a pitch as possible direct to a catch-basin, both to prevent stoppage and to facilitate cleaning out, should stoppage occur. The drain will surely give trouble if laid with many turns. On opposite sides of this tank are lugs or hooks to receive poles by which two men carry the tank about the job, wherever its use is required.

In front of the open fires is a special brine tank used for hardening cutters, reamers, etc. A section of this special tank is shown in Fig. 3. The brine is admitted at the bottom through a 2-inch brass inlet pipe, and spurts in through a large number of ⅛-inch holes drilled in the 12-inch cast-iron inner tank. The combined area of these small holes is designed to be about 20 per cent in excess of the area of the inlet pipe. A 4-inch cast-iron soil pipe takes care of the overflow. The advantage claimed for this tank is that the brine spurting through the small holes on all sides strikes all the teeth or flutes of the cutter or reamer at the same time, thus tending to prevent cracking.

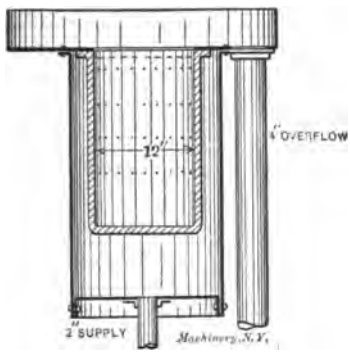


Fig. 3. Section of Special Brine Tank

A 5-inch by 4-inch centrifugal circulating pump set in the pit in the corner of the building, and driven by a 15-horse-power motor, supplies the brine system. The required pressure which must be kept on this system to secure good efficiency is 15 pounds per square inch. The pump is set sufficiently low to be always primed from the storage tank built in the ground outside the building. That the brine may be kept sufficiently cool in the summer months, this storage tank must have a capacity equivalent to a fifteen minutes' supply for the entire system when all tanks are in operation at full capacity. The brine overflow from all service tanks is returned by gravity to the storage tank through the drain shown in Fig. 1.

The regular oil tanks are 20 inches in diameter by 2 feet deep inside, but the shell is made 30 inches high to bring their tops to the same level as the brine tanks. The cooling apparatus consists of a coil of ½-inch brass pipe through which a part of the factory service water is circulated. The large 4-foot oil tank is of the same depth and is cooled through a 1-inch brass coil. It is not necessary to keep the oil as cool as the brine. A 2-inch by 3-inch belt-driven centrifugal pump supplies the circulating water. Certain concerns cool their oil by circulating it through a series of trombone coils placed in the monitor of the hardening room, but the practice has never appealed to the writer. The expense necessitated is comparatively great, the oil makes hard work for the pump, and the main heat from the building must pass out around these coils if so placed.

Advantages of Fuel Oil

Having in a general way described the equipment of each department, let us return to the question of fuel. The primary considerations controlling the efficiency of such departments are undoubtedly the ease of regulation and heating capacity of their fires. It is in this regard, even more than in the reduction of fuel cost, that the greatest economy is attained by the use of fuel oil. The reasons are obvious. The blacksmith's time may be given entirely to his work in hand, since once the valves are properly adjusted they require little or no

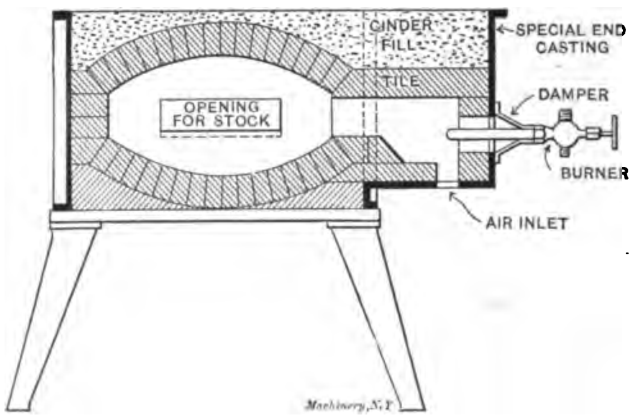


Fig. 4. Common Blast Forge Refitted to use Fuel Oil

attention and an even heat is assured. No labor is required to bring coal to, or take ashes from, the forge, and when no work is being done no fuel is required. If the flame is run a little on the yellow, there is absolutely no scale. The cleanliness of the fire renders it especially adapted to such work as welding, etc. For the departments under discussion, the writer prefers an air-pressure system to those using steam, his preference being chiefly due to the fact that these departments are generally somewhat isolated from the source of steam supply. Of the air-pressure systems, those using the lowest pressures consistent with best efficiency are evidently the most desirable. Excellent systems are now on the market using from 8 to 16 ounces pressure. These systems require, however, furnaces of rather special design, the most efficient having ample combustion or mixing chambers in which the oil spray is combined with a primary air supply and volatilized before being admitted to the main chamber, where the stock is to be heated. In a plant where the installation is to be of entirely new forges, a carefully selected system of this type is ideal. In many cases, however, it may not be thought desirable to entirely discard such equipment of coal-burning forges as may be on hand. Where such is the case, but small outlay is required to make the necessary alterations to permit them being used in conjunction with a moderately low-pressure system. By this the writer means a pressure of about 2 pounds per square inch, which can, of course, be readily discharged by

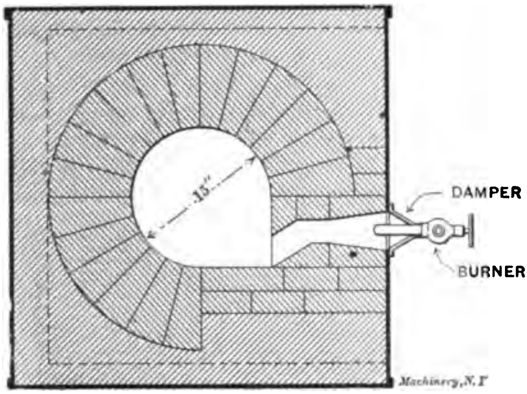


Fig. 5. Horizontal Section of Refitted Lead Pot Furnace

the ordinary "high-pressure blower," without requiring the installation of an air compressor, which is necessary with a system using from 15 to 18 pounds pressure.

Refitted Coal Forges and Furnaces for Fuel Oil

In refitting coal forges and furnaces to use fuel oil, it is desirable, as far as possible, to give the spray a whirling motion which tends to

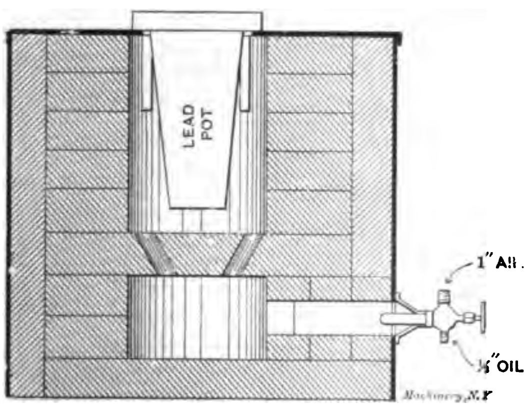


Fig. 6. Vertical Section of Refitted Lead Pot Furnace

more completely vaporize the oil, and also makes a much less noisy fire than is the case where the oil strikes against flat surfaces. In the latter case, where the oil strikes flat against the white-hot tile, it causes what appears to be a series of rapid explosions sufficiently loud in a large shop to be a source of annoyance.

In Fig. 4 is shown a method of refitting a common blast forge. Common arched firebrick and skewbacks are used and a few special tiles which may readily be ground to form on the common grindstone. Common red brick may be used as backing. A special casting is required, the end of which may be made to bolt onto the original side castings. In very large sizes it is sometimes advisable to install a burner at each end of the forge, which arrangement is very satisfactory and gives an intense heat at the center of the fire box.

Figs. 5 and 6 show horizontal and vertical sections of the common form of lead pot furnace refitted. Either wedge or cupola brick may be used. Two courses form the bottom tile, and forming the top of the mixing chamber, is a tile through which are drilled at an angle, six 1½-inch holes. For this operation a common star drill may, with care, be used. In the top two courses, four bricks in each are omitted

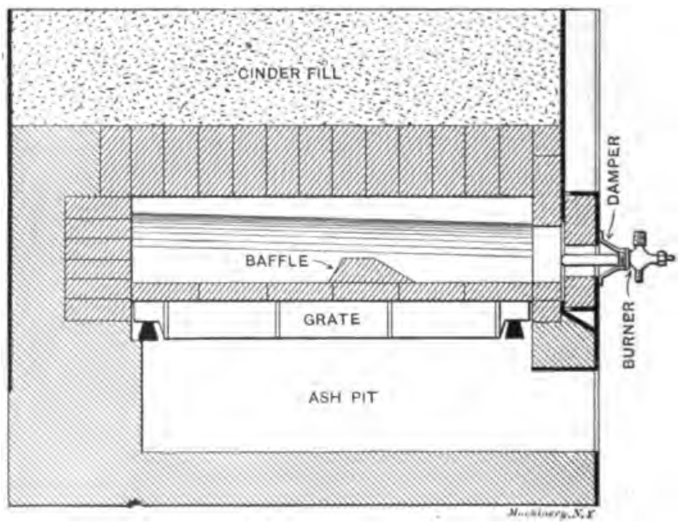


Fig. 7. Longitudinal Section of Refitted Casehardening Furnace

at 45 degrees for vents. As before, the firebrick is backed up with common red brick.

Figs. 7 and 8 show cross and longitudinal sections of a refitted No. 2 Brown & Sharpe casehardening furnace. In this case the coal grates are left in place and simply paved with firebricks laid on their sides. A 3-inch fire tile, ground to the form shown, is centrally located in the firebox to act as a baffle. If the furnace is to be set up new for the use of fuel oil, it is desirable that the bridge wall be sloped as shown, to leave an opening at the back of 2 inches over the wall, and 4 inches at the front. The reason for this construction is to counteract the tendency of the heat to drive to the back of the oven. This tendency exists, but is not marked, and in cases where the furnace is already set up it hardly pays to rebuild the bridge wall. A special fire door casting, designed to take the burner, must take the place of the former vertical sliding door. These few examples will give a general idea of the changes necessary to remodel an installation of coal fires.

Arrangement of Piping

In the two departments under discussion, the oil is supplied to all furnaces through a 1¼-inch wrought-iron main, making a complete closed loop around each department in order to keep the pressure even. A 1-inch steam pipe must be laid with it to keep the oil from congealing in cold weather. These two pipes should be laid preferably in the ground itself and not in a trench, and should never be laid above the floor, the reason being that the gases from all petroleum distillates are heavier than air, and will run to the low parts of the floor or the trench. These gases, though not themselves explosive, may become so if confined with a large proportion of air.

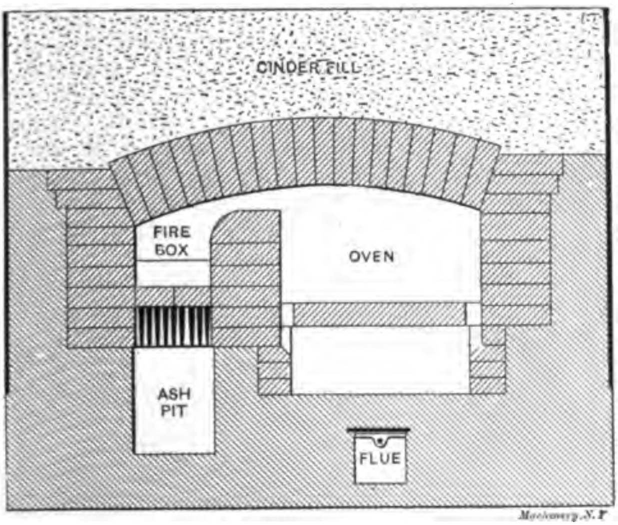


Fig 8. Cross-section of Refitted Casehardening Furnace

The air piping should preferably be suspended overhead with outlets looking down into the risers from the oil mains. The speed of the air in these pipes should not exceed 15 feet per second in the first installation, which will permit of about 30 per cent increase, due to growth, without the speed becoming excessive. A rule-of-thumb measurement sometimes used is that the area of the air pipe shall equal six times the area of the jet, but the foregoing method is much the safer one for computation. To facilitate calculations, the following notes may prove of interest:

At 2 pounds pressure there will be required at the blower, roughly, about 1,000 cubic feet of free air per minute per gallon of oil burned.

Blast forges burn per day of ten hours approximately 0.15 gallon of oil per square inch of horizontal area of firebox.

Open fires for hardening, as above, 0.025 gallon.

Lead pots, oil tempering, casehardening and annealing furnaces, 0.05 gallon.

About 10 H. P. is required to transmit 1,000 cubic feet free air against 2 pounds pressure.

From the foregoing, a close estimate of the size of the required blower and the horsepower required to drive it may be obtained. Included in this estimate must be a figure on the amount of air required to blow the drop-hammer dies. The blow-pipes required are one 1½-inch pipe with flattened nozzle for each small drop- and trip-hammer, and two of the same size for the larger drop-hammers. As the use of these blow-pipes is rather intermittent, this figure is generally in the nature of an off-hand estimate, based on the judgment of the engineer.

CHAPTER II

DROP AND STAMPED FORGINGS*

The employment of drop forgings and stampings increases constantly and rapidly. Several firms are now equipped wholly for this class of work, and supply enormous numbers of forgings to the metal working trades. Drop forgings or stampings bear the same relation to the work of the blacksmith shop that machine-molded castings bear to that of the foundry. In each case the skilled labor of the craftsman is dispensed with, yet good wages are earned by men working by the piece. In each case the cheaper product has the advantage of much greater accuracy, and uniformity in shapes and dimensions. The numbers turned out from the dies or stamps, as from the molding machines, are often twenty or thirty times as great as those which can be produced by hand by skilled men. In each case, too, the question of machining is often inseparable from that of the methods of production adopted, because accuracy of shape and uniformity of dimensions in forgings and castings alike are favorable to the most economical machining, since allowances which are either insufficient or excessive for the machines are equally undesirable and troublesome. The smith working at the anvil, even with the aids afforded by templets and gages, is unable to produce two pieces, to say nothing of twenty intricate and elaborate pieces, absolutely alike, unless at an enormous expenditure of time. It is cheaper therefore, and is the practice to "leave plenty on" to insure that the work shall "finish" all over when machined, otherwise the final corrections would occupy much more time than the actual formative work of the forging. But forgings which are stamped, all come out exactly alike from the dies, without any extra care or time spent on the part of the workman.

The accuracy of stampings, however, is further advantageous in the fact that a considerable amount of machining is often avoided altogether. The smooth, glossy, polished and accurate surfaces left from the dies are often good enough for handles, levers, webs, and bossed parts. Or, if they are required to be bright for good appearance, then a polished surface imparted by an emery wheel and buff are sufficient, without any machining in the lathe, shaper, or milling machine. Punched holes may be simply lapped, instead of being drilled and reamed, the locations of the holes being fixed with accuracy by the dies.

Development of Stamping Processes

The history of die stamping goes back fifty years or more in the Black Country, and Birmingham district, England. In the blacksmith

* MACHINERY, May, 1908.

shops a limited amount of work in dies had been done previously for as long a period, but only, or chiefly, as a device for imparting a final finish to work which had been already prepared and nearly completed at the anvil. This practice arose from the fact that only in this way was uniformity in a number of similar forgings economically possible. Such uniformity could only be produced on the anvil with flatters and

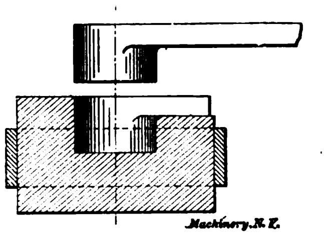
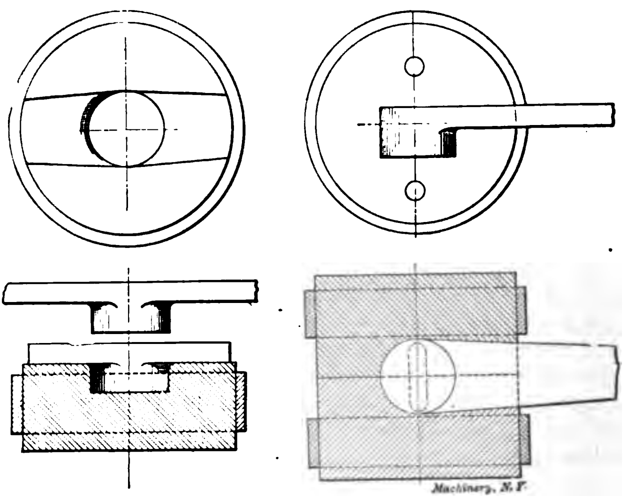


Fig. 9. Die Used for Correcting or Finishing Levers

swages, at the sacrifice of much time and labor. Hence, long before the practice of *producing* forgings by stamping existed in the blacksmith shops, the practice had grown of *correcting* and *finishing* anvil-made forgings in dies under the power hammer. The dies were often of a sectional form, as they are still to-day when heavy forgings are in question. Thus, a die or pair of dies would include a boss only,



Figs. 10 and 11. Other Examples of Dies Used for Finishing, but not for Rough Forging, Bossed Levers

on a lever, Figs. 9, 10 and 11, the lever ends standing out beyond the dies; or a die would be used to punch a hole, and correct the boss at the same time, Fig. 12. Lever ends, either forked or solid, are suitable objects for finishing in this way. So are the ends of connecting-rods, Fig. 13, the eyes of the tie rods, and the bridles or loops of slide valves. In the old practice, as to a large extent now, these were made of wrought iron, bent, and welded. These operations were done at the anvil, and the correction and finish done at another heat in the dies. These dies were, and are, made of cast iron from a pattern. Later, cast steel has been often used with a view either to increase the strength, or to lessen the weight.

Even on the anvil, in little shops where there was not as yet a steam hammer, the old Oliver-hammer was utilized in finishing the heads of bolts in dies, and the writer remembers seeing these in operation. And on the anvil, little devices were rigged up for finishing bosses, and punching holes, the type of which was the spring swage, Fig. 14,

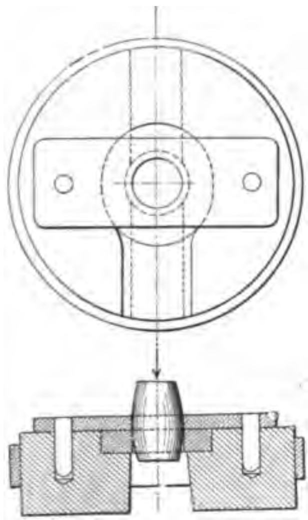
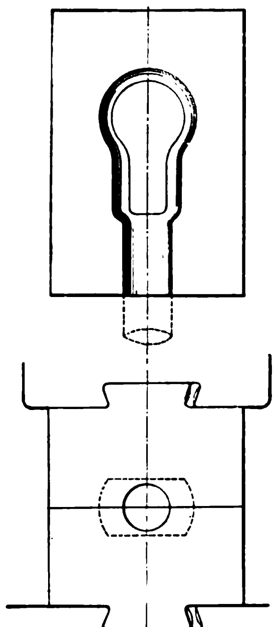


Fig. 12. Die used for Punching Hole through Boss, Correcting Shape of Boss at Same Time



Machinery, N.Y.

Fig. 13. Die for Finishing the End of a Connecting Rod

the jaws of which were fashioned independently of aid from the machine shop, by a process of ***typing***, or ***hubbing***, from a dummy, or a duplicate forging. Very many simple forms can be and are done in this way still as a legitimate and suitable method. Light swages are used on the anvil, just as the heavier ones are operated under the steam or drop-hammer.

The sectional dies are used very extensively now in the blacksmith shop for the purpose of final correction and finishing only. But along with the use of these, there has grown the practice of stamping wholly, either as a sub-department of the shop, or carried on in a distinct shop. Generally, however, the merely corrective dies are used for the heavier forgings, and the regular stamps for the smaller class, as in Figs. 15 to 18. To make the larger forgings entirely by stamping operations would often require heavier hammers and appliances than most shops are equipped with, and the numbers wanted of the large forgings might not be sufficient to render heavier installation remunerative. But a heavy forging may be corrected in dies when it would

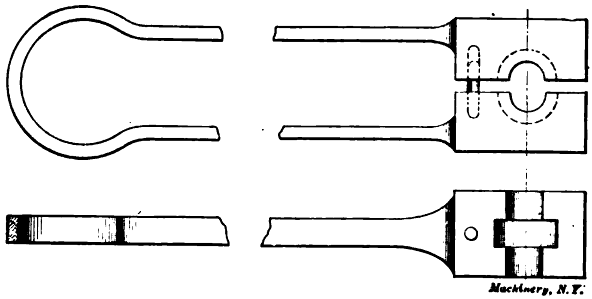


Fig. 14. Device for Shaping Bosses on Work, made on the Principle of the Spring Swage

not be practicable to produce it entirely from a rude lump. Among work of this kind may be instanced large tie-rod eyes, large bossed levers, Figs. 9 and 10, rings, cranks, and such like. Some of these are too long to be embraced wholly in a single die. A long two- or

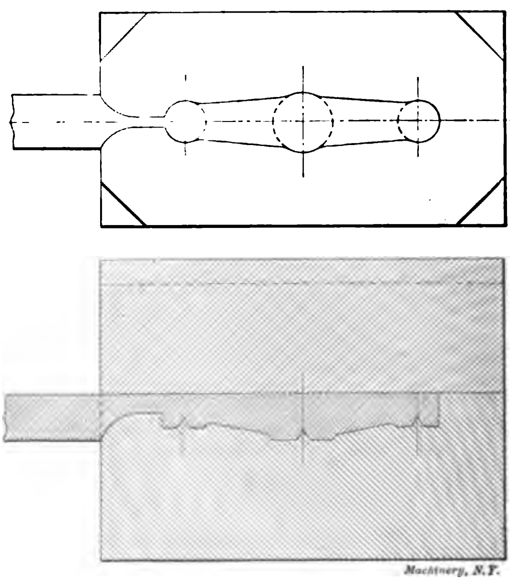


Fig. 15. Example of Forging Die Forming Center Holes in the Bosses of the Work

three-bossed lever, for example, is then corrected only on its bosses, and for an inch or two away therefrom. A pillar for a handrailing would have its bossed portions corrected separately, and the body corrected by swaging at the anvil, or in other dies.

Materials Used for Dies

The number of similar forgings required is often insufficient to justify a large outlay for cut steel dies. But dies made in cast iron are not costly, and therefore they are frequently made when only half a dozen or a dozen of similar articles are required. They may, of course, be kept for future use, and should be, when a job is likely to be repeated, but, apart from that, a very small number of forgings will pay the cost of cast dies.

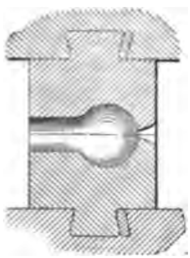


Fig. 16. Type of Die Forming the End of a Ball Crank

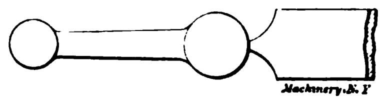


Fig. 17. Forging Made in Dies from a Bar

The growth of stamping has been gradual and natural. The mere fact of having cast dies lying by from previous jobs has been the cause of their utilization for pieces of work which might not otherwise have been thought to justify the expense of new dies. But being in stock, slight and unimportant alterations in some dimensions in new jobs would often render the dies available. In this way the beginnings of standardization arose. For as the dies began to accumulate, one pair or set was made to do duty for work for which it was not originally intended. Thus, the difference of half a ton or a ton of crane power was not allowed to involve the making of minute differences in the forged work for the cranes, but one standard set was used for both. So in engine and pump work the same standard sets came to be used for powers and sizes of mechanisms that were not

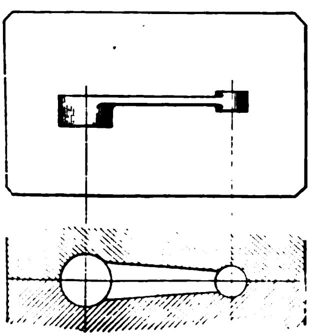


Fig. 18. Dies for a Lever with Hubs at Both Ends

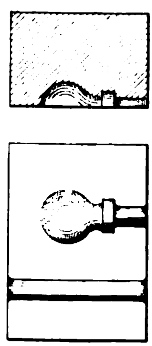


Fig. 19. Dies for Forging an Eye Bolt

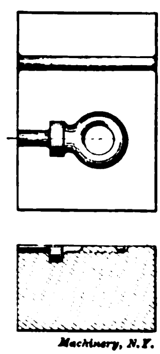


Fig. 20. Dies for Finishing the Eye Bolt

very dissimilar, and when a difference of ⅛ inch, or so, in dimensions could make no possible difference in the proper operation or strength of the forged details.

Principles of Drop Forging and Stamping

Comparatively few articles can be produced in one pair of dies, and those are chiefly circular forms, the diameters of which at different sections do not vary greatly. If they do vary, some preliminary reduction or "breaking down" is necessary. And if a portion of the article takes the form of an eye, or a boss, three or four successive operations may be necessary to produce the forging, as in the eye-bolt produced in Figs. 19 and 20. The die-maker has then to settle how the work shall be done, whether in one or more pairs of dies, and whether

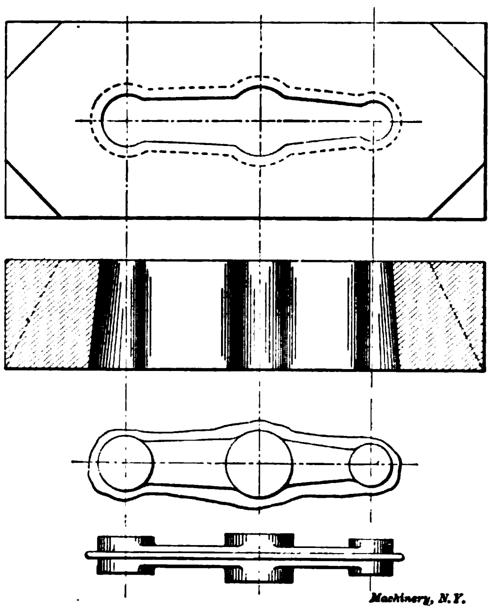
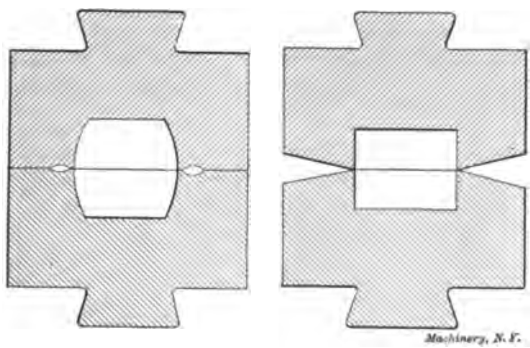


Fig. 21. Stripping Die for Removing Fin Produced by Forging Process, and Work for which it is Used

under one hammer or two. As a rule, to which there are exceptions, it is desirable to do all the work at a single heat. Then, if several operations are required, they must be done either in one set of dies, or in separate dies. For small forgings it is easy to get three or four recesses in one pair of dies, for roughing down, for formation, and for cutting off, or nicking for breaking off. In larger pieces it is necessary to have two hammers adjacent, so that the stamper can use them both without walking away from either. But a few hammers are made double headed, with two anvils, and tups to facilitate such work. When two heats are necessary, then it may be convenient to perform the earlier operations on a large number of similar pieces, and then change the dies for the subsequent work. This, perhaps, is more often done in the regular machine shops than in the drop forging works, in which the work is divided between two adjacent hammers.

Though the smith working at the anvil endeavors to gage by a very rough mental estimation the amount of material which is required for a forging, in order to lessen labor, the stamper may be comparatively indifferent to that consideration. He will not, of course, have much excess of metal if it can be avoided, yet he is much in the same position as the anvil smith who has a steam or drop-hammer available adjacent to the anvil. The power hammer is often resorted to for roughing down an odd lump quickly, in place of taking a smaller section, which would involve the alternative of upsetting, or of welding. The shapeless lump is simply roughed down rapidly in far less time than would be occupied in fullering on the anvil, or in performing the alternative operations of upsetting, or welding. In this way, too, very many odds and ends, cropped from iron or steel bars, are utilized, which would otherwise go to swell the scrap heap.

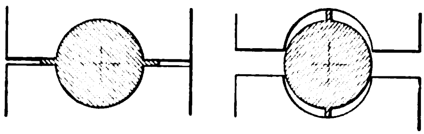


Figs. 22 and 23. Dies Provided with Space for Receiving the Fin

The case of stamping is analogous. Though forgings having considerable difference in cross-sectional areas, are, as a general rule, broken down in one or more operations, preliminary to finishing, yet a great deal of work is done without this step-by-step process. A cubical lump is taken and put into the dies and reduced. A large amount of fin being squeezed out in the process, this is removed in an adjacent stripping die, Fig. 21, and the forging put back, and finished in the first, or in another, recess, followed sometimes by a final stripping. This heavy reduction is only possible, first, because the lump is raised to a high temperature, and second, because the mechanical work done on it maintains the heat until the reduction is completed. At the anvil, two or three heats would often be required to accomplish the same amount of work which is done in one heat in dies.

Removal of Fin Produced in Drop Forging

The formation of fin, it will be noted, is peculiar to stamping; it does not occur in anvil work. Sometimes dies are cut like Figs. 22 and 23 to receive the fin. In Fig. 22, a wide and shallow groove is cut all around the recess to receive the fin. In Fig. 23, the faces are sloped away with the same object. Work which is of cylindrical form does not necessarily involve the formation of permanent fin, because it can be rotated, as the reduction is going on, and such excess of metal which is squeezed out laterally is removed at once when a partial rotation is given to the piece, as in Figs. 24 and 25. In Fig. 24 the fin is shown squeezed out; in Fig. 25 it is being driven into the forging



Figs. 24 and 25. Showing how Fin Produced on Round Work is forged into the Bar by Rotating it

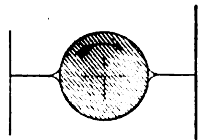


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Fig. 26. Die with Rounded Edges to Receive Fin

again. Such being the case, Fig. 26 is the shape given to circular dies in cases where the circular form is not hampered by the proximity of shapes which would interfere with rotation. When the work can be rotated, the result is a fine, smooth, polished surface, which in many classes of work renders any subsequent machining unnecessary, or, if finish is essential, a little grinding may suffice. In some forgings a

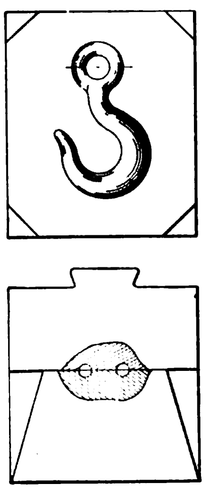

Fig. 27. Dies for Crane Hook

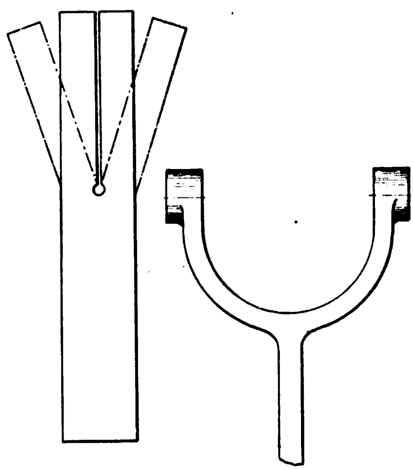

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Fig. 28. Fork Lever and Wrought-iron Bar from which it is made

portion only, a stem or shank, can be so treated, the remainder consisting of an eye, or a flattened portion, or a square shape.

Difference between Treatment of Steel and Wrought Iron

In the blacksmith shop, wrought iron is still used as extensively as steel for common forgings. But many forms when made of wrought iron must not be stamped from a solid lump because of the loss of strength which occurs across the grain. Large thin rings and curves of light section should always be bent. But if these are made of steel, no such reason exists, because steel has practically no difference in strength with or across the direction of rolling. The partial substitution of steel for wrought iron has therefore been favorable to the development of stamping. Many jobs are now stamped from a solid

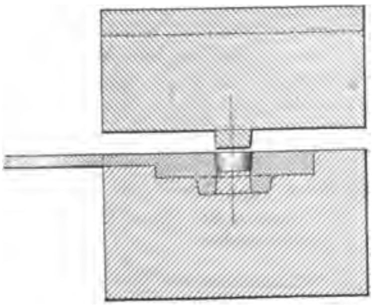


Fig. 29. Dies for a Circular Loose Hub

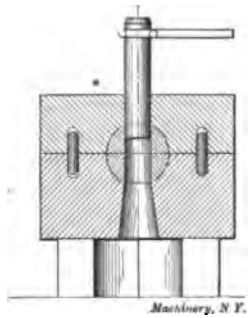


Fig. 30. Punching a Small Hole through the Work in the Dies

bar, or lump of steel, which were formerly made from wrought iron by bending and welding. Hence, while wrought iron is still extensively used for anvil-made forgings, steel is employed much more for stampings. The crane hook, Fig. 27, when made of wrought iron, is always bent from the bar before being finished in the dies. Made from

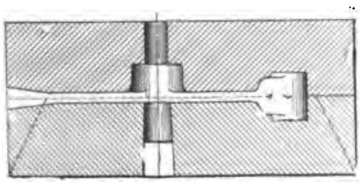


Fig. 31. Dies for Punching Holes through Bosses

Fig. 32. Holes Punched by Punches Integral with Die

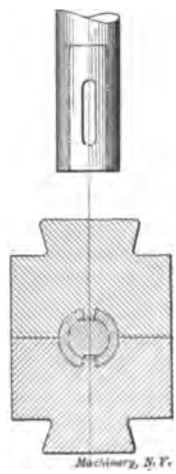


Fig. 33. Method of Forging the Slots in Collets

steel, it is stamped from a solid lump. For the forked end, Fig. 28, if made of wrought iron, a bar is split, and opened out, and bent over a form, and finished in dies. When made of steel, it may be stamped from a solid mass. The flange, Fig. 29, is stamped in steel from a solid chunk, handled by a porter bar temporarily.

Work with Holes Forged through it

The old method of punching holes is that shown in Fig. 12, in which the punch is guided by a plate doweled on the body of the die. This is suitable for large holes. Frequently, for small holes, the punch is separate, and driven through a hole in an upper die as in Fig. 30; in Fig. 31, a hole without its punch is shown. But punches are also often included solidly in the die, as in Fig. 34, half in top, and half in bottom, and not quite meeting at the center. In a shallow boss the punch may be in one half of the die only, as for a forging like Fig. 32. The metal becomes squeezed into the boss, and is improved by consolidation. Often, when holes are left to be drilled, the centers are stamped by small conical projections in the dies which serve as accurate guides for the driller. Sometimes holes are punched only through a portion of the metal, Fig. 33, when the central part has to be bored out subsequently, as indicated by the dotted lines.

Methods of Applying Impact or Pressure on Dies

Formerly all die work was done with hammer blows. As the demand grew for an extension of the system to heavier forgings, and to

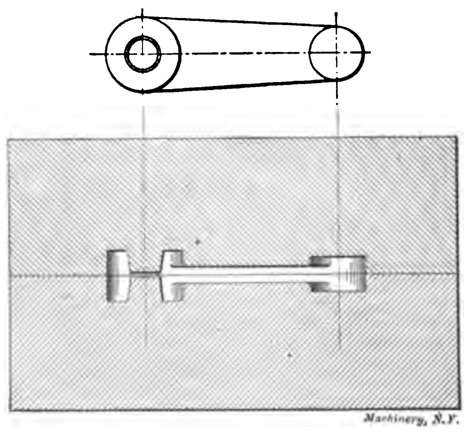


Fig. 34. Construction of Die for Forging a Hole through a Boss

articles involving the bending of plates and sheets, the steam and drop-hammers were not able to deal so well with these. The demand was met by the presses, which are actuated by hydraulic power or by gears, cranks, and toggle levers. These will easily deal with dies and articles several feet in length, many of which are too intricate to be dealt with by hammers, even if their dimensions did not set a limit to such treatment. They are practicable on the hydraulic presses, because two rams can be utilized, one acting in the vertical, the other in the horizontal direction, so working at right angles with each other. This is utilized for bending, welding, and punching, for closing up joints, for dealing with undercut designs, and with hollow spaces formed by bending and welding, or by stamping. Typical of much work of this class is the die and punch used for stamping the rings for uptakes of vertical boilers and the man-hole and mud-hole seatings for boilers, Fig. 35, from a plain piece of steel plate. Fig. 36 shows the dies for forging a crank by pressure. A large amount of work of this kind is done in the railway car shops.

Stamped forgings thus diverge into two great groups, according as they are produced by hammer blows, or by gradual pressure. Broadly, the first group includes articles of small and medium dimensions, the latter those of a massive character, and all large work done in plates. This is now a generally accepted division, and one which harmonizes with the difference in hammer blows delivered on comparatively small masses, and of pressure on thicker bodies. Where mass is the condition present, slow pressure is more penetrating than impact, just as it is in large shafts and forgings. Moreover, the blows delivered

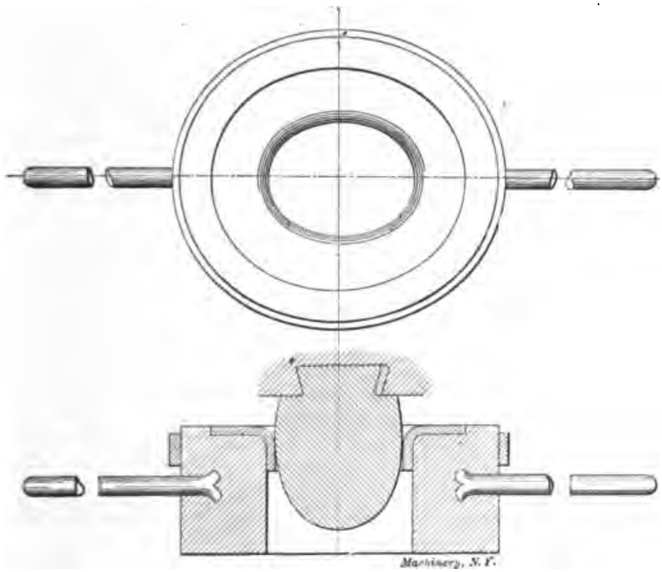


Fig. 35. Die Used for Forging and Bending Man-hole Seatings

from a very heavy hammer are destructive to dies, and if these are made massive enough to withstand these blows, then they are too heavy for convenient handling. Massive dies are, of course, required to resist pressure, but that is not nearly so destructive as the violent, incessant jarring action of a hammer.

Methods Used for Making Dies

The stamps or dies used are as varied in their details and cost as the forgings themselves are. A great advantage of stamping dies is, that like machine molding, they are as readily adaptable to the demands for a very few identical articles, say ten or a dozen, as to hundreds or thousands. But the amount of work put into the dies, and the patterns and the materials used for them have to bear a definite relation to the number of pieces required. Hence, we have at extremes, dies of cast iron made cheaply, and those of mild steel cut out with care and hardened. Except in name and function, the examples at each extreme have little in common. They are not made in the same way, and the periods of their service are much less in the first than in the second case.

The cast dies are molded from suitable patterns. They may have to be cleaned up a little by the machinist. As they are liable to fracture, unless made very massive, they are frequently encircled with bands of wrought iron, shrunk on, as in Figs. 9 and 12. They are, when small, lifted with circular tongs, Fig. 37, or by the hands, but larger dies have handles cast in for lifting them, Fig. 35. Or, alternatively, holes are cast for the insertion of rods for the same purpose. Some cast dies will endure long service, others fracture soon. Dies of cast steel are stronger, but are more liable to inaccuracy.

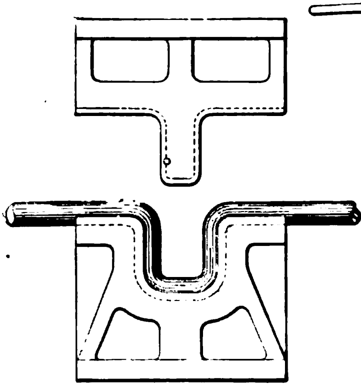


Fig. 36. Die for Forging Crank

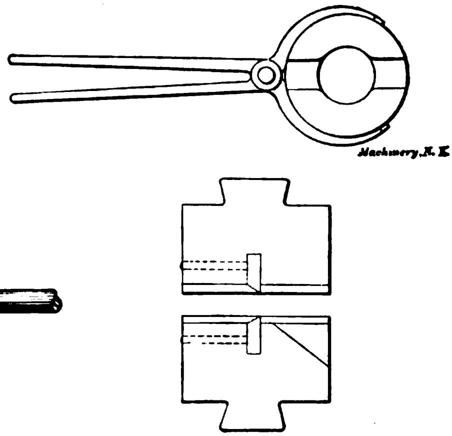


Fig. 37. Tongs for Holding Dies, and Cutters for Nicking the Stock, Fitted at the End of Dies

Dies of forged steel are marked out on their faces, and recessed by various machine tools, and by hand work. All the aids afforded by machine tools are utilized, as boring, slotting, milling, and shaping. But often very much is left for the chisel and file to complete. There are several special machines designed wholly or chiefly for the use of die sinkers, but much can be done by the ordinary tools in the shops. Templets are used to check the progress of the work, including those of sheet metal for local sections, and those which represent the actual forgings which have to be stamped. These are made of lead, or tin, or a first sample forging is prepared. Contact is insured by the transference of red lead from the templet to the recesses which are being cut.

Reference has been made to the typing or hubbing process. It bears an essential resemblance to the operation of stamping medals and coins by a hard blow. Only the operation is reversed, the die itself being produced by stamping it, while white-hot, from a cold forging.

It has the advantage of being cheaper than cutting dies, and in circular outlines is accurate enough, but is not well adapted for intricate shapes. The spring swages are frequently made in this way. In obtaining circular shapes thus, the hub or type is rotated between each successive blow, so correcting any inaccuracies that might form. The edges are of necessity produced with a slight convexity, Fig. 26. But this is an advantage in producing circular forgings which are rotated in the dies. It is not necessary to have complete circles in such a case, because metal squeezed out laterally, and what would soon form a fin, becomes obliterated by the next blow when the rotation info a new position takes place.

In one of the illustrations, Fig. 11, dowels are shown, which are inserted to serve as guides to secure the alignment of top and bottom dies. These are only used when the dies are not attached in any way to the anvil below, and tup above, as is often the practice in heavy dies. But generally the dies are secured by dovetails and keys, as in Fig. 13. In some cases locating screws are used on the anvil for dies cut at the corners, like Figs. 21 and 27, and the dovetail is only on the tup. The locating screws permit of making slight adjustments.

Forgings are often included in their dies, and are knocked out by a kicker device, or are pried out, or pushed out. Often a porter bar is used, generally the plain length of the bar from which the forgings are being stamped, as in Figs. 15 and 17. Then the forging is easily nicked off by reducing at the neck as shown, or a pair of cutters is fitted at the end of the dies, as in the lower part of Fig. 37.

The foregoing is an outline of the methods of drop forging in use, from which it is seen that the practice is divisible into three great groups: that done under hammers, and that in presses, and a further subdivision between the methods of the general shops, and the drop forgers who work for the trade.

CHAPTER III

MAKING DROP FORGING DIES*

Drop forging dies are made of 0.45 to 0.60 carbon steel, and are, usually, from 5 to 8 inches thick. At *A*, Fig. 38, is given a general idea of their appearance when finished. The dies are marked *T* and *B* (top and bottom) to prevent their getting mixed in the laying out. The front and left-hand sides are squared up, and from these sides the center lines of the impressions are laid out and the dies set up when ready for use. The edger, or breaking down impression, is on the right-hand side of the die. It is used for breaking down the rough heated stock into something like the shape required, before it goes into the finishing die. The heaviest part of the forging is always nearest the front. In deep dies, shapes which show parallel sides on the drawing are given from 5 to 7 degrees taper on each side, to prevent the forging from sticking in the die. For machining the forging 1/32 inch is usually allowed, and for shrinkage 0.012 to 0.015 per inch. When the dies are finished, a specimen casting of lead is made in them for ascertaining whether or not they will give the desired result.

The round portion of the impression is sunk first. Swinging the die blank in a lathe, when there is much stock to remove, is a convenient method. In some shops a cast-iron bolster for the lathe face-plates is used. This bolster has a web on its back, which fits the slot in the face-plate. The face of the bolster has a dove-tail slot, which is identical with those in the hammer, and is at right angles to the web on the back. By this means a circle is quickly trued up. When the round portion is under 1½ inch in diameter, a profiling machine is better adapted for the work, using the half-round cutter shown at *C*, Fig. 38, to finish with, after roughing out the stock with a two-lipped cutter similar to that shown at *D*. The half-round cutter is very useful, being strong, easily made, and is easily ground by hand. The one illustrated at *C* leaves a point in the center of the impression for spotting the center of the boss on the forging.

A die for forging a ball is sunk with a two-lipped spherical cutter. If there is to be a large hole drilled in the forging, a plug is left, when sinking, or is afterward inserted in the die to lighten the forging at that point, and is shown at *E*. This plug should have a taper of 15 degrees on each side, and the top well rounded. In making the dies for forging the piece illustrated at *E*, the round portion *F* can be machined out after the part *H* is sunk. This may be done with a spherical cutter. A special attachment for the die-sinker may be used, by means of which a cutter can be sunk to its center in the work. The cutter is held in the fixture on a short arbor between half-round centers, around which the cutter is rotated by means of a rawhide gear. The

* MACHINERY, January, 1905.

teeth of the gear engage the back of the teeth of the cutter. This is only used for finishing. Parts *K* could be done with this device. It saves time, makes an accurate, clean job and does work that would have to be typed out, *i.e.*, sunk by hand. Some circular impressions are sunk in the milling machine, using one long half-center, and a forming cutter with a small shank, a groove being first cut to clear the shank.

The parts *K* would, however, have to be typed in most shops. A type is a hardened steel templet, of the size and form that the impression is to be, with the top left soft to prevent the steel from flying when struck with a hammer. Portions of the die that cannot be machined, owing to their irregular shape, or the lack of shop facilities, must be

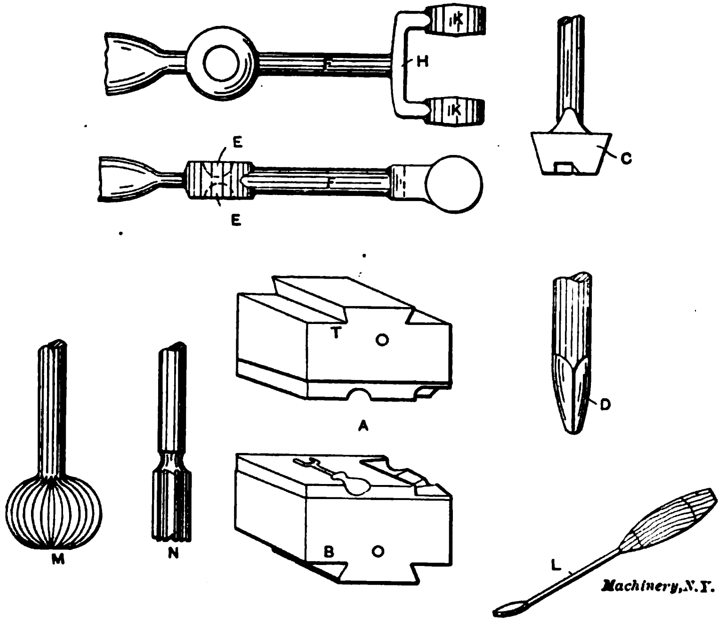


Fig. 38. Tools and Methods for Making Drop Forging Dies

sunk by hand. This requires especial skill with the hammer and chisel, scrapers and gravers, as well as a good eye. The chisels must be ground to the proper angle on the cutting edge, for chipping the curved surfaces and awkward corners. Scrapers may be made of various shapes, to suit the requirements of the work. One of the most useful is the three-cornered scraper, with two edges rounded; the third, being the cutting edge, is left sharp and is curved toward the point. Another handy scraper is shown at *L*, Fig. 38. It is leaf- or heart-shaped, and is convenient for getting at small curves and corners, especially those at the bottom of the impression. The type is covered with a thin coating of Prussian blue, or red lead, and driven into the die from time to time, as the work progresses, and the high places worked down until the correct form is produced.

For the fillets and small corners, a graver or scraper is made from Stubb's steel drill rod, of the desired radius. To save room in the tool-box, a 3/16- or 1/4-inch rod may be threaded on one end, and these scrapers fitted to it. A hole is drilled in the cutting end to save time in grinding. The scrapers leave small ridges in the work, which are filed out with rifflers, or bent files. Some impressions are polished with a soft pine block and powdered emery, but this is not the usual practice. When the impressions are worked out to the lines, a lead casting is taken to see where they need matching or evening up. The lead is tested for size, and if all right, a half-lead is taken from the top die, to be used as a templet in laying out the trimming dies, that is, in shops where sheet metal templets are not used. If the lead is overheated, or is heated too often, it will not flow freely and chills before the impression is filled. Powdering the impression with chalk causes the lead to flow freer.

The edger, or breaking-down form, on the right of the die, is made from 1/16 to 3/16 inch smaller than the horizontal cross-section of the forging, and has no abrupt shoulders or curves. The idea is to get the heated stock smaller in width than the finishing impression, so that the bottom of the impression strikes the stock first, and spreads it to the sides, filling the die. Cast-iron dies are also used for breaking down heavy work.

The flash, which is a recess 0.015 to 0.025 inch in depth, and about ⅞ inch wide, milled around the outline of each impression, allows the surplus stock to escape from the die. This surplus is afterward trimmed off in the trimming dies. The top die, also, has a groove about 1/16 inch in depth, milled around the impression, ¼ inch from the edge. The gate for clearing the stock tapers gradually toward the front from the impression so as not to weaken the die at that point.

In dies for making small forgings in large quantities there are several impressions sunk, one of which is used for a rougher, and should be about 1/32 inch narrower and deeper than the finishing impression. Some dies have to be interlocked when difficult shapes are to be forged, that is, the faces have to be shaped to suit the offset in the forging. Care must be taken to have the interlocking parts high enough so that the dies will not glance off when striking the stock, and make an imperfect forging. When the face of the dies is curved, special cutters are made, similar to those at *M* and *N* for surfacing and flashing. As a guide for machining curved impressions, some mechanics transfer the lines to the side of the die blank and lay out the curve there, then clamp a surface gage to the profiling machine, and with the needle set to the face of the cutter, work out the stock by following the lines with the needle point. Dies for forging gears, or similar work, are finished with a broach having the teeth machined in it, which is then driven into the die.

CHAPTER IV

DROP FORGING DIES IN AN AUTOMOBILE SHOP*

The making of drop forging dies, together with the hardening process through which they are put, is a trade in itself, though closely allied to tool and die making as understood in the big shops of to-day. Each branch of shop work presents its individual problems, and a tool- and die-maker, though skilled in other lines, cannot go into a forging shop and make drop forge dies without special instruction and training.

In drop forge die work, as in other kinds of tool work, there are various grades of accuracy and finish required. Some forgings must come from the hammer practically finished to size, while others are made large enough to allow considerable machining. Where only a

Fig. 39. Planing a Die-block on a Shaper

few pieces of a rough nature are required, little skill is needed in the making or maintenance of the dies, but where small accurate parts are to be made in large quantities, special tools for both hand and machine use, and trained, skillful die-makers are needed, as well as a careful selection of the steel used.

Materials for, and Life of, Drop Forging Dies

Steel, cast into blocks, is not suitable for this work, as flaws or blowholes are likely to develop where least expected or desired, so as a general rule, forged blocks of open hearth crucible steel are used. These blocks are either purchased ready forged, in various sizes, from

* MACHINERY, September, 1908.

the steel manufacturers, or are forged in the shop where they are used, the former plan being the usual one.

A rough estimate as to the average life of a drop forging die, used for medium-sized work on Bessemer steel, was given by a foreman of long experience, as about forty thousand pieces. Some dies might be broken immediately when put in operation, while others might stand for a hundred thousand pieces or even more.

Automobile Shop Drop Forging Practice

In preparing the present chapter, the photographs and data were obtained in the factory of Thomas B. Jeffery & Co., Kenosha, Wis.. the manufacturers of the famous "Rambler" automobile. This company's drop forging department is comparable to those of the big concerns that make a specialty of drop forgings, and consists of a

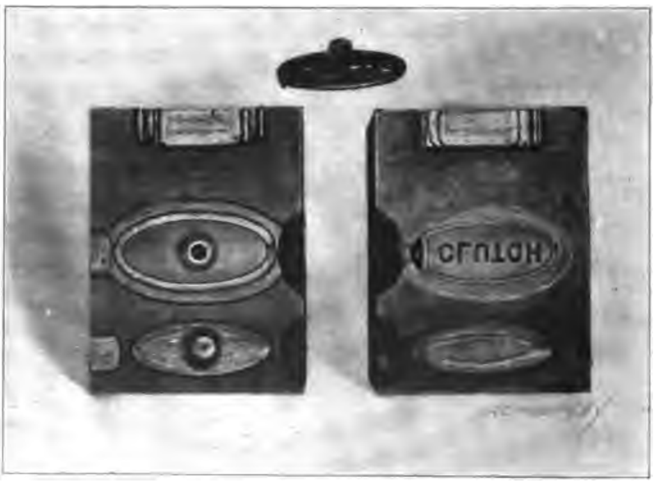


Fig. 40. A Pair of Typical Drop Forging Dies and their Work

well-lighted, finely-equipped tool-room, used only for drop forge die work, a thoroughly up-to-date hardening plant, and a big building full of steam hammers, punch presses, heating furnaces and every appliance necessary for first-class work.

The greater part of the drop forgings made here are of Bessemer bar steel, though some of the more particular automobile fittings are made of special grades of tool steel. All of the drop forging dies are of the highest class, calling for the best die-making skill, and necessitating a great deal of hand work in addition to the most accurate machining.

Making a Die

In the original outlining of a set of drop forging dies, the measurements for the forming cavities may be taken from a blue-print supplied by the drafting-room, or they may be taken from a piece already made—possibly a forging or a lead casting obtained from some former set of dies, or perhaps a piece made up for a model. Sometimes a sheet metal templet is made to assist in obtaining the desired shape of the die cavities, while in other cases, only the outline scribed on the coppered surface together with the necessary measurements, is needed. The size and outline of the forging to be made, as well as the accuracy required, govern the method of procedure.

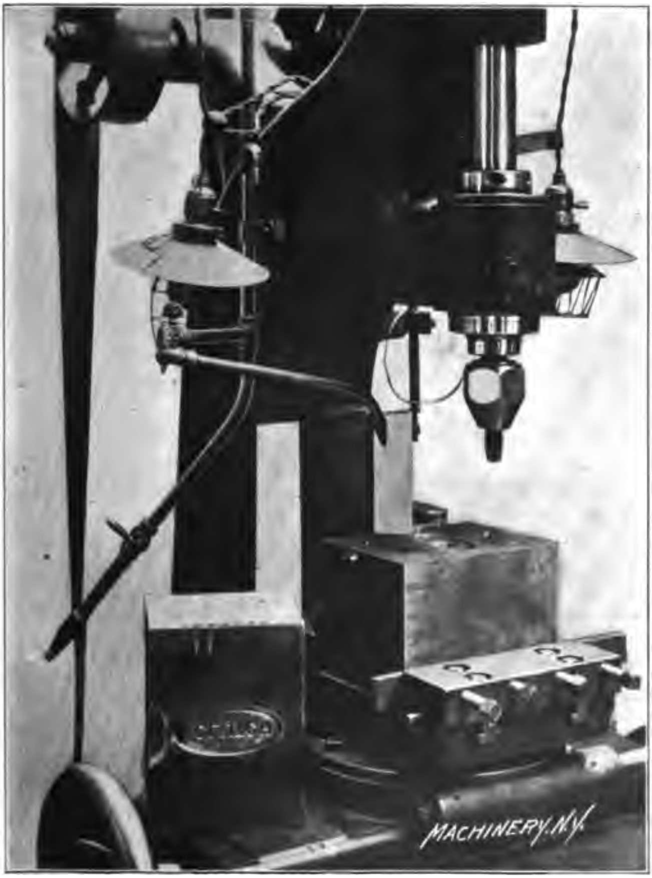


Fig. 41. Profiling Machine much Used in Die-sinking

The die blocks, which, as already stated, are forged of open hearth crucible steel, are first placed in a shaper and carefully surfaced off to the required dimensions, as shown in Fig. 39. These blocks are made over-size, so that enough of the surface can be machined off to insure good, sound metal to work on. The outlines for the breaking-down or roughing, the finishing, and sometimes the bending forms are then laid off on the coppered faces, and the cavities roughed out on the drill press or lathe as the case may require, or on the profiling machine, as shown in Fig. 41.

The same set of dies shown in this engraving is shown still further roughed out in Fig. 40. The shape of the forging to be made in this set is shown at the top of the illustration—it is a foot pedal for a clutch lever. The channel for the fin, or "flash," which is formed in the finishing operation, is plainly shown in the middle cavities.

The letters, C L U T C H, were first lightly stamped on the metal with special steel letters to get the outline, then they were chiseled out,

Fig. 42. Finishing the Die Shown in Fig. 40 on the Profiling Machine

and finally finished by driving in the steel letters to smooth up the roughness caused by chiseling.

Fig. 42 shows the final cuts being taken on the breaking-down part of this die, the rest of the work consisting of scraping, gouging and chiseling.

Tools Employed in Making Dies

For the hand work, the die block is held in a special "ball vise" which is shown in Fig. 43. A vise of this type is the handiest device imaginable for heavy die work. This illustration also shows the breaking-down part of the die a little more plainly than the previous examples.

Fig. 44 shows a few of the tools, scrapers, and rifflers used in the

Fig. 43. Special "Ball Vise" Used in Sinking Drop Forging Dies

Fig. 44. Scrapers, Files, Rifflers and Other Tools used by Die-sinkers

finishing work. These are mostly made of old files and are ground or bent to suit the needs of particular cases.

In Fig. 45 are some of the milling tools that have been made especially for this work. Only twenty-four of them are shown, though several hundreds of all shapes and sizes are in stock. Another set of special cutters is shown in Fig. 46. Two of these have a single inserted

blade or "fly-cutter" held in place by a set-screw, and are very useful tools for some kinds of work.

The tools shown in Fig. 47 are known as "types," and are used in scraping out cylindrical cavities to size. These types are turned to the proper size, and when used are smeared with lead and rocked back and

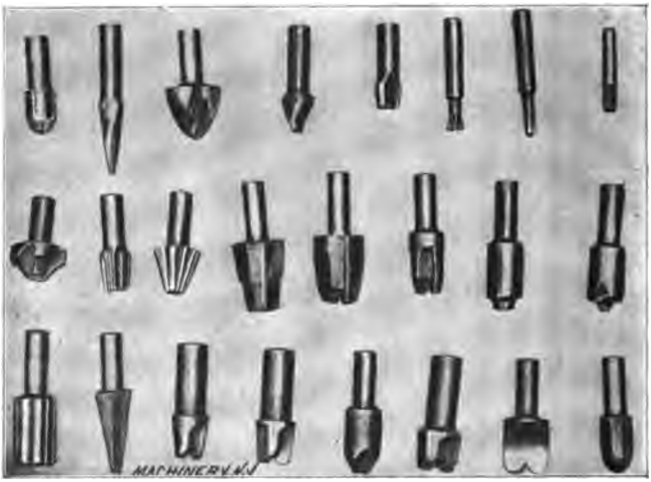


Fig. 45. A Few Milling Tools used in Die-sinking

Fig. 46. Milling Tools Used in Die-sinking, with Examples of Fly-cutters

forth in the partly finished cavity. The metal is then scraped away wherever the lead shows. For cylindrical work, these types are indispensable tools.

The tools shown in Fig. 48 were made by one of the expert die-sinkers in the Jeffery shop. The tool shown at the right is used to scribe

an outline from a forging. It consists of a hardened steel blade, with a point on one end, set into a flat steel block in such a way that it is free to move up and down to a limited extent. The rivet shown on the side passes through a short slot in the blade. When in use, a flat spring on the top edge of the tool presses the point down onto the

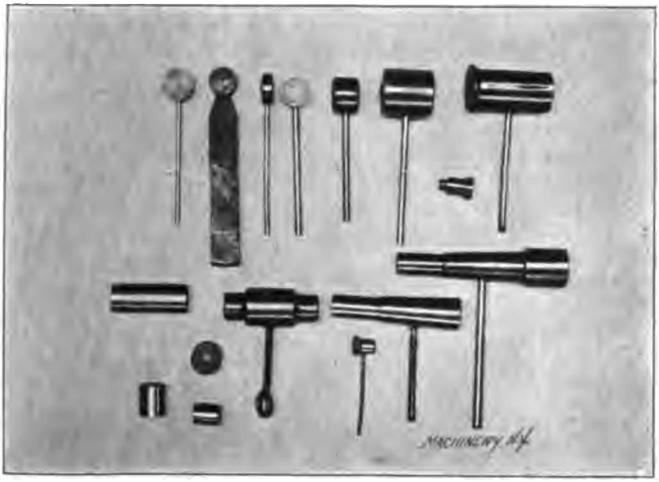


Fig. 47. "Typing Tools" Used by Die-sinkers to Form Circular Cavities

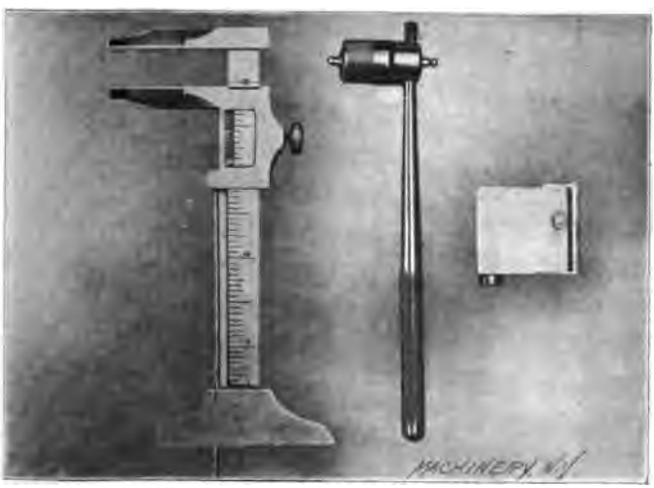


Fig. 48. Vernier Caliper Depth Gage, Inside Micrometer, and Scribing Block

coppered surface, causing a mark wherever moved. To use this tool, it is held on edge with the point down and the edge of the hardened blade in contact with the forging. The steel block keeps the blade perpendicular, and by keeping the edge of the blade in contact with the forging while scribing, a correct outline is obtained, which could not be done with an ordinary scriber on account of the working outline being considerably above the die face.

The middle tool shown in Fig. 48 is a one-inch inside micrometer, which was made by the die-sinker because he could not buy one small enough for the purpose. The other tool is a regular stock caliper square, to which has been added a depth gage. The gage is so made that the rod projects the same distance that the caliper jaws are apart. The usefulness and convenience of this tool are at once apparent to a tool-maker.

The Lead Casting or Proof

After the mechanical work on a set of dies is done, a lead casting of the cavity is made and sent to the superintendent to be passed upon. If it is correct, the dies are hardened and sent to the forging shop, but if it is off size or shape, or for any reason not satisfactory, suitable changes are made, and another lead impression taken and passed

Fig. 49. Samples of Lead Castings or Proofs Taken from Drop Forging Dies for Testing the Accuracy of Outline

upon as before. Fig. 49 shows a number of these lead castings which are kept in the tool-room for reference, and they often save considerable trouble when making duplicate dies.

Staking Tools Used for Repairing Dies

After a set of dies has been in use for some time, the dies are likely to develop cracks or drawing seams which cause ridges and rough spots on the forgings. These cracks are closed up by hammering first on one side and then on the other with a hammer and what are called "staking" tools, which are simply specially shaped, tempered steel punches made of chisel steel stock. Some of these staking tools are shown in Fig. 50.

Examples of Drop Forging Dies

One-half of a die set, showing the breaking-down and fininshing forms, is illustrated in Fig. 51. In this illustration the method of leaving a ridge around the finishing form and cutting a channel for the fin is very plainly shown. This method is followed in all of the drop forge dies made in the Jeffery shop. Fig. 52 shows a more complicated die. In this, both edging and flatting breaking-down die forms are shown. In using this die, the hot bar from which the forging is being

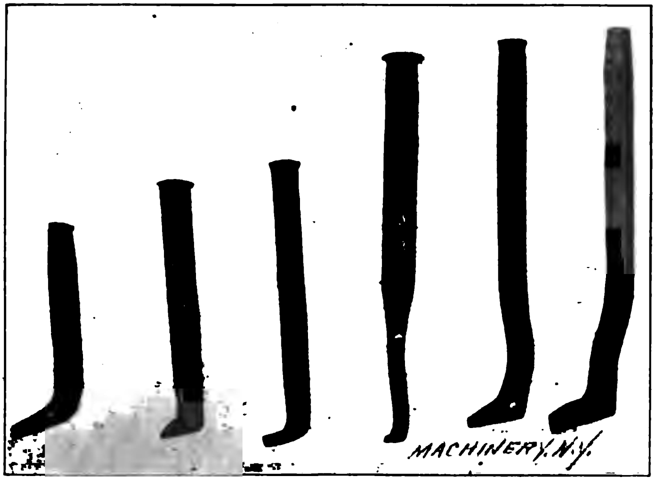


Fig. 50. Staking Tools Used for Repairing Worn and Cracked Drop Forging Dies

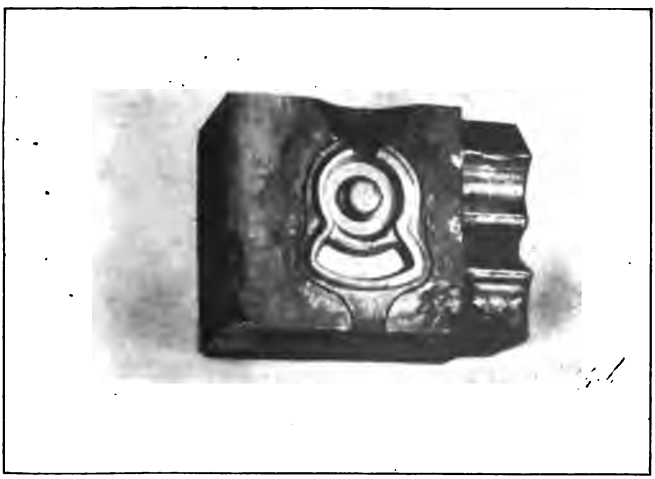


Fig. 51. An Example of Drop Forging Die Showing Breaking-down Die at the Right

made, is alternately swung from one to the other form, it being held edgewise in one and flat in the other, and given a blow or two until sufficiently reduced for the finishing form, after which it is cut off from the bar by a shear fastened to the hammer at one side of the die block.

In Fig. 53 the roughing or breaking-down die is shown and also a bending form, the bar being roughed into shape, and then bent and finished. Of course, in these last two illustrations it is understood that the cuts show only one-half of the set, the other half correspond-

Fig. 52. Drop Forging Die Showing both Edging and Flatting Breaking-down Dies

Fig. 53. Drop Forging Die Showing Bending Form in Front

ing in shape to the one shown in such a way as to produce the desired shape. To better illustrate this for the benefit of those not familiar with this class of work, both halves of a set of dies are shown in Figs. 54 and 55. These show the complete forging and bending parts for this particular piece. The end of the finishing form also shows a place where one of the types illustrated in Fig. 47 was used when first working out the cavity.

Trimming Dies

Some of the forgings are of such shape that the fin or flash formed is easily ground or machined off, while others are put through a trim-

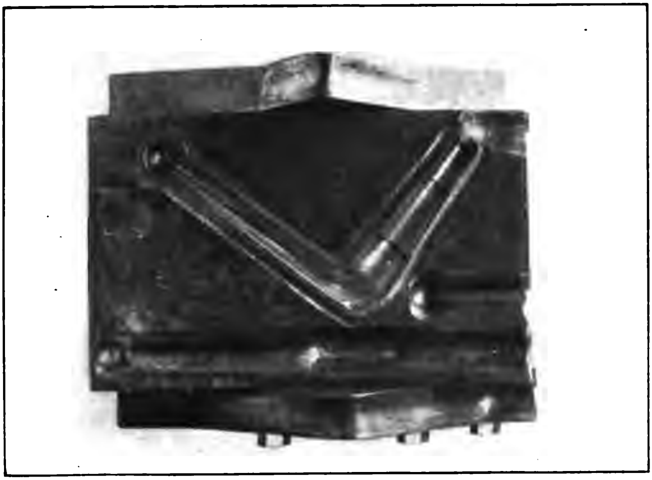


Fig. 54. Drop Forging Die and Bending Die for Steering Gear Part

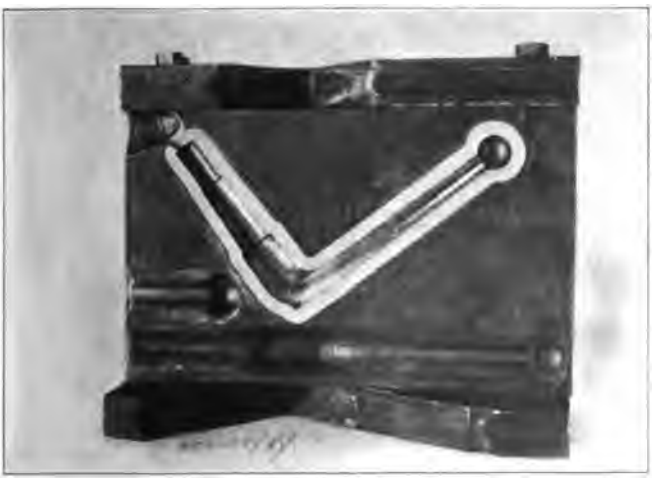


Fig. 55. Mating Die to Die in Fig. 54

ming die. These trimming dies are about the same as the trimming dies used for other classes of work, and so need little comment. Fig. 56 shows a set of forging and trimming dies used for making "Rambler" wrenches. The breaking-down form is very plainly shown as is also the finishing cavity. The trimming punch is at one side, while the trimming die in the middle is shown made up of four separate parts. This is done because the die parts that shear out the wrench slots wear or break sooner than the rest of the die, and when made this way they are easily replaced without necessitating a wholly new die, which would be the case if made solid.

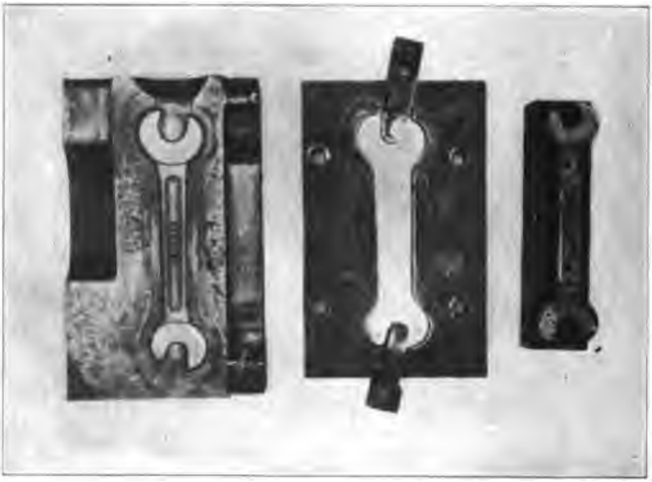


Fig. 56. Drop Forging Die for Wrench, and Trimming Die for Same

Fig. 57. A Few Examples of Drop Forging Dies in Storage

Fig. 57 shows a number of dies on the storage shelves, only one-half of each set being shown, the other half of each set being back of the one visible. The trimming dies which are in constant use are kept conveniently near the presses in the forge room. Both the trimming and forging dies are stored on heavy shelves close to where they are used, thus saving the unnecessary "toting" that is practiced in so many shops.

Heating Furnaces

The heating furnaces in a forging shop must be set near the hammers, and Fig. 58 shows how the oil furnaces are placed, so that little

Fig. 58. Oil Heating Furnace and Drop Hammer

Fig. 59. Brown & Sharpe Heating and Annealing Furnaces

time is lost getting the heated metal to the hammers. Fig. 59 is an illustration of two of the big Brown & Sharpe furnaces in the hardening room. For small work several smaller furnaces are used, but those shown are used for large work, and are said to be the best obtainable.

Hardening Drop Forging Dies

In hardening drop forge dies only the face is hardened. The die is heated and placed face down in a tank of water on a sort of spider support, and a stream of water pours upward against it. Fig. 60 shows

Fig. 60. Hardening the Face of a Drop Forging Die

how this is done. In the illustration a round piercing die is being hardened, so the water appears to be boiling up through the center, which would not be the case were it a solid block like a forging die. Large specially shaped tongs make the handling of the heavy steel blocks of the drop forge dies comparatively easy.

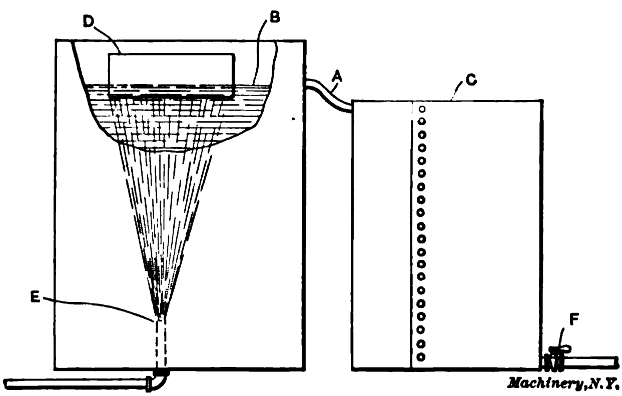


Fig. 61. Arrangement of Brine Tank for Hardening

On the subject of hardening drop forging dies, Mr. J. F. Sallows has contributed the following to MACHINERY.*

Uneven heating and uneven cooling, with consequent uneven contrac-

* MACHINERY, January, 1908.

tion, is the cause of so many drop forging dies cracking in hardening. There is no necessity for this trouble if the dies are properly handled. If drop forging dies are made from machine steel, they should be packed in No. 1 raw bone and fine wood charcoal, three parts charcoal being used for each two parts raw bone. They are then heated in an oven for eight hours, at a temperature of 1,600 degrees F., and are then dipped the same as described in the following for tool steel. When

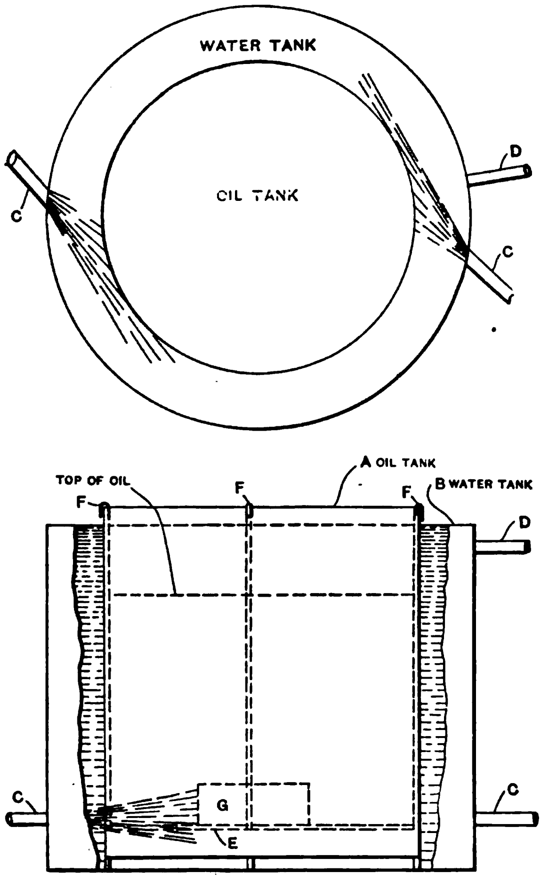


Fig. 62. Oil Tank for Hardening Room

the dies are made of tool steel, the heating of the dies in an open furnace, even if covered with coke, is very injurious to the steel, as the carbon is removed from the surface of the steel, and the dies will not harden on the outside, but will be harder further in. This does not matter so much with tools that are to be ground to size after hardening, but it is a poor practice with any kind of tool-steel tools. Tool-steel dies should be packed in fine wood charcoal in a box large enough to allow plenty of charcoal between the die and the box walls, say about two inches or more. Seal the cover on tightly with asbestos cement, place the box containing the die in the furnace, and, if a pyrometer is attached to the furnace, hold the furnace at about 1,500 degrees F., leaving the die in for at least four hours. For a small die, shorter time will be sufficient, but a die weighing 50 pounds or more should be allowed four hours to heat slowly and uniformly. Then, instead of immersing the whole die in a tank of cold, clear water, have two tanks, a large one and a smaller one, as shown in Fig. 61. An overflow pipe or hose *A* from the water line *B* in the large tank should connect it with the small tank *C*. When ready to dip the die *D*, place the face only in the water. Plenty of salt should be well dissolved in the water, about 4 pounds to the gallon; this extracts the heat from the die quicker than clear water, and prevents steam formation on the face of the die. A water pipe *E* should be carried in at the center of the large tank at the bottom, and should be supplied with water at fairly high pressure. When placing the die in the bath, open the valve of the pipe *E*, thus forcing the cold solution against the face of the die, while the warm water passes into the smaller tank. The solution collecting in the smaller tank, when cool enough, can be used for smaller tools, and, when so desired, can be run off by outlet *F*. Another bath, in an oil tank, inside of a water tank, as shown in Fig. 62, should be provided. The size of the tanks must be determined by the size of the dies to be hardened. Fish oil should be used in this latter tank, and the tank should have two water inlets *C*, at opposite sides of the tank, and so arranged as to allow water to flow around all sides of the oil tank as indicated in the plan view. Pipe *D* is the overflow. A coarse mesh sieve *E* is suspended in the oil tank, and held by rods *F*. The oil tank should have four legs about 6 inches long, to allow water underneath the tank. When the die face has been cooled in the salt water solution, remove the die quickly to the oil tank, and lower it until it rests on the sieve (see *G*, Fig. 62). Let the die remain in this position until cold. It requires no further attention than removal from the oil. Dies hardened in this manner will not crack.

CHAPTER V

FOUNDATIONS FOR DROP-HAMMERS*

The concrete foundations for drop-hammers, described in the following are used in the Pratt & Whitney Co.'s shops at Hartford, Conn. The blacksmith shop is located on what one might say is the second floor of the building, there being a basement about 11 feet high under the blacksmith shop, which is used as a stock-room and where the case-hardening furnaces are located. The foundations for the drop-hammers in the blacksmith shop must therefore be carried down clear through the basement, and then down approximately another 11 feet to hard pan. The construction of these concrete foundations is shown in Fig. 63. At *A* is shown a cast-iron base-plate, into which the base of the drop-hammer sets. This plate is bolted to the concrete column by four 1¼-inch anchor bolts. Between the cast-iron plate and the top of the column a double layer of wood and also a thick layer of tar paper are interposed, the purpose of which will be referred to later. The column, as shown, reaches nearly up to the ceiling of the basement, *C* being the floor line of the blacksmith shop. At *D* is shown a line representing the floor of the basement. As will be seen, reinforcements have been placed around the concrete column in the form of heavy planks *B*, having one-inch bolts through the concrete to clamp them up against the concrete surface. It was found later, however, that this reinforcement was not necessary, and that the foundations would have served their purpose fully as well had the column been left plain all the way down.

The installation of these concrete foundations, as compared with the wooden foundations formerly used, has proved to be a very economical move. Previously, with hammers working on wooden foundations, it was not possible to make certain medium-sized drop forgings on anything but a 200-pound hammer. Since these foundations were put in, it has been found possible to make them on a 100-pound hammer, and, at the same time, the rapidity of completing the drop forgings has been increased, so that a saving in time of 20 per cent has resulted in the making of these forgings. Other elements of saving in comparing the making of these forgings on a 200- or a 100-pound hammer are that the tools cost more for a larger machine, and it consumes a great deal more power. The reason why there is a saving in the making of these forgings, even in regard to the time consumed, is because the strokes, even on a smaller hammer, can now be made shorter, so that a greater number can be struck in the same time, the blows, however, having an equally good, or better, effect, on account of the solid foundations under the base of the hammer. In the case of drop hammers, where

* MACHINERY, April and August, 1908.

the hammer was previously raised three feet, it is now not necessary to raise it more than two feet, in order to accomplish the same results.

When the foundations were first put in, the cast-iron plate *A*, already mentioned, was laid directly on a surface of cement, three inches thick,

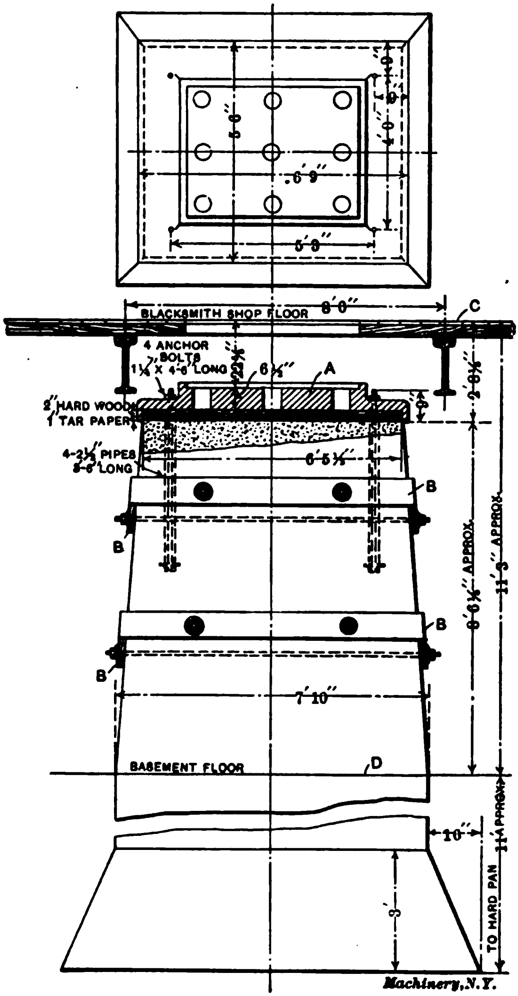
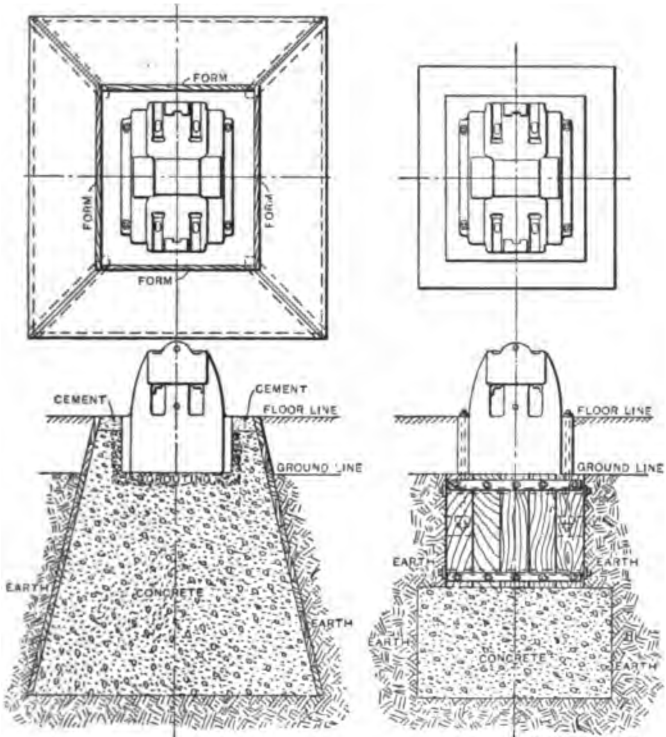


Fig. 63. Concrete Foundations for Drop-hammers in the Pratt & Whitney Co.'s Blacksmith Shop

placed on the top of the concrete foundations. The cast-iron base-plate, of course, was not finished on the bottom, but was more or less rough. The cement itself did not have a perfectly plane surface, and it was found that, after the hammer had been used for some time, the top layer of the cement would be ground to powder, on account of the rough surfaces coming in contact, constantly cutting and grinding the surface of the cement. In order to prevent this, a layer of tar paper, one inch thick, was first placed on the top of the concrete foundation, and on top of this, two layers of hard wood, each one inch thick, were laid diagonally, the cast-iron base-plate being placed directly on the hard wood, after which the anchor bolts were tightened down, clamping the base-plate tightly against the wood and the tar paper, and consequently pressing the latter firmly against the top of the concrete. The tar paper would fill in all crevices and rough places on the top of the



Figs. 64 and 65. Drop-hammer Foundations of Solid Concrete, and with Wood Cushion

concrete, and the impact of the hammer blows would be distributed equally over the whole surface. After this improvement had been made, no more troubles were experienced with the top of the concrete being pulverized by the blows of the hammer.

At first it was feared that these solid foundations, having practically no springing action whatever, would cause trouble in regard to the dies so that a greater cost would be incurred in regard to the replacing of broken dies, but this apprehension proved to have no foundation; the dies seem to stand up fully as well as with the old wooden foundations.

The concrete used for these foundations is what is known as 1—3—5 mixture. This mixture consists of one bag of cement, one barrel of heaped sand, and two barrels of stone.

The E. W. Bliss Co., Brooklyn, N. Y., builder of drop forge hammers, has given out the following information regarding the construction of drop-hammer foundations.

The endurance and effectiveness of drop-hammers depend in no small degree upon the proper ratio between the weight of the base and the weight of the hammer. It has been demonstrated that 12 to 1 is decidedly better than a smaller ratio, and that the best results are obtained with a ratio of 15 to 1 or 16 to 1 with all parts made in proportion, the extra cost of the heavier machine being more than compensated for by the larger quantity and better quality of the finished product and by the comparative freedom from breakdowns.

For the successful operation of drop-hammers, it is very essential to have a good foundation. Both of the types illustrated in Figs. 64 and 65 have been found to give good results. The wood cushion foundation, as shown in Fig. 65, is used where the bottom is not good and where jarring the surrounding buildings is objectionable. The solid concrete foundation shown in Fig. 64 is recommended as best when it can be used, as it is like a continuation of the base on the hammer, and therefore makes the drop more efficient. In deciding the depth of foundation of either of the above types, care should be taken to determine the best point at which to stop the excavation. Bed rock is the best bottom, cement gravel next best, and a stratum of sand or clay, say 4 feet thick, in its original and undisturbed condition, also makes a good bottom. The trouble with sand or clay is that on account of the heat of a drop forge shop drying the soil, and the continual jar, they are apt to shift, provided they get an outlet into other adjacent excavations. By spreading the bottom of the foundation, the desired result is sometimes obtained without going very deep, but for any size of drop-hammer the concrete should not be less than 4 feet thick, whether a wood cushion is used or not.

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SECOND REVISED EDITION

CONTENTS

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In the present (the second) edition of this Reference Series Book, considerable matter specifically pertaining to the hardening and tempering of steel has been added, and revisions have been made in the remainder wherever necessary. In order to provide space for the added material, the chapter on case-hardening and case-hardening furnaces, included in the first edition, has been eliminated. This chapter, together with other matter on case-hardening, a thorough treatment on the theory of the heat treatment of steel, electric hardening furnaces, and kindred subjects, is included in MACHINERY'S Reference Book No. 63, "Heat Treatment of Steel."

CHAPTER I

MODERN STEEL HARDENING PLANTS

From time immemorial when iron in its most crude form was introduced into the manufacturing and commercial field, it has been a well-known and accepted fact that heat with its varying degrees of intensity has a direct action on both the physical and chemical properties of the metal when the iron is submitted to its action; and, as a direct result, the entire structure of the iron is altered, and by altering or changing the methods of application of the heat treatment. any desired structure of the metal, either steel of cast iron, may be obtained. In spite of the fact that the truth of the above exposition was generally acknowledged, very little, if any, use was made of it; but as science developed, competition grew keener and keener, and the general cry in the manufacturing world became "reduced cost and greater output." To balance the effect of increased power and consequently larger machines, the working strength of the cutting tool, together with the working stress of the machine members, had to be greatly increased, and, during the past decade, the heat treatment has done more than its share in the work of accomplishing the desired results.

There are but few properly planned and equipped hardening plants. In the present chapter, however, two examples of first-class hardening rooms will be described, the one being that of the Worcester Polytechnic Institute, Worcester, Mass., and the other the hardening plant installed by Wheelock, Lovejoy & Co., in their New York store.

The Worcester Polytechnic Institute Plant*

The Worcester Polytechnic plant consists of a room of spacious size in the design of which the comfort of the operator was well provided for. The temperature and ventilation of the room is controlled both by a fan and large windows which admit subdued natural light but exclude the direct sunlight, which is so undesirable in this kind of work. These windows are provided with shutters so that the natural light may be excluded; artificial illumination is obtained by means of incandescent electric bulbs. The room appears to a visitor, at first, somewhat like a dungeon, as the walls and ceiling are painted a "dead black," which color prevents any reflection of the various colored rays when the operator is experimenting on "color work." After this first impression has left the visitor and he has become accustomed to the light, the next thing that catches his eye is the row of various shaped furnaces placed symmetrically on the right side of the room. For convenience and simplicity, we will designate these furnaces (from right to left in Fig. 1) by the letters *A*, *B*, *C* and *D*. Furnace *A* (constructed

* MACHINERY, April, 1909.

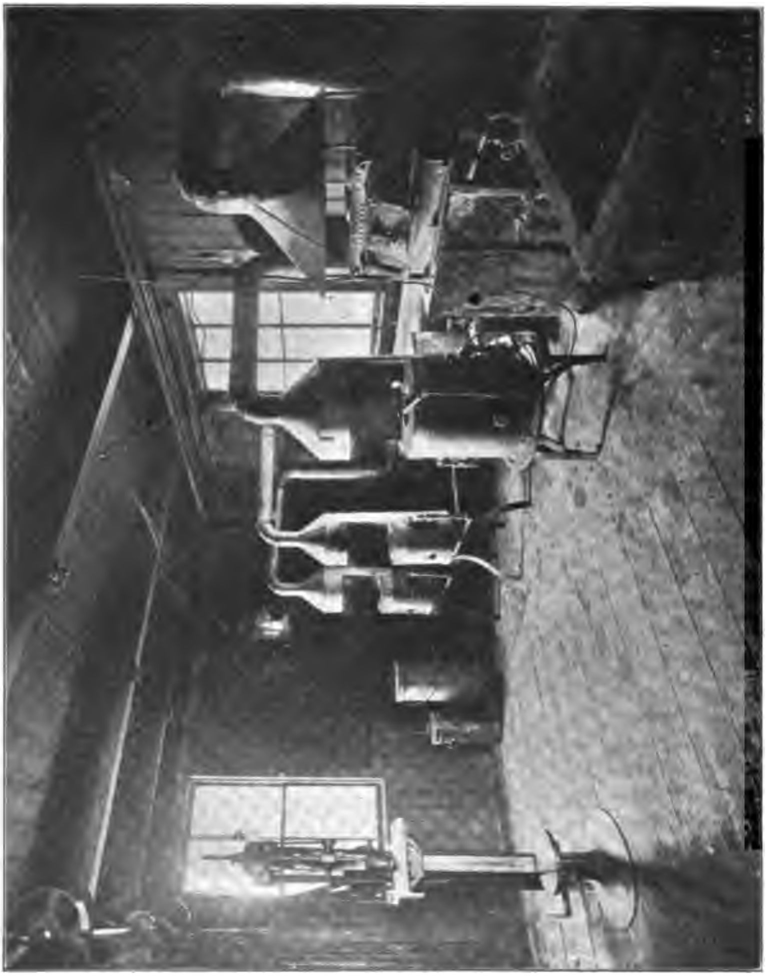


Fig. 1. Plant for the Heat Treatment of Steel, in Worcester Polytechnic Institute

by the American Gas Furnace Co.) is built on the principle of the muffle furnace, is of the box type, and will readily heat a block of steel 8 x 4 x 14 inches. A temperature of from 2000 to 2100 degrees F. may be readily obtained by means of this heater, which is used to heat such work as requires an even heat and which would be destroyed by oxidation and the decarbonizing action of the air. Reamers, mandrels, taps and drills in their finished state are good examples of this type of work. Furnace *B*, known as the "barium chloride heater," is circular in form and lined with fire-brick, and the chloride solution is heated in a crucible built of fire-resisting material. This furnace is of sufficient size to accommodate all ordinary tools, and is employed to heat such grades of steel as require a rather high temperature, as high-speed steels, and which, at the same time, must be well protected in heating. This form of heat treatment is well adapted to those types and forms of tools which tend to heat unevenly, thus producing an unbalanced distribution of the shrinkage strains with the accompanying cracks. Furnace *C* is of the same general design as furnace *B*, with the exception that this heater is made use of in connection with the lead bath. As the lead melts at a comparatively low temperature, this furnace is used when a lower temperature than that obtained with the chloride solution is desired, for example, when heating carbon alloy steel. Furnace *D* is devoted to an entirely different operation, namely, oil tempering. Either linseed or machine oil is used in this heater, which is brought into action when the desired range of temperature is between the limits of 300 and 630 degrees F. The fuel used in all of these furnaces is the ordinary city gas, due to its convenience and ready accessibility, but oil fuel could be employed if so desired by the operator. As will be seen from the engraving, all the furnaces are provided with hoods of convenient form connected with an exhaust line, so that all poisonous fumes and gases from the lead, cyanide, barium chloride, etc., may be eliminated from the atmosphere of the room. At various and convenient positions about the plant are to be found rectangular tanks of convenient size, containing water and brine of varying densities. All the other baths, as for example, the various grades of oil and other cooling baths, are kept in covered cylindrical galvanized iron tanks. In order to properly care for and treat the air-hardening steels, an air jet is provided with a pressure of about 2 pounds.

The one feature which removes this plant from the class of the ordinary manufacturing establishment and places it in the ranks of those of scientific research and investigation, is its complete set of measuring instruments, including the Briston and Le Chatelier pyrometers and thermometers covering a range of temperature between the limits of 0 and 2960 degrees F. On one of the walls of the room is to be found the Bristol pyrometer, which is of the thermo-electric type, and consists of a permanent magnet moving coil type of galvanometer. The scale is graduated to read direct in degrees. Leads from the instrument extend over the entire room, so that it is a matter of a few seconds only to connect with the thermo-couple and obtain any desired temperature. If any question as to the accuracy of the instrument, or the action of gravity on its oscillating parts is advanced, a Le Chatelier pyrometer, operating on the same principle but having a vertical support, may be brought into action and the first readings verified.

As indicated by the above description, all grades of steel from the 15-point carbon steel to the high-speed, alloy, air- and water-hardening steel may be conveniently and efficiently handled and treated.

Wheelock, Lovejoy & Co.'s Hardening Plant*

The illustrations, Figs. 2 and 3, show two views of a hardening plant installed by Wheelock, Lovejoy & Co., (selling agents for Firth Sterling

* MACHINERY, November, 1908.

Steel Co., McKeesport, Pa.) in the basement of their New York store at 23 Cliff St. The equipment is interesting in that it represents the latest development of gas furnace hardening and tempering baths. Fig. 2 shows a general view of the plant looking toward the street, while Fig. 3 is a view taken from the street end. The furnace in the rear, with a hood similar to the one in the foreground of Fig. 2, is for heating a chloride of barium bath, this being very successfully used for hardening "Blue Chip" steel, and the following description relates to the practice.

The tools to be hardened are first pre-heated, using the small American gas furnace shown next to the chloride of barium furnace. The preheating saves time in the barium bath, and is absolutely necessary to avoid checking or cracking the tools, as will be conceded when it is

Fig. 2. Hardening Plant, Wheelock, Lovejoy & Co., looking toward Street

known that the temperature of the barium bath is kept at between 2100 and 2200 degrees F. After the tools are pre-heated, they are immersed in the barium bath, being suspended by an iron wire, or, in the ease of small parts, in sheet nickel baskets. The reason for using sheet nickel for the baskets is that chloride of barium has a slight dissolving effect on iron and the exposure of a large area of sheet iron in the bath would eventually destroy the baskets. Nickel is not affected to a perceptible extent, nor is the thin iron wire used to suspend ordinary tools.

The temperature of the barium bath is regulated by a Bristol thermoelectric pyrometer. This instrument, shown at the left in Fig. 4, is similar to a Weston ammeter or voltmeter, and the fire end is a thermoelectric couple. The heat of the bath effects the thermo-electric couple and generates a current that deflects the indicator of the indicating instrument to correspond with the temperature. For convenience in operation, the indicating instrument is provided with a double hand, one hand, *A*, being controlled by the temperature of the bath, while the other, *B*, is a marker set by the operator to indicate the temperature which he desires to carry. This marker is made with a disk at the end that covers a hole in the indicating hand when the two coincide, as they do when the temperature has reached the predetermined point. Thus, an operator whose eyes are dazzled by the heat of the bath does not have to painfully study the graduations to see whether the pointer has reached the correct position, but by glancing at the instrument he can readily determine when the indicator is directly beneath the marker referred to.

The immersion of a piece pre-heated to a dull red immediately causes the indicator to drop, the temperature of the bath falling perhaps 30,

Fig. 3. View of Hardening Plant shown in Fig. 2, taken from Street End

40 or even 50 degrees. The fall in temperature is due to absorption of heat by the piece, being the same as the refrigerating effect of a lump of ice thrown into a pot of boiling water, and several minutes may be required to raise the temperature of a large piece to the temperature that is required. For hardening "Blue Chip" steel, a temperature of 2120 to 2140 degrees F. has been found most suitable. After this temperature is attained, the part is allowed to soak for a few moments, then is lifted out and dipped into the cooling bath shown at the right, Fig. 2, and left in Fig. 3, which consists of cotton-seed oil agitated by compressed air admitted at the bottom. The cotton-seed oil is contained in a large iron barrel surrounded by water in a wooden tub. The part hardened is allowed to remain in the bath until it is quite cold. In practice, the operator hardens a batch and then removes the pieces by means of a wire basket hanging immersed in the oil. It is recommended that milling cutters, end mills, slitting saws, etc., made of

"Blue Chip" steel, be used, in general, without drawing the temper. They will have the requisite hardness and toughness to stand up to the majority of work. However, an oil bath heated by gas and regulated by a thermometer is provided for tempering such tools as require it.

Chloride of barium is a white transparent salt ($BaCl_2OH_2$) which melts at a temperature of about 1700 degrees, the water of crystallization being driven off at a much lower heat. The salt volatilizes at an extremely high temperature, the loss at the temperature required for heating high-speed steel being negligible. The waste because of volatilization is, say, two pounds from a mass of barium weighing 75 pounds when held at a temperature between 2000 and 2300 degrees for five hours. This property of the chloride of barium bath of standing high temperatures without rapid volatilization is joined with others equally important. The piece heated is protected from the atmosphere during

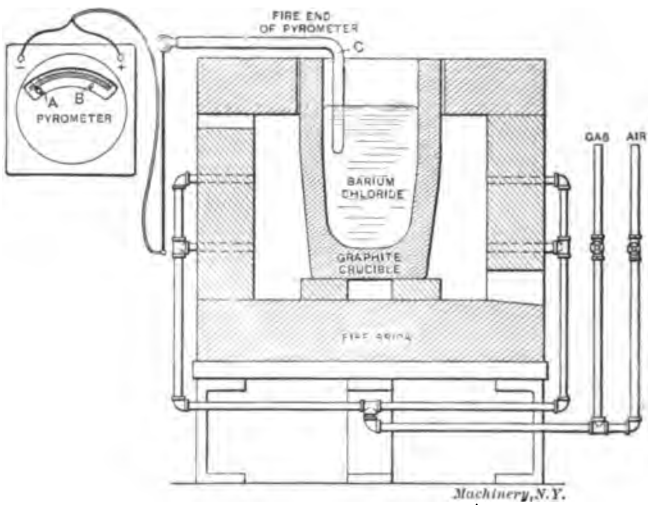


Fig. 4. Vertical Cross-section of Chloride of Barium Furnace

the heating period by the bath, of course, but the protective influence extends still further. A thin coating of barium clings to the piece when it is lifted out for immersion in the cooling bath, thus preventing oxidation. The effect of the barium on the steel seems to be limited to a slight mottling that quickly disappears under the action of cleaning and buffing wheels. The coating of barium remaining when dipped prevents the coating of burned oil so troublesome to remove, so that on the whole the process probably produces the cleanest work of any bath known.

Wheelock, Lovejoy & Co. have improved the furnace and crucible used for the chloride of barium bath. The common form of furnace and crucible in use employs a comparatively shallow crucible, which necessitates making a joint between the top of the crucible and the fire-brick cover. This gives trouble by loosening and permitting the hot gases to escape around the edge of the crucible. The improved construction illustrated in Fig. 4 utilizes a deeper crucible, the top of which comes flush with the fire-brick cover and simplifies the construction. The deep crucible also gives a greater volume of chloride of barium, consequently the refrigerating effect of the pre-heated steel parts, when immersed in the bath, is not so great. This illustration also shows the fire end, *C*, of the pyrometer immersed in the bath. It has been found advisable to employ crucibles made for steel melting, the ordinary graphite crucible used for brass melting giving trouble by flaking off into the barium.

The equipment of the plant includes an air compressor and exhauster, the former being required for the air blast in the furnaces and for agitating the oil bath, while the exhauster connected with the smoke pipes and hood, draws off the hot air and gases, thus keeping the working conditions fairly comfortable, even in the hottest weather. An efficient ventilating system is a prime requirement, inasmuch as the fumes of the barium are somewhat obnoxious and besides would have a serious rusting effect on the steel stock if permitted to pervade the basement where it is stored.

CHAPTER II

HARDENING STEEL*

Every shop has one or more men who are considered authorities on hardening. In many cases the man is really an expert, is careful, and uses good judgment in heating the steel and in quenching in the bath; and if the piece is of sufficient size, he is sure to take the strains out by reheating directly after taking from the bath. In some cases, however, the success of one operation is measured by the failure of others. Thus if the steel passes through the fiery ordeal with enough of it left intact to do the work it is considered a *successful operation;* if not, the fault *must* be in the steel. A manufacturing concern once changed the brand of tool steel they were using three times in less than a year, because the man doing the hardening reported adversely on each make, after attempting to harden it. The brands furnished were from three of the leading makers of tool steel. After receiving repeated complaints in regard to the man's inability to harden the steel successfully, one of the makers advised the manufacturer to let some expert in hardening try the steel. Some milling machine cutters were made from each brand of the rejected steel and sent to the steel makers. They all came back hard enough, without cracks, proving that the trouble was not in the steel.

An expensive steel is not necessarily a satisfactory investment, and a "cheap" brand may be *very expensive.* It is necessary to understand just what is needed in a steel for a given purpose. Some makers have different grades of steel for different purposes—one for taps and similar tools, another for milling machine cutters, etc.—while others put out a steel that is very satisfactory for most purposes. Each has a good argument in favor of his particular method of manufacture. In some shops it is thought advisable to use a grade of steel adapted to each individual class of tool; while in other shops, where detail is not followed as closely, this would cause no end of confusion. That part of the subject must be left to the judgment of the individual shop. But the treatment of the steel in the fire and the bath, in order to be successful, must be along certain lines. The successful hardener is he who finds out what particular quality is needed in the piece he is to harden—whether extreme hardness, toughness, elasticity, or a combination of two of these qualities. Then he must know the method to use in order to produce the desired result. The shape of the piece, the nature of the steel, the use to be made of the article, must all be taken into consideration. He must also be governed somewhat by the kind of fire he is to use.

* MACHINERY, February, 1902.

Heating the Steel

Some brands of steel will not stand, without injury, the range of heat that others will; some require more heat than others in order to harden at all. When hardening, no steel should be heated hotter than is necessary to produce the desired result. With some brands that give off their surface carbon very readily it is not advisable to heat them in an open fire, exposed to the action of the blast and outside air, as the products of combustion extract the carbon to such an extent that the surface will be soft even when the interior is extremely hard. While this might not materially affect a tool that is to be ground, it would spoil a tap, a formed cutter, or similar article, whose outside surface could not be removed. In hardening anything of this nature in an open fire, it should be placed in a piece of tube or some receptacle, so that the fire cannot come in contact with it while heating. There are a number of gas and gasoline hardening furnaces made which have a muffler to receive the work. The fire circulates around the muffler but does not come in contact with the steel. Very excellent results may be obtained when one of these furnaces is used. The front can be closed by means of a door, thus keeping all outside air away from the work. It will be found a great advantage if several large holes are drilled in the door, these being covered with isinglass, to enable the operator to see the work without opening the door.

Taking carbon from the steel is not the only injury done to a high grade of steel when heated in an ordinary blacksmith's forge by a careless operator. Most inexperienced men are apt to use a small fire, particularly if they find one already built. It may be mostly burned out, but the operator will not care to take the time to get fresh coal, and get the fire to the proper heat; so he puts on the blast and endeavors to heat the work. After a time the piece has all kinds of heats, ranging from a low red to a white heat. The operator thinks it *averages* well, and dips it in the bath. If it comes out in one piece he is fortunate.

Heating in a small fire is dangerous business, as the work not only comes in contact with the surrounding air, but with the cold air from the blast, which will cause minute surface cracks, making the steel look as though full of hairs. It will also fill the steel with "strains," causing ends of projections to crack and drop off in the bath.

If obliged to use the blacksmith's forge, use plenty of good charcoal. Make a large, high fire if the piece to be hardened is of any size; keep it up well from the blast inlet, using only blast enough to keep the fire lively, and bring the piece to the proper heat, burying it well in the fire to keep it from the air. The lowest heat that will give the desired result should be used. This varies in different makes of steel, and must also be varied somewhat according to size and shape of the work. The teeth of a milling machine cutter will harden at a lower heat than a solid piece of the same size made from the same bar. Most steelmakers in their instructions advise hardening at a low cherry red. To the average man this is a very uncertain degree; his cherries may be of a different hue from some other fellow's. Most of the leading brands of tool steel in small sizes give the best results, however, when hardened just after the black has disappeared from the center of the piece, provided it is heated slowly so as to get a uniform heat. In no case should steel be dipped when there is a trace of black in it.

The higher a piece of steel is heated—to a certain degree—the harder it will be; but if it is heated higher than to this degree the grain is opened, making it coarse and brittle, and it will be very liable to flake off under strain. For this reason, in the case of cutting tools, it is best to harden at as low a heat as possible. If the work gets too hot, yet not to a point where it is burned, it is always best to allow it to cool until the red has entirely disappeared, then reheat to the proper degree and harden, and the grain will be fine; but if allowed to cool to the proper hardening heat and dipped, it would be as coarse as if hardened at the high heat, and would also be very liable to crack.

Annealing

In hardening, a great deal depends on the annealing. It is as necessary to understand how to anneal properly as it is to know how to harden correctly. As generally understood, the purpose of annealing is to soften the steel, which is all right, so far as the person is concerned who works it to shape, but its relation to hardening is another matter. It removes all strains in the steel, incident to rolling and hammering in the steel mill and forging in the blacksmith shop. Experience teaches the hardener that it is necessary to anneal any odd-shaped piece or one with a hole or impression in it, after it has been blocked out fairly well to shape, a hole somewhat smaller than the finished size being drilled in it, and all surface scale being removed. The most satisfactory method to pursue is to pack in an iron box with granulated charcoal, not allowing any of the pieces to come within one inch of the box at any point. This box should then be placed in the furnace and kept at a bright red heat for a length of time dependent on the size of the steel. Pieces one inch in diameter should be kept at a red heat for one hour after the box is heated through; larger pieces should be kept hot correspondingly longer, allowing the work to cool off as slowly as possible. An annealing heat should be higher than a heat for hardening the same piece. The proper heat for annealing, in order that all strains may be overcome, should be nearly as high as for forging the same piece; in other words, the work should be heated to a bright red and kept so long enough to overcome any strain or tension liable to manifest itself when the piece is hardened. Tool steel for annealing should never be packed in cast-iron chips or dust, as this extracts the carbon to such an extent that there will be trouble when hardening is attempted. Packing too near the walls of the annealing box will have the same effect to a less extent, but will be more troublesome, as the carbon will be extracted from the surfaces nearest the box, and not affected anywhere else, making the hardening very uneven.

If not situated so that this method can be used, very satisfactory results may be obtained by heating in a large charcoal fire to a uniform forging heat. Put two or three inches of ashes in the bottom of an iron box; on this place a piece of soft wood board, put the work on it, cover with another piece of board, and fill the box with ashes. The boards will char and smolder, keeping the work hot for a long time. Some blacksmiths use a box of cold ashes, while others use cold lime; either way is liable to chill the piece, making it harder than if allowed to cool in the air, and if either material is used it should be hot to get good results. Excellent results may be obtained by heating in a muffler oven, as a very uniform heat of any degree may thus be obtained. It can be run any length of time, but when a piece is heated through in this way it takes a long time to cool.

Hardening Baths

Hardening a piece of steel is generally accomplished by heating to a low red, and plunging in some cooling bath. As so much depends on the bath, it is quite necessary to understand the effects of the use of the different kinds. The one most commonly used is clear cold water, though many use salt and water or brine. For hardening small articles that must be extremely hard, the following will be found very satisfactory: One pound citric acid crystals dissolved in one gallon of water. For very thin articles a bath of oil is necessary. For hardening springs, sperm oil is very satisfactory; when hardening cutting tools, raw linseed oil is excellent. There are hundreds of formulas for hardening compounds, some of which are excellent for certain classes of work. Some hardening solutions are poisonous, and are dangerous to have around; but for ordinary work the ones mentioned are sufficient.

Many successful hardeners use water that has been boiled, claiming better results from its use than from fresh water. Small odd-shaped pieces are not so liable to crack nor to harden unevenly when the water is slightly warm.

Examples of Hardening

We will now consider a few pieces of work to be hardened by the open-fire method. If we have a muffler furnace, so much the better, as with this it is easier to get certain results; but with care very satisfactory work can be done when the blacksmith forge is used. If it is a small tap, reamer, counterbore, or similar article we are to harden, it is best to heat it in a tube, bring it to a low red, and plunge it in slightly warm water, or in the citric acid solution. If it is a hollow mill, with a hole running part way through it, we should dip it in the bath with the hole up, or the steam will keep the water from entering the hole, leaving the inside walls soft. The steam would also have a tendency to crack the piece; but with the hole up when dipping, by working the piece up and down well in the bath, the steam can escape, and the water can get at the work. Much trouble may be saved the hardener if attention is paid to the steam likely to be generated, and some way provided to prevent its keeping the water from the work. Brine does not steam as readily as clear water; neither do the different acid solutions used by many.

In hardening a milling machine cutter, it is best to have a large high fire, to bury the cutter well in the fire, and to use only blast enough to bring the work to the required heat, which should be uniform throughout. If the piece has not been annealed after drilling a hole through it, remove it from the fire when red hot, then allow it to cool off slowly until the red has entirely disappeared, when it can be again placed in the fire and slowly brought to the required heat; it is then plunged in a bath of tepid water or brine and worked around well until it stops "singing." At this point it should be removed and instantly plunged in an oil bath, and left there until it is cool, when the strain should be removed by holding it over the fire until it is warm enough to "snap" when touched with the moistened finger. It can then be laid aside, and the temper drawn at leisure. In hardening punch-press dies we can treat them the same; if there are any screw holes for stripper or guide screws they should be plugged with fire clay or graphite.

Metal-slitting saws can be hardened nicely between iron plates whose surfaces are kept oiled. The saws should be heated in such a manner that the fire does not come in contact with them. It is best to heat on a flat plate, as the tendency to warp is much less than if laid on an uneven surface. When the saw is properly heated, place it on the lower oiled plate, placing the other one on it as quickly as possible; hold the upper plate down hard until the saw is cool. If there are many such pieces to harden, a fixture can be made so that one man can handle the saws and fixture alone—otherwise it requires two operators.

If there are no other means of drawing temper, the work may be brightened and drawn by color; but, if possible, do the drawing to temper in a kettle or crucible of oil over the fire, gaging the heat by a thermometer. Much more satisfactory results can be obtained by this latter method; and if very many pieces are to be done, it will be found much cheaper. A very light yellow is 430 degrees; a straw color is 460 degrees; a brown yellow, 500 degrees; a light purple, 530 degrees. A milling machine cutter for ordinary work should be drawn to 430 degrees; a punch-press die to 500 degrees; the punch to 530 degrees, and metal-slitting saws to 530 degrees.

CHAPTER III

PACK-HARDENING GAGES*

Pack-hardening, as the term is generally applied, consists in treating steel, generally tool steel, with some carbonaceous material until it will harden in oil. It is well known that steel hardened in oil is less liable to spring than when hardened in water. The tendency to crack is almost entirely done away with, unless the steel is improperly treated in the fire, and has the maximum of toughness. Now, if we are able to treat the steel so that it will be as hard as though dipped in water, and yet have the toughness due to oil-hardening, and at the same time reduce the tendency to spring to the minimum, it would seem that we have the ideal method of hardening.

The process consists essentially in supplying the surface of the steel with an additional amount of carbon by some material that will not in any way injure the steel. In order to provide the additional carbon, the steel must be packed in iron hardening boxes with the carbonizing material. Some have used charcoal for this purpose. While charcoal is a carbonizing agent, and is used many times in case-hardening machinery steel, and also in the cementation process for converting wrought iron into steel, yet its effect on high-grade steel in the process of carbonizing is not satisfactory, as it renders the steel coarse, and very similar to blister steel. No form of bone should be used when pack-hardening tool steel, as bone contains a high percentage of phosphorus, and the effect of this is to make steel weak and brittle.

For steel that does not contain more than 1¼ per cent carbon (125 points), charred leather gives the best results. Above this percentage use charred hoofs, or horns, or a mixture of the two. The leather, hoofs, or horns, may be used over and over by adding a quantity of new material each time.

The work should be packed in the hardening boxes so that no part of any piece of work comes in contact with the boxes; in fact, there should be at least ½ inch space between the work and the box. A layer of the carbonizing material should be placed in the bottom of the box, and a layer of work placed on this, taking care that no two pieces touch each other. If we are treating gages, or pieces of steel that are apt to spring unless care is used, we should make sure that they are so placed in the box that there will be as little liability of springing as possible when they are drawn up through the packing material. They must not be dumped into the hardening bath, as is the case when ordinary case-hardening is done.

In order to be able to properly handle the work, each piece should be wired with a piece of *iron* binding wire, as shown in Fig. 5, and

* MACHINERY, June, 1908.

the pieces so placed in the box that there will be the least resistance possible when drawing them out. At times they may stand on edge, as shown in Fig. 5. For certain shapes, however, it is advisable to stand them on end.

When several layers of work are packed in a box, the wires should be so arranged around the edge of the box that the various layers may be taken out in order, commencing with the top row. This is easily accomplished by marking the sides of the box with chalk, designating the side where the top row of wires is, as 1, the one where the second row is, as 2, and so on. Unless we adopt some such method, the pieces get all mixed up, and some will be drawn to the surface of the packing material, and will cool before the operator has a chance to dip them.

As in all heat treatment of tool steel, the heats should be as low as is consistent with desired results, and the heats must be uniform

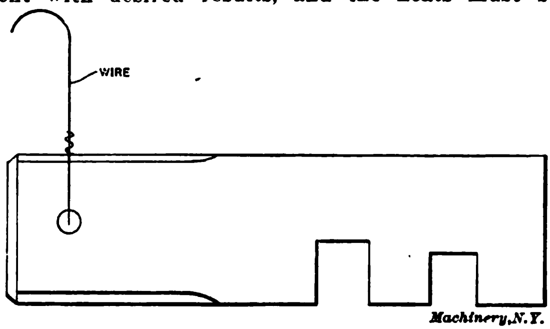


Fig. 5. Piece to be Hardened and Wire for Handling

throughout the box. It is also necessary that we gage the length of time the steel is exposed to the action of the carbonaceous material. Unsatisfactory results follow any attempt to gage the length of time by the time the boxes are in the furnace. In order that the operator may know when the contents of the box are heated, holes are drilled through the cover of the box at the center, and test wires are run down to the bottom of the box, as shown in Fig. 6. These wires should project about one inch above the top of the cover. The holes in the cover may be of any size to accommodate the wire to be used; a good size is 1/4-inch holes and 3/16-inch wire. When the box has been in the fire, according to the judgment of the operator, until the contents are heated to a low red, a wire may be drawn, by means of long tongs, and its condition noted; if it is red hot, begin timing the heat; if it is not red, wait a little while, and drawn another. Continue doing this until one is drawn that is of the desired temperature. The wires passing down at the center of the box, and between the pieces, will not be red until the pieces are of the same temperature.

The length of time necessary to expose the pieces to the action of the heat depends upon how deep we wish to harden the steel. For ordinary snap gages 1½ to 2 hours after the steel is red-hot is sufficient, but the time must be varied according to the percentage of carbon that the steel contains and its intended use.

Sometimes locating gages are made with the gaging holes made to the finished size of the gage. This method is not to be advocated where it is possible to use hardened bushings. In the latter case, the holes in the gage may be made of the proper size for the bushings, and the gage left soft, while the bushings are hardened, ground and lapped, and pressed into place without any tendency to distort the gage. But when it is necessary to make the gage of one piece, and have the gaging holes to size in the gage without bushings, then the pack-hardening

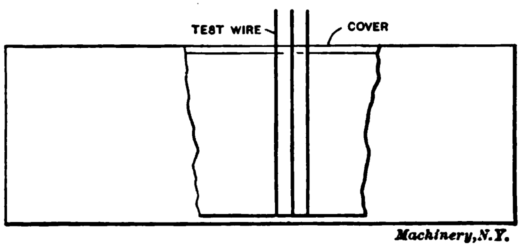


Fig. 6. Hardening Box with Test Wires which Enable the Operator to Determine when to Begin Timing the Heat

method will be found to work satisfactorily, as the heats may be very low, and the tendency to distortion will be eliminated, provided the processes of annealing and machining have been properly done.

As an example of pack-hardening gages, a case from practice may be cited. The gage was of the form shown in Fig. 7, and it was necessary that the walls of the opening through the gage be hard, yet the opening must retain its shape. The hole was filled with finely pulverized charred leather; the handle and the portion connecting it with the body were covered with fire clay which was wound with fine iron bind-

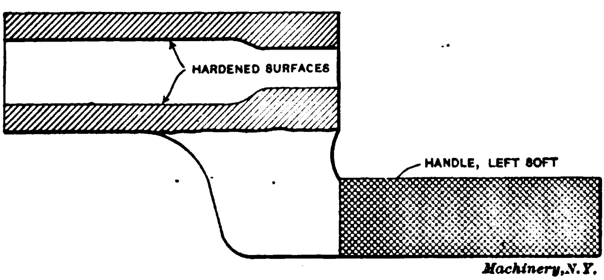
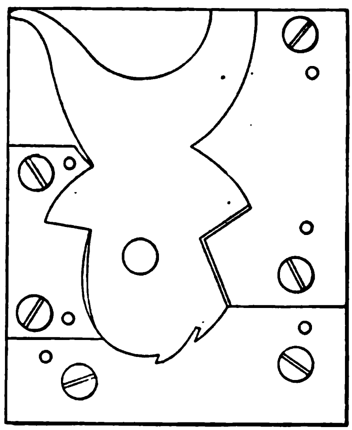


Fig. 7. A Gage to be Hardened as Indicated

ing wire to prevent it falling away when baked. The gages were packed in scale collected in the forge shop. This scale came from the outside of pieces of iron and steel as they were being forged. Being free from carbon, they absorbed or took the carbon from the surface of the steel. The ends of the opening through the gages were covered with fire clay mixed with water to the consistency of dough, which was allowed to harden before the gages were packed. The fire clay prevented the carbon gas escaping from the leather, as the scale would have taken it up very quickly.

When the gages had been exposed to the carbonizing influence of the leather for one and one-half hour, they were removed from the box in which they were heated, placed in a bath of raw linseed oil, one at a time, and a jet of oil was pumped through the opening after the leather had been removed. The fire clay around the handle and the portion connecting it with the body was left on until the gage was hardened, when it was removed. The walls of the hole were found to be hard, and as the surface of the gage was practically decarbonized, there was little danger of its pulling the piece of steel out of shape. The handle and adjoining portion, being protected by the fire clay, did not harden, or even cool quickly enough to distort the gaging portion in any way.

Many times receiving gages are made of several pieces which are fastened to a plate as shown in Fig. 8, which is a receiving gage for a



Machinery,N.Y.

Fig. 8. Receiving Gage of a Type Advantageously Hardened by the Pack-hardening Process

gun hammer, and it is necessary that the various portions be gaged accurately, and that each portion bear a certain relation to every other portion.

As shown, the various portions of the gage are made in sections, fitted in place and hardened. Unless these pieces are hardened by some method that eliminates the tendency to spring, they will be of little use after they are hardened. This is a case for pack-hardening. Pack the pieces in leather in a small iron box, run for one hour after they reach a low, red heat, and harden in raw linseed or sperm oil. It will not be found necessary to heat the steel treated in this way as hot as if heated in an open fire and dipped in water. It is not necessary to heat steel in the form of gages quite as hot as if it were made into cutting tools; but, even in the latter case, be sure to keep the heat down, and do not dip in extremely cold oil; have it warm, but not hot.

CHAPTER IV

FORGING, HARDENING AND ANNEALING HIGH-SPEED STEEL*

The rapid progress of tool steel manufacture, and particularly the advent of high-speed steel, makes it more and more necessary for the successful toolsmith to devote some of his spare time to a careful study of the nature and adaptability of new steels with special reference to their use in tool-making. The ease with which high-speed steel may be forged, shaped and hardened permits its use in the construction of many tools and dies. Hence, we not only find it in use in the machine shop for cutting tools, but in the press room for the construction of forming dies for hollow ware; also for wire-forming dies, and in the bolt mill for bolt-heading dies on hot work. It is used for shearing dies for hot and cold bar work and for many other purposes unthought of in connection with air-hardening steel. But, unfortunately, owing to the number of different makes of alloy steel now in use, no standard rule can be adopted for manipulation. Therefore, in order to determine the proper forging and hardening heats, it must be a matter of experiment for the toolsmith, and he will find it a very good method to test the particular brand he is about to use by giving a piece of it as much heat as he thinks the steel can properly stand and noting the result.

Forging High-speed Steel

The majority of the high-speed alloy steels should be heated, whenever possible, in block fire with a good body of forge coke. Thoroughly heat the steel in a clean, bright fire to a full yellow plastic heat, which means a temperature of 1650 to 1850 degrees F. This, of course, is a much higher temperature than can safely be used in forging air-hardening or carbon steel. In fact, the heat treatment given alloy steels of the high-speed variety is so diametrically opposite the generally accepted practice of working carbon steel that it seems to be a difficult matter to persuade the average smith to raise the heat to the proper temperature when working high-speed steels, but when this fact is once impressed, he will be surprised at the ease with which it can be worked. By rapid forging and repeated and thorough heating, it will be found no difficult matter to give alloy steel almost any desired shape, but, unlike carbon steels, it will not do to run the heat down low in forging, as in such practice the steel will most likely be found cracked or split. To heat thoroughly and often is the essential point to remember.

* MACHINERY, February, 1906.

Annealing High-speed Steel

After forging alloy steel for lathe, planer and shaper tools, it is, of course, unnecessary to anneal them except to let them cool down in the air in a dry place. When cold, rough grind to a proper edge; then they are ready for hardening, which process will be described later. In making use of alloy steel for taps, reamers, twist drills, milling cutters, or forming dies, it will be necessary to anneal the forgings in order to enable them to be worked in the machine shop.

The different sizes and shapes of this steel can generally be procured already annealed from the steel-maker, but when unable to obtain the annealed bar, and the work is required to be annealed, proceed in the following manner: A very successful method of annealing high-speed steel, and also self-hardening steel, consists of placing the tool in a wrought-iron or cast-iron tube, having space large enough in circumference and length to accommodate the work and plenty of packing material. One end of the tube can be threaded for a cast-iron cap, which can be screwed on and off as desired; the other end can be permanently fixed on the tube, as it is generally only necessary to use the one end. Have a number of ⅛-inch holes drilled in the tube, and also a few 3/16-inch holes in the end caps. The idea of the holes in the tube is to procure a vent for letting off the gas which is generated when heating the packing material. The end holes can be used for a number of test wires, which can be withdrawn as the heating progresses, and by this means the operator will be able to ascertain the proper heat desired, which should be a bright orange or a trifle higher, according to the nature of the steel. When the desired heat is reached, regulate the blast sufficiently to hold the muffle and its contents at this heat for a period long enough to allow the heat to thoroughly penetrate the steel. Then the muffle with its contents may be buried in dry slaked lime or sawdust and ashes, and allowed to cool down slowly. If a furnace is used for the heating, allow the muffle to stay in until furnace and all cools down, when the steel will be found quite easy to work in the machine. Respecting this "dead heating" in the furnace, unless the steel is properly packed in the muffle in order to exclude the oxygen blown into the furnace by the blast, the steel is apt to oxidize and the carbon content thereby becomes lowered, resulting in overannealed steel. The packing material used may be any one of several kinds now commonly used for other work, but charred leather gives the best results, and dry, fine smith coal of a good, clean quality is effective.

Hardening High-speed Steel

The hardening of high-speed steel can be done in numerous ways according to the requirements desired for the tool. For turning and cutting tools for lathe, planer, shaper and slotter, it will be found a good practice to heat the nose of the tool slowly to a bright red; bring it rapidly with a good, quick fire to a white fusing heat, about 2200 degrees F., on the point, then quench it quickly in oil and leave until it is cold. It must be borne in mind, however, that when a tool is at this high fusing heat it must not come in contact with the fuel of the fire, as, should that occur, the nose of the tool would be ruined and require considerable grinding or reforging into shape. After regrinding the tool on a wet stone it will be ready for work and should give a good account of itself, and incidentally reflect credit on the smith who worked it.

The oil used may depend on how hard the tool is desired. We will suppose it is required "dead" hard on the cutting edges; this is as hard as it is possible to make it for machine shop use and still retain sufficient toughness. To obtain this result, after fusing the point or cutting edges, quench quickly in thin lard oil, or for extreme hardness, quench the tool in kerosene oil, when about the maximum hardness of this steel may be obtained. In using oils, especially the kerosene, great care should be taken, or the oil may flame and burn the operator. The oil tanks used for hardening should be constructed preferably of galvanized iron, fitted with close-fitting covers, and provided with a screen a few inches from the bottom on which to rest the work in order to facilitate the quenching by allowing free circulation of the quenching bath to all parts of the tool.

In hardening machine-finished work, such as dies, milling cutters, taps, etc., made from this steel, we must proceed differently, as the course described would not answer for all purposes. All machine-finished work is to be packed in muffles or iron boxes as described for annealing, bringing the heat up in a similar manner, and testing as described. When heated sufficiently, remove the cover of the muffle and quench the tool in a bath of oil composed of half parts each of thin lard and raw linseed oils, keeping the tool in motion while in the bath until it has cooled to a little below the boiling point of the oil. Then it can be removed from the bath and left to cool in a warm, dry place, when, after being cleaned and polished, the temper may be drawn to a dark straw for general purposes. I may add that it is not always necessary to draw the temper on this character of tools; neither is it always necessary to harden such tools as milling cutters, dies, reamers, taps and drills in the oil. Very often it will be found only necessary to heat them to a good, bright red heat about 1500 degrees F. and lay them in a cold blast; when cold they will be hard enough for ordinary work. The objectionable feature of the cold-air blast for such work is the liability of the steel to scale on the finished parts, possibly causing a slight loss in size, though this seldom occurs when proper care is used, and the steel is not heated to a scaling point. The cold-air treatment, however, is applicable to work such as forming dies, wire dies and tools required to withstand some shock.

Sometimes it is unnecessary to pack the work, as it may be successfully heated by just using the tube and closing one end only. Place the tube in the fire and the work in it, bring it to the required heat with a gentle blast, and turn the tube frequently to insure an even heat,

CHAPTER V

LOCAL HARDENING AND TEMPERING*

In describing the shield process or method of local hardening and tempering of tool steel, some of the results of over four years of experimenting and practical application are recorded. The process is a radical departure from any practice in use up to the present time and acts on a principle that appears not to have been recognized heretofore. The wearing qualities of dies and tools so treated have been demonstrated by every-day use, and the efficiency of these as compared with tools treated by the conventional processes is decidedly superior. Breakage is reduced to a minimum, both in hardening and tempering and in use.

In using the shield method, the same judgment and common sense must be employed as in hardening by the regular method. If the hardener is hardening a piece that should be dipped in clear water, following the usual practice, it should be dipped in clear water when provided with the shield, and allowed to cool with the shield on. Or, if the piece is complicated and of a delicate structure that requires cooling in oil, the same practice should be followed with the covered piece, dipping it in oil in the same manner. Again, if a special bath is required for certain work, use the bath in the same way for the shielded work. The results are exactly the same, except that with the shield method only the parts exposed harden, while the parts covered remain soft and in their natural condition.

Heating

For heating tool steel to be hardened by the shield method, the operator has the choice of any fire he prefers. An open forge answers the purpose for small work, but the furnace is better on account of the more even heat. A lead bath cannot be used because of the lead getting between the covers and the steel to be hardened, which will cause an explosion when dipped into water. This is not a serious drawback, as the lead bath has no marked advantages over a good coke or gas furnace. Moreover, the lead bath has a disadvantage in that it leaves a thin film or coating on the steel, which tends to keep the cooling bath from penetrating to the steel and cooling the piece as rapidly as it would cool if heated in a furnace.

General Application of the Shield or Cover Method

The shield method can be applied to almost all tool steel. Any brand or grade that is desirable to use can be handled in exactly the same way as without the shield. The advantage of the shield is that the essential wearing surfaces are hardened, and if these parts only

* MACHINERY, August, 1908.

require hardening, why harden the piece all over? A piece hardened all over is weakened because of the internal strains and stresses which are likely to develop cracks and fractures and perhaps ruin an expensive part after it has been made all ready for use.

Gages of all kinds for external and internal use can be treated to advantage, and many gages now being made of machine steel and case-hardened can be made advantageously of tool steel in this manner, only the wearing parts being actually hardened, while the remainder is left soft. Multiple-throw crank-shafts for automobiles and high-duty automobile parts are readily treated by the shield method so that the actual wearing parts are hardened while the remainder of the piece is unchanged. Tool steel bearings for machinery may be hardened on the inside only, whether the bearing is in one piece or is split in two parts. Large rolls for rolling mills can be made with the journals soft or partly soft, thereby avoiding their breakage at the shoulders. Hammer faces for pneumatic hammers can be treated at the shank so that the shank is soft while the die part is hard, thus avoiding the breakages now generally experienced. All kinds of drill jig bushings can be hardened, either externally or internally, as desired. Shear blades and other large pieces for similar work can be hardened on the cutting edges while the bulk of the metal is left soft.

Materials Used for Shields

In practice the thinnest possible cover to accomplish the desired results should be used. Material thicker than 0.020 inch for ordinary work is not required, but not thinner than 0.010 inch for small work should be used. The thickness that serves best for average work is about 0.014 inch. The object of the shield is to cool the steel as quickly as possible under the cover without hardening it and without leaving a line of tension between the hardened and unhardened areas. The cover or shield can be made of any sheet iron or sheet steel; scrap pieces, even if rusty, answer the purpose satisfactorily. Galvanized iron or tin plate should not be used, as the coating of zinc or tin when heated enters the steel and deteriorates it.

The shields or covers are made in different ways to suit the conditions. Some are made with top and bottom pieces with another strip or piece for the edge to act as a binder to hold the top and bottom in place and to protect the edges of the piece. Some shields are made in one piece where the shape is not irregular. This applies in the case of round drawing dies and similar parts. In such cases, of course, the shield is formed to shape by cutting and bending. Where an irregular shape is to be cut out, the piece to be hardened is laid on the sheet metal and the outline scratched on it. The shape is cut out with a chisel, leaving a margin of the required width around the edges that are to be hardened. The width of this margin depends on the size of the part and the nature of the work. A pair of hand shears or snips, a small chisel, a scriber, hammer, punch and pliers are the principal tools necessary. A supply of sheet metal, rivets, and iron binding wire completes the outfit.

How the Shield Method Differs from Other Protective Methods

Mechanical journals and books on shop practice have not hitherto treated of this method, although other methods very similar have been described. There are several methods moderately successful for local hardening and tempering, one being by dipping the piece part way into a bath, a practice that is commonly followed in hardening chipping chisels. Another method is holding a heated piece over and above the bath and directing a stream of water onto the part to be hardened. Large, round drawing dies having to be hardened on the inside are examples of this practice, a cone-shape spout being used at the bottom of the pipe to deflect the stream into the interior of the die. A third method is that of making a box or form of heavy steel, cutting or drilling out the shape of the piece to be hardened. A lid is fitted to the box and the piece is heated in the fire, and after being heated is placed in the box and quenched. This method is objectionable in that the box, being made of thick material, causes uneven

A B C
Fig. 9. Blanking and Threading Dies in Protective Covers

cooling, most of the heat having to be drawn off through the exposed parts of the piece. A fourth method is the use of fire-clay or asbestos wrapped around the parts to be left soft, the holes being plugged with fire-clay, asbestos or even putty. Iron wire is used to wrap around a non-conducting material to hold it in place. It then has to be baked in an oven or furnace until the moisture is dried out. Then the part is heated in the furnace to the hardening heat, and dipped. Inasmuch as these materials are poor conductors of heat and as the heat must be drawn quickly in order for the steel to contract evenly with the hardened or exposed parts, this method has not been very successful.

A piece of steel heated to a proper hardening heat and quenched in a box or shield of very thin steel or iron material, will remain soft because the water cannot cool it directly. Steam or vapor forms between the cover and the steel, driving the water away until the piece has cooled down. If holes are cut through the cover to let the steam out more rapidly, that part of the steel exposed will harden. To show that it is the steam imprisoned between the steel and the shield which is sufficiently non-conductive to produce the difference between hardening and annealing, take a round piece of tool steel and fit a cover tightly around it, leaving half of its length exposed. Heat this piece all over and cool all over. It will be found that the steel has hardened its full length under the cover, as well as on the exposed parts. The reason is that when the cover is tightly fitted, no water can penetrate between the shield and the steel, and hence no steam is formed. The cover being thin, the steel cools rapidly and hardening takes place. This proves that the cover itself is a good conductor of heat, and that it is the thin stratum of steam which will always exist between the cover and the piece as ordinarily fitted, which is sufficient to check the hardening process.

Examples of Work Locally Hardened

The part shown in Fig. 9 at *A* is on ordinary blanking or cutting die and is an example showing how any shape to be hardened can be outlined in the cover. The cover is made in two pieces, the top and sides being one piece and the bottom the other piece. The material of this shield is No. 26 sheet steel and is about 0.018 inch thick.

The second piece shown in Fig. 9 at *B* is a round threading die, and the shield is applied so that the threads only are hardened, the exterior remaining soft. It illustrates a very practical use of the shield method. The die is split at one point, being of the adjustable type. Inasmuch as only the teeth are hardened, there is no danger of cracking the die in adjustment, and there is less distortion and change of pitch. The cover is made in one piece and can be used several times before being destroyed by the heat.

Fig. 10. Square Threading Die and Press Dies with Covers in Place, Ready for Hardening

The third piece shown in Fig. 9 at *C* is a plain blanking die, but instead of being hardened around the edge of the cutting part as at *A*, it is hardened half the thickness of the steel, leaving the whole lower half soft, this being protected by the cover, while the upper half is hardened. This gives the die all the advantages of a die made of composite steel, a material that is made of half tool steel and half soft steel or iron welded together. This material is extensively used on small die work, but the shield method makes its use unnecessary as all its advantages are obtained very simply, without the risk of splitting at the weld, as sometimes happens with composite steel.

A square threading die is shown in the shield at *A* in Fig. 10, and the same remarks apply in regard to distortion and change of pitch as in the case of the round threading die. At *B* is shown a press die in its cover ready to be hardened. The exposed portion is not large in proportion to the size of the die, but it will harden just as well as if there were a half-inch margin exposed all around the edge.

The cover is held on by iron wire. Brass wire or rivets should not be used, as the heat destroys them. At *C* is shown a progressive or following die. There is nothing of special interest in the design, but the method of hardening a narrow ring around each hole is unique. The cover is cut out so as to leave a narrow margin of exposed steel around each hole. The die is hardened exactly as the cover shows, the remainder of the body being as soft as before dipping.

Fig. 11, at *A*, shows a forming die for a drop-hammer. It is 8½ inches long, ¾ inch thick and 4 inches high, and has been hardened all around the outline of the top or face for a width of ½ inch. The scale is still on the steel and no finishing has been done. The cover had two large holes cut out to balance the cooling as the narrow center would warp the bottom. This piece was hardened without warping. At *B* is shown a large blanking punch with the face up. In hardening large punches it is only necessary to harden an area around

A B
Fig. 11. Drop Hammer Die and Punch with Shields

the cutting edge. The steel plate or cover on the face of the punch is 0.020 inch thick and was held to the face of the punch by three 3/16 inch screws, holes being drilled in the face of the punch to correspond. This is a good example of cover hardening and demonstrates its value, as the punch retains its shape perfectly after being dipped.

Two drawing dies are shown in Fig. 12 with the covers on ready to harden, and a third die is shown without a shield. These shields are made in one piece and can be used over again. A drawing die needs to be made as hard as possible, and yet when a die is hardened all over it is necessary to draw the temper in order to relieve the internal strains. By the shield method the working part is made as hard as it can be made while the soft part gives it a suitable backing and strength. The shrinkage can be regulated by the thickness of the shield or by putting vent holes around its edges. The vent holes let out the steam and cause the shielded part to cool more rapidly. Dies hardened by the shield process can be shrunk repeatedly to take up the wear.

A reverse drawing die 6 inches outside diameter, 5 inches inside diameter, with a hardened ring riveted to the top or wearing edge, is shown in Fig. 13 at *A*. At *B* is illustrated the method of hardening the ring, leaving the shoulder or bottom edge soft by covering it with a shield of thin steel. The ring can be fitted after hardening, driven on a shoe and holes drilled through from outside of the machine steel shoe, and riveted. The hardened portion is then ground to size. If the top rings were welded to the shoe it would have to be discarded when worn down.

In Fig. 14 is shown an embossing die made of tool steel. It is 8½ inches in diameter and 3 inches thick. This die was covered on the bottom and sides with No. 25 sheet steel, 0.020 inch thick, and placed in a basket or hanger so that it could be immersed by a tackle. The

Fig. 12. Two Drawing Dies Prepared for Local Hardening and One Without Cover

embossed part was filled with bone dust for protecting it in the fire, but charcoal or any suitable filling will do as well. When covering shallow dies, the top edge should be left standing about half an inch above the face of the die instead of being folded over, as shown in the illustration. This face is filled in as described above, as the filling will protect the face of the die. It should be left in, when dipped, and the die should be suspended face up and about 3 inches below the water level, while a stream of water of large volume but low pressure is directed against the center of the die while the die is

A B

Fig. 13. Reverse Drawing Die

Fig. 14. Embossing Die

moved around in the tank. This can be done with one hand holding the tackle, while the other hand directs the stream. The filling or packing will float away, leaving the surface of the die clean. A ¾-inch hose without nozzle is about right for ordinary work.

In this connection it may be mentioned that a skeleton platform with hanger is an advantage for handling large work, as any piece too large for tongs can be placed on the platform and lowered into the tank. It may be cooled from the bottom, if necessary, as well as from the top. Some shapes give better results if covered only on the sides, leaving the top and bottom exposed. The hanger gives the bottom a chance to cool off, but not as rapidly as the top on which the stream of water is directed. This method is an imporevement over the present way of hardening drop forging dies, this class of hardening being regarded as very difficult where the shapes are irregular and the thickness of the walls uneven. It will apply to all deep or hollow dies.

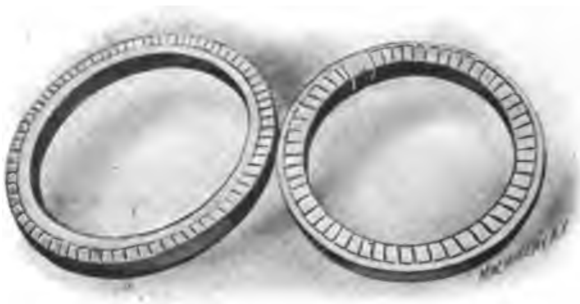
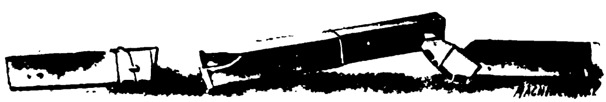


Fig. 15. Blanking Die and Punch

To the left in Fig. 15 is shown a blanking die 11⅛ inches inside diameter, 1¼ inch thick and 1¼ inch width of walls. This die is covered and hardened in the regular way. The temper is drawn, after which it can be placed in the lathe and trued up. The outside is as soft as it was before dipping. Obviously, this die is much stronger than one hardened all over. At the right is shown a blanking punch 11⅛ inches outside diameter, 1⅛ inch thick, with walls 1⅛ inch wide. It is hardened on the outside only and the temper is drawn. The inside is as soft as before hardening, and is made a



A B C

Fig. 16. Samples of Lathe Tools with Shields

driving fit on a cast-iron holder. The fit can be made a very tight drive without danger of cracking the ring.

Fig. 16 shows the application of the shield method to hardening lathe tools. At *A* is shown a right-hand side tool of carbon steel hardened on the cutting face only, the back being left soft. The cutting edge can be left much harder than usual without danger of weakening the tool. At *B* is shown a self-hardening tool that has been heated up to the proper temperature without cover, and the cover applied to the tool before dipping in oil. This method works equally well on air-hardened tools, the cover being put on before holding the tool in the air-blast. The breakage of self-hardening steel tools is an expensive item and usually amounts to more than the actual wear of the tools, but if they are made with a soft back or partly soft back and

Fig. 17. Miscellaneous Examples

with only the working parts hard, as will be the case with the shield process, the tool is much stronger, and is much less liable to fracture in service. At *C* is a half diamond point lathe tool which is hardened only on the working face. The sheet covers can be applied to

Fig. 18. Group of Large Dies and Covers

any shape of lathe or planer tool by any one of ordinary mechanical skill.

In Fig. 17 a ball-peen hammer is shown made ready for hardening; the eye for the handle is not filled, but is covered with a shield of steel wrapped around the part to be kept soft. The eye will not harden, as the heat of the steel inside of the cover, when dipped, creates steam which drives the water back until the heat is reduced. The milling cutter in this illustration is shielded with two circular plates 0.020 inch thick, and the hole in the center is not filled. The disks of sheet metal are held together by iron wire, and any desired area

Fig. 19. Another Group of Large Dies

on the sides of the cover can be left soft by making the size of the disks to suit. This is far better than the heavy plates that are generally used, as the heat is drawn off more rapidly, leaving less internal stresses in the steel. The tap shown has been hardened on the teeth only, the body and shank being shielded so that they are left soft.

Fig. 20. Miscellaneous Collection of Shields or Covers Showing Range of Application

Taps hardened in this manner are truer in the pitch and the size is less likely to be changed than if hardened all over. The preparation of the cover took less than 5 minutes' time, only two strips of sheet steel and a short section of iron binding wire being required. Flat drills are hardened on the point and sides only, the center being left soft. Such drills will not snap off short when caught in the work, but will bend before breaking. The shield consists simply of two thin plates held on by iron wire.

Fig. 18 illustrates a group of large dies and their covers. In Fig. 19 is illustrated another group of large dies, and in Fig. 20 is shown a miscellaneous collection of covers that have been used to shield work from ¼ inch diameter to 12 inches diameter. The shields are made mostly from stock 0.010 to 0.020 inch thick. Some of the circular shields have been in the fire several times.

The shield method of local hardening is applicable to a vast range of work, and the cutting tools, dies, taps, gages, etc., locally hardened and tempered, are less likely to warp and change in shape in hardening and are more durable in service than when hardened in the common way. The application of the shields is cheap, and any one of ordinary skill is able to cut them out and apply them to the work. The saving in breakage alone will more than pay the expenses of applying the shields, while the greater durability of tools so hardened makes the process profitable to use.

CHAPTER VI

ELECTRIC HARDENING FURNACES*

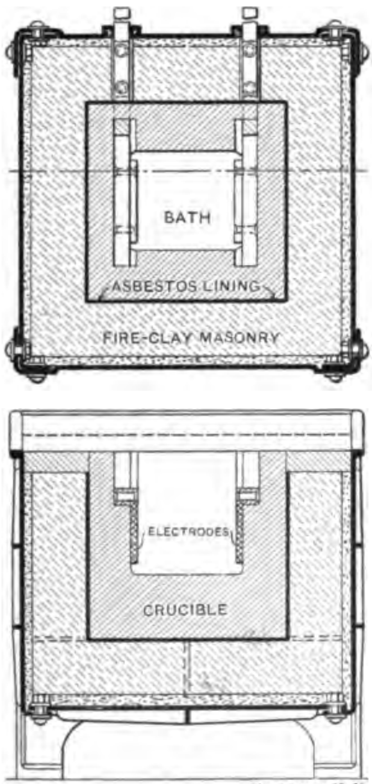
In externally-fired furnaces, the heat losses are always considerable, and only a small part of the energy used in heating is utilized for raising the temperature of the metal to be hardened. There is also a disadvantage in employing gas or oil-fired furnaces in that the high temperatures rapidly destroy the crucibles. Electric hardening furnaces, therefore, possess marked advantages for this work over the various types of externally-fired furnaces. The electric furnace described in the following has been brought out by the Allgemeine Elektricitäts-Gesellschaft of Berlin, Germany. A bath of melted metallic salts is contained within a fire-brick crucible, inside of which, at two opposite sides, are fixed electrodes of iron very low in carbon, the melting point of which is higher than that of ordinary steel. This crucible is surrounded by a thick layer of asbestos, which is, in turn, imbedded in a layer of some heat-insulating material, the whole being held together by a steel case. The walls of the furnace are made so thick in relation to the dimensions of the crucible that the steel case of the apparatus may be touched with the hand without injury after having been in operation for 10 hours, at a temperature of 2370 degrees F.

The soft iron supply conductors to the electrodes are connected to the secondary copper bars of a regulating transformer which transforms the normal voltage to the low voltage (5 to 70 volts) employed in the operation of the furnace. A typical arrangement of the equipment of a large works has the furnaces provided with a hood in a central position, and a quenching tank immediately beside the furnace on one side. By this latter arrangement the change in temperature caused by carrying pieces from the furnace to the water tank is reduced to a minimum. The tank is supplied with heating and cooling coils with steam or cold water, so that the temperature of the quenching bath can be easily regulated.

A pure metallic salt or a mixture of several salts is placed in the crucible and melted by the passage of an electric current. Potassium chloride which fuses at about 1425 degrees F. is selected for carbon steel; for high-speed steels, barium chloride, which fuses at 1740 degrees F., is employed. Mixtures of these two salts will give all intermediate temperatures. For low temperatures, say between 400 and 750 degrees F., potassium and sodium nitrates may be used, and for very high temperatures, magnesium fluoride and fluorspar. The salt is melted by a movable electrode and a small piece of arc-light carbon placed in the circuit between one of the fixed electrodes and the movable one. Sparking between the carbon and the movable electrode

* MACHINERY, September and December, 1908.

causes salt immediately adjacent to melt and very soon a circuit is set up through a part of the salt. As the movable electrode is gradually drawn away, it leaves behind a streak of melted salt, which is extended by degrees to the opposite electrode. When this point is reached, the fusion of the remainder of the salt proceeds at a rapid rate. The temperature produced depends on the voltage employed, and may be varied by changing the intensity of the current, which is accomplished by means of a regulating transformer.



Machinery, N. Y.

Fig. 21. Arrangement of Crucible and Electrodes for Electrically Heated Hardening Furnace

Even at a temperature of 2400 degrees F., attainable in laboratory tests but not usually employed in commercial hardening, the damage to the crucibles of the electric furnace is very small. Working ten hours a day with this temperature, a crucible will last six months, and for ordinary hardening temperatures, fifteen months.

The hardening process used by the firm of Ludwig Loewe & Co., Berlin, consists of an electrically heated barium salt bath, the arrangement of the crucible and the electrodes being as shown in Fig. 21. By means of this process, it has been possible to harden large milling cutters in about half an hour, including the time for preheating, which takes the greatest part of the time. Bringing the cutters up to a temperature of 750 degrees F. constitutes this preheating. After that, it takes only about a minute to bring an average-sized cutter to 1400 or 1500 degrees F., and then another minute to bring it up to about 2370 degrees F., which is, by this firm, considered the right hardening temperature. The time stated above refers to average-sized and heavy milling cutters, whereas it only takes from 6 to 10 minutes to bring a small milling cutter to the right temperature in the electrically heated salt bath.

The advantage of electrically heated salt baths is stated as being the total absence of any scale on the tool thus hardened, and that the tools are not distorted in the hardening process. The bright appearance is retained by the hardened tool, so that it is sometimes difficult to tell from the appearance whether a tool has been hardened or not.

In regard to cooling the cutters, the firm of Ludwig Loewe has found that when high-speed steel tools are cooled in an air blast, any moisture coming in contact with the hot tool has a tendency to crack it, so, that it becomes necessary to dry the air before it enters into the nozzles. It has also been found that it is absolutely impossible to cool a cutter which has a very heavy body and fine teeth in the air blast, as the heat from the central portion is not extracted fast enough. and therefore does not permit a sufficiently rapid cooling of the teeth to insure proper hardening. For this reason, the firm has adopted a method of cooling the cutters from the hardening heat of 2370 degrees F., to a temperature of about 1100 degrees F. by quenching in an electrically heated salt bath. After having been cooled to about 1100 degrees F. in the bath, the cutters are allowed to cool down slowly in the air, and the whole process has the advantage of being cheap and reliable, as well as effecting a considerable saving in time.

It must, however, be understood that electrically heated barium salt baths are advantageous to use only when a large quantity of tools is to be hardened, because this method will otherwise prove expensive. It has also been remarked that the electrically heated bath is more advantageous for heavy than for small tools, but it is not clear why the process should be thus limited to the former class of tools.

CHAPTER VII

MISCELLANEOUS HARDENING METHODS AND SUGGESTIONS

The Gaging of Heats for Hardening*

It takes an experienced man to gage the heat for hardening with the eye, at all times, and under all conditions, without heating some tools just a little hotter than they should be to get the best results. There are various reasons why heats are not always gaged correctly. In the first place, the man has no gage to go by, and again, the light conditions, prevailing at the time, may interfere. This can be overcome by having shades at the windows, that can be adjusted. Sometimes the eye gets "off-color" and needs rest for a few minutes. The use of the "magnetic influence" in gaging the heats for hardening has therefore a great deal in its favor. This method is practically new; in fact, a great many experienced mechanics, versed in the handling of carbon steels, have never heard of it.

We all know that the proper heat for hardening steel to get the best and most lasting results, is the lowest heat at which the steel will harden. How are we to determine this? By the use of the magnetic needle, no matter what the make, or brand of steel. The gaging of heats by the magnetic needle, is done in such a way that every piece can be tested; or one may test every second, or third or fifth piece, or only the first piece and then, noting the color very carefully, harden several pieces and make no mistake. In general, the work can thus be carried on without constant reference to the magnetic needle, provided the steel is of the same carbon content, but in all cases where the carbon content changes, the test must be made again.

Mr. George T. Coles of Decatur, Ill., has experimented extensively along these lines, and describes his experiments as follows:

"In starting my experiments, I bought a small pocket compass with a jeweled pivot and needle stop, about 2 inches in diameter, and costing a dollar and a half. I got a wooden steel to rest it on close to the furnace, as shown in Fig. 22. The stool and compass should be set in such a position that the natural swing of the work back and forth when testing, will be in a plane at right angles to the needle; in other words the piece being hardened should be swung east and west. By passing the tool being hardened (in this case a milling cutter) forwara and backward close to the compass, the magnetism of the tool will cause the needle to be deflected first one way, then the other, and the tool will continue to deflect the needle until the right degree of heat has been obtained, that is, the proper heat for dipping in the bath. Briefly, the right heat is reached when the tool loses its magnetism. It does not follow that if the needle remains stationary, the

* MACHINERY, April, 1908.

first time you test, that the heat is right, because, after the tool has reached a certain degree of heat the magnetism leaves the steel, so there is no influence on the needle, and the steel may be too hot. The different carbon contents and different grades of steel require different degrees of heat, and the magnetism leaves the steel at a certain degree of heat to correspond to the different points of carbon in the steel, and in every case this is the proper heat for dipping. After testing until the right degree of heat is obtained, I put the tool back in the furnace for about twenty seconds, just to even up the heat. I then dip the

Fig. 22. Testing a Milling Cutter, when Hardening, by Swinging it Back and Forth past a Magnetic Needle

tool in a water bath to set the hardness, and then remove it from the water bath to a lard oil bath where it remains until cold."

This method applies only to tools that can be heated all over, as it is obvious that heating a tool, say a tap, on the end to be hardened only, would have a disturbing effect on the needle because only part of the tap would be hot, leaving magnetism in the shank. In using the magnetic needle, if it points due north and south, a large body of metal would deflect the needle to a certain extent from its natural position, but no matter what the position of the needle, the moment a tool is held close to it, it is influenced by the tool, and will move until the right degree of heat is reached.

Hardening Without Cracking*

The following method for hardening punching dies is recommended by Mr. Frank E. Shailor of Great Barrington, Mass. He has used this method of hardening successfully for more than a dozen years.

The first operation is heating. Do not prepare a die for the fire by plugging up the screw holes with fire clay, for when the die becomes warm the water is evaporated from the fire clay, causing the clay to shrink away and allowing steam and hot water to get in between the clay and hole, thus causing more trouble than if the hole had been left open for the water to flow freely through it. Place the article in the fire, with a slight draft blowing, and change its position frequently to insure uniform heating. Too much importance can not be attached to even heating, as this is the ground work of successful hardening. It should be borne in mind that steel expands nearly one-eighth inch

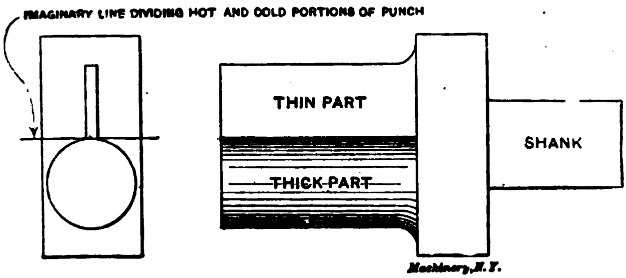


Fig. 23. Example of Work which must be Hardened with Care to Avoid Cracking

to the foot when at bright heat. Therefore, if one-half of a die is dark red and the other half is bright red, it is clear that one-half of the die has expanded more than the other half, thereby causing forces to push against each other. The condition tends to warp the die while it is hot; and if the die is dipped while in this state, as is too often done, there will be uneven contraction, causing internal strains, strongest along the line that divided the two shades of red, and causing a "set" in the die that holds it in a curved line caused by one end of the die expanding more than the other and pushing that end out of a true line.

Assume that we are to harden the punch, Fig. 23. We heat this punch carefully and evenly in a charcoal fire or gas furnace. For a bath we have a tub of clear water. The punch is removed from the fire the instant the proper heat is attained. We now immerse the punch in water, but do not allow the water to remain at the same level on the punch, as this causes either a crack or a huge swell. Now place one hand down in the water and keep feeling of the punch. The moment that the punch is not too hot for the fingers, remove it from the bath. Under no consideration allow the punch to become cold in the bath, for this is just what causes cracks, for this reason: When we immersed the punch, the slender stem was immediately attacked

* Machinery, February, 1906.

by the water, contracted to its normal size and became cold and hard, while the body of the punch was still red hot. This caused a distinct line between the hot and cold portions of the punch shown by the imaginary line in Fig. 23. Now, as the body of the punch begins to cool and contract, it is obvious that it must be pulling away from the stem, which has already contracted. If a crack does not appear, it is no sign that it will not sooner or later, as there must be a tremendous internal stress which will crack the punch later, and the operator will be taken to task for his carelessness. But, on the other hand, if we remove the punch as soon as we can bear our fingers on it in the

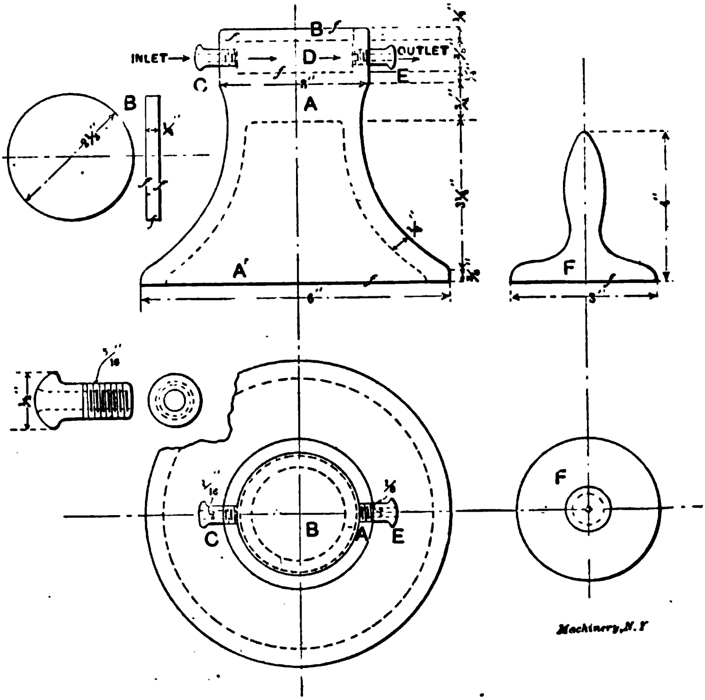


Fig. 24 Fig. 25
Pedestal and Hand Block for Hardening Thin Saws

bath (when it is still so hot that it steams), then the heat from the body of the punch will run out into the slender portion and the contraction will be uniform, excepting for the little effect the atmosphere may have.

The above could be summarized in a very few words, thus: "To prevent dies from cracking, do not allow them to become cold in the bath."

To Harden and Temper Thin Circular Saws Without Warping*

After hardening the very thinnest saws possible to make, it is not the easiest thing to straighten them, but by employing the following

* S. C. Smith, Machinery, May, 1906.

method there will be no trouble. It is not necessary to use oil or other preparation in hardening the saws, but simply a cast-iron pedestal, Fig. 24, through which flows a stream of water to keep it cold, and the hand block, Fig. 25.

A is the cast-iron pedestal, having its base *A'* reduced by coring. The top of the pedestal is bored for chamber *D* and receives the cast iron disk *B*, which is faced parallel and pressed tightly into place. Before *B* is pressed into place, however, holes for *C* and *E* are drilled and tapped into the casting *A*, these holes being made to receive brass nipples to which are attached rubber hose. Rubber hose is used inasmuch as it saves time in making the connection at the faucet and is most convenient to take down. *C*, being the inlet, is made larger than the outlet *E*, thus causing the chamber *D* to be constantly filled with

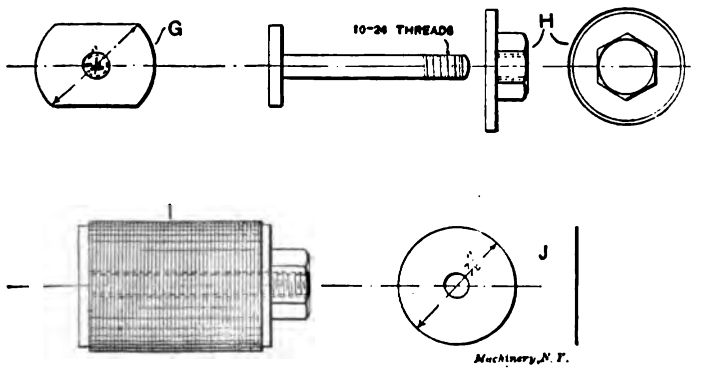


Fig. 26. Method Used for Tempering Thin Saws

water. The flow of water can be regulated at the faucet, and where there is no water faucet at the forge, a tank may be improvised by placing a pail of water above the pedestal, having a nipple connection on the side of the pail one inch above the bottom. A pail below the pedestal can serve as a drip tank. In this way a circulation of water through chamber *D* is assured and *B* is kept cold.

When sufficiently heated, the saw is laid on *B* and the hand block *F* is instantly placed on top, thus cooling and pressing it flat. The hand block should not remain on the saw more than five seconds. While another saw is being heated the operator removes the hardened saw and any scale which may have accumulated. After all the saws are hardened, the hose and fittings are "shelved" until another lot is ready.

The next operation is the tempering of the saws. In drawing the temper, use a gang arbor *G*, as shown in Fig. 26, which fits the hole in the saws closely. Place the saws on this arbor, as many being put on as possible, making allowance for a polished washer and nut, *H*. The saws are then clamped together by screwing up the nut as tightly as possible.

The saws should be drawn slowly, and should be kept revolving, now and then being dipped in water. This process is continued until the desired temper is shown by the polished washer, which should be repolished after each operation.

This method is used for very thin saws, from 0.0035 inch to 1/64 inch thick. For saws 1/64 inch thick, or thicker, it would be advisable to use oil, putting on just enough to keep the top of the pedestal well oiled.

Hardening Shear Blades

As a rule the hardening of shear blades, such as shown in Fig. 27, is attended by more or less trouble when attempted in a shop not specially fitted for it; yet if care is exercised and a method used which is adapted to the character of the piece, the trouble from springing

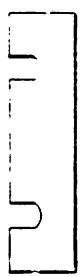


Fig. 27. Shear Blade to be Hardened

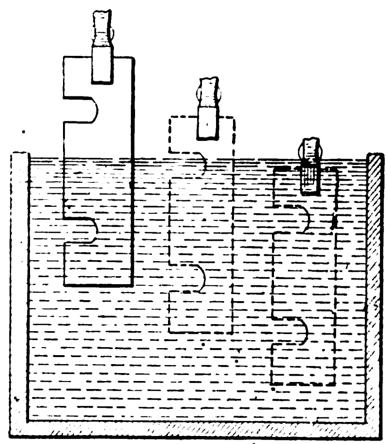


Fig. 28. Method of Dipping Shear Blade when Hardening

may be materially reduced in most cases. If the blade is made from a comparatively high carbon steel the tendency to spring will be greater than if a low carbon steel is used; but the blade will last a great deal longer if made of high carbon steel. When heating for hardening, place the blade in a hardening box and heat this in a furnace, if one is at hand. In this manner a uniform heat may be attained. If obliged to heat in a forge of the ordinary type, build a large, high fire, so as to have as nearly as possible a uniform heat. The edges and corners should be no hotter than the balance of the piece, or the uneven heat will cause the blade to crack from uneven contraction when plunged in the bath.

The bath used should be brine which is of a temperature of about 60 degrees F. Grasp the blade by one end with a suitable pair of tongs, dipping it in the bath in a vertical position, as shown in Fig. 28. It should be lowered slowly into the bath and moved edgewise while being lowered, as shown by the dotted lines. This brings the cutting edge in contact with the fresh, cool contents of the bath and allows the steam which is generated to pass from this edge to the one containing the slots. The steam thus leaves the cutting edge so that it can be acted upon by the bath, and forms a cushion at the other edge, preventing it from hardening as rapidly as it otherwise would, thus reducing the tendency to springing to the minimum.

Composition of Quenching Baths for Tempering Cutting Tools*

The composition of a number of baths for quenching and tempering cutting tools was given by H. Le Chatelier, in an article in *Revue de Metallurgie*. Fused nitrates of potassium and of sodium are too high in temperature for certain cutting tools, as they do not permit of cooling below 220 degrees F. Mixtures of nitrate of potassium and of nitrate of sodium can, however, be employed, and a series of mixtures, fusing at different temperatures, can be obtained. He gives the following proportions for these mixtures:

Temperature, Degrees F.	Nitrate of Potassium.	Nitrate of Sodium.
280	0	100
230	20	80
172	40	60
137	55	45
145	60	40
225	80	20
335	100	0

Higher temperatures than 400 degrees F. cannot be obtained with these mixtures. At 400 degrees F. potassium nitrate freely decomposes, whereas for steels where without extreme hardness absolute absence of brittleness is necessary, 500 degrees F. to 600 degrees F. are temperatures more suitable. The following bath gives, on fusion, a temperature of 500 degrees F.:

Sodium chloride	1 part
Potassium chloride	1 part
Fused calcium chloride	2 parts
Hydrated barium chloride	1 part
Hydrate strontium chloride	3 parts

For a bath fusing at 700 degrees F., the following mixture may be used:

Hydrated boric acid crystals	1 part
Silver sand	1½ part
Anhydrous potassium carbonate	1 part
Anhydrous sodium carbonate	1 part

When prolonged treatment is required a little cyanide of charcoal may be added to prevent superficial decarbonization; but in view of the strongly cementating action of cyanide, this salt must be used with caution.

* MACHINERY, May, 1905.

Temper Colors and Temperatures and Colors for Hardening*

The following tables of temper colors, and temperatures and colors for hardening, are published in a booklet issued by the Halcomb Steel Co., Syracuse, N. Y., and Chicago, Ill. The temperatures tabulated are a result of personal investigations made by Mr. Garson Myers, manager of the Chicago branch; a gas furnace equipped with a pyrometer was used. After the records were made, they were tested by two experienced tool steel hardeners, one using an electric heating furnace with a pyrometer and the other a magnetic heating furnace also connected with a pyrometer.

Heat Temperatures and Colors for Hardening

Degrees C.	Degrees F.	Colors.
400	752	Red heat, visible in the dark.
474	885	Red heat, visible in the twilight.
525	975	Red heat, visible in the daylight.
581	1077	Red heat, visible in the sunlight.
700	1292	Dark red.
800	1472	Dull cherry red.
900	1652	Cherry red.
1000	1832	Bright cherry red.
1100	2012	Orange red.
1200	2192	Orange yellow.
1300	2372	Yellow white.
1400	2552	White welding heat.
1500	2732	Brilliant white.
1600	2912	Dazzling white (bluish white).

The heat and temper colors, given below, to which tools should be drawn, were contributed by a hardener and temperer of long experience, working on all grades of tool steels.

Heats and Temper Colors of Steel

Degrees C.	Degrees F.	Colors.
215.6	420	Very faint yellow.
221.1	430	Very pale yellow.
226.7	440	Light yellow.
232.2	450	Pale straw yellow.
237.8	460	Straw yellow.
243.3	470	Deep straw yellow.
248.9	480	Dark yellow.
254.4	490	Yellow brown.
260.0	500	Brown yellow.
265.6	510	Spotted red brown.
271.1	520	Brown purple.
276.7	530	Light purple.
282.2	540	Full purple.
287.8	550	Dark purple.
293.3	560	Full blue.
298.9	570	Dark blue.
315.6	600	Very dark blue.

To Prevent Hot Lead Sticking to Work

To prevent hot lead sticking to the work, mix common whiting or cold-water paint with wood alcohol, and paint the part that is to be

* MACHINERY, December, 1908.

hardened. The hot lead will not stick, no matter how long the piece is held in the pot. Water will do as well as alcohol for mixing with the paint, but alcohol is the most convenient, inasmuch as it can be used without waiting for the paint to dry. If water is used, the paint must be thoroughly dry, as otherwise the moisture will cause the lead to fly.

Hardening Drop Forging Dies*

On the subject of hardening drop forging dies, Mr. J. F. Sallows has contributed the following to MACHINERY:

Uneven heating and uneven cooling, with consequent uneven contraction, is the cause of so many drop forging dies cracking in hardening. There is no necessity for this trouble if the dies are properly handled. If drop forging dies are made from machine steel, they should be

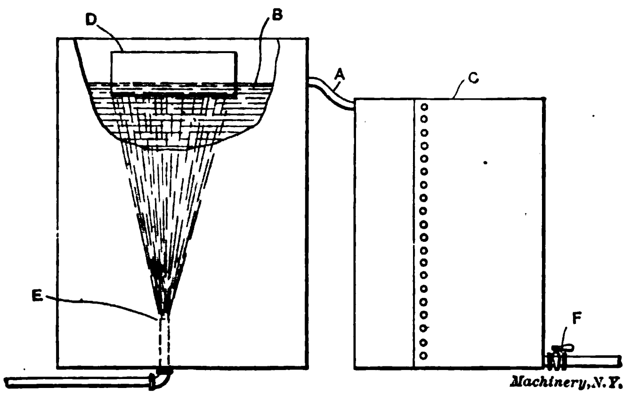


Fig. 29. Arrangement of Brine Tank for Hardening

packed in No. 1 raw bone and fine wood charcoal, three parts charcoal being used for each two parts raw bone. They are then heated in an oven for eight hours, at a temperature of 1600 degrees F., and are then dipped the same as described in the following for tool steel. When the dies are made of tool steel, the heating of the dies in an open furnace, even if covered with coke, is very injurious to the steel, as the carbon is removed from the surface of the steel, and the dies will not harden on the outside, but will be harder further in. This does not matter so much with tools that are to be ground to size after hardening, but it is poor practice with any kind of tool steel tools. Tool steel dies should be packed in fine wood charcoal in a box large enough to allow plenty of charcoal between the die and the box walls, say about two inches or more. Seal the cover on tight with asbestos cement, place the box containing the die in the furnace, and, if a pyrometer is attached to the furnace, hold the furnace at about 1500 degrees F., leaving the die in for at least four hours. For a small die, shorter time will be sufficient, but a die weighing 50 pounds or more should be allowed four hours to heat slowly and uniformly. Then,

* MACHINERY, January, 1908.

instead of immersing the whole die in a tank of cold, clear water, have two tanks, a large one and a small one, as shown n Fig. 29. An overflow pipe or hose *A* from the water line *B* in the large tank should connect it with the small tank *C*. When ready to dip the die *D*, place the face only in the water. Plenty of salt should be well dissolved in the water, about 4 pounds to the gallon; this extracts the heat from

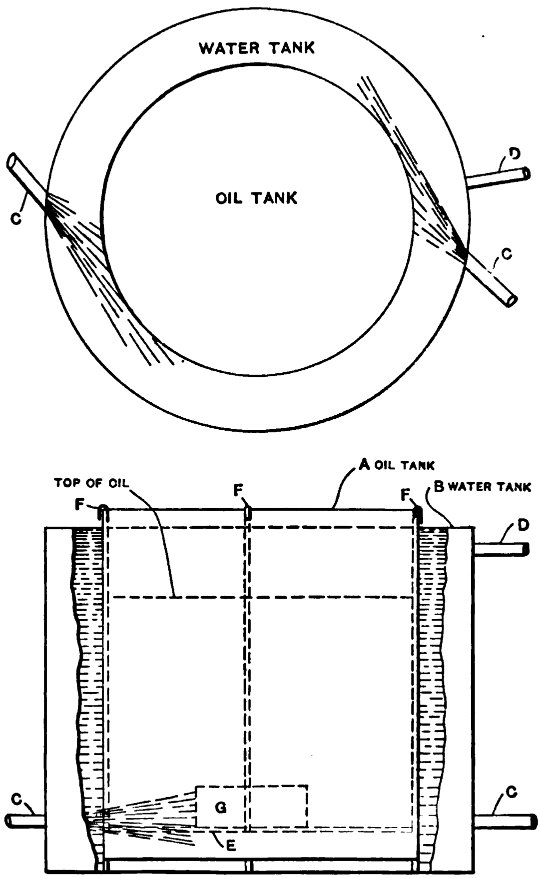


Fig. 30. Oil Tank for Hardening Room

the die quicker than clear water, and prevents steam formation on the face of the die. A water pipe *E* should be carried in at the center of the large tank at the bottom, and should be supplied with water at fairly high pressure. When placing the die in the bath, open the valve of the pipe *E*, thus forcing the cold solution against the face of the die, while the warm water passes into the smaller tank. The solution collecting in the smaller tank, when cool enough, can be used for smaller tools, and, when so desired, can be run off by outlet *F*. Another bath, in an oil tank, inside of a water tank, as shown in Fig. 30, should be provided. The size of the tanks must be determined by the size of the dies to be hardened. Fish oil should be used in this latter tank, and the tank should have two water inlets *C*, at opposite sides of the tank, and so arranged as to allow water to flow around all sides of the oil tank as indicated in the plan view. Pipe *D* is the overthrow. A coarse mesh sieve *E* is suspended in the oil tank, and held by rods *F*. The oil tank should have four legs about 6 inches long, to allow water underneath the tank. When the die face has been cooled in the salt water solution, remove the die quickly to the oil tank, and lower it until it rests on the sieve (see *G*, Fig. 30). Let the die remain in this position until cold. Dies hardened in this manner will not crack.

To Anneal Spots in Hardened Saws

An easy way to anneal spots in hardened saws is to take two pieces of, say, 1-inch rod machine steel about 2 feet long and bring the ends thereof up to a white heat. Then, having previously laid the saws on a flat surface of some sort and marked the spots to be annealed with a bit of red lead, hold the heated end onto the spot a fraction of a minute. While one rod is being used the other is being heated.

Annealing High-speed Steel*

A cast-iron box, large enough to permit proper packing of the pieces to be annealed is used. Charcoal ashes or cast-iron chips may be used for packing. Pack the work carefully, placing the larger pieces to the outside of the box, and the smaller pieces in the center. After the pieces are packed, they are then ready for the furnace. Heat slowly, raising the temperature to 1470 degrees F. (dull cherry red). Then hold the heat at this point for about 5 hours, and finally raise the heat in the furnace to 1650 degrees F. (cherry red). Shut off the fire, close the door, and let the furnace cool for 12 hours. The entire heating can be done in 5 hours, and the steel can be worked as nicely as any annealed by the steel mills. This is not the only method of annealing, but it is the best method when the steel is considered.

Annealing after hardening of high-speed steel can be accomplished by the following method in about one hour. Where a change in the tool is required to be done quickly, I often take the tool and heat to 1290 degrees F., then let it cool in the open air. Then heat the tool again, raising the temperature to 1290 degrees F. (somber red), and hold it there for 40 minutes. It is then taken from the fire, and permitted to cool in the open air. When one has at one's disposal 5 hours in which to anneal, however, the heat anneal is preferable. This is done by heating the tool or piece constantly for 5 hours. After the piece has been heated for 5 hours at 1290 degrees F. or less, take it from the fire and let it cool in the open air. One can also raise the heat to 1470 degrees F. (dull cherry red) and put the tool in lime to cool. Do not raise the heat to this degree, however, unless the piece is to be placed in lime. These methods are used only where a loss of

* C. U. Scott, MACHINERY, November, 1907.

time is to be considered. It is possible to anneal high-speed steel at as low a heat as 977 degrees F., red visible in daylight, but this heat will not make the steel very soft.

There is also another method of annealing high-speed steel. That is where a lead bath is in use. Take the piece to be annealed and place

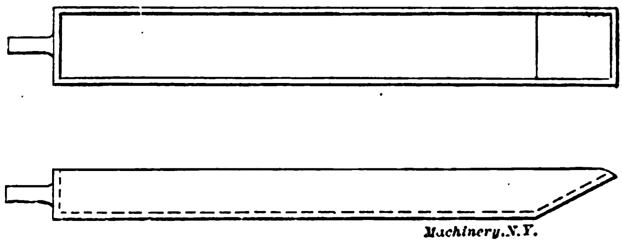


Fig. 31. Cast-iron Box in which Blades are Packed and Heated

it in the lead while it is at a dull cherry red. If the lead is of sufficient bulk to hold the heat for several hours, it will not be necessary to continue the heat. Leave the work in the lead and remove it the next morning, by heating the lead again. Remove the tool as soon as the lead is hot enough not to adhere to the work. Then dip the work in oil, after which, returning to the lead bath, the lead will leave the

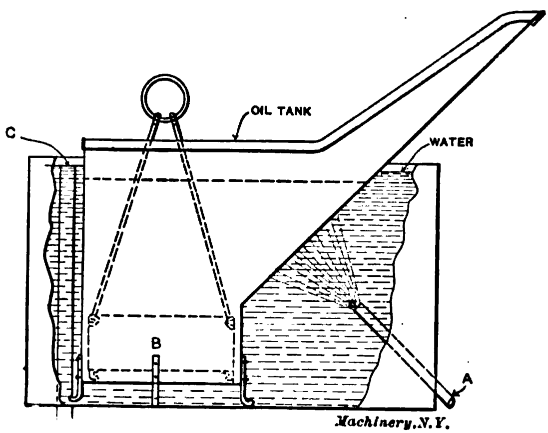


Fig. 32. Oil Tank for Hardening Hack-saw Blades

work if it is removed just as the oil burns off. After this the piece should be allowed to cool in the open air.

Hardening Hack-saw Blades in Quantities*

Hack-saw blades may be hardened in large quantities by using cast-iron boxes of the style shown in Fig. 31 in which to heat them. The boxes should be large enough to accommodate about three dozen blades placed on edge with the back down. A little charcoal should be used at the sides to keep the teeth of the outside blades from coming in contact with the sides of the box. The blades are then placed in the

* James Cran, MACHINERY, October, 1908.

muffle of a furnace and allowed to remain until they have reached the proper temperature for hardening. They can then be removed with a pair of tongs made to fit the shanks on the ends of the boxes. The blades should then be carefully dumped on the inclined chute of a linseed oil bath which is shown in Fig. 32. The tank containing the oil is placed inside a wooden tank that is filled with water which keeps the oil from getting overheated. Water is supplied through pipe *A*, and strikes directly on the lower side of the chute down which the blades slide on their way to the bottom, where they collect in a wire or perforated sheet metal basket *B*. An overflow pipe *C* is placed at one

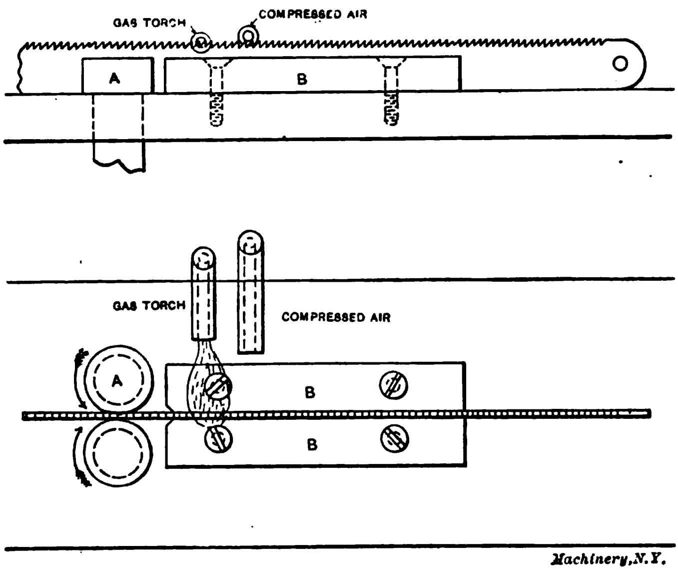


Fig. 33. Method of Hardening Flexible Hack-saw Blades

end of the water tank to carry off the warm water which rises to the top. The oil tank should rest upon legs several inches long, so as to raise it above the bottom of the water tank to allow a free circulation of the water. When the blades are fairly cooled off, the basket containing them can be removed from the oil and allowed to drip over the tank until most of the oil has left the blades; they can then be thoroughly cleaned by being immersed in a soda kettle or by placing them in clean sawdust. Flexible blades, being hardened on the teeth only, are treated differently. A fixture of the style shown in Fig. 33 is used for this method of hardening. The blades are placed, back down, between two power-driven rolls *A* which rotate in different directions, and which feed the blades, by friction, between two guides *B* and past the flame from a gas torch which heats the teeth sufficiently for hardening. A compressed air jet strikes the hot teeth immediately after they pass the torch. The temper does not have to be drawn, except at the ends, which is usually done with a torch.

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NUMBER 57

METAL SPINNING

CONTENTS

CHAPTER I

PRINCIPLES OF METAL SPINNING*

Metal spinning, that process of sheet metal goods manufacturing which deals with the forming of sheet metal into circular shapes of great variety by means of the lathe, forms and hand-tools, is full of kinks and schemes peculiar to itself. It is the purpose of this treatise to give a description of spinning in general, and to outline some of the methods and tools used in spinning for rapid production.

The products of metal spinning are used in a great many lines of manufacture. Examples of this work are chandelier parts, cooking utensils, silver and brittania hollow-ware, automobile lamps, cane-heads and many other sheet metal specialties. Brass, copper, zinc, aluminum, iron, soft steel, and, in fact nearly all metals yield readily to the spinner's skill. At best spinning is physically hard work, and the softer the stock, the easier and quicker the spinner can transform it into the required product.

There are but two practical ways of forming pieces of sheet metal into hollow circular articles: by dies and by spinning. By far the cheapest and best method of producing quantities of this class of work is by the use of dies, but there are many cases where it is impractical or impossible to follow this course. Dies are expensive and there is constant danger of breakage, whereas spinning forms are easily and cheaply made and are almost never damaged by use beyond a reasonable amount of wear. Thus it will be seen that when the production is small, it does not pay to make costly dies. Again, the styles or designs of many articles that are spun are constantly being changed; if made by dies each change would necessitate a new die, while in spinning merely a new wooden form is required—and sometimes the old form can be altered, costing practically nothing. Still other advantages of spinning are that in working soft steel, a much cheaper grade may be spun than can be drawn with dies; beads may be rolled at the edges of shells at little expense; experimental pieces may be made quickly, and, added to these features comes the fact that very difficult work that cannot possibly be made with dies can be spun with comparative ease. It must not be construed from the above that spinning is to be preferred to die work in all or even in the majority of cases, because, on the contrary, die work is a more economical method of manufacture, and should always be used when possible on production work. The cases already cited are merely given to point out some of the instances in which, for economical reasons, spinning is to be preferred to die work.

* MACHINERY, December, 1909.

The Spinning Lathe

The principal tool used in the operation of spinning is the spinning lathe, shown in Fig. 1. While in many respects this machine is similar to any other lathe, it is built without back-gears, carriage or lead-screw, is very rigid in construction, and, on the whole, very much resembles a speed lathe. Like other lathes, the spinning lathe is fitted with a cone pulley (preferably of wood, because of its lightness and gripping qualities), allowing the use of four or five different speeds. Speed is an important factor in spinning. Arbitrary rules for spinning speeds cannot be given, as the thicker the stock the

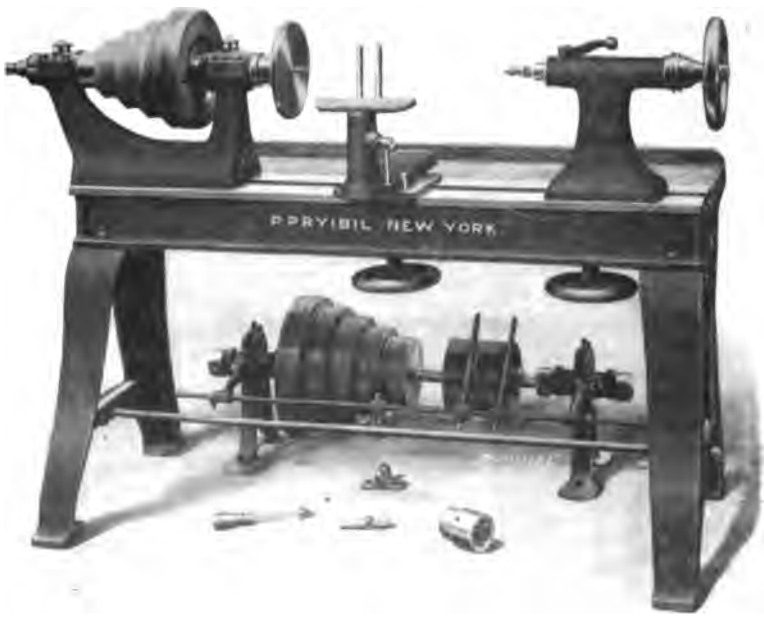


Fig. 1 Spinning Lathe

slower must be the speed; thus while 1/32-inch iron can be readily spun at 600 revolutions, 1/16-inch iron would necessitate reducing the speed to 400 revolutions per minute. Zinc spins best at from 1,000 to 1,400 revolutions; copper works well at 800 to 1,000; brass and aluminum require practically the same speed, from 800 to 1,200; while the comparatively slow speed of 300 to 600 revolutions is effective on iron and soft steel. Brittania and silver spin best at speeds from 800 to 1,000 revolutions.

One of the essential parts of the spinning lathe is the T-rest. The base of this rest is movable on the ways of the lathe, and it has at the side nearest the operator, a stud about four inches in diameter and six inches high, through which is swiveled the T-rest proper.

As the illustration shows, provision is made for raising and lowering the rest, and the entire rest may be clamped in any desired position by means of the hand-wheel shown beneath the ways. The rest proper consists of an arm, 12 to 15 inches long, similar to a wood turner's rest, and through the face of this arm are from twelve to sixteen closely spaced ⅝-inch holes. These holes are to receive the pin against which the hand tools are held while spinning. The pin is three inches long and of ¾-inch steel, turned down on one end to loosely fit the holes in the rest.

Another important part of the spinning lathe is the tail-center. This center is sometimes the ordinary dead center that is in general

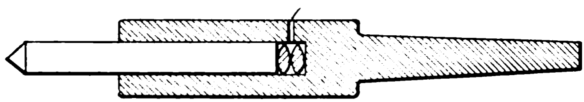


Fig. 2. Revolving Center

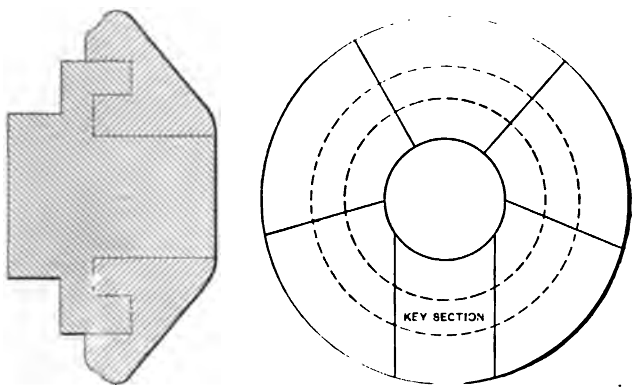
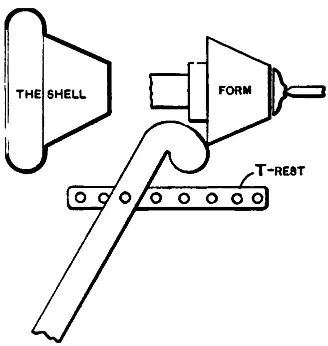


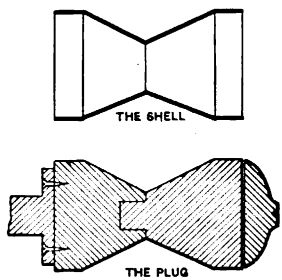
Fig. 3. Sectional Spinning Chuck

machine shop use, but nearly all spinners use the revolving center, shown in Fig. 2. The revolving center is ¾ inch diameter (without taper) and about six inches long, and is fitted into the socket in which it runs; this socket is, in turn, fitted to the taper hole in the tail-stock. At the bottom of the hole in the socket are two steel buttons, hardened and ground convex on their faces. These buttons act as ball bearings and reduce friction to a minimum.

Forms and Chucks for Spinning

The shape of a shell made by spinning is dependent on the form or chuck upon which the metal is spun. Forms are used for plain spinning where the shape of the shell will permit of its being readily taken from the form after the spinning has been completed; but when the shape of the shell is such that it will not "draw," as the molders say, it becomes necessary to employ sectional chucks, similar to the one shown in Fig. 3. Generally speaking, spinning forms are made of kiln dried maple. After being bored and threaded to fit the lathe spindle, the spinner turns the maple block to agree with a templet shaped in outline to the sample shell. When no sample is furnished, the templet must be laid out from a sketch or drawing; in either case proper allowance is made for the thickness of the stock. When large quantities of shells are to be spun, all alike, the form is sometimes made of lignum vitæ. Another method is to turn the maple form small enough so that one shell may be spun and cemented to it and then this metal-cased form is used to spin the balance of the shells. For continuous spinning, forms are made of cast iron or steel, which of course makes a most satisfactory surface to spin on and gives indefinite service.





Machinery, N.Y.

Fig. 4. Quick Method of Spinning Difficult Shell Without Sectional Chuck

Fig. 5. Spinning on Plugs

A sectional or "split" chuck, as it is sometimes called, is, as the name implies, a spinning chuck or form which may be taken apart in sections after the shell has been spun over it. As before stated, this class of spinning chuck is only used when the finished shell could not be removed from an ordinary form after spinning. After a shell has been spun over a sectional chuck, the shell and the sections of the chuck are together pulled lengthwise from the core of the chuck. Then, starting with the key section, it is an easy matter to remove each section from the inside of the shell. As the sections are removed, they are replaced upon the core, slipped under the retaining flange and the chuck is ready for spinning a new shell. The whole operation of removing and replacing the sections of a chuck takes less time than it does to tell it, and, as the sections are of different sizes, it is easy to replace the them in the proper order. Like other forms, sectional chucks are made of wood or metal, according to the requirements of the job. The core and retaining ring are first made from one piece and then the sections are turned in a continuous ring and split with a fine saw. In some cases it is necessary to add a small piece to the last section to make up for the stock lost in splitting the sections.

Another kind of sectional chuck, known to the trade as a "plug" (shown in Fig. 5) is used extensively in some shops in cases where the shell must have projections or shoulders at both ends, and no bottom to the shell is required. In making the plug, which is always in two parts, the first half is turned to take the shell from one end to the center of the smallest diameter. Into the end of this part is bored a hole to which is fitted the end of the second part, which is afterwards turned to fit the shell. Over this two-part plug the shell is spun; then the bottom of the shell is cut out and the first half of the plug removed, thus allowing the shell to be withdrawn. The first part is then replaced and the plug is ready for use again. Fig. 4 shows a method of spinning difficult shells that ordinarily would require a sectional chuck. The shell shown at the left of Fig. 4 is first spun as far as the bulged part on an ordinary form that ends at this

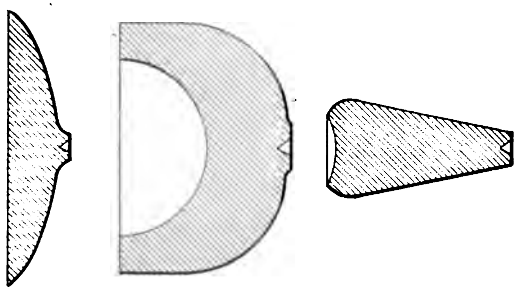


Fig. 6. Three Types of Followers

point. Then after annealing, it is replaced on the form and while another operator holds the wooden arm, supported with a pin in the T-rest, the spinner forms the metal around the bulge-shaped end of the arm. The arm, being stationary on the inside of the shell, acts as a continuation of the spinning form, and by this method as good a shell is obtained as could be spun with a sectional chuck.

For spinning operations upon tubing or press-drawn tubes, steel arbors are generally used. Tubing may be readily spun upon an arbor and it can be reduced or expanded to comply with the shape of shell required much more quickly than the shell could be spun from the blank.

Followers

For holding the sheet metal blank to the spinning form, a block of wood known as the follower, is used (see Fig. 6). Followers are made to suit the shape of the work with which they are to be employed, always being made with the largest possible bearing on the work; thus a shell with a flat bottom twelve inches in diameter would be turned with the aid of a follower having an 11¾-inch face, while a shell with a 4-inch face would take a follower with a 3⅞-inch face. All shells do not have flat bottoms, consequently, in spinning such as do not, it becomes necessary to employ hollow followers. Hollow followers have their bearing surfaces turned out to fit the ends of the

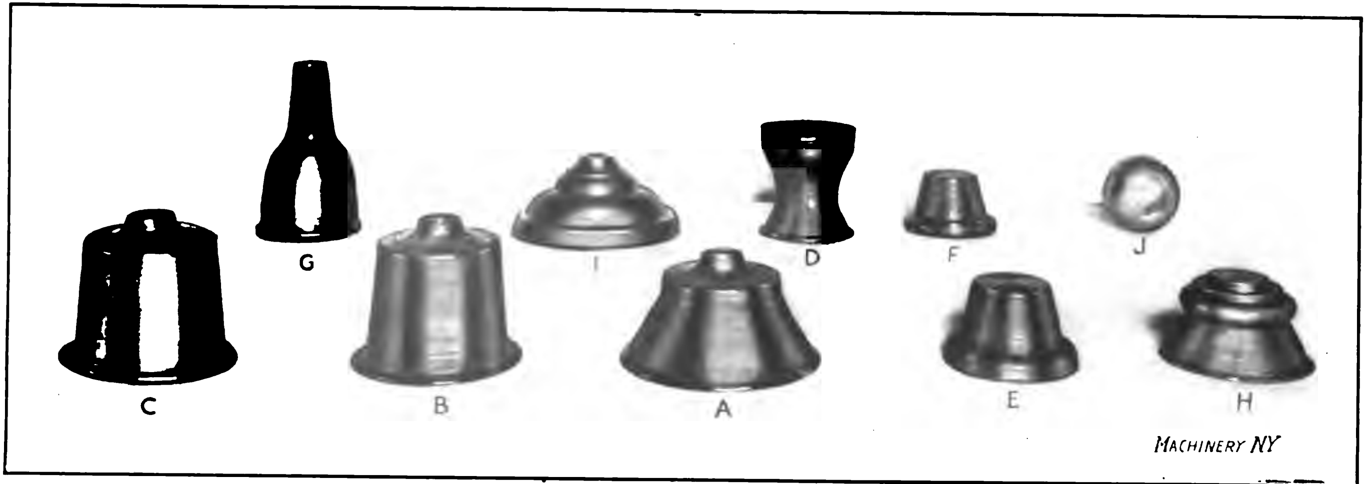
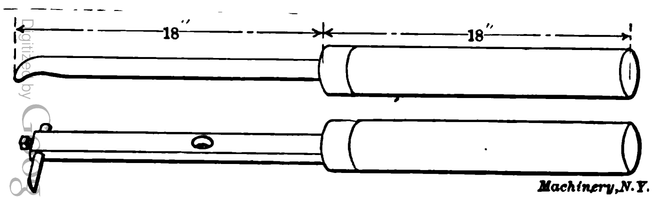


Fig. 7. Specimens of Metal Spinning



Figs. 8 and 9. Spinning Tool and Swivel Cutter

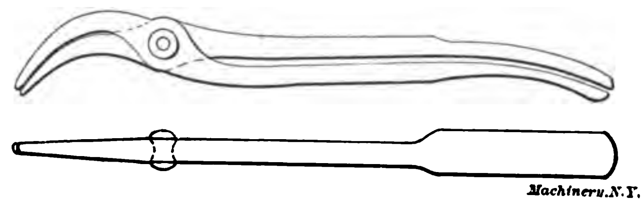


Fig. 10. Spinners' Pliers

forms with which they are to be used. In practice, the blank is held against the end of the spherical form with a small flat follower until enough of the shell has been spun to admit of the hollow follower being used. All followers are made with a large center hole in one end to receive the revolving tail-center.

In starting to spin a difficult shell it sometimes happens that the necessarily small follower will not hold the blank. To prevent this slipping, the face of the follower is covered with emery cloth. Often, however, on rough work, the spinner will not stop to face the follower, but will make a large shallow dent at the center of the blank; the extra pressure required to force the metal against the form will usually overcome the slipping tendency.

Hand Tools

Hand tools, in great variety, form the principal asset of the spinner's kit. Spinning tools are made of tool steel forged to the required shapes, and are hardened and polished on the working end. The round steel from which they are made varies from ½ inch to 1½ inch in diameter, according to the class of work upon which they are to be used. The length of a spinning tool is about 2 feet, and it is fitted into a wooden handle 2 inches diameter and 18 inches long, making the total length of the handled tool about 3 feet, as shown in Fig. 8. As the spinner holds this handle under the right armpit, he secures a great leverage upon the work and is better able to supply the physical power required to bring the metal to the desired shape.

The commonest and by far the most useful of the spinning tools is the combination "point and ball" which together with a number of other tools, is shown in Fig. 11. This tool is used in doing the bulk of the spinning operations—for starting the work and bringing it approximately to the shape of the form. Its range of usefulness is large on account of the many different shapes that may be utilized by merely turning the tool in a different direction. Next in importance comes the flat or smoothing tool which, as the name implies, is for smoothing the shell and finishing any rough surfaces left by the point and ball tool. The fishtail tool, so named from its shape, is used principally in flaring the end of a shell from the inside, "spinning on air," as it is sometimes termed. This tool is used to good advantage in any place where it is necessary to stretch the metal to any extent, and its thin rounding edge proves useful in setting the metal into corners and narrow grooves. Other tools are the ball tool which is adapted to finishing curves; the hook tool, used on inside work; and the beading tool which is needed in rolling over a bead at the edge of a shell when extra strength or a better finish is desired.

When much beading of one kind is being done, a large heavy pair of round-nose pliers (Fig. 10) with the jaws bent around in a curve and sprung apart enough to allow for the thickness of the metal proves to be a handy tool. After the edge of the shell has been flared out to start the bead, the pliers are opened enough to admit the metal and then closed and the stock guided around to form the bead as far as possible. In this way the larger part of a bead is rapidly formed, one jaw of the pliers acting as a spinning tool and the other corresponding to the back-stick. During this operation, the pliers are, of course, supported by being held against the T-rest.

Closely allied with these spinning tools are two other tools (also shown in Fig. 11) known as the diamond point and the skimmer. The diamond point is for trimming the edges of the shell during the spinning operation and for cutting out centers or other parts of the work. The skimmer is for cleaning up the surface of a shell, removing a small amount of metal in doing so, the amount depending upon the skill the spinner used in the spinning proper.

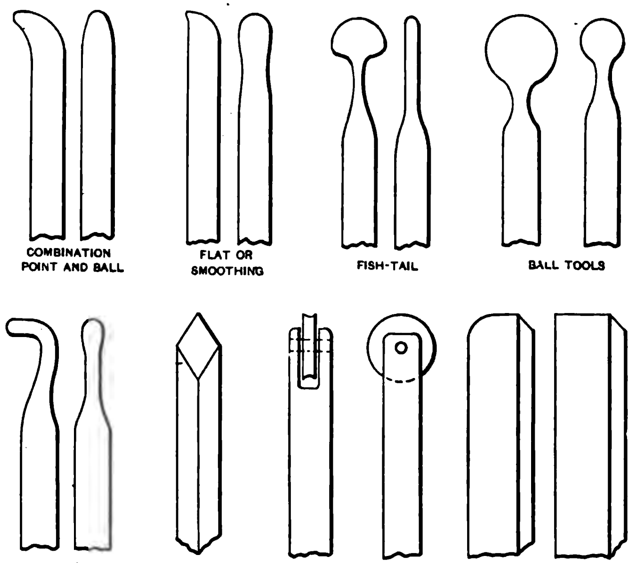


Fig. 11. Hand Tools of Various Forms used in Spinning

When the bottoms are to be cut from a large number of shells and it is necessary that they be cut exactly alike, a tool known as a swivel cutter is used. This tool (see Fig. 9) is simply an iron bar with a cutter on one end, which swivels near the center around a pin in the T-rest; thus by a slight movement of the arm the cutter is brought up to the work, cutting a piece from the shell of exactly the same size each time.

The Spinning Operation

In order to make clear the successive steps in spinning, let us briefly consider the making of a copper head-light reflector, and the way the work is handled when a few hundred pieces are to be made.

By trial spinning, the size of the blank required for one of the reflectors is determined, and with the square shears the copper sheets are cut into pieces an eighth of an inch larger each way. These squares are then taken to the circular shears and cut to round shapes ready for the spinning lathe. The spinning form, of kiln-dried maple, is screwed to the spindle and the belt thrown to that step of the cone pulley which will bring the speed nearest to 1,200 revolutions. From the stock-room a follower is selected whose face will nearly cover the bottom of the form. It is now "up to" the spinner. Holding a blank and also the follower against the end of the form, he runs the tail-center up to the center in the follower just hard enough to hold the blank in place. Then, starting the lathe, he centers the blank by lightly pressing against its edge a hard wood stick. As soon as it "lines up" he runs the center up a little harder and clamps it in place. Some spinners will "hop in" a blank with the lathe running, but this is dangerous practice and sometimes the blank will go sailing across the room. Often this happens in truing up the blank and for this reason it is considered advisable to have a wire grating at the further side of the lathe to prevent serious accidents; for a sheet metal blank is a dangerous missile traveling at the high rate of speed which is imparted to it by the lathe.

With a piece of beeswax (soap is sometimes used for economical reasons) the spinner lightly rubs the rapidly revolving blank and then adjusts the pin in the T-rest to a point near enough to the blank to obtain a good leverage with the spinning tool. Holding the handle of his point and ball tool under his right armpit and using the tool as a lever and the pin on the rest as a fulcrum, he slowly forces the metal disk back in the direction of the body of the form, never allowing the tool to rest in one spot, but constantly working it in and out, applying the pressure on the way out to the edge of the disk and letting up as he comes back for a new stroke. In the meantime his left hand is busy holding a short piece of hard wood (called the back-stick), firmly against the reverse side of the metal at a constantly changing point opposite the tool. The object of the back-stick is to keep the stock from wrinkling as it is stretched toward the edge of the disk. Wrinkles cause the metal to crack at the edges and for this reason they must be kept from the stock as much as possible.

After a few strokes of the spinning tool have been taken, the shell will appear about as shown at *B*, Fig. 12, and at this point it is necessary to trim the shell at the edges with the diamond-point tool. Trimming is required because spinning stretches the stock and the resulting uneven edge will cause splits in the metal if it is not trimmed occasionally. As a carpenter is known by his chips, so a spinner is known by the way his work stretches. While the even pressure of a good spinner will stretch the stock very little, the uneven pressure of the inexperienced man will lead him into all sorts of trouble on account of the way the stock will "go." In either case the metal always stretches least in the direction in which the sheet stock was originally rolled, consequently giving the edge a slight oval shape. In trimming zinc, the spinner holds a "swab" of cloth just above the diamond point, to prevent the chips from flying into his face and eyes—or those of his neighbors. With other metals the swab is unnecessary.

The reflector is now taking shape. With each successive stroke the spinner sets a little more of the metal against the form. Not only does spinning stretch the metal, but it hardens it as well; therefore, at the stage *C* it becomes necessary to anneal the partially completed reflector, which is done by heating it to a low red in a gas furnace. In running through a lot of shells, the common practice is to spin them all as far as possible without annealing, and after annealing the whole lot, to complete the spinning.

After replacing the shell upon the form, it is trimmed and worked further along the form, gradually assuming the appearance shown at

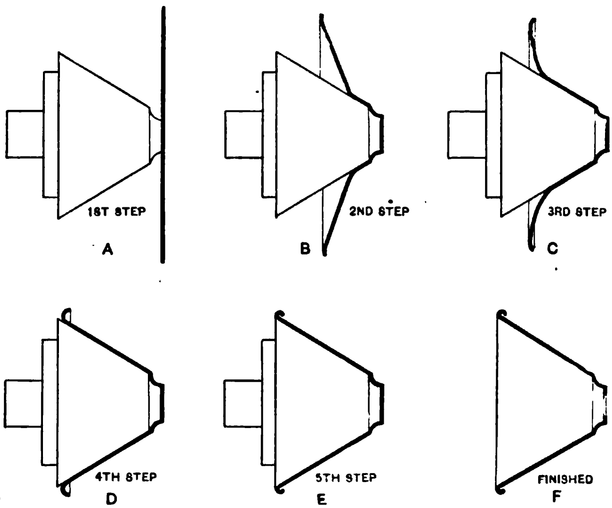


Fig. 12. Successive Steps in Spinning a Reflector

D. At this time, the spinner goes back to the small radius at the front end of the shell and with a ball tool he closes the annealed metal hard down against the form, for the spinning has tended to pull the stock slightly from the form at this point. The body of the reflector is now practically completed and the spinner directs his attention to rolling the bead at the outside edge. Slowly he begins to roll the edge of the shell back, using his hook tool to complete the bead as far as possible and exercising care to keep the back-stick firmly against the metal so as to keep the wrinkles out. Now, with the diamond point, he gives the edges a final trim, and with the beading tool closes down the bead snugly against the rest of the shell, as shown at *E*. Lastly, the swivel cutter is placed in the proper hole of the T-rest and a turn of the tool cuts out the center to the exact size, and the reflector is completed. If any burrs or rough places remain they are easily removed at this time with the skimmer or diamond point, and a little emery cloth gives the shell a finished appearance.

Referring to the illustration Fig. 7, *A*, *B* and *C* represent the three most important stages of spinning a shell like that shown at *C*. Annealing is necessary between steps *A* and *B*. *D* is a shell spun upon a form of the plug variety, and *E* and *F* are two views of a shell spun after the method shown in Fig. 4, *F* being the completed shell. *G* illustrates a very difficult shell to spin, on account of the small follower that must be used; the length of the small diameter also adds to the difficulty. *H* shows a shell that must be spun upon a sectional chuck, while *I* is a plain easy job of ornamental spinning. The ball shown at *J* was spun from one piece of aluminum and it is more of a curiosity than a specimen of practical spinning. It was first spun over a form that would leave one half of the ball complete and the stock for the other half straight out like a short tube. Next a wooden split chuck was made, hollowed out to receive the finished end of the ball and the open end was gradually spun down and in until the ball was complete with but a 1/16-inch hole at the end. This hole was plugged and the hollow ball was done.

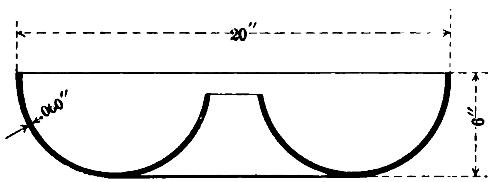


Fig. 13. An Interesting Example of Metal Spinning

As another example of metal spinning, assume the shape shown in Fig. 13. The shell is to be 20 inches in diameter, 6 inches deep, and 0.060 inch thick. The metal to be used is zinc. This is an interesting metal spinning job, and not a particularly difficult one. The shell can be best spun with the aid of two spinning forms, such as are illustrated in Figs. 14 and 15. These forms should be made of kiln-dried maple if there are comparatively few shells to be spun. If there are many, the forms should be made of cast iron. Fig. 14 shows the first form to be used, which conforms to the outside of the shell as far as the centers of the spherical ring. Beyond these points, the form is straight. The blank to be spun is placed as indicated by the dotted lines, and follower No. 1 is used to hold the work against the form. The chief trouble will be met in properly starting the shell, because of the small follower that must be employed. However, follower No. 2 may be substituted after working the metal back against the form a few inches, and as this gives a better grip on the shell, there will be no further danger of slipping. After spinning the zinc shell to the shape of the first form (Fig. 14) it will probably have to be annealed, but this can only be determined by trial. In annealing zinc, the flame should not be allowed to touch the metal. The half completed shell is then put on form No. 2 shown in Fig. 15. It is an easy matter to spin the metal round to complete the arc. The dotted line shows the position of the shell before starting the last part of the spinning. Of course, it will be understood that the shell must be trimmed several times during the spinning, and if the trimming is frequently done, a well-shaped shell should result. For spinning on form No. 2, follower No. 3 must be used. Either beeswax or soap should be frequently rubbed over the work while spinning. If it is necessary to cut out the center, it can be done before removing the shell from the last form by simply removing the follower and using a diamond point tool, or in large product work the swivel cutter will work well. The shell will cling to the form without the follower. The spinning speed should be from 800 to 1,000 R. P. M.

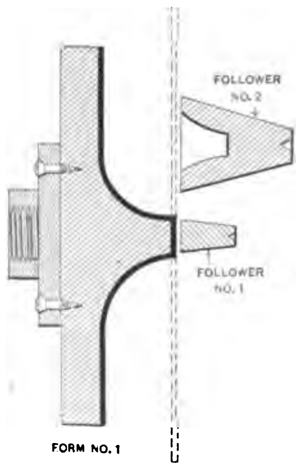


Fig. 14

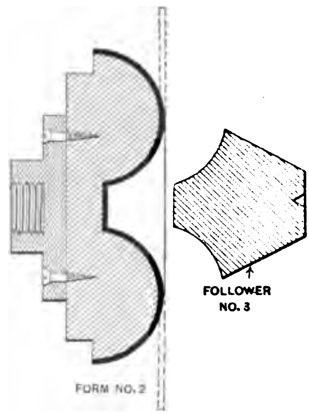


Fig. 15

While the operation of spinning is a comparatively simple one to describe, it is not easily learned, and to-day good all-around spinners are hard to find. The limits of accuracy are not as closely defined as in straight machine work, but there are times when good fits are absolutely necessary, as in cases where two shells must slip snugly together. In this chapter we have taken up only the plain every-day kind of spinning, and were we to follow its work in the gold and silversmith's trade, we would see it evolve into a fine art. In order to insure really good work coming from the spinning lathe, there is a wide range of knowledge that the spinner must have. That knowledge may be brought together and summed up by a single word—*judgment*.

CHAPTER II

TOOLS AND METHODS USED IN METAL SPINNING*

The principal object of this chapter is to describe in detail the various operations of spinning metal so that a tool-maker or machinist who has not access to a metal spinner, will be able to make his own tools, rig up an engine or speed lathe, and make the simple forms or models that are required in experimental work. To do this intelligently, it is necessary to follow in detail every step in metal spinning from the circular blank to annealing, pickling, dipping, burnishing, etc., and also to know how to make the simpler forms of spinning tools, what lubricants to use on the different kinds of metals, what material to make the spinning chuck of, and how far the metal can be worked before annealing.

Spinning metal into complicated and elaborate shapes, is an art fully as difficult as any craft, and the man is truly an artist that can make artistic and graceful outlines in metal, especially when only a few pieces are required and the cost will not allow of making special chucks to do the work on and with no outline chucks to govern his design, the forms being made by skill and manipulation of tools alone. Such skill is far superior to that of the Russian metal worker, who, instead of making a vase or ornament of one piece, cuts up several sections and soft solders them together, after covering them with crude "gingerbread" work to disguise his poor metal work.

The amateur can imitate the Russian work, but never the work of the skilled spinner. There are several grades of spinners, most of them never attaining the skill of the model-maker or the facility for handling the different metals. A man that has had several years of experience spinning brass or copper would not be able to spin britannia or white metal without stretching it to a very uneven thickness. As brass or copper is harder than the other metals mentioned, they resist the tool more and require more pressure in forming, and if the operator used the same pressure on the softer metals, he would stretch or distort them, so that they would be perhaps one-quarter of the original thickness at angles and corners where the strain in spinning would be greatest, which would ruin the articles. The best test for skill in ordinary spinning, is to take a long difficult shape, after being finished, and saw it in two lengthwise, and if the variation in thickness is less than 25 per cent of the original gage, it is good practice. Some spinners can keep within 10 per cent of the gage on ordinary work, but they are scarce.

The spinning trade in this country is mostly followed by foreigners, Germans and Swedes being the best. The American that has intelli-

* MACHINERY, March and April, 1910.

gence and skill enough to be a first class spinner, will generally look around for something easier about the time that he has the trade acquired. It is an occupation that cannot be followed up in old age, as it is too strenuous, the operator being on his feet constantly, and having to use his head as well as his muscles.

General Remarks on Metal Spinning Chucks

For common plain shapes, a patternmaker's faceplate, with a tapered center screw, is sufficient for holding the wood chuck. The hole in the wood should be the same taper as the screw, thus giving an even grip on the thread. If a straight hole only is used, and it is not reamed out before screwing to the plate, it will only have a bearing on one or two threads, and if the chuck is taken off and replaced on the faceplate, it will not run true. Care should also be taken to face off the end of the chuck flat, or to slightly recess it, so that it will screw up evenly against the faceplate, as a high center will cause it to rock and run out of true.

In large chucks (over five inches) it is best to have three or four wood screws, besides the center screw. The holes for these can be spaced off accurately on a circle in the iron faceplate, and drilled and countersunk. It is best to have twice as many holes as screws; that is, if four screws are used there should be eight holes, so that if the chuck has to be replaced at any time and the wood has shrunk, it can be turned one eighth of a revolution further than the original chucking.

Where a chuck has to be used several times, it is better practice to cut a thread in the wood and screw the chuck directly to the spindle of a lathe, not using the faceplate. This thread can be chased with a regular chasing tool, where the operator has the skill, or if not, the wood can be bored out and a special wood tap used. Such a tap has no flutes and it is bored hollow, there being a wall about 3/16 inch thick. One tooth does all the cutting, that is the one at the end of the thread. The chips go into the hollow part of the tap. The end of the tap for about ¼ inch should have the same diameter as the hole before threading to act as guide for the cutting tooth.

It is essential that a chuck should run very true and be balanced perfectly, as the high speed at which it runs will cause it to vibrate and run out of true, causing the finished metal to show chatter marks. The best wood for chucks is hard maple, and it should be selected for its even grain and absence of checks and cracks. It is best to paint the ends with paraffine or red lead, or to immerse the chucks in some vegetable oil after turning. Cottonseed oil is very good for this purpose, but care should be taken not to soak the chucks too long.

For a man not skilled in spinning, it is better to use metal chucks than wood, for if there are many shells of a kind, the operator is liable to bear too hard on the tool, thus compressing the chuck and making the last shells smaller than the first. Corners and angles not well supported might also be knocked off. The writer prefers cold rolled steel for chucks up to 6 inches in diameter and cast iron for the larger ones, but where good steel castings can be obtained, a good chuck can be made by turning roughly to shape a wood pattern, allowing enough for shrinkage and finishing, and hollowing out the back to lighten it. When the chuck is finished all over in the lathe, it should balance much better than a cast iron one, as there are not the chances of having blow holes in the iron, thus throwing the chuck out of balance.

Annealing

The distance that metal can be drawn without annealing, can only be learned by experience. A flat blank rotated in the lathe, being soft, will offer little resistance and it can be gradually drawn down by a tool held under the chuck and against the blank. This tool is pushed from the center outward and forward at the same time, and every time it passes over the blank or disk the metal becomes harder by friction, and the change of formation and the resistance at the point of the tool greater. This can be felt as the tool is under the operator's arm. When the spring of the metal is such that the tool does not gain any, but only hardens the metal, the shell should be taken off and annealed. If the metal has been under a severe strain, it should be hammered on the horn of an anvil or any metal piece that will support the inside. The hammer should be a wood or rawhide mallet, but never metal, the object being to put dents or flutes in the metal to relieve the strain when heating for annealing; if this is not done the shell will crack.

After annealing the shell it should be pickled to clean the oxide or scale from the surface; otherwise the metal will be pitted. When the scale is crowded into the metal and when it will not finish smooth after spinning to shape, the metal can be finished by skimming or shaving the outer surface which cuts out all tool marks; it can then be finished with medium emery cloth or the shell can be bright dipped, and be run over with a burnishing tool before buffing. Burnishing can be done on the spinning chuck, but the speed should be higher than for spinning; this requires some skill for a good job, and it can be done only on metal chucks.

Annealing is best accomplished in a wood or gas oven, where a forge fire is used. The metal should never touch the coke or other fuel, but it should be held in the flame above the fire. Where only part annealing is required, the shell can be immersed in water, the part to be annealed being exposed above the water, and a blowpipe used on it. The remainder of the shell will then be hard. This way of annealing is sometimes necessary on a special shapes.

Brass should be heated to a cherry red, and held at that point for a few minutes, in a muffle furnace. If an open furnace is used, just bring the metal to a cherry red and then dip it in water; this method is better than when waiting for it to cool, the action being just the opposite to that on steel. Brass such as the common yellow brass is not suitable for spinning, there being but 55 per cent copper and 45 per cent zinc. There are two grades of brass suitable for spinning. These are known as "spinning and drawing," having 60 per cent copper and 40 per cent zinc, and "extra spinning and drawing" having 67 per cent copper and 33 per cent zinc. There is also a better grade known as "low brass" having from 75 to 80 per cent copper; it has the color of bronze and is only used on very deep and difficult spinning.

The scale, after annealing, should be pickled off in an acid bath (described further on in this chapter), and the part thoroughly washed in running water. Brass, German silver and the harder metals should be hammered before annealing; it is not necessary to hammer zinc, copper, aluminum, etc.

A pyrometer in an annealing furnace would be an advantage where quantities of the softer metals such as zinc, aluminum, etc., are being heated. Copper is annealed the same as brass and is also pickled. Zinc is coated with oil before being put in the oven, and when the oil

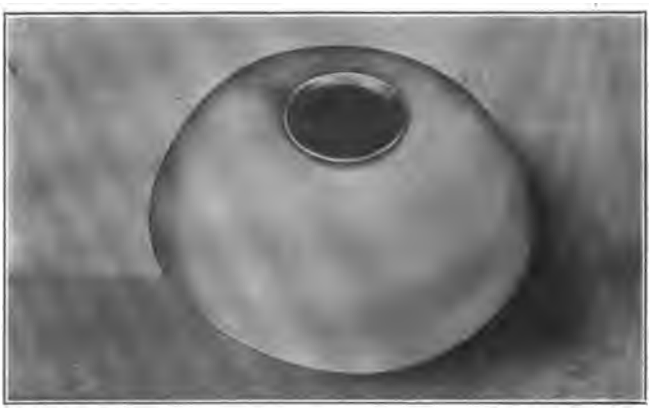


Fig. 16. Zinc Lamp Shade Spun in One Operation without Annealing

turns brown, which occurs when the temperature is about 350 degrees, the metal is ready to take out; it should then be plunged in water to shed the scale, but not pickled. The melting point of zinc is 780 degrees F. Aluminum can be annealed the same as zinc, as the melting point is 1,140 degrees F.

Steel should be annealed by heating to a cherry red and then allowing it to cool slowly; it should be scaled in a special pickle, thoroughly washed, and then put back in the fire long enough to evaporate every particle of acid that may have remained from the pickling operation. Any acid remaining on the steel will neutralize any lubricant that is applied when spinning. Annealing should be avoided wherever possible. Open hearth steel only should be used. It should be free from scale and preferably cold rolled. Bessemer steel is not suitable, except for very shallow spinnings. Tin plate made from open hearth steel can be spun about one-half as deep as its diameter where the shape is not too irregular. German silver is difficult to spin, especially when it contains over 15 per cent nickel; it has to be hammered before annealing, the same as brass, to avoid cracks.

Lubricants

Common yellow soap cut up in strips about ½ inch or ¾ inch square is a good lubricant for spinning most metals. It should be applied evenly to the disk or blank while it is revolving, by holding the soap in the hand and drawing it across the surface. Beeswax is the best for spinning steel, but it is expensive. Lard oil mixed with white lead is a fair substitute. Either mutton or beef tallow applied with a cloth swab is very good on most all metals; also vaseline and graphite mixed to a paste and applied the same as tallow.

Examples of Spinning Various Metals

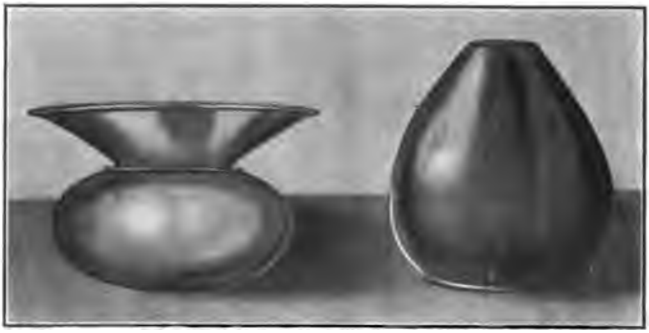
The different metals are malleable, ductile and tenacious in the following order; white metal or britannia, aluminum, zinc, copper, low brass, high brass, German silver, steel, tin plate. White metal does not harden in spinning, but it requires special skill in handling,

Fig. 17. Gas Burner for Heating Spinning Chuck

or the metal will be of very uneven gage. The best metal for an amateur to start on is copper, as it is both tenacious and ductile, and will stand much abuse in the fire and on the lathe. One of the peculiar properties of zinc is that it has a grain or texture, and when spinning, the two sides that went through the rolls lengthwise will be longer than the sides that have the cross grain, requiring the shell to be trimmed off quite a distance to even the edge.

To show the possibilities of working the different metals, and their relative spinning values, a number of articles made from different materials are illustrated herewith.

A zinc lamp shade is shown in Fig. 16 that is 14¼ inches in diameter and 4¾ inches deep. This shade was spun in one operation, without annealing, from a flat circular blank. All zinc should be warmed before spinning, either over a gas burner at the lathe or in hot soap water, and the chuck also should be heated, as otherwise the blank will soon chill, if spun on a cold metal chuck, as the chuck absorbs the heat long before the operation is finished. Of course this does not apply to wooden chucks. The chuck may be heated by using the burner shown in Fig. 17, which is located around the spindle of the lathe. The size of the burner should, of course, be in proportion to that of the chuck used. The burner illustrated is 8 inches in diameter. It has several small holes drilled for the gas on the side facing the chuck. The heat of the chuck is regulated by varying the supply of gas to the burner. The blank is heated before it is put on the



Figs. 18 and 19. Examples of Aluminum and Copper Spinning

chuck and the friction of the spinning tool helps to keep it warm until it comes in contact with the chuck. The metal retains its heat until the job is finished, and this sometimes saves an annealing operation.

In Fig 18 is shown an example of aluminum spinning. The article illustrated is a cuspidor having a top 7¾ inches in diameter, a neck with a 4-inch flare, a diameter at the top of 9½ inches, and a height

Fig. 20. German Silver Reflector

Fig. 21. Open Hearth Cold-rolled Steel Shell

of 6½ inches. This shell was spun without annealing, which shows the extreme ductility of aluminum. The copper shell shown in Fig. 19, has a maximum diameter of 7 inches, and a depth of 8 inches; it was spun with four annealings. A German silver reflector, which is 10 inches in diameter at the largest end and 5 inches deep, is shown in Fig. 20. The spinning of such a reflector, when made from this material, is quite difficult. An open hearth cold-rolled steel shell with a maximum diameter of 3 inches and a depth of 4 inches is shown in Fig. 21. This shell was spun without annealing, which shows that the grade of steel used is well adapted for this work.

In Fig. 22 two finished brass shells are shown to the right, and also the number of operations required to change the form of the metal. The upper shell is 6 inches long and 3½ inches in diameter at the

Fig. 22. Various Steps in Spinning the Two Brass Shells at the Right

large end, while the lower one is 7¼ inches long by 3¾ inches in diameter. It was necessary to anneal these shells between each operation, the upper shell being annealed four times and the lower one three times. These pieces were made in quantities sufficient to warrant the making of chucks for each operation, which enabled them to be spun with less skill than would be required if a finishing chuck

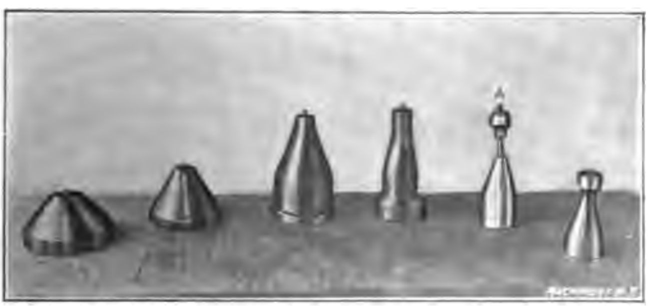


Fig. 23. Another Brass Spinning Operation; the Chuck used is shown at A

only were made. When a single finishing chuck is used, the various operations in spinning a shell of this kind would be left to the judgment of the spinner, who would decide the limit of the stretch of metal between the operations before annealing.

A brass shell that is made in five operations and with four annealings is shown in Fig. 23. The finishing chuck used is a split or key chuck on which it is necessary to cut out the end of the shell in order to withdraw the key after the shell is spun. This shell, which is shown finished to the right, is 5½ inches long. It is spun smooth on a machine steel chuck, and is not skimmed, but gone over with a planishing tool at the last operation. The two pieces shown in Fig. 22 were also finished in this way.

Fig. 24. An Example of "Air Spinning" and the Chucks used

Fig. 24 shows a brass shell, which is a good example of "air spinning," so called because the finishing or second operation on part of the shape is done in the air, thus avoiding the use of a sectional or split chuck. The shell shown is about 5½ inches in diameter. The first or breaking-down chuck is shown at *A*. The neck or small part

Fig. 25. Miscellaneous Collection of Spinning Chucks

of the piece, and also a portion of the spherical surface, is formed by the spinning tool without any support from the chuck. After the shell is spun or broken down on chuck *A*, it is annealed and pickled. It is then put back on chuck *A* and planished or hardened on the part that is to retain its present shape. The work is then placed on the chuck *B* and the soft part is manipulated by the tool until it conforms to the shape shown to the right. While this soft part of the metal is being formed, the part which was previously hardened retains its shape.

Various Types of Metal-spinning Chucks and their Construction

A miscellaneous collection of spinning chucks is shown in Fig. 25. As will be seen, the larger ones are machined out in the back to lighten them, and also to give them an even balance. The larger of those illustrated measure about 9½ inches in diameter, and they are made of cast iron, while the smaller chucks shown in this view are of machine steel. The chuck marked *A* is a key chuck. Another collection of spinning chucks of various shapes is shown in Fig. 26.

Fig. 26. Another Group of Spinning Chucks. Those in the Upper Row are of the Split or Key Type

Those in the upper row are all key or split chucks, and the keys are shown withdrawn from the sockets. All these chucks, up to 6 inches in diameter, are made of machine steel; those seen in the lower row are shapes which are comparatively easy to spin.

A collection of hard maple chucks is shown in Fig. 27, some of which represent shapes that are difficult to spin. The chuck *A* is 15 inches long, and the maximum diameter of *B* is 12½ inches. These figures will serve to give an idea of the proportions of the other chucks. All of the chucks shown have threads cut in them and they are screwed directly to the spindle of the lathe, the faceplate being dispensed with. Some of the larger wooden chucks used measure approximately 5 feet in diameter. A chuck of this size is built up of sections which are glued together.

A number of bronze sectional split chucks are shown in Fig. 28. When spinning over a sectional chuck, it is first necessary to break down the shell as far as is practicable on a solid chuck. Care should be taken, however, to leave sufficient clearance so that the work may be withdrawn. The shell is then annealed, after which it is put on the sectional chuck and the under cut or small end is spun down to the chuck surface. When the entire surface of the shell is spun down to a bearing, the shell is planished or skimmed to a smooth surface;

Fig. 27. Various Forms of Spinning Chucks made from Hard Maple

Fig. 28. A Group of Bronze Sectional Chucks

the open edge is also trimmed even and the shell is polished with emery cloth.

A large bronze chuck of seven sections, one of which is a key section, is shown at *A*. The largest diameter of this chuck is 10 inches. It has a cast iron center hub and a steel cap at the top for holding the sections in place. This cap, when in place in the retaining groove shown, is flush with the top of the chuck. Another large chuck having five sections and one key section is shown at *B*. The retaining cap in this case is of a different form. The lower parts of the sections of all these chucks fit in a groove at the bottom of the hub. A chuck of five sections that is without a binding cap, is shown at *C*. This is not a good design as the hub or center is too straight, and all of the grip or drive is from the bottom groove, which is not sufficient. The shape shown at *D* is more difficult to spin than any of the others, as it is smaller at the opening in proportion to its size. This chuck also requires more sections in order that it may be withdrawn from the shell after the latter is spun. The chuck *E* is intended for a small shell that is also difficult to spin. The drive pins which prevent the segments of the chuck *E* from turning may be seen projecting from its base. The centering pins at the outer end of chucks *D* and *E* and

Fig. 29. Sectional Chucks made from Wood

the binding caps may also be seen. The chuck *A*, because of its size, is hollowed out to reduce the weight. All of these chucks were made for hard service, and they have been used in spinning thousands of shells.

Another group of sectional chucks is shown in Fig. 29. They are mostly made from hard maple. The sections of chuck *A* are planed and fitted together and thin pieces of paper are glued to these sections before they are glued collectively for turning. By using the paper between the joints, the sections may be easily separated after they are turned to the proper size and form. If the different sections were glued without paper between them, the joint formed would be so good that the separation of the sections could not be controlled, and parts from opposite sections would be torn away. The use of the paper, however, between the glued joints, controls the separation of the sections. The chuck shown at *D* is also made with the paper between the sections. Chucks *B* and *E* are turned from the solid, care being taken to have the grain of the wood lengthwise. After they are turned to the required form, they are split into sections with a sharp chisel. Before doing this, the key section should first be laid out. There should be as few sections as possible, the number being just sufficient to enable the withdrawing of the chuck from the shell after the latter is spun to shape. This method of making a chuck, while quicker than the other, is not good practice, except for small work.

A lignum vitæ chuck is shown at *A* in Fig. 30; this was made with paper between the sections. The key-section is shown on top. This wood, while being more durable than hard maple, costs sixteen cents a pound in the rough and, counting the waste material, is not any cheaper than bronze, and is less durable. The hard maple chucks *B* and *C* were turned from the solid, after which the sections were split. The segments shown in the center of the illustration did not split evenly, owing to a winding or twisting grain.

Fig. 30. Other Examples of Wooden Sectional Chucks

The construction of a sectional spinning chuck is shown in Fig. 31. This illustration also shows the proper proportion for the central hub and its taper. This hub should never be straight, but should have from 5 to 7½ degrees taper on the central part. There should also be a taper of 1½ degree on the other binding surfaces as indicated. These parts are made tapering so that the shell can be released from the lathe after spinning, without hammering or driving; when straight surfaces are used the work has to be pried off, and it is also harder to set up the sections for the next shell. Another disadvantage is that with straight fittings the wear cannot be taken up. An end cap or binder should be used wherever possible as it steadies the chuck. A drive pin should also be used and the hole for it drilled in the largest section; this is important, as it gives the sections a more positive drive. If they slip they will soon wear themselves loose and leave openings at the joints.

The plan view shows the method of laying out the various sections. The key should be laid out first. One key is enough for the particular form of chuck illustrated, but it is often necessary to use two key sections when the shell opening is small.

When a sectional chuck is to be made, it is important to decide first on the size of the central hub *A*, the number of sections *C*, and also the design of the cap or binder *B*. This cap must not exceed in size the opening in the finished shell, as it would be impossible to remove it after the chuck sections were taken out. After the size of the hub *A* has been decided upon, a wooden form should be turned that is a duplicate of *A*, except that a spherical surface *E* should be added. This spherical part should be slightly smaller than the inner diameter of the bronze sections in order to allow for machining them. In turning this wooden pattern on which the plaster patterns for the sections are to be formed, the shoulder *D* should be omitted, as a removable metal ring will take its place.

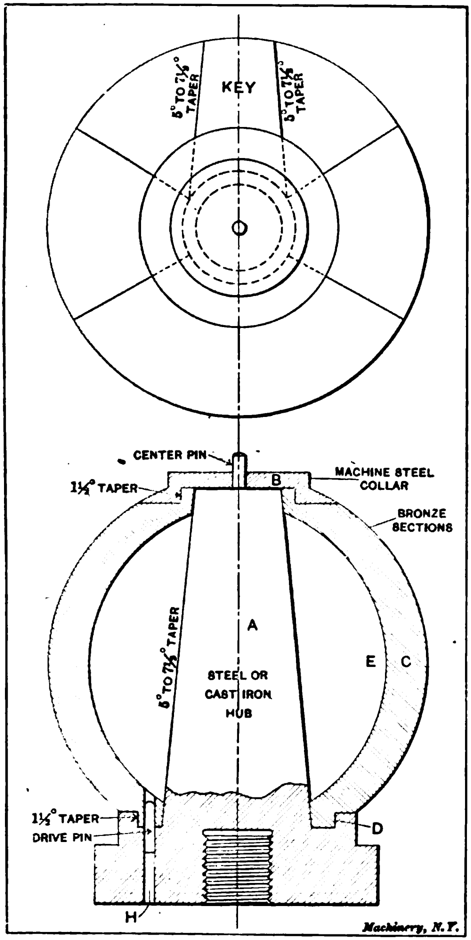


Fig. 31. Elevation and Plan showing Construction of Sectional Chuck

When the wooden hub is ready, two metal partitions or templets of the same outline as the chuck, though about one-half inch larger than its total diameter, for shrinkage and finishing, are fastened to the hub in the correct position for making a plaster pattern for the key section. These patterns should have extension ends so that the sections when cast may be held by them while they are being turned. The templets should be banked around with a wad of clay, and they should also be coated on the inside with sperm oil to keep the plaster from sticking. There should be two brads driven in the hub for each section of plaster to hold the sections in place while they are being turned. After the plaster for the key section has hardened, the templets should be located one on each side of the key section, so that the two adjacent sections may be made. In this way all the sections are finished. After about forty-eight hours the plaster will be hard enough to turn in the lathe with a hand tool. The form should be roughly outlined and plenty of stock left for shrinkage, as bronze shrinks considerably. Before taking the sections off the wooden frame, the metal band *D* should be removed to allow the sections to be separated. This should not be done, however, until they are numbered, so that they can be again placed in their proper positions. After the sections are cast, they should be surfaced on a disk grinder, or finished with a file, care being taken to remove as little metal as possible. Each section is next tinned on both contact faces, and then

Fig. 32. A Modern Spinning Lathe

all are assembled and sweated or soldered together by a blow-pipe. It is sometimes necessary to put a couple of strong metal bands around the sections to hold them firmly in place when soldering and also to support them during the turning operation.

The central hub *A* should be machined first; then the assembled outside shell should be machined to fit the hub *A*, both on the taper part and at the point *D*. While the segments are being bored and faced, they are held by the extension ends (not shown) which were provided for this purpose. This outer shell should also be machined all over the inside so that it will be in balance. It is then taken out of the chuck and a hole is drilled in the largest section for drive pin *H*. The hub *A* is then caught in the lathe chuck with the assembled sections on it, and a seat is turned for the cap *B*. After this is done the binder bands can be removed, but not before. The chuck can be finished with a hand tool and file after the roughing cut is taken. After the sections are removed from the hub and numbered at the bottom or inner ends, they can be separated by heating them. If the joints are properly fitted there will be only a thin film of solder, which can be wiped off when hot.

A twenty-four-inch metal spinning lathe that is rigged up in a modern way, is shown in Fig. 32. The hand wheel of the tailstock has been discarded for the lever *A*, which is more rapid and can be manipulated without stopping the lathe. This lathe has a roller bearing for the center *B* which is a practical improvement over types previously used. The pin *C*, which is used in the rest as a fulcrum for the spinning tools, is also an improvement, being larger than those ordinarily used. It is ¾ inch in diameter, 6 inches long, and it has

Fig. 33. View showing how the Tool is held when Spinning

a reduced end for the holes in the rest, ⅝ inch in diameter by 1 inch long. This pin is large enough so that the spinner can conveniently hold it with his left hand when necessary, and it can also be rapidly changed to different holes. The pins ordinarily used, because of their small size, do not have these advantages. The speed of a spinning lathe having a five-step cone should be about 2,250 to 2,300 revolutions per minute with the belt on the smallest step, and from 600 to 700 revolutions per minute with the belt on the largest step. The fastest speed given is suitable for all work under 5 inches in diameter, and the slowest for work within the capacity of the lathe. On large shells it is sometimes necessary to change from one speed to another as the work progresses. Figs. 33 and 34. show the spinner at work, and illustrate how the tool should be held, and also the proper position of the left hand.

Construction of the Tailstock and Back-center

Fig. 35 shows a spinning-lathe tailstock, which has been changed from the hand-wheel-and-screw type to one having a lever and a roller bearing. The spindle *A* which is withdrawn from the lever and turned one-quarter of a revolution to give a better view of the rollers, is made from 1¾-inch cold rolled steel. The rollers against which the center bears do not project beyond the spindle, so that the latter can be withdrawn through the tailstock. This eliminates the excessive overhang caused by ball bearings and other centers. When the center projects too far, the tailstock cannot be set close to the work, owing to the necessity of withdrawing the center when removing the

Fig. 34. Another View showing the Position of the Spinner and the Way the Tool is held when forming the Metal

spun part. The application of this principle to a spinning lathe is original and the type of center illustrated was used only after all other kinds had failed, including all the types of ball bearings and revolving pins. The best forms of ball bearing centers do not last over a year, if in constant use, and they will not always revolve on small work. Two other spindles are shown in this engraving, which were taken from other lathes in order to show different views of the parts. The cylindrical pieces *B* are the hardened friction rollers which belong in the slot of the spindle *F*, and *C* is the hardened pin upon which they revolve. The hardened center *D* has a threaded end on which the back-centers *E* of different lengths and shapes are screwed. The friction rollers should always be in a vertical position, and care should be taken to have them exactly central with the spindle.

and also gives the principal dimensions of a roller bearing for a 1¾-inch spindle. *A* is a hardened steel bushing, which is driven into the machine steel spindle. The parts *B* are the hardened steel rollers which travel in opposite directions. These rollers have a small amount of friction, and this is distributed over a large area. A spindle revolv-

Fig. 35. Detailed View of a Spinning-lathe Tailstock

ing at 2,300 revolutions per minute will not cause these rollers to rotate very rapidly, while a ball bearing with balls traveling in a channel 1½ inch or 2 inches in diameter would be traveling at the same speed as the driving spindle. They also wear out rapidly as the end strain is very great, it being necessary to force the center against

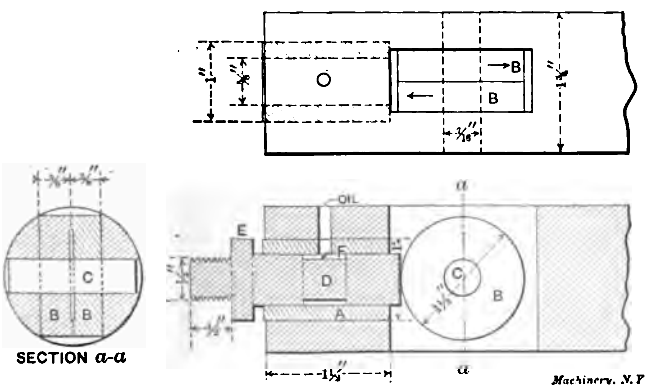


Fig. 36. Sectional View showing the Back-center and its Double Roller Bearing

the metal with considerable pressure to keep it from slipping. *C* is the hardened pin upon which the rollers revolve, and *D* is the hardened spindle on which the various back-centers are screwed. The collar *E* should either be flattened for a wrench, or a 5/16-inch hole, in which a wire can be inserted, should be drilled through the spindle, so that it can be kept from rotating when screwing on the back-centers. Some spinners prefer the spindle loose, so that it can be withdrawn when changing the centers, while others prefer one with considerable lateral motion, but not enough to permit of withdrawal. By inserting a screw-point in the recess *F*, the center has considerable lateral motion, but not enough to allow it to be withdrawn. This recess is useful in that it helps to distribute the oil. All parts should be hardened and drawn to a light straw color; they should also be ground or lapped to a true fit after hardening. Back-centers of this construction

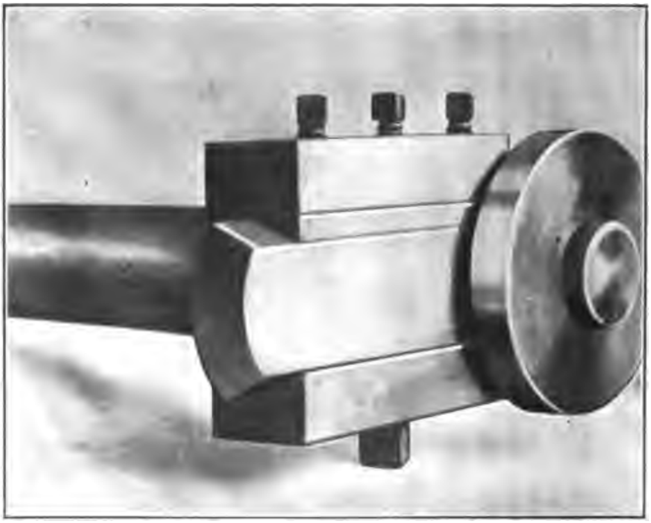


Fig. 37. Attachment used for Rolling Sharp Turns and Beads

have been in use for over three years in one establishment, and it has not been necessary to replace a single part.

Tools Used in Metal Spinning

Fig. 37 shows an attachment which is used to roll any bead or form. This tool, when in use, is inserted in the tailstock spindle in place of the regular center. It is adjustable for any diameter. The roll illustrated is for making a sharp turn, but rounds and other forms are used. The shell being spun by this tool should be held on a hollow chuck. The roll is set at a point where the metal is to be turned over, and by its use the curve may be governed and made uniform with less skill than when the work is done by "air spinning." In addition, the spinning may be done in less time. This attachment, for some shapes, makes the use of sectional chucks unnecessary.

Fig. 38 shows several spinning tools, the heads of which were turned in the lathe instead of being forged. This method of making spinning tools is believed to be original. The spinners prefer them to the tools which are forged in one piece, because the heads which are screwed to the shanks are made of the best quality of steel, such as the high-speed or self-hardening steel. The shapes are also better and the surfaces more true. The heads of these tools are all threaded with standard ¼-inch, ⅜-inch and ½-inch pipe taps, according to the size. Obviously, a spinner can have as many different shaped heads as may be required of each of the sizes given, and only one handle.

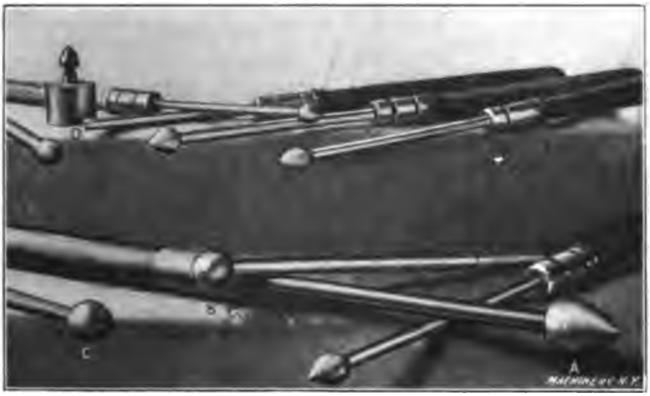


Fig. 38. Metal Spinning Tools with High-speed Steel Removable Heads

The tapering threads in these heads insure that they will always screw on the shanks tightly no matter how often they may be replaced. The ¼-inch size takes a ½-inch cold rolled holder; the ⅜-inch, a ⅝-inch holder, and the ½-inch, a ¾-inch holder. These will be found large enough for the heaviest work. The egg-shaped tool *A* is a good

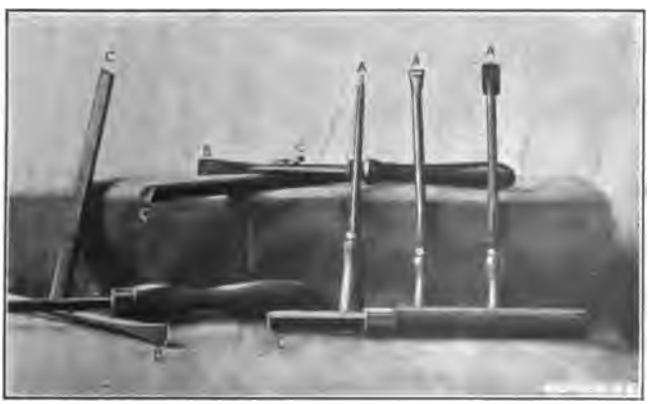


Fig. 39. Tools used for Trimming and Skimming Spun Work

form for roughing or breaking down, as it has plenty of clearance on the heel, and a blunt point that will not tear the metal. This tool is shown in four sizes. The ball or spherical tool *B* is a good one to to use on curves and large sweeps. The tool *C* is elliptic, and is slightly different from *A*, as it has a blunter point. One of these heads is shown at *D* screwed onto a reducer by which it is held in the lathe chuck while being turned. These heads or points can also be turned while on the handle by using a steady rest.

Fig. 40. A Group of Spinning Tools of Various Shapes

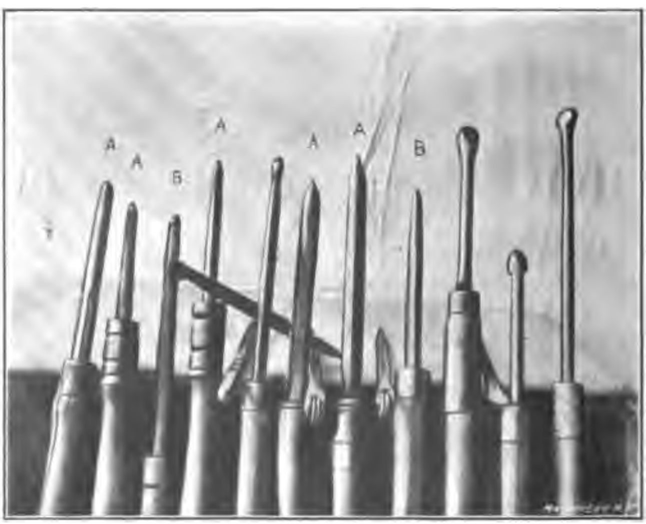


Fig. 41. Another Group of Spinning Tools

A group of trimmers, skimmers and edgers is shown in Fig. 39. Three skimmers of the built-up type are illustrated, the shanks being of machine steel and the blades being riveted to the holders. These blades are made of either high-speed or regular steel. Skimmers which are forged in the regular way from one piece of steel, are shown at *B*. A number of edgers *C*, which are made of high-speed or self-hardening steel, are also illustrated. These tools are used without handles until they are worn down short, after which tangs are forged on their ends and they are used in handles. Edgers are utilized on all kinds of work for trimming the ends of the shells. The skimmer is seldom used on metal chucks, but mostly in connection with wooden chucks, where the metal cannot be smoothed down with a planisher. The skimmer is run over the metal lightly, taking a thin shaving and smoothing the uneven surfaces. It requires con-

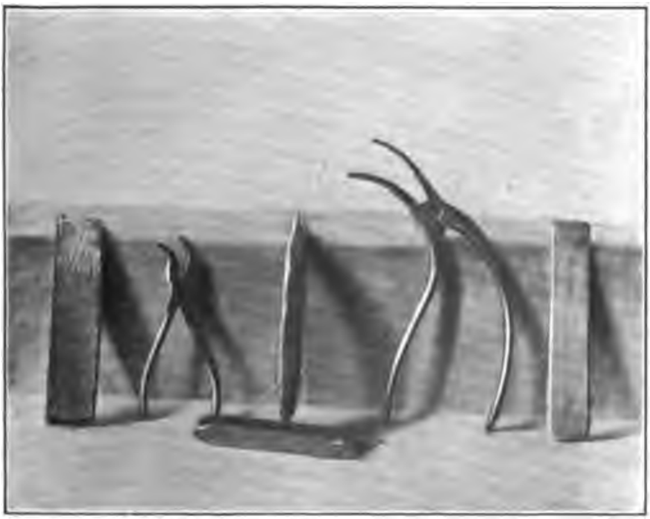


Fig. 42. Spinners' Pliers which are used for turning the Edge of the Metal when making a Large Bend

siderable skill to use this tool without wasting the metal. The surface of the work is finished with emery cloth after skimming.

Figs. 40 and 41 show a number of spinning tools of various shapes. The letters *A* indicate the breaking-down or round-nosed tools of different sizes. This type of tool, which is finished smooth and has a blunt point, is used for forming corners and sharp angles, and it is the tool most commonly used by spinners. The planishers and burnishers *B* are used on all convex surfaces and for finishing on metal chucks where there is to be no skimming done. The tools *C* are known as hook or poker tools, and they are used to turn up beads or curves from the inside of the shell. The holders having rollers are used for turning over beads, the metal first being trimmed and turned to a vertical position. The other shapes shown are irregular tools for special work and they are not in daily use.

Two pairs of spinners' pliers for turning over the edge of the metal when making large curves are shown in Fig. 42. The wedge-shaped pieces shown in this illustration are used when breaking down or roughing shells to give a bearing to the metal in order to prevent it from wrinkling or buckling when changing its formation. These pieces are made of hard wood with the exception of the one to the right, which is of steel. When one of these pieces is in use it is held in the left hand at a point directly opposite the spinning tool, the metal being between the two. Wood is preferable in most cases, as it does not harden the metal blank.

The tools shown in Fig. 43 are used in spinning steel. The round tools are of drawn brass, and they can be used where the steel tools

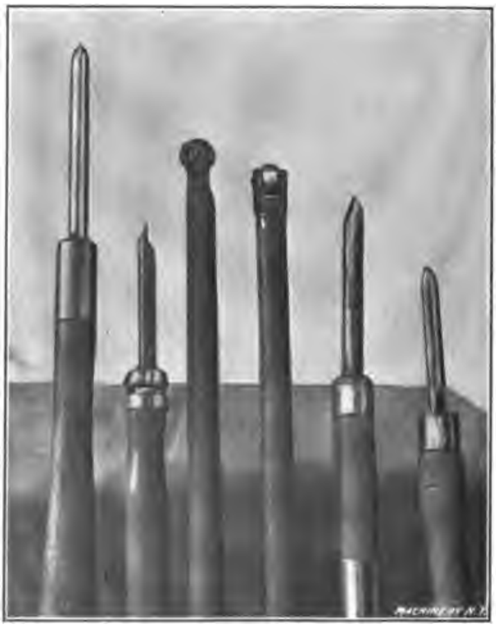


Fig. 43. Some Spinning Tools used in Working Steel

cannot, for while a steel tool is perfection on brass, a brass tool is the only thing on steel. It wears out, however, much more rapidly than one of steel. The rolls shown in the center are used for breaking down steel shells. These tools are hardened and have hardened roller bearings. The handles are made of one-inch iron pipe, which is filled with lead to give weight and strength.

Hard wood tools that are used for breaking down large thin copper blanks ranging from 2 to 5 feet in diameter are shown in Fig. 44. These tools are also used where the surface that the tool will cover without hardening the metal is important. Blanks which are broken down with these tools are finished with the regular types.

The handles of spinning tools vary in diameter from 1¼ to 1¾ inch, and in length from 16 inches to 20 inches. The tools should project from the handles from 9 to 18 inches, and the total length of the tool and handle should average from 30 to 34 inches.

A group of wood working tools is shown in Fig. 45. These tools are of the type commonly used by spinners for turning the various shapes of wooden spinning chucks. As the tools illustrated are the kind regularly used for wood turning by patternmakers and other wood-workers generally, they will need no description.

Preparation of the Metal

Brass, copper, and German silver should be pickled after annealing in order to get the scale or oxide from the surface. There are furnaces

Fig. 44. Wooden Tools which are used on Large Thin Copper Blanks

that anneal without scaling by excluding the air when heating, but they are not in general use. A pickling bath may be made by using one part of oil of vitriol (sulphuric acid) and five parts of water. The shells can be put in hot, or the bath can be heated by a coil of lead or copper pipe running through it. Steam in no case should enter the bath, as the iron in the feed pipe will spoil the pickle. Any basket or box that may be used to hold the shells in the pickle should not contain any iron. If a box is used it should be held together with copper nails. The pickle can be used cold, but it will take a little longer time to remove the scale. As soon as the scale is free, which will be in about half an hour, the shells should be removed or washed thoroughly in running water. The shells should be allowed to dry before the next operation, which is that of spinning. A lead-lined wooden tank or an earthen jar may be used for holding the pickle. The pickle which is used for steel should be about half as strong as that employed for brass. After the work is in this pickle, the latter should be brought to the boiling point, after which the pieces should

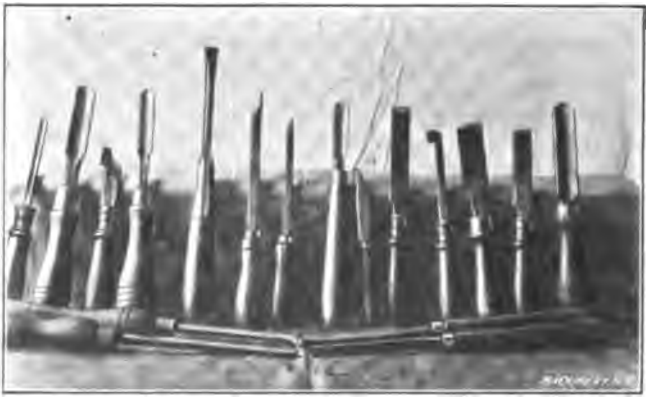


Fig. 45. Wood-turning Tools which are used in turning Spinning Chucks

be taken out and washed. They are then replaced in the fire for a short time to evaporate any acid that may remain after washing.

Finished brass articles may be given different shades by dipping them in a solution consisting of one part aqua fortis (nitric acid) and two parts oil of vitriol. This solution should stand seven or eight hours to cool after mixing, and be kept in a crock immersed in a water bath.

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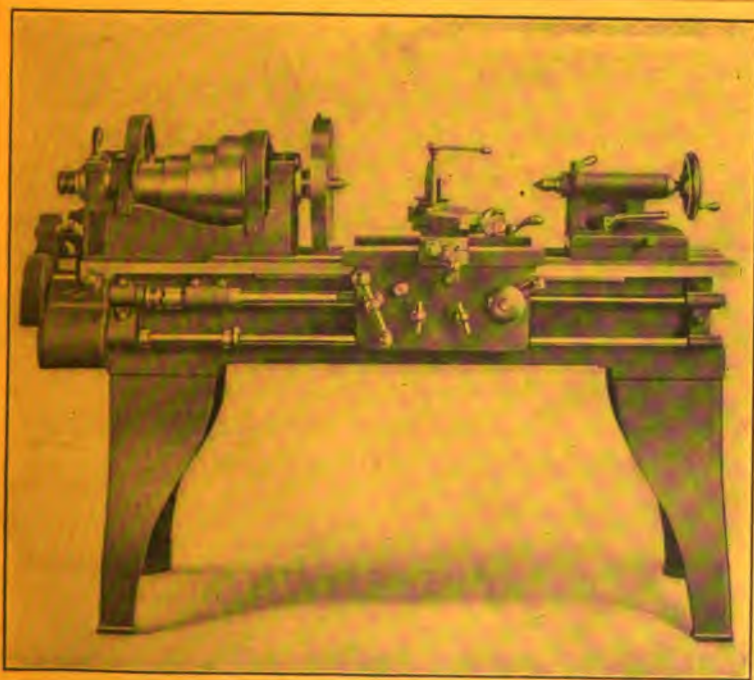

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OPERATION OF MACHINE TOOLS

By FRANKLIN D. JONES

SECOND EDITION

THE LATHE

PART I

CONTENTS

INTRODUCTION

MACHINERY'S Reference Book, No. 91, is the first of a series containing, in condensed form, information on the operation of various types of machine tools. The first two books (Nos. 91 and 92) are descriptive of lathe work, and the succeeding numbers deal with machines of other types, such as the planer, shaper, drill-press, horizontal and vertical boring machines, milling machine, and grinder. In each case, a tool of typical design has been selected, and the important points connected with its operation and use have been considered. The method of setting up a Brown & Sharpe automatic screw machine, with a detailed description of its operation, is also given in this series. In the operation or manipulation of machine tools, as well as in other branches of machine construction, there are many things which are learned more easily by experience than in any other way; in fact, it would be impossible by a written explanation to convey more than a crude idea regarding many methods connected with shop practice. Therefore, in this series, no attempt has been made to cover every phase of machine work, but we have endeavored to explain the more important features connected with the use of standard machine tools. The various methods referred to are not, in every case, given as the best from a standpoint of accuracy, nor has the time element always been considered, but an effort has been made, instead, to select simple methods and examples which would clearly illustrate the principles involved. As the variety of machine tools now in use is extensive, and as different types can often be employed for the same kind of work, it might be well, in the beginning, to call attention to the fact that the best type of tool to use for machining a given class of work frequently depends on circumstances. To illustrate, a certain part might be turned in a lathe, which could be finished in some form of automatic or semi-automatic turning machine much more quickly. It does not necessarily follow, however, that the automatic is the best machine to use; because the lathe is designed for general work and the part referred to could doubtless be turned with the regular lathe equipment, whereas the automatic machine would require special tools and it would also need to be carefully adjusted. Therefore, if only a few parts were needed, the lathe would be the best tool to use, but if a large number were required, the automatic or semi-automatic machine would probably be preferable, because the saving in time effected by the latter type would more than offset the expense for tool equipment and setting the machine. It is also necessary, in connection with some work, to consider the degree of accuracy required, as well as the rate of production, and it is because of these varying conditions that work of the same general class is often done in machines of different types, in order to secure the most efficient results. This matter has been referred to at the outset to indicate, in a general way, the principle of tool selection.

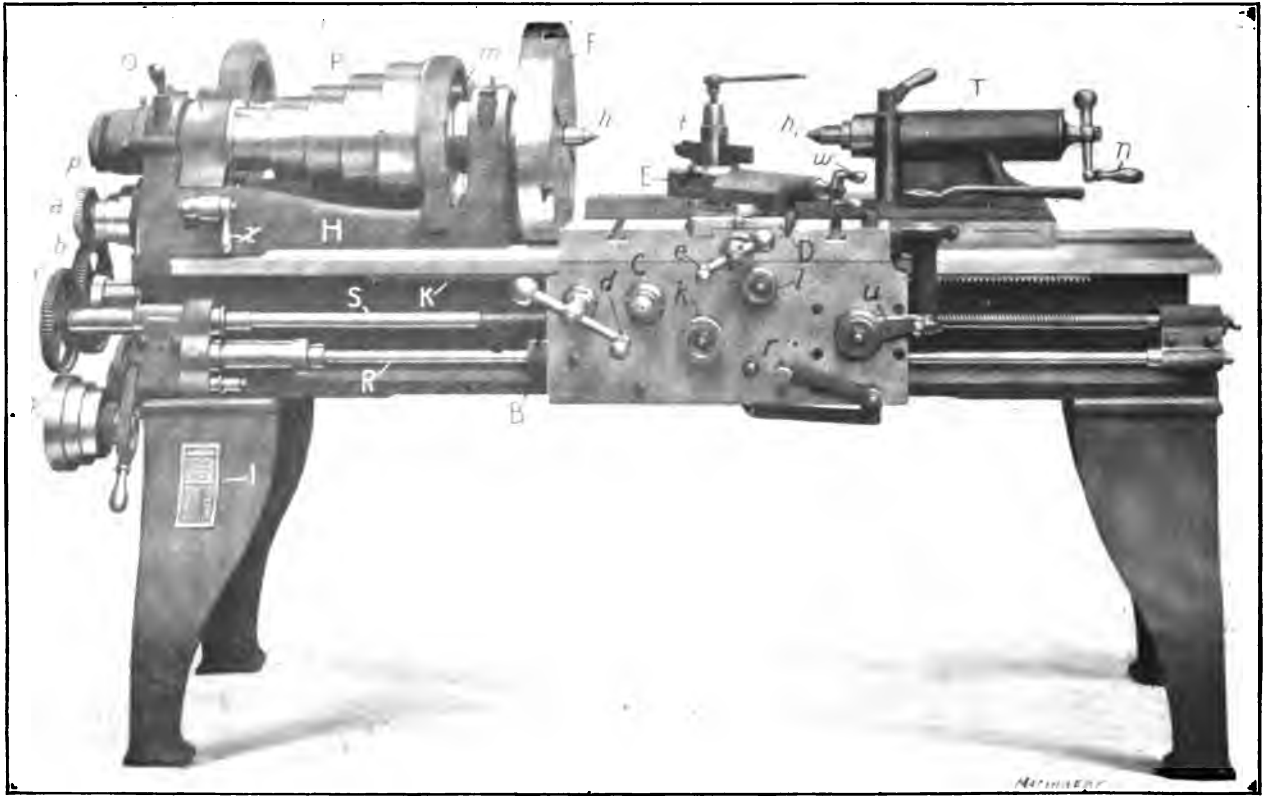


Fig. 1. Bradford Standard Lathe—View of Front or Operating Side

CHAPTER I

GENERAL DESCRIPTION OF AN ENGINE LATHE

The standard "engine" lathe, which is the type commonly used by machinists for doing general work, is one of the most important tools in a machine shop, because it is adapted to a great variety of work, such as turning all sorts of cylindrically shaped parts, boring holes, cutting threads, etc. The illustration Fig. 1 shows a lathe which, in many respects, represents a typical design, and while some of the parts are arranged differently on other makes, the general construction is practically the same as on the machine illustrated.

The principal parts are the bed *B*, the headstock *H*, the tailstock *T*, and the carriage *C*. The headstock contains a spindle which is rotated by a belt that passes over the cone-pulley *P*, and this spindle rotates the work, which is usually held between pointed or conical centers *h* and h_1 in the headstock and tailstock, or in a chuck screwed onto the spindle instead of the faceplate *F*. The carriage *C* can be moved lengthwise along the bed by turning handle *d*, and it can also be moved by power, the movement being transmitted from the headstock spindle either through gears *a*, *b*, *c*, and screw *S*, or by a belt operating on pulleys *p* and p_1, which drive the feed-rod *R*. The screw *S* is used when cutting threads, and the feed-rod *R* for ordinary turning operations; in this way the screw is worn as little as possible, and its accuracy is preserved. On the carriage, there is a cross-slide *D* which can be moved at right angles to the lathe bed by handle *e*, and on *D* there is an upper or compound slide *E* which can be swiveled to different positions. The tool *t*, that does the turning, is clamped to the upper slide, as shown, and it can be moved with relation to the work by the lengthwise movement of the carriage *C* on the bed, by moving slide *D* crosswise, and by slide *E*, which can be set to any required angle. The first two movements can be effected by power, the lengthwise feed being engaged by tightening knob *k*, and the cross-feed by tightening knob *l*. The direction of either of these movements can also be reversed by shifting lever *r*. Ordinarily the carriage and slide are adjusted by hand to bring the tool into the proper position for turning to the required diameter, and then the power feed (operating in the desired direction) is engaged. The tailstock *T* can be clamped in different positions along the bed, to suit the length of the work, and its center h_1 can be moved in or out for a short distance, when adjusting it to the work, by turning handle *n*.

As some metals are much harder than others, and as the diameter of the part that is to be turned also varies, speed changes are necessary, and these are obtained by placing the driving belt on different steps of cone-pulley *P*, and also by the use of back-gears. The cone-pulley can be connected directly with the spindle or be disengaged from it by means of bolt *m*. When the pulley and spindle are connected, five speeds (with this particular lathe) are obtained by simply shifting the driving belt to different steps of the cone. When a slower speed is required than can be obtained with the belt on the largest step of the cone, the latter is disconnected from the spindle, and the back-gears *G* and G_1, (shown in the plan view Fig. 2) are moved forward into mesh by turning handle *O;* the drive is then from cone-pulley *P* and gear *L* to gear *G*, and from gear G_1 to the large gear *J* on the spindle. When driving through the back-gears, five more speed changes are obtained by shifting the position of the driving belt, as before. Changes of feed for the tool are also required, and these are obtained by shifting the belt operating on pulleys *p* and p_1 to different-sized steps.

Front and rear views of the carriage apron, which contains the

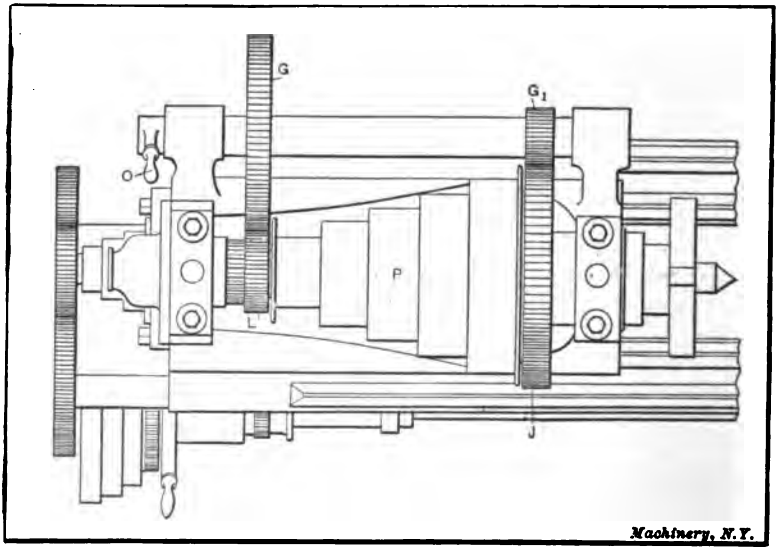


Fig. 2. Plan View of Headstock showing Back-gears

feeding mechanism, are shown in Figs. 3 and 4, to indicate how the feeds are engaged and reversed. The feed-rod *R* (Fig. 1) drives the small bevel gears *A* and A_1 (Figs. 3 and 4) which are mounted on a slide *S* that can be moved by lever *r* to bring either bevel gear into mesh with gear *B*. Gear *B* is attached to pinion *b* (see Fig. 3) meshing with gear *C*, which, when knob *k* is tightened, is locked by a friction clutch to pinion *c*. The latter pinion drives gear *D* which rotates shaft *E*. A pinion cut on the end of shaft *E* engages rack *K* (Fig. 1) attached to the bed, so that the rotation of *E* (which is controlled by knob *k*) moves the carriage along the bed. To reverse the direction of the movement, it is only necessary to throw gear *A* into mesh and gear A_1 out, or *vice versa*, by operating lever *r*. When the carriage is traversed by hand, shaft *E* and gear *D* are rotated by pinion d_1 connected with handle *d*.

The drive for the cross-feed is from gear *C* to gear *F* which can be engaged through a friction clutch (operated by knob *l*) with gear *G* meshing with a pinion *H*. The latter rotates the cross-feed screw, which passes through a nut attached to slide *D* (Fig. 1), thus moving

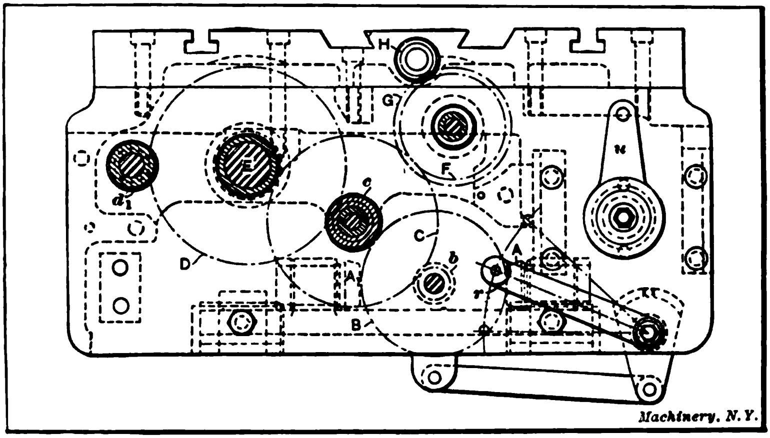


Fig. 3. Lathe Apron

the latter at right angles to the ways of the bed. The cross-feed is also reversed by means of lever *r*. As previously explained, lead-screw *S* is only used for feeding the carriage when cutting threads. The carriage is engaged with this screw by means of two half-nuts *N*

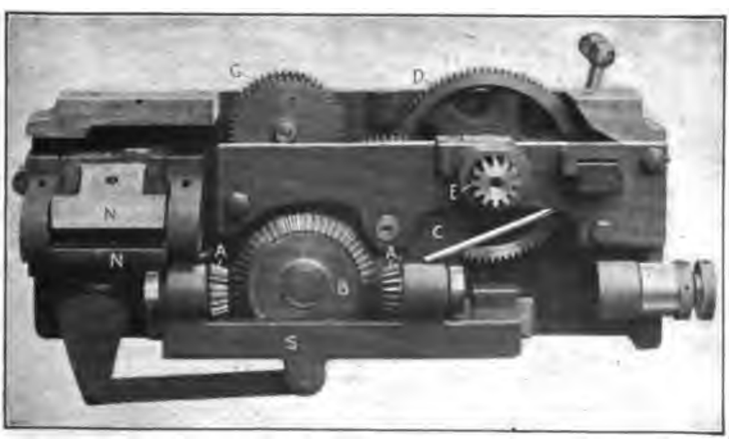


Fig. 4. Rear View of Lathe Apron

that are free to slide vertically and are closed around the screw by operating lever *u*. These half-nuts can only be closed when lever *r* is in a central or neutral position, so that the screw feed and the regular turning feed cannot be engaged at the same time.

CHAPTER II

EXAMPLE OF CYLINDRICAL TURNING

Having now considered the principal features of what might be called a standard lathe, the method of using it in the production of machine parts will be explained. The first example of work that will be referred to is shown in Fig. 6, which represents a drawing of the part. It is a steel shaft, the diameter of which must be $2\frac{1}{4}$ inches and the length $14\frac{1}{2}$ inches, these being the finished dimensions. We will assume that the rough stock is cut off to a length of $14\frac{5}{8}$ inches and has a diameter of $2\frac{5}{8}$ inches. The first step in this operation is to form conically shaped center-holes in each end of the piece as indi-

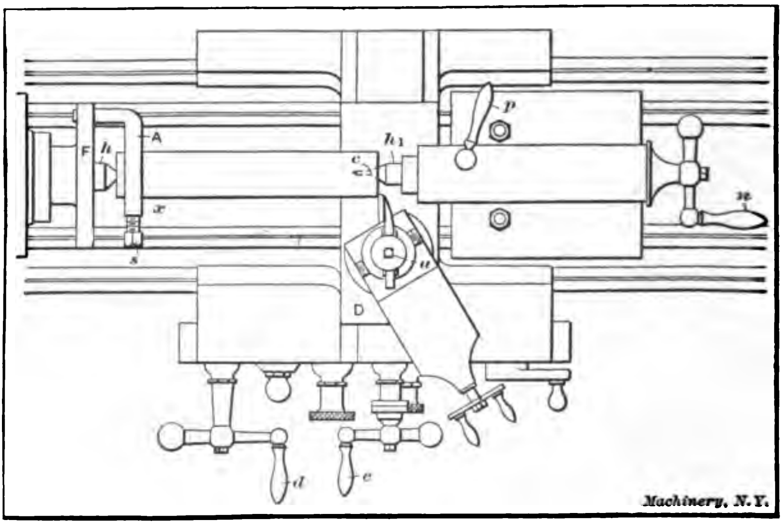


Fig. 5. Plan View showing Work Mounted Between Centers

cated at *c* in Fig. 5. As all work of this kind is held, while being turned, between the centers *h* and h_1, holes corresponding in shape to these centers are necessary to keep the work in place. There are several methods of forming these center-holes, as explained in Chapter III.

After the work is centered, a dog *A* is clamped to one end by tightening screw *s*, and is then placed between the centers. The dog has a projecting end or tail, as it is commonly called, which enters a slot in the faceplate *F* and thereby drives or rotates the work, when power is applied to the lathe spindle onto which the faceplate is screwed. The tailstock center h_1, after being oiled, should be set up just tight enough to eliminate all play, without interfering with a free rotary movement of the work. This is done by turning handle *n*, and when the center is properly adjusted, the tailstock spindle containing the center is locked by tightening handle *p*.

Facing the Ends Square with a Side Tool

Everything is now ready for the turning operation. The ends of the piece should be faced square before turning the body to size, and the tool for this squaring operation is shown in Fig. 7; this is known

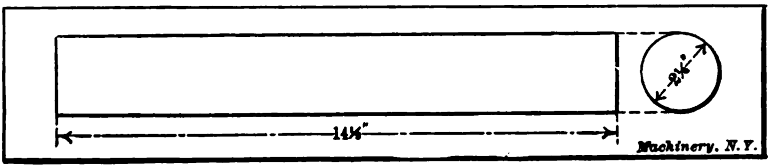


Fig. 6. Example of Plain Cylindrical Work

as a side tool. It has a cutting edge *e* which shaves off the metal as indicated in the end view by the dotted lines. The side *f* is ground to an angle so that when the tool is moved in the direction shown by the arrow, the cutting edge will come in contact with the part to be turned; in other words, side *f* is ground so as to provide clearance for the cutting edge. In addition, the top surface against which the chip bears, is beveled to give the tool keenness so that it will cut easily. As the principles of tool grinding are treated separately in Chapter V of MACHINERY's Reference Book, No. 92, we shall for the present consider the tool's use rather than its form. For facing the end, the side tool is clamped in the toolpost by tightening the screw *u*,

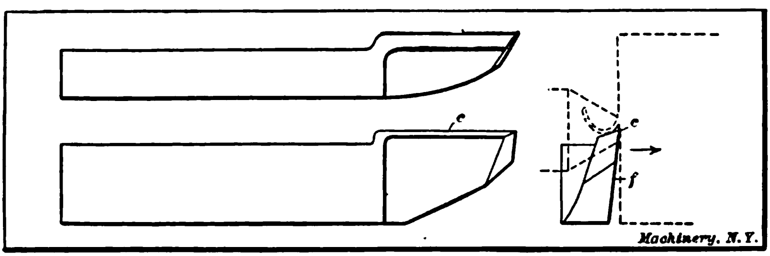


Fig. 7. Right-side Tool

Fig. 5, and it should be set with the cutting edge slightly inclined from a right-angled position as shown. The cutting edge should also be about the same height as the center of the work. When the tool is set, the lathe (if belt-driven) is started by shifting an overhead belt and the tool is then moved in until the point is in the position shown at *A*, Fig. 8. The tool-point is then fed against the end by handle *d*, Fig. 5, until a light chip is being turned off, and then it is moved outward by handle *e* (as indicated by the arrow at *B*, Fig. 8), the carriage remaining stationary. As the movement of the tool-point is guided by the cross-slide *D*, which is at right angles with the axis of the work, the end will be faced square. For short turning operations of this kind, the power feeds are not used as they are intended for comparatively long cuts. If it were necessary to remove much metal from the end, a number of cuts would be taken across the end; in this case, however, the rough stock is only ⅛ inch too long so that this end need only be made true. After taking a cut as described, the surface, if left rough by the tool-point, should be made smooth by a second or finishing cut. If the tool is ground slightly round at the point and the cutting edge is set almost square, as at *C*, Fig. 8. a smooth finish can be obtained; the cut, however, should be light and the outward feed uniform. The work is next reversed in the centers and the driving dog is placed on the end just finished; the other end is then faced, enough metal being removed to make the piece 14½ inches long, as called for on the drawing. This completes the facing operation.

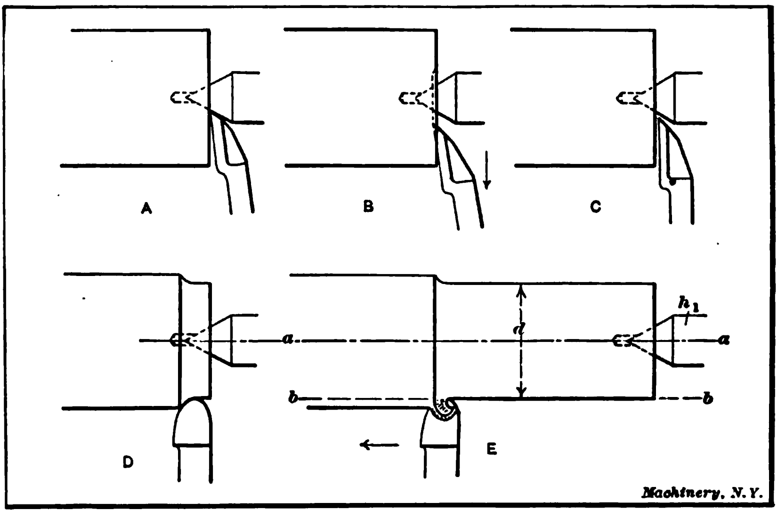


Fig. 8. Facing End with Side Tool and Turning Work Cylindrical

If the end of the work does not need to be perfectly square, the facing operation can be performed by setting the tool in a right-angled position and then feeding it sidewise, thus removing a chip equal to the width of one side. Evidently this method is confined to comparatively small diameters and the squareness of the turned end will be determined by the position of the tool's cutting edge.

Lathe Turning Tool—Turning Work Cylindrical

The tool used to turn the body to the required diameter is shaped differently from the side tool, the cutting edge *E* being curved as shown in Fig. 9. A tool of this shape can be used for a variety of cylindrical turning operations. As most of the work is done by that part of the edge marked by arrow *a*, the top of the tool is ground to slope back from this part to give it keenness. The end *F*, or the flank, is also ground to an angle to provide clearance for the cutting edge; for without such clearance, the flank would rub against the work and the cutting edge would be ineffective. This type of tool is placed about square with the work, for turning, and with the cutting end a little above the center.

Before beginning to turn, a pair of outside calipers should be set

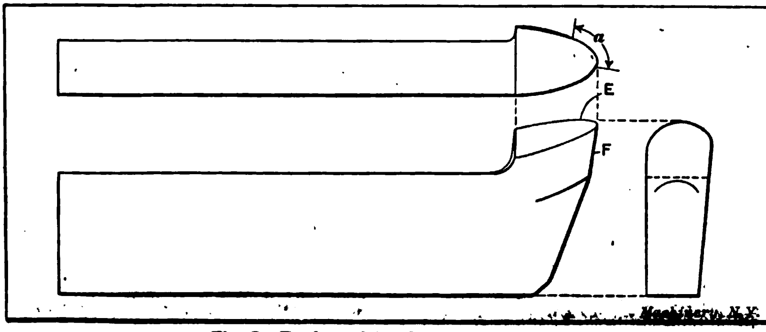


Fig. 9. Tool used for Cylindrical Turning

to 2¼ inches, which, in this case, is the finished diameter of the work. Calipers are sometimes set by using a graduated scale as at *A*, Fig. 10, or they can be adjusted to fit a standard cylindrical gage of the required size as at *B*. Very often fixed caliper gages *C* are used instead of the adjustable spring calipers. These fixed gages, sometimes called "snap" gages, are accurately made to different sizes, and they

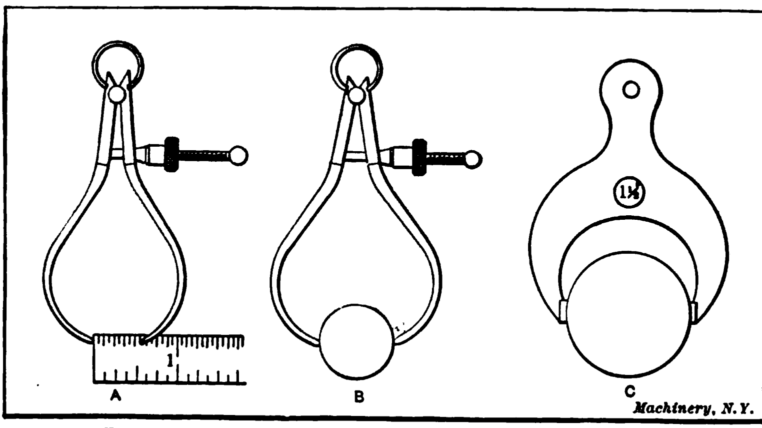


Fig. 10. Setting Calipers by Scale—Setting by Gage—Fixed Gage

are particularly useful when a number of pieces have to be turned to exactly the same size.

The turning tool is started at the right end of the work and the carriage should be moved with the left hand when beginning a cut, as shown in Fig. 11, in order to have the right hand free for calipering. A short space is first turned by hand feeding, as at *D*, Fig. 8, and when the calipers show that the diameter is slightly greater than the finished size (to allow for a light finishing cut), the power feed for the carriage is engaged; the tool then moves along the work reducing it as at *E*. Evidently, if the movement is along a line *b—b*, parallel with the axis *a—a*, the diameter *d* will be the same at all points, and a true cylindrical piece will be turned. On the other hand, if the axis *a—a* is inclined one way or the other, the work will be made tapering; in fact, the tailstock center h_1 can be adjusted laterally for turning tapers, but for straight turning, both centers must be in alignment with the carriage travel. Most lathes have lines on the stationary and movable parts of the tailstock base which show when the centers are set for straight turning. These lines, however, may not be absolutely correct, and it is good practice to test the alignment of the centers before beginning to turn. This can be done by taking

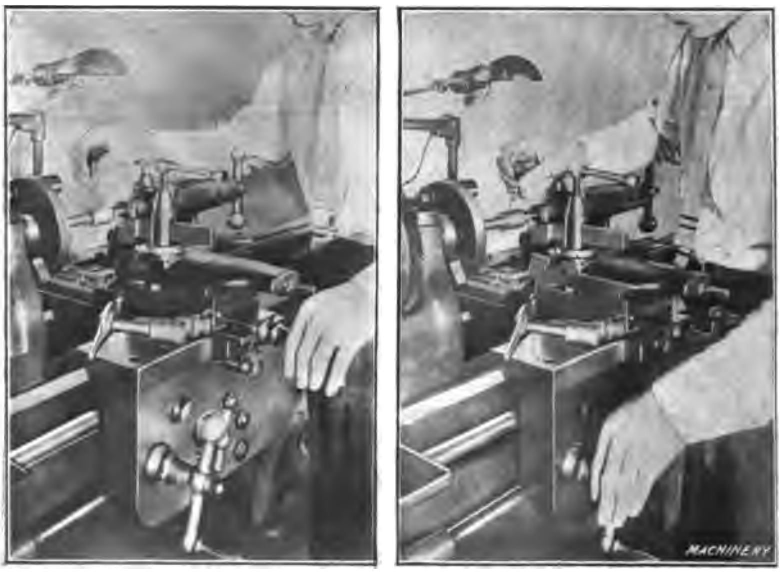


Fig. 11. Views showing how the Cross-slide and Carriage are Manipulated by Hand when Starting a Cut

trial cuts, at each end of the work (without disturbing the tool's crosswise position), and then comparing the diameters, or by testing the carriage travel with a true cylindrical piece held between the centers.

If the relative positions of the lathe centers is not known, the work should be callipered as the cut progresses to see if the diameter *d* is the same at all points. In case the diameter gradually increases, the tailstock center should be shifted slightly to the rear before taking the next cut, but if the diameter gradually diminishes, the adjustment would, of course, be made in the opposite direction. The diameter is tested by attempting to pass the calipers over the work. When the measuring points just touch the work as they are gently passed across it, the diameter being turned is evidently the same as the size to which the calipers are set.

As the driving dog is on one end, the cut cannot be taken over the entire length, and when the tool has arrived at say position x, Fig. 5, it is returned to the starting point and the work is reversed in the centers. The large end is then turned, and if the cross-slide has not been moved, the tool will meet the first cut. The two cuts will not be joined or blended together perfectly, however, and for this reason a cut should be continuous when this is possible.

Roughing and Finishing Cuts

Ordinarily in lathe work, as well as in other machine work, there are two classes of cuts, known as roughing and finishing cuts. Roughing cuts are for reducing the work as quickly as possible almost to

Fig. 12. Filing Work after Finishing Cut is taken

the required size, whereas finishing cuts, as the name implies, are intended to leave the part smooth and of the proper size. When the rough stock is only a little larger than the finished diameter, a single cut is sufficient, but if there is considerable metal to turn away, one or more deep roughing cuts would have to be taken, and, finally, a light cut for finishing. In this particular case, one roughing and one finishing cut would doubtless be taken, as the diameter has to be reduced $\frac{3}{8}$ inch. Ordinarily the roughing cut would be deep enough to leave the work about 1/32 or perhaps 1/16 inch above the finished size. When there is considerable metal to remove and a number of roughing cuts have to be taken, the depth of each cut and the feed of the tool are governed largely by the pulling power of the lathe and the strength of the work to withstand the strain of a heavy cut.

Of course, just as few cuts as possible should be taken in order to save time. The speed of the work should also be as fast as the conditions will allow for the same reason, but as there are many things which govern the speed, the feed of the tool, and the depth of the cut, these important points are referred to separately in Chapter III of MACHINERY'S Reference Book No. 92.

Filing and Finishing

In many cases the last or finishing cut does not leave as smooth a surface as is required and it is necessary to resort to other means. The method commonly employed for finishing in the lathe is by the use of a file and emery cloth. The work is rotated considerably faster for filing than for turning, and the entire surface is filed by a flat, single-cut file, held as shown in Fig. 12. The file is passed across the work and advanced sidewise for each forward stroke until the entire surface is finished. The file should be kept in contact with the work continually, but on the return stroke, the pressure should be relieved.

The movement of the file during the forward or cutting stroke should be much slower than when filing in a vise. By moving the file slowly, the work can make a number of revolutions for each stroke, which tends to keep it round, as practically the same amount of metal is removed from the entire circumference. On the other hand, short rapid strokes tend to produce flat spots, or at least an irregular surface, especially if the work can only make part of a revolution for each cutting stroke. The pressure on the file during the forward stroke, should also be kept as nearly uniform as possible. It is very difficult to file a part smooth and at the same time to keep it round and cylindrical, and the more filing that has to be done, the greater the chance of error. For this reason, the amount left for filing should be very small; in fact, the metal removed by filing should be just enough to take out the tool marks and give a smooth finish. Very often a satisfactory finish can be obtained with a turning tool, and filing is not necessary at all.

Sometimes particles of metal collect between the teeth of a file and make deep scratches as the file is passed across the work. When this, occurs, the teeth should be cleaned by using a wire brush or a file card, which is drawn across the file in the direction of the teeth. This forming of tiny particles between the teeth is known as "pinning" and it can sometimes be avoided by rubbing chalk on the file. Filing is not only done to obtain a smooth finish, but also to reduce the work to an exact diameter, as a very slight reduction can be made in this way. If a polish is desired, this can be obtained by holding a piece of emery cloth tightly around the work as it revolves. Most cylindrical parts can be finished more quickly and accurately in the grinder than in the lathe, and many classes of work are, at the present time, simply rough-turned in the lathe and then ground to size in a cylindrical grinding machine.

CHAPTER III

CENTERING

As mentioned in the preceding chapter, there are a number of different methods of forming center-holes in the ends of parts that have to be turned while held between lathe centers. A method of centering light work, which requires few special tools, is first to locate a central point on the end and then drill and ream the center-hole by using the lathe itself.

Locating the Center—Drilling in the Lathe

Hermaphrodite dividers are useful for finding the center, as illustrated at *A*, Fig. 13, but if the work is fairly round, a center-square *B* is preferable. A line is scribed across the end and then another line at right angles to the first by changing the position of the square; the

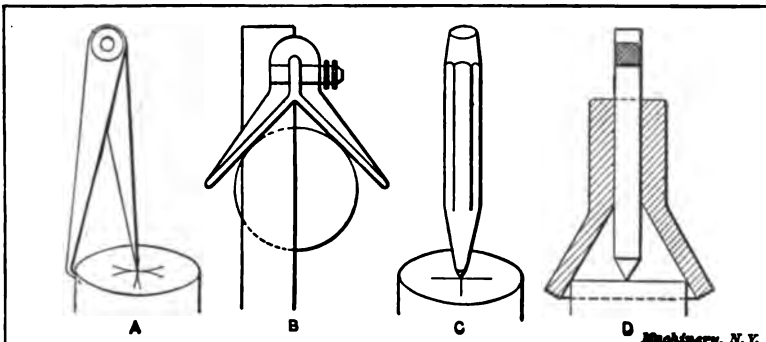


Fig. 13. Centering End with Punch preparatory to Drilling

intersection of these two lines will be the center, which should be marked by striking a pointed punch *C* with a hammer. If a cup or bell center-punch *D* is available, it will not be necessary to first make center lines, as the conical part shown locates the punch in a central position. This style of punch should only be used on work which is fairly round.

After small centers have been located in both ends, their position can be tested by placing the work between the lathe centers and rotating it rapidly by drawing the hand quickly across it. By holding a piece of chalk close to the work as it spins around, a mark will be made on the "high" side if the centers are not accurate; the centers are then shifted toward these marks. If the work is close to the finished diameter, the centers should, of course, be located quite accurately in order that the entire surface of the work will be turned true when it is reduced to the finished size.

One method of finishing these center-holes is indicated in Fig. 14. A chuck *C* is screwed onto the spindle in place of the faceplate, and a combination center drill and reamer *R* is gripped by the chuck jaws and set to run true. The center is then drilled and reamed at one end by pressing the work against the revolving drill with the tailstock spindle, which is fed out by turning handle *n*. The piece is then reversed for drilling the opposite end. The work may be kept from revolving while the centers are being drilled and reamed, by attaching

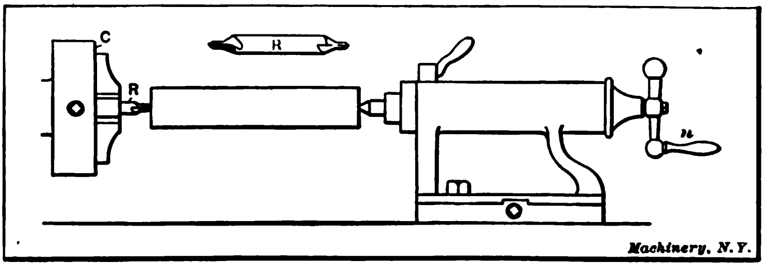
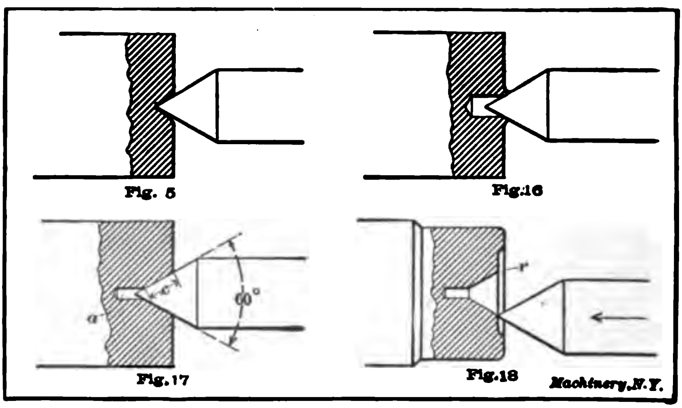


Fig. 14. Drilling Centers in the Lathe

a dog to it close to the tailstock end and then adjusting the cross-slide until the dog is in contact with it. From the foregoing it will be seen that the small centers made by punch *C*, Fig. 13, serve as a starting point for the drill and also as a support for the outer end of the work while the first hole is being drilled.

The form of center-hole produced by a combination drill and reamer is shown in Fig. 17. A small straight hole *a* in the bottom prevents



Figs. 15 to 18. Centers of Incorrect and Correct Form

the point of the lathe center from coming in contact with the work and insures a good bearing on the conical surface *c*. The standard angle for lathe centers is sixty degrees, as the illustration shows, and the tapering part of all center-holes should be made to this angle.

Centering Machine

Many shops have a special machine for forming centers which enables the operation to be performed quickly. One type of centering machine is shown in Fig. 19. The work is gripped in a chuck *C* that automatically locates it in a central position so that it is not necessary to lay out the end before drilling. There are two spindles s and s_1 one of which holds the drill and the other the countersink, and these are rotated by a belt passing over pulley P. Each of these spindles is advanced by lever L and either of them can be moved to a position central with the work, as they are mounted in a swiveling frame. In operating this machine, a small straight hole is first made by a twist drill held in one of the spindles; the other spindle is then moved over to the center and the hole is reamed tapering. The

Fig. 19. Special Machine for Centering

arrangement is such that neither spindle can be advanced by the feeding lever except when in a central position. The amount that each spindle can be advanced is limited by a fixed collar inside the head, and there is also a swinging adjustable stop against which the end of the work should be placed before tightening the chuck. These two features make it possible to ream center holes of the same size or depth in any number of pieces.

Different Forms of Centers

In some poorly equipped shops it is necessary to form centers by the use of a center-punch only, as there is no better tool. If the end of the punch has a sixty-degree taper, a fair eenter can be formed in this way, but it is not a method to be recommended, especially when accurate work is required. Sometimes centers are made with punches that are too blunt, producing a shallow center, such as the one shown in Fig. 15. In this case all the bearing is on the point of the lathe center, which is the worst possible place for it. Another way is to simply drill a straight hole as in Fig. 16; this is also bad practice

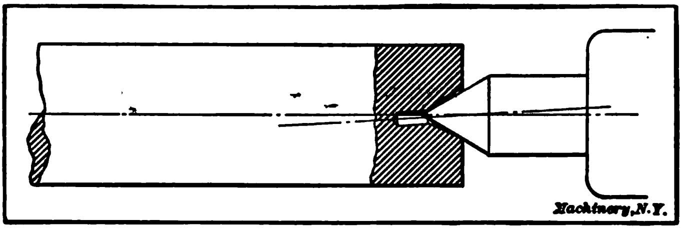


Fig. 20. The Imperfect Center Bearing is the Result of Centering before Straightening

in more than one respect. Fig. 18 shows a form of center which is orten found in the ends of lathe arbors, the mouth of the center being rounded, at *r*, and the arbor end recessed as shown. The rounded corner prevents the point of the lathe center from catching when it is moved rapidly towards work which is not being held quite centrally, and the end is recessed to protect the center against bruises. Stock that is bent should always be straightened before the centers are drilled and reamed. If the work is centered first and then straightened,

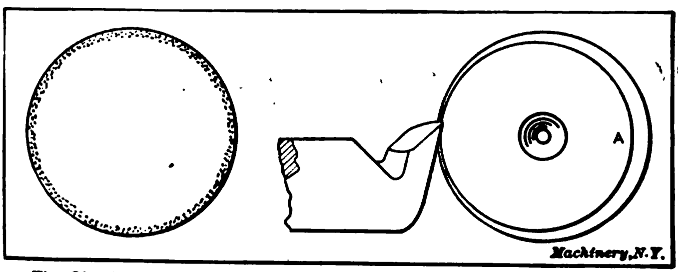


Fig. 21. Tool Steel should be centered Concentric, in order to remove the Decarbonized Outer Surface

the bearing on the lathe center would be as shown in Fig. 20. The center will then wear unevenly with the result that the surfaces last turned will not be concentric with those which were finished first.

Precaution When Centering Tool Steel

Ordinarily centers are so located that the stock runs approximately true before being turned, but when centering material to be used in making tools, such as reamers, mills, etc., which need to be hardened, particular care should be taken to have the rough surface run fairly true. This is not merely to insure that the piece will "true-up," as there is a more important consideration the disregard of which often affects the quality of the finished tool. As is well known, the degree of hardness of a piece of tool steel that has been heated and then suddenly cooled, depends upon the amount of carbon that it contains, steel that is high in carbon becoming much harder than that which contains less carbon. Furthermore the amount of carbon found at the surface, and to some little depth below the surface of a bar of steel, is less than the carbon contained in the rest of the bar. This is illustrated diagrammatically in Fig. 21 by the shaded area in the view to the left. (This decarbonization is probably due to the action of the oxygen of the air on the bar during the process of manufacture.) If stock for a reamer is so centered that the tool removes the decarbonized surface only on one side, as illustrated to the right, evidently when the reamer is finished and hardened, the teeth on the side *A* will be harder than those on the opposite side, which would not have been the case if the rough bar had been centered true. To

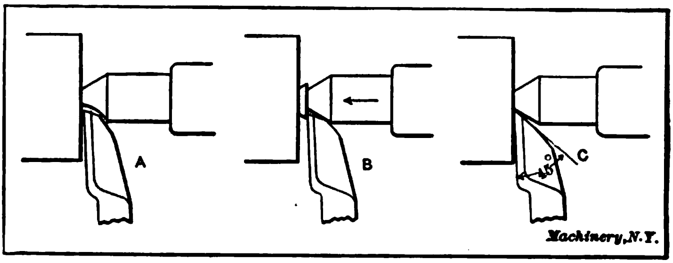


Fig. 22. Three Methods of Facing the End Square

avoid any trouble of this kind, stock that is to be used for hardened tools, should be enough larger than the finished diameter and so centered that this decarbonized surface will be entirely removed in turning.

Facing the Ends of Centered Stock

As a piece of work is not properly centered until the ends are faced square, we will consider this operation in connection with centering. Some machinists prefer lathe centers that are cut away as shown at *A*, Fig. 22, so that the point of the side tool can be fed in far enough to face the end right up to the center hole. Others, instead of using a special center, simply loosen the regular one slightly and then, with the tool in a position as at *B*, face the projecting teat by feeding both tool and center inward as shown by the arrow. Whenever this method is employed, care should be taken to remove any chips from the center hole which may have entered. A method which makes it unnecessary to loosen the regular center, or to use a special one, is to provide clearance for the tool-point by grinding it to an angle of approximately forty-five degrees, as shown at *C*. If the tool is not set too high, it can then be fed right up to the lathe center and the end squared without difficulty. As for the special center *A*, the use of special tools and appliances should always be avoided unless they effect a saving in time or their use makes it possible to accomplish the same end with less work.

CHAPTER IV

THE USE OF LATHE MANDRELS

When it is necessary to turn the outside of a part having a hole through it, centers cannot, of course, be drilled in the ends and other means must be resorted to. We shall assume that the bushing *B*, Fig. 24, has a finished hole through the center, and it is desired to turn the outside cylindrical and concentric with the hole. This could be done by forcing a tightly-fitted mandrel *M*, having accurately-centered ends, into the bushing, and inserting the mandrel and work between the lathe centers h and h_1 as shown. Evidently, if the mandrel runs true on its centers, the hole in the bushing will also run true and the outside can be turned the same as though the mandrel and

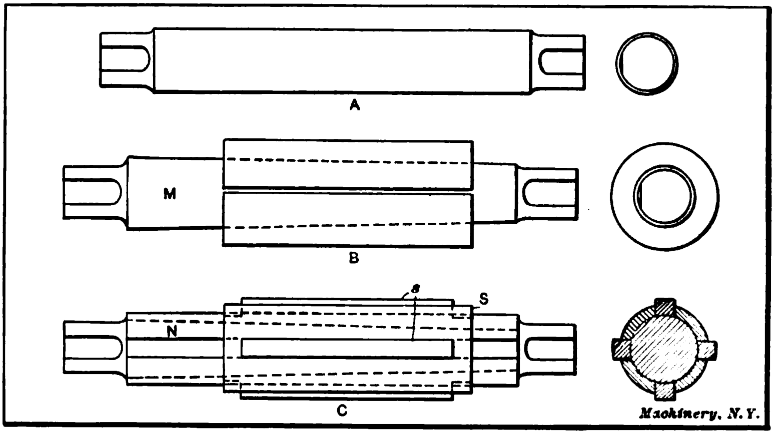


Fig. 23. Different Types of Mandrels

bushing were a solid piece. From this it will be seen that a mandrel simply forms a temporary support for work that is bored and therefore cannot be centered.

Another example of work that would be turned on an arbor is shown in Fig. 25. This is a small cast-iron wheel having a finished hole through the hub, and the outer surface and sides of the rim are to be turned true with this hole. In this case, the work would also be held by pressing a mandrel through the hub as shown. This method, however, would only apply to comparatively small wheels because it would be difficult, if not impossible, to prevent a large wheel from turning on the arbor when taking a cut, and even if it could be driven, large work could be done to better advantage on another type of machine. (The vertical boring mill is used extensively for turning large wheels). When turning the outside of the rim, a tool similar to that shown at *t* should be used, but for facing or turning the sides, it might be better, if not necessary, to use tools having bent ends as shown by the dotted lincs; in fact, turning tools of various kinds are made with the ends bent to the right or left, as this enables

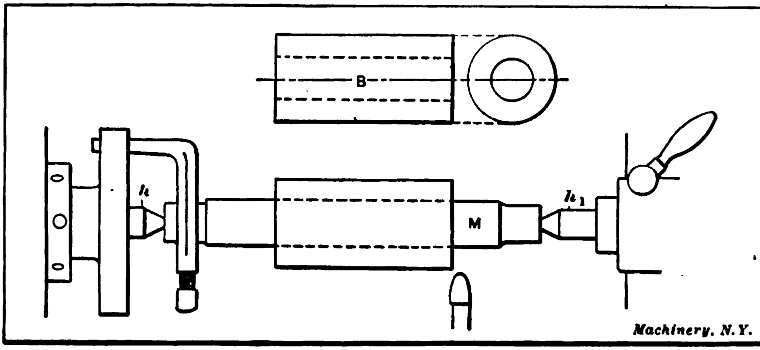


Fig. 24. Bushing mounted on Mandrel for Turning

them to be used on surfaces that could not be reached very well with a straight tool.

If a comparatively large pulley is mounted near the end of the mandrel, it can be driven directly by pins attached to the faceplate and

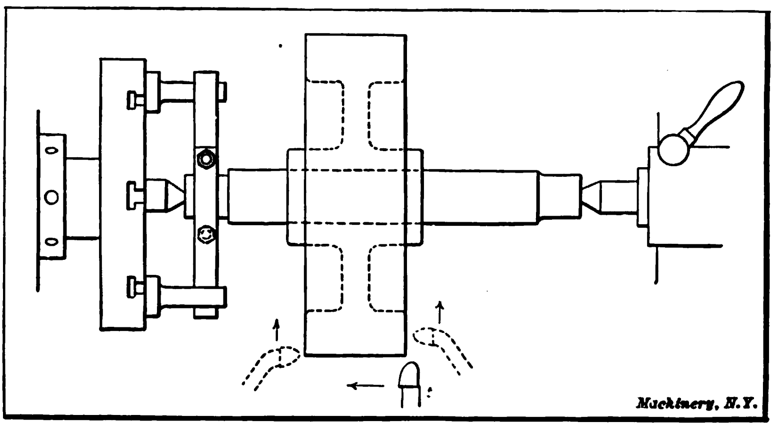


Fig. 25. Turning Pulley Held on Mandrel

engaging the pulley arms. When this method is employed, a dog is, of course, unnecessary.

Different Types of Lathe Mandrels

Three different types of lathe mandrels are shown in Fig. 23. The kind shown at *A* is usually made of tool steel and the body is finished to a standard size. The ends are somewhat reduced and flat spots are milled, as shown, to give the clamping screw of the dog a good grip. This type is used very extensively, but in shops where a great variety of work is being done and there are many odd-sized holes, the expanding mandrel *B* can be used to advantage. This type, instead of being solid, consists of a tapering inner mandrel *M* on which is placed a split bushing that can be expanded, within certain limits, by driving in the tapering member. The advantage of this type is that a compartively small stock of mandrels is required, as different sized bushings can be used. This type can also be fitted to holes of odd sizes, whereas a solid mandrel must be provided for each different size of hole. The latter are, however, more accurate than the expanding type. Another form of expanding mandrel is shown at *C*. This type has a straight body *N* in which four tapering grooves are cut lengthwise, as shown, and there is a sleeve *S*, containing four slots that are located to correspond with the tapering grooves. Strips *s* are fitted in these slots, and as the part *N* is driven in, the strips are moved outward as they ascend the tapering grooves. By having different sets of these strips of various heights, one mandrel of this type can be made to cover quite a range of sizes. It is not suited, however, to thin work, as the pressure, being concentrated in four places, would spring it out of shape.

Fig. 26. Press for Forcing Mandrels into Work

Particular care should be taken to preserve the accuracy of the centers of lathe mandrels by keeping them clean and well-oiled while in use.

Mandrel or Arbor Press

The best method of inserting a mandrel in a hole is by using a press, Fig. 26, designed for that purpose, but if such a press is not available and it is necessary to drive the mandrel in, a "soft" hammer, made of copper, lead or other soft material, should be used to protect the end of the mandrel. In either case, the mandrel should not be forced in too tightly, for if it fits properly, this will not be necessary in order to hold the work securely. On the other hand, the work might easily be broken by attempting to force the mandrel in as far and as tightly as possible. In using the arbor press, the work is placed on the base *B* with the hole in a vertical position, and the arbor (which should be oiled slightly) is forced down into it by ram *R*, operated by lever *L*. Slots are provided in the base, as shown, so that the end of the arbor can come through at the bottom of the hole. The lever of this particular press is counterweighted so that it rises to a vertical position when released. The ram can then be adjusted quickly to any required height by the handwheel seen at the left.

Some shops are equipped with power-driven mandrel or arbor presses. This type is particularly desirable for large work, owing to the greater pressure required for inserting mandrels that are comparatively large in diameter. One well-known type of power press is driven by a belt, and the downward pressure of the ram is controlled by a handwheel. The ram is raised or lowered by turning this handwheel in one direction or the other, and a gage shows how much pressure is being applied. This type of press can also be used for other purposes, such as forcing bushings or pins into or out of holes, bending or straightening parts, or for similar work.

CHAPTER V

CHUCK AND FACEPLATE WORK

Many parts that are turned in the lathe are so shaped that they cannot be held between the lathe centers like shafts and other similar pieces and it is often necessary to hold them in a chuck *A*, Fig. 27, which is screwed on the lathe spindle instead of the faceplate. The work is gripped by the jaws *J* which can be moved in or out to accommodate various diameters. There are three classes of chucks ordinarily used on the lathe, known as the independent, universal, and combination types. The independent chuck is so named because each jaw can be adjusted in or out independently of the others by turning the jaw screws *S* with a wrench. The jaws of the universal chuck all move together and keep the same distance from the center, and

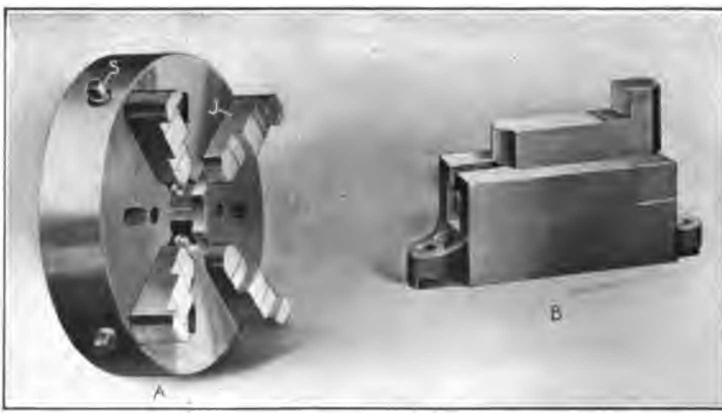


Fig. 27. Chuck and Faceplate Jaw

they can be adjusted by turning any one of the screws *S*, whereas with the independent type the chuck wrench must be applied to each jaw screw. The combination chuck, as the name implies, may be changed to operate either as an independent or universal type. The advantage of the universal chuck is that round and other parts of a uniform shape are located in a central position for turning without any adjustment. The independent type is, however, preferable in some respects as it is usually stronger and adapted for holding odd-shaped pieces because each jaw can be set to any required position.

Radial Facing or Turning

As an example of chuck work, we shall assume that the sides of disk *D*, Fig. 28, are to be turned flat and parallel with each other and that an independent chuck is to be used. First the chuck is screwed on the lathe spindle (after removing the faceplate) by holding it with the right hand and turning the lathe spindle with the left by pulling down on the belt. The chuck jaws are then moved out or in, as the case may be, far enough to receive the disk and each jaw is set about the same distance from the center by the aid of concentric circles on the face of the chuck. The jaws are then tightened while the disk is held back against them to bring the rough inner surface in a vertical plane. If the work is quite heavy, it can be held against the chuck, before the jaws are tightened, by inserting a piece of wood between it and the tailstock center; the latter is then run out far enough to force the work back. The outside or periphery of the disk should run nearly true and it may be necessary to move

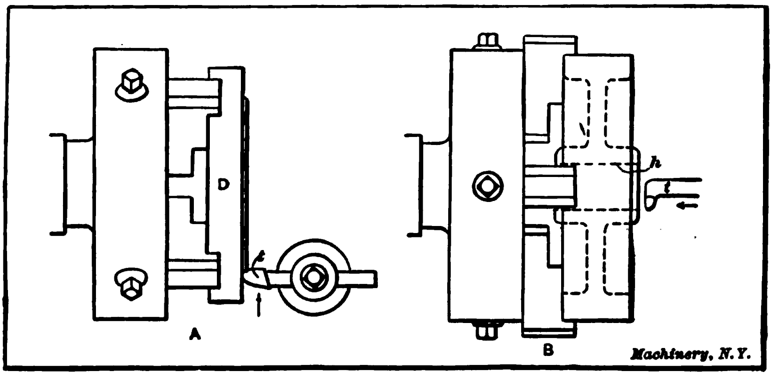


Fig. 28. Radial Facing—Boring Pulley Held in Chuck

the jaws in on one side and out on the other to bring the disk to a central position. To test its location, the lathe is run at a moderate speed and a piece of chalk is held near the outer surface. If the latter runs out, the "high" side will be marked by the chalk, and this mark can be used as a guide in adjusting the jaws. It should be remembered that the jaws are moved only one-half the amount that the work runs out.

A round-nosed tool *t* of the shape shown is used for radial facing or turning operations of the kind illustrated. This tool is similar to the kind used when turning between centers, the principal difference being in the direction of the top slope. The radial facing tool should be ground to slope downward toward *a* (see Fig. 29) whereas the regular turning tool slopes toward *b*, the inclination in each case being away from that part of the cutting edge which does the work. The cutting edge should be the same height as the lathe centers, and the cut is taken by feeding the tool from the outside in to the center. The cut is started by hand and then the power feed is engaged, except for small surfaces. The first cut should, if possible, be deep enough to get beneath the scale, especially if turning cast iron, as a tool which just grazes the hard outer surface in spots will be dulled in a comparatively short time. If it were simply necessary to turn a true flat surface and the thickness of the disk were immaterial, two cuts would be sufficient, unless the surface were very uneven, the first or roughing cut being followed by a light finishing cut. For a finishing cut, the same tool could be used but if there were a number of disks to be faced, a square-nosed tool *F*, Fig. 29, could probably be used to better advantage. This type has a broad flat cutting edge that is set parallel with the rough-turned surface and this broad edge

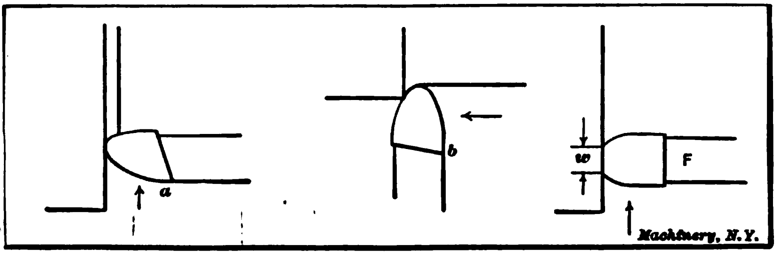


Fig. 29. Top of Tool should Slope away from Working Part of Cutting Edge

enables a coarse feed to be taken, thus reducing the time required for the finishing cut. If a coarse feed were taken with the round tool, the turned surface would have spiral grooves in it, whereas with the broad cutting edge, a smooth surface is obtained even though the feed is coarse. The amount of feed per revolution of the work, however, should always be less than the width *w* of the cutting edge. Very often broad tools cannot be used for finishing cuts, especially when turning steel, because their greater contact causes chattering and results in a rough surface. An old and worn lathe is more liable to chatter than one that is heavy and well-built, and as the diameter of the work also makes a difference, a broad tool cannot always be used for finishing, even though, theoretically, it would be preferable. After

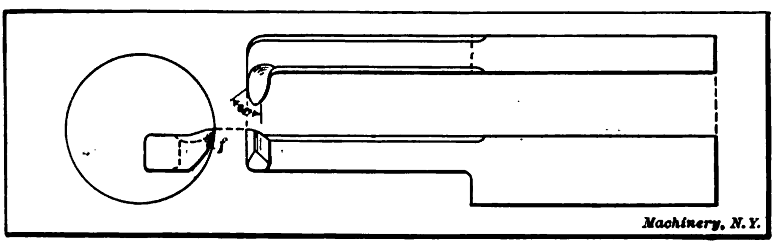


Fig. 30. Boring Tool

one side of the disk is finished, it is reversed in the chuck, the finished surface being placed against the jaws. The remaining rough side is then turned, care being taken when starting the first cut to caliper the width of the disk at several points to make sure that the two sides are parallel.

Example of Boring—Tool Used

Another example of chuck work is shown at *B*, Fig. 28. In this case a cast-iron pulley is to have a true hole *h* bored through the hub. (The finishing of internal cylindrical surfaces in a lathe is referred to as boring rather than turning). The casting should be set true by the rim instead of by the rough-cored hole in the hub; this can be done by the use of chalk as previously explained. Even though a universal type of chuck were used, the jaws of which, as will be recalled, are self-centering, it might be necessary to turn the pulley relative to the chuck as a casting sometimos runs out because of

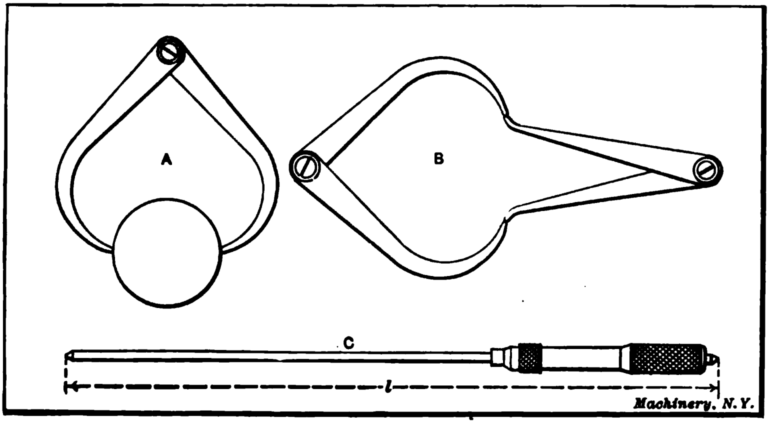


Fig. 31. Setting Outside Calipers—Transferring Measurement to Inside Calipers—Micrometer Gage

rough spots or lumps which happen to come beneath one or more of the jaws. The shape of tool *t* for boring is quite different from one used for outside turning, as shown by Fig. 30. The cutting end is forged approximately at right angles to the body or shank, and the

Fig. 32. Standard Plug Gage

top surface is ground to slope away from the working part *w* of the cutting edge, as with practically all turning tools. The front part or flank *f* is also ground away to give the edge clearance. This type of tool is clamped in the toolpost with the body about parallel with the lathe spindle, and ordinarily the cutting edge would be about as high as the center of the hole, or a little below if anything. When starting a cut, the tool is brought up to the work by moving the carriage and it is then adjusted radially to get the right depth of cut.

The power feed for the carriage is then used, the tool feeding back through the hole as indicated by the arrow, Fig. 28. In this case, as with all turning operations, the first cut should be deep enough to cut beneath the hard outer scale at every part of the hole. Usually a rough-cored hole is so much smaller than the finished size that several cuts are necessary; in any case the last or finishing cut should be

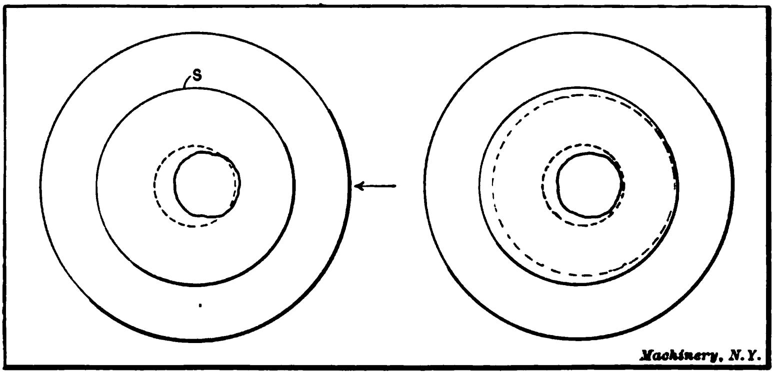


Fig. 33. Setting Work with reference to Surfaces to be Turned

very light to prevent the tool from springing away from the work, so that the hole will be as true as possible. Boring tools, particularly for small holes, are not as rigid as those used for outside turning, as the tool has to be small enough to enter the hole and for this reason comparatively light cuts have to be taken. When boring a

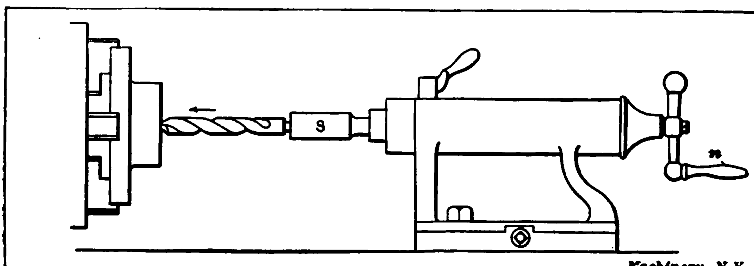


Fig. 34. Drilling in the Lathe

small hole, the largest tool that will enter it without interference should be used to get the greatest rigidity possible.

Measuring Bored Holes

The diameters of small holes that are being bored are usually measured with inside calipers or standard gages. If the pulley were being bored to fit over some shaft, the diameter of the shaft would first be measured by using outside calipers as shown at *A*, Fig. 31, the measuring points of the calipers being adjusted until they just made contact with the shaft when passed over it. The inside calipers are then set as at *B* to correspond with the size of the shaft, and the hole is bored just large enough to admit the inside calipers easily. Very accurate measurements can be made with calipers, but to become expert in their use requires experience. Some mechanics never become proficient in the art of calipering because their hands are "heavy" and they lack the sensitiveness and delicacy of touch that is necessary. For large holes, a gage *C* is often used, the length *l* being adjusted to the diameter desired. Small holes are often bored to fit hardened steel plug gages (Fig. 32), the cylindrical measuring ends of which are made with great accuracy to standard sizes. This type of gage is particularly useful when a number of holes have to be bored to the same size, all holes being made just large enough to fit the gage without any perceptible play.

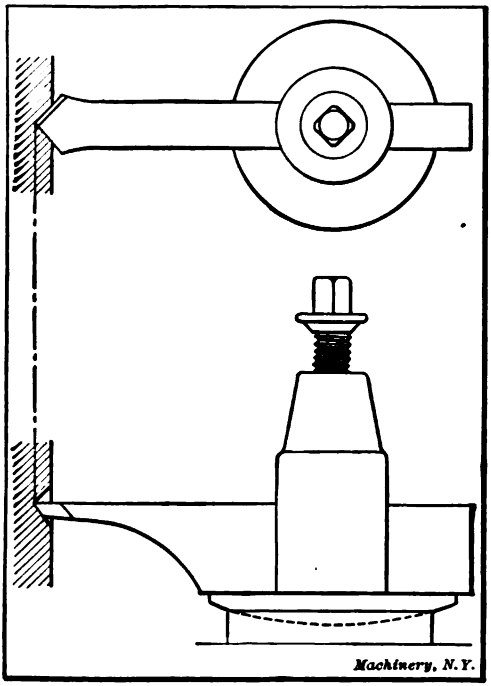


Fig. 35. Special Tool which Forms a Center for Starting the Drill

Setting Work in the Chuck

When setting a part in a chuck, care should be taken to so locate it that every surface to be turned will be true when machined to the finished size. As a simple illustration, let us assume that the hole through the cast-iron disk, Fig. 33, has been cored considerably out of center as shown. If the work is set by the outside surface *S*, as it would be ordinarily, the hole is so much out of center that it will not be true when bored to the finished size, as indicated by the dotted lines. On the other hand, if the rough hole is set true, the outside cannot be finished all over, without making the diameter too small, when it is finally turned. In such a case, the casting should be shifted, as shown by the arrow, to divide the error between the two surfaces, both of which can then be turned as shown by the dotted lines in the view to the right. This principle of dividing the error when setting work can often be applied in connection with turning and boring. Hence, after a casting or other part has been set true by the most important surface, all other surfaces which require machining should then be tested to make sure that they all can be finished to the proper size.

Drilling and Reaming

When a hole is to be bored from the solid, it is necessary to drill a hole before a boring tool can be used. One method of drilling in the lathe is to insert an ordinary twist drill in a holder or socket *S*, Fig. 34, fitted in the tailstock spindle in place of the center. The drill is then fed through the work by turning the handle *n* and feeding the spindle outward as shown by the arrow. Before beginning to drill, it is well to turn a conical spot or center for the drill point by using a special tool, Fig. 35, having a point like a flat drill. This tool is clamped in the toolpost with the point at the same height as the lathe centers. It is then moved to the center of the work and a conical center is turned as shown by the sectional view. If the drill were not given this true starting point, it probably would enter the work more or less off center. Drills can also be started without

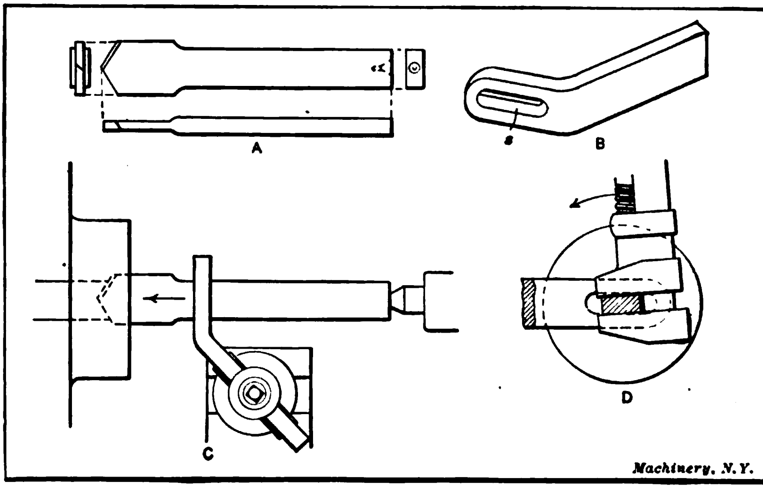


Fig. 36. Flat Drill and Holder

turning a center by bringing the square end or butt of a tool-shank held in the toolpost, in contact with the drill near the cutting end. If the point starts off center, thus causing the drill to wobble, the stationary tool-shank will gradually force or bump it over to the center.

Small holes are often finished in the lathe by drilling and reaming without the use of a boring tool. The form of drill that is used quite extensively for drilling cored holes in castings is shown in Fig. 36 at *A*. This drill is flat and the right end has a large center hole for receiving the center of the tailstock. To prevent the drill from turning, a holder *B*, having a slot *s* in its end through which the drill passes, is clamped in the toolpost, as at *C*. This slot should be set central with the lathe centers, and the drill, when being started, should be held tightly in the slot by turning or twisting it with a wrench as indicated in the end view at *D;* this steadies the drill and causes it to start fairly true even though the cored hole runs out considerably.

Another style of tool for enlarging cored holes is shown in Fig. 37, at *A*. This is a rose chucking reamer, having beveled cutting edges on the end and a cylindrical body, which fits closely in the reamed hole, thus supporting and guiding the cutting end. The reamer shown at *B* is a fluted type with cutting edges that extend from *a* to *b*; it is used for finishing holes and the drill or rose reamer preceding it should leave the hole very close to the required size. These reamers are held while in use in a socket inserted in the tailstock spindle, as when using a twist drill.

Holding Work on Faceplate

Some castings or forgings are so shaped that they cannot be held in a chuck very well, or perhaps not at all, and work of this kind is often held by clamping it to the faceplate. An example of faceplate work is shown in Fig. 38, This is a rectangular cast-iron plate having a round boss or projection, the end *e* of which is to be turned parallel with the back face of the plate which was previously finished on a planer. A rough cored hole through the center of the boss also

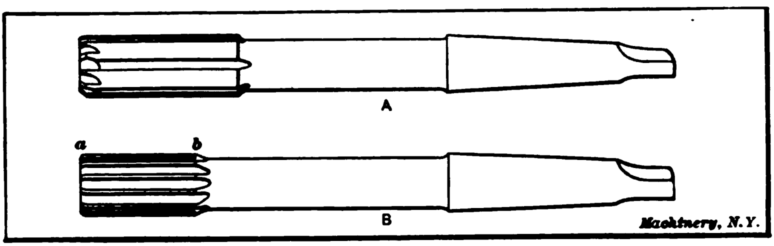


Fig. 37. Rose and Fluted Reamers

needs to be bored true. The best way to perform this operation in the lathe would be to clamp the finished surface of the casting directly against the faceplate by bolts and clamps *a*, *b*, *c*, and *d*, as shown; the work would then be turned just as though it were held in a chuck. By holding the casting in this way, face *e* will be finished parallel with the back surface because the latter is clamped directly against the true-running surface of the faceplate. If a casting of this shape were small enough it could also be held in the jaws of an independent chuck, but if the surface *e* needs to be exactly parallel with the back face, it is better to clamp the work to the faceplate. Most lathes have two faceplates: One of small diameter used principally for driving work turned between centers, and a large one for holding heavy or irregularly shaped pieces; either of these can be screwed on the spindle and the large faceplate has a number of slots through which clamping bolts can be inserted.

The proper way to clamp a piece to the faceplate depends, of course, largely on its shape and the location of the surface to be machined, but in any case it is necessary to hold it securely to prevent any shifting after a cut is started. Sometimes castings can be held by inserting bolts through previously drilled holes, but when clamps are used in connection with the bolts, their outer ends are supported by hard wood or metal blocks which should be just high enough to make the clamp bear evenly on the work. When deep roughing cuts have to be taken, especially on large diameters, it is well to bolt a piece to the faceplate and against one side of the casting, as at *D*, to act as a driver and prevent the work from shifting; but a driver would not be needed in this particular case. Of oourse a faceplate driver is always placed to the rear, as determined by the direction of rotation, because the work tends to shift backward when a cut is being taken. If the surface which is clamped against the faceplate is finished as in this case, the work will be less likely to shift if a piece of paper is placed between it and the faceplate. Work mounted on the faceplate is generally set true by some surface before turning. As the hole in this casting should be true with the round boss, the casting is shifted on the faceplate until the rough outer surface of the boss runs true;

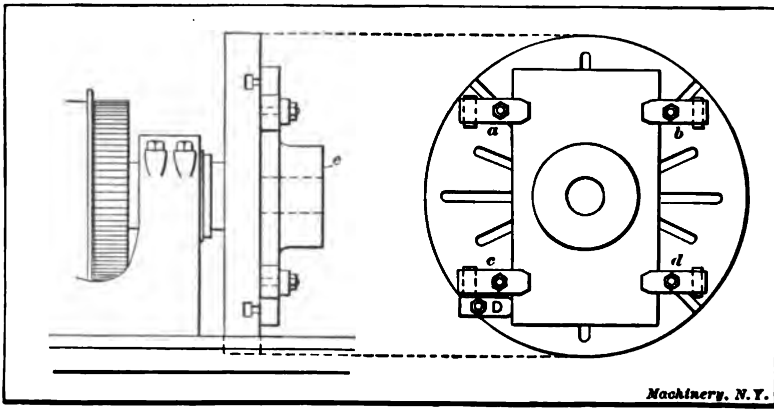


Fig. 38. Casting Clamped to Faceplate for Turning

the clamps which were previously set up lightly are then tightened. The face *e* is first turned by using a round-nosed tool. This tool is then replaced by a boring tool and the hole is finished to the required diameter. If the hole being bored is larger than the central hole in the faceplate, the casting should be clamped against parallel pieces, and not directly against the faceplate, to provide clearance for the tool when it reaches the inner end of the hole and prevent cutting the faceplate. The parallel pieces should be of the same thickness and be located near the clamps to prevent springing the casting.

Application of Angle-plate to Faceplate

Another example of faceplate work is shown in Fig. 39. This is a cast-iron elbow *E*, the two flanges of which are to be faced true and square with each other. The shape of this casting is such that it would be very difficult to clamp it directly to the faceplate, but it is easily held on an angle-plate *P*, which is bolted to the faceplate. The two surfaces of this angle-plate are square with each other so that when one flange of the elbow is finished and bolted against the angle-plate, the other will be faced square. When setting up an angle-plate for work of this kind, the distance from its work-holding side to the center of the faceplate is made equal to the distance *d* between the center of one flange and the face of the other, so that the flange to be faced will run about true when bolted in place. As the angle-plate and work are almost entirely on one side of the faceplate, a weight *W* is attached to the opposite side for counterbalancing. Very often weights are also needed to counterbalance offset parts that are

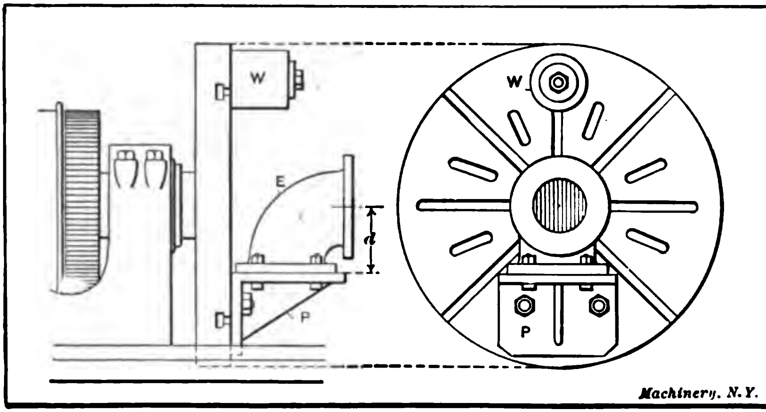


Fig. 30. Work Held on Angle-plate attached to Faceplate

bolted directly to the faceplate. Sometimes it is rather difficult to hold heavy pieces against the vertical surface of the faceplate while applying the clamps, and occasionally the faceplate is removed and placed in a horizontal position on the bench; the work can then be located about right, and after it is clamped, the faceplate is placed on the lathe spindle by the assistance of a crane.

Special faceplate jaws such as the one shown to the right in Fig. 27, can often be used to advantage for holding work on large faceplates. Three or four of these jaws are bolted to the faceplate which is converted into a kind of independent chuck. These faceplate jaws are especially useful for holding irregularly shaped parts as the different jaws can be located in any position.

CHAPTER VI

LATHE TURNING TOOLS

Notwithstanding the fact that a great variety of work can be done in the lathe, the number of turning tools required is comparatively small. Fig. 41 shows the forms of tools that are used principally, and typical examples of the application of these various tools are indicated in Fig. 42. The reference letters used in these two illustrations correspond for tools of the same type, and both views should be referred to in connection with the following description.

The tool shown at *A* is the form generally used for rough turning, that is for taking deep cuts when considerable metal has to be removed. At *B* a tool of the same type is shown, having a bent end which enables it to be used close up to a shoulder or surface *s* that might come in contact with the tool-rest if the straight form were employed. Tool *C*, which has a straight cutting end, is used on certain classes of work for taking light finishing cuts, with a coarse feed. As explained in Chapter V, this type of tool will leave a smooth finish even though

Fig. 40. Turning Tool with Inserted Cutter

the feed is coarse, provided the flat cutting edge is set parallel with the tool's travel so as to avoid ridges. Broad-nosed tools and wide feeds are better adapted for finishing cast iron than steel. When turning steel, if the work is at all flexible, a broad tool tends to gouge into it and for this reason round-nosed tools and finer feeds are generally necessary. A little experience in turning will teach more on this point than a whole chapter on the subject.

The side tools shown at *D* and *E* are for facing the ends of shafts, collars, etc. The first tool is known as a right-side tool because it operates on the right end or side of a shaft or collar, whereas the left-side tool *E* is used on the opposite side, as shown in Fig. 42. Side tools are also bent to the right or left because the cutting edge of a straight tool cannot always be located properly for facing certain surfaces. A bent right-side tool is shown at *F*. A form of tool that is frequently used is shown at *G;* this is known as a parting tool and is used for severing pieces and for cutting grooves, squaring corners, etc. The same type of tool having a bent end is shown at *H* (Fig.

42) severing a piece held in the chuck. Work that is held between centers should not be entirely severed with a parting tool unless a steady-rest is placed between the tool and faceplate, as otherwise the tool may be broken by the springing of the work just before the piece is cut in two. It should be noted that the sides of this tool slope inward

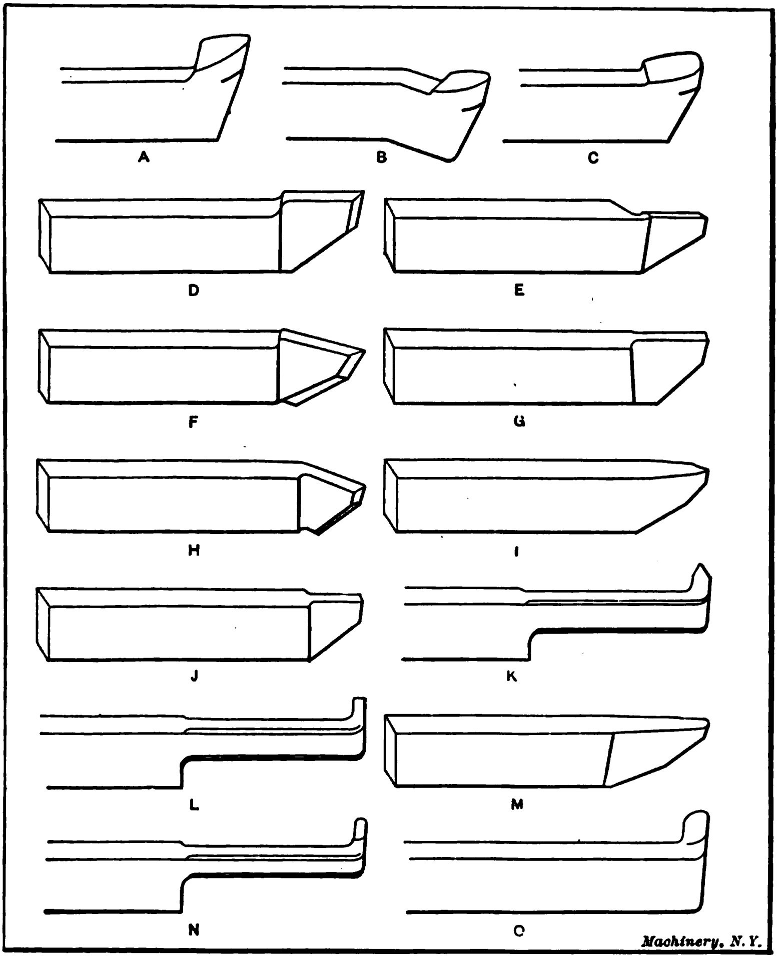


Fig. 41. Set of Lathe Turning Tools for General Work

back of the cutting edge to provide clearance when cutting in a narrow groove.

At *I* a thread tool is shown for cutting a U. S. standard thread. This thread is the form most commonly used in this country at the present time. A tool for cutting a square thread is shown at *J*. This is shaped very much like a parting tool except that the cutting

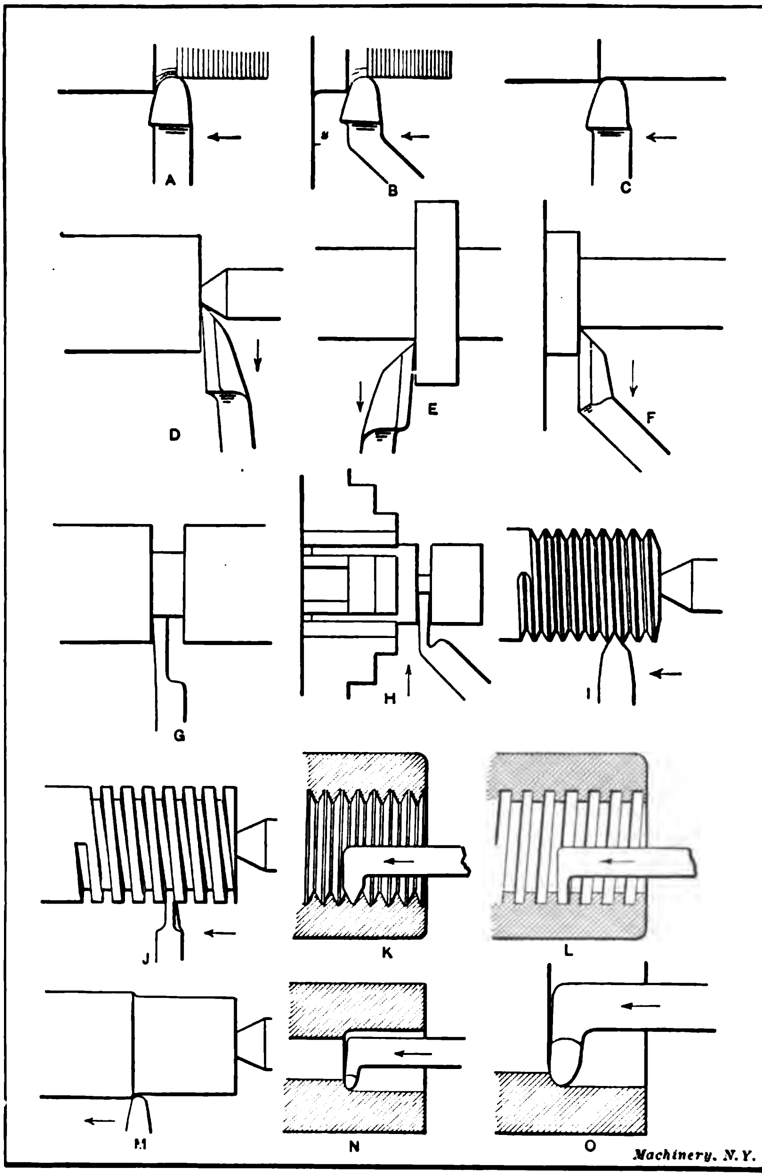


Fig. 42. Views illustrating Use of Various Types of Lathe Tools

end is inclined slightly to correspond with the helix angle of the thread, as explained in Chapter IV, of MACHINERY'S Reference Book, No. 92, which contains descriptions of different thread forms and methods of cutting them. Internal thread tools are shown at *K* and *L* for cutting U. S. standard and square threads in holes. It will be seen that these tools are somewhat like boring tools excepting the ends which are shaped to correspond with the thread which they are intended to cut.

A tool for turning brass is shown at *M*. Brass tools intended for general work are drawn out quite thin and they are given a narrow rounded point. The top of the brass tool is usually ground flat or without slope as otherwise it tends to gouge into the work, especially

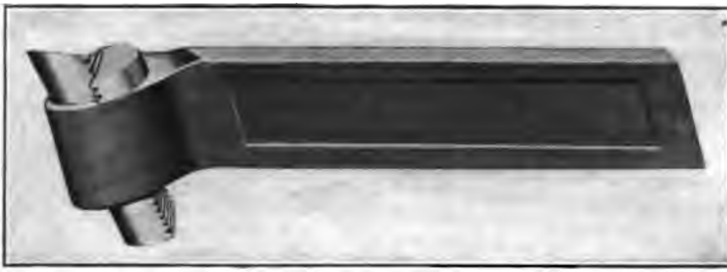


Fig. 43. Heavy Inserted-cutter Turning Tool

if the latter is at all flexible. The end of a brass tool is sometimes ground flat for turning large rigid work, such as brass pump linings, etc., so that a coarse feed can be used without leaving a rough surface. The tools at *N* and *O* are for boring or finishing drilled or cored holes. Two sizes are shown, which are intended for small and large holes, respectively.

The different tools referred to in the foregoing might be called the standard types because they are the ones generally used, and as Fig.

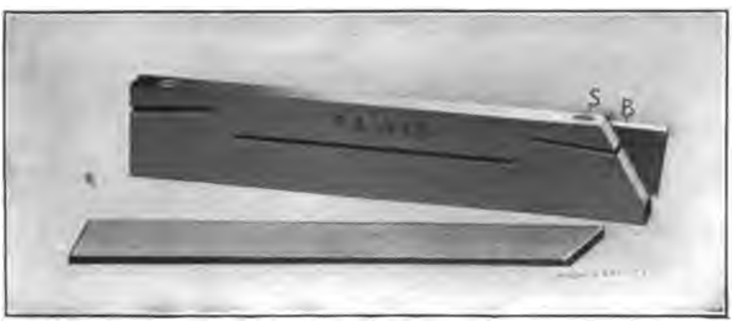


Fig. 44. Parting Tool with Inserted Blade

42 indicates, they make it possible to turn an almost endless variety of forms. Occasionally some special form of tool is needed for doing odd jobs, having, perhaps, an end bent differently or a cutting edge shaped to some particular form. Tools of the latter type, which are known as "form tools," are sometimes used for finishing surfaces that are either convex, concave, or irregular in shape. The cutting edges of these tools are carefully filed or ground to the required shape, and

the form given the tool is reproduced in the part turned. Ornamental or other irregular surfaces can be finished very neatly by the use of such tools. It is very difficult, of course, to turn convex or concave surfaces with a regular tool; in fact, it would not be possible to form a true spherical surface, for instance, without special equipment, because the tool could not be moved along a true curve by simply using the longitudinal and cross feeds. Form tools should be sharpened by

Fig. 45. Boring Tool with Inserted Cutter and Adjustable Bar

grinding entirely on the top surface, as any grinding on the end or flank would alter the shape of the tool.

Tool-holders with Inserted Cutters

All of the tools shown in Fig. 41 are forged from the bar, and when the cutting ends have been ground down considerably it is necessary to forge a new end. To eliminate the expense of this continual dressing of tools and also to effect a great reduction in the amount of tool

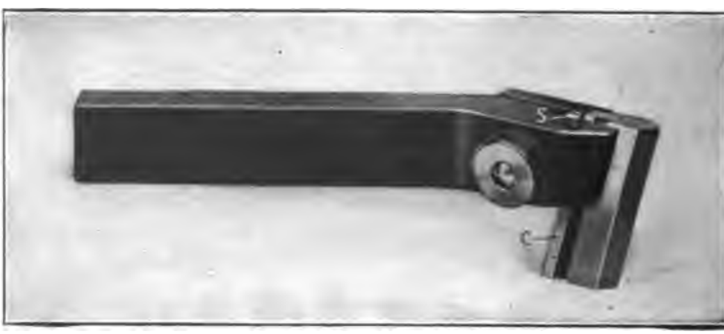


Fig. 46. Threading Tool

steel required, tool-holders having small inserted cutters are used in many shops.

A tool-holder of this type for outside turning is shown in Fig. 40. The cutter *C* is held in a fixed position by the set-screw shown, and it is sharpened, principally, by grinding the end, except when it is desired to give the top of the cutter a different slope from that due to its angular position. Another inserted-cutter turning tool is shown in Fig. 43, which is a heavy type intended for roughing. The cutter in this case, has teeth on the rear side engaging with corresponding teeth cut in the clamping block which is tightened by a set-screw on the side opposite that shown. With this arrangement, the cutter can be adjusted upward as the top is ground away.

A parting tool of the inserted blade type is shown in Fig. 44. The blade *B* is clamped by screw *S* and also by the spring of the holder when the latter is clamped in the tool-post. The blade can, of course, be moved outward when necessary. Fig. 45 shows a boring tool consisting of a holder *H*, a bar *B* that can be clamped in any position, and an inserted cutter *c*. With this type of boring tool, the bar can be extended beyond the holder just far enough to reach through the hole to be bored, which makes the tool very rigid. A thread tool of the holder type is shown in Fig. 46. The angular edge of the cutter *C* is accurately ground by the manufacturers, so that the tool is sharpened by simply grinding it flat on the top. As the top is ground away, the cutter is raised by turning screw *S* which can also be used for setting the tool to the proper height.

CHAPTER VII

STEADY- AND FOLLOW-RESTS

Occasionally long slender shafts, rods, etc., which have to be turned, are so flexible that it is necessary to support them at some point between the lathe centers. An attachment for the lathe known as a steadyrest is often used for this purpose. A steadyrest is composed of a frame containing three jaws *J* (Fig. 47), that can be adjusted in or out radially by turning screws *S*. The frame is hinged at *h*, thus allowing the upper half to be swung back (as shown by the dotted lines) for inserting or removing the work. The bolt-clamp *c* holds the hinged part in the closed position. The base of the frame has

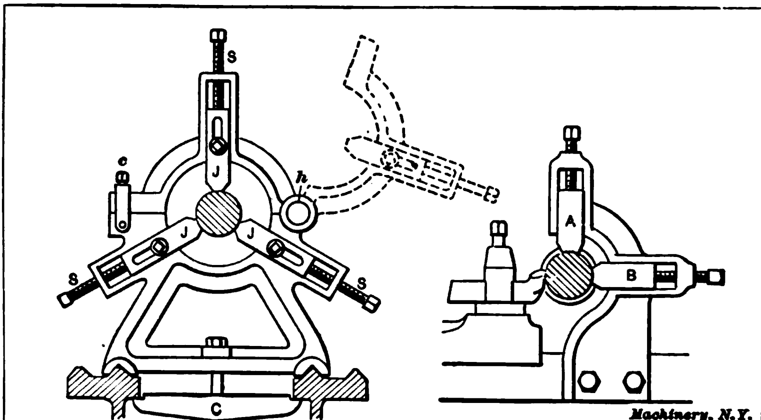


Fig. 47. Steady- and Follow-rests for Supporting Flexible Parts while Turning

V-grooves in it that fit the ways of the lathe bed. When the steadyrest is in use, it is secured to the bed by clamp *C*, and the jaws *J* are set in against the work, thus supporting or steadying it during the turning operation. The steadyrest must, of course, be located at a point where it will not interfere with the turning tool.

Supporting Flexible Work with a Steadyrest

Fig. 48 shows the application of the steadyrest to a long forged rod, having one small end, which makes it too flexible to be turned without support. As this forging is rough, a true surface *n* a little wider than the jaws *J* (Fig. 47) is first turned as a bearing for the jaws. This should be done very carefully to prevent the work from mounting the tool. A sharp pointed tool should be used and very light cuts taken. The steadyrest is next clamped to the lathe bed opposite the turned surface, and the jaws are adjusted in against the work, thus forming a kind of bearing. Care should be taken not to set up the jaws too tight as the work should turn freely but without play. The large part of the rod and central collar are then turned to size, this half being machined while the small part is in the rough and as stiff as possible. The rod is then reversed and the steady-rest is applied to the part just finished, as shown at *B*, thus supporting

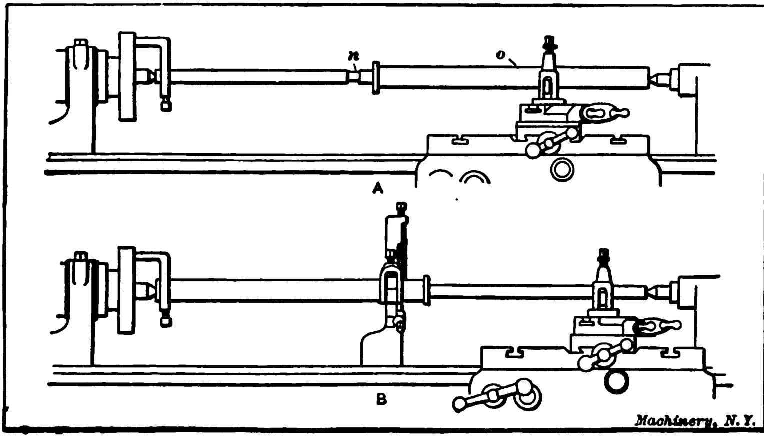


Fig. 48. Application of Steadyrest

the work while the small end is being turned. That part against which the jaws bear should be kept well oiled and if the surface is finished, it should be protected by placing a strip of emery cloth beneath the jaws with the emery side out; a strip of belt leather is also used for this purpose, the object in each case being to prevent the jaws from scratching and marring the finished surface, as they tend to do, especially if at all rough.

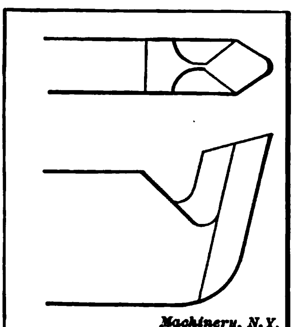


Fig. 49. Diamond-point Turning Tool

If the work were too flexible to permit turning a spot at *n*, this could be done by first "spotting" it at some point *o*, and placing the steady-rest at that point while turning another spot at *n*. The tool shown in Fig. 49 is a good form to use for work of this kind because of its narrow point. This is known as a "diamond point," and is frequently used for light turning. The shape of this tool is clearly shown in the illustration. The V-shaped cutting edge is usually rounded slightly at the point, and the top slopes backward from the cutting edge, as shown.

Sometimes it is desirable to apply a steady-rest to a surface that does not run true and one which is not to be turned; in such a case a device called a "cat-head" is used. This is simply a sleeve *S* (Fig. 51) which is placed over the untrue surface to serve as a bearing for the steadyrest. The sleeve is made to run true by adjusting the four set-screws at each end, and the jaws of the steadyrest are set against it, thus supporting the work.

Application of Steadyrest when Boring—Use of "Bridles" or "Hold-backs"

Another example illustrating the use of the steadyrest is shown in Fig. 50. The rod *R* is turned on the outside and a hole is to be bored in the end (as shown by dotted lines) true with the outer surface. If the centers used for turning the rod are still in the ends, as they would be ordinarily, this work could be done very accurately by the following method: The rod is first placed between the centers as for turning, with a driving dog *D* attached, and the steady-rest jaws *J* are set against it near the outer end, as shown.

Before any machine work is done, means must be provided for holding

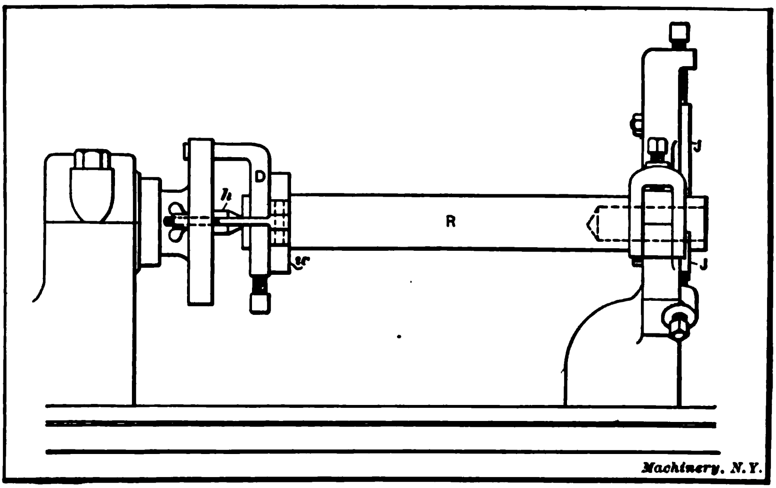


Fig. 50. Shaft supported by Steadyrest for Drilling and Boring End

the rod back against the headstock center *h*, because, for an operation of this kind, the outer end cannot be supported by the tailstock center; consequently the work tends to shift to the right. One method of accomplishing this is shown in the illustration. A hard-wood piece *w*, having a hole somewhat larger than the work, is clamped against the dog, in a crosswise position, by the swinging bolts and thumb-screws shown. If the dog is not square with the work, the wood piece should be canted so that the bearing will not be all on one side. For large heavy parts a similar "bridle" or "hold-back"—as this is commonly called—is made by using steel instead of wood for the part *w*. Another very common method which requires no special equipment is illustrated in Fig. 52. Ordinary leather belt lacing *L* is attached to the work and faceplate while the latter is screwed off a few turns as shown. Then the lacing is drawn up by hand and tied, and the faceplate is screwed on the spindle, thus tightening the laeing and drawing the work against the headstock center. The method of applying the lacing is quite clearly indicated in the illustration. If a small driving faceplate is used, it may be necessary to drill holes for the belt lacing, as shown.

A hole is next drilled in the end of the rod by using a twist drill and the tailstock, as explained in connection with Fig. 34, Chapter V. If the hole is finished by boring, a depth mark should be made on the

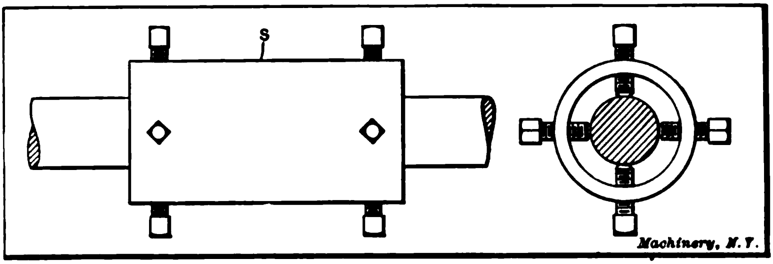


Fig. 51. Cat-head which is sometimes used as Bearing for Steadyrest

tool shank that will warn the workman of the cutting end's approach to the bottom. A chuck can also be used in connection with a steady-rest for doing work of this kind as shown in Fig. 53, the end of the rod being held and driven by the chuck *C*. If the work is centered, it can be held on these centers while setting the steadyrest and adjusting the chuck, but if the ends are without centers, a very good way is to make light centers in the ends with a punch; after these are properly

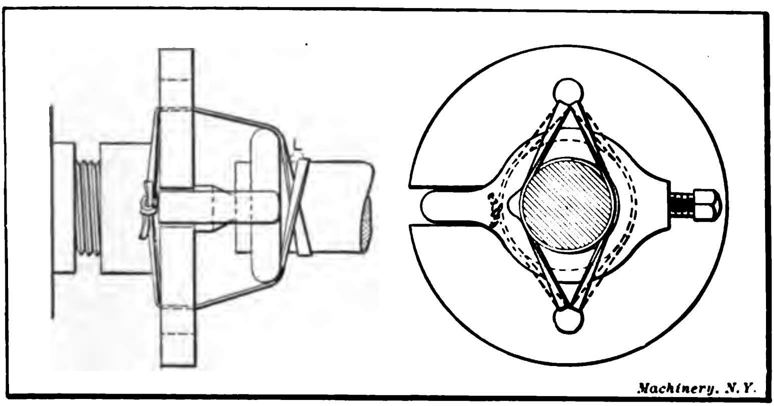


Fig. 52. Hold-back used when Outer End of Work is held in Steadyrest

located they are used for holding the work until the steadyrest and chuck jaws have been adjusted. In case it is necessary to have the end hole very accurate with the outside of the finished rod, a test indicator *I* should be applied to the shaft as shown. This is an instrument which shows with great accuracy whether a rotating part runs true and it is also used for many other purposes in machine shops. The indicator is held in the lathe toolpost and the contact point beneath the dial is brought against the work. If the latter does not run true, the hand of the indicator vibrates and the graduations on the dial show how much the work is out in thousandths of an inch.

The Follow-rest

For certain classes of long slender work, such as shafts, etc., a follow-rest is often used for supporting the work while turning. The follow-rest differs from the steadyrest in that it is attached to and travels with the lathe carriage. The type illustrated to the right in

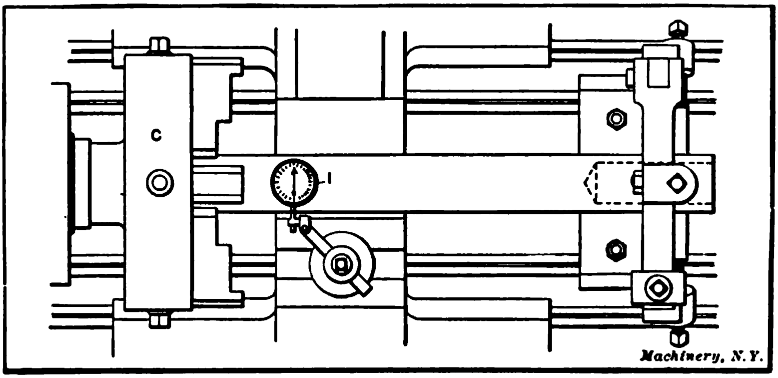


Fig. 53. Testing Work with Dial Indicator

Fig 47 has two adjustable jaws which are located nearly opposite the turning tool, thus providing support where it is most needed. In using this rest, a cut is started at the end and the jaws are adjusted to this turned part. The tool is then fed across the shaft, which cannot spring away from the cut because of the supporting jaws. Some follow-rests have, instead of jaws, a bushing bored to fit the diameter being turned, different bushings being used for different diameters. The bushing forms a bearing for the work and holds it rigidly. Whether a bushing or jaws are used, the tool is slightly in advance of the supporting member.

CHAPTER VIII

HOW TO CUT A THREAD IN A LATHE

When threads are cut in the lathe a tool *t* is used (see Fig. 55), having a point corresponding to the shape of the thread, and the carriage is moved along the bed a certain distance for each revolution of the work (the distance depending on the number of threads to the inch being cut) by the lead-screw *S* which is rotated by gears *a*, *b* and *c*, which receive their motion from the spindle. As the rate of the carriage travel per revolution of the work, and, consequently, the number of threads per inch that is cut, depends on the size of the gears *a* and *c* (called change gears) the latter have to be changed for cutting different threads. The proper change gears to use for cutting a given number of threads to the inch, is ordinarily determined

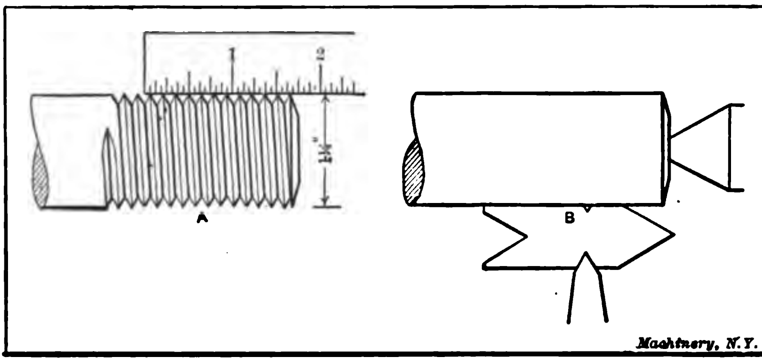


Fig. 54. Measuring Number of Threads per Inch—Setting Thread Tool

by referring to a table or "index plate" *I* which shows what the size of gears *a* and *c* should be, or the number of teeth each should have, for cutting any given number of threads per inch.

Selecting the Change Gears

Suppose a V-thread is to be cut on the end of the bolt *B*, having a diameter of 1¼ inch and seven threads per inch of length, as shown at *A* in Fig. 54, which is a standard number for that diameter. First the change gears to use are found on plate *I* which is shown enlarged in Fig. 56. This plate has three columns: The first contains different numbers of threads to the inch, the second the size gear to place on the "spindle" or "stud" at *a* for different threads, and the third the size of gear *c* for the lead-screw. As the thread selected as an example has seven threads per inch, gear *a* should have 48 teeth, this being the number given in the second column opposite figure 7 in the first. By referring to the last column, we find that the lead-screw gear should

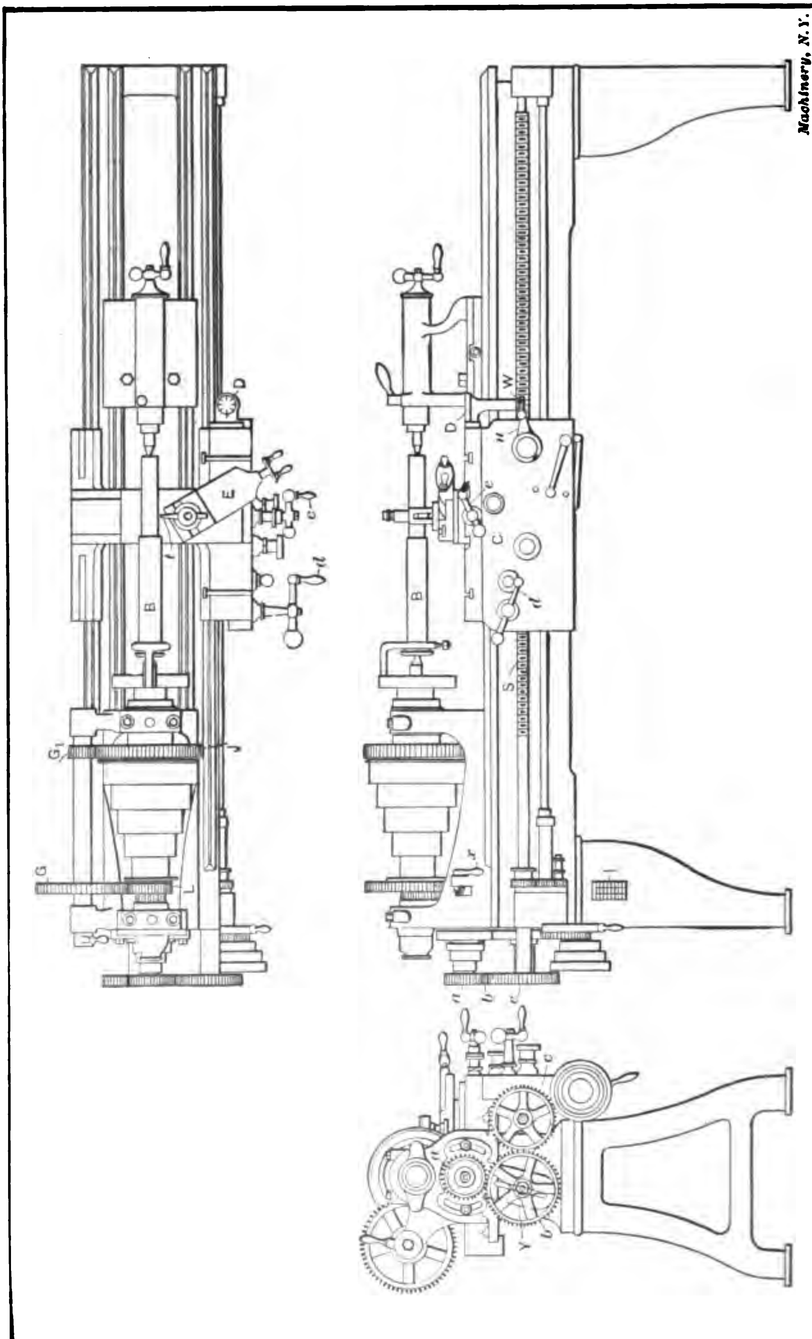


Fig. 55. Plan and Elevations of Engine Lathe

have 84 teeth. These gears are selected from an assortment provided with the lathe and they are placed on the spindle and lead-screw, respectively. Intermediate gear *b* does not need to be changed as it is simply an "idler" for connecting gears *a* and *c*. Gear *b* is mounted on a swinging yoke *Y* so that it can be adjusted to mesh properly with different gear combinations; after this adjustment is made, the lathe is geared for cutting seven threads to the inch. (The change gears of many modern lathes are so arranged that different combinations are obtained by simply shifting a lever. A lathe having this quick-change gear mechanism is described in Chapter VI of MACHINERY'S Reference Book No. 92.) The work *B* is then placed between the centers just as it would be for turning, with the end to be threaded turned to a diameter of 1¼ inch, which is the outside diameter of the the thread.

16" LATHE

THREAD	SPINDLE	SCREW
2	96	48
3	96	72
4	48	48
5	48	60
6	48	72
7	48	84
8	48	96
9	48	108
10	24	60
11	24	66
11½	24	69
12	24	72
13	24	78
14	24	84
16	24	96
18	24	108
20	24	120

Machinery, N.Y.

Fig. 56. Index Plate showing Gear Changes for Threading

The Thread Tool

The form of tool used for cutting a V-thread is shown at *A*, Fig. 57. The end is ground V-shaped and to an angle of 60 degrees, which corresponds to the angle of a standard V-thread. The front or flank *f* of the tool is ground back to an angle to provide clearance, but the top is left flat or without slope. As it is very important to grind the end to exactly 60 degrees, a gage *G* is used, having 60-degree notches to which the tool-point is fitted. The tool is clamped in the toolpost as shown in the plan view, Fig. 55, square with the work, so that both sides of the thread will be cut to the same angle with the axis of the work. A very convenient way to set a thread tool square is illustrated at *B*, Fig. 54. The thread gage is placed against the part to be threaded, as shown, and the tool is adjusted until the angular sides of the point bear evenly in the 60-degree notch of the gage. The top of the tool point should also be at the same height as the lathe centers, as otherwise the angle of the thread will not be correct.

Cutting the Thread

The lathe is now ready for cutting the thread. This is done by taking several cuts, as indicated at *A*, *B*, *C* and *D* in Fig. 58, the tool being fed in a little farther for each successive cut until the thread is finished. When these cuts are being taken, the carriage is moved along the bed ,as previously explained, by the lead-screw *S*, Fig. 55. The carriage is engaged with the lead-screw by turning lever *u* which causes the halves of a split nut to close around the screw. The way a lathe is handled when cutting a thread is as follows: After the lathe is started, the carriage is moved until the tool-point is slightly beyond the right end of the work, and the tool is fed in far enough to take the first cut. The carriage is then engaged with the lead-screw, by operating lever *u*, and the tool moves to the left (in this case 1/7 inch for each revolution of the work) and cuts

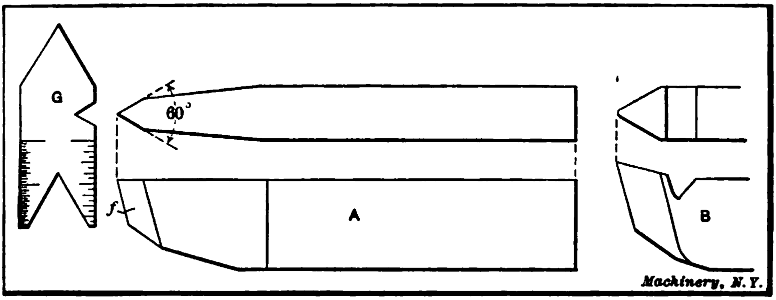


Fig. 57. Thread Tools and Gage for Testing Angle of End

a winding groove as at *A*, Fig. 58. When the tool has moved as far as the thread is wanted, it is withdrawn by a quick turn of handle *e*, and the carriage returned to the starting point for another cut. The tool is then fed in a little farther and a second cut is taken as at *B*, and this operation is repeated as at *C* and *D* until a "full" thread is cut or until the top of the thread is sharp. The thread is then tested for size, but before referring to this part of the work, the way the carriage is returned to the starting point after each cut, should be explained.

When the tool is withdrawn at the end of the first cut, if the carriage is disengaged from the lead-screw and returned by hand, the tool may or may not follow the first cut when the carriage is again engaged with the lead-screw. If the number of threads to the inch being cut is a multiple of the number on the lead-screw *S*, then the carriage can be returned by hand and engaged with the lead-screw at random and the tool will follow the first cut. For example, if the lead-screw has six threads per inch, and 6, 12, 18 or any number of threads is being cut that is a multiple of six, the carriage can be engaged at any time and the tool will always follow the original cut. This is not the case, however, when the number of threads being cut is not a multiple of the number on the lead-screw. One method of bringing the carriage back to the starting point when cutting threads which are not multiples, is to reverse the lathe (by shifting the overhead driving belts) in order to bring the tool back to the starting point without disengaging the carriage; in this way the tool is kept in the same relation to the work, and the carriage is not disengaged from the lead-screw until the thread is finished. This is a good method when cutting short threads having a length of say two or three inches; but when they are longer, and especially when the diameter is comparatively large (which means a slower speed), it is rather slow as considerable time is wasted while the tool is moving back to its starting point. This is due to the fact that the carriage is moved slowly by the lead-screw, but when disengaged, it can be traversed quickly by turning handle *d*, Fig. 55.

A method of returning the carriage by hand when the number of threads being cut is not a multiple of the number on the lead-screw is as follows: The tool is moved a little beyond the right end of the work and the carriage is engaged. The lathe is then turned forward by hand to take up any lost motion, and a line is made on the lathe bed showing the position of the carriage. The positions of the spindle and lead-screw are also marked by chalking a tooth on both

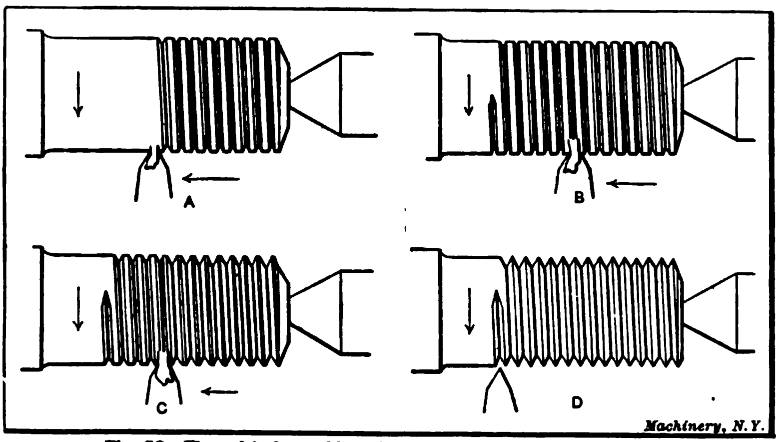


Fig. 58. Thread is formed by taking a number of Successive Cuts

the spindle and lead-screw gears, which happens to be opposite a corner or other point on the bed. After a cut is taken, the carriage is returned by hand to the original starting point as shown by the line on the bed, and is again engaged when the chalk marks show that the spindle and lead-screw are in their original position; the tool will then follow the first cut. If the body of the tailstock is moved against the bridge of the carriage before starting the first cut, the carriage can be located for each following cut by moving it back against the tailstock, and it will not be necessay to have a line on the bed.

Indicator or Chasing Dial for Catching Threads

On some lathes there is an indicator for "catching threads," as this is called in shop language. This is a simple device attached to the carriage and consists of a graduated dial *D* and a worm-wheel *W* (see Figs. 55 and 59) which meshes with the lead-screw, so that the dial is revolved by the lead-screw when the carriage is stationary, and when the carriage is moved by the screw, the dial remains stationary.

The indicator is used by engaging the carriage when one of the graduation lines is opposite the arrow mark; after a cut is taken the carriage is returned by hand and when one of the graduation lines again moves opposite the arrow, the half-nuts are thrown into mesh, as before, and this is repeated for each successive cut, thus causing the tool to always come right with the thread. If the number of threads per inch is even, engagement can be made when any line is opposite the arrow, but for odd numbers such as 3, 7, 9, 11, etc., one of the four long or numbered lines must be used. Of course, if the thread being cut is a multiple of the number on the lead-screw, engagement can be made at any time.

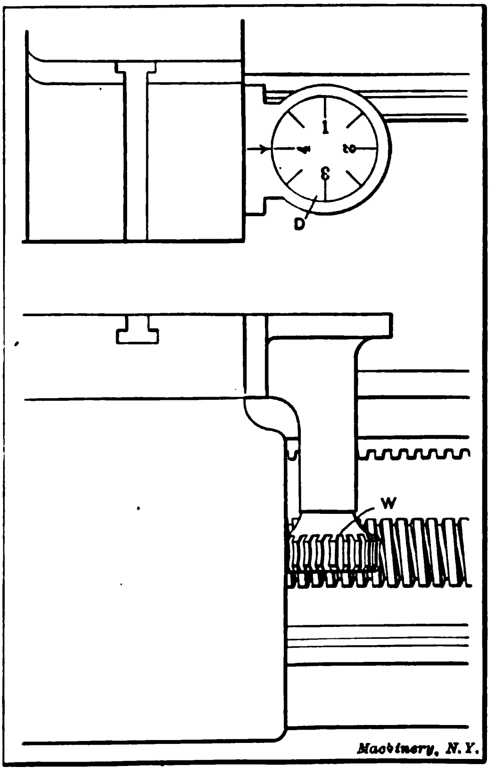


Fig. 59. Indicator used when Cutting Threads

Having considered the use of the indicator, its principle will be explained. The number of teeth in worm-wheel *W* is some multiple of the number of threads per inch of the lead-screw, and the number of teeth in the wheel, divided by the pitch of the screw, equals the number of graduations on the dial. For example, if the lead-screw has six threads per inch, the worm-wheel could have twenty-four teeth, in which case the dial would have four divisions, each representing an inch of carriage travel, and by sub-dividing the dial into eighths (as shown) each line would correspond to ½ inch of travel. The dial, therefore, would enable the carriage to be engaged with the lead-screw at points equal to a travel of one-half inch. To illustrate the advantage of this, suppose ten threads per inch are being cut and (with the lathe stationary) the carriage is disengaged and moved 1/6 inch or one thread on the lead-screw; the tool point will also have moved 1/6 inch, but it will not be opposite the next thread groove in the work as the pitch is 1/10 inch. If the carriage is moved another thread on the lead-screw, or 2/6 inch, the tool will still be out of line with the thread on the work, but when it has moved three threads, or

½ inch, the tool will then coincide with the original cut because it has passed over exactly five threads. This would be true for any number of threads per inch that is divisible by 2. If the thread being cut had nine threads per inch, or any other odd number, the tool would only coincide with the thread at points 1 inch apart. Therefore, the carriage can only be engaged when one of the four graduations representing an inch of travel is opposite the arrow, when cutting odd threads; whereas even numbers can be "caught" by using any one of the eight lines.

This indicator can also be used for "catching" fractional threads. As an illustration, suppose 11½ threads per inch are being cut, and the carriage is engaged the first time when graduation line 1 is opposite the arrow; engagement would then be made for each successive cut, when either line 1 or 3 were opposite the arrow, or in other words

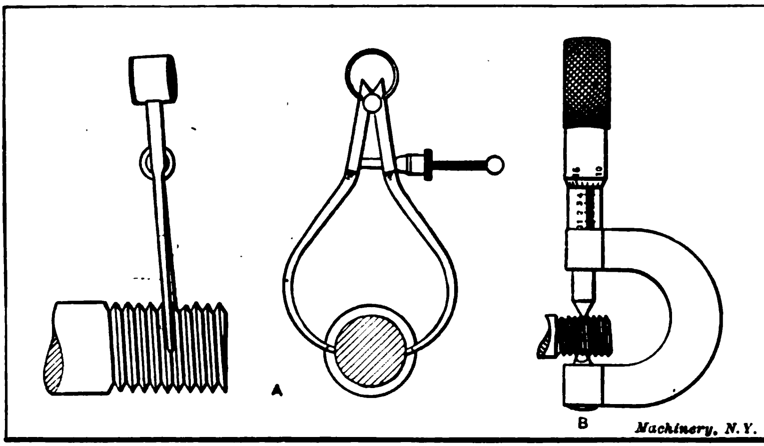


Fig. 60. Testing Diameter of Thread with Calipers and Micrometer

at spaces equal to a carriage movement of 2 inches. As the use of the indicator when cutting fractional threads is liable to result in error, it is better to keep the half-nuts in engagement and return the carriage by reversing the lathe.

Testing the Size of the Thread

When the thread tool has been fed in far enough to form a complete thread as at *D*, Fig. 58, the thread is then tested for size. If we assume that the bolt is being threaded for a standard 1¼ nut, it would be removed from the lathe and the test made by screwing a nut on the end. If the thread were too large, the nut might screw on very tightly or not at all; in either case, the work would again be placed in the lathe and a light cut taken over it to reduce the thread to the proper size. When replacing a threaded part between the centers, it should be put back in the original position, that is, with the tail of the driving dog in the same slot of the faceplate previously occupied. As it is difficult to tell just when a thread is cut to the exact size, special thread calipers having wedge-shaped ends are sometimes used for measuring the diameter of the thread at the bottom of the grooves, or the root diameter, as shown at *A*, Fig. 60. These calipers can be set from a tap corresponding to the size of the thread being cut, or from a previously threaded piece of the right size. Another form of caliper for testing threads is shown at *B*. This is one of the micrometer type and is intended for very accurate work. The spindle of this micrometer has a conical end and the "anvil" is

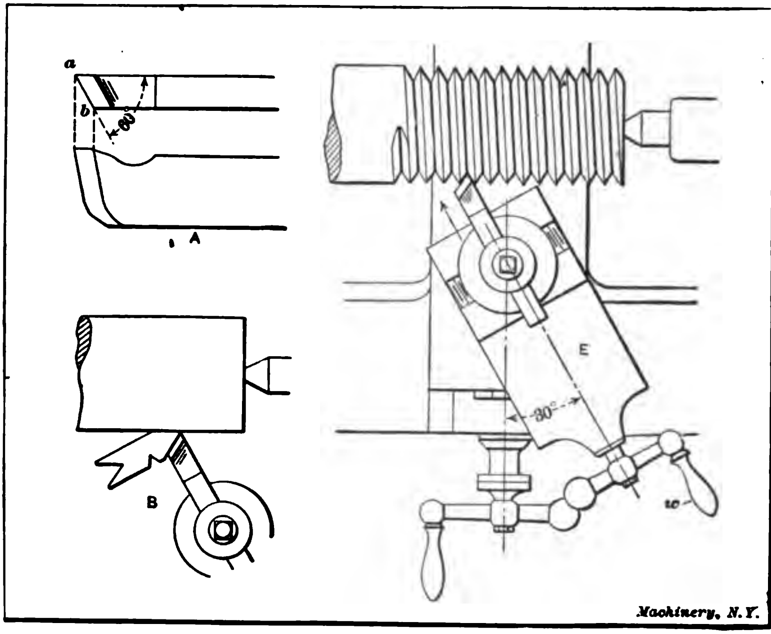


Fig. 61. Cutting Thread by using Compound Rest

V-shaped, and these ends bear on the sides of the thread or the surfaces which form the bearing when the screw is inserted in a nut or threaded hole.

Replacing Sharpened Tool—Tool for Roughing

If it is necessary to sharpen the thread tool before the thread is finished, it should be re-set square with the work by testing with the thread gage as at *B*, Fig. 54. The carriage is then engaged with the lead-screw and the lathe is turned forward to bring the tool opposite the partly finished thread and also to take up any backlash or lost motion in the gears or half-nut. If the tool-point is not in line with the thread groove previously cut, it can be shifted sidewise by feeding the compound rest *E* in or out, provided the latter is set in an angular position as shown in the plan view, Fig. 55.

If the thread tool is ground flat on the top as at *A*, Fig. 57, it is not a good tool for removing metal rapidly as neither of its two cutting edges has any slope. In order to give each cutting edge a backward slope, it would be necessary to grind the top surface hollow or concave, which would be impracticable. When a coarse thread is to be cut, a tool shaped as at *B* can be used to advantage for rough turning the thread groove, which is afterward finished to the correct depth and angle by tool *A*. This roughing tool is ground with a backward slope from the point and the latter is rounded to make it stronger.

Use of Compound Rest for Thread Cutting

Another form of thread tool is shown at *A*, Fig. 61, which is very good, especially for cutting coarse threads. When this tool is used, the compound rest *E* is set to an angle of 30 degrees, as shown, and it is fed in for the successive cuts by handle *w* in the direction indicated by the arrow. It will be seen that the point *a* of the tool moves at an angle of 60 degrees with the axis of the work, thus forming one side of the thread, and the cutting edge *a*—*b*, which can be set as shown at *B*, forms the opposite side and does all the cutting. As this edge is given a backward slope, as shown, it cuts easily and enables threading operations to be performed quickly. Threads cut in this way are often finished by taking a light cut with a regular thread tool. The cutting edge *a*—*b* is ground to an angle of 60 degrees (or slightly less, if anything) with the side, as shown by the top view.

All the threads that have been illustrated in connection with the foregoing description have been of the simple V-form. There are, however, several other forms of threads in use and these various threads and the way in which they are cut is explained in Chapter IV of MACHINERY's Reference Book No. 92.

When cutting threads in steel or wrought iron, some sort of lubricant is usually applied to the tool to preserve the cutting end and give a smooth finish to the thread. Sperm or lard oil is commonly used for this purpose. If the thread is small, the lubricant may be applied from an ordinary oil can, but when cutting comparatively large threads, it is better to have a stream of oil constantly playing upon the tool-point. This constant flow may be obtained by mounting a can having a spout leading to the tool on a bracket at the rear of the carriage.

It should be mentioned in this connection that cooling compounds are also used on regular turning tools cutting steel or wrought iron. Cast iron and brass are machined dry. A compound that is widely used is composed of water in which a quantity of sal soda has been dissolved. The use of cooling water permits higher cutting speeds, and gives a smoother finish, known as a "water" finish. To secure the best results, a rather large flow of soda water should be applied continuously on the chip at the point where it is being severed by the tool.

CHAPTER IX

CALCULATING CHANGE GEARS FOR THREAD CUTTING

As explained in Chapter VIII, the change gears for cutting threads of various pitches are shown by a table attached to the lathe. The proper gears to be used can be calculated, but the use of the table saves time and tends to avoid mistakes. Every machinist, however, should know how to determine the size of gears used for cutting any number of threads to the inch, but before referring to any rules, let us first consider why a lathe cuts a certain number of threads to the inch and how this number is changed by the use of different gears.

As the carriage *C* and the tool are moved by the lead-screw *S*, Fig. 55, which is geared to the spindle, the number of threads to the inch that are cut depends, in every case, on the number of turns the work makes while the lead-screw is moving the carriage one inch. If the lead-screw has six threads per inch, it will make six revolutions while the carriage and the thread tool travel one inch along the piece to be threaded. Now if the change gears *a* and *c* are so proportioned that the spindle makes the same number of revolutions as the lead-screw, in a given time, it is evident that the tool will cut six threads per inch. If the spindle revolved twice as fast as the lead-screw, it would make twelve turns while the tool moved one inch, and consequently twelve threads per inch would be cut; but to get this difference in speeds it is necessary to use a combination of gearing that will cause the lead-screw to revolve once while the lathe spindle and work make two revolutions.

Suppose that nine threads to the inch are to be cut and the lead-screw has six threads per inch. In this case the work must make nine revolutions while the lead-screw makes six and causes the carriage and thread tool to move one inch, or in other words, one revolution of the lead-screw corresponds to one and one-half revolution of the spindle; therefore, if the lead-screw gear has 36 teeth, the gear on the spindle stud should have only 24 teeth. The spindle stud will then revolve one and one-half times faster than the lead-screw, provided it rotates at the same rate of speed as the main lathe spindle. The number of teeth in the change gears that is required for a certain pitch, can be found by multiplying the number of threads per inch of the lead-screw, and the number of threads per inch to be cut, by the same multiplier. The formula which expresses the relation between threads per inch of lead screw, threads per inch to be cut, and the number of teeth in the change gears, is as follows:

$$\frac{\text{threads per inch of lead-screw}}{\text{threads per inch to be cut}} = \frac{\text{teeth in gear on spindle stud}}{\text{teeth in gear on lead-screw}}$$

Applying this to the example given, we have $\frac{6}{9} = \frac{24}{36}$ The values of 36 and 24 are obtained by multiplying 6 and 9, respectively, by 4, which, of course, does not change the proportion. Any other number could be used as a multiplier, and if gears having 24 and 36 teeth were not available, this might be necessary. For example, if there were no gears of this size, some other multiplier as 5 or 6 might be used.

A general rule for finding change gears by this method would be as follows: Place the number of threads in the lead-screw in the numerator and the number to be cut in the denominator and then multiply both numerator and denominator by some number, until numbers are obtained which correspond to the numbers of teeth in gears that are available. The number obtained by multiplying the numerator represents the gear for the spindle stud, and the number obtained by multiplying the denominator, the gear for the lead-screw. As an example, suppose the number of teeth in the change gears supplied with the lathe are 24, 28, 32, 36, etc., increasing by four teeth up to 100, and assume that the lead-screw has six threads per inch and that ten threads per inch are to be cut. Then,

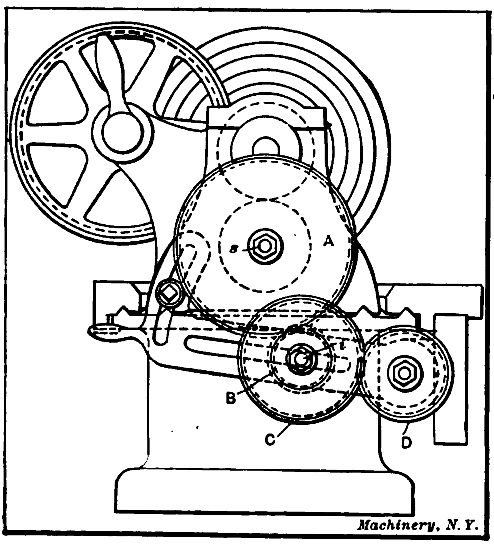


Fig. 62. Lathe having Compound Gears

$$\frac{6}{10} = \frac{6 \times 4}{10 \times 4} = \frac{24}{40}$$

By multiplying both numerator and denominator by 4, we obtain two available gears having 24 and 40 teeth, respectively. The 24-tooth gear goes on the spindle stud and the 40-tooth gear on the lead-screw. The number of teeth in the intermediate gear *b* which connects the stud and lead screw gears, is of no consequence.

We have assumed in the foregoing that the spindle stud (on which gear *a* is mounted) and the spindle made the same number of revolutions. In some lathes, however, these two members do not rotate at the same speed, so that if equal gears were placed on the lead-screw and spindle stud, the spindle would not make the same number of revolutions as the lead-screw. A very convenient way to determine the gears to use in such a case is as follows: First find the number of threads per inch cut when gears of the same size are placed on the lead-screw and spindle, either by actual trial or by referring to the index plate. Then use this number as the numerator instead of the actual number of threads per inch in the lead-screw, and proceed as previously described.

Change Gears for Lathes with Compound Gearing

When gearing is arranged as shown in Fig. 55, it is referred to as simple gearing, but sometimes it is necessary to introduce two gears (*B* and *C*) between the stud and screw as in Fig. 62, which is termed compound gearing. The method of figuring compound gearing is practically the same as that for simple gearing, except that the numerator and denominator are divided into two factors, each of which is multiplied by the same number to obtain the number of teeth in the change gears, as before.

Suppose the lathe has a lead-screw with six threads per inch and that the numbers of teeth in the gears available are 30, 35, 40 and so on, increasing by 5 up to 100. If for example, 24 threads per inch are to be cut, 6 is placed in the numerator and 24 in the denominator as before. The numerator and denominator are then divided into factors and each pair of factors is multiplied by the same number to find the gears, thus:

$$\frac{6}{24} = \frac{2 \times 3}{4 \times 6} = \frac{(2 \times 20) \times (3 \times 10)}{(4 \times 20) \times (6 \times 10)} = \frac{40 \times 30}{80 \times 60}$$

The last four numbers indicate the gears which should be used. The upper two, having 40 and 30 teeth, are the driving gears and the lower two having 80 and 60 teeth, are the driven gears. The driving gears are gear *A* on the spindle stud and gear *C* on the intermediate stud, meshing with the lead-screw gear, and the driven gears are gears *B* and *D*. It makes no difference which of the driving gears is placed on the spindle stud, or which of the driven is placed on the lead-screw. As another illustration, suppose we are to cut 1¾ thread per inch on a lathe with a lead-screw having six threads per inch, and that the numbers of teeth in the gears range from 24 to 100, increasing by 4.

$$\frac{6}{1\frac{3}{4}} = \frac{2 \times 3}{1 \times 1\frac{3}{4}} = \frac{(2 \times 36) \times (3 \times 16)}{(1 \times 36) \times (1\frac{3}{4} \times 16)} = \frac{72 \times 48}{36 \times 28}$$

The gear having 72 teeth is placed on the spindle stud *s*, the one with 48 on the intermediate stud *i*, meshing with the lead-screw gear. These two gears (72 and 48 teeth) are the driving gears. The gears with 36 and 28 teeth are placed on the lead-screw and on the intermediate stud and are the driven gears.

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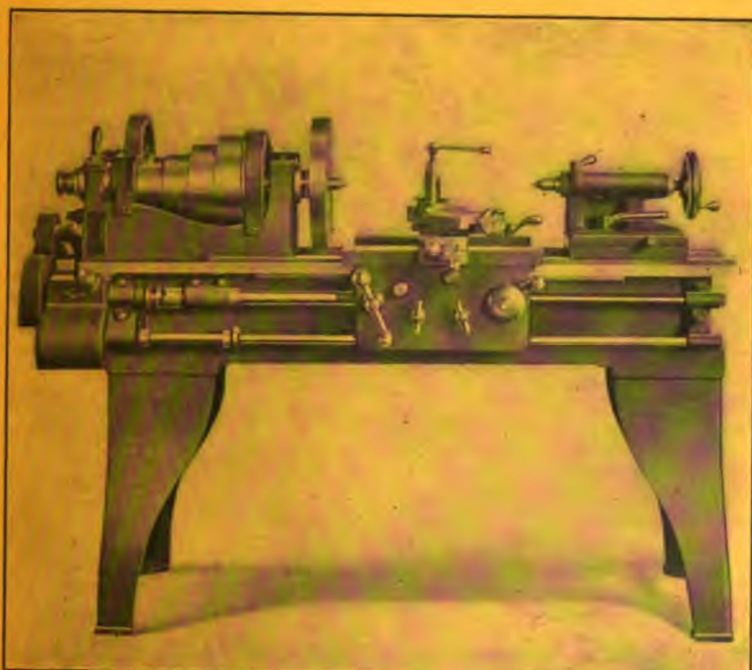

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NUMBER 92

OPERATION OF MACHINE TOOLS

By **Franklin D. Jones**

Second Edition

THE LATHE

PART II

CONTENTS

CHAPTER I

TAPER TURNING

It is often necessary, in connection with lathe work, to turn parts tapering instead of straight or cylindrical. If the work is mounted between the centers, one method of turning a taper is to set the tailstock center out of alignment with the headstock center. When both of these centers are in line, the movement of the tool is parallel to the axis of the work and, consequently, a cylindrical surface is produced; but if the tailstock h_1 is set out of alignment as shown in

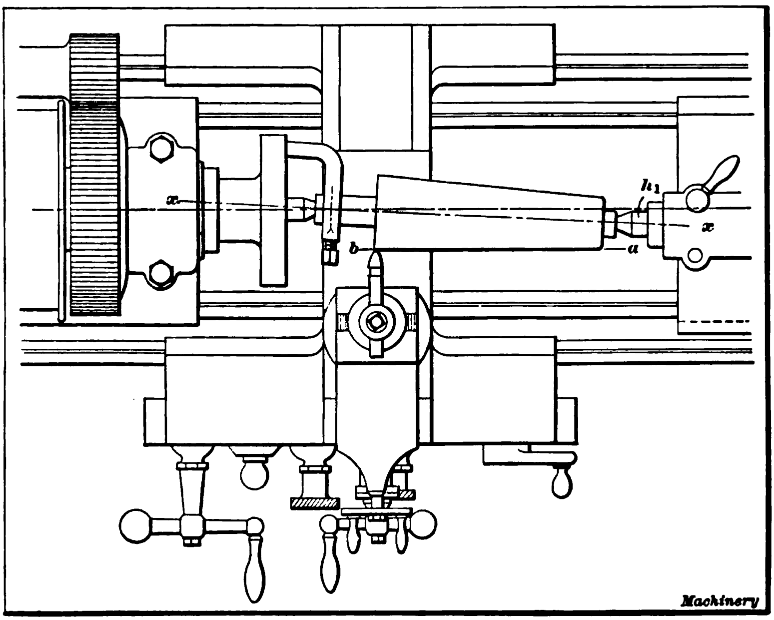


Fig. 1. Taper Turning by the Offset-center Method

Fig. 1, the work will then be turned tapering as the tool is traversed from a to b, because the axis $x—x$ is at an angle with the movement of the tool. Furthermore the amount of taper or the difference between the diameters at the ends for a given length, will depend on how much center h_1 is set over from the central position.

The amount of taper is usually given on drawings in inches per foot, or the difference in the diameter at points twelve inches apart. For example, the taper of the piece shown at A, Fig. 2, is 1 inch per foot, as the length of the tapering surface is just twelve inches and the difference between the diameters at the ends is 1 inch. The conical roller shown at B has a total length of 9 inches and a tapering surface 6 inches long, and in this case the taper per foot is also 1 inch, there being a difference of ½ inch in a length of 6 inches or 1 inch in twice that length. When the taper per foot is known, the amount that the tailstock center should be set over for turning that taper, can easily be estimated, but it should be remembered that the setting obtained in this way is not absolutely correct, and is only intended to locate the center approximately. When a taper needs to be at all accurate, it is tested with a gage, or by other means, after taking a trial cut, as will be explained later, and the tailstock

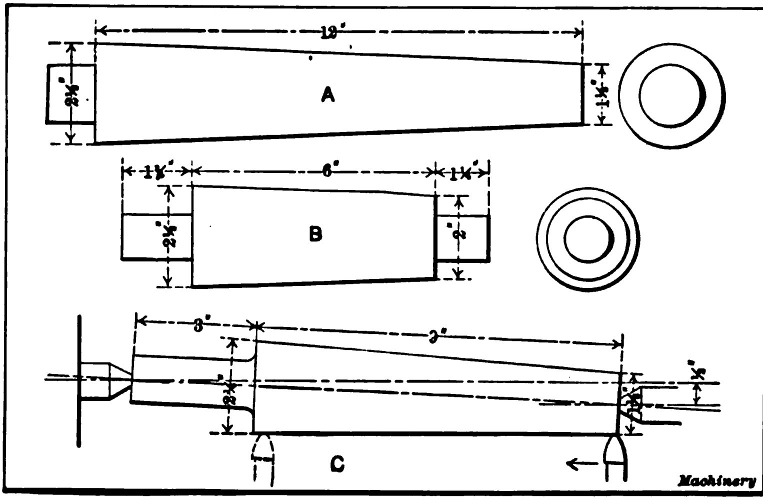


Fig. 2. Examples of Taper Work

center is re-adjusted accordingly. There are also more accurate methods of setting the center, than by figuring the amount of offset, but as the latter is often convenient, this will be referred to first.

Setting Tailstock Center for Taper Turning

Suppose the tailstock center is to be set for turning part *C*, Fig. 2, to a taper of approximately 1 inch per foot. In this case the center would simply be moved toward the front of the machine ½ inch, or one-half the required taper per foot, because the total length of the work happens to be just 12 inches. This setting, however, would not be correct for all work requiring a taper of 1 inch per foot, as the adjustment depends not only on the *amount* of the taper but on the *total length* of the piece.

For example, the taper roller *B* has a taper of 1 inch per foot, but the center, in this case, would be offset less than one-half the taper per foot, because the total length is only 9 inches. For lengths longer or shorter than twelve inches, the taper per inch should be found first; this is then multiplied by the *total* length of the work (not the length of the taper) which gives the taper for that length, and one-half this taper is the amount to set over the center. For example, the taper per inch of part *B* equals 1 inch divided by 12 = 1/12 inch. The total length of 9 inches multipled by 1/12 inch = 3/4 inch, and ½ of ¾ = ⅜, which is the distance that the tailstock center should be offset. In this example if the taper per foot were not known, and only the diameters of the large and small ends of the tapered part were given, the difference between these diameters should first be found (2½ — 2 = ½); this difference should then be divided by the length of the taper (½ ÷ 6 = 1/12 inch) to obtain the taper per inch. The taper per inch times the *total* length represents what the taper would be if it extended throughout the entire length, and one-half of this equals the offset, which is ⅜ inch.*

Example of Taper Turning

As a practical example of taper turning let us assume that the piece *A*, Fig. 4, which has been centered and rough turned as shown, is to be made into a taper plug, as indicated at *B*, to fit a ring gage as at *C*. If the required taper is 1½ inch per foot and the total length is 8 inches, the tailstock center would be offset ½ inch.

To adjust the tailstock, the nuts *N* (Fig. 3) are first loosened and then the upper part *A* is shifted sidewise by turning screw *S*. Scales are provided on some tailstocks for measuring the amount of this adjustment; if there is no scale, draw a line across the movable and stationary parts *A* and *B*, when the tailstock is set for straight turning. The movement of the upper line in relation to the lower will then show the offset, which can be measured with a scale.

Fig. 3. Detail View of Lathe Tailstock

When the adjustment has been made, nuts *N* are tightened and the work, with a dog attached, is placed between the centers the same as for straight turning. The taper end is then reduced by turning, but before it is near the finished size, the work is removed and the taper tested by inserting it in the gage. If it is much out, this can be felt, as the end that is too small can be shaken in the hole. Suppose the plug did not taper enough and only the small end came in contact with the gage, as shown somewhat exaggerated at *D;* in that case the center would be shifted a little more towards the front, whereas if the taper were too steep, the adjustment would, of course, be in the opposite direction. A light cut would then be taken, to be followed by another test. If the plug should fit the gage so well that there was no perceptible shake, it could be tested more closely as follows: Draw three or four chalk lines along

*See also MACHINERY's Reference Book No. 18, "Shop Arithmetic for the Machinist."

the tapering surface, place the work in the gage and turn it a few times. The chalk marks will then show whether the taper of the plug corresponds to that of the gage; for example, if the taper is too great, the marks will be rubbed out on the large end, but if the taper is correct, the lines throughout their length will be partially erased.

Another and more accurate method of testing tapers, is to apply a thin coat of Prussian-blue to one-half of the tapering surface, in a lengthwise direction. The work is then inserted in the hole or gage and turned to mark the bearing. If the taper is correct, the bearing marks will be evenly distributed, whereas if the taper is incorrect, they will appear at one end. Tapering pieces that have to be driven tightly into a hole, as a piston-rod, can be tested by the location of the bearing marks produced by actual contact.

After the taper is found to be correct, the plug is reduced in size until it just enters the gage as at *C*. The final cut should leave it slightly above the required size, so that a smooth surface can be

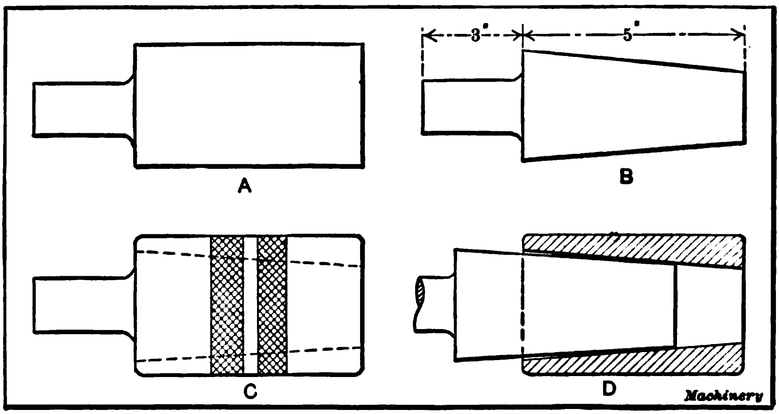


Fig. 4. Taper Plug and Gage

obtained by filing. It should be mentioned that on work of this kind the final finish is very often obtained by grinding in a regular grinding machine instead of by filing. When this method is employed, a lathe is used merely to rough turn the part close to size.

When the amount that the tailstock center should be offset is determined by calculating, as in the foregoing example, it is usually necessary to make slight changes afterward, and the work should be tested before it is too near the finished size so that in case one or more trial cuts are necessary, there will be material enough to permit this. When there are a number of tapered pieces to be turned to the same taper, the adjustment of the tailstock center will have to be changed unless the total length of each piece and the depth of the center holes are the same in each case.

Setting the Tailstock Center with a Caliper Tool

Another method of setting the tailstock center for taper turning is illustrated in Fig. 5. The end of a rod is to be made tapering as at *A* and to dimensions *a*, *b*, *c* and *d*. It is first turned with the centers in line as at *B*. The end *d* is reduced to diameter *b* up to the beginning of the taper and it is then turned to diameter *a* as far as the taper part *c* extends. The tailstock center is next set over by guess and a caliper tool is clamped in the toolpost. This tool,

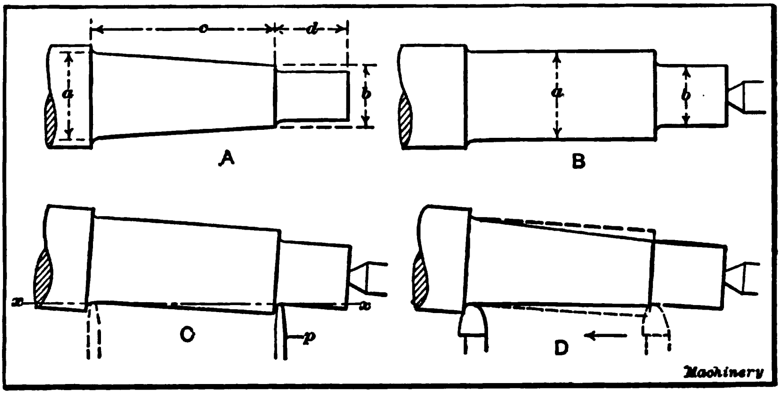


Fig. 5. Setting Work for Taper Turning by use of Caliper Gage

a side view of which is shown in Fig. 6, has a pointer *p* that is free to swing about pivot *r*, which should be set to about the same height as the center of the work. The tailstock center is adjusted until this pointer just touches the work when in the positions shown by the full and dotted lines at *C*, Fig. 5; that is, until the pointer makes

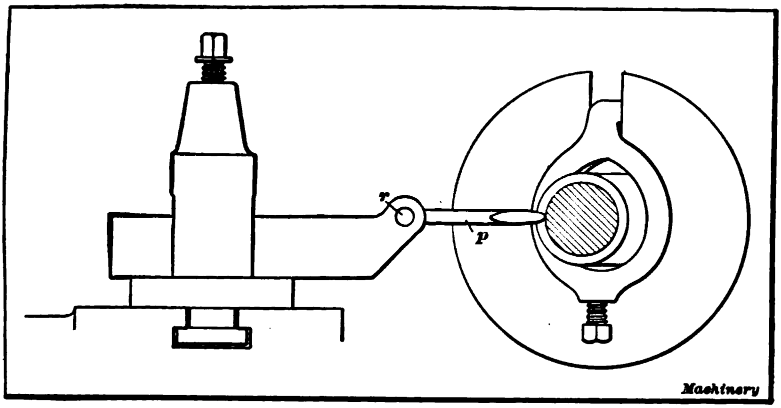


Fig. 6. Side View showing Relative Positions of Gage and Work

contact at the beginning and end of the taper part. The travel of the carriage will then be parallel to a line *x—x*, representing the taper; consequently, if a tool is started at the small end, as shown by the dotted lines at *D*, with the nose just grazing the work, it will also just graze it when fed to the extreme left as shown. Of course, if the taper were at all steep, more than one cut would be taken. If these various operations are carefully performed, a fairly accurate taper can be produced. The straight end *d* is reduced to size after the tail-center is set back to the central position. Some mechanics turn notches or grooves at the beginning and end of the tapering part, having diameters equal to the largest and smallest part of the taper; the work is then set by these grooves with a caliper tool. The advantage of the first method is that most of the metal is removed while the centers are in alignment.

Setting the Tailstock Center with a Square

Still another method of adjusting the tailstock for taper turning, which is very simple and eliminates all figuring, is as follows: The part to be made tapering is first turned cylindrical or straight

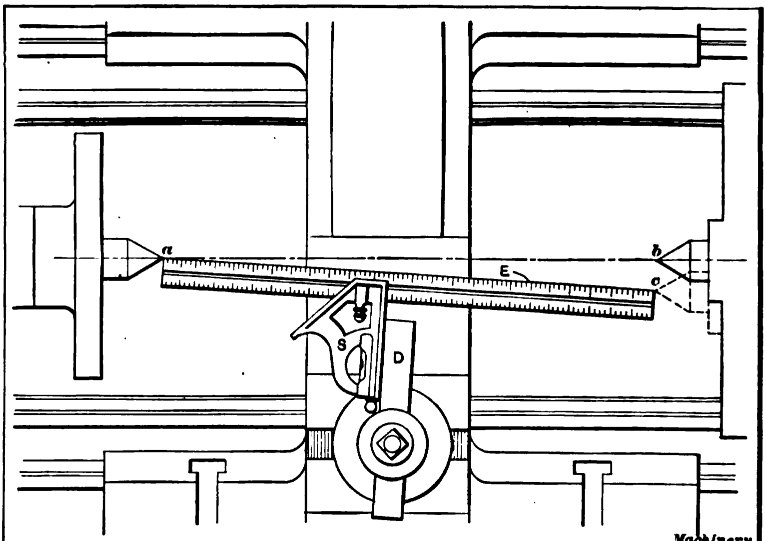


Fig. 7. Obtaining Tailstock Center Adjustment by use of Square

for 3 or 4 inches of its length, after the ends have been properly centered and faced square. The work is then removed and the tailstock is shifted along the bed until the distance *a—b* between the extreme points of the centers, is exactly 1 foot. The center is next offset a distance *b—c* equal to one-half the required taper per foot, after which a parallel strip *D*, having true sides, is clamped in the toolpost. Part *D* is then set at right angles to a line passing from one center point to the other. This can be done conveniently by holding a 1-foot square (preferably with a sliding head) against one side of *D* and adjusting the latter in the toolpost until edge *E* of the square blade is exactly in line with both center points. After part *D* is set, it should be clamped carefully to prevent changing the position. The angle between the side of *D* and an imaginary line which is perpendicular to axis *a—b*, is now equal to one-half the angle of the required taper. The axis of the part to be turned should be set parallel with line *E*, which can be done by setting the cylindrical surface which was previously finished, at right angles to the side of *D*. In order to do this the work is first placed between centers, the tailstock being shifted along the bed if necessary; the tail-center is then adjusted laterally until the finished cylindrical surface is square with the side of *D*. A small try-square can be used for testing the position of the work, as indicated in Fig. 8. If the length of the work is less than 1 foot, it will be necessary to move the center toward the rear of the machine, and if the length is greater than 1 foot, the adjustment is, of course, in the opposite direction. (This method has been described in MACHINERY by Mr. H. C. Lord.)

The Taper Attachment

Turning tapers by setting over the tailstock center has some objectionable features. When the lathe centers are not in alignment,

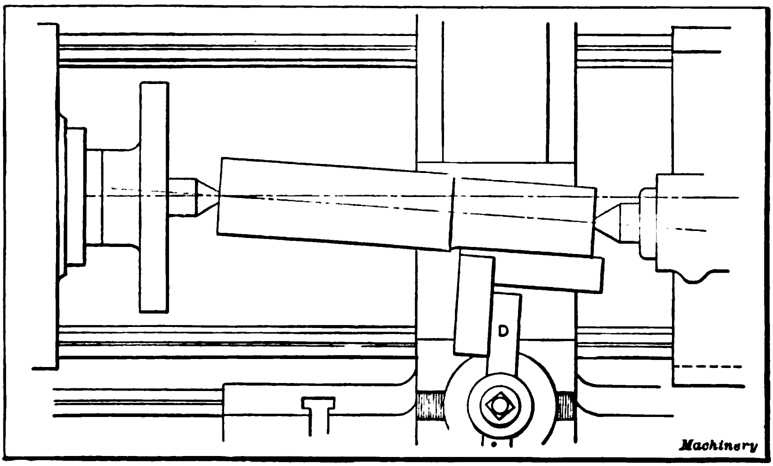


Fig. 8. Second Step in Adjusting Tailstock Center by use of Square

as when set for taper turning, they bear unevenly in the work centers because the axis of the work is at an angle with them; this causes the work centers to wear unevenly and results in inaccuracy. Furthermore, the adjustment of the tailstock center must be changed when turning duplicate tapers, unless the length of each piece and the depth of the center holes are the same. To overcome these objections, many modern lathes are equipped with a special device for turning tapers, known as a taper attachment, which permits the lathe centers to be kept in alignment, and enables more accurate work to be done.

Taper attachments, like lathes, vary some in their construction, but all operate on the same principle. An improved form of taper attachment is illustrated in Figs. 9 and 10, which show a plan view of a lathe carriage with an attachment fitted to it, and also a sectional view. This attachment has an arm *A* on which is mounted a slide *S* that can be turned about a central pivot by adjusting screw *D*. The arm *A* is supported by, and is free to slide on a bracket *B* (see also sectional view) that is fastened to the carriage, and on one end of the arm there is a clamp *C* that is attached to the lathe bed when turning tapers. On the slide *S* there is a shoe *F* that is connected to bar *E* which passes beneath the tool slide. The rear end of the cross-feed screw is connected to this bar, and the latter is clamped to the tool-slide when the attachment is in use.

When a taper is to be turned, the carriage is moved opposite the taper part and clamp *C* is fastened to the bed; this holds arm *A* and slide *S* stationary so that the carriage, with bracket *B* and shoe *F* can be moved with relation to the slide. If this slide *S* is set at an angle, as shown, the shoe as it moves along, causes the tool-slide and tool to move in or out, but if the slide is set parallel to the carriage travel, the tool-slide remains stationary. Now if the tool, as it feeds lengthwise of the work, is also gradually moved crosswise, it will turn a taper, and as this crosswise movement is caused by the angularity of slide *S*, different tapers are obtained by setting the slide to different positions. By means of a graduated scale at *G*, just what taper would be obtained for any angular position of the slide, is shown. On some attachments there are two sets of graduations, one giving the taper in inches per foot and the other in degrees. While tapers are ordinarily given in inches per foot on drawings, sometimes the taper is given in degrees instead. Fig. 11 shows an enlarged view of the scale with the slide set for turning a taper of 1 inch per foot. The attachment is set for turning tapers by adjusting slide *S* until pointer *p* is opposite the division or fractional part of a division representing the taper. The whole divisions on the scale represent taper in inches per foot, and by means of the subdivisions, the slide can be set for turning frac-

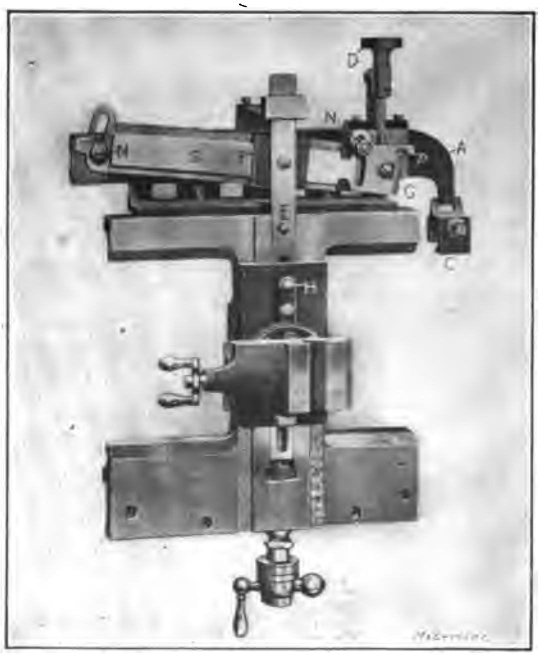


Fig. 9. A Lathe Taper Attachment

tional parts of an inch per foot. When slide *S* is properly set, it is clamped to arm *A* by the nuts *N*. Bar *E* is also clamped to the tool-slide by bolt *H*, as previously stated. The attachment is disconnected

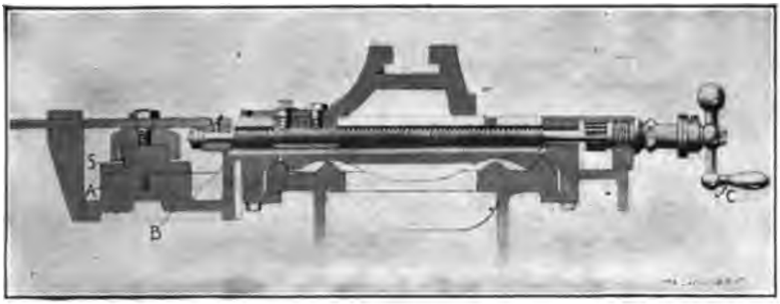


Fig. 10. Sectional View of Taper Attachment

for straight turning by simply loosening clamp *C* and the bolt *H*. An example of taper turning with the attachment is given in Chapter II.

Height of Tool when Turning Tapers

The cutting edge of the tool, when turning tapers, should be at the same height as the center or axis of the work, whether an attachment is used or not. The importance of this will be apparent by referring to Fig. 12. To turn the taper shown, the tool *T* would be moved back a distance *x* (assuming that an attachment is used) while traversing the length *l*. If the tool could be placed as high as point *a*, for the sake of illustration, the setting of the attachment remaining as before, it would again move back a distance *x*, while moving a distance *l*, but the large end would be undersized (as shown exaggerated by the dotted line) if the diameters of the small ends were the same in each case. Of course, if the tool point were only slightly above or below the center, the resulting error would also be small. The tool can easily be set central by comparing the height of the cutting edge at the point of the tool with one of the lathe centers before placing the work in the lathe.

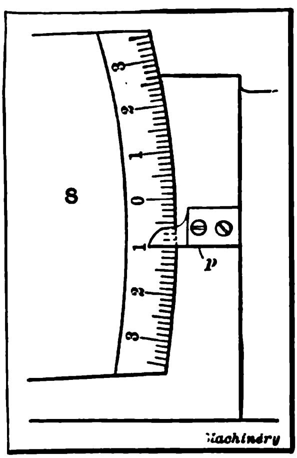


Fig. 11. Scale of Taper Attachment

Taper Turning with the Compound Rest

The amount of taper that can be turned by setting over the tail-stock center and by the taper attachment, is limited, as the centers can only be offset a certain distance, and the slide *S* of the attachment cannot be swiveled beyond a certain position. For steep tapers, the compound rest *E* is swiveled to the required angle and used as indicated in Fig. 14, which shows a plan view of a rest set for turning the valve *V*. This compound rest is an upper slide mounted on the lower or main cross-slide *D*, and it can be turned to any angular position so that the tool, which ordinarily is moved either lengthwise

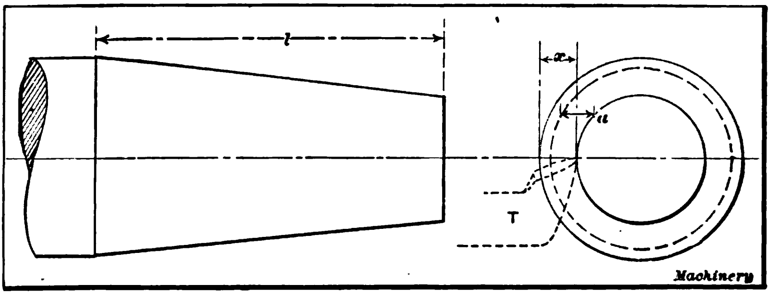


Fig. 12. Tool Point should be in same Horizontal Plane as Axis of Work for Taper Turning

or crosswise of the bed, can be fed at an angle. The base of the compound rest is graduated in degrees and the position of these graduations shows to what angle the upper slide is set. Suppose the seat of valve *V* is to be turned to an angle of 45 degrees with the axis or center, as shown on the drawing at *A*, Fig. 13. To set the compound rest, nuts *n* on either side, which hold it rigidly to the lower slide, are first loosened and the slide is then turned until

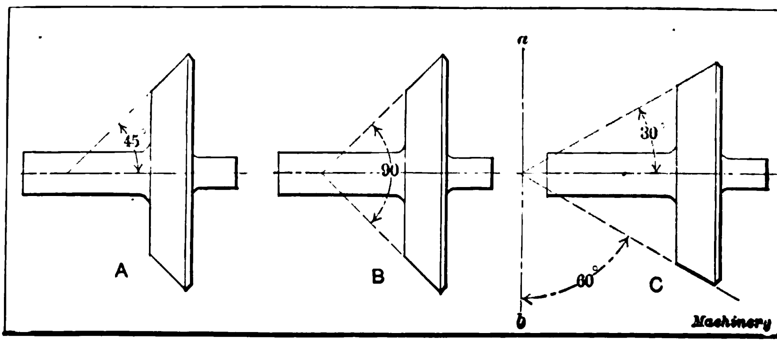


Fig. 13. Example of Taper Work Turned by using Compound Rest

the 45 degree graduation is exactly opposite the zero line; the slide is then tightened in this position. A cut is next taken across the valve by operating handle *w* and feeding the tool in the direction of the arrow.

In this particular instance the compound rest is set to the same angle given on the drawing, but this is not always the case. If the draftsman had given the included angle of 90 degrees, as shown at *B*, which would be another way of expressing it, the setting of the compound rest would, of course, be the same as before, or to 45 degrees, but the number of degrees marked on the drawing does not correspond with the angle to which the rest must be set. As another illustration, suppose the valve were to be turned to an angle of 30 degrees with the axis as shown at *C*. In this case the compound rest would not be set to 30 degrees but to 60 degrees, because in order to turn the work to an angle of 30 degrees, the rest must be 60 degrees from its zero position, as shown. From this it will be seen that the number of degrees marked on the drawing does not necessarily correspond to the angle to which the rest must be set, as the gradu-

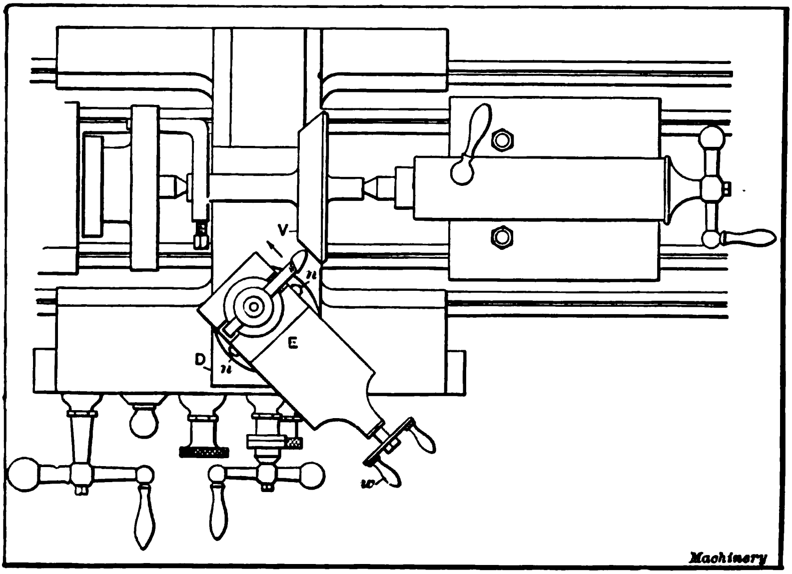


Fig. 14. Plan View showing method of Turning a Taper with the Compound Rest

ations on the rest show the number of degrees that it is moved from its zero position, which corresponds to the line *a*—*b*. The angle to which the compound rest should be set can be found, when the drawing is marked as at *A* or *C*, by subtracting the angle given from 90 degrees. When the included angle is given, as at *B*, subtract one-half the included angle from 90 degrees to obtain the required setting. Of course, when using a compound rest, the lathe centers are set in line as for straight turning, as otherwise the angle will be incorrect. The compound rest can also be used for boring taper holes by setting it to the angle that would give the right taper and then feeding the boring tool by hand, as when turning.

CHAPTER II

EXAMPLES OF CYLINDRICAL AND TAPER TURNING, BORING AND THREAD CUTTING

A practical example of lathe work which requires both straight and and taper turning, thread cutting, taper boring, reaming, and turning by the use of a mandrel, is illustrated in Fig. 15, which represents the drawing of an engine piston and rod. The various steps connected with turning these two parts in an ordinary engine lathe will be explained.

The piston is usually bored and reamed before the rod is turned so that the latter can afterward be fitted to it. The first turning opera-

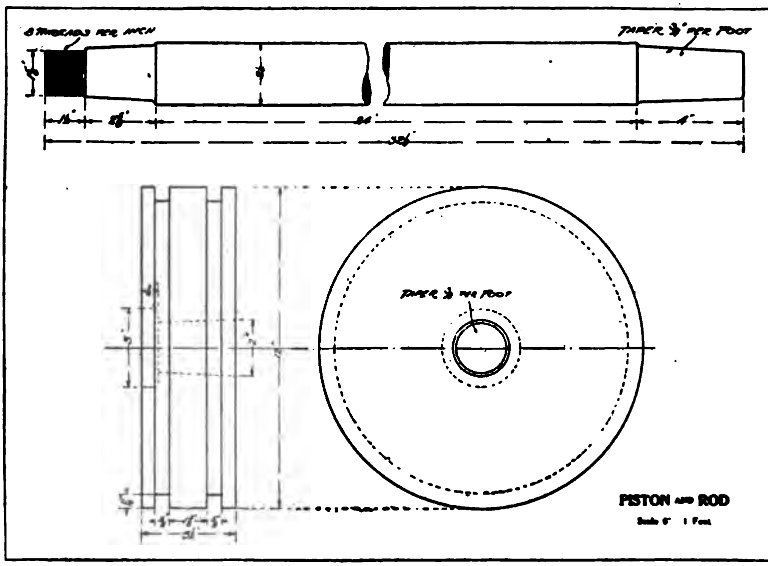


Fig. 15. Drawing of Engine Piston and Rod

tion consists in boring the hole into which the rod is to be fitted; therefore, the casting must be held either in a chuck *C*, as in Fig. 16, or on a faceplate if too large for the chuck. The side of the casting (after it has been "chucked") should run true and also the circumference, unless the cored hole for the rod is considerably out of center, in which case the work should be shifted to divide the error. The side of the casting for a short space around the hole is faced true with a round nose turning tool, after which the rough cored hole is bored with an ordinary boring tool *t*, and then it is finished with a reamer to exactly the right size and taper. If the lathe has a taper attachment, the hole can be bored to the right taper, by setting the attachment to the taper given on the drawing, which, in this example, is ¾ inch per foot. This is done, as will be recalled, by loosening nuts *N* and turning slide *S* until pointer *P* is opposite the ¾-inch division on the scale; the attachment is then ready, after bolt *H* and nuts *N* are tightened, and clamp *C* is fastened to the lathe bed. The hole is bored just as though it were straight, and as the carriage advances, the tool is gradually moved inward by the attachment.

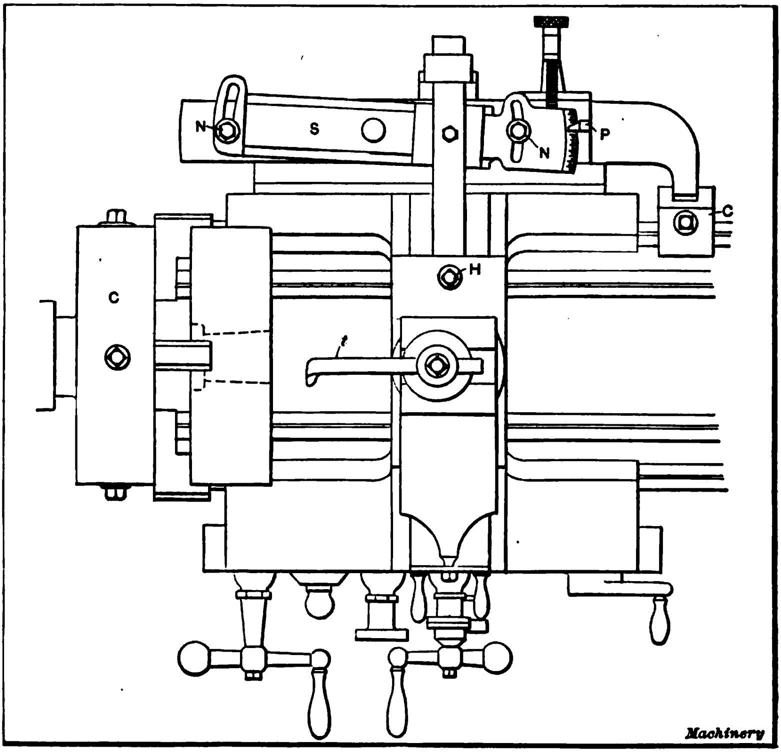


Fig. 16. Lathe with Taper Attachment arranged for Boring Taper Hole

If the lathe is without an attachment, the hole must be bored by using the compound rest. A convenient way to set the compound rest to the required angle is illustrated in Fig. 17. A bevel protractor *P* is first set to the taper of the reamer; this protractor is then placed against the finished spot on the casting as shown in Fig. 17, or against the faceplate, if the casting has not been chucked, and the compound rest is adjusted to the same angle as the protractor blade. The tool is set for boring by adjusting the carriage and cross-slide *D*, and it is fed by hand through the hole by compound slide *E*.

The hole is bored slightly under the finished size, and then a reamer is placed in the hole. The outer end of the reamer, which should have a deep center hole, is supported by the tailstock center. The lathe is run very slow for reaming and the reamer is fed into the hole by feeding out the tailstock spindle. The reamer can be kept from revolving with the work, either by attaching a heavy dog to the end or, if the end is squared, by the use of a wrench. A common method is to clamp a dog to the reamer shank, and then place the tool-rest beneath it to prevent rotation. If the shank of a tool is clamped to the toolpost so that the dog rests against it, the reamer will be prevented from slipping off the center as it tends to do; with this arrangement, the carriage is gradually moved along as the tailstock spindle is fed outward. A reamer of the type illustrated at *B*, Fig. 18, is fed in until the stop collar *S* comes against the finished side of the casting. By having this stop, the holes in any number of

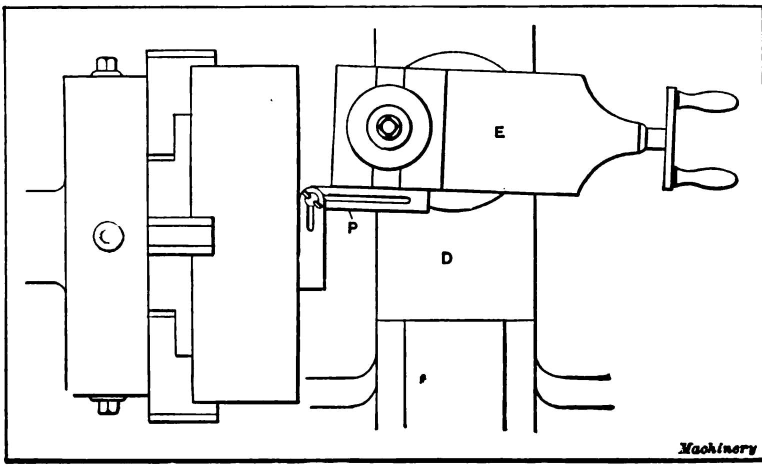


Fig. 17. Setting Compound Rest to Required Angle by using Bevel

pistons can be reamed to the same size. If a plain reamer *A* were used, the hole would probably be tested by inserting a plug gage.

After the reaming operation, the casting is removed from the chuck and a taper mandrel is driven into the hole for turning the outside of the piston. This mandrel should run true on its centers, as otherwise the outside surface of the piston will not be true with the bored hole. The mandrel *M* and the casting are next mounted between the lathe centers as shown in Fig. 19, after the chuck has been replaced with a faceplate. The driving dog *D*, especially for large work of this kind, should be heavy and stiff, because light flexible clamps or dogs vibrate and frequently cause chattering. For such heavy work it is also preferable to drive at two points on opposite sides of the faceplate, but the driving pins must be carefully adjusted to secure a uniform bearing on both sides. The outside of the piston might be turned either to the diameter given on the drawing, or be fitted to the cylinder of the engine for which the piston is intended. When turning work of this diameter, it must revolve quite slowly as otherwise the turning tool will be quickly dulled, and it is for such large work that the slow speeds obtained by driving through the back-gears are used. Ordinarily a piston casting could be reduced to finished diameter by taking one roughing and one light finishing cut, though

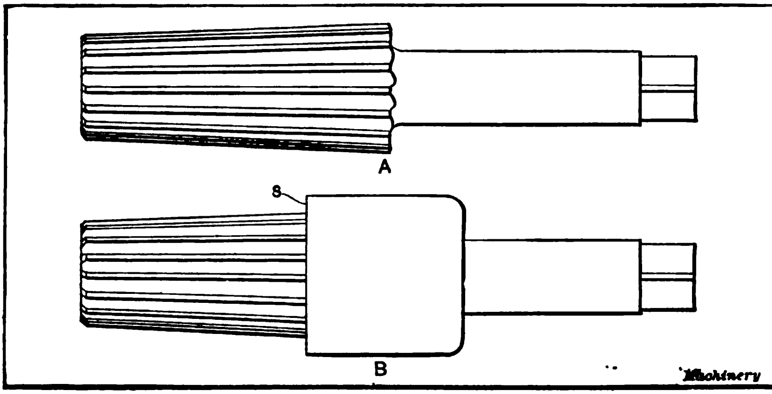


Fig. 18. Plain Reamer—Reamer with Stop Sleeve

this would depend, of course, on the diameter of the rough casting.

After turning the outside, grooves for the packing rings are laid out, as shown at *A*, Fig. 20, by scribing arcs from a central point *a*, that are the same distance apart as the grooves. The dimensions are

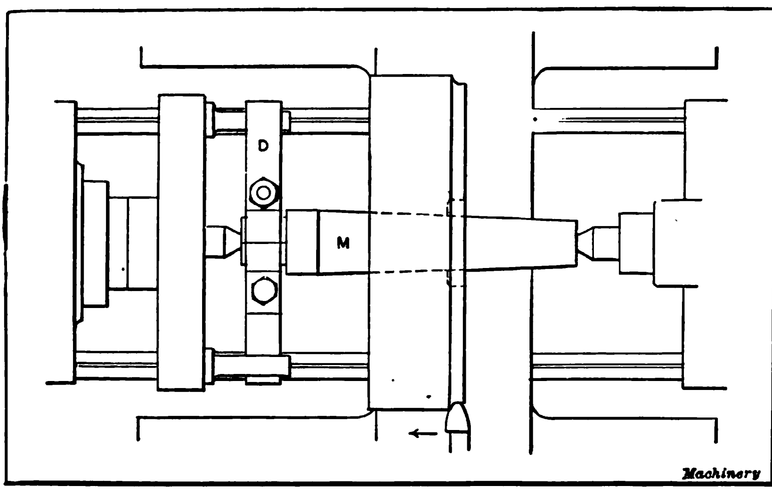


Fig. 19. Piston Mounted on Mandrel, in Position for Turning

obtained from the drawing, and the lines should be marked by light punch marks as shown. One method of cutting these grooves would be to use a square-nosed tool *t* (similar in shape to a parting tool) for turning them to depth, and side tools for finishing the sides. Grooves that are quite wide would be formed by first taking a cut on each side and then turning away the central part, as shown at *B*. The grooves should then be finished to the required width either by using right- and left-hand side tools, or a "square nose" ground to the right size. The width of the grooves should be exactly the same, and ordinarily they are fitted to some form of gage *g*. This particular style is double-ended, the upper end being used to measure the packing rings that fit into the grooves. When the grooves are finished, the outside of the piston is filed to make it smooth.

The final operation is to finish the pocket for the rod nut, which can be done by using a bent square-nosed tool t_1. It may be necessary to grind part of the under side of this tool away to provide

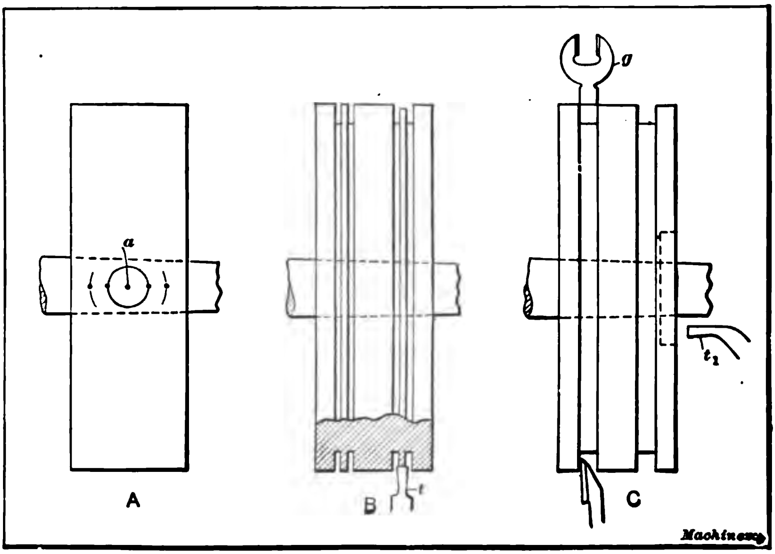


Fig. 20. Successive Steps in Turning Packing-ring Grooves

clearance, or in other words, to make a kind of special tool that would be kept for this particular job.

The foregoing method of machining a piston is one that would ordinarily be followed when using a standard engine lathe, and it would, perhaps, be as economical as any if only one piston were being made; but where such work is done in large quantities, time could be saved by proceeding in a different way. For example, the boring and reaming operation could be performed much faster in a turret lathe, which is a type designed for just such work, but a turret lathe cannot be used for as great a variety of work as a lathe of the regular type. There are also many other classes of work that can be turned more quickly in special types of machines, but as more or less time is required for arranging these special machines and often special tools have to be made, the ordinary lathe is frequently indispensable when only a few parts are needed; in addition, it is better adapted to some turning operations than any other machine.

Turning the Piston-rod

The stock for the piston-rod is cut off to the right length (probably in a hacksaw machine), and the ends are centered. The work is then placed between the lathe centers with a driving dog *D* (Fig. 21) attached to the faceplate end, and the tailstock center, after being oiled, is adjusted rather snugly but not tight enough to prevent a free rotary movement of the work. The body of the rod is first rough turned say 1/16 inch above the finished size, the cut being continued until the tool is near the driving dog. Light punch marks *a* and *b* are then made on the rod to mark the location of the shoulders or the length of the rod body which, in this case, is 24 inches. The

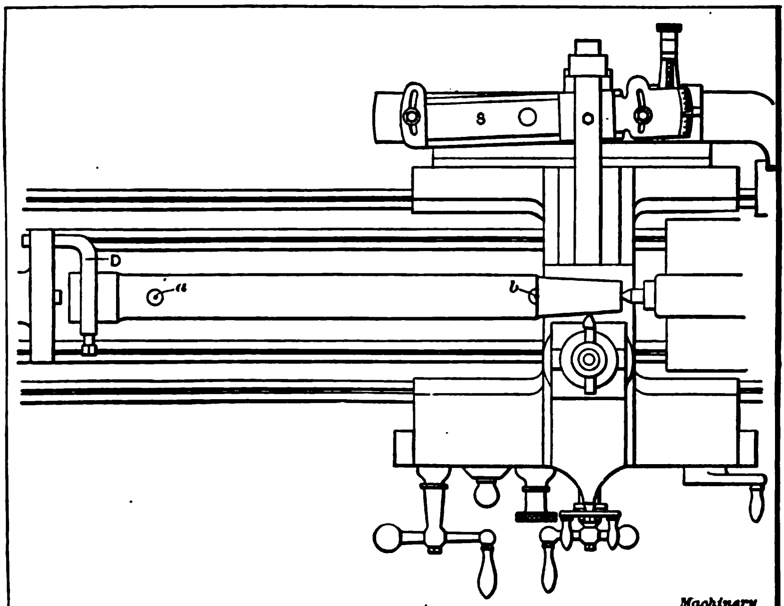


Fig. 21. Taper Attachment Set for Turning Taper End of Rod

marks should also be the right distance from the ends. The right-hand mark is laid out for the crosshead end which is to be fitted first. The taper attachment is next set to turn a taper of ¾ inch per foot, as marked on the drawing. While this taper corresponds to the taper of the hole in the piston, slide *S* will have to be re-set to the ¾-inch division on the opposite side of the central zero mark (see Fig. 11, Chapter I) because the taper of the hole decreased in size during the boring operation whereas the rod is smallest at the beginning of the cut, so that the tool must move outward rather than inward as it advances. The taper part is turned practically the same as a cylindrical part; that is, the power feed is used and, as the carriage moves along the bed, the tool is gradually moved outward by the taper attachment. If the rod is being fitted directly to the crosshead, as is usually the case, the approximate size of the taper end could be determined by calipering, the calipers being set to the size of the hole at a point 4 inches (in this case) from the shoulder or face side. If the crosshead was bored originally to fit a standard plug-gage, the taper on the rod could be turned with reference to this gage, but, whatever the method, the taper should be tested before turning too close to the finished size. The test is made by removing the rod from the lathe and driving it tightly into the crosshead. This shows how near the taper is to size, and when the rod is driven out, the bearing marks show whether the taper is exactly right or not. If the rod could be driven in until the shoulder is say 1/8 inch from the crosshead face, it would then be near enough to finish to size by filing. When filing, the lathe is run much faster than for turning, and the most filing should be done where the bearing marks are the heaviest, to distribute the bearing throughout the length of the taper. Care should be taken when driving the rod in or out, to protect the center-holes in the ends by using a "soft" hammer or by holding a piece of soft metal against the driving end.

After the crosshead end is finished, the rod is reversed in the lathe for turning the piston end. The dog *D* is clamped to the finished

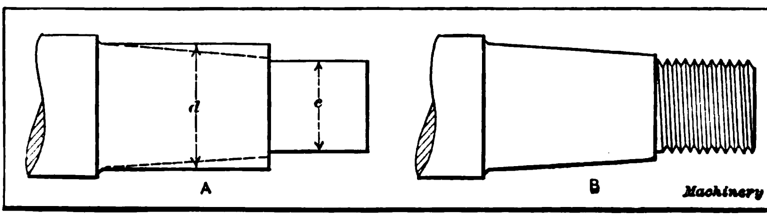


Fig. 22. Final Operations on Piston Rod

end, preferably over a piece of sheet copper to prevent the surface from being marred, and the end is then rough turned as at *A*, Fig. 22, diameter *d* being made slightly greater than the largest diameter of the taper, and *e* equal to the diameter of the thread. The attachment is then engaged and the taper part turned to the same taper as the opposite end, as called for on the drawing. When turning this end, either the piston reamer or the finished hole in the piston can be calipered. The size and angle of the taper are tested by driving the rod into the piston, and the end should be fitted so that by driving tightly, the shoulder will just come up against the finished face of the piston. When the taper is finished, the attachment is disengaged and a finishing cut is taken over the body of the rod with a sharp tool and rather fine feed to obtain a smooth surface.

The next and final turning operation is that of threading the end as at *B*. As there are eight threads per inch (see drawing, Fig. 15) the lathe is geared for cutting that number, and the thread is cut as explained in Part I of this treatise. (See Chapter VIII, MACHINERY'S Reference Book, No. 91.) The final operation consists in filing and polishing the body of the rod, the file being used first to take off the ridges left by the tool, and then emery cloth to polish the surface.

CHAPTER III

CUTTING SPEEDS AND FEEDS

In all turning operations there are two very important questions that must be considered: One has to do with the cutting speed that is used, and the other relates to the feed of the tool and depth of the cut. The cutting speed is the number of feet per minute that the tool point passes over, or practically speaking, it is equivalent to the length of a chip which would be turned in one minute. The term cutting speed should not be confused with revolutions per minute, because the cutting speed depends not only on the speed of the work but also on its diameter. The feed of a tool is the amount it moves across the surface of the work for each revolution; that is, when turning a cylindrical piece, the feed is the amount that the tool moves sidewise for each revolution of the work. Evidently the time required for turning is governed largely by the cutting speed, the feed, and the depth of the cut; therefore, these elements should be carefully considered. It is impossible to give any definite rule for determining either the speed, feed, or depth of cut, because these must be varied to suit existing conditions. We shall, however, point out some of the underlying principles which must be considered in determining the proper speed and feed.

TABLE OF CUTTING SPEEDS FOR TURNING STEEL

Depth of Cut in Inches	Feed in Inches	Cutting Speed in Feet per Minute for a Tool which is to last 1 Hour and 30 Minutes before Regrinding		
		Soft Steel	Medium Steel	Hard Steel
$\frac{3}{32}$	$\frac{1}{64}$	476	238.0	108.0
	$\frac{1}{32}$	325	162.0	73.8
	$\frac{1}{16}$	222	111.0	50.4
	$\frac{3}{32}$	177	88.4	40.2
$\frac{3}{16}$	$\frac{1}{64}$	352	176.0	80.0
	$\frac{1}{32}$	240	120.0	54.5
	$\frac{1}{16}$	164	82.0	37.3
	$\frac{3}{32}$	131	65.5	29.8
	$\frac{1}{8}$	112	56.0	25.5
$\frac{3}{8}$	$\frac{1}{64}$	264	132.0	60.0
	$\frac{1}{32}$	180	90.2	41.0
	$\frac{1}{16}$	122	61.1	27.8

The cutting speed is governed principally by the hardness of the metal to be turned; the kind of steel of which the turning tool is made; the shape of the tool and its heat treatment; the feed and depth of cut; the power of the lathe and also its construction. It is the durability of the turning tool or the length of time that it will turn effectively without grinding, that limits the cutting speed; and the hardness of the metal being turned combined with the quality of the tool, are the two factors which largely govern the time that a tool can be used before grinding is necessary. The cutting speed for very soft steel or cast iron can be three or four times faster than the speed for hard steel or hard castings, but whether the material is hard or soft, the kind of tool to use must also be considered as the speed for a tool made of ordinary carbon steel will have to be much slower than for a tool made of modern "high-speed" steel.

When the cutting speed is too high, even though high-speed steel is used, the point of the tool is softened to such an extent by the heat resulting from the pressure and friction of the chip, that the cutting edge is ruined in too short a time. On the other hand, when the speed is too slow, the heat generated is so slight as to have little

TABLE OF CUTTING SPEEDS FOR TURNING CAST IRON

Depth of Cut in Inches	Feed in Inches	Cutting Speed in Feet per Minute for a Tool which is to last 1 Hour and 30 Minutes before Regrinding		
		Soft Cast Iron	Medium Cast Iron	Hard Cast Iron
3/32	1/32	169.0	84.6	49.4
	1/16	122.0	61.2	35.7
	1/8	86.4	43.2	25.2
	3/16	70.1	35.1	20.5
3/16	1/32	137.0	68.6	40.1
	1/16	99.4	49.7	29.0
	1/8	70.1	35.0	20.5
	3/16	56.8	28.4	16.6
3/8	1/32	111.0	55.4	32.3
	1/16	80.0	40.0	23.4
	1/8	56.4	28.2	16.5
	3/16	45.8	22.9	13.4

effect and the tool point is dulled by being slowly worn or ground away by the action of the chip. A tool operating at such a low speed can, of course, be used a comparatively long time without re-sharpening, but this is more than offset by the fact that too much time is required for removing a given amount of metal when the work is revolving so slowly. Generally speaking, the speed should be such that a fair amount of work can be done before the tool requires regrinding. Evidently it would not pay to grind a tool every few minutes in order to maintain a high cutting speed; neither would it be economical to use a very slow speed and waste considerable time in turning, just to save the few minutes required for grinding. For example, if a number of roughing cuts had to be taken over a heavy rod or shaft, time might be saved by running at such a speed that the tool would have to be sharpened (or be replaced by a tool previously sharpened) when it had traversed half-way across the work; that is, the time required for sharpening or changing the tool would be short as compared with the gain effected by the high work speed.

On the other hand, it might be more economical to run a little slower and take a continuous cut across the work with one tool.

Sometimes the work speed cannot be as high as the tool will permit, because of the chattering that often results when the lathe is old and not massive enough to absorb the vibrations, or when there is unnecessary play in the working parts. The shape of the tool used also effects the work speed, and as there are so many things to be considered, the proper cutting speed is best determined by experiment. The two accompanying tables, giving cutting speeds for hard, medium, and soft steel and cast iron will be found useful, in a general way, in determining the most economical speed. These tables represent a few of the experiments conducted by Mr. Fred W. Taylor, and the figures given are based on the use of a tool correctly ground and made of a good grade of high-speed steel, properly heat treated.

It will be noted that the cutting speed is much slower for cast iron than for steel, and also that the feed and depth of cut have a very decided effect on the speed. Cast iron is cut with less pressure or resistance than soft steel, but the slower speed for cast iron is probably because the pressure of the chip is concentrated closer to the cutting edge, combined with the fact that cast iron wears the tool faster than steel, the wear occurring close to the cutting edge.

The number of revolutions required to give any desired cutting speed can be found by multiplying the cutting speed, in feet per minute, by 12 and dividing the product by the circumference of the work in inches. Expressing this as a formula we have

$$R = \frac{C \times 12}{\pi d}$$

in which

$R =$ revolutions per minute;

$C =$ the cutting speed in feet per minute;

$\pi = 3.1416$; and

$d =$ the diameter in inches.

For example if a cutting speed of 60 feet per minute is wanted and the diameter of the work is 5 inches, the required speed for the work would be found as follows:

$$R = \frac{60 \times 12}{3.1416 \times 5} = 46 \text{ revolutions per minute.}$$

If the diameter is simply multiplied by 3 and the fractional part is omitted, the calculation can easily be made, and the result will be close enough for practical purposes. In case the cutting speed, for a given number of revolutions and diameter, is wanted, the following formula can be used:

$$C = \frac{R \pi d}{12}$$

Of course, machinists that operate lathes do not know, ordinarily, what cutting speeds in feet per minute are used for different classes of work, but are guided entirely by past experience.

The amount of feed and depth of cut also vary, like the cutting speed, with different conditions. Ordinarily coarser feeds and a greater depth of cut can be used for cast iron than for soft steel because cast iron offers less resistance to turning, but in any case, with a given depth of cut, metal can be removed more quickly by using a coarse feed and the necessary slower speed, than by using a fine feed and the accompanying higher speed. When the turning operation is simply to remove metal, coarse feeds and deep cuts are taken, but sometimes the cut must be comparatively light, either because the work is too fragile and springy to withstand the strain of a heavy cut, or the lathe has not sufficient pulling power. The difficulty with light slender work is that a heavy cut may cause the part being turned to bend under the strain, thus causing the tool to gouge in which would probably result in spoiling the work. Steady-

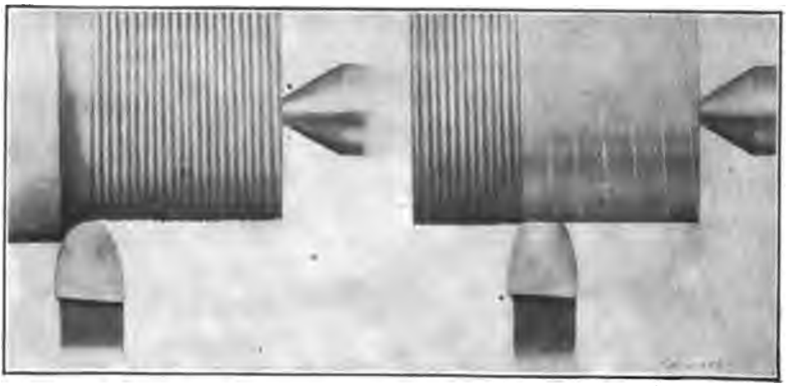


Fig. 23. Roughing Cut—Light Finishing Cut and Coarse Feed

rests can often be used to prevent flexible parts from springing, but there are many kinds of light work to which the steadyrest cannot be applied to advantage.

The amount of feed to use for a finishing cut might, properly, be either fine or coarse. Ordinarily fine feeds are used for finishing steel, especially if the work is at all flexible, but a finishing cut in cast iron is often accompanied by a coarse feed. Fig. 23 illustrates the feeds that are often used when turning cast iron. The view to the left shows a deep roughing cut and the one to the right, a finishing cut. By using a broad flat cutting edge set parallel to the tool's travel, and a coarse feed for finishing, a smooth cut can be taken in a comparatively short time. Some castings which are close to the finished size in the rough, can be finished by taking one cut with a broad tool, provided the work is sufficiently rigid. It is not always practicable to use these broad tools and coarse feeds, as they sometimes cause chattering, and when used on steel, a broad tool tends to gouge or "dig in" unless the part being turned is rigid. Heavy steel parts, however, are sometimes finished in this way. Much of the work that is turned, at the present time, is afterwards finished in a grinding machine so that often it is not necessary to take a finishing cut to secure a smooth surface.

CHAPTER IV

THREADS OF DIFFERENT FORM AND METHODS OF CUTTING

Three forms of threads which are very common in this country are shown in Fig. 24; these are the V-thread *A*, the U. S. standard *B*, and the square thread *C*. The shapes of these threads are shown by the sectioned parts. The V-thread has straight sides which make an angle of 60 degrees with each other and a like angle with the axis of the screw. The U. S. standard thread is similar to the V-thread except that the top of the thread and bottom of the groove is left flat, as shown, and the width of these flats is made equal to 1/8 of the pitch. The square thread is square in section, the width *a*, depth *b* and space *c* being all equal. All of these threads are right-hand, which means that the grooves wind around to the right so that a nut will have to be turned toward the right to enter it on the thread. A left-hand thread winds in the other direction, as shown at *D*, and a nut is screwed on by turning it to the left. Threads, in addition to being right- and left-handed, are single, as at *A*, *B*, *C*, and *D*, double, as at *E*, and triple, as at *F*, and for certain purposes quadruple threads are employed. A double thread is different from a single thread in that it has two grooves, starting diametrically opposite, whereas a triple thread has three grooves cut as shown at *F*. The object in having these multiple threads is to obtain an increase in lead without weakening the screw. For example, the threads shown at *C* and *E*, have the same pitch, but the lead of the double-threaded screw is twice that of the one with a single thread so that a nut would advance twice as far in one revolution, which is often a very desirable feature. To obtain the same lead with a single thread, the pitch would have to be double, thus giving a much coarser thread, which would weaken the screw, unless its diameter were increased. (The lead is the distance *l* that one thread advances in a single turn, or the distance that a nut would advance in one turn, and it should not be confused with the pitch *p*, which is the distance between the centers of adjacent threads. The lead and pitch of a single thread are the same.)*

Cutting a U. S. Standard Thread

A U. S. standard thread is cut in the same way described for a V-thread, in Chapter VIII, MACHINERY'S Reference Series No. 91, but as it has a different form, a tool of corresponding shape is used. This tool is first ground to an angle of 60 degrees, as it would be for cutting a V-thread, and then the point is made flat as shown in Fig. 25. As the width of this flat is equal to 1/8 of the pitch, it varies, of course, for different pitches. By using a gage like the one shown at *G*, the tool can easily be ground for any pitch, as the notches around the

*See also MACHINERY'S Reference Book No. 31: "Screw Thread Tools and Gages."

periphery of the gage are marked for different pitches and the tool-point is fitted into the notch corresponding to the pitch wanted.

When the cutting the thread, the tool is set square with the blank, and a number of successive cuts are taken, the tool being fed in until the width w of the flat at the top of the thread is equal to the width at the bottom. The thread will then be the right size provided the outside diameter D is correct. As it would be difficult to measure

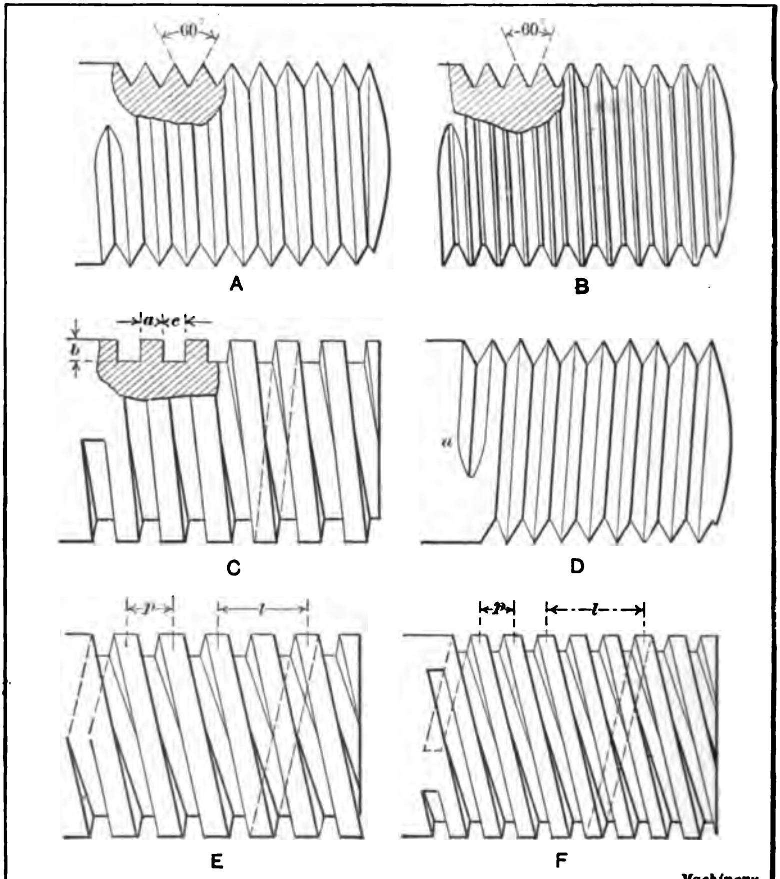


Fig. 24. (A) V-thread. (B) U. S. Standard Thread. (C) Square Thread. (D) Left-hand Thread. (E) Double Square Thread. (F) Triple Square Thread

the width of this flat accurately, the thread can be tested by screwing a standard nut over it if a standard thread is being cut. If it is being fitted to a tapped hole, the tap itself is a very convenient gage to use, the method being to caliper the tap and then compare its size with the work. Calipers or micrometers, such as illustrated in Fig. 60 (Part I), can be used.

A good method of cutting a U. S. standard thread to a given size is as follows: First turn the outside of the blank accurately to diameter *D*, and then turn a small part on the end to diameter *r* of the thread at the root. The finishing cut for the thread is then taken with the tool point set to just graze diameter *r*. If ordinary calipers were set to diameter *r* and measurements taken in the thread groove, the size might be incorrect owing to the angularity of the groove, which makes it necessary to hold the calipers at an angle when meas-

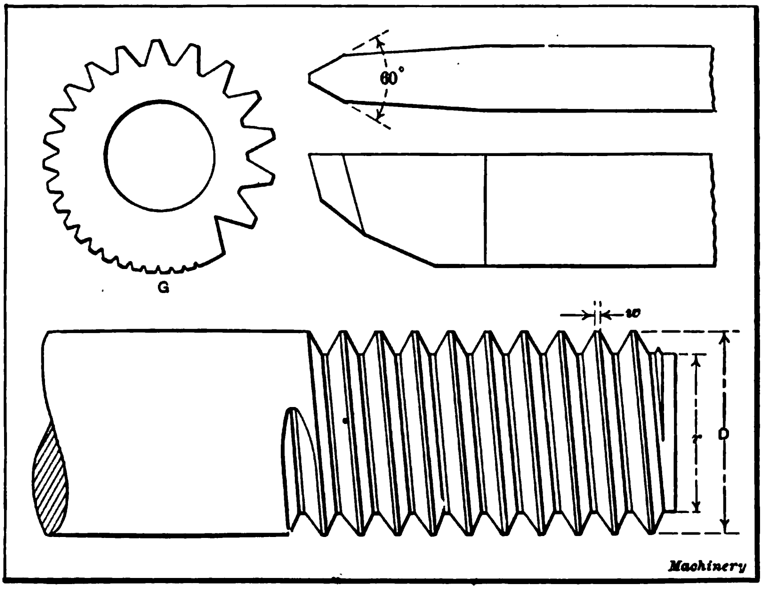


Fig. 25. U. S. Standard Thread, Thread Tool, and Gage

uring. A table, giving root diameters for various pitches, is convenient to have, but this diameter can be found by the following formula:

$$D - \left(\frac{1.299}{N}\right) = r$$

in which *D* equals outside diameter, *N* the number of threads per inch, and *r* the root diameter. The number 1.299 is a constant that is always used.

Cutting a Left-hand Thread

The only difference between cutting left-handed and right-handed threads in the lathe, is in the movement of the tool with relation to the work. When cutting a right-hand thread, the tool moves from right to left, but this movement is reversed for left-hand threads because the thread winds around in the opposite direction. To make the carriage travel from left to right, the lead-screw is rotated backwards by means of reversing gears *a* and *b* (Fig. 26) located in the headstock. Either of these gears can be engaged with the spindle gear by changing the position of lever *R*. When gear *a* is in engagement, as shown, the drive from the spindle to gear *c* is through gears *a* and *b*, but when lever *R* is raised thus shifting *b* into mesh, the drive is direct and the direction of rotation is reversed. The thread is cut by starting the tool at *a*, Fig. 24, instead of at the end.

Cutting a Square Thread

The form of tool used for cutting a square thread is shown in Fig. 27. The width *w* is made equal to one-half the pitch of the thread to be cut and the end *E* is at an angle with the shank, which corresponds to the inclination *x–y* of the threads. This angle *A* depends on the diameter of the screw and the lead of the thread; it can be determined graphically by laying off a line *a–b* equal to the circumference of the screw to be cut, and a line *b–c*, at right angles, equal to the lead of the thread. The angle *a* between lines *a–b* and

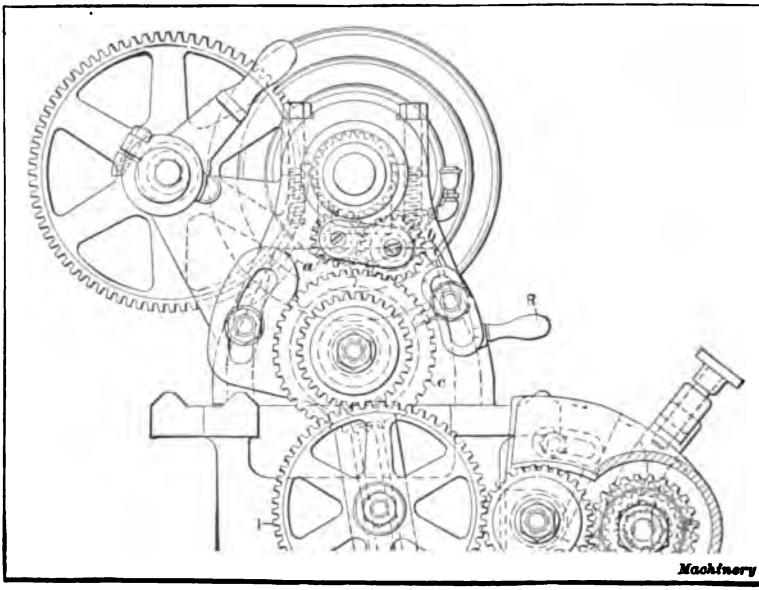


Fig. 26. End View of Lathe Headstock

a–c will be the required angle *A*. It is not necessary to have this angle accurate, ordinarily, as it is simply to prevent the tool from binding against the sides of the thread. The end of a square thread tool is shown in section to the right to illustrate its position with relation to the threads. The sides *e* and e_1 are ground to slope inward, as shown, to provide additional clearance.

When cutting multiple threads, which, owing to their increased lead, incline considerably with the axis of the screw, the angles for each side of the tool can be determined independently as follows: Lay off *a–b* equal to the circumference of the thread, as before, to obtain the required angle *f* of the rear or following side e_1; the angle *l* of the opposite or leading side is found by making *a–b* equal to the circumference at the root of the thread. The tool illustrated is for cutting right-hand threads; if it were intended for a left-hand thread, the end, of course, would incline in the opposite direction. The square thread is cut so that the depth *d* is equal to the width.

Cutting Multiple Threads

When a multiple thread is to be cut, as a double or triple thread, the lathe is geared with reference to the number of single threads to the inch. For example, the lead of the double thread, shown at *B*, Fig. 28, is one-half inch, or twice the pitch, and the number of single threads to the inch equals $1 \div \frac{1}{2} = 2$.

Therefore, the lathe is geared for cutting two threads per inch. The first cut is taken just as though a single thread were being cut, leaving the work as shown at *A*. When this cut is finished the work is turned one-half a revolution (for a double thread) without disturbing the position of the lead-screw or carriage, which brings the tool midway between the grooves of the single thread as indicated by

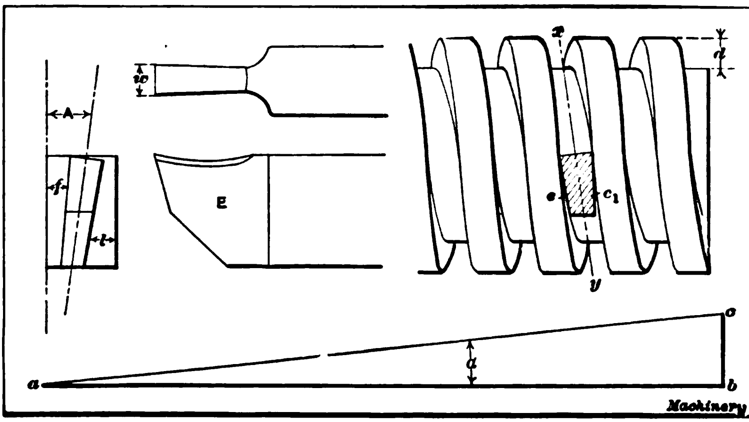


Fig. 27. End of Square Thread Tool, and Graphic Method of Determining Helix Angle of Thread

dotted lines. The second groove is then cut, producing a double thread as shown at *B*. In the case of a triple thread, the work would be indexed one-third of a revolution after turning the first groove, and then another third revolution to locate the tool for cutting the last groove. Similarly, for a quadruple thread, it would be turned one-quarter revolution after cutting each successive groove or thread.

There are different methods of indexing work when cutting multiple threads. Some machinists, when cutting a double thread, simply remove the work from the lathe and turn it one-half a revolution by placing the tail of the driving dog in the opposite slot of the faceplate. This is a very simple method, but if the slots are not directly opposite or 180 degrees apart, the last thread will not be central with the first. Another and better method is to disengage the idler gear from the gear on the stud, turn the spindle and work one-half, or one-third, of a revolution, as the case might be, and then connect the gears. For example, if the stud gear had 96 teeth, the tooth meshing with the idler gear would be marked with chalk, the gears disengaged, and the spindle turned until the chalked tooth had made the required part of a revolution, which could be determined by counting the teeth. When this method is used, the number of teeth in the stud gear must be evenly divisible by two if a double thread is being cut, or by three for a triple thread. If the stud is not geared to the spindle so that each makes the same number of revolutions, the ratio of the gearing must be considered.

Special faceplates are sometimes used for multiple thread cutting, that enable work to be easily and accurately indexed. One of these is illustrated in Fig. 29, and consists of two parts *A* and *B*, part *A* being free to rotate in relation to *B* when bolts *C* are loosened. The driving pin for the lathe dog is attached to plate *A*. When one

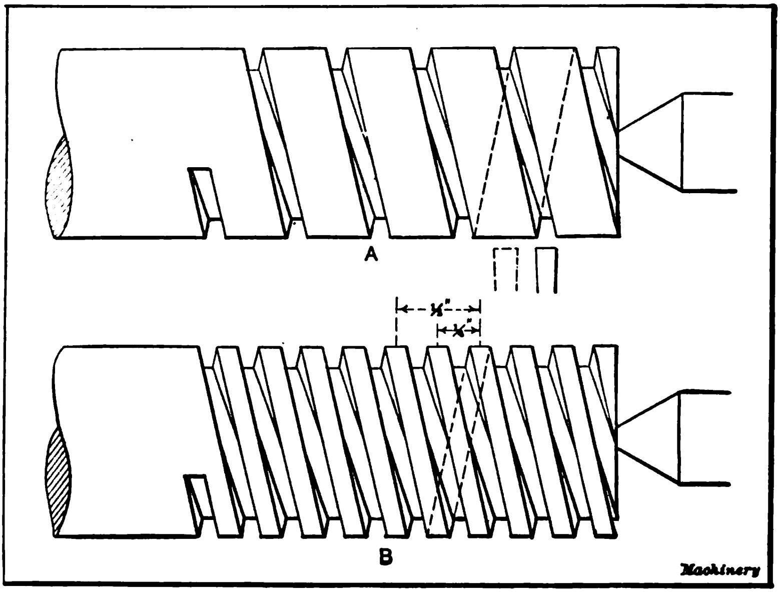


Fig. 28. Views illustrating how a Double Square Thread is Cut

groove of a multiple thread is finished, bolts *C* are loosened and plate *A* is turned around an amount corresponding to the type of thread being cut. The periphery of plate *A* is graduated in degrees, as shown, and for a double thread it will be turned one-half revolution or 180 degrees, for a triple thread 120 degrees, etc. This is a very good arrangement where multiple thread cutting is done frequently.

Taper Threading

When a taper thread is to be cut, the tool should be set square with axis *a—a* as at *A*, Fig. 30, and not by the tapering surface as at *B*. If there is a cylindrical part, the tool can be set as indicated by the dotted lines. All taper threads should be cut by the use of taper attachments. If the tailstock is set over to get the required taper, the curve of the thread will not be true, or in other words the thread will not advance at a uniform rate; this is referred to by machinists as a "drunken thread."

Internal Threading

Internal threading, or cutting threads in holes, is an operation performed on work held in the chuck or on a faceplate, as for boring. The tool used is similar to a boring tool except that the working end is shaped to conform to the thread to be cut. An internal threading

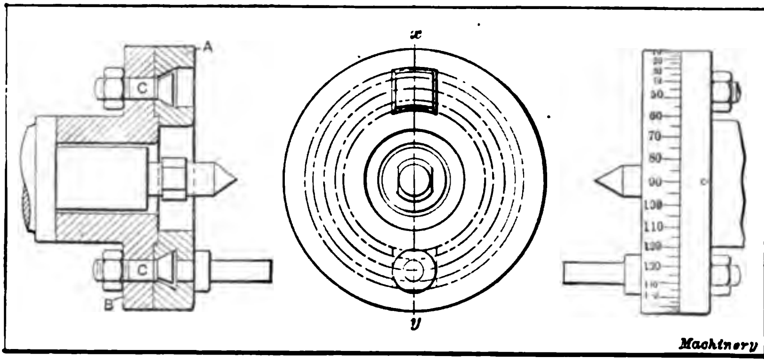


Fig. 29. Indexing Faceplate used for Multiple Thread Cutting

tool for cutting a V-thread is shown in Fig. 31. The method of procedure, when cutting an internal thread, is similar to that for outside work, as far as handling the lathe is concerned. The hole to be threaded is first bored to the root diameter of the thread that is to fit into it. The tool-point is then set square by holding a gage *G* against the true side of the work and adjusting the point to fit the notch in the gage as shown. Very often the size of a threaded hole

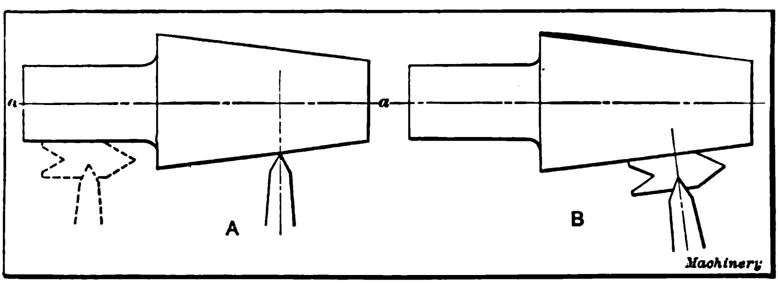


Fig. 30. Correct and Incorrect Positions of Tool for Taper Thread Cutting

can be tested by using as a gage the threaded part that is to fit into it. When making such a test, the tool is, of course, moved back out of the way. It is rather difficult to cut an accurate thread in a small hole, especially when quite deep, owing to the flexibility of the tool; for this reason threads are sometimes cut slightly under size with the tool, after which a tap with its shank end held straight by the tailstock center, is run through the hole. In such a case, the tap should be calipered and the thread made just small enough with the tool to give the tap a light cut. Small square-threaded holes are often finished in this way, and if a number of pieces are to be threaded, the use of a tap makes the holes uniform in size.

Stop for Thread Tools

When cutting a thread, it is rather difficult to feed in the tool just the right amount for each successive cut, because the tool is moved in before it feeds up to the work. A stop is sometimes used for threading which overcomes this difficulty. This stop consists of a screw which enters the tool slide and passes through a block clamped in front of the slide. The hole in the block through which the stop-screw passes is not threaded, but is large enough to permit the screw to move freely. When cutting a thread, the tool is set for the first cut and the

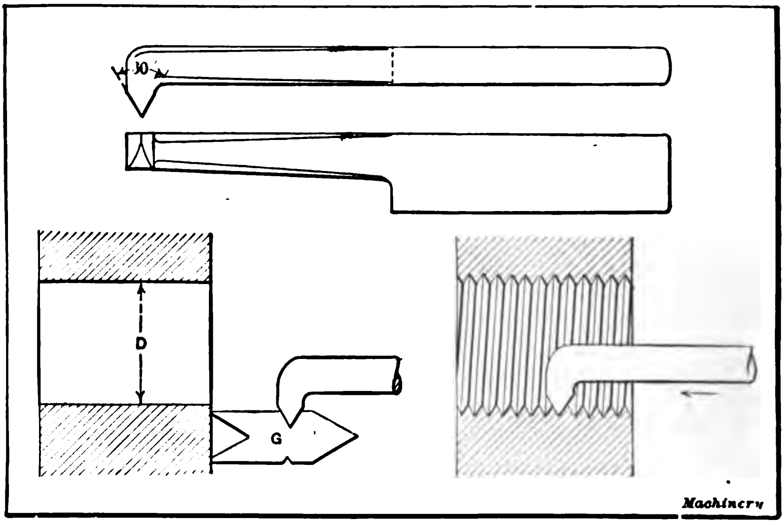


Fig. 31. Inside Thread Tool—Method of Setting and Using

screw is adjusted until the head is against the fixed block. After taking the first cut, the stop-screw is backed out, say one-half revolution, which allows the tool to be fed in far enough for a second cut. If this cut is about right for depth, the screw is again turned about one-half revolution and this is continued for each successive cut until the thread is finished. By using a stop of this kind, there is no danger of feeding the tool in too far as is often done when the tool is set by guess. If this form of stop is used for internal threading, the screw, instead of passing through the fixed block, is placed in the slide so that the end or head will come against the stop. This change is made because the tool is fed outward when cutting an internal thread.

Rivett-Dock Threading Tool

A special form of thread tool, which overcomes a number of disadvantages common to an ordinary single-point thread tool, is shown in Fig. 32. This tool has a circular-shaped cutter *C*, having ten teeth around its circumference, which, beginning with tooth No. 1, gradually increase in height, cutter No. 2 being higher than No. 1, etc. This cutter is mounted on a slide *S*, that is fitted to the frame *F*, and can be moved in or out by lever *L*. The hub of this lever has an eccentric stud which moves slide *S* and locks it when in the forward or cutting position. The action of the lever in moving the slide, engages the cutter with pawl *P*, thus rotating the cutter one tooth at a time and presenting a different tooth to the work for each movement of the lever. When the slide is moved forward, the heel or underside of the tooth which is in the working position, rests on a stop that takes the thrust of the cut. When the tool is in use, it is mounted on the tool-block of the lathe as shown in the illustration. The cutter is

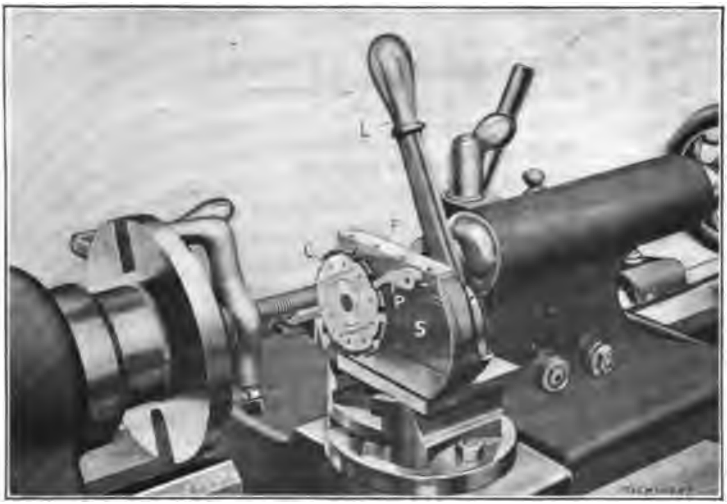


Fig. 32. Rivett-Dock Circular Threading Tool in Working Position

set for height by placing a tooth in the working position and setting the top level with the lathe center. The cutter is also set square with the work by using an ordinary square, and it is tilted slightly from the vertical to correspond with the angle of the thread to be cut, by adjusting frame *F*. At first a light cut is taken with lever *L* moved forward and tooth No. 1 on the stop. After this is completed, the lever is reversed which rotates the cutter one tooth, and the return movement places tooth No. 2 in the working position. This operation is repeated until the tenth tooth finishes the thread. It is often necessary, when using a single-point thread tool, to re-sharpen it before taking the finishing cut, but with a circular tool this is not necessary for by using the different teeth successively, the last tooth, which only takes finishing cuts, is kept in good condition. This tool has a micrometer adjustment which enables threads to be cut to the same size without the use of a gage.

CHAPTER V

TOOL GRINDING

In the grinding of lathe tools, there are three things of importance to be considered: First, the cutting edge of the tool (as viewed from the top) needs to be given a certain shape; second, there must be a sufficient amount of clearance; and third, tools, with certain exceptions, are ground with a backward slope or a side slope, or with a combination of these two slopes on that part against which the chip bears when the tool is in use.

Meaning of Terms Used in Tool Grinding

In Fig. 33 a few of the different types of tools which are used in connection with lathe work are shown. This illustration also

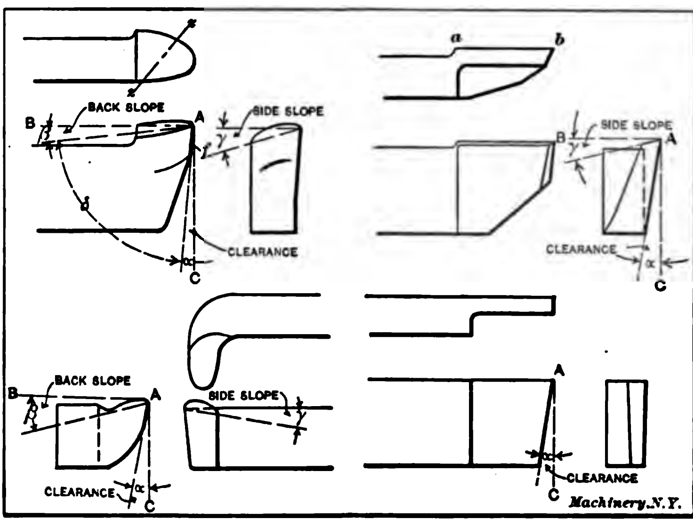


Fig. 33. Illustration showing the Meaning of Terms used in Tool Grinding as applied to Tools of Different Types

indicates the meaning of the various terms used in tool grinding. As shown, the clearance of the tool is represented by the angle α, the back slope is represented by the angle β, and the side slope by the angle γ. The angle δ for a tool without side slope, is known as the lip angle cr the angle of keenness. When, however, the tool has both back and side slopes, this lip angle would more properly be the angle between the flank f and the top of the tool, measured diagonally along a line z—z. It will be seen that the lines A—B and A—C from which the angles of clearance and back slope are measured, are parallel with the top and sides of the tool shank, respectively. For lathe tools, however, these lines are not necessarily located in this way when the tool is in use, as the height of the tool point with relation to the work center determines the position of these lines so that the *effective* angles of back slope, clearance and keenness are changed as the tool point is lowered or raised. The way the position of the tool effects these angles will be explained later.

While tools must, of necessity, be varied considerably in shape to adapt them to various purposes, there are certain underlying principles governing their shape which apply generally; so in what follows we shall not attempt to explain in detail just what the form of each tool used on the lathe should be, as it is more important to understand how the cutting action of the tool and its efficiency is affected when it is improperly ground. When the principle is understood, the grinding of tools of various types and shapes is comparatively easy.

Shape or Contour of Cutting Edge

In the first place we shall consider the shape or contour of the cutting edge of the tool as viewed from the top, and then take up the

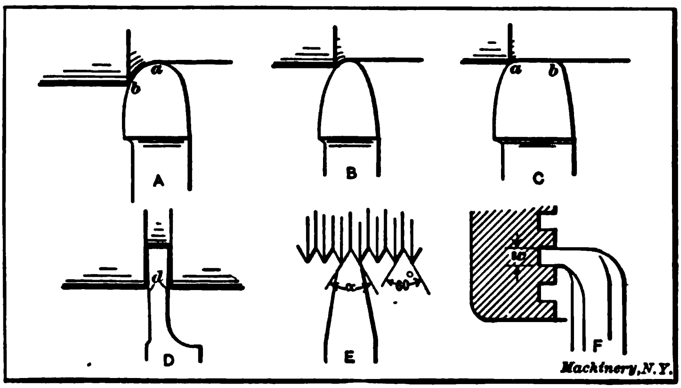


Fig. 34. Plan View of Lathe Turning and Threading Tools

question of clearance and slope, the different elements being considered separately to avoid confusion.

The contour of the cutting edge depends primarily upon the purpose for which the tool is intended. For example, the tool *A*, in Fig. 34, where a plan view of a number of different lathe tools is shown, has a very different shape from that of, say, tool *D*, as the first tool is used for rough turning, while tool *D* is intended for cutting grooves or severing a turned part. Similarly, tool *E* is V-shaped because it is used for cutting V-threads. Tools *A*, *B* and *C*, however, are regular turning tools, that is, they are all intended for turning plain cylindrical surfaces, but the contour of the cutting edges varies considerably, as shown. In this case it is the characteristics of the work and the cut that are the factors which determine the shape. To illustrate, tool *A* is of a shape suitable for rough turning large and rigid work, while tool *B* is adapted for smaller and more flexible parts. The first tool is well shaped for roughing because experiments have shown that a cutting edge of a large radius is capable of higher cutting speed than could be used with a tool like *B*, which has a smaller point. This increase in the cutting speed is due to the fact that the tool *A* removes a thinner chip for a given feed than tool *B*. Therefore, the speed may be increased without injuring the cutting edge to the same extent. If, however, tool *A* were to be used for turning a long and flexible part, chattering would result. Consequently, a tool *B* having a point with a smaller radius would be preferable, if not absolutely necessary. The character of the work also affects the shape of tools. The tool shown at *C* is used for taking light finishing cuts with a wide feed. Obviously, if the straight or flat part of the cutting edge is in line with the travel of the tool, the cut will be smooth and free from ridges, even though the feed is coarse, and by using a coarse feed the cut is taken in less time; but such a tool cannot be used on work that is not rigid, as chattering would result. Therefore, a smaller cutting point and a reduced feed would have to be employed. Tools with broad flat cutting edges and coarse feeds are often used for taking finishing cuts in cast iron, as this metal offers less resistance to cutting than steel, and is less conducive to chattering.

The shape of a tool (as viewed from the top) which is intended for a more specific purpose than regular turning, can be largely determined by simply considering the tool under working conditions. This point may be illustrated by the parting tool *D* which, as previously stated, is used for cutting grooves, squaring corners, etc. Evidently this tool should be widest at the cutting edge; that is, the sides *d* should have a slight amount of clearance so that they will not bind as the tool is fed into a groove. As the tool at *E* is for cutting a V-thread, the angle *a* between its cutting edges must equal the angle between the sides of a V-thread, or 60 degrees. The tool illustrated at *F* is for cutting inside square threads. In this case the width *w* should be made equal to one-half the pitch of the thread, and the sides should be given a slight amount of side clearance, the same as with the parting tool *D*. So we see that the outline of the tool, as viewed from the top, must conform to and be governed by its use.

Direction of Top Slope for Turning Tools

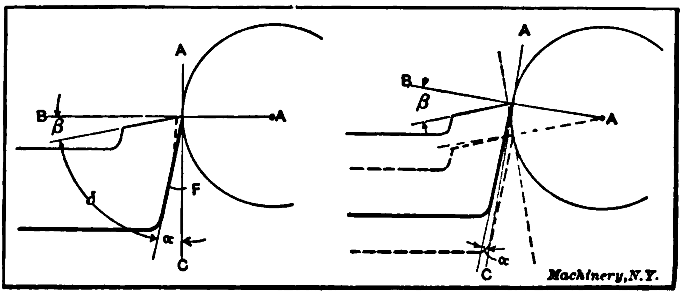
Aside from the question of the shape of the cutting edge as viewed from the top, there remains to be determined the amount of clearance that the tool shall have, and also the slope (and its direction) of the top of the tool. By the top is meant that surface against which the chip bears while it is being severed. It may be stated, in a general way, that the direction in which the top of the tool should slope should be away from what is to be the *working part* of the cutting edge. For example, the working edge of a roughing tool *A* (Fig. 34), which is used for heavy cuts, would be, practically speaking, between points *a* and *b*, or in other words, most of the work would be done by this part of the cutting edge; therefore the top should slope back from this part of the edge. Obviously, a tool ground in this way will have both a back and a side slope. When most of the work is done on the point or nose of the tool, as for example, with the lathe finishing tool *C* which takes light cuts, the slope should be back from the point or cutting edge *a–b*. As the side tool shown in

Fig. 33 does its cutting along the edge *a–b*, the top is given a slope back from this edge as shown in the end view. This point should be remembered, for when the top slopes in the right direction, less power is required for cutting. Tools for certain classes of work, such as thread tools, or those for turning brass or chilled iron, are ground flat on top, that is, without back or side slope.

Clearance for the Cutting Edge

Now, in order that the cutting edge may work without interference, it must have clearance; that is, the flank *f* (Fig. 33) must be ground to a certain angle α so that it will not rub against the work and make the cutting edge ineffective. This clearance should be just enough to permit the tool to cut freely. A clearance angle of eight or ten degrees is about right for lathe turning tools.

The back slope of a tool is measured from a line *A–B* which is parallel to the shank, and the clearance angle, from a line *A–C* at right angles to line *A–B*. These lines do not, however, always occupy this position with relation to the tool shank when the tool is in use.



Figs. 35 and 36. Illustrations showing how Effective Angles of Slope and Clearance change as Tool is raised or lowered

As shown in Fig. 35, the base line *A–B* for a turning tool in use, intersects with the point of the tool and center of the work, while the line *A–C* remains at right angles to the first. It will be seen then, that by raising the tool, as shown to the right (Fig. 36), the *effective* clearance angle α will be diminished, whereas lowering it, as shown by the dotted lines, will have the opposite effect.

A turning tool for brass or other soft metal, particularly where considerable hand manipulation is required, could advantageously have a clearance of twelve or fourteen degrees, as it would then be easier to feed the tool into the metal; but, generally speaking, the clearance for turning tools should be just enough to permit them to cut freely. Excessive clearance weakens the cutting edge and may cause it to crumble under the pressure of the cut.

Angle of Tool-point and Amount of Top Slope

The lip angle or the angle of keenness δ (Fig. 33) is another important consideration in connection with tool grinding, for it is upon this angle that the efficiency of the tool largely depends. By referring to the illustration it will be seen that this angle is governed by the clearance and the slope β, and as the clearance remains practically the same, it is the slope which is varied to meet different conditions. Now, the amount of slope a tool should have depends on the work for which it is intended. If, for example, a turning tool is to be used for roughing medium or soft steel, it should have a back slope of eight degrees and a side slope ranging from fourteen to twenty degrees, while a tool for cutting very hard steel should have a back slope of five degrees and a side slope of nine degrees. The reason for decreasing the slope and thus increasing the lip angle for harder metals is to give the necessary increased strength to the cutting edge to prevent it from crumbling under the pressure of the cut. The tool illustrated at *A*, Fig. 37, is much stronger than it would be if ground as shown at *B*, as the former is more blunt. If a tool ground as at *A*, however, were used for cutting very soft steel, there would be a greater chip pressure on the top and, consequently, a greater resistance to cutting, than if a keener tool had been employed; furthermore the cutting

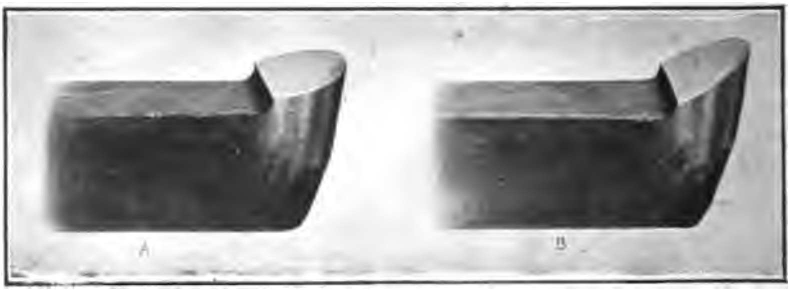


Fig. 37. (A) Blunt Tool for Turning Hard Steel. (B) Tool-point Ground to Give Keenness

speed would have to be lower, which is of even greater importance than the chip pressure; therefore, the lip angle, as a general rule, should be as small as possible without weakening the tool so that it cannot do the required work. In order to secure a strong and well-supported cutting edge, tools used for turning very hard metal, such as chilled rolls, etc., are ground with practically no slope and with very little clearance. Brass tools, while given considerable clearance, as previously stated, are ground flat on top or without slope; this is not done, however, to give strength to the cutting edge, but rather to prevent the tool from gouging into the work, which it is likely to do if the part being turned is at all flexible and the tool has top slope.

Experiments conducted by Mr. F. W. Taylor to determine the most efficient form for lathe roughing tools, the results of which have already been published in MACHINERY (January to August, 1907, engineering edition), showed that the nearer the lip angle approached sixty-one degrees, the higher the cutting speed. This, however, does not apply to tools for turning cast iron, as the latter will work more efficiently with a lip angle of about sixty-eight degrees. This is because the chip pressure, when turning cast iron, comes closer to the cutting edge which should, therefore, be more blunt to withstand the abrasive action and heat. Of course, the foregoing remarks concerning lip angles apply more particularly to tools used for roughing.

The way a turning tool is held while the top surface is being ground is shown in Fig. 38. By inclining the tool with the wheel face, it will be seen that both the back and side slopes may be ground at the same time. When grinding the flank of the tool it should be held on the tool-rest of the emery wheel or grindstone, as shown in Fig. 39. In order to form a curved cutting edge, the tool is turned about the face of the stone while it is being ground. This rotary movement can be effected by supporting the inner end of the tool with one hand while the shank is moved to and fro with the other.

Often a tool which has been ground properly in the first place, is greatly mis-shapen after it has been sharpened a few times. This is usually the result of attempts on the part of the workman to resharpen it hurriedly; for example, it is easier to secure a sharp edge on the turning tool shown in Fig. 35, by grinding the flank as indi-

Figs. 38 and 39. Grinding the Top and Flank of a Turning Tool

cated by the dotted line, than by grinding the entire flank. The clearance is, however, reduced and the lip angle changed.

There is great danger when grinding a tool of burning it or drawing the temper from the fine cutting edge, and, aside from the actual shape of the cutting end, this is the most important point in connection with tool grinding. If a tool is pressed hard against an emery or other abrasive wheel, even though the latter has a copious supply of water, the temper will sometimes be drawn.

When grinding a flat surface, to avoid burning, the tool should be frequently withdrawn from the stone so that the cooling water (a copious supply of which should be provided) can have access to the surface being ground. A moderate pressure should also be applied, as it is better to spend an extra minute or two in grinding, than to ruin the tool by burning it in an attempt to sharpen it quickly. Of course, what has been said about burning, applies more particularly to carbon steel, but even self-hardening steels are not improved by being overheated at the stone.

In some shops tools are ground to the theoretically correct shape in special machines instead of by hand. The sharpened tools are then kept in the tool-room and are given out as they are needed.

CHAPTER VI

QUICK CHANGE-GEAR TYPE OF LATHE

A type of lathe that is much used at the present time is shown in Fig. 40. This is known as the quick change-gear type, because it has a system of gearing which makes it unnecessary to remove the change gears and replace them with different sizes for cutting threads of various pitches. Changes of feed are also obtained by the same mechanism, but the feeding movement is transmitted to the carriage by the rod *R*, whereas the screw S_1 is used for screw cutting. As previ-

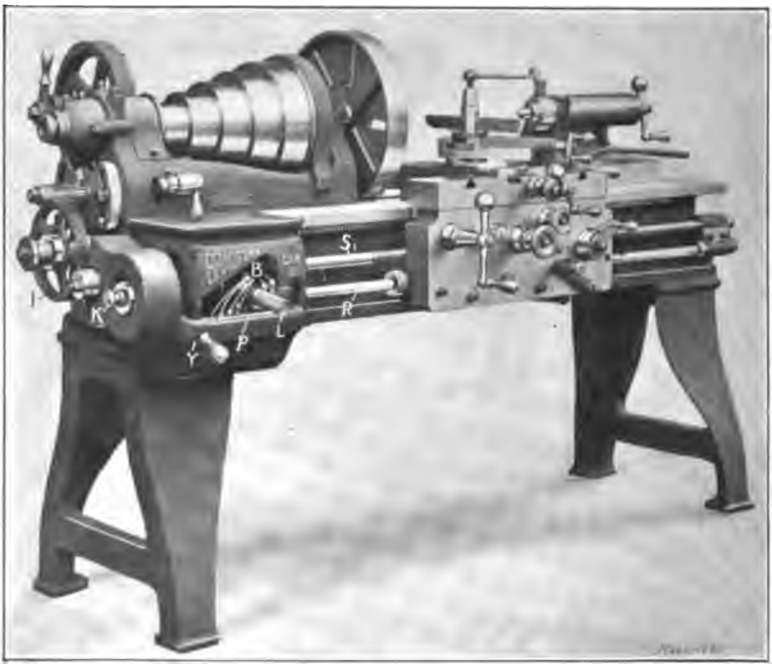


Fig. 40. Lathe Having Quick Change-gear Mechanism

ously explained the idea of using the screw exclusively for threading is to prevent it from being worn excessively, as it would be if continually used in place of rod *R*, for feeding the carriage when turning.

The general construction of this quick change gear mechanism and the way the changes are made for cutting threads of different pitch, will be explained in connection with Figs. 40, 41 and 42, which are marked with the same reference letters for corresponding parts. Referring to Fig. 40, the movement is transmitted from gear *s* on

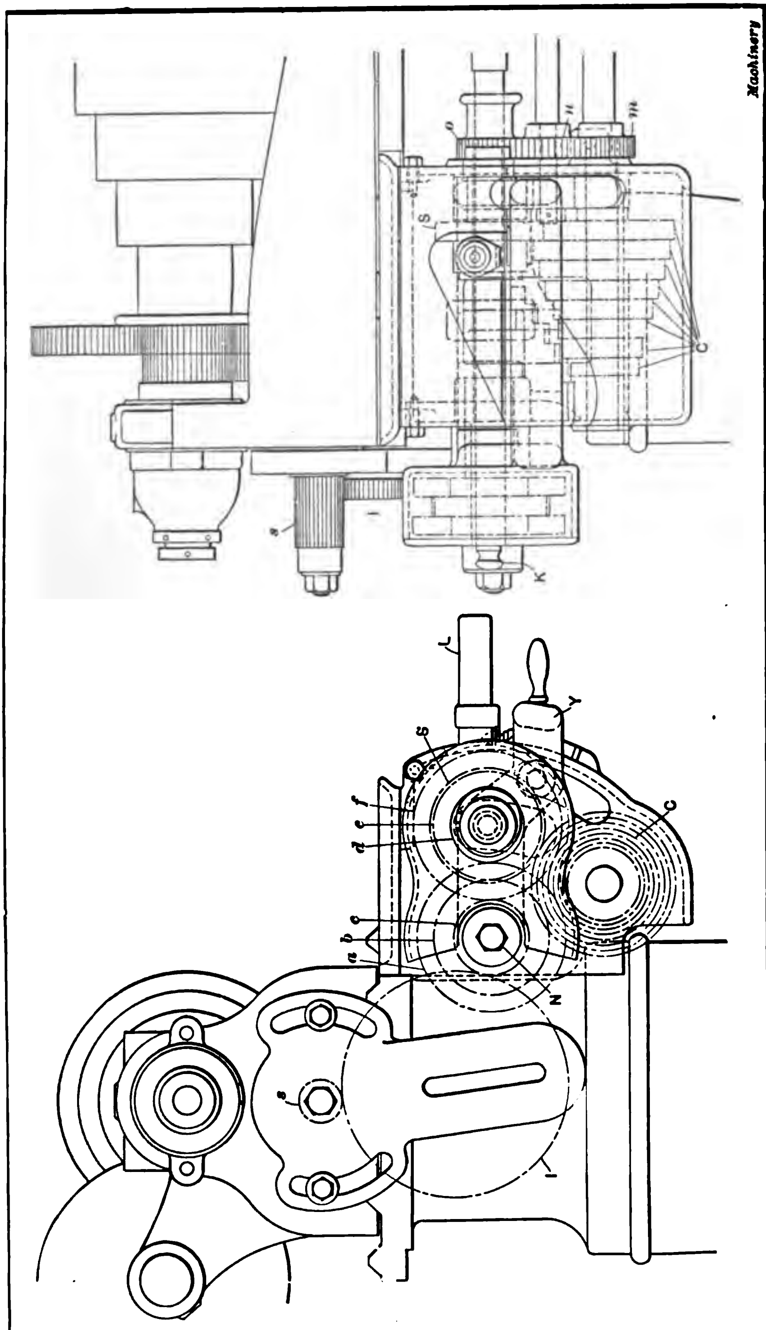


Fig. 41. End and Side Views of Quick Change-gear Mechanism

the spindle stud through idler gear *I*, which can be moved sidewise to mesh with either of the three gears *a*, *b* or *c*, Fig. 41. This cone of three gears engages gears *d*, *e* and *f*, any one of which can be locked with shaft *T* (Fig. 42) by changing the position of knob *K*. On shaft *T* there is a gear *S* which can be moved along the shaft by hand lever *L* and, owing to the spline or key *t*, both the sliding gear and shaft rotate together. Shaft *T*, carrying gears *d*, *e* and *f* and the sliding gear *S*, is mounted in a yoke *Y*, which can be turned about shaft *N*, thus making it possible to lower sliding gear *S* into mesh with any one of a cone of eight gears *C*, Fig. 41. The shaft on which the eight gears are mounted, has at the end a small gear *m* meshing with gear *n* on the feed-rod, and the latter, in turn, drives the lead-screw, unless gear *o* is shifted to the right out of engagement, which is its position

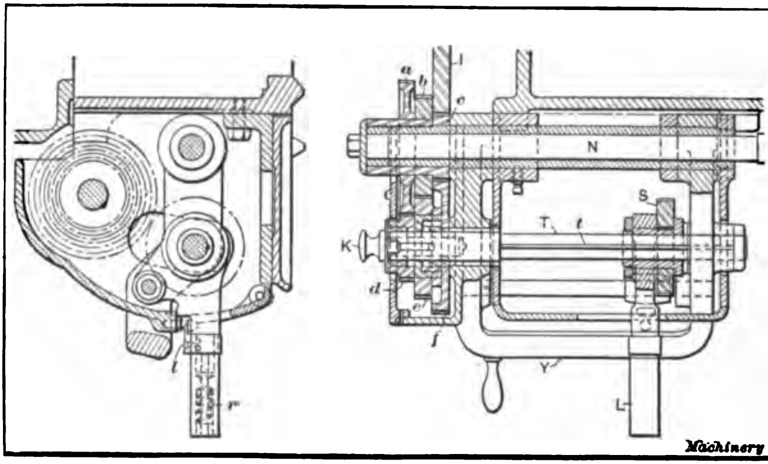


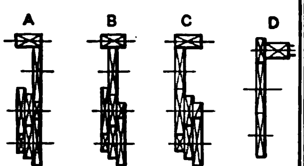
Fig. 42. Sectional Views of Quick Change-gear Mechanism

except when cutting threads. With this mechanism, eight changes for different threads or feeds are obtained by simply placing gear *S* into mesh with the various sized gears in cone *C*. As the speed of shaft *T* depends on which of the three gears *d*, *e* and *f* are locked to it, the eight changes are tripled by changing the position of knob *K*, making twenty-four. Now by shifting idler gear *I*, three speed changes may be obtained for gears *a*, *b* and *c*, which rotate together, so that the twenty-four changes are also tripled, giving a total of seventy-two variations without removing any gears, and if a different sized gear *s* were placed on the spindle stud, an entirely different range could be obtained, but such a change would rarely be necessary. As shown in Fig. 40, there are eight hardened steel buttons *B*, or one for each gear of the cone *O*, placed at different heights in the casing. When lever *L* is shifted sidewise to change the position of sliding gear *S*, it is lowered onto one of these buttons (which enters a pocket on the under side) and in this way gear *S* is brought into proper mesh with any gear of the cone *C*. To shift lever *L*, the handle is pulled outward against the tension of spring *r* (Fig. 42) which disengages latch

I and enables the lever to be lifted clear of the button; yoke *Y* is then raised or lowered, as the case may be, and lever *L* with the sliding gear is shifted to the required position.

The position of lever *L* and knob *K* for cutting threads of different pitches, is shown by an index plate or table attached to the lathe and arranged as shown in Fig. 43. The upper section *a* of this table shows the different numbers of threads to the inch that can be obtained when idler gear *I* is in the position shown by the diagram *A*. Section *b* gives the changes when the idler gear is moved, as shown at *B*, and, similarly, section *c* gives the changes for position *C* of the idler. The horizontal row of figures from 1 to 8 below the word "stops", represents the eight positions for lever *L* which has a plate *p* (Fig. 40) just beneath it with corresponding numbers, and the column to the left shows whether knob *K* should be out, in a central position, or in. In order to find what the position of lever *L* and knob *K* should be for cutting any given number of threads to the inch, find what "stop" number is directly above the number of threads to be cut, which will indicate the location of lever *L*, and also what position should be occupied by knob *K*, as shown in the column to the left. For example, suppose the lathe is to be geared for cutting eight threads to the inch. By referring to section *a* we see that lever *L* should be in position 4 and knob *K* in the center, provided the idler gear *I* were in position *A*, as it would be ordinarily, because all standard numbers of threads per inch (U. S. standard) from ¼ inch up to and including 4 inches in diameter, can be cut with the idler gear in that position. As another illustration, suppose we want to cut twenty-eight threads per inch. This is listed in section *c*, which shows that lever *L* must be placed in position 3 with knob *K* pushed in and the idler gear shifted to the left as at *C*.

DIRECTIONS FOR COMPOUNDING



POSITION OF KNOB	STOPS								
	1	2	3	4	5	6	7	8	
	THREADS WITH COMP. A								
OUT	3	3¼	3½	4	4½	5	5½	5¾	*a*
CENT	6	6½	7	8	9	10	11	11½	
IN	12	13	14	16	18	20	22	23	
	THREADS WITH COMP. B								
OUT	4½	4⅞	5¼	6	6¾	7½	8¼	8⅝	*b*
CENT	9	9¾	10½	12	13½	15	16½	17¼	
IN	18	19½	21	24	27	30	33	34½	
	THREADS WITH COMP. C								
OUT	6	6½	7	8	9	10	11	11½	*c*
CENT	12	13	14	16	18	20	22	23	
IN	24	26	28	32	36	40	44	46	

Fig. 43. Index Plate showing Positions of Control Levers for Cutting Threads of Different Pitch

The simplicity of this method as compared with the time-consuming operation of removing and changing gears, is apparent. The diagram *D* to the right, shows an arrangement of gearing for cutting nineteen threads per inch. A 20-tooth gear is placed on the spindle stud (in place of the regular one having 16 teeth) and one with 95 teeth on the end of the lead-screw, thus driving the latter direct as with ordinary change gears.

CHAPTER VII

MISCELLANEOUS POINTS ON LATHE WORK

The production of accurate lathe work depends partly on the condition of the lathe used and also on the care and judgment exercised by the man operating it. Even though a lathe is properly adjusted and in good condition otherwise, errors are often made which are due to other causes which should be carefully avoided.

If the turning tool is clamped so that the cutting end extends too far from the supporting block, the downward spring of the tool, owing to the thrust of the cut, sometimes results in spoiled work, especially when an attempt is made to turn close to the finished size by taking a heavy roughing cut. Suppose the end of a cylindrical part is first

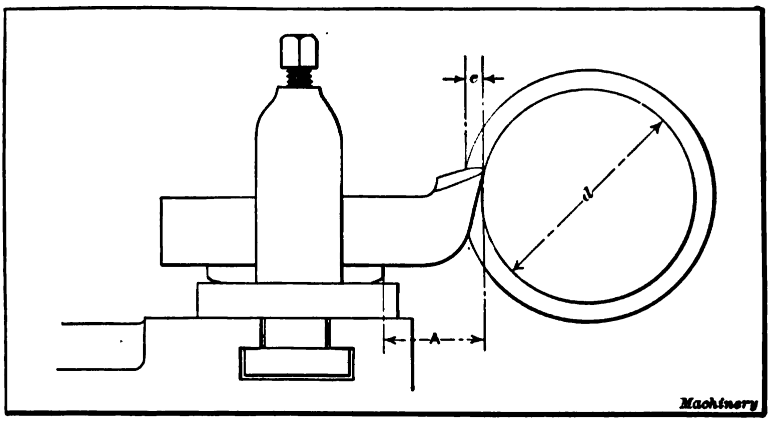


Fig. 44. To avoid springing, Overhang A of Tool should not be too great

reduced for a short distance by taking several trial cuts until the diameter *d*, Fig. 44, is slightly above the finished size and the power feed is then engaged. When the tool begins to take the full depth *e* of the cut, the point, which ordinarily would be set above the center, tends to spring downward into the work, and if there were considerable springing action, the part would probably be turned below the finished size, the increased reduction beginning at the point where the full cut started. This springing action, as far as the tool is concerned, can be practically eliminated by locating the tool so that the distance *A* between the tool-block and cutting end, or the "overhang," is as short as possible. Even though the tool has little overhang it may tilt downward because the tool-slide is loose on its ways, and for this reason the slide should have a snug adjustment that will permit an easy movement without unnecessary play.

When roughing cuts are to be taken, the tool should also be located so that any change in its position caused by the pressure of the cut, will not spoil the work. This point is illustrated at *A* in Fig. 45. Suppose the end of a rod has been reduced by taking a number of trial cuts, until it is 1/32 inch above the finished size. If the power feed is then engaged with the tool clamped in an oblique position, as shown, when the full cut is encountered at *c*, the tool, unless very tightly clamped, may be shifted backward by the lateral thrust of the cut, as indicated by the dotted lines. The point will then begin turning smaller than the finished size and the work will be spoiled. To prevent any change of position, it is good practice, especially when roughing, to clamp the tool square with the surface being turned, or in other words, at right angles to its direction of movement. Occasionally, however, there is a decided advantage in having the tool

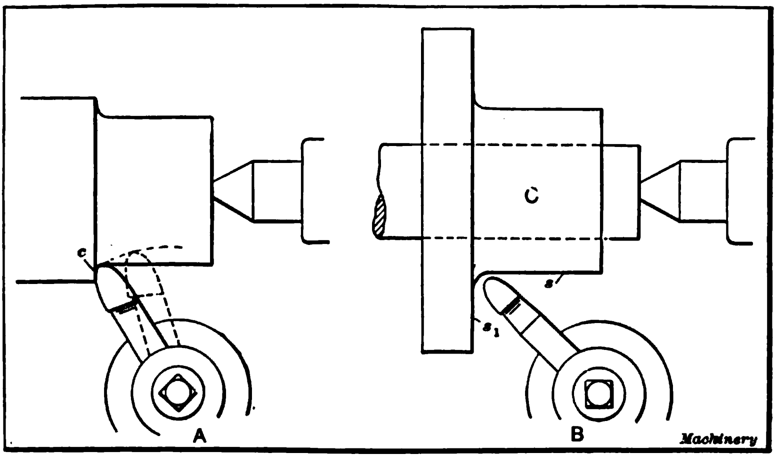


Fig. 45. (A) The Way in which Tool is sometimes displaced by Thrust of Cut, when set at an Angle. (B) Tool Set for Finishing Cylindrical and Radial Surfaces

set at an angle. For example, if it is held about as shown at *B*, when turning the flange casting *C*, the surfaces *s* and s_1 can be finished without changing the tool's position.

Work that is held in a chuck is sometimes sprung out of shape by the pressure of the chuck jaws so that when the part is bored or turned, the finished surfaces are untrue after the jaws are released and the work has resumed its normal shape. This applies more particularly to frail parts, such as rings, thin cylindrical parts, etc. Occasionally the distortion can be prevented by so locating the work with relation to the chuck jaws that the latter bear against a rigid part. When the work cannot be held tightly enough for the roughing cuts without springing it, the jaws should be released somewhat before taking the finishing cut, to permit the part to spring back to its natural shape.

Work that is turned between centers is sometimes driven by a dog which is so short for the faceplate that the bent driving end bears against the bottom *a* of the faceplate slot, as shown at *A*, Fig. 46. If the dog is nearly the right length, it may allow the headstock center to enter the center in the work part way, with the result that the turned surface is not true with the centers. When a driving dog of this type is used, care should be taken to see that it moves freely in the faceplate slot and does not bind against the bottom. By using a straight dog (*B*), which is driven by a pin *b* bolted to the faceplate, all danger from this source is eliminated. The straight dog, however, is used more particularly to do away with the leverage *l* of a bent dog, as this leverage tends to spring the part being turned. Straight dogs are also made with two driving ends which engage pins on opposite sides of the faceplate. This type is preferable because it applies the power required for turning, evenly to the work, which still further reduces the tendency to spring it out of shape. The principal objec-

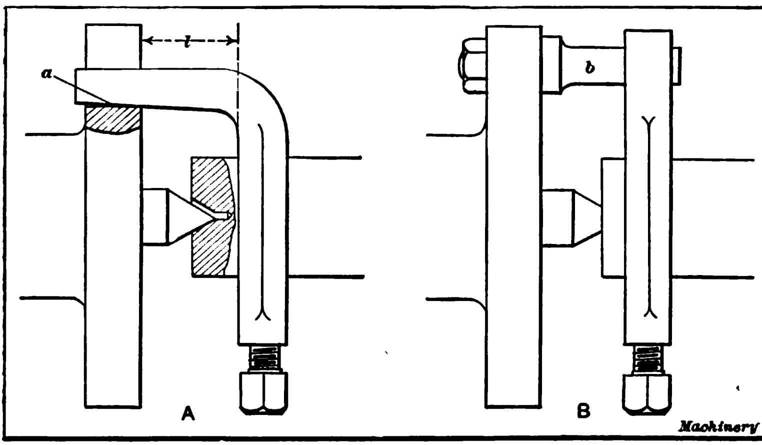


Fig. 46. (A) Dog that is too Short for Faceplate. (B) Straight Driving Dog

tion to the double-ended type lies in the difficulty of adjusting the driving pins so that each bears with equal pressure against the dog.

The lathe centers should receive careful attention especially when accurate work must be turned. If the headstock center does not run true as it revolves with the work, a round surface may be turned, but if the position of the driving dog with reference to the faceplate is changed, the turned surface will not run true because the turned surface is not true with the work centers. Furthermore, if it is necessary to reverse the work for finishing the dogged or driving end, the last part turned will be eccentric to the first. Therefore, the lathe centers should be kept true in order to produce turned surfaces that are true or concentric with the centered ends, as it is often necessary to change the part being turned "end for end" for finishing, and any eccentricity between the different surfaces would, in many cases, spoil the work.

Some lathes are equipped with hardened centers in both the head- and tail-stock and others have only one hardened center which is in the tailstock. The object in having a soft or unhardened headstock center is to permit its being trued by turning, but as a soft center is quite easily bruised and requires truing oftener than one that is hard, it is better to have both centers hardened. Special grinders are used for truing these hardened centers. One type that is very simple and easily applied to a lathe is shown in Fig. 47. This grinder is held in the lathe toolpost and is driven by a wheel *A* that is held in contact with the cone-pulley. The emery wheel *B* is moved to a position for grinding by adjusting the carriage and cross-slide, and it is traversed across the conical surface of the center by handle *C*. As the grinding proceeds, the wheel is fed inward slightly by manipulating the cross-slide. This grinder is set to the proper angle by placing the two centered ends *D* and D_1 between the lathe centers, which should be aligned as for straight turning. The grinding spindle will then be 30 degrees from the axis of the lathe spindle. The grinder should be carefully clamped in the toolpost so that it will remain

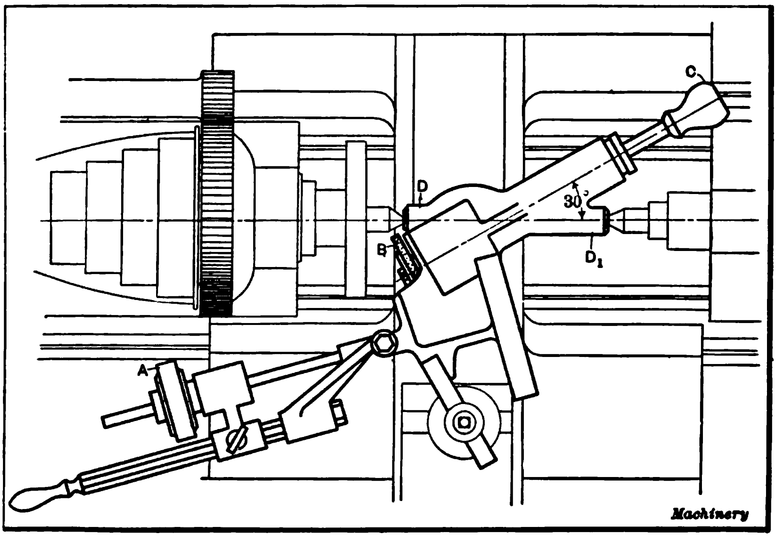


Fig. 47. Lathe Center Grinder

as located by the centered ends. The tailstock center is next withdrawn and the emery wheel is adjusted for grinding. As the wheel spindle is 30 degrees from the axis of the lathe spindle, the lathe center is not only ground true but to an angle of 60 degrees, which is the standard angle for lathe centers. There are many other styles of center grinders on the market, some of which are driven by a small belt from the cone-pulley and others by electric motors which are connected with ordinary lighting circuits. The tailstock center is ground by inserting it in the spindle in place of the headstock center. Before a center is replaced in its spindle, the hole should be perfectly clean as even a small particle of dirt may seriously affect the alignment.

When a rod or shaft must be turned cylindrical or to the same diameter throughout its entire length, it is good practice to test the alignment of the centers, before inserting the work. The position of the tailstock center for cylindrical turning may be indicated by the coincidence of graduation marks on the base, but if accuracy is necessary, the relative position of the two centers should be determined in a more positive way. A very simple and convenient method of testing the alignment is shown at *A* in Fig. 48. The work is first turned for a short distance, near the dogged end, as shown, and the tool is left as set for this cut; then the tailstock center is withdrawn and the work is moved sufficiently to permit running the tool back to the tailstock end without changing its original setting. A short cut is then taken at this end and the diameters d and d_1 are carefully compared. In case there is any variation, the tailstock center is

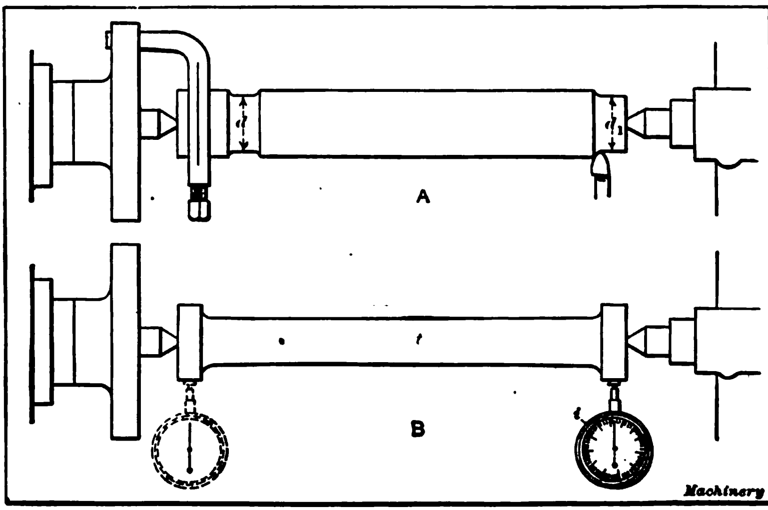


Fig. 48. Two Methods of Aligning Centers for Cylindrical Turning

adjusted laterally, other trial cuts are taken, and the test repeated.

Another method is illustrated at *B*, which requires the use of a test-bar *t*. This bar should have accurately made centers and the ends finished to exactly the same diameter. The lathe centers are aligned by placing the bar between them and then testing the position of the ends. This can be done by comparing each end with a tool held in the toolpost and moved from one to the other by shifting the carriage, but a better method is to clamp a test indicator *i* in the toolpost and bring it in contact with first one end of the bar and then the other. If the dial does not register the same at each end, it shows that the lathe centers are not in line.

Even when centers are correctly set, lathes that have been in use a long time do not always turn cylindrical or straight because if the ways that guide the carriage are worn unevenly, the tool as it moves along does not remain in the same plane and this causes a variation in the diameter of the part being turned.

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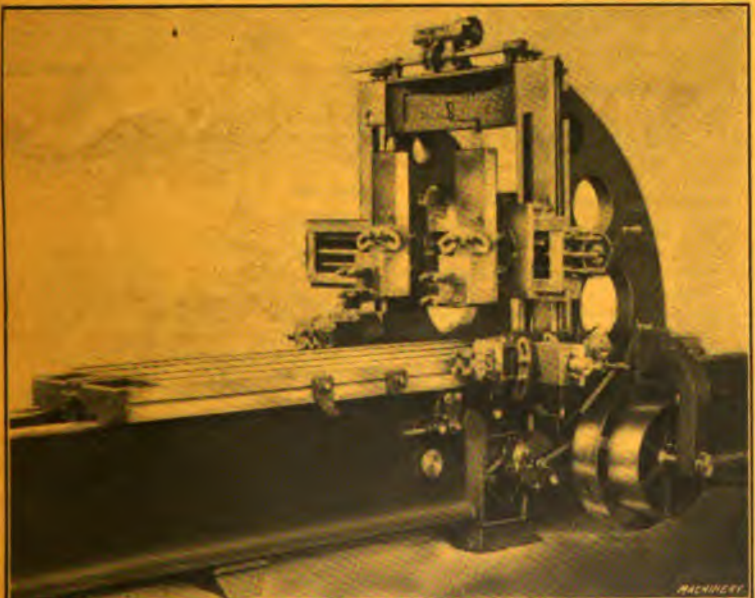

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OPERATION OF MACHINE TOOLS

By FRANKLIN D. JONES

PLANER—SHAPER—SLOTTER

CONTENTS

49-55 Lafayette Street, New York City

CHAPTER I

CONSTRUCTION AND OPERATION OF A PLANER

The planer is used principally for producing flat surfaces. The construction or design of planers of different makes varies somewhat, and special types are built for doing certain kinds of work. There is, however, what might be called a standard type which is found in all machine shops and is adapted to general work. A typical planer of small size is illustrated in Fig. 1. The principal parts are the bed *B*, the housings *H* which are bolted to the bed, the table or platen *P* to which the work is attached, the cross-rail *C*, and the toolhead *T*

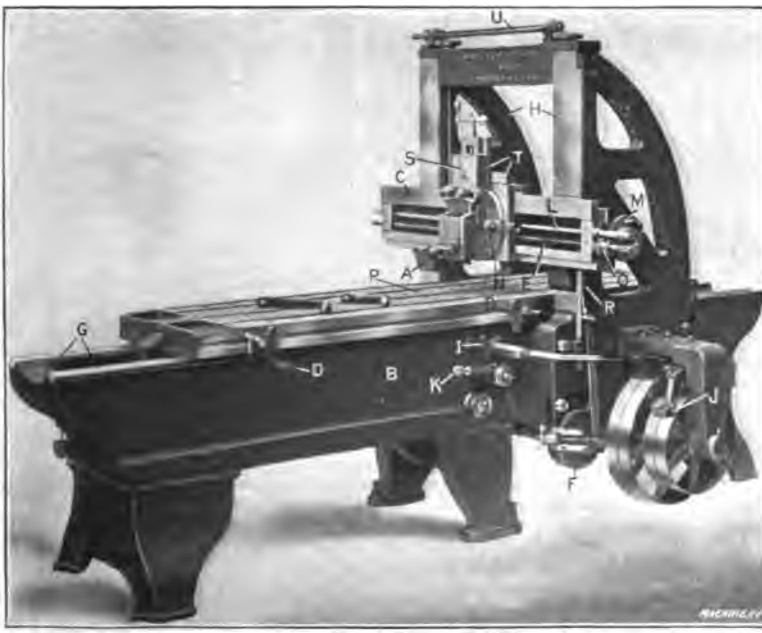

Fig. 1. Flather Single-head Planer

which is mounted on the cross-rail. When the planer is in operation, the platen slides back and forth on the bed in V-shaped grooves *G* which cause it to move in a straight line. While this reciprocating movement takes place, the work, which is clamped to the platen, is planed by a tool held in position by clamps *A*. This tool remains stationary except at the end of each stroke of the platen, when the toolhead and tool feed slightly for a new cut. The amount of feed for each stroke can be varied to suit the conditions, as will be explained later. The movement of the table or of the length of its stroke is governed by the position of the dogs *D* and D_1. These dogs may be adjusted along the groove shown and they serve to reverse the table movement by engaging tappet *I*. Before explaining just how the movement of tappet *I* controls the point of reversal, the arrangement of the driving mechanism, a plan view of which is shown in Fig. 2, will be explained.

The Driving and Reversing Mechanism

The shaft on which the belt pulleys *f*, f_1, and *r*, r_1 are mounted carries a pinion *a* that meshes with a gear on shaft *b*. This shaft drives, through the gears *c* and *d*, a second shaft which carries a pinion *e*, and

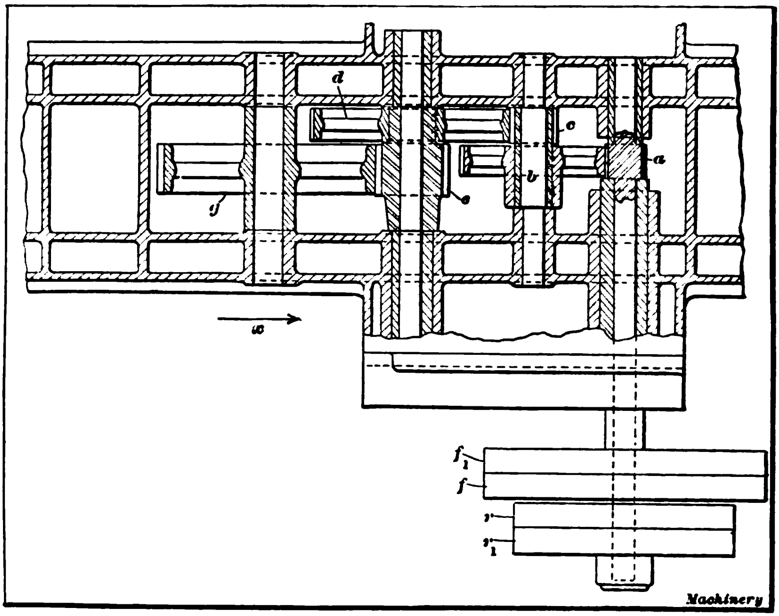

Fig. 2. Driving Mechanism of a Spur-geared Planer

which meshes with a large gear *g*. This large gear, which is called the "bull-wheel," in turn engages a rack attached to the under side of the table, and, as the gear revolves, the table moves along the ways of the bed. There are two pairs of driving pulleys and also two driving belts connecting with an overhead countershaft. One pulley of each set is keyed to the shaft and the other is loose and revolves freely. The belt operating on the large pulleys *f* and f_1 is "open" whereas the belt for the smaller pulleys *r* and r_1 is crossed, which gives a reverse motion. The position of both belts is controlled by guides *J* (one of which is seen in Fig. 1) which are operated by tappet *I*. Now when the open belt is running on the tight pulley *f*, the reverse belt is on the loose pulley r_1, and the table moves as shown by the arrow *x*, which is in the direction for the cutting stroke. When the table is advanced far enough to bring dog *D* (Fig. 1) into engagement with tappet *I*, the latter is pushed over, which shifts the open belt on loose pulley f_1 and the cross belt on the tight pulley *r*. The pulley shaft and the entire train of driving gears is then rotated in the opposite direction by the crossed belt and the table movement is reversed. This is the return stroke, during which the planing tool glides back over the work to the starting point for a new cut. To change the length of the stroke, it is simply necessary to shift dogs *D* and D_1 as their position determines the point of reversal. When the workman desires to reverse the table by hand or stop it temporarily, this can be done by operating hand lever *K*. It will be noted that there is considerable difference in the diameter of the two sets of belt pulleys, those for the forward or cutting stroke being much

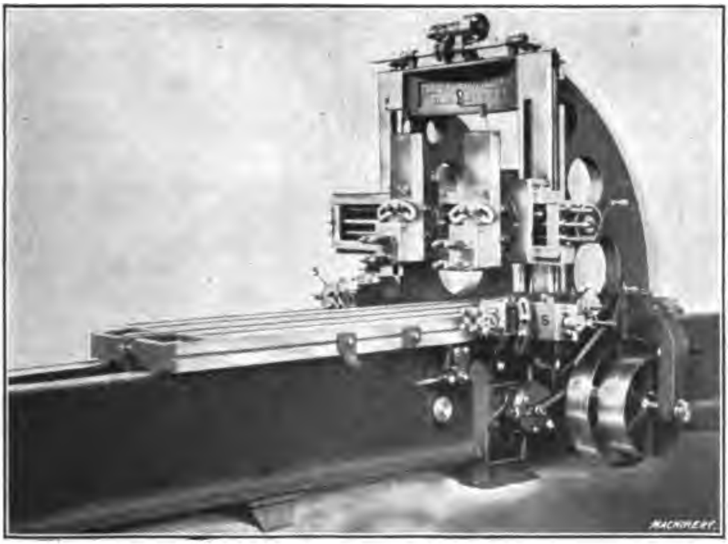

Fig. 3. Cincinnati Four-head Planer

larger than those for the return movement. As the size of the countershaft pulleys is in the reverse order, the speed of the table is much less when the large pulley is driving than when the cross belt is shifted to the small pulley. The result is that the table is returned quickly after the cutting stroke in order to reduce the idle time that elapses between the end of one cut and the beginning of the next.

The Feeding Mechanism

The feeding movement of the tool takes place just before the cutting stroke begins. If a horizontal surface is being planed, the tool has a crosswise movement parallel to the platen, but if the surface is vertical, the tool is fed downward at right angles to the platen. In the first case, the entire toolhead *T* moves along the cross-rail *C*, but for vertical planing, slide *S* moves downward. Surfaces which are at an angle with the table can also be planed by loosening nuts *N* and swiveling slide *S* to the required angle as shown by graduations on the circular base. The horizontal and vertical movements of the tool can be effected by hand or automatically. The hand feed is used principally for adjusting the tool to the proper position for starting a cut. The tool can be set to the right height by a crank at the top of the tool-head, and the crosswise position of the tool and head can be varied by turning horizontal feed-screw *E*. This screw is turned for a hand adjustment by placing a crank on the squared outer end. The automatic feeding movement is derived from a feed disk *F*, which turns part of a revolution at each end of the stroke and is connected to a rack *R*. This rack slides up and down with each movement of the crank and imparts its motion to gear *M* by means of an inner pinion which it engages. Gear *M*, in turn, meshes with a gear *O* placed on the feed-screw. The feeding movement is engaged, disengaged or reversed by a pawl attached to gear *M* (on this particular planer) and the amount of feed per stroke is varied by adjusting the crankpin of the disk *F*, to or from the center. The vertical feed is operated by a splined shaft *L* which transmits its motion to the toolhead feed-screw through gearing. This shaft is also driven by gear *O* which is removable and is placed on it when an automatic vertical feed is desired.

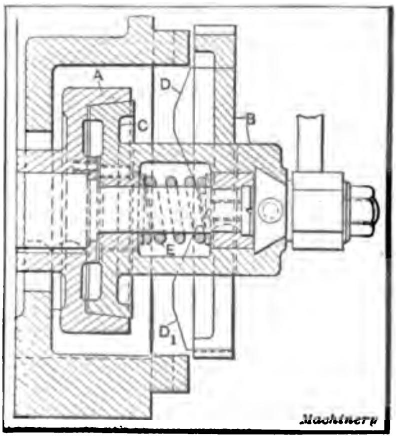

Fig. 4. Friction Feed Disk

The friction disk *F* is turned by pinion shaft *c* (Fig. 2), of the driving mechanism. The number of revolutions made by this pinion shaft for each stroke depends, of course, on the length of the stroke, but the feed disk is so arranged that it only rotates part of a revolution at each end of the stroke, so that the feeding movement is not governed by the length of the stroke. In other words the feed disk is disengaged from the driving shaft after being turned part of a revolution. One type of feed disk is shown in the sectional view Fig. 4. The cup-shaped part *A* having an inner tapering surface is attached to the main pinion shaft. Crank-disk *B* has a tapering hub *C* which fits into part *A* as shown. If the hub is engaged with cup *A* when the planer is started, the crank-disk is turned until a tapered projection *D* strikes a stationary taper boss on the bed which disengages hub *C* from the driving member by moving it outward against the tension of spring *E*. The disk then stops turning and remains stationary until the driving member *A* reverses at the end of the stroke. The hub then springs back into engagement and the disk turns in the opposite direction until another taper projection D_1, on the opposite side, strikes a second boss on the bed which again arrests the feeding movement. It will be seen that this simple mechanism causes the disk to oscillate through the same arc whether the stroke is long or short.

Double Head Planers—Use of Side-heads—Two-speed Planer

Modern planers, with the exception of comparatively small sizes, are ordinarily equipped with two tool-heads on the cross-rail, as shown in Fig. 3, so that two tools can be used at the same time. Some planers also have side-heads *S* mounted on the housings below the cross-rail for planing vertical surfaces or for doing other work on the sides of a casting. These side-heads have an automatic vertical feed and can often be used while the other tools are planing the top surface, the method being to start first the regular tools (which usually have the largest surfaces to plane) and then the side-heads. If the planing on the side requires hand manipulation, as when forming narrow grooves,

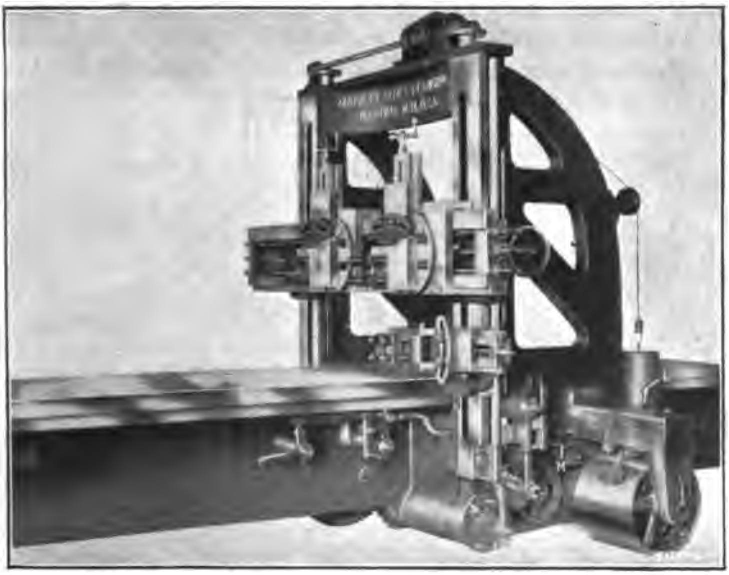

Fig. 5. Flather Two-speed Planer

etc., the planing would be done on first one side and then the other, assuming that both sides required machining, but when the surfaces are broad the automatic feed enables both side-heads to be used at the same time, on some classes of work. These side-heads often greatly reduce the time required for planing and they also make it possible to finish some parts at one setting, whereas the work would have to be set up in one or two different positions if a planer without side-heads were used.

The planer illustrated in Fig. 5 has two speeds for the "cutting stroke" of the table, instead of a single speed. This feature is very desirable as it enables the cutting speed to be varied in accordance with the kind of material to be planed or the character of the work. The speed is changed from fast to slow or *vice versa* by operating lever *L* which, through a segment pinion and rack *M*, shifts sliding gears which are located inside the bed and form a part of the driving train.

CHAPTER II

EXAMPLES OF PLANER WORK AND ADJUSTMENT OF MACHINE

A simple example of planing is illustrated in Fig. 6. The work *W* is a base casting, the top surface of which is to be planed true. The casting is first fastened to the table by bolts and clamps *C* and C_1, and it is further held from shifting by stop-pins *S*. The platens of all planers are provided with a number of slots and holes for the

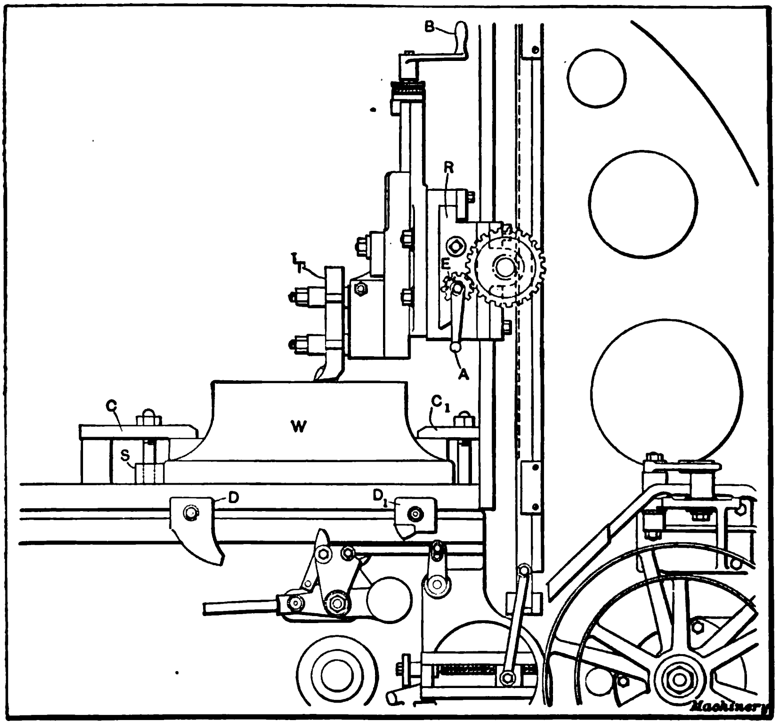

Fig. 6. Side View of Planer with Work in Position

reception of clamping bolts and stop-pins. When the casting is securely attached to the platen, a planing tool *T* is clamped in the toolpost, and cross-rail *R* is set a little above the top surface of the work. The dogs *D* and D_1 are then placed opposite the work and are set far enough apart to give the platen and work a stroke slightly greater than the length of the surface to be planed. The movement of the work during a stroke is illustrated in Fig. 7, the full lines showing its position with relation to the tool at the beginning of the cutting stroke, and the dotted lines the end of the stroke or the point of reversal. The dogs should be adjusted so that the distance *x* is not more than $1\frac{1}{2}$ to 2 inches and the tool should just clear the work at the other end. If the stroke is much longer than the length of the surface being planed, obviously more time is required for planing than when the stroke is properly adjusted.

Taking the Cut

The tool is moved over to the work by handle *A* and is fed down to the right depth for a cut by handle *B*. The planer is started by shifting an overhand belt (assuming that it is belt- and not motor-driven) and the power feed is engaged by throwing the feed pawl into mesh. On this particular planer, the feed pawl is inside the gear and it is engaged or disengaged by handle *E*. The tool planes the surface of the casting by feeding horizontally across it and removing a chip

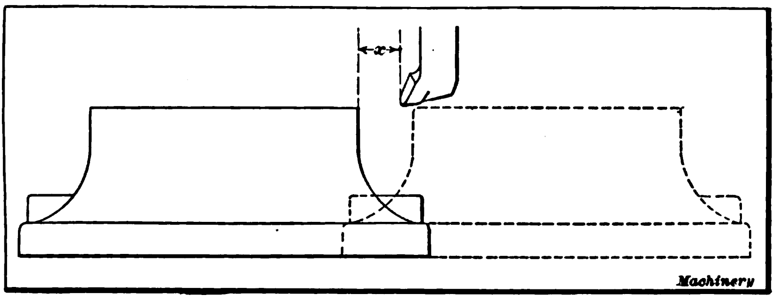

Fig. 7. Movement of Work with Relation to Planing Tool

during each forward stroke of the work. If there is not much metal to be planed off, one roughing and one finishing cut would probably be all that is necessary. For the finishing cut, a broad tool having a flat edge is often used, especially for cast iron, as it enables wide feeds to be taken, which reduces the time required for the finishing cut. The different types of tools ordinarily used on a planer, are illustrated in Chapter IV, which also explains how they are ground and gives typical examples of their use.

Planing Work held in a Chuck

Another planing operation is illustrated in Fig. 8. In this case, the sides of a cast-iron block *B* are to be planed parallel and square to each other. One method of holding the work would be to grip it in the planer chuck *A*. A cut can then be taken over the entire surface of one side, whereas if ordinary clamps *C*, Fig. 6, were used, they would interfere with the movement of the tool. This chuck, an end view of which is shown at *A* in Fig. 9, has one fixed jaw *J* and one movable jaw J_1 and the work is clamped between the jaws by the screws shown. The work is "bedded" by hammering it lightly, until the sound indicates that it rests solidly on the bottom of the chuck.

After a cut has been taken over the upper side *a* (Fig. 8), the casting is turned to bring its finished face against the stationary jaw *J* as shown at *A*, Fig. 9. A finished or planed surface should always be located against the fixed or stationary jaw of the vise, because the movable jaw is more liable to be out of alignment. If the fixed jaw is square with the planer table, and face *a* is held flat against it, evidently face *b*, when planed, will be at right angles to face *a*. Unless care is taken, however, the work may be tilted slightly as the movable jaw is set up, especially if the latter bears against a rough side of the casting. . The way this occurs is indicated at *B*. Suppose, for example, that the rough side *c* is tapering (as shown somewhat exaggerated) and the jaw J_1 only touched the upper corner as shown. The

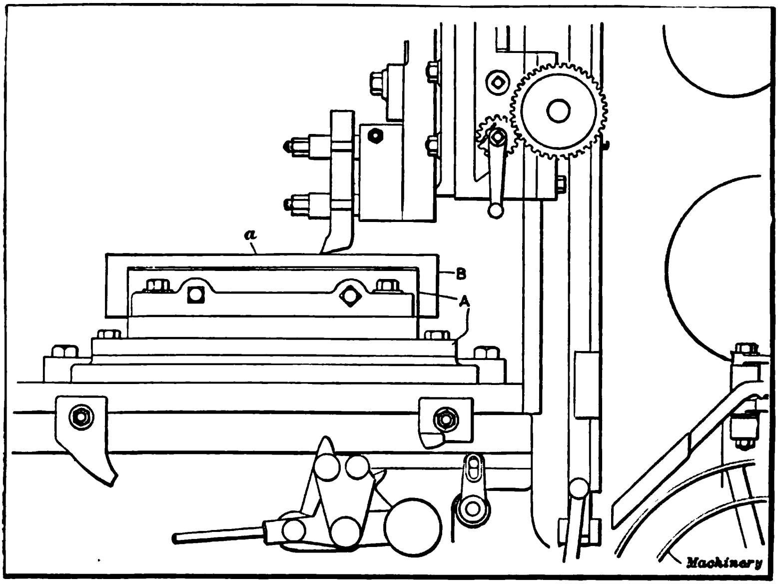

Fig. 8. Planing Work held in Chuck

finished face will then tend to move away at *x* (sketch *C*) as jaw J_1 is tightened, so that face *b*, when planed, would not be square with the side *a*. One method of overcoming this difficulty is to insert narrow strips of tin (or strips of paper when the irregularity is small) in the space *s* (sketch *B*) to give the clamping jaw a more even bearing. This tilting can also be prevented by placing a wire or cylindrical rod *w* along the center of the work as shown at *D*; the pressure of clamping is then concentrated at the center and the opposite side is held firmly against the fixed jaw. Sometimes a special packing strip *p*, having a rounded face, is inserted between the jaw and the work to prevent tilting, as at *E*. This strip acts on the same principle as the wire, and it is more convenient to use.

When the sides *a* and *b* are finished and the casting is being set for planing side *c*, it is necessary not only to have a good bearing against the fixed jaw, but as the sides are to be parallel, the lower side *a* must, at this setting, bear evenly on the bottom of the chuck. A simple method of determining when work is firmly bedded, is as follows: Place strips of thin paper beneath each end of the work, and after tightening the chuck and hammering the casting lightly to give it a good bearing, try to withdraw the paper strips. If both are held tightly, evidently the casting rests on the chuck and the upper side will be planed parallel, provided the chuck itself is true.

The foregoing method of planing a block square and parallel, by holding it in a chuck, is not given as one conducive to accuracy, but rather to illustrate some of the points which should be observed when

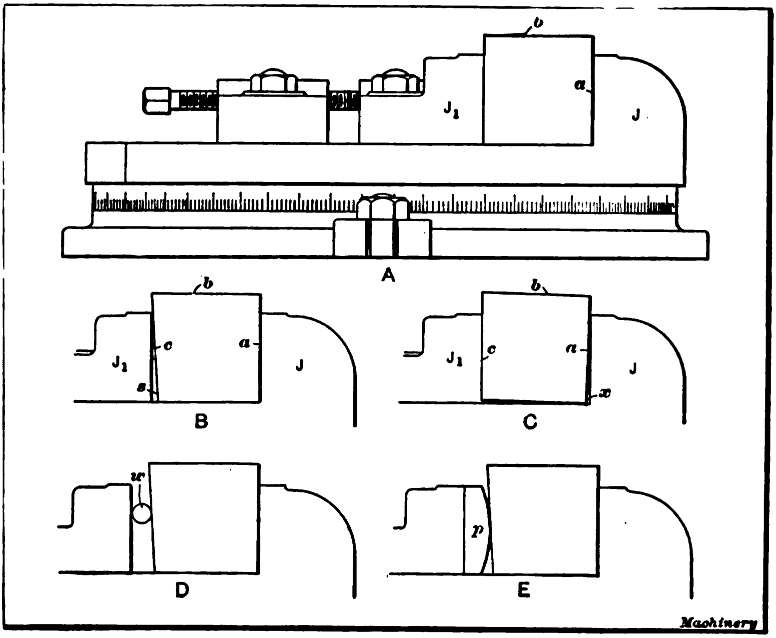

Fig. 9. Planer Chuck—Diagrams showing how Work is Tilted and Methods of Holding it Square

clamping work in a planer chuck. If considerable accuracy were required, the work could be held to better advantage by fastening it directly to the table with special clamps, as indicated in Fig. 10. The particular clamps illustrated have round ends which are inserted in holes drilled in the work. Of course, such clamps can only be used when the holes are not objectionable. As will be seen, these clamps are not in the way of the planing tool, and the block is held directly against the true surface of the platen.

This block could be planed accurately as follows: A roughing cut is first taken over all the sides to remove the hard outer surface, and then one side is finished. This finished surface is next clamped to the platen, thus permitting the opposite side to be planed. These two surfaces will then be parallel, provided the planer itself is in good condition. The finished sides are next set at right angles to the platen by using an accurate square, and the third side is planed. The fourth and last side is then finished with the third side clamped against the platen. By this method of holding the work, it would be easier to secure accurate results than by using a chuck; a chuck, however, is often very convenient for holding small parts.

Planing Vertical and Angular Surfaces

When vertical surfaces or those which are at right angles to the platen are to be planed, a tool having a bent end as shown at *A* in Fig. 11 is ordinarily used, unless the planer has side-heads, in which case a straight tool is used. The tool-block is also set at an angle, as shown, by loosening bolts *E*, which permit it to be swiveled to the right or left from its vertical position. The tool-block is set over in this way to prevent the tool from dragging over the planed surface on the return stroke. It should be explained that the tool-block of a planer is

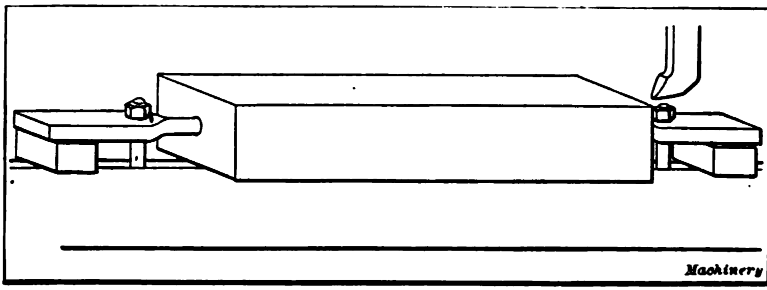

Fig. 10. Holding Block directly against Planer by Finger-clamps

free to swing forward so that the tool can lift slightly when returning for another cut. When a heavy cut is being taken, the tool is sprung sidewise to some extent, as well as backward, and if it were held rigidly on the return stroke, the cutting edge would drag heavily over the work and this would soon dull the edge. When a horizontal surface is being planed, the tool on its return tends to lift upward at right angles to the surface, because the tool-block is then set square with the platen. If, however, the tool-block were left in this position for vertical planing, the tool-point would swing upward in a plane *y–y*, and drag over the finished surface, but by setting the block in an angular position, as shown, the tool-point swings in a plane *x–x*, or at right angles to the axis *a–a* of the pin on which the block swivels. As plane *x–x* is at an angle with the surface of the work, the tool-point moves away from the finished surface as soon as it swings upward. The angular position of the tool-block does not, of course, affect the direction of the tool's movement, as this is governed by the position of slide *S* which is changed by swiveling the graduated base *D*.

A vertical surface is planed by adjusting the saddle *G*, horizontally along the cross-rail until the tool is in position for taking a cut. The tool is then fed down by hand, until the cut is started, after which the vertical feed is engaged, thus causing slide *S* and the tool to feed downward a certain amount for each stroke, while the saddle remains stationary on the cross-rail. The surface *y–y* will be planed square with the platen, provided the swiveling base *D* is set in the proper position. Before planing surfaces that are intended to be square with the platen, the position of the tool-slide *S* should be noted by referring to the graduation marks on the base *D*. When the zero marks on the stationary and swiveling parts of the base exactly coincide, the slide should be at right angles to the platen. Its position, however, can be determined more accurately by holding the blade of a square which

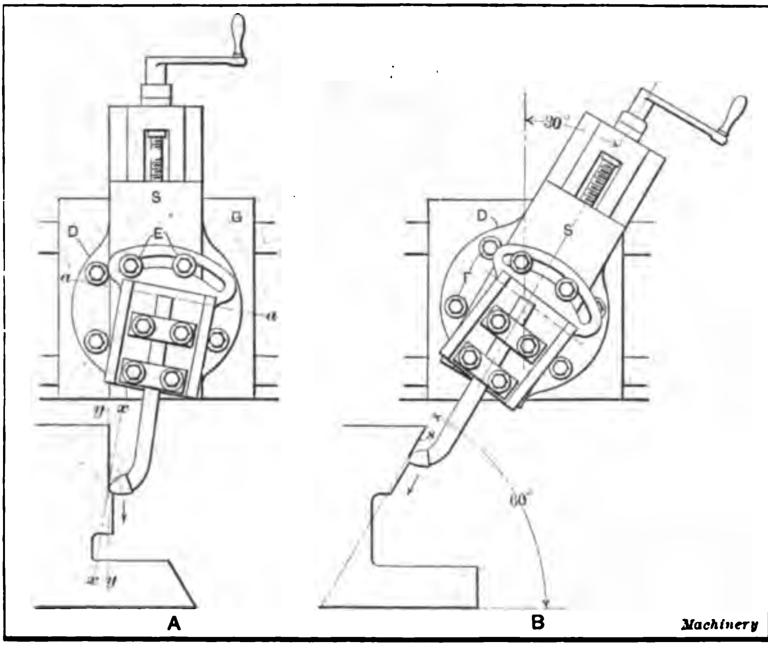

Fig. 11. Positions of Tool and Head for Planing Vertical and Angular Surfaces

rests on the platen, against one side of the tool-slide, as it is difficult to set graduation lines to exactly coincide, and even though they were in line, errors might result from other causes.

The planing of an angular surface is illustrated at *B*. The tool-head is first set to the proper angle by loosening bolts *F* and turning the base *D* until the graduations show that it is moved the required number of degrees. For example, if surface *s* were to be planed to an angle of 60 degrees with the base, as shown, the head should be set over 30 degrees from the vertical or the difference between 90 and 60 degrees. The tool would then be fed downward, as indicated by the arrow. The tool-block is also set at an angle with slide *S*, when planing angular surfaces, so that the tool will swing clear on the return stroke. The top of the block should always be turned *away from the surface to* *be planed*, which applies to the planing of either vertical or angular surfaces when using the cross-rail head.

An example of angular work is illustrated in Fig. 12, which shows a planer arranged for planing the V-shaped ways or guides on the bottom of a planer platen. Both tool slides are set to the required angle for planing one side of each vee. As there are two tool-heads, both vees can, of course, be planed simultaneously. The sides of the

Fig. 12. Double-head Planer set for Planing Angular Surfaces

platen are also planed at the same setting by tools held in the side-heads.

Position of the Tool and Cross-rail—Alignment of Cross-rail

The tool should be set about square with the work, as shown at *A*, Fig. 13, when planing horizontal surfaces. If it is clamped in the tool-block at an angle, as shown at *B*, and the lateral thrust or pressure of the cut is sufficient to move the tool sidewise, the cutting edge will sink deeper into the metal, as indicated by the dotted line, whereas a tool that is set square will swing upward. Of course, any shifting of the tool downward may result in planing below the level of the finished surface which would spoil the work. The tool should also be clamped with the cutting end quite close to the tool-block, so that it will be rigidly supported.

As previously mentioned, the cross-rail should be lowered until it is quite close to the top surface of the work. If it is set much higher than the work, the tool-slide has to be lowered considerably to bring the tool in position for planing; consequently, both the slide and the tool extend below the rail and they are not backed up and supported against the thrust of the cut as solidly as when the rail is more directly in the rear. The vertical adjustment of the cross-rail on the face of the housings is effected by two screws which are connected through bevel gearing with the horizontal shaft *U* (Fig. 1) at the top. On small planers this shaft is turned by hand, but on larger ones it is driven by a belt. Before making the adjustment, bolts at the rear which clamp the cross-rail to the housings must be loosened, and care should be taken to again tighten these bolts before using the planer. The ways on which the cross-rail slides, should be wiped clean before

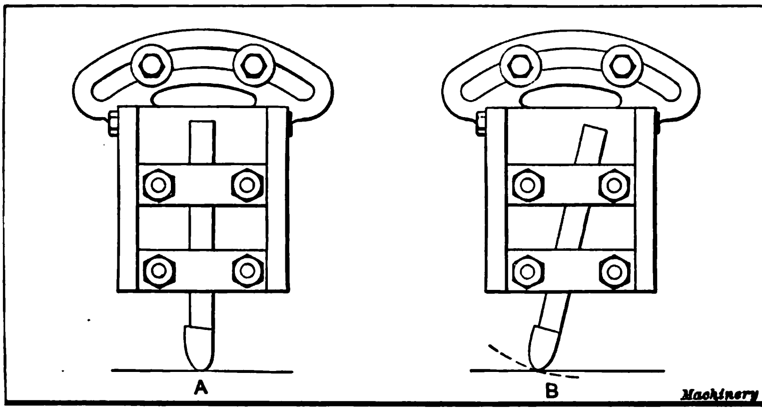

Fig. 13. Correct and Incorrect Positions for Planing Tool

making an adjustment, to prevent dirt from getting back of the rail as this would affect its alignment.

The cross-rail of a planer which is in good condition, is parallel with the upper surface of the platen, so that the planing tool, as it feeds horizontally, moves in a line parallel with the platen. Unfortunately this alignment is not always permanent and if accurate work is to be done, especially on a planer that has been in use a long time, it is well to test the cross-rail's position.

One method of making this test is as follows: An ordinary micrometer is fastened to the tool-head in a vertical position either by clamping it to the butt end of a tool, or in any convenient way, and the head is lowered until the end of the micrometer thimble is slightly above the platen. The thimble is then screwed down until the end just touches the surface to be tested, and its position is noted by referring to the regular graduations. The thimble is then screwed up slightly for clearance and, after the tool-head is moved to the opposite side, it is again brought into contact with the platen. The second reading will then show in thousandths of an inch any variations in the cross-rail's position.

Multiple or Gang Planing—Use of Planer with Double- and Side-heads

When a number of duplicate parts have to be planed, much time can often be saved by arranging the castings in a straight row along the platen so that they can all be planed at the same time. This method enables a number of parts to be finished more quickly than would be possible by machining them separately, and it also insures duplicate work. An example of multiple or gang planing is shown in

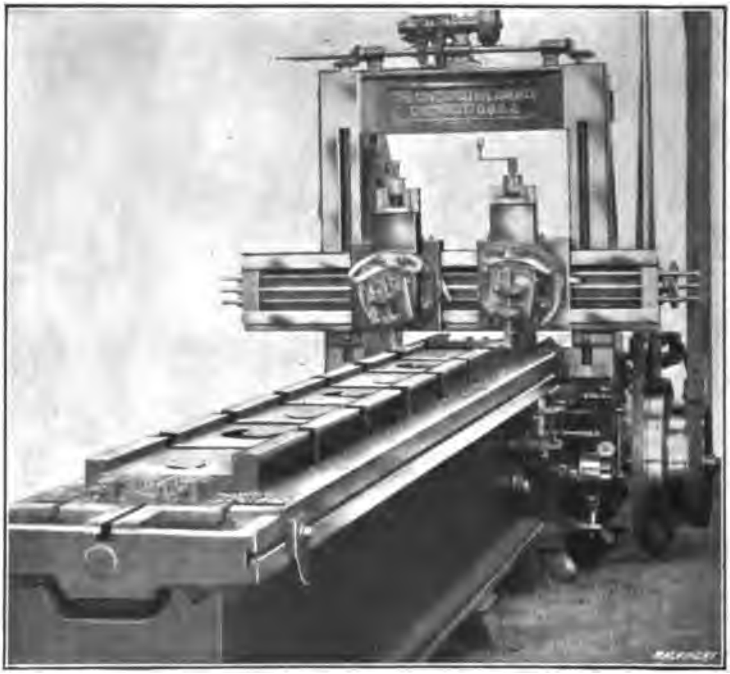

Fig. 14. Planing a Row of Duplicate Parts

Fig. 14. The particular castings illustrated are the "saddles" of planer tool-heads and eight castings are being planed at the same time. Both tool-heads are in use, and the tops and sides of the castings are finished at this setting.

This method of planing cannot always be employed to advantage as the shape of the work or location of the surfaces to be machined sometimes makes gang planing impracticable and even impossible. If the castings are so shaped that there will be considerable space between the surfaces to be planed, when they are placed in a row, so much time might be wasted while the tool was passing between the different surfaces that it would be better to plane each part separately. Some castings also have lugs or other projections which make it impossible for the tool to pass from one to the other without being raised to clear the obstruction. On the other hand, when castings are quite symmetrical in form and the surfaces are so located that the planing tool can pass from one to the other with a continuous stroke, as indicated in Fig. 14, the gang method of planing insures a uniform product and greatly reduces the time required for machining.

Two or more tools can often be used at the same time in connection with many planing operations. Fig. 15 shows a cross-section of an engine bed and illustrates how a double-head planer would be used on this particular job. The tool to the left is started first because it is the *leading* tool, as determined by the direction of the feed. This is

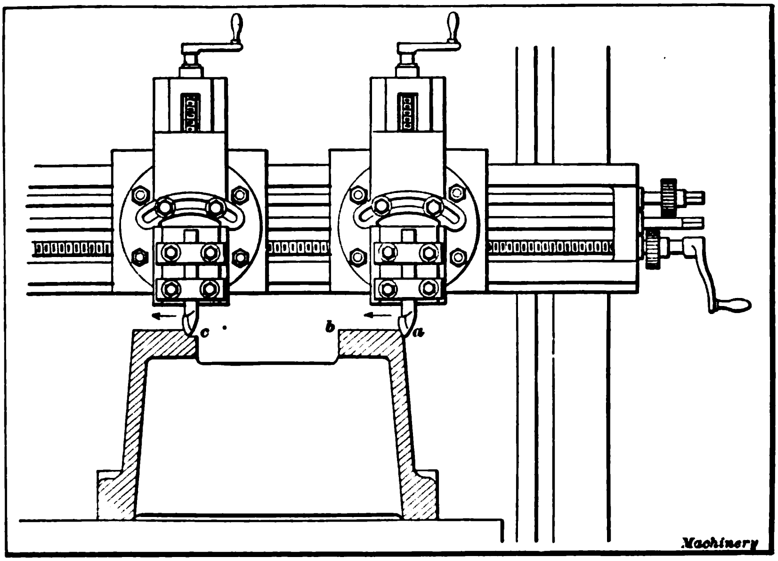

Fig. 15. Planing Two Surfaces Simultaneously with Two-head Planer

a good rule to follow especially when the tool-heads are quite close, as it prevents one head from feeding against the other, which might occur if the *following* tool were started first. The tools illustrated, cut principally on the side and are intended for deep roughing cuts in cast iron. The surfaces should be finished with a broad tool with a wide feed. If the planer were heavy and rigid, a feed of ½ or ¾ inch for each stroke, or even more, could be used for the finishing cut, but if the planer were rather light or in poor condition, it might be necessary to reduce the feed to ¼ inch or less, to avoid chatter. It is impossible to give any fixed rule for the amount of feed as this is governed not only by the planer itself, but also by the rigidity of the work when set up for planing, the hardness of the metal, etc. The final cut should be taken by a single tool to insure finishing both sides to the same height. This tool should be fed by power from *a* to *b*, and then rapidly by hand from *b* to *c* for finishing the opposite side.

The use of two tools for rough planing, greatly reduces the time required for machining work of this kind.

A typical example of the class of planer work on which a side-head can be used to advantage, is shown in Fig. 16. The operation is that of planing the edge and face of a large casting. The tool in the side-head is rough planing the vertical surface, while the other tool planes the edge. As the side-tool has the broadest surface to plane, it is started first. On some work two side-tools can be used simultaneously. The use of both cross-rail tool-heads at the same time is very common in

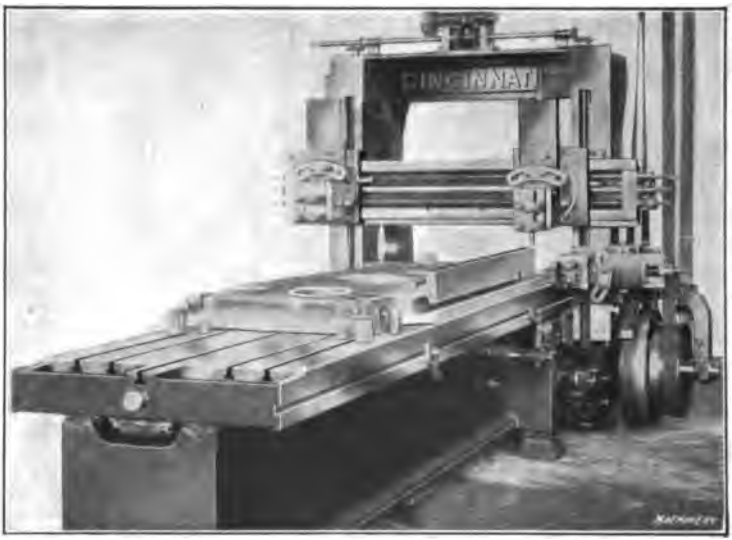

Fig. 16. Planing Top Edge and Side of Casting—Illustrating use of Side-head

connection with modern planer practice. Whether it is feasible to use one tool or four, simultaneously, depends altogether on the shape of the work and the location of the surfaces to be machined. Very often only one tool can be used and, occasionally, four tools can be operated at the same time, provided, of course, the planer is equipped with four heads. There are few fixed rules which can be applied generally to planer work, because the best way to set up and plane a certain part depends on its shape, the relative location of the surfaces to be finished, the degree of accuracy necessary, and other things which vary for different kinds of work. Before beginning to plane any part, it is well to consider carefully just what the requirements are and then keep them in mind as the work progresses.

CHAPTER III

HOLDING AND SETTING WORK ON THE PLANER

A great deal of the work done on a planer is very simple as far as the actual planing is concerned, but often considerable skill and ingenuity are required in setting the work on the planer and clamping it in the best manner. There are three things of importance that should be considered when doing work of this kind. First, the casting or forging must be held securely to prevent its being shifted by the thrust of the cut; second, the work should not be sprung out of shape by the clamps; and third, the work must be held in such a position

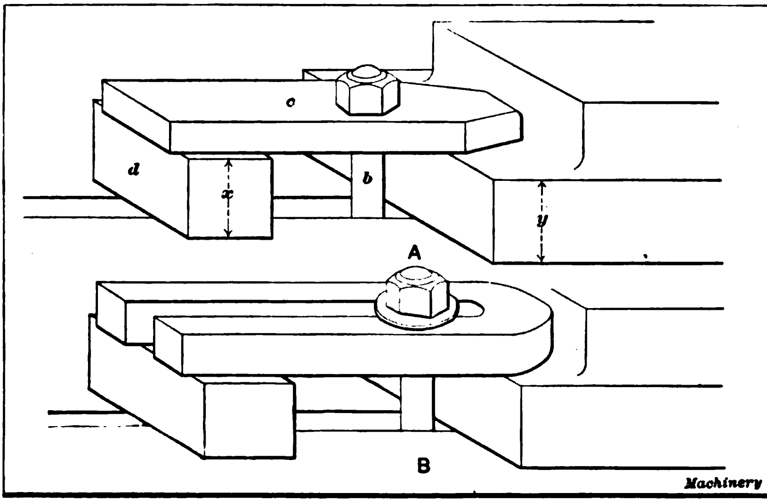

Fig. 17. Clamps for Attaching Work to Planer Platen

that it will be possible to finish all the surfaces that require planing, in the right relation with one another. Frequently a little planning before the "setting up" operation, will avoid considerable worry afterwards, to say nothing of spoiled work.

Different Forms of Planer Clamps and Bolts

Most of the work done on a planer is clamped directly to the platen. A form of clamp that is often used is shown at *A* in Fig. 17, *c* being the clamp proper, *b* the bolt, and *d* the packing block on which the outer end of the clamp rests. Obviously when the bolt is tightened, the clamp presses the work downward against the platen, and as this pressure is greatest when the bolt is close to the work, it should, if possible, be placed in that position. If the bolt were located near the packing block, the latter would be held tightly instead of the work. Another point to be observed is the height of the packing block. This height x should equal the height y of the part being clamped, provided a straight clamp is used. The end of the clamp will then have an even bearing on the work which will be held more securely than it would be if the clamp were inclined so that all the bearing was on the end or at the edge of the work. Packing blocks are made of either hard wood or cast iron.

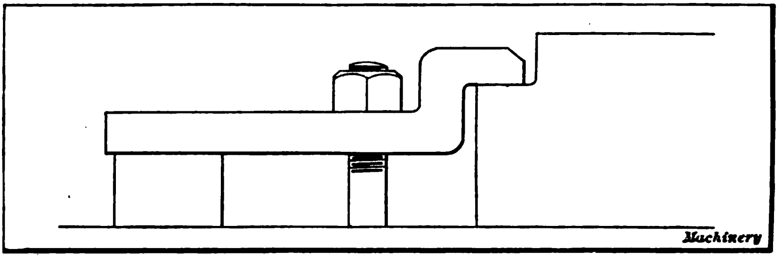

Fig. 18. Off-set Clamp

An excellent form of clamp, known as the U-clamp, is shown at *B*. This type is made by simply bending a square or rectangular bar of steel around, as shown, so as to form a slot in which the bolts can be placed. This continuous slot enables a bolt to be located in the best position, which is not always the case with clamps having holes.

Bent or off-set clamps are preferable to the straight type for holding certain kinds of work. Fig. 18 shows an off-set clamp applied to a casting which, we will assume, is to be planed on the top. If in this

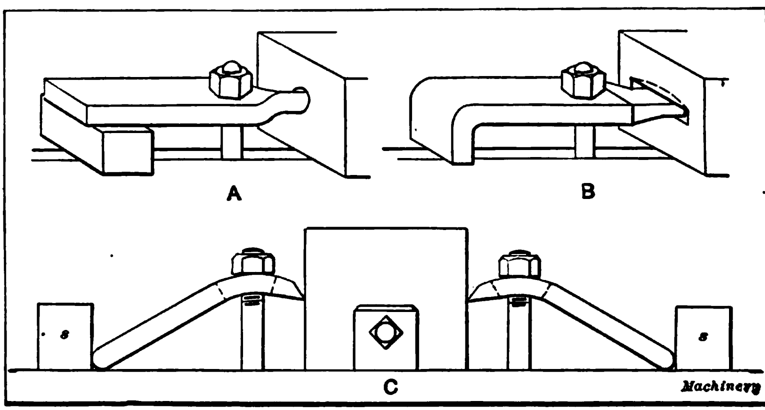

Fig. 19. Methods of Clamping Work which cannot be held by Ordinary Means

case a straight clamp were used, the clamping nut might be high enough to interfere with the planer tool, but the off-set clamp enables a shorter bolt to be used.

Frequently the "finger" clamps illustrated at *A* and *B* in Fig. 19 are convenient if not absolutely necessary. This type is used for holding work which cannot be held by ordinary means without interfering with the planer tool. The style to the left has a round end which enters a hole drilled in the work, whereas the clamp to the right has a flat end which engages a milled slot. An illustration of the use of finger clamps is given in connection with Fig. 10, Chapter II. As previously stated, they are only adapted to work in which holes or slots are not objectionable. Sometimes these clamps can be inserted in cored pockets or holes that are needed for other purposes. Sketch *C* illustrates a method that is sometimes resorted to when there are no projections for clamps and when holes or slots are not desirable. The clamps are placed in an angular position between the work and stop-pins *s* or strips clamped to the platen, and when the bolts are tightened, the work is forced downward. The bolt holes are elongated to permit the angular position of the clamps to be varied somewhat, and the nuts bear on the curved ends.

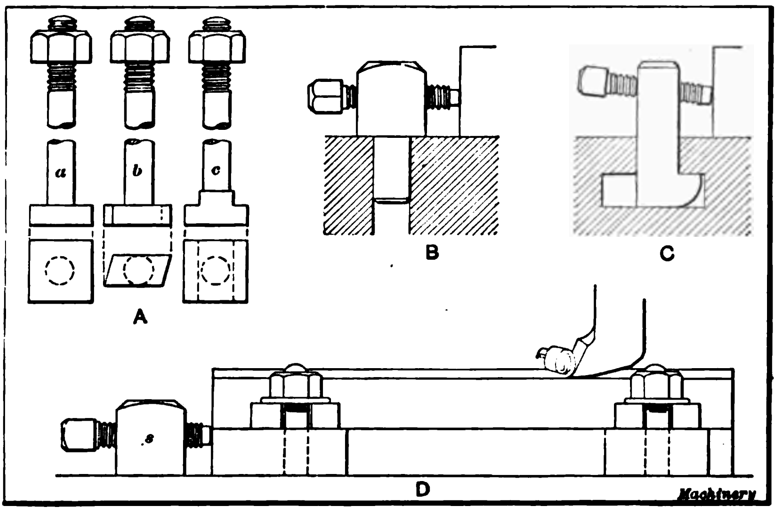

Fig. 20. Planer Clamping Bolts—Stop-pins—Use of Stop-pins

Three styles of bolts that are generally used for planer work are shown at *A*, Fig. 20. Bolt *a* has a square head so that it must be inserted at the end of a platen slot and then be moved to the required position. Occasionally it is desirable to place a bolt through some opening in a casting, in which case the bolt *b* can be used. The head is narrow enough to be inserted in the T-slot from above, and when the bolt is given a quarter turn, it is held the same as the square-headed type. Another style is shown at *c* which can be inserted from above. The lower end or head of this bolt is in the form of a nut planed to fit the T-slot. When the bolt is to be inserted from above, this nut is moved along the T-slot to the proper position and then the bolt is screwed into it after which the upper clamping nut is tightened.

Stop-pins and Braces

It would be very difficult to hold work securely by using only clamps and bolts, because the pressure of the clamp is in a vertical direction, whereas the thrust of the cut is in a horizontal direction, which tends to shift the work along the platen. To prevent such a movement, practically all work that is clamped to the platen is further secured by one or more stop-pins *s*, which are placed at one end of the part being planed as indicated at *D*, Fig. 20. These pins are generally made in two styles, one of which has a shank that fits the holes in the planer platen as shown at *B*, and the other an end which enters the T-slot as at *C*. By having one type for holes and another for T-slots, the stop-pins can be located in practically any position. After the pins are inserted in the platen, the screws shown are adjusted against the work. Stop-pins are ordinarily placed at one end of the work to take the thrust of the cut, and sometimes they are needed along the sides to prevent lateral movement. The screws of some stop-pins are inclined, as shown at *C*, in order to force the work down against the platen. These pins are also made without adjusting screws.

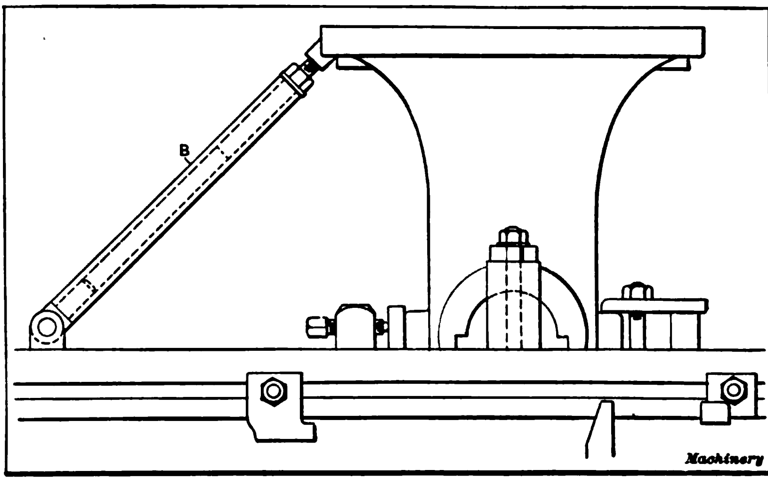

Fig. 21. High Work supported by Brace which takes Thrust of Cut

Some castings have surfaces to be planed that are a considerable distance above the platen, as shown in Fig. 21, which illustrates a large pillow-block set up for planing the base. As will be seen, the end resting on the platen is comparatively small, and if the casting were simply clamped at the lower end, it would tend to topple over when being planed, because the thrust of the tool is so far above the point of support. To prevent any such movement, braces *B* are used. These braces serve practically the same purpose as stop-pins. The style of brace shown has a hinged piece in its lower end, which enters a hole in the platen, and the body of the brace is a piece of heavy pipe. At the upper end there is an adjustable fork-shaped piece which engages the work, and the hinged joint at the lower end enables the brace to be placed at any angle. In some shops, wooden blocks are used as braces. The arrangement of these braces and the number employed for any given case, depends of course on the shape and size of the casting, and this also applies to the use of stop-pins and clamps. The location of all braces and clamping appliances should be determined by considering the strains to which the part will be subjected during the planing operation.

Use of Stop-pins and Planer Strip—Parallel Strips

An arrangement which can often be used to advantage in place of a chuck is shown in Fig. 22. The part to be planed is held between ordi-

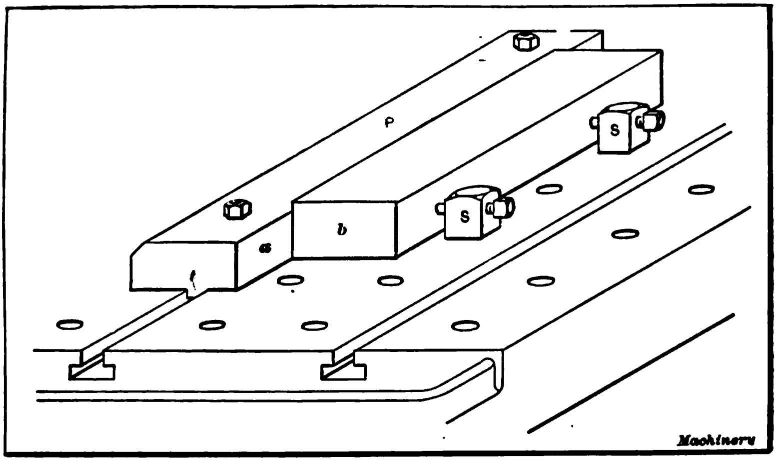

Fig. 22. Work held between Stop-pins and Strip Bolted to Platen

nary stop-pins *S* and a "planer strip" *P* that is bolted to the platen. This strip has a tongue piece *t*, which fits into the T-slot and locates the side *a* parallel to the travel of the platen. A stop-pin should be placed against the end *b* of the work to prevent longitudinal movement.

Parallel strips are placed beneath parts to be planed usually for the purpose of raising them to a suitable height, or to align a finished

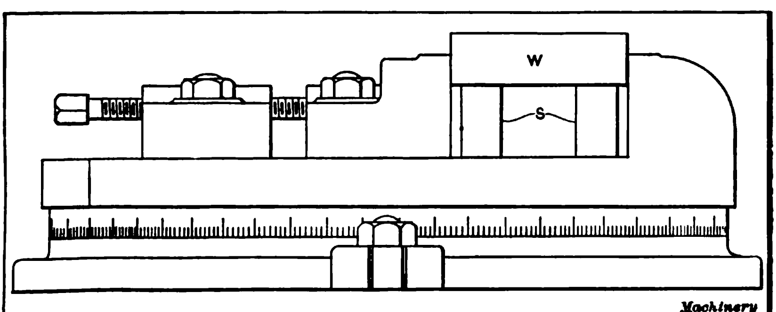

Fig. 23. Illustration showing use of Parallel Strips

surface on the under side with the platen, when such a surface cannot be placed in direct contact with the platen. These strips are made in pairs of different sizes and their sides are square and parallel to one another. An example showing the use of parallels in connection with chuck work, is illustrated in Fig. 23. If the part *W* were placed down on the bottom of the chuck, the top surface would be lower than the chuck jaws and the latter would interfere with the planing tool. By mounting the work on two parallel strips *S*, it is raised, and at the same time the under side is kept in line with the chuck, provided the parallels are accurate and the work is properly "bedded" on them.

Holding Castings of Irregular Shape—Holding Thin Work

The method of holding an odd-shaped casting on an angle-plate is illustrated in Fig. 24. The angle-plate *A* has two faces *a* and *b*

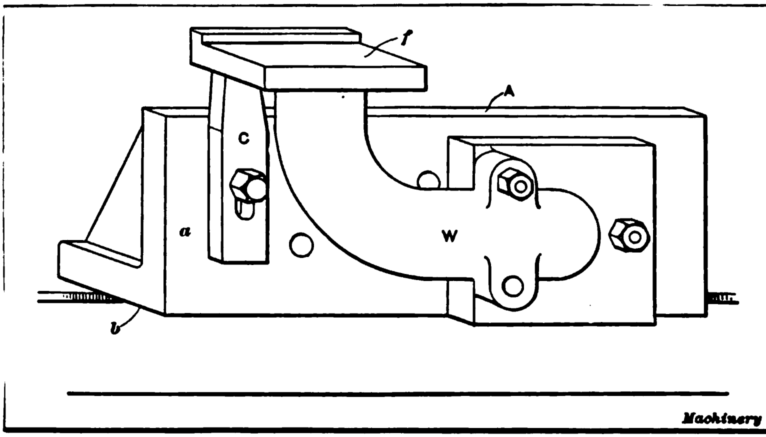

Fig. 24. Odd-shaped Casting attached to Angle-plate

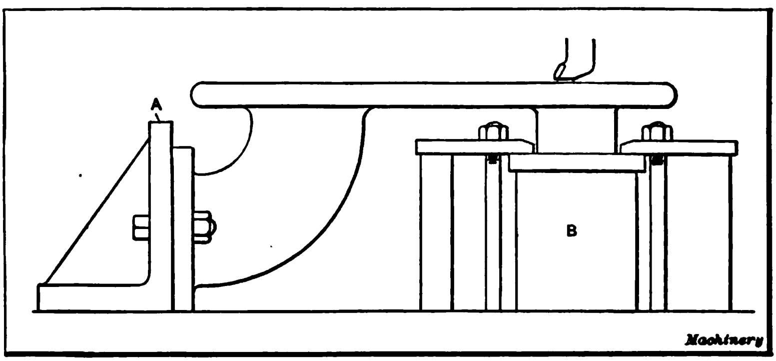

Fig. 25. Use of Angle-plate in Conjunction with Clamps for Holding Work

which are square with each other, and the work *W* is bolted or clamped to the vertical face, as shown. The arrangement of the clamps or bolts depends, of course, on the shape of the work. The particular part illustrated, which is to be planed at *f*, is held by bolts inserted through previously drilled holes, and the left end is supported by a clamp *C*, set against the under side to act as a brace and take the downward thrust of the cut. Angle-plates are generally used for holding pieces, which, because of their odd shape, cannot very well be clamped directly to the platen. Occasionally an angle-plate can be used in conjunction with clamps for holding castings, as illustrated in Fig. 25. In this example the angle-plate *A* is placed across the platen and serves as a stop for taking the thrust of the cut. The flange on the opposite end is supported by a block *B* against which the casting is clamped.

Some castings are so shaped that a great deal of time would be required for clamping them with ordinary means and for such work, special fixtures are often used. These fixtures are designed to support the casting in the right position for planing, and they often have clamps for holding it in place. Some work which could be clamped to the platen in the usual way, is held in a fixture because less time is required for setting it up. This is the practice where a large number of pieces have to be planed.

When it is necessary to plane thin plates or similar work which cannot be clamped in the usual way, either wedge-shaped or pointed pieces similar to those shown at *A* and *B*, Fig. 26, are used. These are known as "spuds" or "toe-dogs," and one way in which they are applied

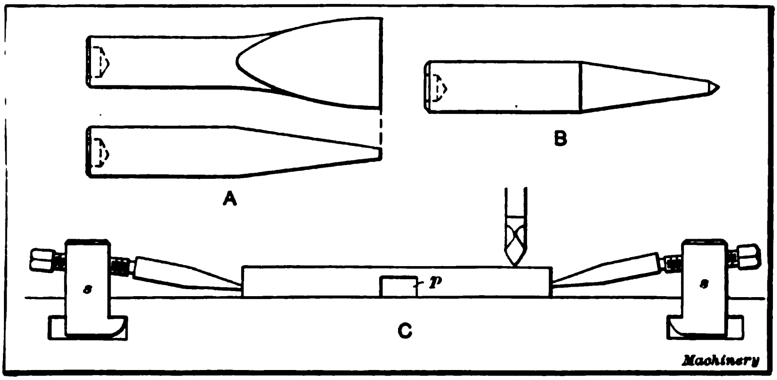

Fig. 26. Method of Holding Thin Flat Plates while Planing

is indicated at *C*. Stop-pins *s* are inserted in the platen on each side of the work, and the dogs are forced against the work by tightening the screws. Owing to the angular position of the dogs, the work is pressed down against the platen. The inclination should not be too great, as the outer end of the dog will move upward when the screws are tightened, without transmitting any pressure to the work. One or more stop-pins *p* should be placed in front of the part being planed to take the thrust, and at least two dogs will be required on each side unless the work is comparatively short.

Planing Round Work

The planer is sometimes used for cutting keyways or splines in shafts, and occasionally, other round work requires a planing operation. In order to hold and at the same time align round work with the platen, V-blocks (Fig. 27), are used. These blocks have a tongue piece *t* at the bottom which fits the T-slots in the platen, and the upper part of the block is V-shaped as shown in the end view. This angular groove is central with the tongue piece so that it holds a round shaft in alignment with the T-slot, which is parallel with the travel of the platen. The diameter of a shaft held in one of these blocks can vary considerably, as indicated by the two circles, without affecting the alignment. In other words, the centers c and c_1 of the large and small circles, respectively, coincide with the vertical center line.

Fig. 28 shows how a shaft is held while a keyseat is being planed in the end. Only one V-block is shown in the illustration, but ordinarily the opposite end of the shaft would be supported in a block

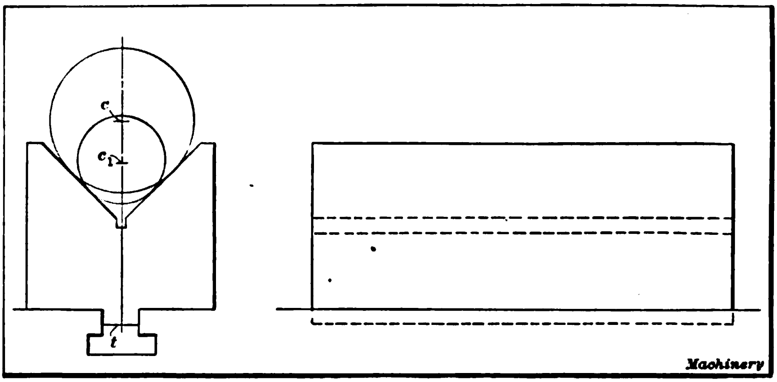

Fig. 27. V-block for Holding Cylindrical Parts

of corresponding size. Before the planing operation, a hole *h* is drilled to form a clearance space for the planing tool. The keyseat is then planed by using a square-nose tool, and if the V-blocks are accurately made, it will be in line with the axis of the shaft.

Fig. 29 illustrates how V-blocks are used in locomotive shops for holding a piston-rod while the cross-head, which is mounted on the

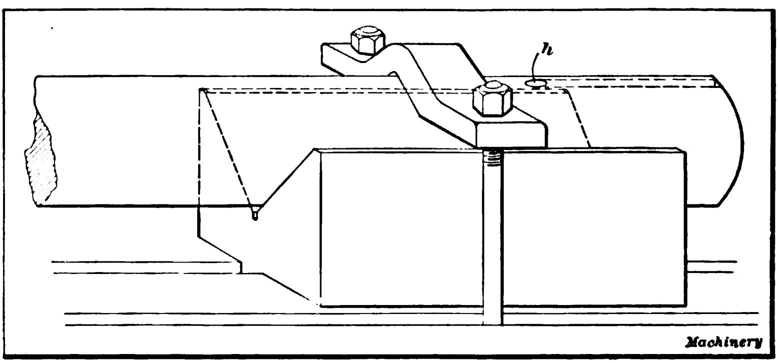

Fig. 28. End of Shaft Clamped in V-block

end, is being planed. The bearing surfaces of the cross-head must be in line with the rod which fits a tapering hole in one end. By assembling the cross-head and rod and then mounting the latter in V-blocks, the bearing surfaces are planed in alignment with the rod.

A good method of making a pair of accurate V-blocks is as follows: First plane the bottom of each block and form the tongue piece *t*, Fig. 27, to fit closely the platen T-slots. Then bolt both blocks in line on the platen and plane them at the same time so that they will be exact duplicates. A square slot or groove is first planed at the bottom of the vee, as shown, to form a clearance space for the tool. The head is then set to the required angle and one side of the vee is planed. The blocks are then reversed or turned "end for end" and the opposite side is finished without disturbing the angular setting of the head. This method of reversing the work, instead of setting the head to the opposite angle, insures equal angles for both sides and a vee that is exactly central with the tongue piece.

A special planer strip which is used in conjunction with screw-stops for holding round parts, is illustrated in Fig. 30. The strip has an angular face *f* so that pressure from the screws *s* tends to force the

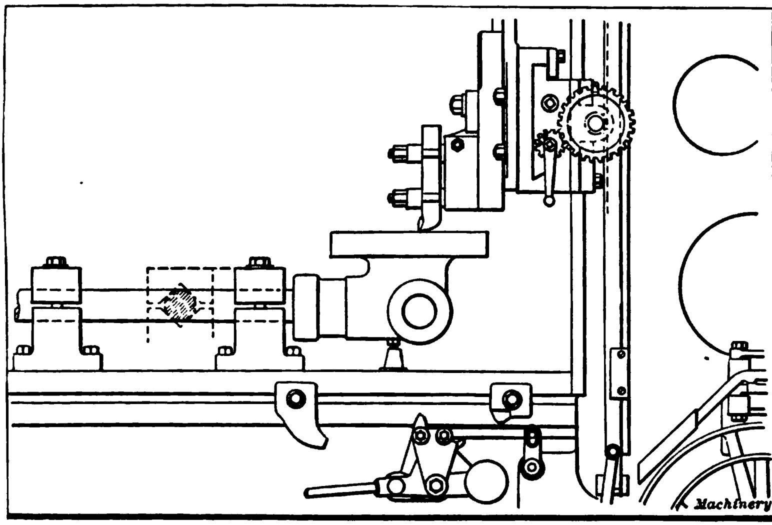

Fig. 29. Piston-rod and Attached Cross-head Mounted in V-blocks for Planing

shaft down against the platen as well as against the strip itself. This angular face is aligned with the platen by the tongue piece *t*.

Distortion of Work

When castings or forgings are set up on the planer for taking the first cut, usually the side that is clamped against the platen is rough and uneven, so that the work bears on a few high spots. This condition is shown illustrated on an exaggerated scale in Fig. 31, which shows a casting that bears at *a* and *b*, but does not touch the platen at the ends where the clamping is to be done. If the clamps were tightened without supporting the work at the end, the entire casting would probably be sprung out of shape more or less, depending on its rigidity, with the result that the planed surface would not be true after the clamps were released, because the casting would then resume its natural shape. To prevent inaccurate work from this cause, there should always be a good bearing just beneath the clamps, which can be obtained by inserting pieces of sheet metal, or even paper when the unevenness is slight. Thin copper or iron wedges are also used for "packing" under the clamps. It is good practice when accuracy is required and the work is not very rigid, to release the clamps slightly before taking the finishing cut This allows the part to spring back to its normal shape and the finished surface remains true after the clamps are released.

Very long castings or those which are rather frail but quite large and

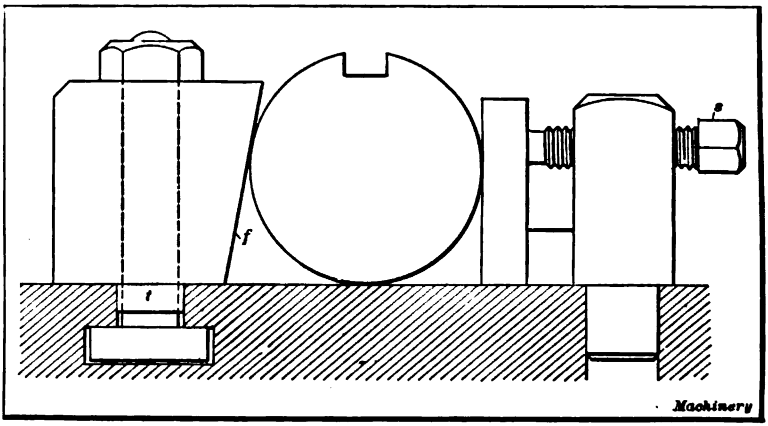

Fig. 30. Method of Holding Shaft for Splining or Keyseating

heavy, sometimes bend by their own weight or are sprung out of shape by the pressure of the planing tool, unless supported at the weak points. In such a case jacks, such as the one illustrated in Fig. 32, form a very convenient means of support. This particular jack has a ball joint at the top which allows the end to bear evenly on the work, and the screw can be locked after adjustment to prevent it from jarring loose. These jacks, which are made in different heights can also be used in various ways for supporting work being planed. Fig. 29 shows

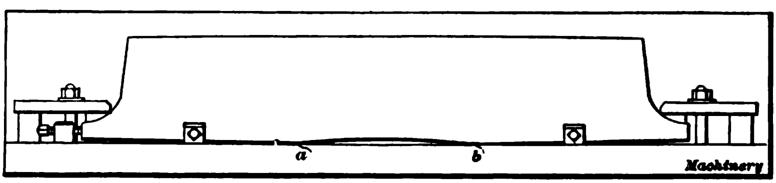

Fig. 31. Class of Work which is sometimes Distorted by Clamping

a practical application of planer jacks, two being inserted beneath the cross-head to prevent any downward spring. Hard-wood blocks cut to the right length are also used as supports.

Castings, even though properly clamped, are sometimes sprung out of shape by the internal stresses existing in the casting itself. These stresses are caused by the unequal cooling of the casting in the foundry. When a casting is made, the molten metal which comes in contact with the walls of the mold, naturally cools first and, in cooling, contracts and becomes solid while the interior is still more or less molten. The result is that when the interior cools and contracts, the tendency is to distort the part which solidified first, and internal stresses are left in the casting. These stresses often act in opposite directions and when a roughing cut is taken from one side of such a casting, thus relieving the stress on that side, a slight distortion takes place. This is illustrated on an exaggerated scale in Fig. 33. Suppose a casting is clamped as at *A*, so as to avoid all spring, and then a roughing cut is taken over side *a*, thus removing the hard outer surface. The chances are that the shape would change as shown (exaggerated) by the dotted lines, because the stresses which formerly counteracted those of the opposite side are now removed. Let us assume that the casting is next turned over and clamped as at *B* without springing it by the pressure of the clamps. If a roughing cut is then taken from the opposite side *b*, another change would probably occur because this would relieve the tension or stress of that side. The work would then assume what might be called its natural shape, and if both sides were then finished, they would tend to remain true, though slight changes might occur even then. Because of this tendency to distortion as the result of internal stresses, all work, especially if not rigid, should be rough-planed before any finishing cuts are taken. Of course, such a change of shape does not always occur, because the stresses may be comparatively slight and the planed surface so small in proportion to the size of the casting, that distortion is impossible.

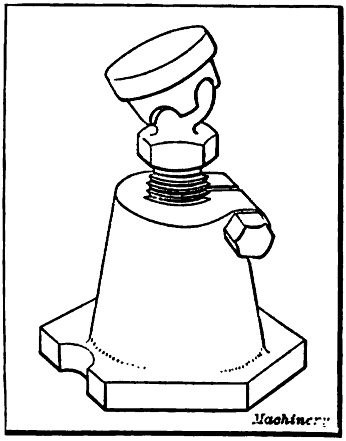

Fig. 32. Planer Jack

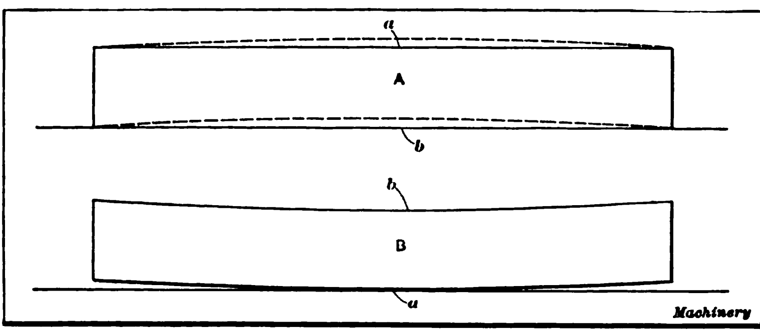

Fig. 33. Diagrams illustrating, on Exaggerated Scale, Distortion from Internal Stresses

Another important point in setting work is to locate it so that all surfaces to be planed can be finished to the required dimensions. On some work it is also desirable to have a planed part fairly true with a surface which remains rough, either to secure a neater finish or for more important reasons. Therefore, when either a casting or forging is being set up on the planer, it should be located according to the requirements for that particular part. As an illustration, suppose a flange *a*, the boss *b* and the surface *c* of a cast-iron cover plate, Fig. 34, is to be planed so that the distance between these surfaces corresponds to the dimensions given on the drawing. The first operation would be to plane the side *c*, the work being set up in the position indicated at *A*. The casting is first set about parallel with the platen, but it should be remembered that the surface which is set level or parallel is not necessarily the one to be planed. In this case the side *d* is to remain rough, and it is desirable to have a uniform thickness *x* when the cover is finished; therefore the casting is set by side *d* rather than by the upper surface *c*, or in other words, is located so that the *finished* surface will be true with the rough side of the casting.

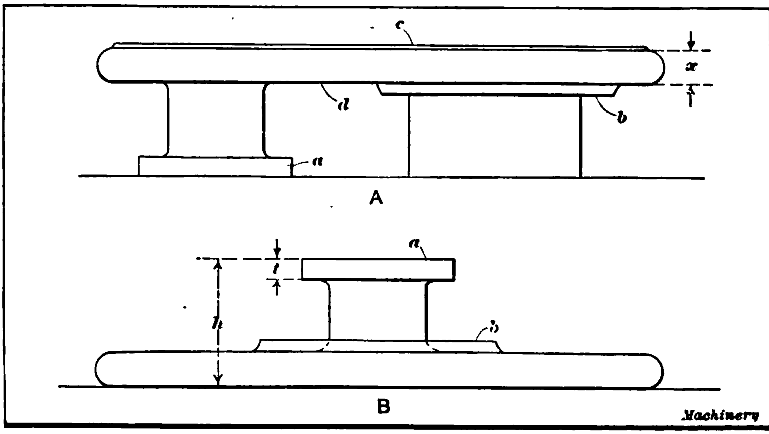

Fig. 34. Diagram illustrating Points relating to Position of Work

The amount of metal to remove when planing side *c* must be determined by considering the relation of this side to the other parts that are to be finished when the casting is turned over. For example, it should be possible to plane flange *a* to a height *h* (as given on the drawing) without removing too much or too little metal from the flange. Suppose a light cut were taken from side *c*. just deep enough to true it and then the casting were turned over, as indicated at *B*, for finishing the opposite side. When planing the flange it might be necessary to make the thickness *t* considerably less than it should be, in order to secure the proper height *h*. This, however, would not occur if when planing side *c*, the thickness of the flange as well as the height *h*, were considered. Therefore, the relation between the different surfaces should be kept in mind. Sometimes it is necessary to set a casting very carefully and to plane off just the right amount, in order to finish the other surfaces to the required dimensions.

The Surface Gage and its Use

The surface gage is used very extensively in connection with planer work for scribing lines that represent finished surfaces and also for setting parts parallel with the platen. This tool, which is shown in Fig. 35, has a rather heavy base on which is mounted a rod carrying a pointer or scriber *S*. The latter can be adjusted in or out and it also can be moved to any position along the rod. After the scriber or pointer has been set to about the right height, it can be set accurately to the position desired by turning screw *A* which gives a fine adjustment. There are two pins *B* in the base which can be pushed down when it is necessary to keep the gage in line with the edge of a plate or the side of a T-slot. The method of using a surface gage for setting a surface parallel to the platen is indicated in Fig. 36. The scriber *s* is first set to just touch the work at some point; the gage is then moved around to the opposite side, as shown by the dotted lines, and in this way the height at various points are compared.

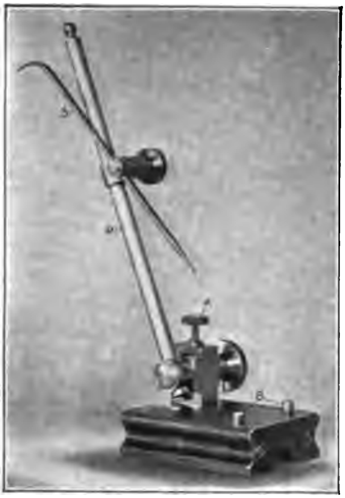

Fig. 35. Surface Gage

The surface gage is also used extensively for laying out work. As a simple illustration, suppose the sides *b* and *c* (Fig. 36) were to be planed and it were necessary to have the thicknesses *x* and *y* of the flanges and the height *z* all conform to given dimensions. If lines *l* and

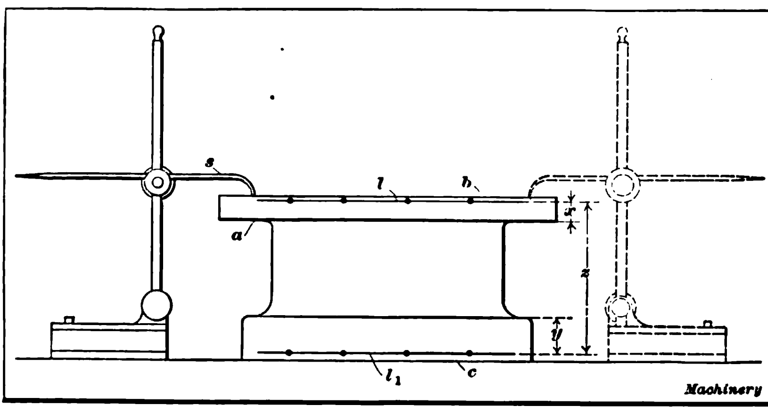

Fig. 36. Testing Alignment by using Surface Gage

l_1 representing the finished surfaces were first scribed on the flanges, these would serve as a guide when planing, and such lines could easily be drawn by using a surface gage, even though the sides did not lie in the same vertical plane. The surface gage is also used for setting lines which have been scribed on the work and represent the location of finished surfaces, parallel with the planer platen.

CHAPTER IV

PLANER TOOLS—VARIOUS FORMS USED AND POINTS ON GRINDING

The number and variety of the tools used on a planer depend on the character of the work which is done on that particular machine. If the work varies considerably, especially in its form, quite a number of tools of different shapes will be needed, whereas, planers that are used principally for making certain parts, do not need a large tool equipment. In Figs. 37 and 38, two sets of tools intended for general work are shown. Occasionally, tools of special form are required, but the various types in the sets illustrated, will take care of practically all ordinary planing operations. Fig. 37 also shows some typical examples of the kind of planing for which the different tools are adapted.

The tool shown at *A* is a roughing tool. This form is particularly adapted for taking deep "roughing" cuts in cast iron, when it is necessary to remove considerable superfluous metal. This style of tool is also made to the opposite hand as at *B*, as it is sometimes desirable to feed the tool toward the operating side of the planer; ordinarily, however, horizontal surfaces are planed by feeding the tool *away* from the operator, the tool moving from right to left, as viewed from the front of the machine. This enables the workman to see just what depth of cut is being taken at the beginning of the cut. The tool *C* with a broad cutting edge is used for taking finishing cuts in cast iron. The cutting edge is set parallel with the planer platen, and the feed for each cutting stroke is a little less than the width of the edge. Notwithstanding the coarse feed, a smooth surface is left on the work, provided the tool is properly ground and set, and does not chatter when in use. Tools of this type are made in various widths, and when planing very large and rigid castings, wide cutting edges and coarse feeds are used. A plain round-nose tool is shown at *D*. This style is often used for rough planing steel or iron. It can also be made into a finishing tool for the same metals by grinding the nose or tip end flat. The width of the flat cutting edge is much less, however, than for cast-iron finishing tools, because if very broad edges and feeds were used when planing steel, there would be danger of the tool gouging into the work. Steel offers a greater resistance to cutting than cast iron and that is why broad tools tend to gouge in, especially if the tool is not held rigidly to prevent its springing downward. Tool *E*, which is known as a diamond point, is also used for rough-planing steel or iron. The bent tools *F* and *G* are used for planing either vertical surfaces or those which are at a considerable angle with the platen. These are right- and left-side roughing tools, and they are adapted to either cast iron or steel. They can also be used for finishing steel. Finishing tools for vertical or angular cast-iron surfaces are shown at *H* and *I*.

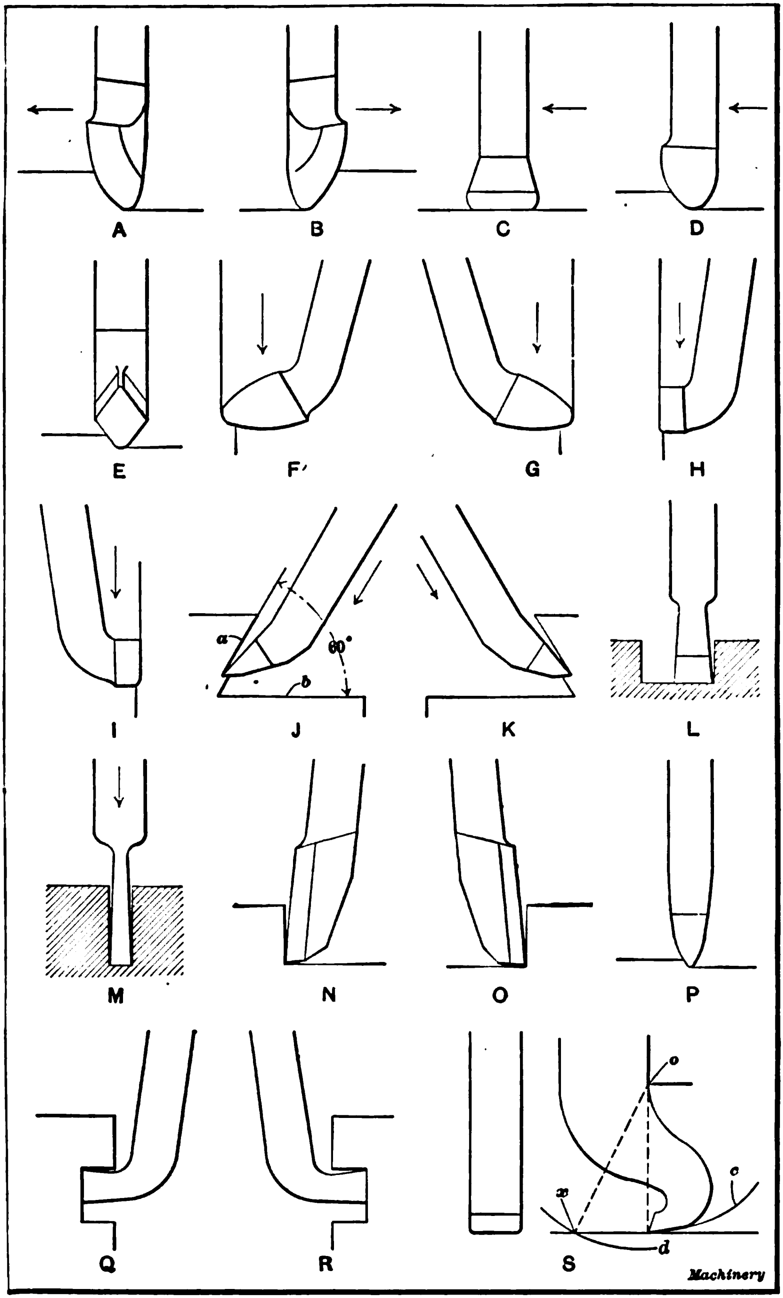

Fig. 87. Planer Tools of Different Form and Work to which they are Adapted

These have wide cutting edges to permit coarse finishing feeds. Vertical surfaces can often be planed to better advantage by using a straight tool in the side-head, when the planer is so equipped. Right and left angle tools are shown at *J* and *K*. This style of tool is for planing angular surfaces which, by reason of their relation to horizontal or other surfaces, can only be finished by a tool having a form similar to that illustrated. A typical example of the kind of angular planing requiring the use of an angle tool is indicated in the illustration. After finishing side *a*, the horizontal surface *b*, (from which a roughing cut should have been taken previously) could be planed by feeding the same tool horizontally. A square-nose tool is shown at *L*. This is used for cutting slots and squaring corners, and

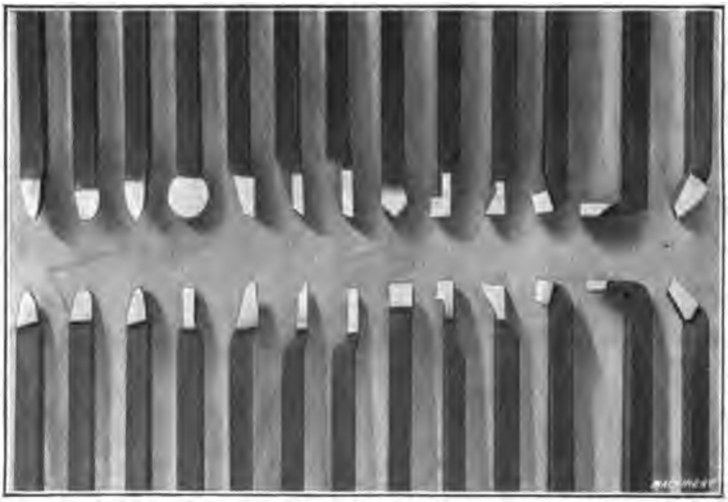

Fig. 38. Set of Planer Tools ground on Sellers Tool-grinding Machine

the same style of tool is made in different widths. A narrow square nose or "parting" tool is shown at *M*. It is adapted to cutting narrow grooves, and can also be used for cutting a part in two, provided the depth does not exceed the length of the narrow cutting end. Right and left side tools are shown at *N* and *O*. These can frequently be used to advantage on vertical or angular surfaces. A tool for planing brass is shown at *P*. It has a narrow rounded cutting edge and is very much like a brass turning tool. For finishing cuts in brass, tools having narrow flat ends are often used. Right and left bent square-nose tools are shown at *Q* and *R*. Such tools are used for cutting grooves or slots in vertical surfaces and for similar operations. The peculiarly-shaped tool shown by front and side views at *S*, is especially adapted to finishing cast-iron surfaces. This type is known as the "goose-neck" because of its shape, and it is intended to eliminate chattering and the tendency which a regular finishing tool has of gouging into the work. By referring to the side view it will be seen that the cutting edge is on a line with the back of the tool shank, so that any backward spring of the tool while taking a cut, would cause the cutting edge to move along an arc *c* or away from the work. When the cutting edge is in advance at some point *x*, as with a regular tool, it will move along an arc *d*, if the strain of the cut causes any springing action, and the cutting edge will "dig in" below the finished surface. Ordinarily the tool and the parts of the planer which support it, are rigid enough to prevent such a movement, so that the goose-neck tool is not always necessary.

All of the tools shown in Fig. 37 are forged from a solid bar of steel, the cutting end being forged to about the right shape, after

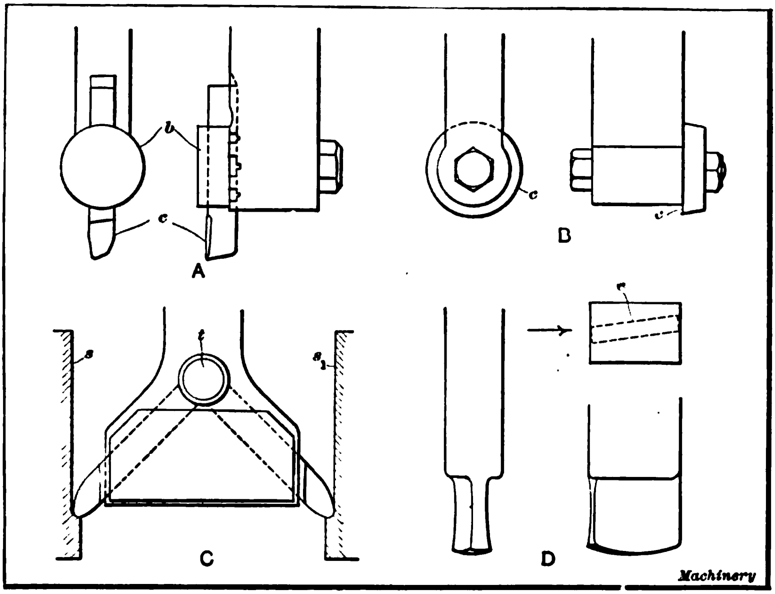

Fig. 39. (A) Planing Tool with Inserted Cutter. (B) Radius Tool (C) Tool having Two Cutters. (D) Finishing Tool

which the end is correctly formed by grinding. After the tool has been worn away considerably by repeated grindings, the end has to be re-forged or "dressed" to bring it back to the original form. To eliminate this work, and also to reduce the amount of steel required, tools are often used on the planer and other machines, having shanks into which small cutters can be inserted. These tools are made in many different designs, one of which is shown at *A* in Fig. 39. This particular style is so arranged that the cutter *c*, which is held against the shank by bolt *b*, can be set either vertically, horizontally, or at an angle of 45 degrees and the cutting edge can be placed on the right or left side of the shank, as required. This adjustment adapts the tool to the planing of horizontal, vertical or angular surfaces. It should be noted that the cutter is firmly seated in slots cut in the face of the shank. This tool can be used with the cutter in advance of the shank or to the rear; when in the latter position it has the advantages of the "goose-neck" tool.

What is known as a form tool is shown at *B*. The cutter *c* is circular and it is held to the shank by a bolt as shown. This particular tool is used for finishing round surfaces, the cutter being made to the required diameter. Form tools are also used for finishing surfaces of irregular form, the cutter being made to correspond in shape to the form required. A tool having two cutters is shown at *C*. This style is sometimes used for planing duplicate work, having two surfaces s and s_1, a given distance apart. By having two cutters, both sides are finished at the same time. As the cutters are ground away, they are moved out to the required width by drawing in the taper bolt *t* against which the inner ends of the cutters rest. This is an example of the special tools sometimes used in planer work. The

Fig. 40. Roughing and Finishing Tools

tool shown at *D* is a solid forged type, that is excellent for finishing steel. The way this tool operates is shown by the plan view. The cutting edge *e* is at an angle with the shank, and as the work moves in the direction shown by the arrow, the corner or edge *e* removes a light shaving and leaves a smooth surface. The edge is curved slightly, as shown by the side view, so that the cutting is done at the center. By using soda water, or even plain water, while planing, a bright surface is obtained. Only very light cuts are taken with this tool.

The action of a planer is quite different from that of a lathe, as it is used principally for producing flat surfaces, whereas the lathe produces cylindrical surfaces. In the forming or grinding of planing and turning tools, however, there are many underlying principles which are common to both classes of tools.

Front and side views of a planer roughing tool are shown at *A*, Fig. 40. As the cutting is done by the curved edge *e*, the front surface *b* is ground to slope backward from this edge, to give the tool keenness. The end or flank of the tool is also ground to slope inwards to provide clearance. The angle *c* of clearance is about 4 or 5 degrees for planer tools, which is much less than for lathe tools. This small clearance is allowable because a planer tool is held about square with the platen, whereas a lathe tool, the height of which may be varied, is not always clamped in the same position. A lathe tool also requires more clearance because it has a continuous feeding movement along a spiral path, whereas a planer tool is stationary during the cut, the feed taking place just before the cut begins. This point should be considered when grinding planer tools, because the clearance of any tool should not be greater than is necessary to permit the tool to cut freely, as excessive clearance weakens a tool. The slope of the top surface *b* depends on the hardness of the metal to be planed, the slope angle being less for hard material, to make the cutting edge more blunt and consequently stronger. When tools are ground by hand, the angles of slope and clearance are not ordinarily measured, the workman being guided by experience. As the cutting is done principally by side *e*, the slope of the top (or front when the tool is in position for planing) is back from this point, or away from the *working part* of the cutting edge. By grinding a flat spot on the nose or lower end, this same tool can be used for taking finishing cuts in steel. Finishing cuts are also taken with a round nose, by using a fine feed. The edge *e* of the cast-iron finishing tool (*B*) should be ground straight by testing it with a small straightedge or scale. The corners should also be rounded slightly, as shown, as a square corner on the leading side will dull quickly. The illustration shows clearly the tool's shape. The square-nose tool (Fig. 41) cuts along its lower edge *e*, and is given clearance on the end and sides as shown in the two views. The lower edge is the widest part of the cutting end, the sides sloping inward in both a vertical and horizontal direction, which prevents the tool from binding as it moves through a narrow slot. The side-tool in the lower part of Fig. 41 cuts along edge *e*, which, as the side view shows, slopes backward. Planer side-tools are not always made in this way, but it is a good form, as the sloping edge starts a cut gradually, whereas a vertical edge takes the full width of the cut suddenly, thus producing a shock.

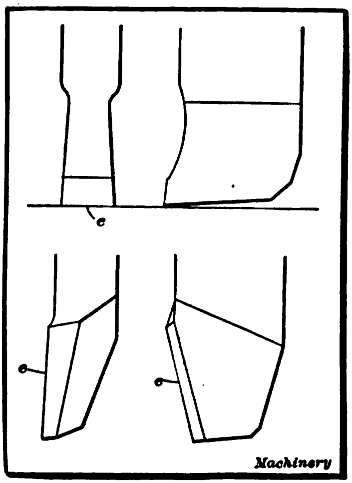

Fig 41. Square-nose Tool—Side-tool with Sloping Edge

Reference has been made to the grinding of these few types of tools, merely to point out some of the principles connected with the grinding of planing tools. When the principle of tool grinding is understood, the various tools required, whether regular or special in form, can be ground without difficulty. One thing that should be remembered when grinding a tool, is that it does not pay to force the tool too hard against the emery wheel or grindstone, as is often done in attempting to grind quickly. The tool should be ground with a moderate pressure, and it should be withdrawn frequently when forming a flat surface, to prevent excessive heating and burning of the tool. The grinding wheel should always be supplied with cooling water.

CHAPTER V

THE SHAPER

The shaper, like the planer, is used principally for producing flat surfaces, but it is intended for smaller work than is ordinarily done on a planer. The shaper is preferable to the planer for work within its capacity because it is less cumbersome to handle and quicker in its movement. The action of a standard shaper, when in use, is quite different from the planer; in fact, its operation is just the reverse, as

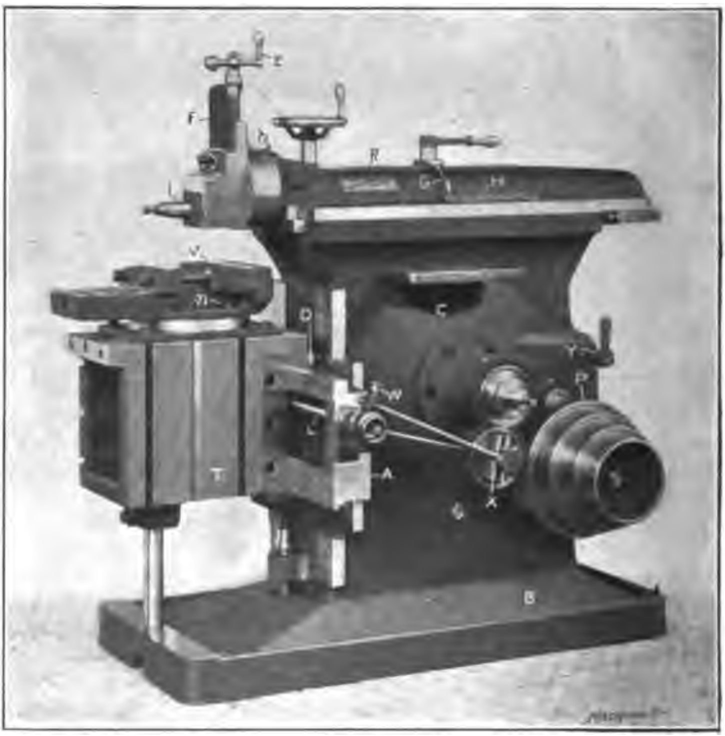

Fig. 42. Cincinnati Back-geared Crank Shaper

the tool moves back and forth across the work, which remains stationary, except for a slight feeding movement for each stroke. A shaper of typical design is shown in Fig. 42. The principal parts are the base and column *B* and *C*, the table *T* which has a vise *V* for holding work, and the ram *R* which carries a planing tool in tool-post *I*, and is given a reciprocating motion by a crank mechanism inside the column. The work-table is mounted on a saddle or cross-slide *D*, and it can be moved along the cross-rail *A* by turning the lead-screw *L* with a crank or by an automatic feeding mechanism. The cross-rail can be adjusted vertically on the face of the column to accommodate work of various heights, and the tool-slide *F* with the tool, can be fed downward by handle *E*.

The driving mechanism for the ram is shown in the sectional views Fig. 43. Shaft *S* on which the driving pulley is mounted, is connected through gearing with crank gear *C*. This gear carries a crank-pin or block *B* which engages a slot in the arm *N*, and this arm in turn, connects with the ram *R* and is pivoted at its lower end. As the crank gear rotates, a vibrating motion is given to arm *N* which imparts a reciprocating movement to the ram. The amount that the arm moves and, consequently, the stroke of the ram, is governed by the position of the crank-block *B* which can be adjusted toward or from the center of the gear by shaft *O*. This shaft connects through spur and bevel gears with a screw that engages the crank-block as shown in the cross-section to the left. The stroke can be changed while the shaper is in motion, and the pointer *G*, as it travels along the stationary scale *H*, shows the length of the stroke in inches (see also Fig. 42). The *position* of the stroke can also be varied (while the machine is in motion) by turning handwheel *J* which causes screw *K* to rotate and shifts the position of block *L* with relation to the ram. Before making this adjustment, block *L*, which is ordinarily clamped to the ram, is loosened by turning lever *M*. By means of this adjustment for the *position* of the stroke, the tool is made to move back and forth over that part of the work that requires planing, whereas the stroke adjustment serves to change the travel of the tool according to the length of the work.

The cross-rail *A* with the attached slide and table, is adjusted vertically on the face of the column by a telescopic screw *Q*, which is rotated through bevel gears, by a horizontal shaft operated by a crank on the left side of the machine. Before making this vertical adjustment, binder bolts at the rear of the slide, which clamp the cross-rail rigidly to the column, must be loosened, and the column ways should also be cleaned to prevent chips or dirt from getting back of the slide. The outer end of the table is prevented from springing downward when taking heavy cuts, by a shaft *U* which rests on the base and can be adjusted for any vertical position of the table.

The feeding movement of the work-table for each stroke of the ram, is derived from a slotted crank *X*, Fig. 42, which is rotated by gearing. This crank is connected by the rod shown, with a pawl *W*. As the crank rotates, this pawl engages a ratchet gear and turns lead-screw *L*, thus moving the work-table along the cross-rail. The amount of this feeding movement for each stroke of the ram, is varied by adjusting the sliding block of crank *X* toward or from the center. When the power feed is not required, it is disengaged on this shaper by turning a sleeve around beneath the pawl, thus preventing the latter from engaging the ratchet gear. To reverse the feed, the pawl is simply given a half turn, which causes it to rotate the ratchet when moving in the opposite direction.

On this particular shaper there are eight speed changes for the

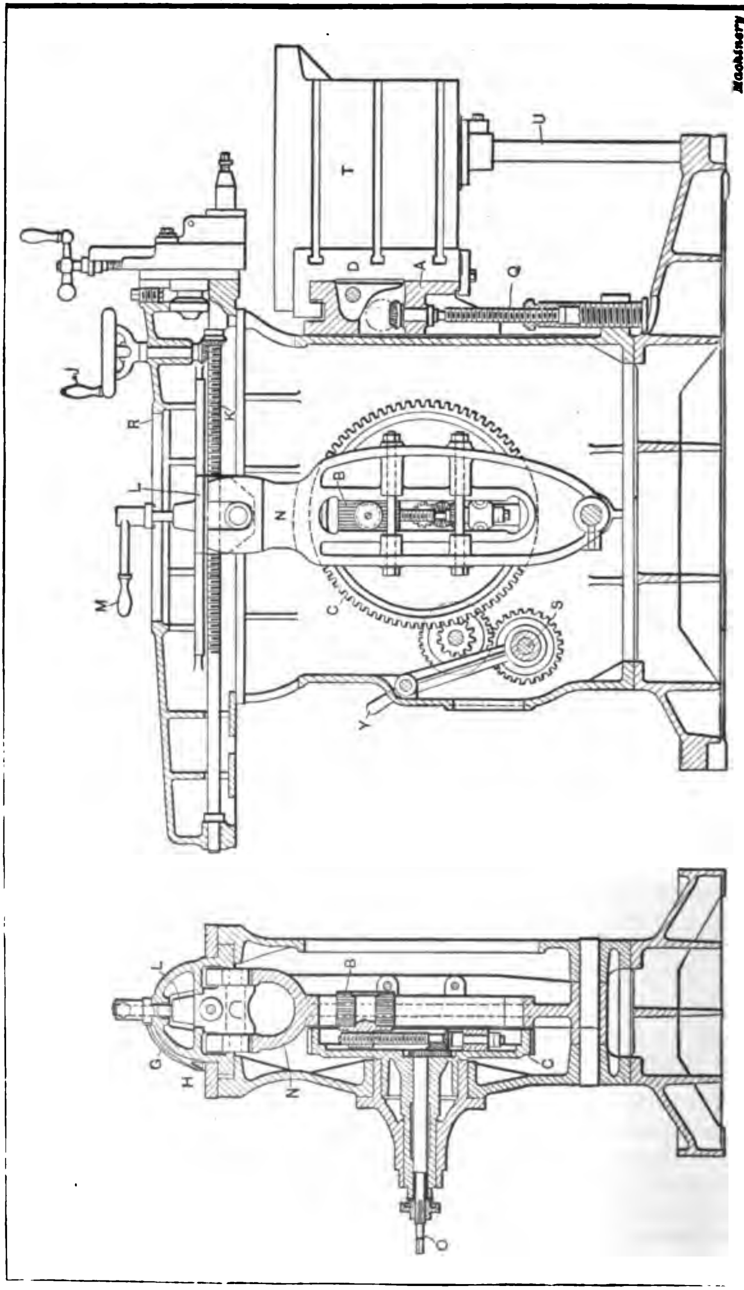

Fig. 43. Cross and Longitudinal Sections of Back-geared Crank Shaper

ram. Four of these are obtained by shifting the driving belt on different steps of the cone-pulley *P* (Fig. 42), and this number is doubled by back-gears inside the column which are engaged or disengaged by lever *Y*. Shapers are also made without back-gears, in which case the number of speed changes equals the number of steps on the driving cone pulley. The higher speeds are used when the tool travel or stroke is comparatively short and the slow speeds for long strokes. If there were no way of changing the speed and the shaper made the same number of strokes per minute regardless of the length, there would, of course, be a wide variation in the cutting speed of the tool. This change of speed, however, which accompanies a change of stroke, only occurs with a crank shaper, the cutting speed of a geared or rack shaper being constant for any length of stroke. The difference between these two types will be referred to later.

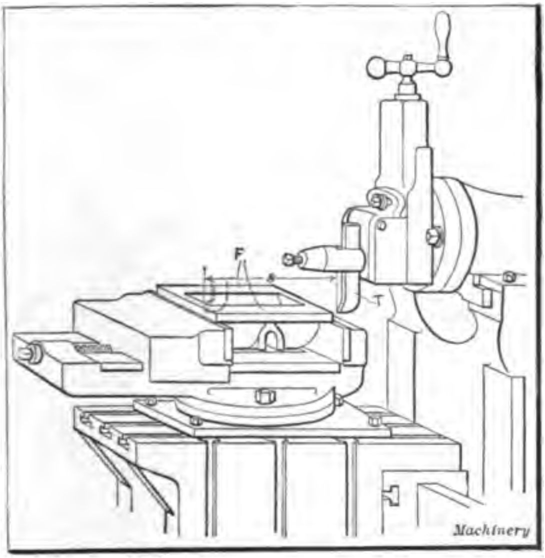

Fig. 44. An Example of Shaper Work

Examples of Shaper Work

Most of the work done in the shaper is either held in the vise *V* (Fig. 42) or is clamped to the table *T*, which is provided with slots for receiving the clamping bolts. The vise resembles a planer vise, and it can be removed readily when work is to be attached directly to the table. It can also be swiveled to any angular position by loosening nuts *n*, the position being shown by degree graduations. The table of this particular shaper is also removable, to permit clamping parts directly to the face of the saddle or cross-slide *D*, which also has bolt-slots in the front face.

Fig. 44 shows an example of the kind of work which is held in the vise. The part illustrated is a small engine slide valve, which is set up for planing the face *F*. After the casting is properly located in the vise and the tool *T* is clamped in place, the shaper is started and the stroke adjusted both for length and position, to give the tool a movement about as indicated by the arrow *s*. The tool is then fed downward to the work and the latter is moved crosswise, by hand, until a cut of the right depth is started; the automatic feed is then engaged by dropping the feed-pawl into mesh with the ratchet gear on lead-screw as previously explained.

The tools used in a shaper are similar in form to planer tools, though smaller. When taking finishing cuts in the shaper, broad tools and wide feeds cannot be used to the same extent as in planer work, because the shaper is less rigid and, consequently, there is a greater tendency for the tool to chatter.

Fig. 45 shows an odd-shaped casting bolted to the side of the table for planing the top surface. The table, in this case, serves the same

Fig. 45. Casting of Irregular Shape bolted to Side of Table

Fig. 46. Table removed and Casting Clamped to Cross-slide

purpose as an angle-plate on the planer, and the method of holding the casting to it is clearly shown in the illustration. Clamp *C* simply forms a stop for supporting the outer end of the casting, which would otherwise tend to sag down under the thrust of the cut. Work that is bolted directly to the table is held by practically the same kind of clamps that are used in connection with planer work.

In Fig. 46 the table is shown removed and a casting is clamped directly to the face of the cross-slide for planing the top bearing surface. This is an illustration of the class of work that can be held to advantage in this way. When setting work in the shaper, a surface gage can often be used effectively the same as in planer work. The tool itself can also be employed as a gage for setting the work level, by comparing the distance between the surface being tested and the tool point. When using the tool in this way, it is placed close to the work and the latter is shifted so that its height at various points can be determined.

When vertical or angular surfaces are planed in the shaper, the tool block is swiveled so that the top of the block inclines away from the surface being planed, to avoid any interference with the tool on the return stroke, as explained in connection with planer work. The entire tool head can also be set to any angle for planing angular surfaces, by loosening locking bolt *h* (Fig. 42), and its position is shown by degree graduations. Some shapers have an automatic verti-

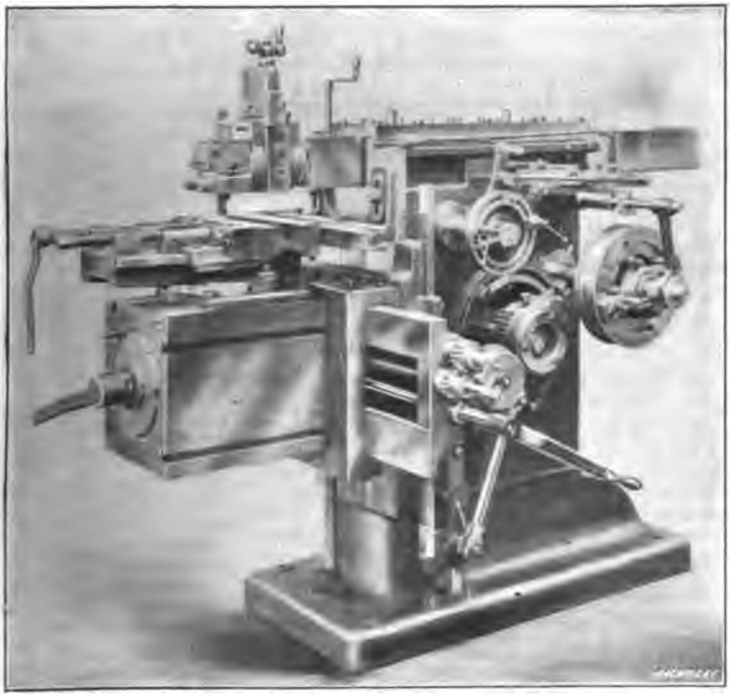

Fig. 47. Morton Draw-cut Shaper

cal feed for the tool as well as an automatic horizontal feed for the work, but most of the shapers now used are not so equipped, the tool being fed vertically by hand. Both the horizontal and vertical feed screws of the machine shown in Fig. 42, have graduated collars which are used when it is desired to feed the tool down or crosswise a definite amount. These collars have graduations representing a movement of 0.001 inch, and they can often be used to advantage for adjusting the tools.

Rack Shaper—Draw-cut Shaper—Special Types

A shaper of the type illustrated in Fig. 42, or one which is operated by a crank and slotted lever, is known as a crank shaper to distinguish it from the rack shaper which has an all-geared drive. The driving mechanism of a rack shaper is similar to that of a spur-gear type of planer. The ram has a rack on its under side and it is driven by a gear which meshes with this rack: The movement of the ram is reversed either by open- and cross-belts which are alternately shifted on tight and loose pulleys, or by friction clutches, which alternately engage the forward and return pulleys. The length of the stroke is controlled by adjustable tappets.

The shaper illustrated in Fig. 47 differs from the ordinary type in that the tool cuts when it is moving towards the column of the machine. In other words, the tool is pulled or drawn through the metal on the cutting stroke instead of being pushed. For this reason the name "draw-cut" is applied to a shaper of this type. The planing tool is, of course, set with the cutting edge reversed. The ram of this

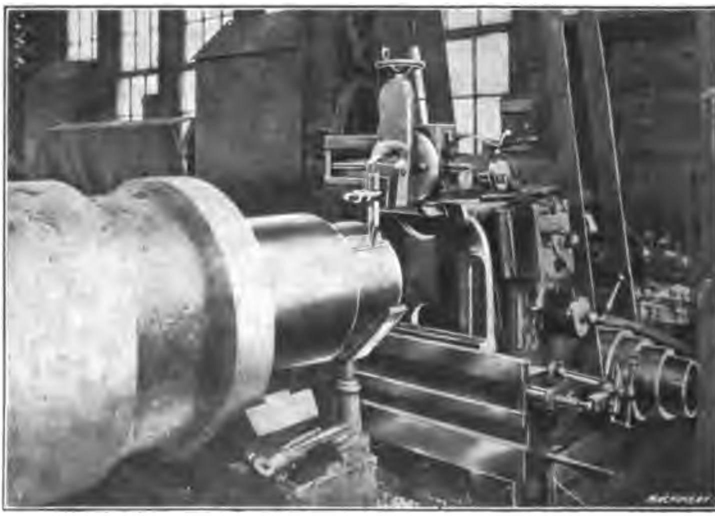

Fig. 48. Planing End of 20-ton Steel Roll, with Shaper having Side-traversing Tool-head

machine is driven by a rack and gearing, and the reciprocating motion is obtained by open- and cross-belts. The forward motion pulley is on one side of the column and the reverse pulley on the other. These pulleys are alternately engaged by friction clutches, and the length of the stroke is regulated by adjustable tappets mounted on the circular disk seen near the top of the column. There is also a hand lever for reversing the ram at any part of the stroke.

The object in designing a shaper to take a draw cut is to secure greater rigidity and, consequently, a higher degree of accuracy. The thrust of the cut is toward the column and this tends to relieve the cross-rail from excessive strains, especially when taking deep cuts.

Shapers of special types are also built in a number of different designs which are varied to suit certain classes of work. These differ from the standard types either in the motion of the ram relative to the work-table or in having a greater range of adjustment which adapts them to work which could not be handled in an ordinary shaper.

A shaper is shown in Fig. 48, which is provided with a cross traverse for the tool-head. The advantage of this feature, for certain classes of work, is indicated by the illustration. The regular table has been removed, and the end of a 20-ton steel roll is being planed. The traversing head enables horizontal cuts to be taken over the work which remains stationary. This shaper is a special design built by Gould & Eberhardt, and it can be used to advantage on large, unwieldy parts such as the one illustrated.

CHAPTER VI

THE SLOTTING MACHINE

The slotting machine or "slotter," as it is commonly called, is a vertical machine and is adapted to cutting keyways in the hubs of flywheels or pulleys and for finishing slots or other enclosed parts which could not be finished by the tool of a horizontal machine like the planer or shaper. The slotter is also used for various other classes of work, requiring flat or curved surfaces, which can be machined to better advantage by a tool which moves vertically. The ram *R* of the slotter, to which the planing or slotting tool is attached (see Fig. 49), has a vertical reciprocating movement at right angles to the work table. This vertical movement is obtained from a crank disk *D* which is connected to the slotter ram by a link and is driven by a cone pulley *P* and the large gearing seen at the rear. The tool is fastened to the end of the ram by the clamps shown, and the work is secured to the platen *T*. There are two sets of clamps on the ram so that the tool can be held in a vertical or horizontal position. The tools used for keyseating or finishing slots, are held in a vertical position, whereas larger surfaces which can readily be reached, are planed by a tool held horizontally against the end of the ram. The platen *T* can be moved crosswise along the saddle *S* and the latter can be traversed at right angles along the bed. In addition, the platen can be rotated about its center for slotting circular surfaces. These three movements can be effected by hand or power. The lengthwise adjustment on the bed is effected by turning squared shaft *A* with a crank; similarly, squared shaft *B* is used for moving the platen crosswise. The platen is rotated by turning shaft *C*. The automatic power feed for these three movements is derived from the cam *E* on the inner side of the large driving gear. This cam is engaged by a roller on the end of lever *F* and whenever the ram or tool is at the top of its stroke, an irregular place in the cam track causes lever *F* to oscillate. This movement is transmitted by connecting link and shaft *G* at the side of the bed, to the slotted crank *H*. This crank turns the large gear *I* slightly for each stroke of the ram, by means of a ratchet disk carrying a double-ended pawl *K* which engages the gear. Gear *I*, in turn, transmits the movement through the intermediate gears shown, to either of the three feed shafts. If a power feed along the bed is wanted, gear *J* is placed on the feed-shaft *A*, as shown in the illustration. On the other hand, if a cross feed is desired, gear *J* is inserted on shaft *B* and, similarly, the rotary feed is obtained by placing this same gear on shaft *C*. The amount of feed is varied by changing the position of the crankpin at *H*, and the direction of the feed is reversed by shifting the double-ended pawl *K*. The stroke of the ram is varied by adjusting the crankpin of disk *D*, to or from the center. The vertical position of the ram is changed so that the tool

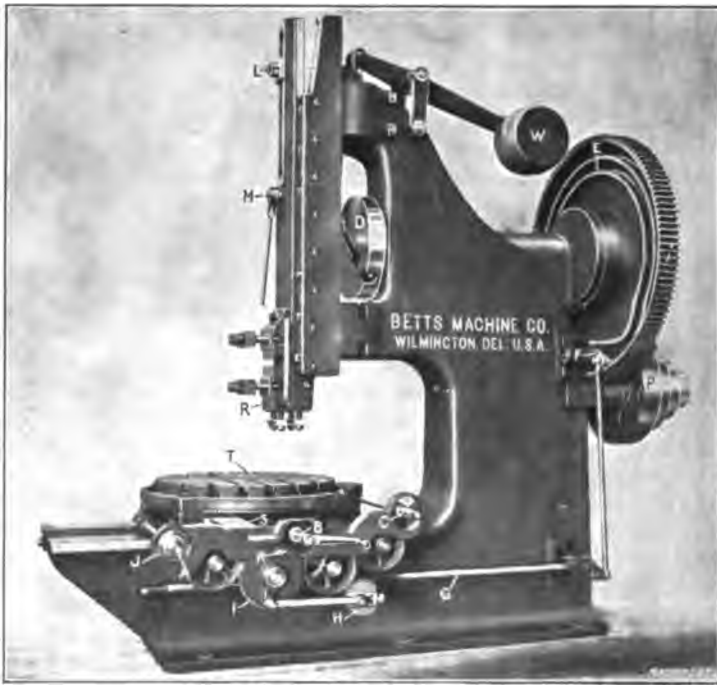

Fig. 49. Betts Slotting Machine

will operate in the right relation to the work, by loosening nut *L* and moving the ram up or down by turning shaft *M* with a hand ratchet. The ram is counterbalanced by a weight *W* and it has a quick return movement for the upward or idle stroke.

A typical example of the kind of work done on the slotter is shown in Fig. 50 which illustrates, diagrammatically, the slotting of a locomotive driving-wheel box. The side and top views at *A*, indicate how the inner sides of the box are finished. The work is set on parallel strips *s* to provide clearance for the tool at the lower end of the stroke, and it is secured to the platen by four clamps. The stroke of the ram *R* should be about one inch greater than the width of the surface to be slotted and most of the clearance between the tool and the work should be at the top of the stroke where the feeding movement takes place. When the stroke is adjusted, the ram is placed in its lowest position and it is lowered until the end is a little above the top of the work. The tool is extended below the end of the ram far enough to allow the cutter *c* to reach through the box when at the bottom of the stroke. The line previously scribed on the work to show the location of the finished surface, is next set parallel to the cross travel of the platen. This can be done by comparing the movement of the line with relation to the stationary tool-point while the work is fed

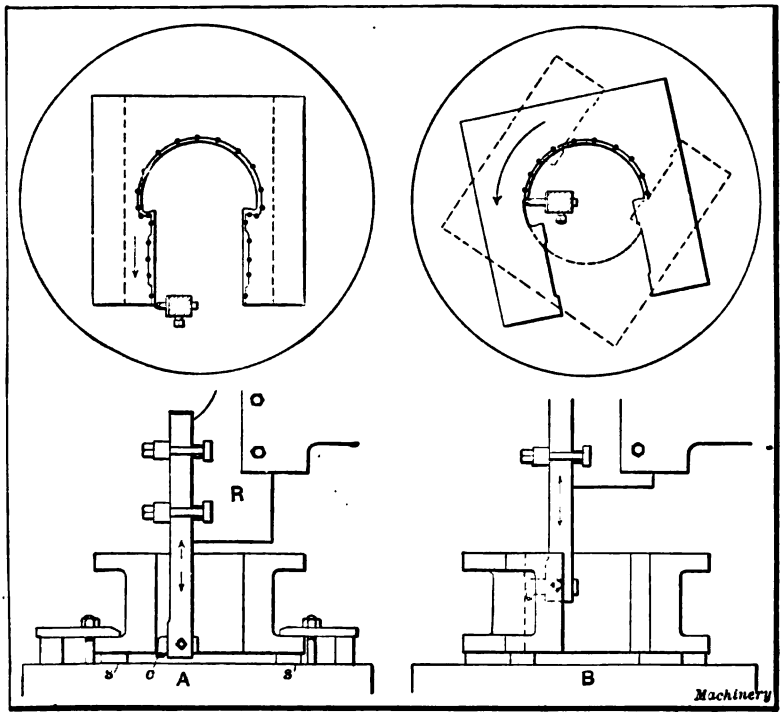

Fig. 50. Example of Straight and Circular Slotting

laterally by hand. If adjustments are necessary, these can be made by swiveling the platen one way or the other as required. When the work is set, the platen is locked to the saddle by clamps provided for that purpose. The cut is started at one end as shown in the plan view and the side is planed by the vertical movement of the tool combined with the lateral feeding movement of the platen and work. The opposite side is slotted without disturbing the position of the work by simply turning the tool half way around. The sketch at *B* indicates how the curved seat for the brass journal is finished. The radius of the seat is shown by a scribed line which must be set concentric with the center or axis about which the platen rotates. The platen must also be adjusted laterally and longitudinally, if necessary, until the tool will follow the finish line as the work feeds around. The position of the work soon after the cut is started is shown in the plan view by the full lines, and the dotted lines indicate how the box feeds around while a cut is being taken across the circular seat. After the slotter is set in motion, the cut is started by hand and then the power feed is engaged. The finish lines on work of this kind usually serve merely as a guide and the final measurements are determined by calipers or special gages.

A number of duplicate parts can sometimes be slotted simultaneously by clamping one piece above the other in a stack or pile. The tool then planes the entire lot to the same shape. This method only applies to work which can readily be stacked up.

Some of the tools used in the slotter are illustrated in Fig. 51. Those shown at *A*, *B* and *C* are forged from the solid bar and have

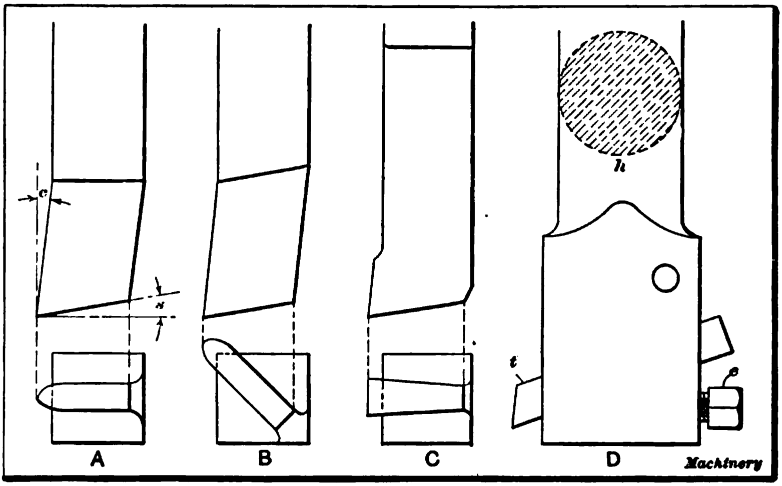

Fig. 51. Some of the Tools used for Slotting

cutting edges formed on the ends, whereas tool *D* consists of a heavy bar in which a small cutter *t* is inserted. Tools *A* and *B* are used principally for slotting interior surfaces, where there is little room for the tool to operate. For exterior slotting, or whenever there is plenty of room, tool *D* is preferable because it is more rigid. The cutting end of tool *B* is inclined to the right or left (as indicated by the end view) for working in corners, etc. The position of tool *D*, which has a round shank *h*, can be varied by turning it in clamps at the upper end which hold it to the slotter ram. The cutter *t* is held by setscrew *e* in a pivoted, spring-relief block which allows the tool point to swing away from the work on the upward stroke. The tool tends to spring away from the work on the downward or cutting stroke, and if there is no relief movement, it drags heavily over the planed surface on the upward stroke. Tool *C* is used for cutting keyways or narrow slots. These tools have a slope *s* at the end and the front side is ground to a clearance angle *c*. The direction of the slope at the end (which is the surface against which the chips bear while being severed) is away from the cutting edge, and this is a rule which applies generally to tools for turning or planing iron or steel.

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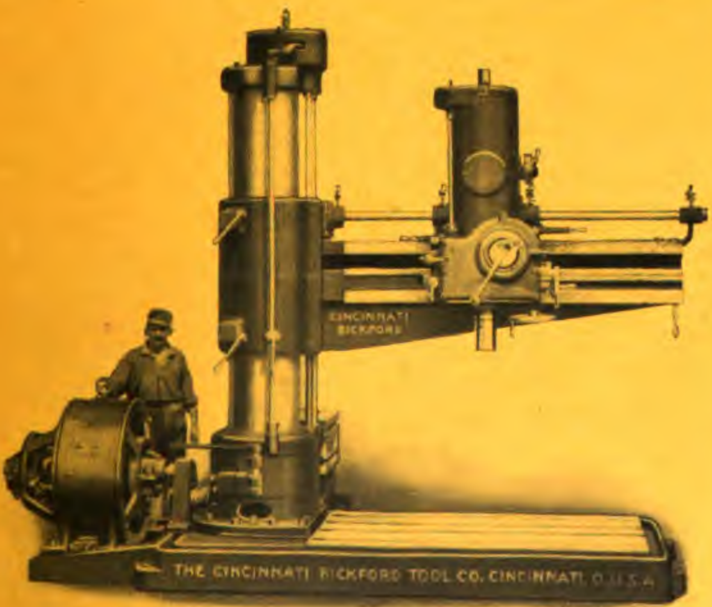
OPERATION OF MACHINE TOOLS

BY FRANKLIN D. JONES

DRILLING MACHINES



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NUMBER 94

OPERATION OF MACHINE TOOLS

By FRANKLIN D. JONES

DRILLING MACHINES

CONTENTS

CHAPTER I

UPRIGHT DRILLING MACHINES

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

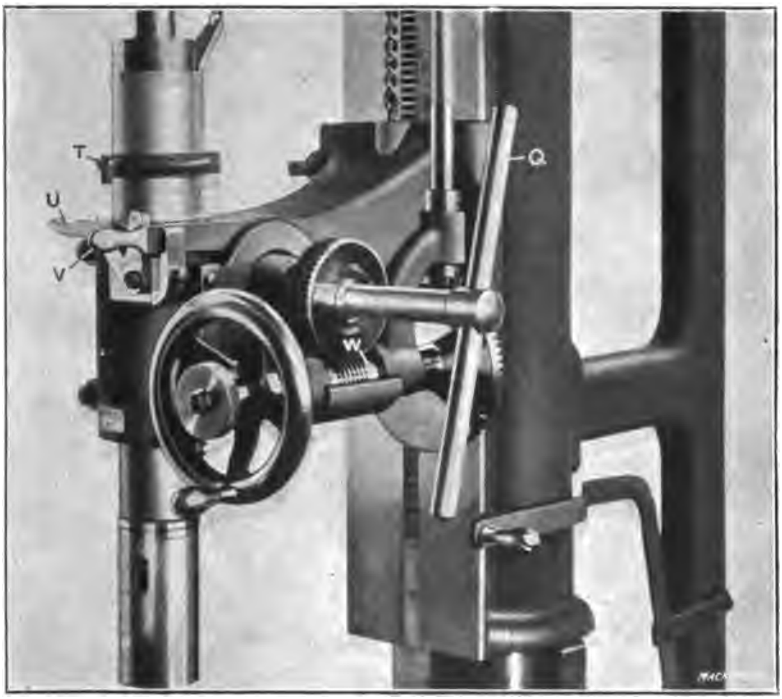

Fig. 1. Drill Spindle Feeding and Automatic Trip Mechanism

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

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

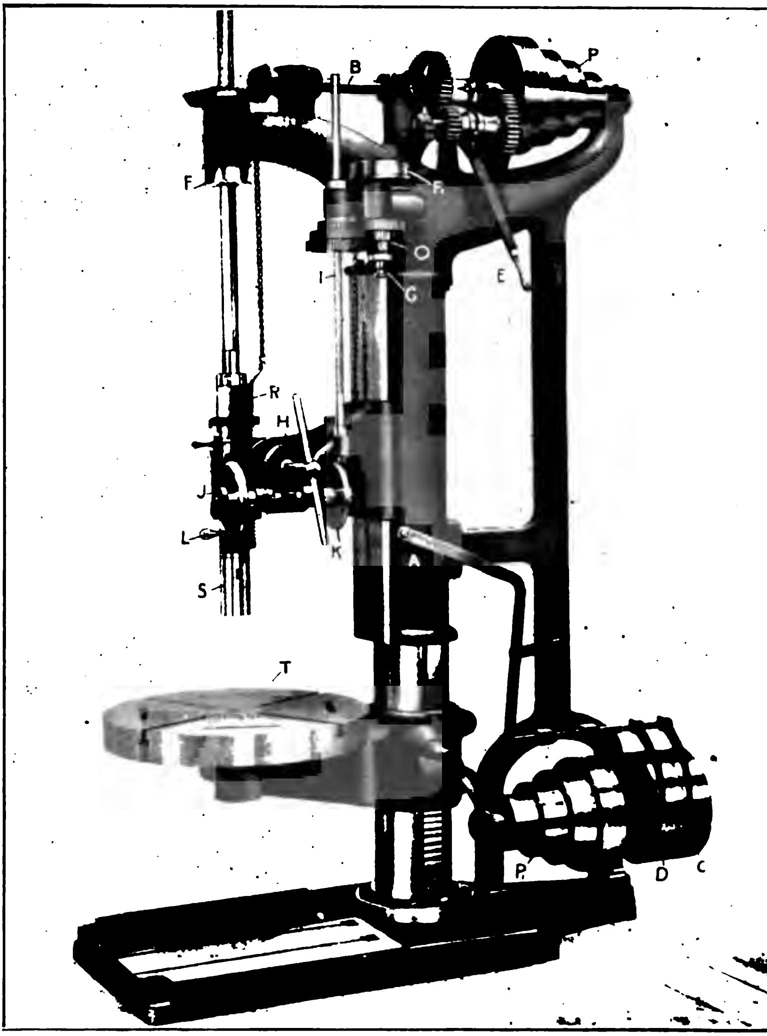

Fig. 2. Hamilton Upright Drilling Machine

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

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

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

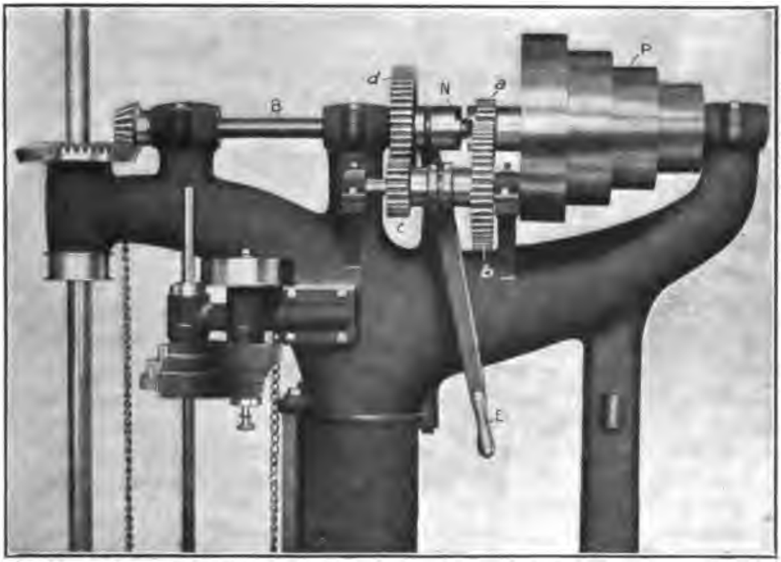

Fig. 3. Back-gearing and Feed Change-gears of Upright Drilling Machine

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

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

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

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

CHAPTER II

DRILLING, REAMING, COUNTERBORING AND TAPPING

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

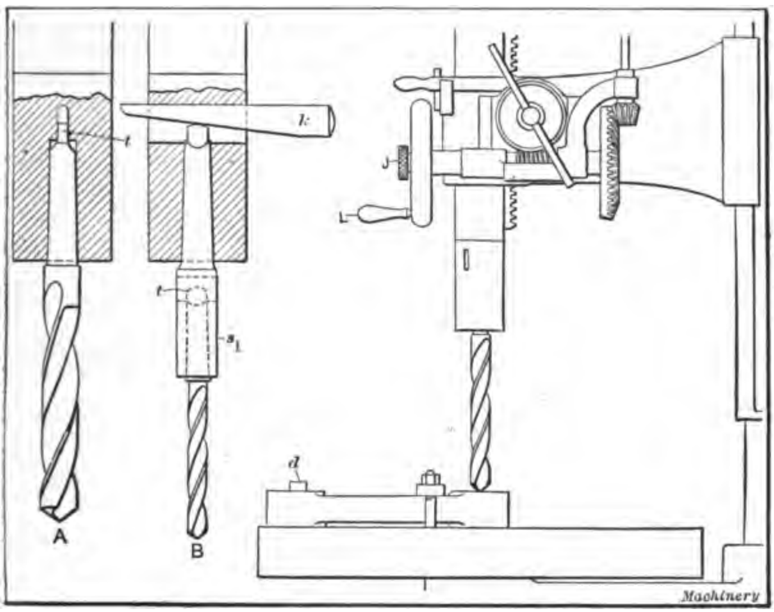

Fig. 4. Method of Holding and Driving Taper-shank Drills. Drilling-head of Upright Machine

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

The drill itself is inserted either directly in the spindle or in a socket, as will be explained later. The type of twist drill commonly used is shown at *A* in Fig. 6. It has two beveled cutting edges *e* at the end, formed by the two spiral grooves or flutes, and the part *s*, called the shank, is made to a standard taper. The size of the shank is the same on all drills up to a certain diameter, and then a larger shank is used for another range of sizes, and so on. In the Morse system of tapers, which is universally used for twist-drill shanks, the sizes are designated by numbers. For this particular operation, the drill would per-

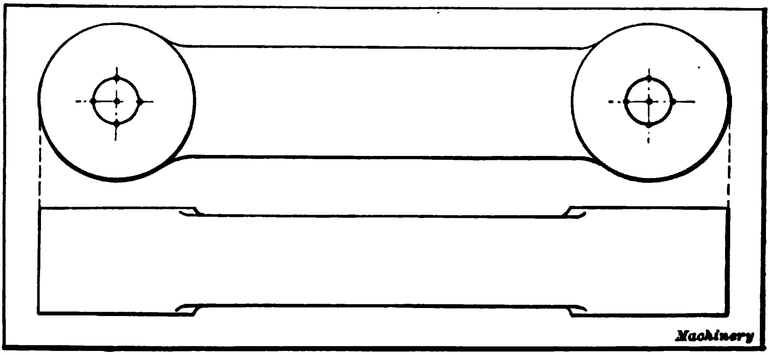

Fig. 5. Example of Drill-press Work

haps be large enough to permit inserting it directly in the spindle as shown at *A* in Fig. 4, though this would depend on the number or size of the taper hole in the spindle. On the other hand, if a comparatively small drill were to be used, it might be necessary to place a socket s_1 (see sketch *B*) in the spindle and insert the drill in the end of this

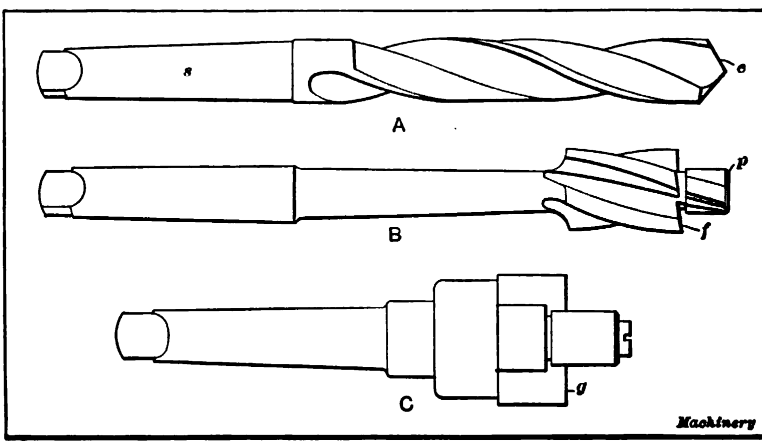

Fig. 6. (A) Twist Drill. (B) Solid Counterbore. (C) Counterbore with Inserted Blade

socket. The drill is caused to rotate with the spindle or socket, principally by a flat end or tang *t* on the shank, which engages a cross-slot at the end of the taper hole, as shown. As the taper of the shank corresponds with the taper of the hole in the spindle or socket, the drill is also driven partly by friction.

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

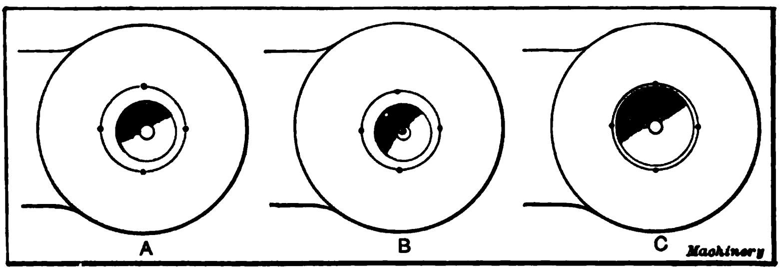

Fig. 7. Method of Starting Drill Concentric with Scribed Circle

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

Finishing Holes by Reaming

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

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

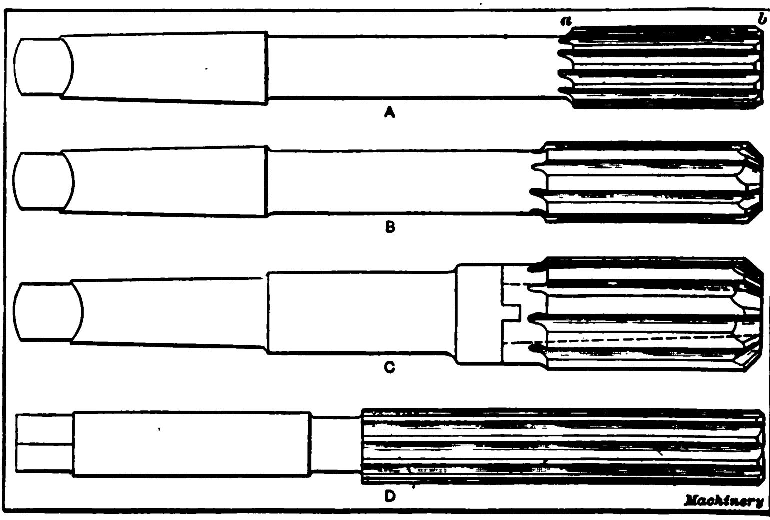

Fig. 8. Reamers of Different Styles

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

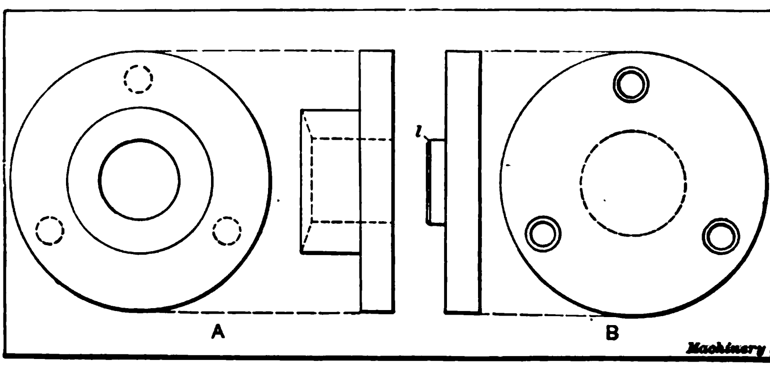

Fig. 9. (A) Packing Gland. (B) Drill Jig for Gland

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

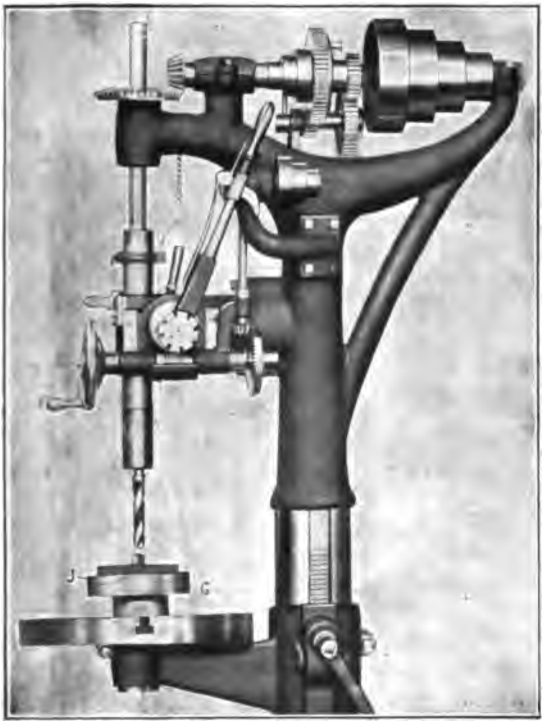

Fig. 10. Drill-press of the Wheel- and Lever-feed Type

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

Drilling by the Use of Jigs

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

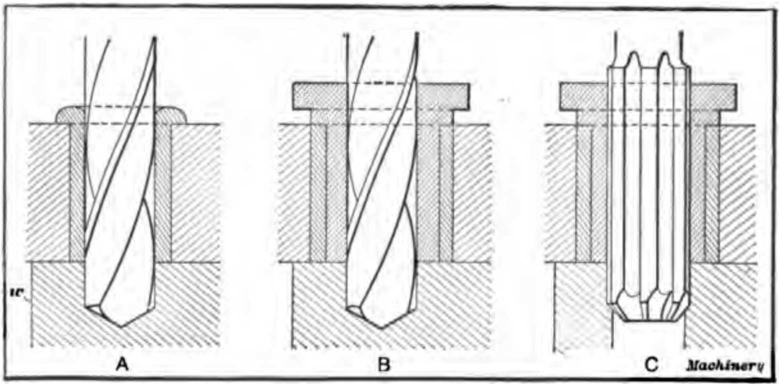

Fig. 11. Fixed and Removable Guide Bushings for Drill Jigs

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

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

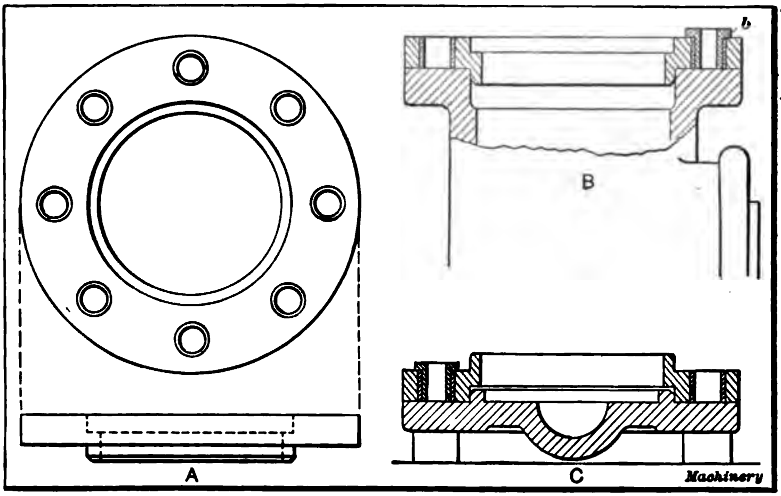

Fig. 12. Jig for Cylinder Flange and Head, and its Application

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

Jigs of the Box Type

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

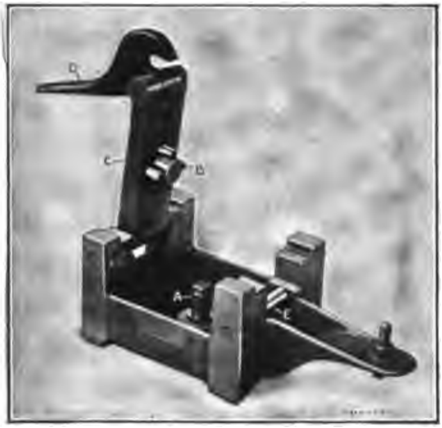

Fig. 13. Drill Jig of the Box Type

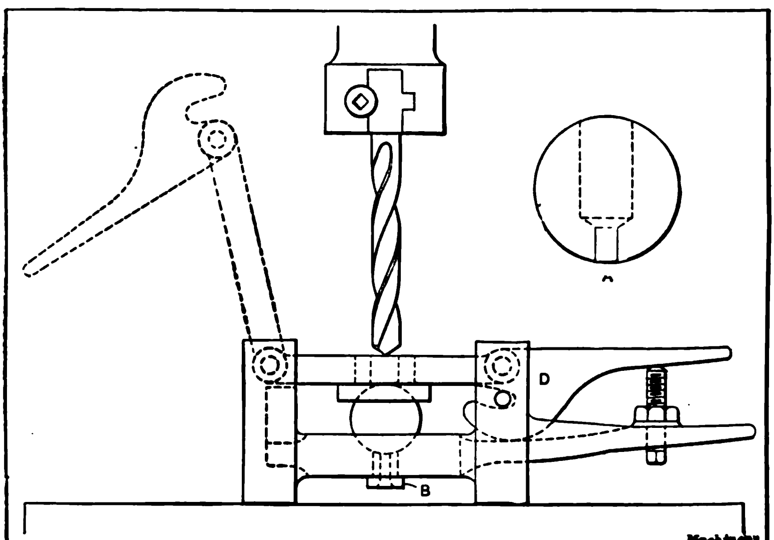

Fig. 14. Box Jig for Drilling Ball shown enlarged at A

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

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

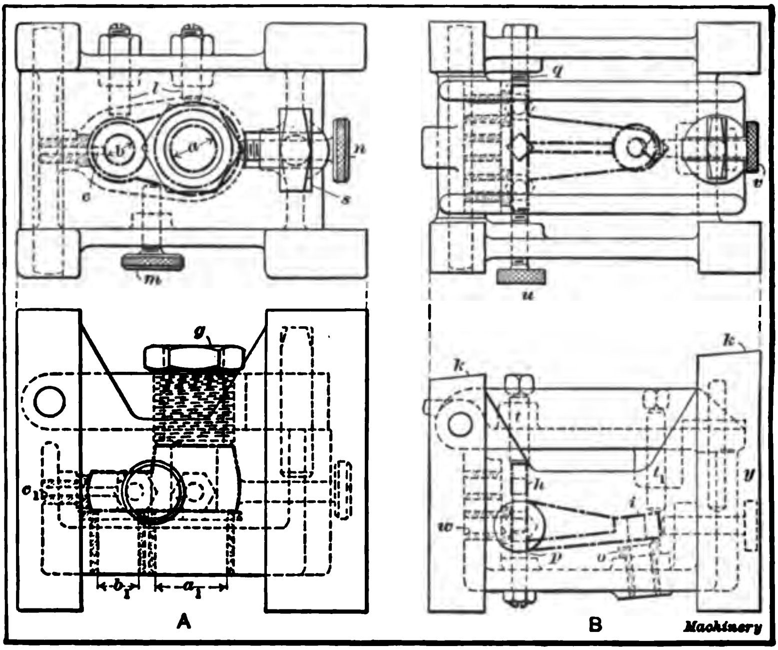

Fig. 15. Box Jigs for Drilling Parts shown by Heavy Dot-and-dash Lines

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

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

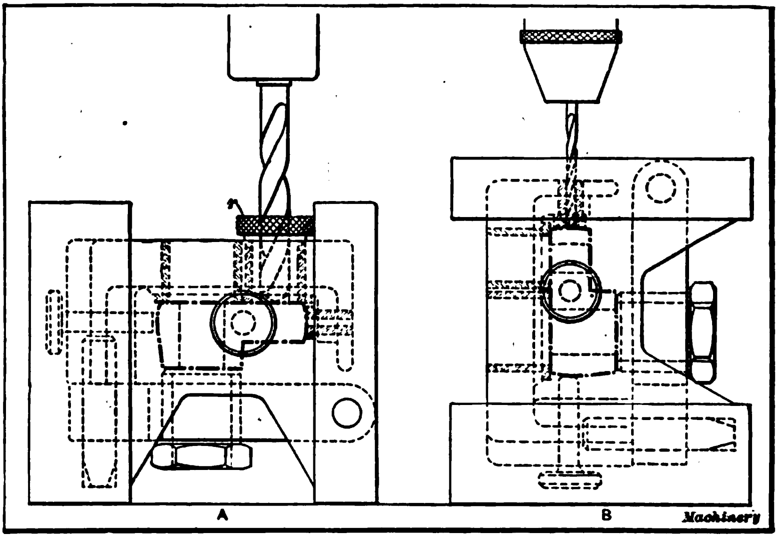

Fig. 16. Method of Using Jig

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

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

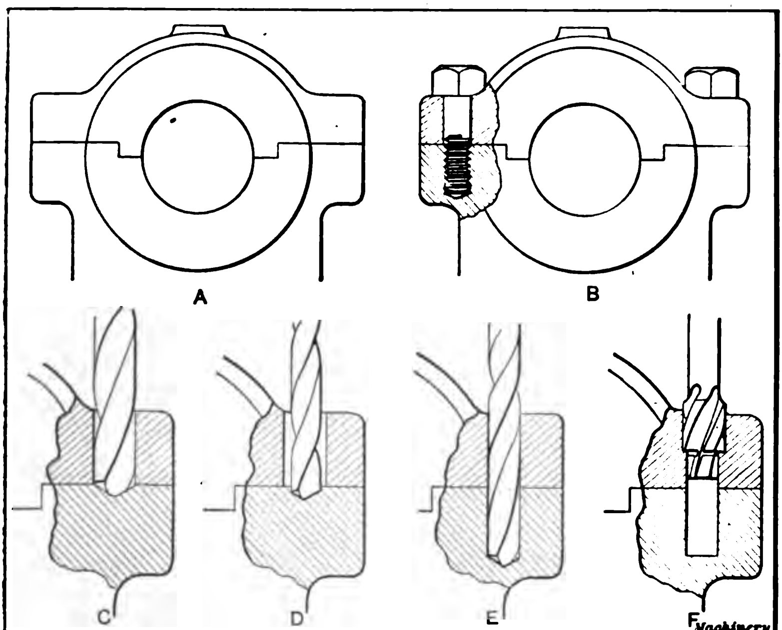

Fig. 17. Views indicating how Work can sometimes be used as a Jig

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

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

Using the Work as a Jig

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

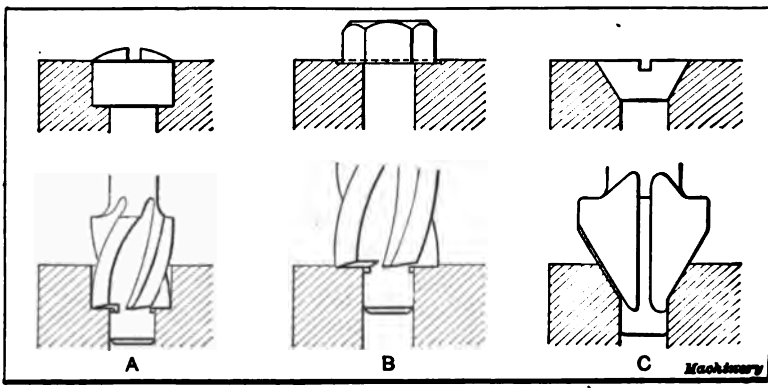

Fig. 18. Use of Counterbore and Countersink

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

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

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

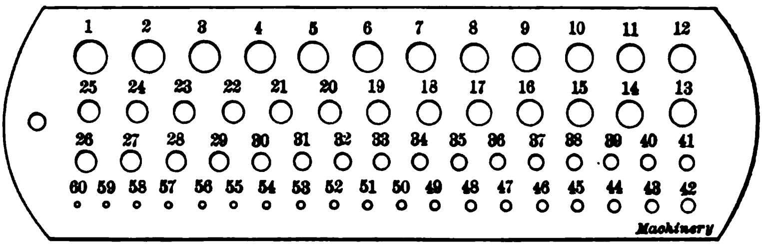

Fig. 19. Twist Drill and Steel Wire Gage

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

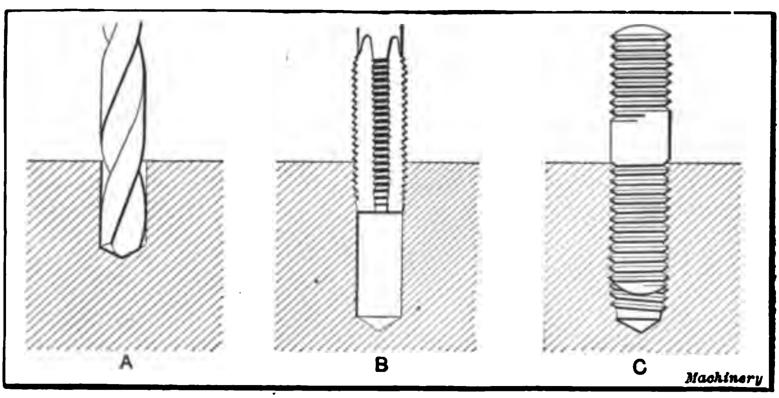

Fig. 20. (A) Tap Drill. (B) Tap for Threading Hole. (C) Stud inserted in Threaded Hole

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

Drill Sizes

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

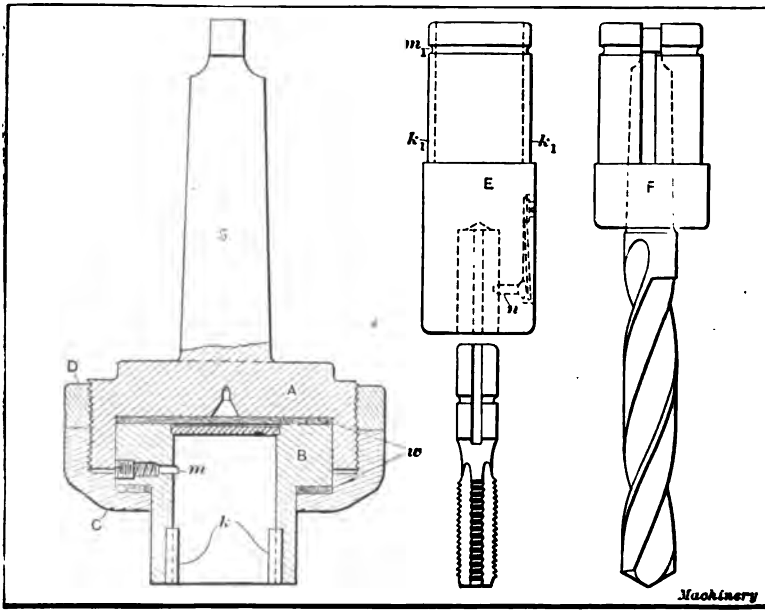

Fig. 21. Beaman & Smith Safety Drill- and Tap-holder

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

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

Machine or Power Tapping

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

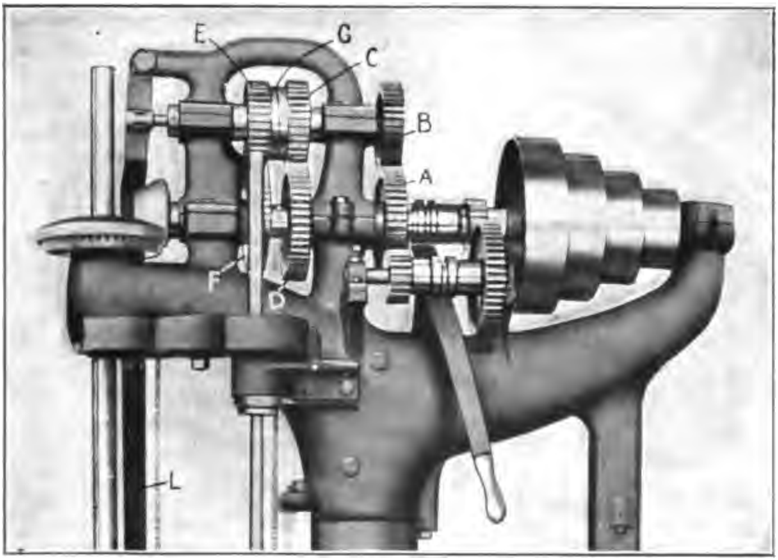

Fig. 22. Hamilton Tapping Attachment

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

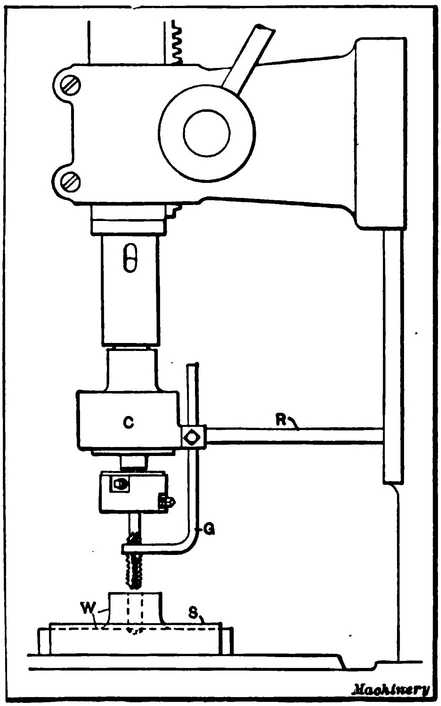

Fig. 23. Errington Automatic-reverse Tapping Chuck

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

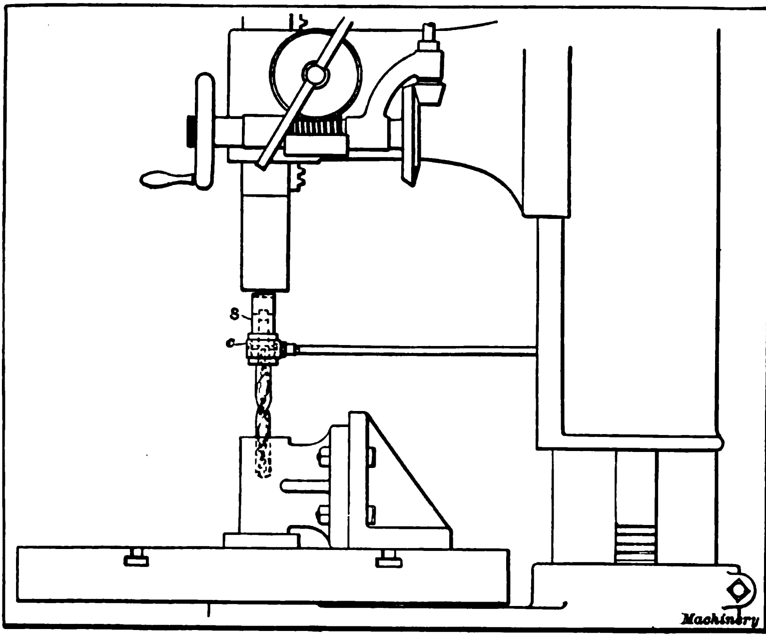

Fig. 24. Method of Applying Oil-tube Drill to Drill-press

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

Errington Automatic-reverse Tapping Chuck

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

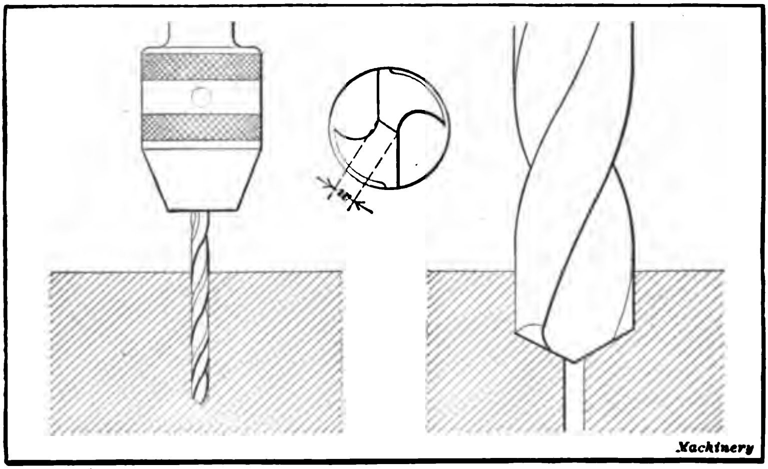

Fig. 25. Pressure for Feeding Large Drill can be reduced by Drilling Small "Lead Hole"

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

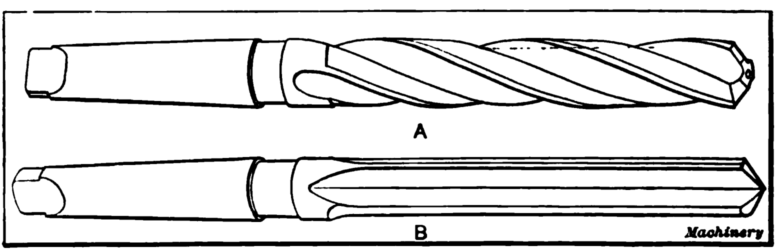

Fig. 26. A) Three-groove Drill. (B) Straight-fluted Drill

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

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

Oil Drills—Drilling Large Holes—Special Drills

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

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

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

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

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

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

Carbon Steel Drills

Size of Drill	Feed per Rev.	Bronze, Brass, 150 Feet	C. Iron Ann'ld, 85 Feet	Hard C. Iron, 40 Feet	Mild Steel, 60 Feet	Drop Forg., 30 Feet	Mal. Iron, 45 Feet	Tool Steel, 30 Feet	Cast Steel, 20 Feet
Inches	Inches	R.P.M.	R.P.M.	R.P.M.	R.P.M.	R. P. M.	R. P. M.	R. P. M.	R. P. M.
1/16	0.003	....	5185	2440	3660	1830	2745	1830	1220
1/8	0.004	4575	2593	1220	1840	915	1375	915	610
3/16	0.005	3050	1728	813	1220	610	915	610	407
1/4	0.006	2287	1296	610	915	458	686	458	305
5/16	0.007	1830	1037	488	732	366	569	366	245
3/8	0.008	1525	864	407	610	305	458	305	203
7/16	0.009	1307	741	349	523	261	392	261	174
1/2	0.010	1143	648	305	458	229	343	229	153
5/8	0.011	915	519	244	366	183	275	183	122
3/4	0.012	762	432	204	305	153	212	153	102
7/8	0.013	654	371	175	262	131	196	131	87
1	0.014	571	323	153	229	115	172	115	77
1 1/4	0.016	458	260	122	183	92	138	92	61
1 1/2	0.016	381	216	102	153	77	106	77	51
1 3/4	0.016	327	186	88	131	66	98	66	44
2	0.016	286	162	77	115	58	86	58	39

High-speed Steel Drills

Size of Drill	Feed per Rev.	Bronze, Brass, 300 Feet	C. Iron Ann'ld, 170 Feet	C. Iron Hard, 80 Feet	Mild Steel, 120 Feet	Drop Forg., 60 Feet	Mal. Iron, 90 Feet	Tool Steel, 60 Feet	Cast Steel, 40 Feet
Inches	Inches	R.P.M.	R.P.M.	R.P.M.	R.P.M.	R.P.M.	R.P.M.	R.P.M.	R.P.M.
1/16	0.003	....	....	4880	....	3660	....	3660	2440
1/8	0.004	....	5185	2440	3660	1830	2745	1830	1220
3/16	0.005	....	3456	1626	2440	1210	1830	1220	807
1/4	0.006	4575	2593	1220	1830	915	1375	915	610
5/16	0.007	3660	2074	976	1464	732	1138	732	490
3/8	0.008	3050	1728	813	1220	610	915	610	407
7/16	0.009	2614	1482	698	1046	523	784	523	348
1/2	0.010	2287	1296	610	915	458	686	458	305
5/8	0.011	1830	1037	488	732	366	569	366	245
3/4	0.012	1525	864	407	610	305	458	305	203
7/8	0.013	1307	741	349	523	261	392	261	174
1	0.014	1143	648	305	458	229	349	229	153
1 1/4	0.016	915	519	244	366	183	275	183	122
1 1/2	0.016	762	432	204	305	153	212	153	102
1 3/4	0.016	654	371	175	262	131	196	131	87
2	0.016	571	323	153	229	115	172	115	77

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

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

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

Speed of Drills

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

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

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

CHAPTER III

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

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

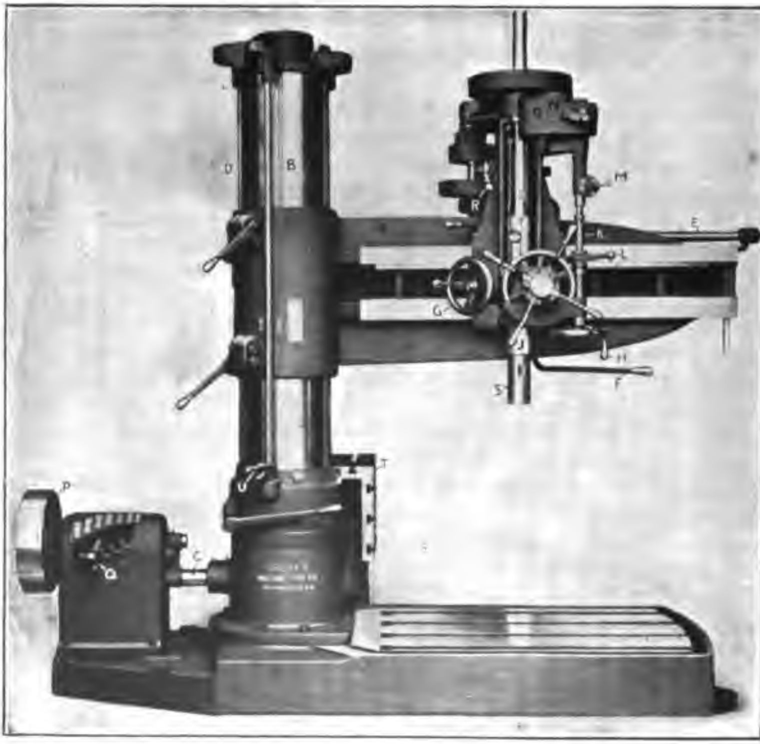

Fig. 27. Dreses Radial Drilling Machine

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

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

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

Sensitive Drill-press

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

Fig. 28. Drill-press of the Sensitive Type

Multiple-spindle Drilling Machines

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

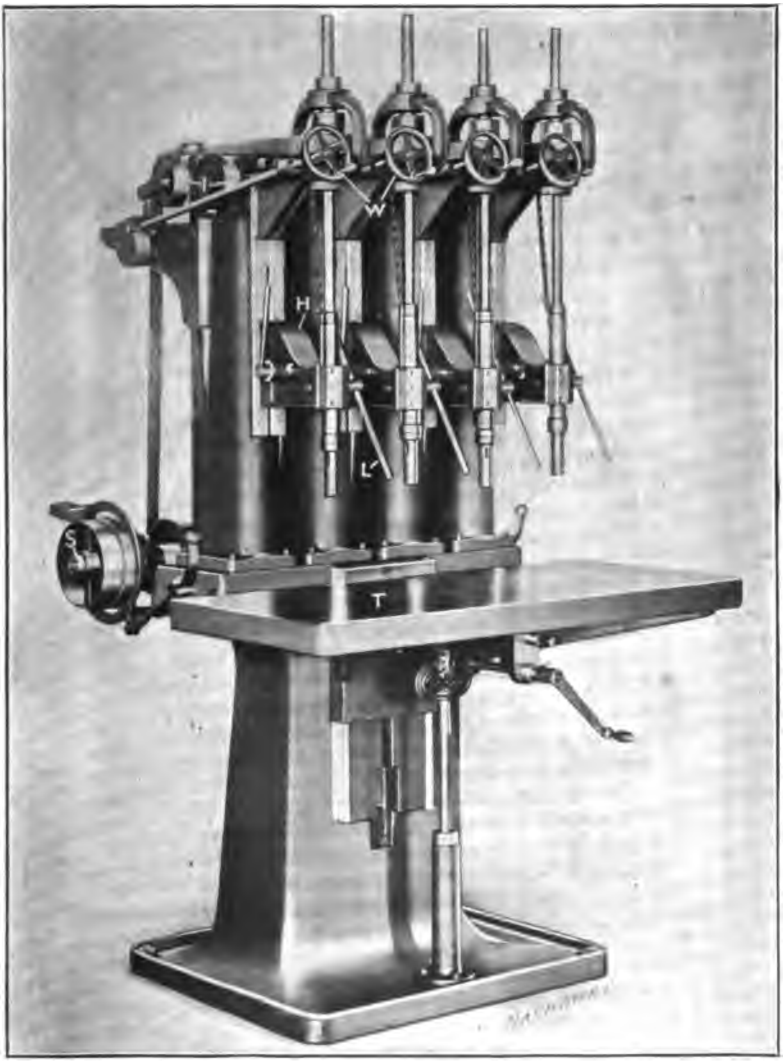

Fig. 29. Henry & Wright Multiple-spindle Drilling Machine

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

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

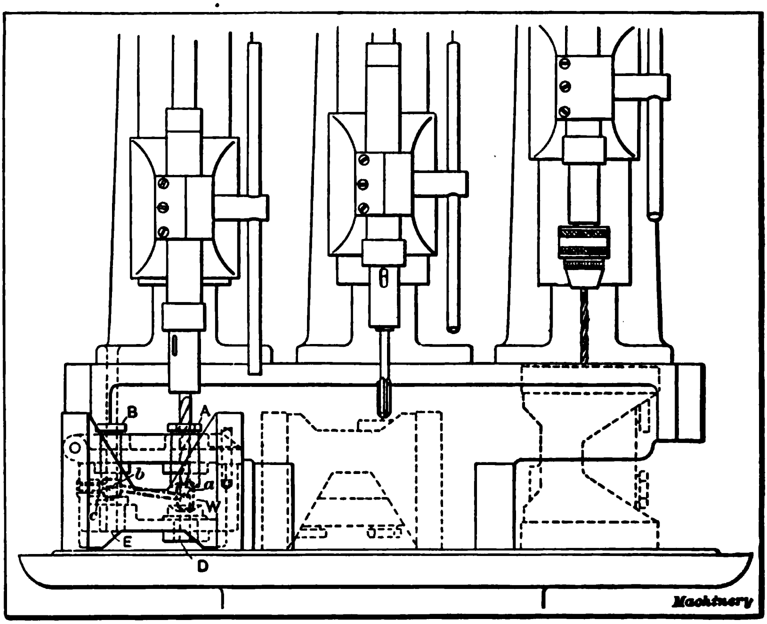

Fig. 30. Method of Using Multiple-spindle Machine for Successive Operations

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

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

Drilling machines of the multiple-spindle type are also commonly

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

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

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

High-duty Drilling Machine

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

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

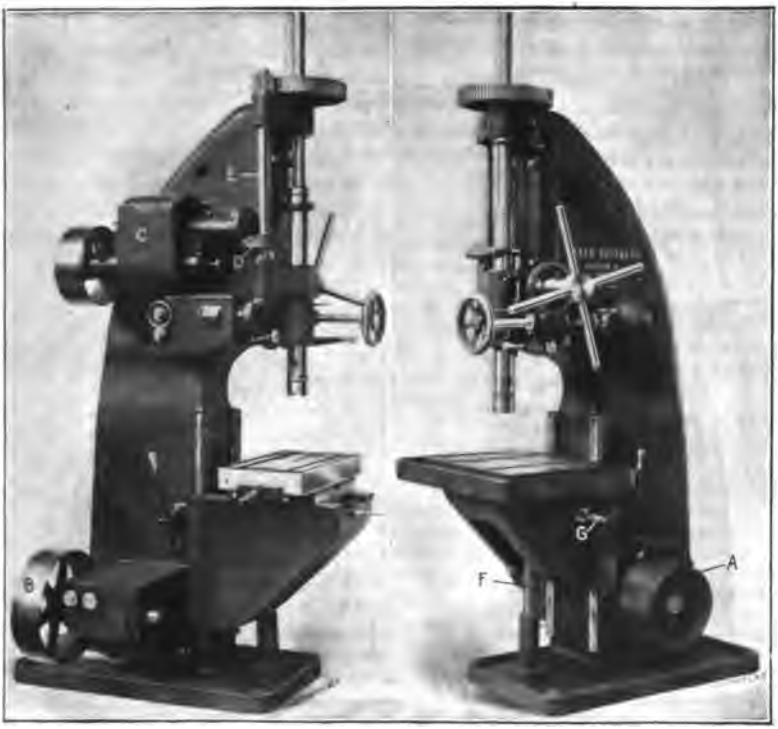

Fig. 32. Baker Bros. High-duty Type of Drilling Machine

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

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

CHAPTER IV

GRINDING TWIST DRILLS

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

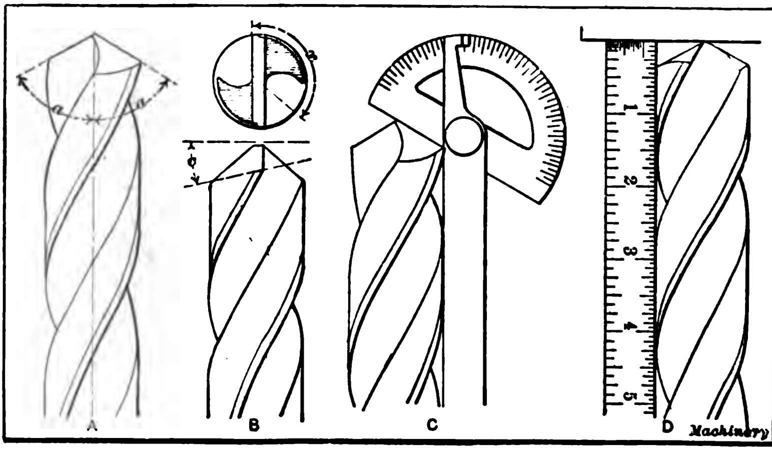

Fig. 33. Views showing Angles to be Considered when Grinding Drills, and Methods of Measuring Lip Angle and Clearance

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

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

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

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

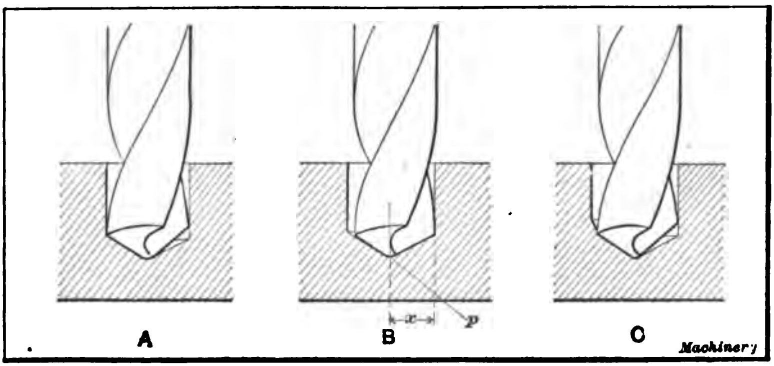

Fig. 34. Three Examples of Incorrect Drill Grinding

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

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

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

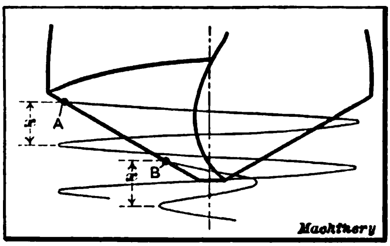

Fig. 35. The Angles of the Helical Paths described by Points A and B show why Angle of Clearance should increase toward Drill Point.

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

Worcester Drill-grinding Machine

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

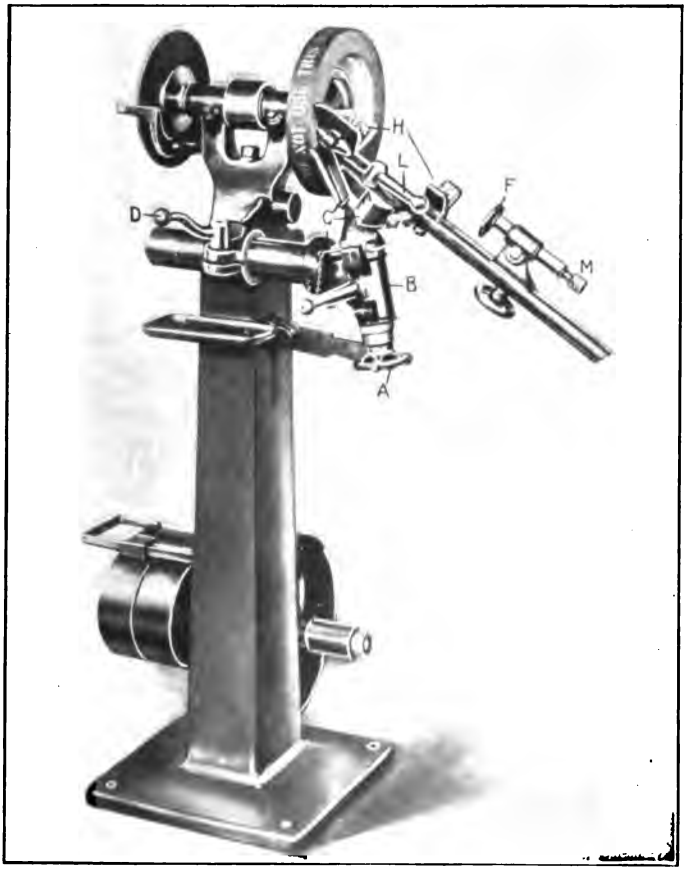

Fig. 36. Grinder for Sharpening Drills

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

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

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

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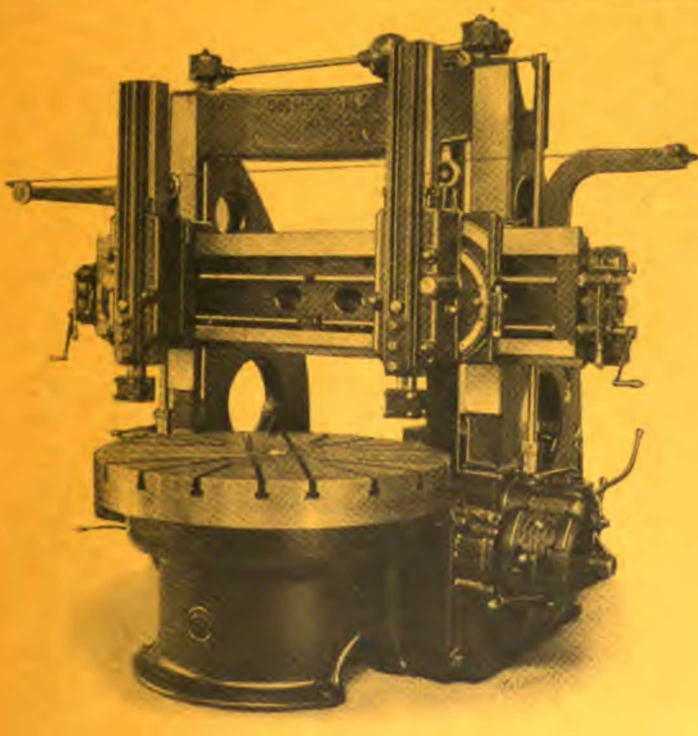

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NUMBER 95

OPERATION OF MACHINE TOOLS

By FRANKLIN D. JONES

VERTICAL AND HORIZONTAL BORING MACHINES

CONTENTS

CHAPTER I

THE VERTICAL BORING MILL

All the different types of turning machines now in use originated from the lathe. Many of these tools, however, do not resemble the lathe because, in the process of evolution, there have been many changes made in order to develop turning machines for handling certain classes of work to the best advantage. The machine illustrated in Fig. 1 belongs to the lathe family and is known as a vertical boring and turning mill. This type, as the name implies, is used for boring and turning operations, and it is very efficient for work within its range. The part to be machined is held to the table *B* either by clamps or in chuck jaws attached to the table. When the machine is in operation, the table revolves and the turning or boring tools (which are held in tool-blocks *T*) remain stationary, except for the feeding movement. Very often more than one tool is used at a time, as will be shown later by examples of vertical boring mill work. The tool-blocks *T* are inserted in tool-bars T_1 carried by saddles *S* which are mounted on cross-rail *C*. Each tool-head (consisting of a saddle and tool-bar) can be moved horizontally along cross-rail *C*, and the tool-bars T_1 have a vertical movement. These movements can be effected either by hand or power.

When a surface is being turned parallel to the work table, the entire tool-head moves horizontally along the cross-rail, but when a cylindrical surfaco is being turned, the tool-bar moves vertically. The tool-heads are moved horizontally by the screws *H* and H_1, and the vertical feed for the tool-bars is obtained from the splined shafts *V* and V_1, there being a separate screw and shaft for each head so that the feeding movements are independent. These feed shafts are rotated for the power feed by vertical shafts *A* and A_1 on each side of the machine. These vertical shafts connect with the feed shafts through bevel and spur gears located at the ends of the cross-rail. On most boring mills, connection is made with one of the splined shafts *V* or screw *H*. by a removable gear, which is placed on whichever shaft will give the desired direction of feed. The particular machine illustrated is so arranged that either the right or left screw or feed shaft can be engaged by simply shifting levers D_1 or *D*.

The amount of feed per revolution of the table is varied for each tool-head by feed-changing mechanisms located at *F* on each side of the machine. These feed boxes contain gears of different sizes, and by changing the combinations of these gears, the amount of feed is varied. Five feed changes are obtained on this machine by shifting lever *E*, and this number is doubled by shifting lever *G*. By having two feed boxes, the feeding movement of each head can be varied independently. The direction of either the horizontal or vertical feed can be reversed by lever *R*. which is also used for engaging or disengaging the feeds. This machine is equipped with the dials *I* and I_1 which can be set to automatically disengage the feed at any predetermined point. There are also micrometer dials graduated to thousandths of an inch and used for adjusting the tools without the use of measuring instruments.

The work table *B* is driven indirectly from a belt pulley at the rear, which transmits the power through gearing. The speed of the table can be varied for turning large or small parts, by levers *J* and *K*, and the table can be started, stopped or rotated part of a revolution by lever *L* which connects with a friction clutch. There are corresponding feed

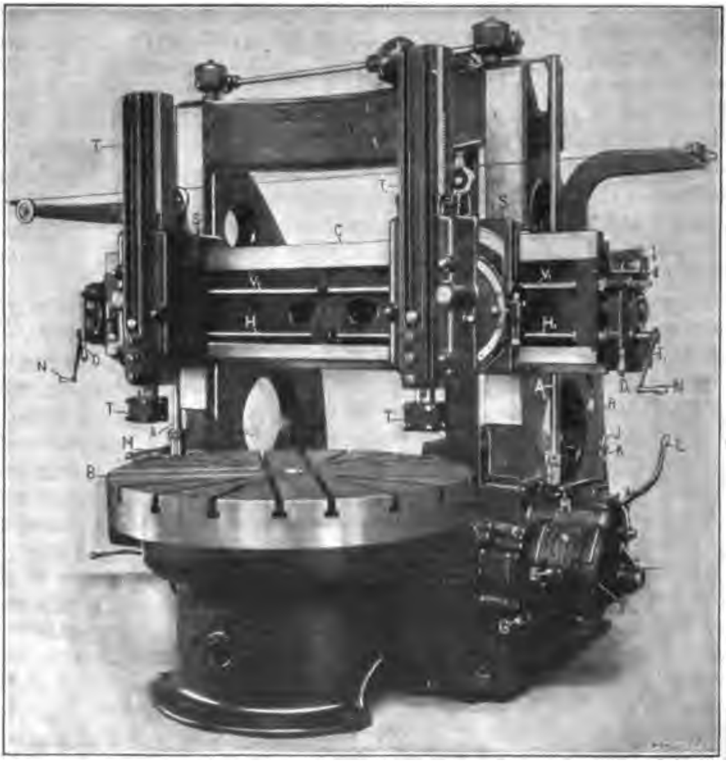

Fig. 1. Gisholt Vertical Boring and Turning Mill

and speed levers on the opposite side, so that the machine can be controlled from either position.

The heads can be adjusted along the cross-rail for setting the tools by hand-cranks *N*, and the tool slides can be moved vertically by turning shafts *V* with the same cranks. With this machine, however, these adjustments do not have to be made by hand, ordinarily, as there are rapid power movements controlled by levers *M*. These levers automatically disengage the feeds and enable the tool-heads to be rapidly shifted to the required position, the direction of the movement depending upon the position of the feed reverse lever *R* and lever *D*. This rapid traverse, which is a feature applied to modern boring mills of medium and large size, saves time and the labor connected with hand adjustments. The cross-rail *C* has a vertical adjustment on the faces of the right and left housings which support it, in order to locate the tool-heads at the right height for the work. This adjustment is effected by power and is controlled by levers at the sides of the housings. Normally, the cross-rail is bolted to the housings, and these bolts must be loosened before making the adjustment, and must always be tightened afterwards.

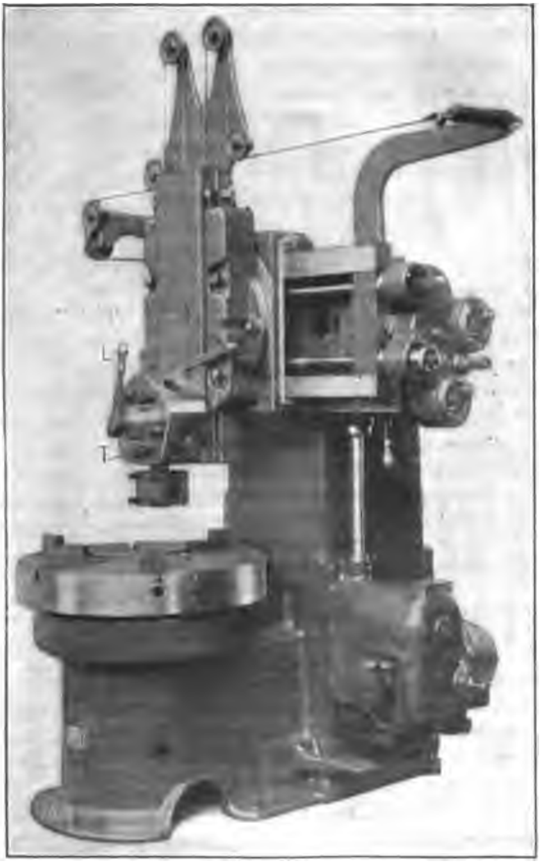

Fig. 2. Small Boring and Turning Mill with Single Turret-head

The function of these different levers has been explained to show, in a general way, how a vertical boring machine is operated. It should be understood, however, that the arrangement differs considerably on machines of different makes. The construction also varies considerably on machines of the same make but of different size. All modern vertical boring mills of medium and large sizes are equipped with two tool-heads, as shown in Fig. 1, because a great deal of work done on a machine of this type can have two surfaces machined simultaneously. On the other hand, small mills of the type illustrated in Fig. 2 have a single head. The tool-slide, instead of having a single tool-block, carries a five-sided turret *T* in which different tools can be mounted. These tools are shifted to the working position as they are needed, by loosening binder lever *L* and turning or "indexing" the turret. The turret is located and locked in any of its five positions by lever *I*, which controls a plunger that engages notches at the rear. Frequently, all the tools for machining a part can be held in the turret, so that little time is required for changing from one tool to the next. Some large machines having two tool-heads are also equipped with a turret on one head.

CHAPTER II

BORING AND TURNING IN A VERTICAL BORING MILL

The vertical boring mill is, in many respects, like a lathe placed in a vertical position, the table of the mill corresponding to the faceplate or chuck of the lathe and the tool-head to the lathe carriage. Much of the work done by a vertical mill could also be machined in a lathe, but the former is much more efficient for work within its range. To begin with, it is more convenient to clamp work to a horizontal table than to the vertical surface of a lathe faceplate, or, as someone has aptly said, "It is easier to lay a piece down than to hang it up." This is especially true of the heavy parts for which the boring mill is principally used. Very deep roughing cuts can also be taken with a vertical mill. The vertical mill is designed for turning and boring work which, generally speaking, is quite large in diameter in proportion to the width or height. The work varies greatly, especially in regard to its diameter, so that boring mills are built in a large range of sizes. The small and medium sizes will swing work varying from about 30 inches to 6 or 7 feet in diameter, whereas large machines, such as are used for turning very large flywheels, sheaves, etc., have a swing of 16 or 20 feet and larger sizes are used in some shops. The size of a vertical mill, like any other machine tool, should be somewhat in proportion to the size of the work for which it is intended, as a very large machine is unwieldy, and, therefore, inefficient for machining comparatively small parts.

Chucking and Setting Work on the Boring Mill Table

There are three general methods of holding work to the table of a boring mill; namely, by the use of chucks, by ordinary bolts and clamps, or in special fixtures. Chucks which are built into the table (as illustrated in Fig. 2) and have either universal or independent adjustments for the jaws, can be used to advantage for holding castings that are either round or irregular in shape. The universal adjustment is used for cylindrical parts, such as disks, flywheels, gear blanks, etc., and the independent adjustment, for castings of irregular shape. Chucks which have either an independent or universal movement for the jaws are known as a "combination" type and usually have three jaws. There is also a four-jaw type which has the independent adjustment only. This style is preferable for work that is not cylindrical and which must be held very securely. Chuck jaws that do not form a part of the machine table but are bolted to it in the required position, are also employed extensively, especially on comparatively large machines. Independent chuck jaws of this type are shown in Fig. 9.

Most of the work done in a vertical mill is held in a chuck. Occasionally, however, it is preferable to clamp a part directly to the table.

This may be desirable because of the shape and size of the work, or because it is necessary to hold a previously machined surface directly against the table in order to secure greater accuracy. Sometimes a casting is held in the chuck for turning one side, and then the finished side is clamped against the table for turning the opposite side. Parts which are to be machined in large quantities are often held in special fixtures. This method is employed when it enables the work to be set up more quickly than would be possible if regular clamps or chuck jaws were used.

Work that is to be turned or bored should first be set so that the part to be machined is about central with the table. For example, the rim of a flywheel should be set to run true so that it can be finished by removing about the same amount of metal around the entire rim; in other words, the rim should be set concentric with the table, as shown in Fig. 3, and the sides of the rim should also be parallel to the table. A simple tool that is very useful for testing the position of any cylindrical casting consists of a wooden shank into which is inserted a piece of wire, having one end bent. This tool is clamped in the toolpost and as the work revolves, the wire is adjusted close to the cylinderical surface being tested. The movement of the work with relation to the stationary wire point will, of course, show whether or not the part runs true. The advantage of using a piece of wire for testing, instead of a rigid tool, is that the wire, owing to its flexibility, will simply be bent backward if it is moved too close to a surface which is considerably out of true. The upper surface of a casting can be tested for parallelism with the table by using this same wire gage, or by comparing it with a tool held in the tool-post. An ordinary surface gage is also used for this purpose. The proper surface to set true, in any case, depends upon the requirements. A plain cylindrical disk would be set so that the outside ran true and the top surface was parallel with the table. When setting a flywheel, if the inside is to remain rough, the casting should be set by this surface rather than by the outside, so that the rim, when finished, will be uniform in thickness.

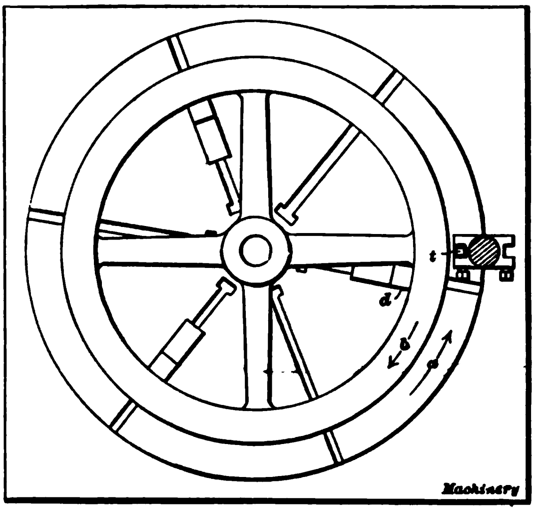

Fig. 3. Plan View showing Flywheel Casting Chucked for Turning

As far as possible, chucks should be used for holding cylindrical parts, owing to their convenience. The jaws should be set against an interior cylindrical surface whenever this is feasible. To illustrate, the flywheel in Fig. 3 is gripped by the inside of the rim which permits the outside to be turned at this setting of the work. The flywheel casting should also be set in the chuck so that a spoke rests against one of the jaws as at *d*. This jaw will then act as a driver and prevent the casting from slipping or turning in the chuck jaws, owing to the tangential pressure of the turning tool. When a cut is being taken, the table and work rotates as shown by arrow *a*, and the thrust of the cut (taken by tool *t*) tends to move the wheel backward against the direction of rotation as shown by arrow *b*. If one of the chuck jaws bears against one of the spokes, this movement is prevented. It is not always feasible to use a

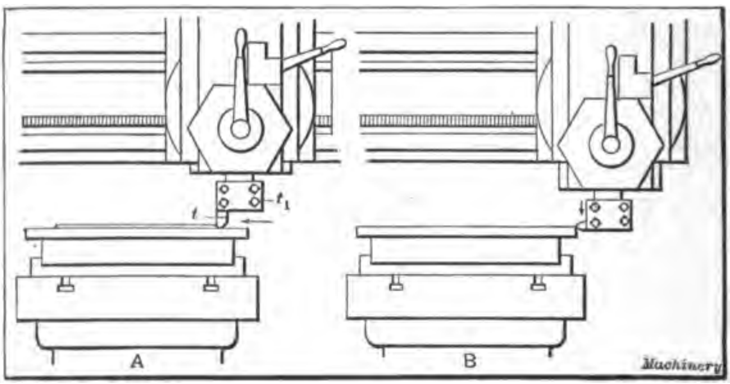

Fig. 4. (A) Turning a Flat Surface. (B) Turning a Cylindrical Surface

chuck jaw as a driver and then a special driver having the form of a small angle-plate, is sometimes bolted directly to the table. Another method of driving is to set a brace between a spoke or projection on the work and a chuck jaw or strip attached to the table. Drivers are not only used for flywheels, but in connection with any large casting, especially when heavy cuts have to be taken. Of course, some castings are so shaped that drivers cannot be employed.

Turning in a Boring Mill

The vertical type of boring mill is used more for turning cylindrical surfaces than for actual boring, although a large part of the work requires both turning and boring. We shall first consider, in a general way, how surfaces are turned and then refer to some boring operations. The diagram *A*, Fig. 4, illustrates how a horizontal surface would be turned. The tool *t* is clamped in tool-block t_1, in a vertical position, and it is fed horizontally as the table and work rotates. The tool is first adjusted by hand for the proper depth of cut and the automatic horizontal feed is then engaged. When a cylindrical surface is to be turned, the tool (provided a straight tool is used) is clamped in a horizontal position and is fed downward as indicated at *B*. The amount that the tool should feed per revolution of the work depends upon the kind of material being turned, the diameter of the turned part and the depth of the cut.

Most of the work machined in a vertical boring mill is made of cast iron and, ordinarily, at least one roughing and one finishing cut is taken. The number of roughing cuts required in any case depends, of

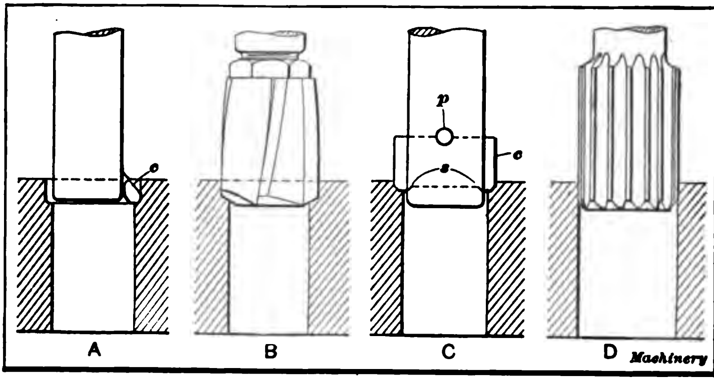

Fig. 5. Methods of Boring and Reaming Holes

course, upon the amount of metal to be removed. An ordinary roughing cut in soft cast iron might vary in depth from 1/8 to 3/8 inch and the tool would probably have a feed per revolution of from 1/16 to 1/8 inch, although deeper cuts and coarser feeds are sometimes taken. These figures are merely given to show, in a general way, what cuts and feeds are practicable. The tool used for roughing usually has a rounded end which leaves a ridged or rough surface. To obtain a smooth finish,

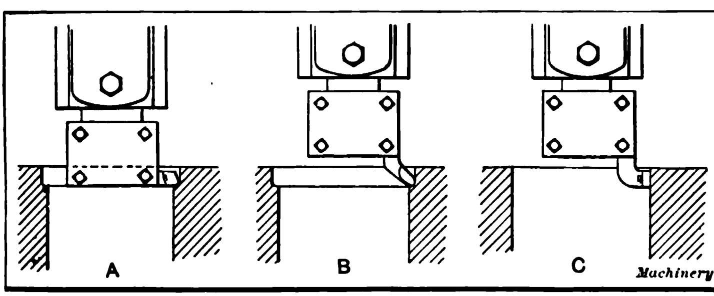

Fig. 6. Boring with Regular Turning Tools

broad flat tools are used. The flat cutting edge is set parallel to the tool's travel and a coarse feed is used in order to reduce the time required for taking the cut. The finishing feeds for cast iron vary from 1/4 to 3/4 inch on ordinary work. The different tools used on the vertical mill will be referred to more in detail later.

All medium and large sized vertical boring mills are equipped with two tool-heads and two tools are frequently used at the same time, especially on large work. Fig. 9 illustrates the use of two tools simultaneously. The casting shown is a flywheel, and the tool on the right side turns the upper side of the rim, while the tool on the left side turns the outside or periphery. As a boring mill table rotates in a counter-clockwise direction, the left-hand tool is reversed to bring the cutting edge at the rear. By turning two surfaces at once, the total time for machining the casting is, of course, greatly reduced. The turning of fly-

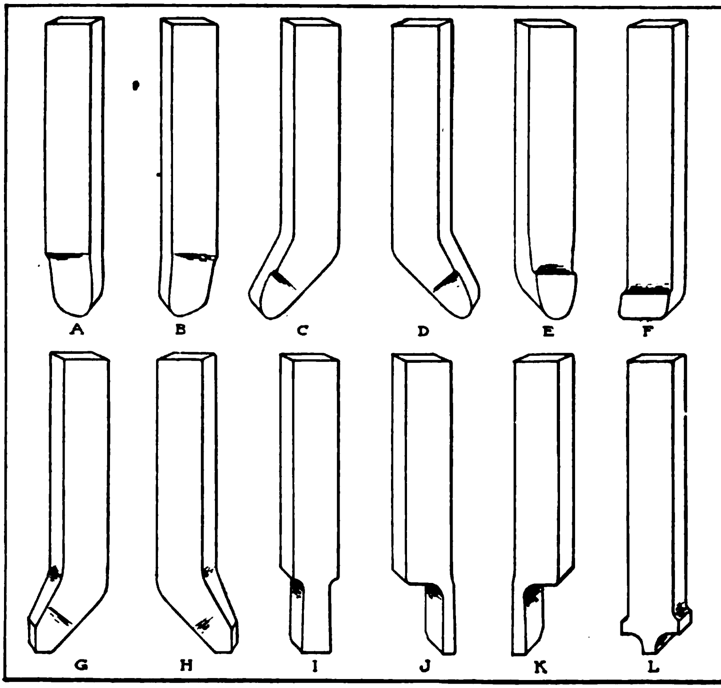

Fig. 7. Set of Boring Mill Tools

wheels is a very common vertical boring mill operation, and this work will be referred to in detail later on.

Boring Operations

There are several methods of machining holes in the vertical boring mill. Ordinarily, small holes are cored in castings and it is simply necessary to finish the rough surface to the required diameter. Some of the tools used for boring and finishing holes are shown in Fig. 5. Sketch *A* shows a boring tool consisting of a cutter *c* inserted in a shank, which, in turn, is held in the tool slide, or in a turret attached to the tool slide. With a tool of this type, a hole is bored by taking one or more cuts down through it. The tool shown at *B* is a four-lipped drill which is used for drilling cored holes preparatory to finishing by a cutter or reamer. This drill would probably finish a hole to within about 1/32 inch of the finish diameter, thus leaving a small amount of metal for the reamer to remove. The tool illustrated at *C* has a double-ended flat cutter *c*, which cuts on both sides. These cutters are often made in sets for boring duplicate parts. Ordinarily, there are two cutters in a set, one being used for roughing and the other for finishing. The cutter passes through a rectangular slot in the bar and this particular style is centrally located by shoulders *s*, and is held by a taper pin *p*. Some cutter bars have an extension end which passes through a close-fitting bushing in the table to steady the bar. Sketch *D* shows a finishing reamer. This tool takes a very light cut and is intended to finish holes that have been previously bored close to the required size.

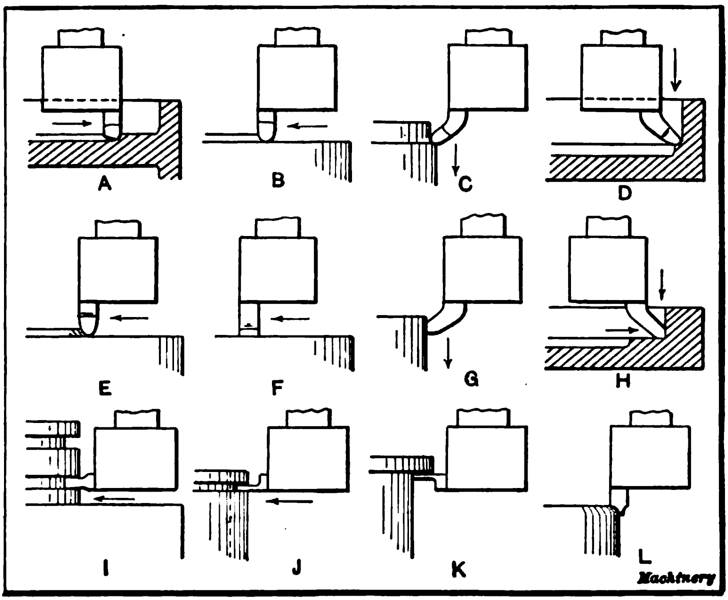

Fig. 8. Diagrams Illustrating Use of Different Forms of Tools

Sometimes a flat cutter *C* is used for roughing and a reamer for finishing. The reamer is especially desirable for interchangeable work, when all holes must have a smooth finish and be of the same size. When a reamer is held rigidly to a turret or tool-slide, it is liable to produce a hole that is either tapering or larger than the reamer diameter. To prevent this, the reamer should be held in a "floating" holder which, by means of a slight adjustment, allows the reamer to align itself with the hole. There are several methods of securing this "floating" movement.

Large holes or interior cylindrical surfaces are bored by tools held in the regular tool-head. The tool is sometimes clamped in a horizontal position as shown at *A*, Fig. 6, or a bent type is used as at *B*. Cast iron is usually finished by a broad flat tool as at *C*, the same as when turning exterior surfaces. Obviously a hole that is bored in this way must be large enough to admit the tool-block.

Turning Tools for the Vertical Boring Mill

A set of turning tools for the vertical boring mill is shown in Fig. 7. These tools can be used for a wide variety of ordinary turning operations. When a great many duplicate parts are to be machined, special tool equipment can often be used to advantage, but as the form of this equipment depends upon the character of the work, only standard tools have been illustrated herewith. The tool shown at *A* is a right-hand, "hog-nose" roughing tool, and a left-hand tool of the same type is shown at *B*. Tool *C* is an offset or bent, left-hand round nose for roughing, and *D* is a right-hand offset tool. A straight round nose is shown at *E*. Tool *F* has a flat, broad cutting edge and is used for finishing. Left- and right-hand

Fig. 8. Turning the Rim of a Flywheel

finishing tools of the offset type are shown at *G* and *H*, respectively. [illegible] Right- and [illegible] is a form fre- [illegible]

[illegible] how each of the tools [illegible] are marked by the [illegible] The right- and [illegible] for taking deep [illegible] to the [illegible] tool is [illegible] turning plain [illegible] feeds toward [illegible] feed in [illegible] be used [illegible] position [illegible] would then [illegible] round-nose tools *C* and *D* are for turning exterior or interior cylinder surfaces. As this form of tool extends below the tool-block, it can be fed down close to a shoulder. The straight type shown at *E* is adapted for steel or iron, and when the point is drawn out narrower, it is also used for brass, although the front is then ground without slope. Tool *F* is for light finishing cuts and broad feeds. The amount of feed per revolution of the work should always be less than the width of the cutting edge. The offset tools *G* and *H* are for finishing exterior and interior cylindrical surfaces. These tools also have horizontal cutting edges and are sometimes used for first finishing a cylindrical and then a horizontal surface, or *vice versa*. Tool *I* is adapted to such work as cutting packing-ring grooves in engine pistons, forming square or rectangular grooves, and

Fig. 10. Tool B set for Boring the Hub

similar work. The parting tools *J* and *K* can also be used for forming narrow grooves or for cutting off rings, etc. The sketch *K* (Fig. 8) indicates how the left-hand tool might be used for squaring a corner under a shoulder. Tool *L* is frequently used on boring mills for rounding the corners of flywheel rims, in order to give them a more finished appearance. It has two cutting edges so that either side can be used.

The turning tools of a vertical boring mill are similar, in many respects, to those used on a lathe, although the shanks of the former are shorter and more stocky than those of lathe tools. The cutting edges of some of the tools also differ somewhat, but the principles which govern the grinding of lathe and boring mill tools are identical, and those who are not familiar with tool grinding are referred to MACHINERY'S Reference Book No. 92 on lathe work, in which this subject is treated.

Turning a Flywheel on a Vertical Mill

The turning of a flywheel is a good example of the kind of work for which a vertical boring mill is adapted. A flywheel should preferably

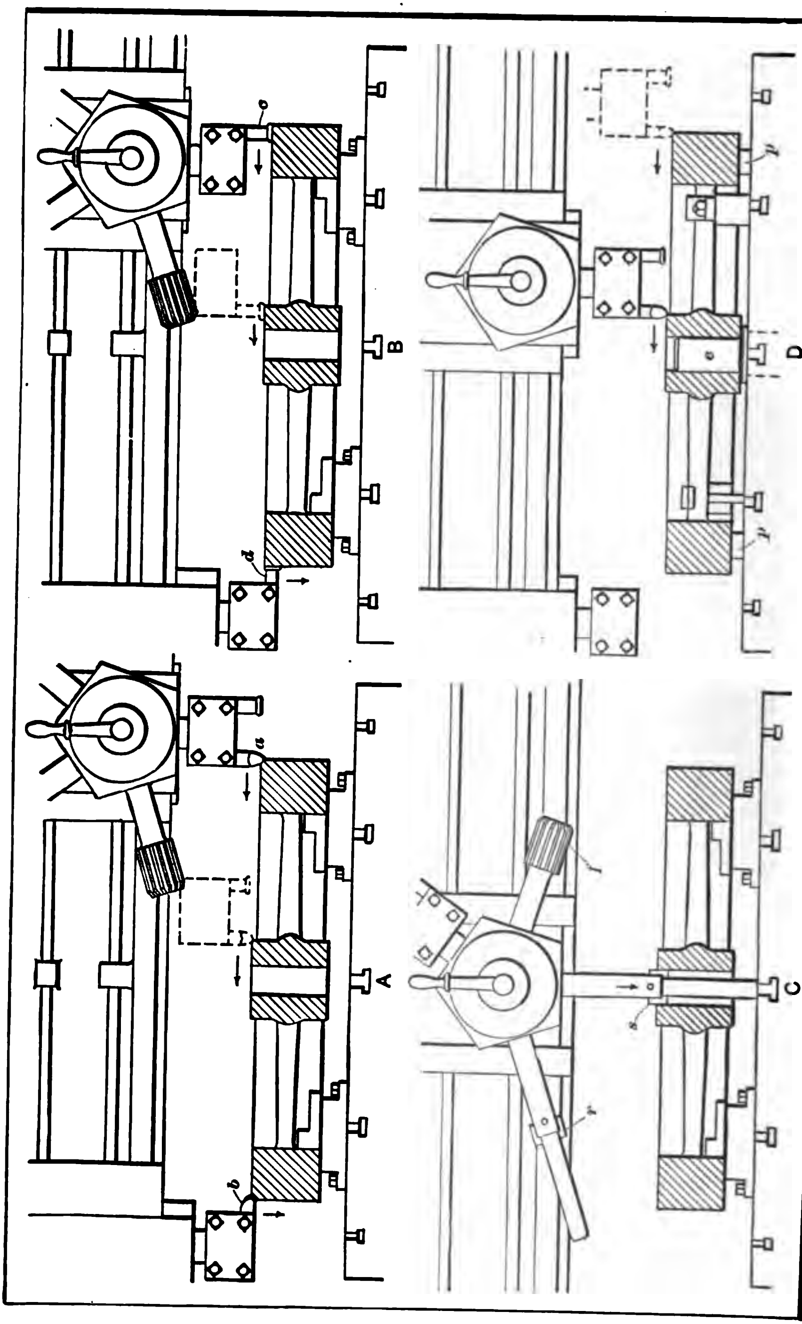

Fig. 11. Diagrams showing Method of Turning and Boring a Flywheel on a Double-head Mill having One Turret Head

be machined on a double-head mill so that one side and the periphery of the rim can be turned at the same time. A common method of holding a flywheel is shown in Fig. 9. The rim is gripped by four chuck jaws *D* which, if practicable, should be on the inside where they will not interfere with the movement of the tool. Two of the jaws, in this case, are set against the spokes on opposite sides of the wheel, to act as drivers and prevent any backward shifting of work when a heavy cut is being taken. The illustration shows the tool to the right rough turning the side of the rim, while the left-hand tool turns the periphery. Finishing cuts are also taken over the rim, at this setting, and the hub is turned on the outside, faced on top, and the hole bored. The three tools *A*, *B*

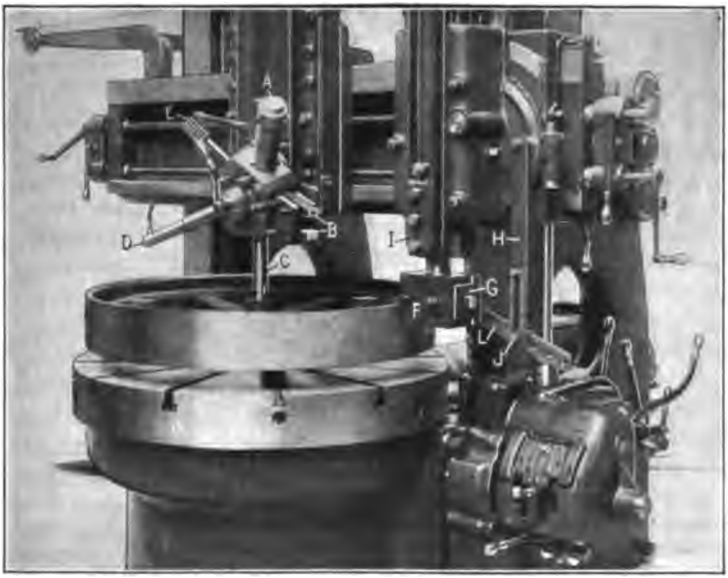

Fig. 12. Gisholt Mill equipped with Convex Turning Attachment

and *C*, for finishing the hole, are mounted in the turret. Bar *A*, which carries a cutter at its end, first rough bores the hole. The sizing cutter *B* is then used to straighten it before inserting the finishing reamer *C*. Fig. 10 shows the turret moved over to a central position and the sizing cutter *B* set for boring. The head is centrally located (on this particular machine) by a positive center-stop. The turret is indexed for bringing the different tools into the working position, by loosening the clamping lever *L* and pulling down lever *I* which disengages the turret lock-pin. When all the flywheels in a lot have been machined as described, the opposite side is finished.

In order to show more clearly the method of handling work of this class, the machining of a flywheel will be explained more in detail in connection with Fig. 11, which illustrates practically the same equipment as is shown in Figs. 9 and 10. The successive order in which the various operations are performed is as follows: Tool *a* (see sketch *A*) rough turns the side of the rim, while tool *b*, which is set with its cutting edge toward the rear, rough turns the outside. The direction in which each tool moves is indicated by the arrows. When tool *a* has crossed the rim, it is moved over for facing the hub, as shown by the dotted lines. The side and periphery of the rim is next finished by the broad-nose finishing tools *c* and *d* (see sketch *B*). The feed should be increased for finishing, so that each tool will have a movement of say 1/4 or 3/8 inch per revolution of the work, and the cuts should be deep enough to remove the marks made by the roughing tools. Tool *c* is also used for finishing the hub as indicated by the dotted lines. After these cuts are taken, the outside of the hub and inner surface of rim are

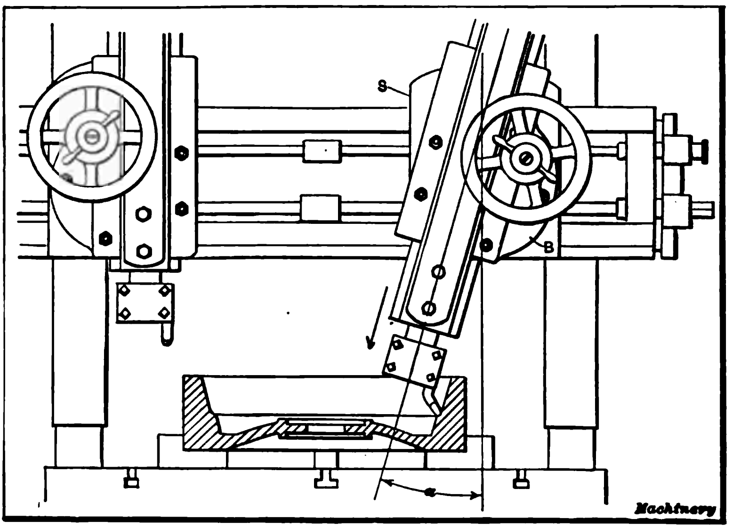

Fig. 18. Turning a Taper or Conical Surface

usually turned down as far as the spokes, by using offset tools similar to the ones shown at *C* and *D* in Fig. 7. The corners of the rim and hub are also rounded to give the work a more finished appearance, by using a tool *L*.

The next operation is that of finishing the hole through the hub. The hard scale is first removed by a roughing cutter *r* (sketch *C*), which is followed by a "sizing" cutter *s*. The hole is then finished smooth and to the right diameter by reamer *f*. The bars carrying cutters *r* and *s* have extensions or "pilots" which enter a close-fitting bushing in the table, in order to steady the bar and hold it in alignment.

When the hole is finished, the wheel is turned over, so that the lower side of the rim and hub can be faced. The method of holding the work for the final operation is shown at *D*. The chuck jaws are removed, and the finished side of the rim is clamped against parallels *p* resting on the table. The wheel is centrally located for turning this side by a plug *c* which is inserted in a hole in the table and fits the bore of the hub.

The work is held by clamps which bear against the spokes. Roughing and finishing cuts are next taken over the rim and hub and the corners are rounded, which completes the machining operations. If the rim needs to be a certain width, about the same amount of metal should be removed from each side, unless sandy spots or "blow-holes" in the casting make it necessary to take more from one side than the other. That side of the rim which was up when the casting was made, should be

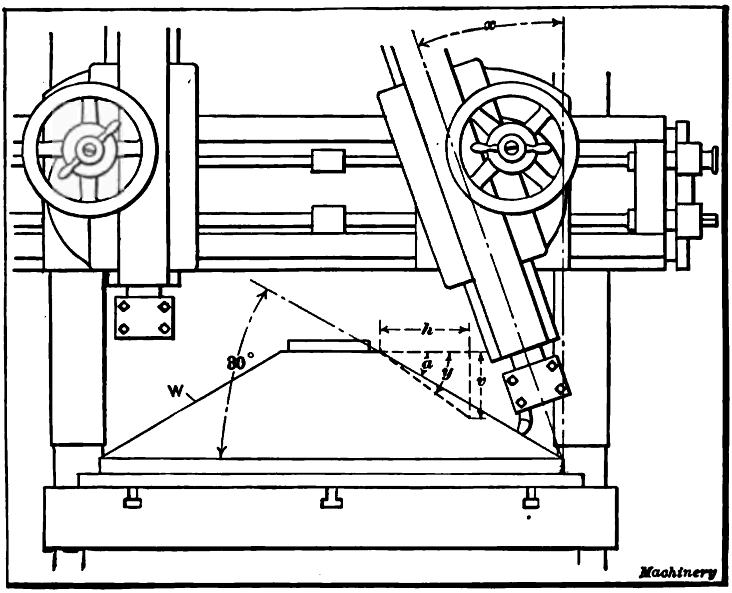

Fig. 14. Turning a Conical Surface by using the Combined Vertical and Horizontal Feeds

turned first, because the porous, spongy spots usually form on the "cope" or top side of a casting.

Convex Turning Attachment for Boring Mills

Fig. 12 shows a vertical boring mill arranged for turning pulleys having convex rims; that is, the rim, instead of being cylindrical, is rounded somewhat so that it slopes from the center toward either side. The reason for turning a pulley rim convex is to prevent the belt from running off at one side, as it sometimes tends to do when a cylindrical pulley is used. The convex surface is produced by a special attachment which causes the turning tool to gradually move outward as it feeds down, until the center of the rim is reached, after which the movement is inward.

This attachment consists of a special box-shaped tool-head *F* containing a sliding holder *G*, in which the tool is clamped by set-screws passing through elongated slots in the front of the tool-head. In addition, there is a radius link *L* which swivels on a stud at the rear of the tool-head and is attached to vertical link *H*. Link *L* is so connected to the sliding tool-block that any downward movement of the tool-bar *I* causes the tool to move outward until the link is in a horizontal position, after which the movement is reversed. When the attachment is first set up, the turning tool is placed at the center of the rim and then link *L* is clamped to the vertical link while in a horizontal position. The cut is started at the top edge of the rim, and the tool is fed downward by power, the same as when turning a cylindrical surface. The amount of curvature or convexity of a rim can be varied by inserting the clamp bolt *J* in different holes in link *L*.

The tools for machining the hub and sides of the rim are held in a turret mounted on the left-hand head, as shown. The special tool-holder *A* contains two bent tools for turning the upper and lower edges of the pulley rim at the same time. Roughing and finishing tools *B* are for

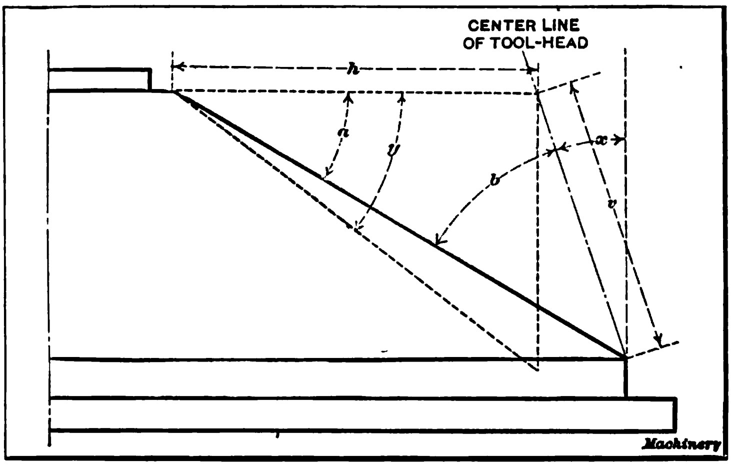

Fig. 15. Diagram showing Method of Obtaining Angular Position of Tool-head when Turning Conical Surfaces by using Vertical and Horizontal Feeding Movements

facing the hub, and the tools *C*, *D*, and *E* rough bore and finish the hole for the shaft.

Turning Taper or Conical Surfaces

Conical or taper surfaces are turned in a vertical boring mill by swiveling the tool-bar to the proper angle, as shown in Fig. 13. When the taper is given in degrees, the tool-bar can be set by graduations on the edge of the circular base *E*, which show the angle *a* to which the bar is swiveled from a vertical position. The base turns on a central stud and is secured to the saddle *S* by the bolts shown, which should be tightened after the tool-bar is set. The vertical power feed can be used for taper turning the same as for cylindrical work.

Occasionally it is necessary to machine a conical surface which has such a large included angle that the tool-bar cannot be swiveled far enough around to permit turning by the method illustrated in Fig. 13. Another method, which is sometimes resorted to for work of this class, is to use the combined vertical and horizontal feeds. Suppose we want to turn the conical casting W (Fig. 14), to an angle of 30 degrees, as shown, and that the tool-head of the boring mill moves horizontally 1/4 inch per turn of the screw and has a vertical movement of 3/16 inch per turn of the upper feed-shaft. If the two feeds are used simultaneously, the tool will move a distance h of say 8 inches, while it moves downward a distance v of 6 inches, thus turning the surface to an angle y. This angle is greater (as measured from a horizontal plane) than the angle required, but, if the tool-bar is swiveled to an angle x, the tool, as it moves downward, will also be advanced horizontally, in addition to the regular horizontal movement. The result is that angle y is diminished, and if the tool-bar is set over the right amount, the conical surface can be turned to an angle a of 30 degrees. The problem, then, is to determine what the angle x should be for turning to a given angle a. The way angle x is calculated will be explained in connection with the enlarged diagram, Fig. 15, which shows one-half of the casting.

The siné of the known angle a is first found in a table of natural sines. Then the sine of angle b is determined as follows: $\sin b = \dfrac{\sin a \times h}{v}$, in which h represents the rate of horizontal feed and v the rate of vertical feed. The angle corresponding to sine b is next found in the table of sines. We now have angles b and a, and by subtracting these angles from 90 degrees, the desired angle x is obtained. To illustrate:

The sine of 30 degrees is 0.5; then $\sin b = \dfrac{0.5 \times 1/4}{3/16} = 0.6666$; hence angle $b = 41$ degrees 49 minutes, and $x = 90° - (30° + 41° 49') = 18$ degrees 11 minutes.

If angle a were greater than angle y obtained from the combined feeds with the tool-bar in a vertical position, it would then be necessary to swing the lower end of the bar to the left rather than to the right of a vertical plane.

CHAPTER III

TURRET-LATHE TYPE OF VERTICAL BORING MILL

The machine illustrated in Fig. 16 was designed to combine the advantages of the horizontal turret lathe and the vertical boring mill. It is known as a "vertical turret lathe," but resembles, in many respects, a vertical boring mill. This machine has a turret on the cross-rail the same as the vertical boring mill, and, in addition, a side-head *S*. The side-head has a vertical feeding movement, and the tool-bar *T* can be fed horizontally. The tool-bar is also equipped with a four-sided turret for holding turning tools. This arrangement of the tool-heads makes it possible to use two tools simultaneously upon comparatively small work. When both heads are mounted on the cross rail, as with a double-head boring mill, it is often impossible to machine certain parts to advantage, because one head interferes with the other.

The drive to the table is from a belt pulley at the rear, and fifteen speed changes are available. Five changes are obtained by turning the pilot-wheel *A* and this series of five speeds is compounded three times by turning lever *B*. Each spoke of pilot-wheel *A* indicates a speed which is engaged only when the spoke is in a vertical position, and the three positions for *B* are indicated by slots in the disk shown. The number of table revolutions per minute for different positions of pilot-wheel *A* and lever *B*, are shown by figures seen through whichever slot is at *C*. There are five rows of figures corresponding to the five spokes of the pilot-wheel and three figures in a row, and the speed is shown by arrows on the sides of the slots. The segment disk containing these figures also serves as an interlocking device which prevents moving more than one speed controlling lever at a time, in order to avoid damaging the driving mechanism.

The feeding movement for each head is independent. Lever *D* controls the engagement or disengagement of the vertical or cross feeds for the head on the cross-rail. The feed for the side-head is controlled by lever *E*. When this lever is pushed inward, the entire head feeds vertically, but when it is pulled out, the tool-bar feeds horizontally. These two feeds can be disengaged by placing the lever in a neutral position. The direction of the feeding movement for either head can be reversed by lever *R*. The amount of feed is varied by feed-wheel *F* and clutch-rod *G*. When lever *E* is in the neutral position, the side-head or tool-bar can be adjusted by the hand-cranks *H* and *I*, respectively. The cross-rail head and its turret slide have rapid power traverse movements for making quick adjustments. This rapid traverse is controlled by the key-handles *J*. The feed screws for the vertical head have micrometer dials *K* for making accurate adjustments. There are also large dials at *L* which indicate vertical movements of the side head and horizontal movements of the tool slide. All of these dials have small adjustable clips *c* which are numbered to correspond to numbers on the faces of the respective turrets. These clips or "observation stops" are used in the production of duplicate parts. For example: suppose a tool in face No. 1 for the main turret is set for a given diameter and height of shoulder on a part which is to be duplicated. To obtain the same setting of the tools for the next piece, clips No. 1, on both the vertical feed rod and screw dials,

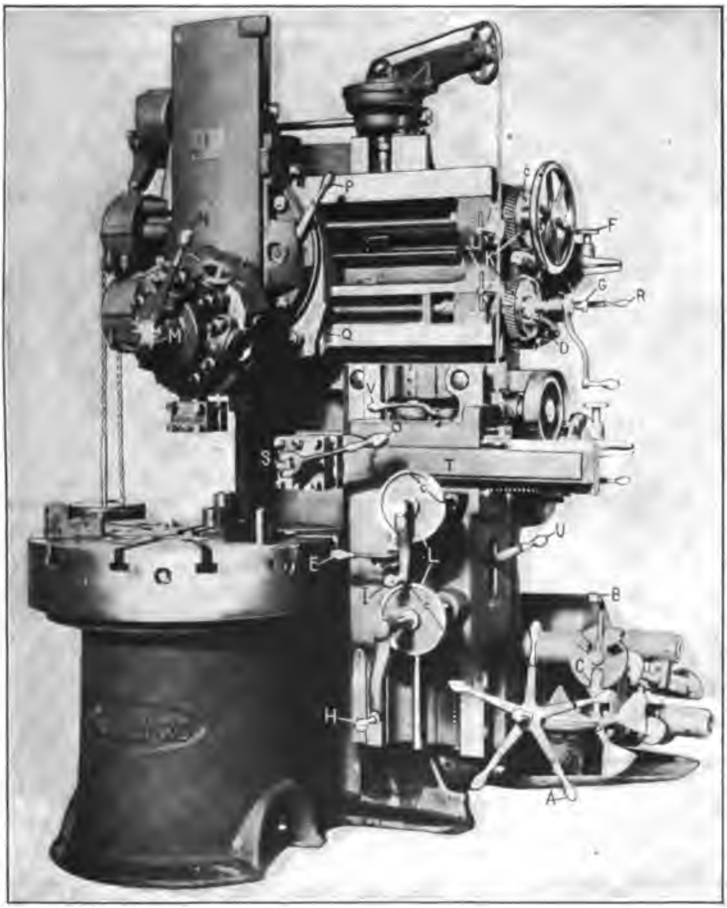

Fig. 16. Bullard Vertical Turret Lathe

are placed opposite the graduations which are intersected by stationary pointers secured to the cross-rail. The clips are set in this way after the first part has been machined to the required size and before disturbing the final position of the tools. For turning a duplicate part, the tools are simply brought to the same position by turning the feed screws until the clips and stationary pointers again coincide. For setting tools on other faces of either turret, this operation is repeated, except that clips are used bearing numbers corresponding to the turret face in use.

The main turret of this machine has five holes in which are inserted the necessary boring and turning tools, drills or reamers, as may be required. By having all the tools mounted in the turret, they can be quickly and accurately moved into working position. When the turret is indexed from one face to the next, binder lever *N* is first loosened. The turret then moves forward away from its seat, thus disengaging the indexing and registering pins which accurately locate it in any one of the five positions. The turret is revolved by turning crank *M*, one turn of this handle moving the turret 1/5 revolution or from one hole to the next. The side-head turret is turned by loosening lever *O*. The turret slide can be locked rigidly in any position by lever *P* and its sad-

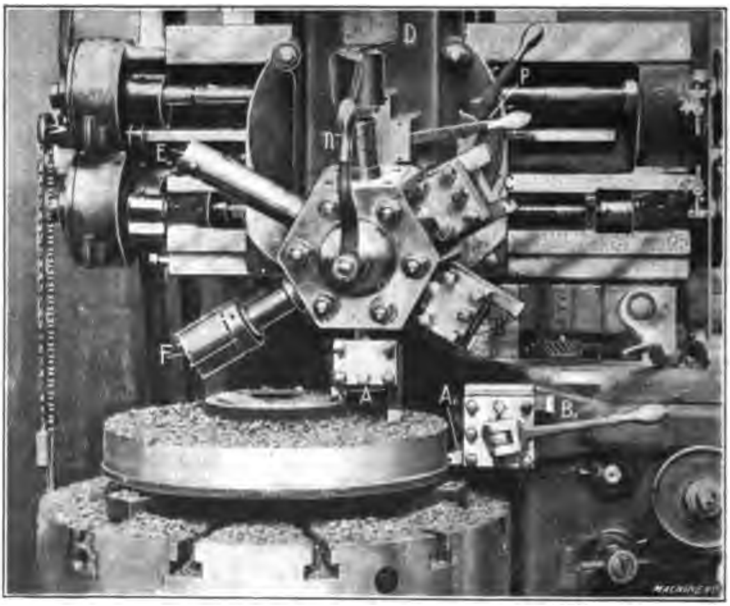

Fig. 17. Turning a Gear Blank on a Vertical Turret Lathe

dle is clamped to the cross-rail by lever *Q*. The binder levers for the saddle and tool-slide of the side-head are located at *U* and *V* respectively. A slide that does not require feeding movements is locked in order to obtain greater rigidity.

The vertical slide can be set at an angle for taper turning, and the turret is accurately located over the center of the table for boring or reaming, by a positive center stop. The machine is provided with a brake for stopping the work table quickly, which is operated by lifting the shaft of pilot-wheel *A*. The side- and cross-rails are a unit and are adjusted together to accommodate work of different heights. This adjustment is effected by power on the particular machine illustrated, and it is controlled by a lever near the left end of the cross-rail. Before making this adjustment, all binder bolts which normally hold the rails rigidly to the machine column, must be released, and care should be taken to tighten them after the adjustment is made.

Examples of Vertical Turret Lathe Work

In order to illustrate how a vertical turret lathe is used, one or two examples of work will be referred to in detail. These examples also indicate, in a general way, the class of work for which this type of machine is adapted. Fig. 17 shows how a cast-iron gear blank is machined. The work is gripped on the inside of the rim by three chuck jaws, and all of the tools required for the various operations are mounted in the main and side turrets. The illustration shows the first operation which is that of rough turning the hub, the side of the blank and its

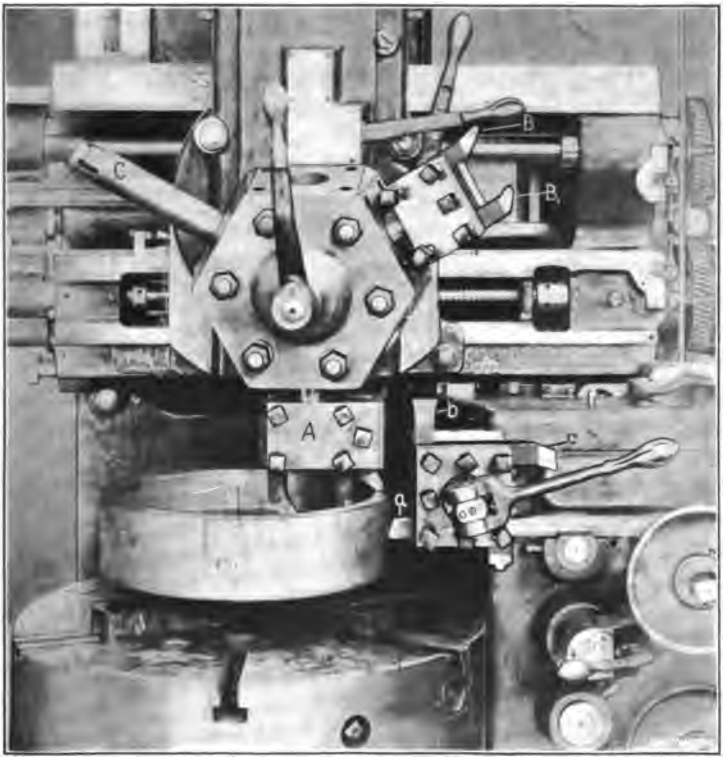

Fig. 18. Turning Gasoline Engine Flywheel on Vertical Turret Lathe—First Position

periphery. The tools *A* for the hub and side are both held in one tool-block on the main turret, and tool A_1 for roughing the periphery is in the side turret. With this arrangement, the three surfaces can be turned simultaneously. The main turret is next indexed one-sixth of a revolution which brings the broad finishing tools *B* into position, and the side turret is also turned to locate finishing tool B_1 at the front. (The indexing of the main turret on this particular machine is effected by loosening binder lever *n* and raising the turret lock-pin by means of lever *p*.) The hub, side and periphery of the blank are then finished. When tools *B* are clamped in the tool-blocks, they are, of course, set for turning the hub to the required height. The third operation is performed by the tools at *C*, one of which "breaks" or chamfers the corner of the cored hole to provide a starting surface for drill *D*, and the other turns the outside of the hub, after the chamfer tool is removed. The four-lipped shell-drill *D* is next used to drill the cored hole and then this hole is bored close to the finished size and concentric with the circumference of the blank by boring tool *E*, which is followed by the finishing reamer *F*. When the drill, boring tool and reamer are being used, the turret is set

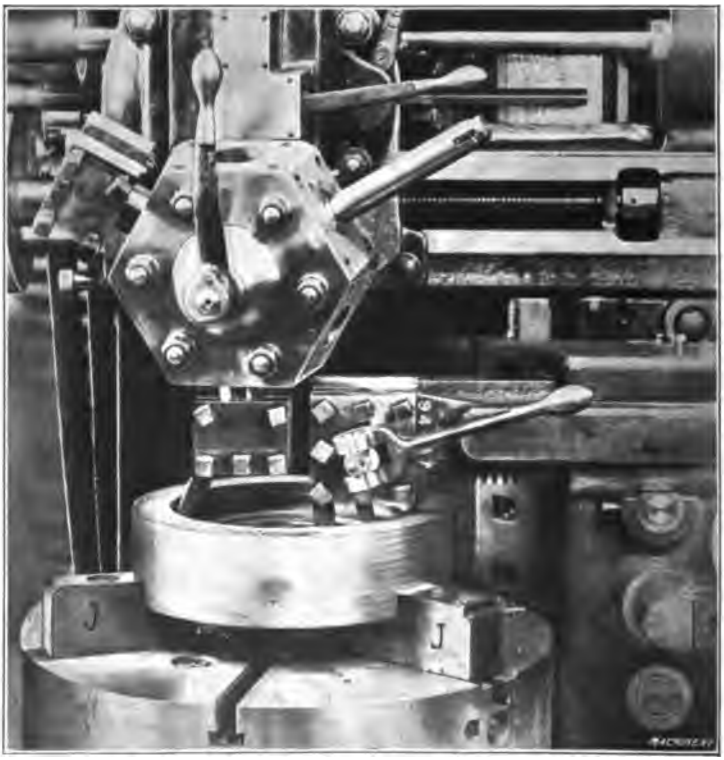

Fig. 19. Turning Gasoline Engine Flywheel—Second Position

over the center or axis of the table by means of a positive center stop on the left-side of the turret saddle. If it is necessary to move the turret beyond the central position, this stop can be swung out of the way.

Figs. 18 and 19 illustrate the machining of an automobile flywheel, which is another typical example of work for a machine of this type. The flywheel is finished in two settings. Its position for the first series of operations is shown in Fig. 18, and the successive order of the four operations for the first setting is shown by the diagrams, Fig. 20. The first operation requires four tools which act simultaneously. The three held in tool-block *A* of the turret, face the hub, the web and the rim of the flywheel, while tool *a* in the side-head rough turns the outside diameter. The outside diameter is also finished by broad-nosed tool *b* which is given a coarse feed. In the second operation, the under face of the rim is finished by tool *c*, the outer corners are rounded by tool *d* and the inner surface of the rim is rough turned by a bent tool *B*, which is moved into position by indexing the main turret. In the third operation, the side-head is moved out of the way and the inside of the rim is finished by another bent tool B_1. The final operation at this setting is the boring of the central hole, which is done with a bar *C* having in-

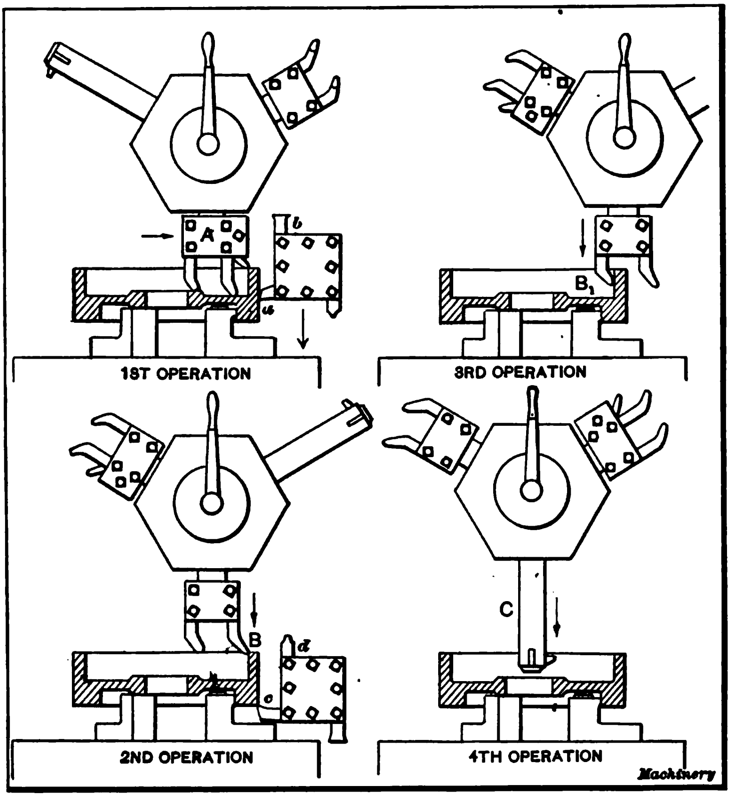

Fig. 20. Diagrams showing How Successive Operations are Performed by Different Tools in the Turret

terchangeable cutters which make it possible to finish the hole at one setting of the turret.

The remaining operations are performed on the opposite side of the work which is held in "soft" jaws *J* accurately bored to fit the finished outside diameter as indicated in Fig. 19. The tool in the main turret turns the inside of the rim and the side-head is equipped with two tools for facing the web and hub simultaneously. As the tool in the main turret operates on the left side of the rim, it is set with the cutting edge toward the rear. In order to move the turret to this position, which is beyond the center of the table, the center stop previously referred to is swung out of the way.

CHAPTER IV

HORIZONTAL BORING, DRILLING AND MILLING MACHINE

A boring machine of the horizontal type is shown in Fig. 21. The construction and operation of this machine is very different from that of a vertical boring mill and it is also used for a different class of work. The horizontal machine is employed principally for boring, drilling or milling, whereas the vertical design is especially adapted to turning and boring. The horizontal type is also used for turning or facing flanges or similar surfaces when such an operation can be performed to advantage in connection with other machine work on the same part.

The type of machine illustrated in Fig. 21 has a heavy base or bed to which is bolted the column *C* having vertical ways on which the spindle-head *H* is mounted. This head contains a sleeve or quill in which the spindle *S* slides longitudinally. The spindle carries cutters for boring, whereas milling cutters or the auxiliary facing arm, are bolted to the end *A* of the spindle sleeve. The work itself is attached either directly or indirectly to platen *P*. When the machine is in operation, the cutter or tool revolves with the spindle sleeve or spindle and either the cutter or the part being machined is given a feeding movement, depending on the character of the work. The spindle can be moved in or out by hand for adjustment, or by power for feeding the cutter as when boring or drilling. The entire spindle-head *H* can also be moved vertically on the face of the column *C*, by hand, for setting the spindle to the proper height, or by power for feeding a milling cutter in a vertical direction. When the vertical position of the spindle-head is changed, the back-rest block *B* also moves up or down a corresponding amount, the two parts being connected by shafts and gearing. Block *B* steadies the outer end of the boring-bar and the back-rest in which this block is mounted, can be shifted along the bed to suit the length of the work, by turning the squared end of shaft *D* with a crank. The platen *P* has a cross-feed, and the saddle *E* on which it is mounted can be traversed lengthwise on the bed; both of these movements can also be effected by hand or power. There is a series of power feeding movements for the cutters and, in addition, rapid power movements *in a reverse direction from the feed* for returning a cutter quickly to its starting position, when this is desirable.

This machine is driven by a belt connecting pulley *G* with an overhead shaft. When the machine is in operation, this pulley is engaged with the main driving shaft by a friction clutch *F* controlled by lever *L*. This main shaft drives through gearing a vertical shaft *I*, which by means of other gears in the spindle head imparts a rotary movement to the spindle. As a machine of this type is used for boring holes of various diameters and for a variety of other work, it is necessary to

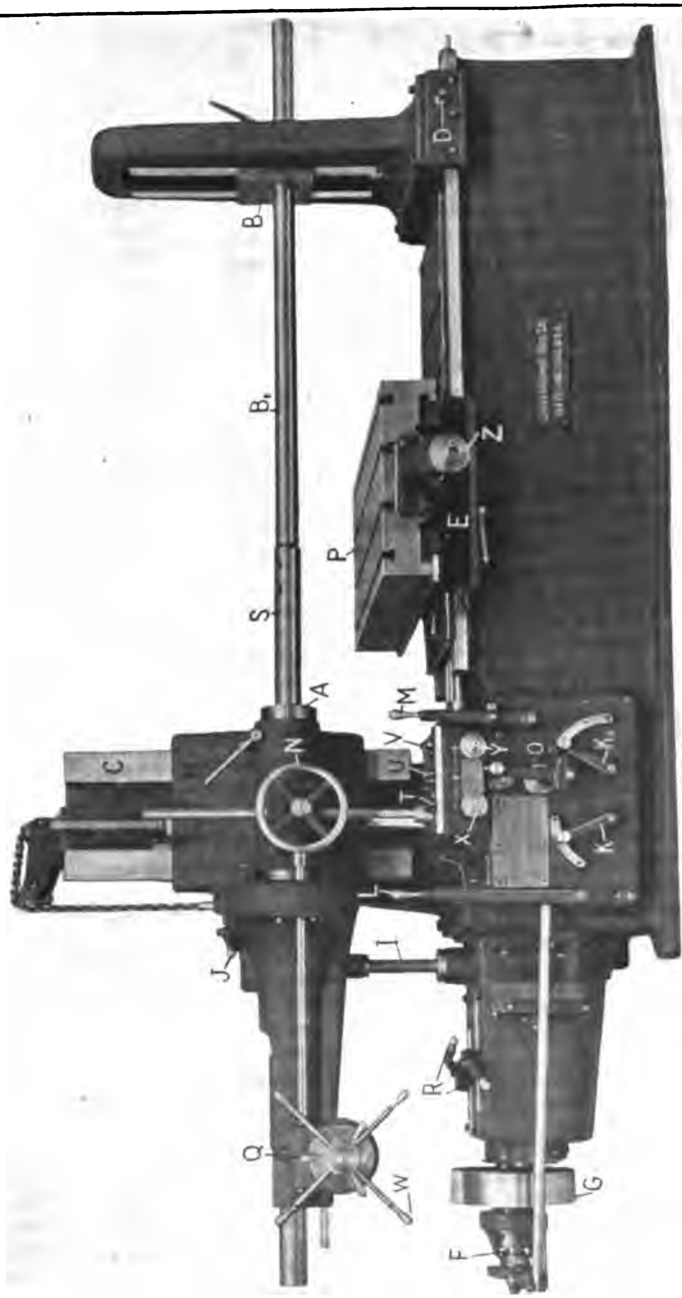

Fig. 21. Lucas Horizontal Boring, Drilling and Milling Machine

have a number of speed changes for the spindle. Nine speeds are obtained by changing the position of the sliding gears controlled by levers *R* and this number is doubled by back-gears in the spindle-head and controlled by lever *J*.

The amount of feed for the spindle, spindle-head, platen or saddle is varied by two levers *K* and K_1 which control the position of sliding gears through which the feeding movements are transmitted. The direction of the feed can be reversed by shifting lever *O*. With this particular machine, nine feed changes are available for each position of the spindle back-gears, making a total of eighteen changes which range from 0.004 to 0.006 inch per revolution of the spindle. The feeding movement is transmitted to the spindle-head, spindle, platen or saddle, as required, by the three distributing levers *T*, *U* and *V*, which control clutches connecting with the transmission shafts or feed screws. When lever *T* is turned to the left, the longitudinal power feed for the spindle is engaged, whereas turning it to the right throws in the vertical feed for the spindle-head. Lever *U* engages the cross-feed for platen *P* and lever *V*, the longitudinal feed for saddle *E*. These levers have a simple but ingenious interlocking device which makes it impossible to engage more than one feed at a time. For example, if lever *T* is set for feeding the spindle, levers *U* and *V* are locked against movement.

The feeds are started and stopped by lever *M* which also engages the rapid power traverse when thrown in the opposite direction. This rapid traverse operates for whatever feed is engaged by the distributing levers and, as before stated, in a reverse direction. For example, if the reverse lever *O* is set for feeding the spindle to the right, the rapid traverse would be to the left, and *vice versa*. The cross-feed for the platen can be automatically tripped at any point by setting an adjustable stop in the proper position and the feed can also be tripped by a hand lever at the side of the platen.

All the different feeding movements can be effected by hand as well as by power. By means of handwheel *N*, the spindle can be moved in or out slowly, for feeding a cutter by hand. When the friction clamp *Q* is loosened, the turnstile *W* can be used for traversing the spindle, in case a hand adjustment is desirable. The spindle-head can be adjusted vertically by turning squared shaft *X* with a crank, and the saddle can be shifted along the bed by turning shaft *Y*. The hand adjustment of the platen is effected by shaft *Z*. The spindle-head, platen and saddle can also be adjusted from the end of the machine, when this is more convenient. Shafts *X*, *Y* and *Z* are equipped with micrometer dials which are graduated to show movements of one-thousandth inch. These dials are used for accurately adjusting the spindle or work and for boring holes or milling surfaces that must be an exact distance apart.

Horizontal Boring Machine with Vertical Table Adjustment

Another design of horizontal boring machine is illustrated in Fig. 22. This machine is of the same type as that shown in Fig. 21, but its construction is quite different, as will be seen. The spindle cannot be adjusted vertically as with the first design described, but it is mounted

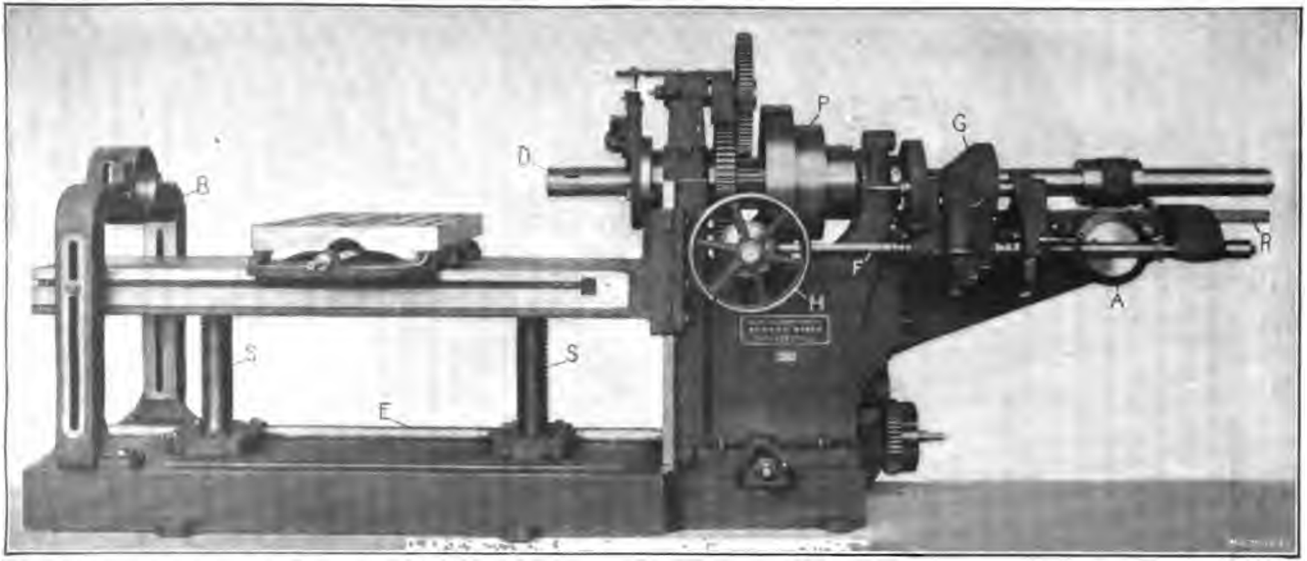

Fig. 22. Bement Horizontal Boring and Drilling Machine

and driven very much like the spindle of a lathe, and adjustment for height is obtained by raising or lowering the work table. The design is just the reverse, in this respect, of the machine shown in Fig. 21, which has a vertical adjustment for the spindle, and a work table that remains in the same horizontal plane. The raising or lowering of the table is effected by shaft *E*, which rotates large nuts engaging the screws *S*. Shaft *E* is turned either by hand or power.

The main spindle is driven by a cone pulley *P*, either directly, or indirectly through the back-gears shown. This arrangement gives six spindle speeds, and double this number is obtained by using a two-speed countershaft overhead. The motion for feeding the spindle longitudinally is transmitted to shaft *F*, which rotates bevel gear *A* and a pinion meshing with rack *R* which traverses the spindle. The large handwheel *H* and a corresponding wheel on the opposite side are used for adjusting the spindle rapidly by hand. The nest of gears at *G* gives the required feed changes by engaging different combinations. The yoke or outboard bearing *B* for the boring-bars can be clamped in any position along the bed for supporting the bar as close to the work as possible.

Horizontal boring machines are built in many other designs, but they all have the same general arrangement as the machines illustrated and operate on the same principle, with the exception of special types intended for handling certain classes of work exclusively. In the next chapter some examples of work done on these machines will be illustrated and described.

CHAPTER V

TOOLS FOR BORING—EXAMPLES OF HORIZONTAL BORING MACHINE WORK

The horizontal boring, drilling and milling machine is very efficient for certain classes of work because it enables all the machining operations on some parts to be completed at one setting. To illustrate, a casting which requires drilling, boring and milling at different places, can often be finished without disturbing its position on the platen after it is clamped in place. Frequently a comparatively small surface needs to be milled after a part has been bored. If this milling operation can be performed while the work is set up for boring, accurate results will be obtained (provided the machine is in good condition) and the time saved that would otherwise be required for re-setting the part on another machine. Some examples of work on which different operations are performed at the same setting will be referred to later. The horizontal boring machine also makes it possible to machine duplicate parts without the use of jigs, which is important, especially on large work, owing to the cost of jigs.

Drilling and Boring—Cutters Used for Boring

Holes are drilled in a horizontal machine by simply inserting a drill of required size either directly in the spindle (*S*, Fig. 21, and *D*, Fig. 22) or in a reducing socket, and then feeding the spindle outward either by hand or power. When a hole is to be bored, a boring-bar B_1 (Fig. 21) is inserted in the spindle and the cutter is attached to this bar. The latter is then fed through the hole as the cutter revolves. The distinction made by machinists between drilling and boring is as follows: A hole is said to be drilled when it is formed by sinking a drill into solid metal, whereas boring means the enlargement of a drilled or cored hole.

There are various methods of attaching cutters to boring-bars and the cutters used vary for different classes of work. A simple style of cutter which is used widely for boring small holes is shown at *A* in Fig. 23. The cutter *c* is made from flat stock and the cutting is done by the front edges *e* and e_1, which are beveled in opposite directions. The cutter is held in the bar by a taper wedge *w* and it is centered by shoulders at *s*. The outer corners at the front should be slightly rounded, as a sharp corner would be dulled quickly. These cutters are made in different sizes and also in sets for roughing and finishing. The roughing cutter bores holes to within about 1/32 inch of the finish size and it is then replaced by the finishing cutter. A cutter having rounded ends as

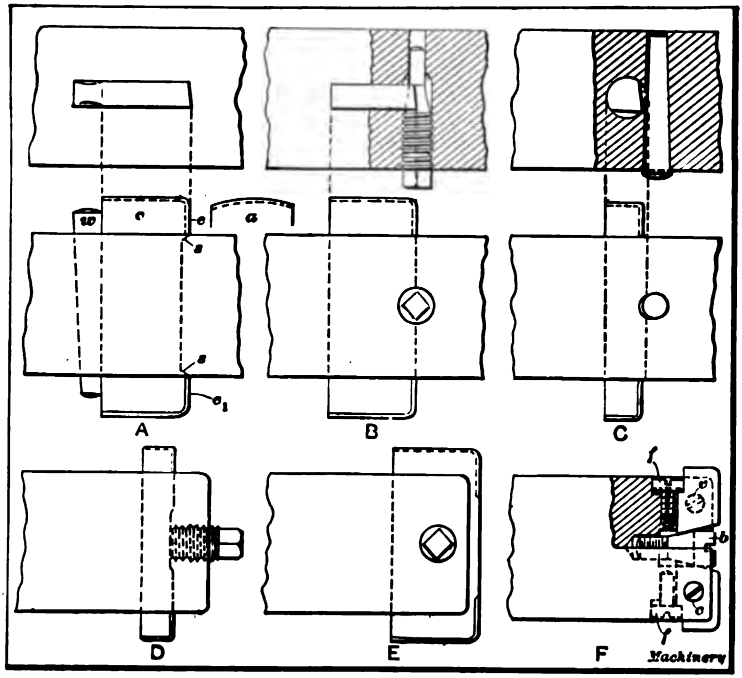

Fig. 23. Boring-cutters of Different Types

shown by the detail sketch *a*, is sometimes used for light finishing cuts. These rounded ends form the cutting edges and give a smooth finish. Another method of holding a flat cutter is shown at *B*. The conical end of a screw bears against a conical seat in the cutter, thus binding the latter in its slot. The conical seat also centers the cutter. A very simple and inexpensive form of cutter is shown at *C*. This is made from a piece of round steel, and it is held in the bar by a taper pin which bears against a circular recess in the side of the cutter. This form has the advantage of only requiring a hole through the boring-bar, whereas it is necessary to cut a rectangular slot for the flat cutter.

Fig. 24 illustrates how a hole is bored by cutters of the type referred to. The bar rotates as indicated by the arrow *a* and at the same time feeds longitudinally as shown by arrow *b*. The speed of rotation depends upon the diameter of the hole and the kind of material being bored, and the feed per revolution must also be varied to suit conditions. No definite rule can be given for speed or feed. On some classes of work a long boring-bar is used, which passes through the hole to be bored and is steadied at its outer end by the back-rest *B*, Figs. 21 and 22. On

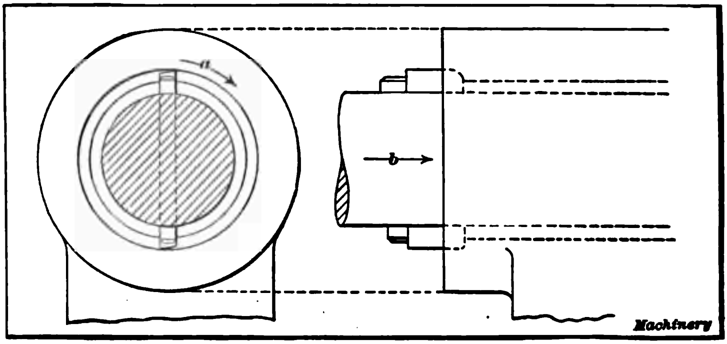

Fig. 24. Boring with a Flat Double-ended Cutter

other work, a short bar is inserted in the spindle and the cutter is attached at the outer end. An inexpensive method of holding a cutter at the end of a bar is shown at *D*, Fig. 23. The cutter passes through a slot and is clamped by a bolt as shown. When it is necessary to bore holes that are "blind" or closed at the bottom, a long boring-bar which passes through the work cannot, of course, be used. Sometimes it is

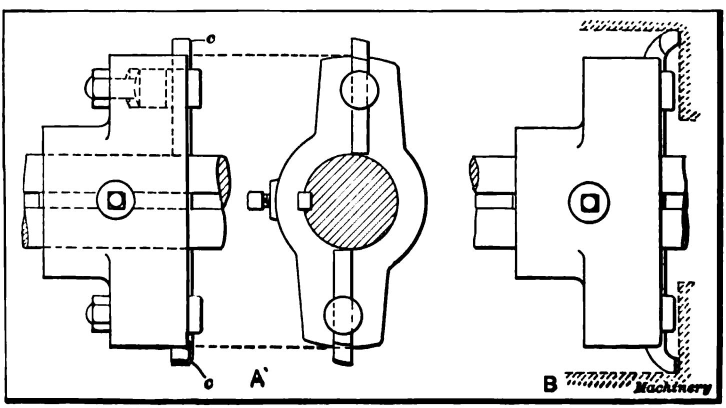

Fig. 25. Cutter-heads for Boring Large Holes

necessary to have a cutter mounted at the extreme end of a bar in order to bore close to a shoulder or the bottom of a hole. One method of holding a cutter so that it projects beyond the end of a bar is indicated at *E*. A screw similar to the one shown at *B* is used, and the conical end bears in a conical hole in the cutter. This hole should be slightly offset so that the cutter will be forced back against its seat. The tool shown at *F* has adjustable cutters. The inner end of each cutter is tapering and bears against a conical-headed screw *b* which gives the required outward adjustment. The cutters are held against the central bolt by fillister-head screws *f* and they are clamped by the screws *c*. Boring tools are made in many different designs and the number and form of the cutters is varied somewhat for different kinds of work.

Cutter-heads for Boring Large Holes

When large holes are to be bored, the cutters are usually held in a cast-iron head which is mounted on the boring-bar. One type of cutter-head is shown in Fig. 25. This particular head is double-ended and carries two cutters *c*. The cutter-head is bored to fit the bar closely and it is prevented from turning by a key against which a setscrew is tightened. By referring to the end view, it will be seen that each cutter

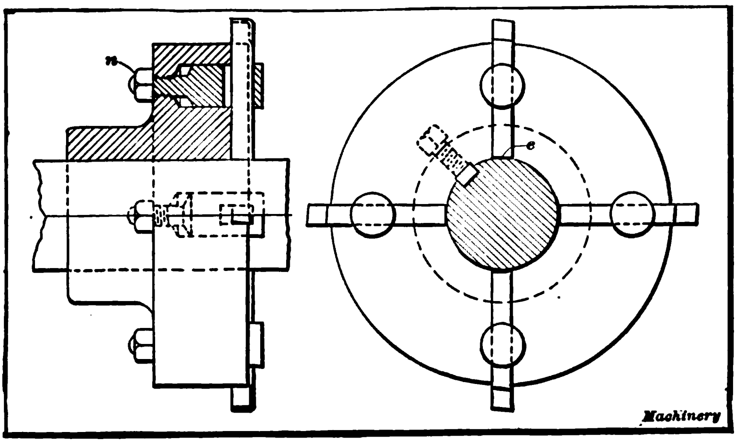

Fig. 26. Cutter-head with Four Boring Tools

is offset with relation to the center of the bar, in order to locate the front of the tool on a radial line. The number of cutters used in a cutter-head varies. There should be at least two, and three or four are often used. By having several cutters, the work of removing a given amount of metal in boring is distributed, and holes can be bored more quickly with a multiple cutter-head, although more power is required to drive the boring-bar. The boring-bar is also steadied by a multiple cutter-head, because the tendency of any one cutter to deflect the bar is counteracted by the cutters on the opposite side.

A disk-shaped head having four cutters is illustrated in Fig. 26. The cutters are inserted in slots or grooves in the face of the disk and they are held by slotted clamping posts. The shape of these posts is shown by the sectional view. The tool passes through an elongated slot and it is tightly clamped against the disk by tightening nut *n*. This head is also driven by a key which engages a keyway in the boring-bar.

Two other designs of cutter-heads are shown in Fig. 27. The one illustrated at *A* has three equally spaced cutters which are held in an inclined position. The cutters are clamped by screws *c* and they can be adjusted within certain limits by screws *s*. The cutters are placed at an angle so that they will extend beyond the front of the head, thus permitting the latter to be moved up close to a shoulder. The cutter-heads shown in Figs. 25 and 26 can also be moved up close to a shoulder

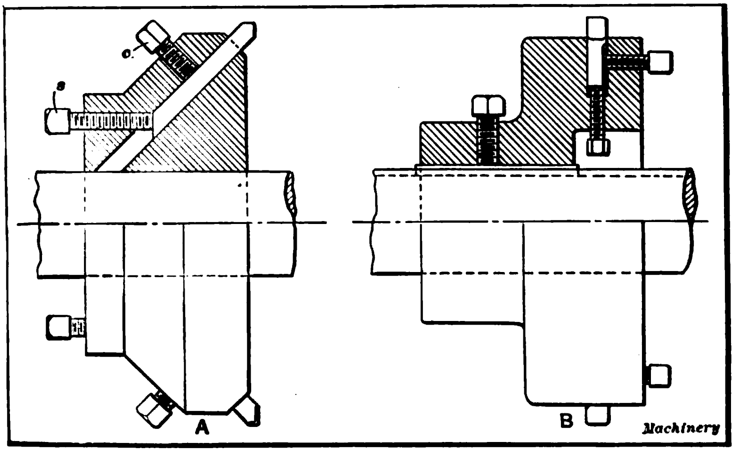

Fig. 27. Cutter-heads equipped with Adjustable Tools

if bent cutters are used as shown in the right-hand view, Fig. 25. The idea in bending the cutters is to bring the cutting edges in advance of the clamping posts so that they will reach a shoulder before the binding posts strike it. The arrangement of cutter head *B* (Fig. 27) is clearly shown by the illustration.

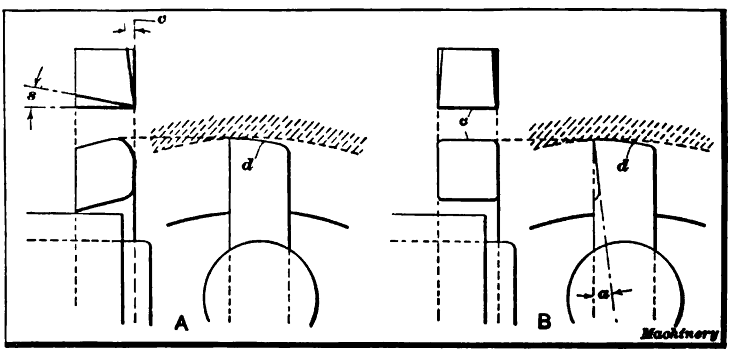

Fig. 28. Boring Tools for Roughing and Finishing Cuts

Fig. 29 illustrates the use of a cutter-head for cylinder boring. After the cylinder casting is set on the platen of the machine, the boring-bar with the cutter-head mounted on it, is inserted in the spindle. The bar *B* has a taper shank and a driving tang similar to a drill shank, which fits a taper hole in the end of the spindle. The cutter-head *C* is fastened to the bar so that it will be in the position shown when the spindle is shifted to the right, as the feeding movement is to be in the opposite direction. The casting *A* should be set central with the bar by adjusting the work-table vertically and laterally, if necessary, and the outer support *F* should be moved close to the work, to make the bar as rigid as possible.

The cylinder is now ready to be bored. Ordinarily, one roughing and one finishing cut would be sufficient, unless the rough bore were considerably below the finish diameter. As previously explained, the speed and feed must be governed by the kind of material being bored and the diameter of the cut. The power and rigidity of the boring machine and the quality of the steel used for making the cutters also effect the cutting speed and feed. Of course, the finishing cut is very light, and a

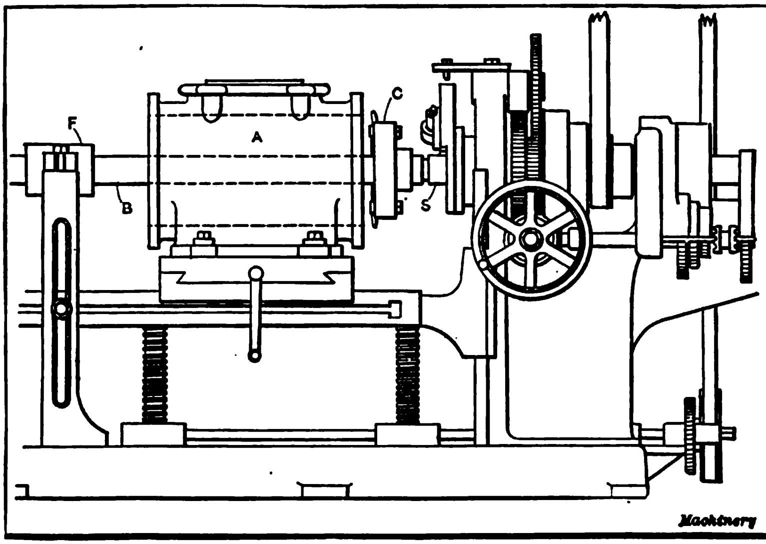

Fig. 29. Cylinder mounted on Horizontal Machine for Boring

tool having a flat cutting edge set parallel to the bar, is ordinarily used when boring cast iron. The coarse feed enables the cut to be taken in a comparatively short time and the broad-nosed tool gives a smooth finish if properly ground.

The coarse finishing feed is not always practicable, especially if the boring machine is in poor condition, owing to the chattering of the tool, which results in a rough surface. The last or finishing cut should invariably be a continuous one, for if the machine is stopped before the cut is completed, there will be a ridge in the bore at the point where the tool temporarily left off cutting. This ridge is caused by the cooling and resulting contraction and shortening of the tool during the time that it is stationary. For this reason independent drives are desirable for boring machines.

Cutter heads are often provided with two sets of cutters, one set being used for roughing and the other for finishing. It is a good plan to make these cutters so that the ends *e* (Fig. 26) will rest against the bar or bottom of the slot, when the cutting edge is set to the required radius. The cutters can then be easily set for boring duplicate work. One method of making cutters in sets is to clamp the annealed stock in

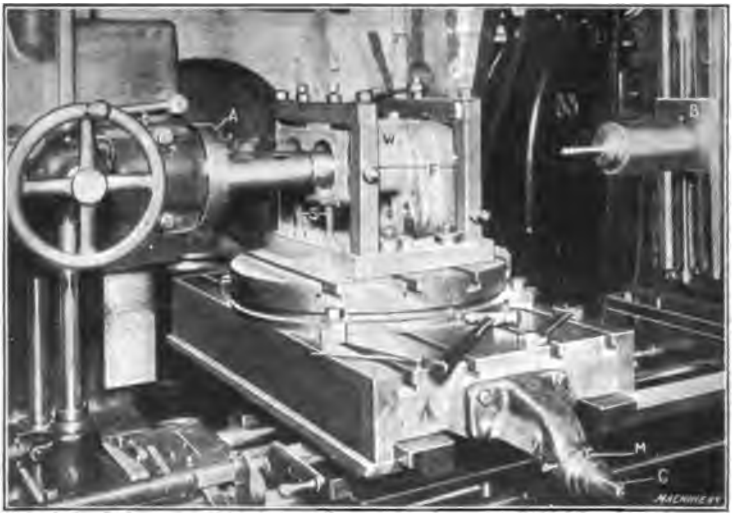

Fig. 30. Boring a Duplex Cylinder on a Horizontal Machine

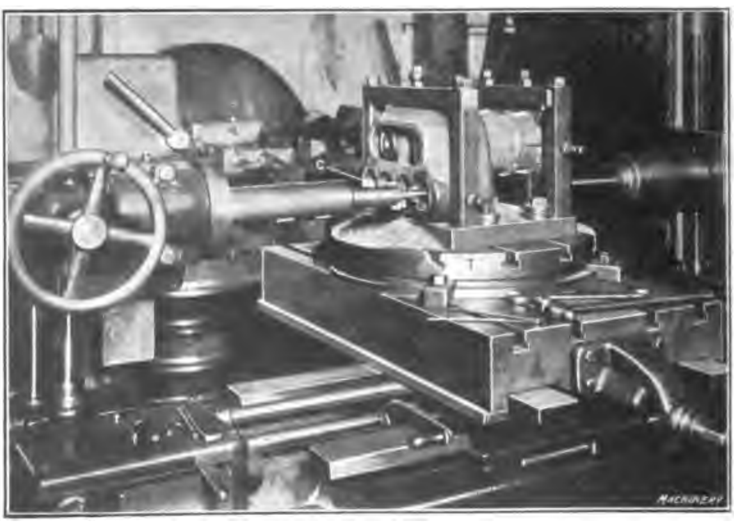

Fig. 31. Cylinder turned around for Machining Valve Seats

the cutter-head and then turn the ends to the required radius by placing the head in the lathe. After both sets of cutters have been turned in this way, they are ground to shape and then hardened.

Boring cutters intended for roughing and finishing cuts are shown in the detail view Fig. 28 at *A* and *B*, respectively. The side of the roughing cutter *A* is ground to a slight angle *c* to provide clearance for the cutting edge, and the front has a backward slope *s* to give the tool keenness. This tool is a good form to use for roughing cuts in cast iron. The finishing tool at *B* has a broad flat edge *e* and it is intended for coarse feeds and light cuts in cast iron. If a round cutting edge is used for finishing, a comparatively fine feed is required in order to obtain a smooth surface. The corners of tool *B* are rounded and they should be ground to slope inward as shown in the plan view. The top or ends *d* of both of these tools are "backed off" slightly to provide clearance. This end clearance should be just enough to prevent the surface back of cutting edge from dragging over the work. Excessive end clearance not

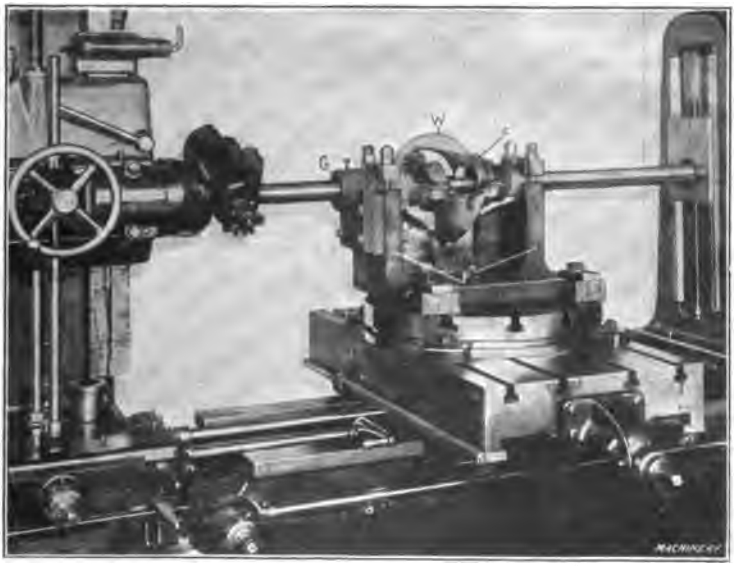

Fig. 32. Boring Differential Gear Casing

only weakens the cutting edge, but tends to cause chattering. As a finishing tool cuts on the upper end instead of on the side, the front should slope backward as shown in the side view, rather than side-wise as with a roughing cutter. The angle of the slope should be somewhat greater for steel than cast iron, unless the steel is quite hard.

Miscellaneous Examples of Boring, Facing and Milling

The method of holding work on a horizontal boring machine depends on its shape. A cylinder or other casting having a flat base can be clamped directly to the platen, but pieces of irregular shape are usually held in special fixtures. Fig. 30 shows how the cylinder casting of a gasoline engine is set up for the boring operation. The work *W* is placed in a fixture *F* which is clamped to the machine table. One end of the casting rests on the adjustable screws *S* and it is clamped by setscrews located in the top and sides of the fixture. There are two cylinders cast integral and these are bored by a short stiff bar mounted in the end of the spindle and having cutters at the outer end. A long bar of the type which passes through the work and is supported by the out-board bearing *B* could not be used for this work, as the top of each cylinder is closed.

When one cylinder is finished the other is set in line with the spindle by adjusting the work-table laterally. This adjustment is effected by screw *C*, and the required center-to-center distance between the two cylinders is obtained by the micrometer dial *M* on the cross-feed screw. After the first cylinder is bored, the dial is set to the zero position by loosening the small knurled screw shown, and turning the dial around.

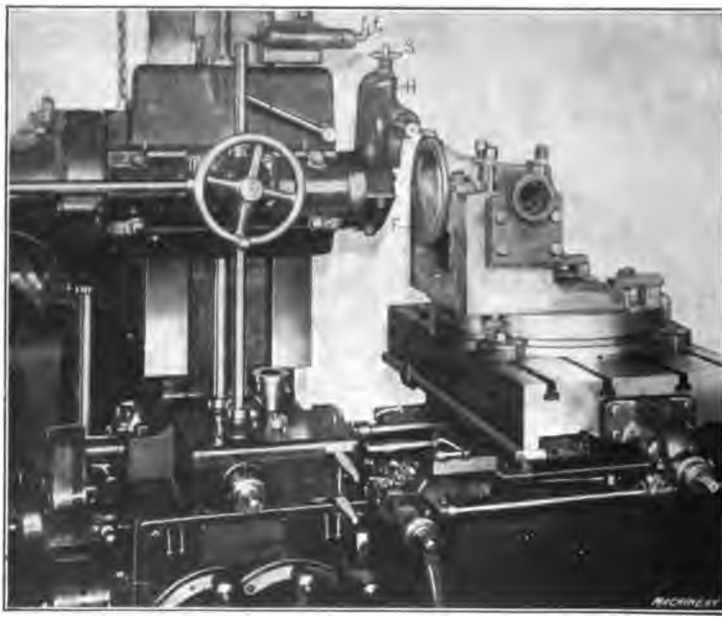

Fig. 33. Facing and Turning Flange of Differential Gear Casing

The feed screw is then rotated until the dial shows that the required lateral adjustment is made, which locates the casting for boring the second cylinder. The end of the casting is also faced true by a milling cutter. Ordinarily, milling cutters are bolted directly to the spindle sleeve *A* on this particular machine, which gives a rigid support for the cutter and a powerful drive.

The next operation is that of boring and milling the opposite end of the cylinder. This end is turned toward the spindle (as shown in Fig. 31) without unclamping the work or fixture, by simply turning the circular table *T* half way around. This table is an attachment which is clamped to the main table for holding work that must be turned to different positions for machining the various parts. Its position is easily changed, and as the work remains fixed with relation to the table, the alignment between different holes or surfaces is assured, if the table is turned the right amount. In this case, the casting needs to be rotated one-half a revolution or 180 degrees, and this is done by means of angular graduations on the base of the table. The illustration shows the casting set for boring the inlet and exhaust valve chambers. The different cutters required for boring are mounted on one bar as shown, and the work is adjusted cross-wise to bring each valve chamber in position, by using the micrometer dial. The single-ended cutter *c* forms a shallow circular recess or seat in the raised pad which surrounds the opening. The cover joint directly back of the cylinders is finished by milling.

Another example of boring, in which the circular table is used, is shown in Fig. 32. The work *W* is a casing for the differential gears of

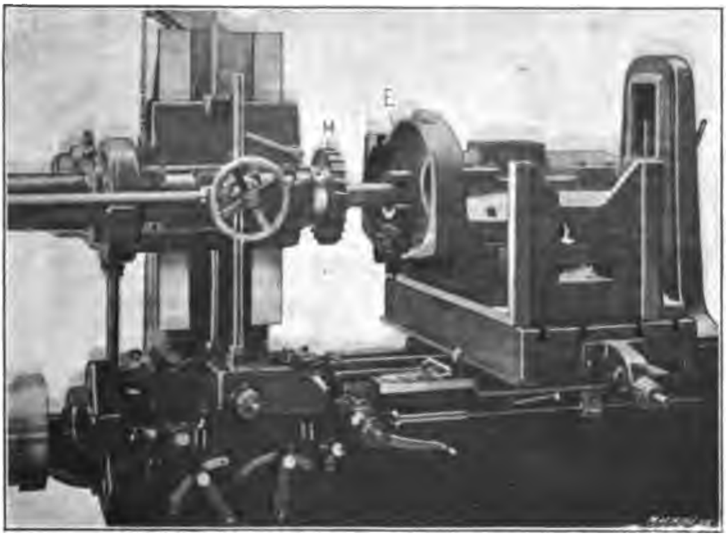

Fig. 34. Example of Work requiring Boring and Milling

an automobile. It is mounted in fixture *F* which is bolted to the table. The casting has round ends, which are clamped in V-blocks, thus aligning the work. This fixture has a guide-bushing *G* which is centered with the bar and cutter in order to properly locate the casting. There is a bearing at each end of the casing, and two larger ones in the center. These are bored by flat cutters similar to the style illustrated at *A* in Fig. 23. The cutter for the inner bearings is shown at *c*. After the bearings are bored, the circular table is turned 90 degrees and the work is moved closer to the spindle (as shown in Fig. 33) for facing flange *F* at right angles to the bearings. Circular flanges of this kind are faced in a horizontal boring machine by a special facing- arm or head *H*. For this particular job this head is clamped directly to the spindle sleeve, but it can also be clamped to the spindle if necessary. The turning tool is held in a slotted tool-post, and it is fed radially for turning the side or face of the flange, by the well-known star feed at *S*. When this feed is in operation the bent finger *E* is turned downward so that it strikes one of the star wheel arms for each revolution; this turns the wheel slightly, and the movement is transmitted to the tool-block by a feed screw. The illustration shows the tool set for turning the outside or periphery of the flange. This is done by setting the tool to the proper radius and then feeding the work horizontally by shifting the work-table along the bed. By referring to Fig. 32 it will be seen that the facing head does not need to be removed for boring, as it is attached to the spindle driving quill and does not interfere with the longitudinal adjustment of the spindle. This facing head is also used frequently for truing the flanges of cylinders which are to be bored, and for similar work.

Fig. 34 shows another example of work which requires boring and milling. This casting is mounted on a fixture which is bolted to the

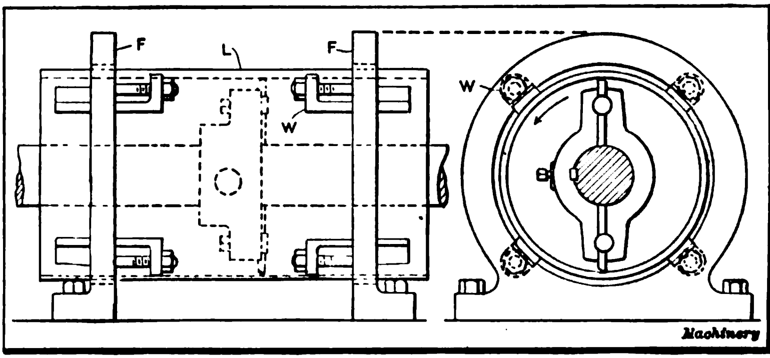

Fig. 35. Cylinder Lining Mounted in Fixture for Boring

main table. In this case the circular table is not necessary, because the work can be finished without swiveling it around. After the boring is completed the edge *E* is trued by the large-face milling cutter *M* bolted to the spindle sleeve. The irregular outline of the edge is followed by moving the table crosswise and the spindle vertically, as required.

A method of holding a lining or bushing while it is being bored is shown in Fig. 35. The lining *L* is mounted in two cast-iron fixtures *F*. These fixtures are circular in shape and have flat bases which are bolted to the table of the machine. On the inside of each fixture, there are four equally spaced wedges *W* which fit in grooves as shown in the end view. These wedges are drawn in against the work by bolts, and they prevent the lining from rotating when a cut is being taken. This form of fixture is especially adapted for holding thin bronze linings, such as are used in pump cylinders, because only a light pressure against the wedges is required, and thin work can be held without distorting it. If a very thin lining is being bored, it is well to loosen the wedges slightly before taking the finishing cut, so that the work can spring back to its normal shape.

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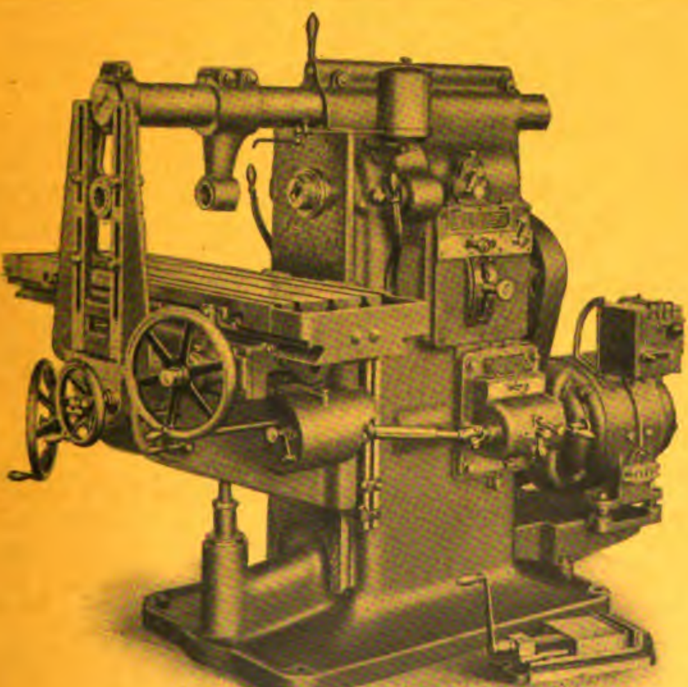

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OPERATION OF MACHINE TOOLS

By FRANKLIN D. JONES

MILLING MACHINES—PART I

CONTENTS

CHAPTER I

PLAIN TYPE OF MILLING MACHINE

Milling machines are used for a great variety of operations, and many types have been designed for milling certain classes of work to the best advantage. The milling machine was originally developed in armories for manufacturing the small irregular-shaped parts used in the construction of fire-arms, and the milling process is still employed very extensively in the production of similar work, especially when intricate profiles are required and the parts must be interchangeable. Milling machines are also widely used at the present time for milling many large castings or forgings, which were formerly finished exclusively by planing; in fact, it is sometimes difficult to determine whether certain parts should be planed or milled in order to secure the best results.

The operation of milling is performed by one or more circular cutters, having a number of teeth or cutting edges which successively mill away the metal as the cutter rotates. These cutting edges may be straight and parallel to the axis of the cutter for milling flat surfaces, or they may be inclined to it for forming an angular-shaped groove or surface, or they may have an irregular outline corresponding to the shape or profile of the parts which are to be milled by them. An end view of a cylindrical or "plain" cutter is shown in Fig. 1, which illustrates, diagrammatically, one method of producing a flat surface by milling. The cutter *C* rotates, as shown by the arrow, but remains in one position, while the work *W*, which is adjusted vertically to give the required depth of cut, slowly feeds to the left in a horizontal direction. Each tooth on the periphery of the cutter removes a chip every revolution, and, as the work moves along, a flat surface is formed.

The function of the milling machine is to rotate the cutter and, at the same time, automatically feed the work in the required direction. As it is necessary to vary the feeding movement and the speed of the cutter, in accordance with the material being milled and the depth of the cut, the milling machine must be equipped with feed- and speed-changing mechanisms and other features to facilitate its operation. As the variety of work that is done by milling is almost endless, milling machines differ widely as to their form, size, and general arrangement. Some are designed for doing a great variety of work, whereas others are intended for performing, as efficiently as possible, a comparatively small number of operations. Some machines are arranged for rotating the cutter horizontally, whereas with other types, the cutter rotates about a vertical axis. In this treatise, no attempt will be made to describe all the different types of milling machines, but rather to refer briefly to the more common designs, and then to illustrate their application and the principles of milling by showing typical examples of common milling operations.

Plain Milling Machine of the Column-and-Knee Type

A type of milling machine that is widely used, especially for milling large numbers of duplicate parts, is shown in Fig. 2. This is known as a plain, horizontal milling machine of the column-and-knee type. The principal parts are the column *C* and knee *K*, the work table *T*, the main spindle *S* which drives the cutter, and the speed- and feed-changing mechanisms encased at *A* and *B*, respectively. The spindle receives its motion from belt-pulley *P* at the rear. This pulley is connected to the driving shaft by a friction clutch operated by lever *M* which is used for starting and stopping the machine. When the friction clutch is engaged, power is transmitted to the main spindle

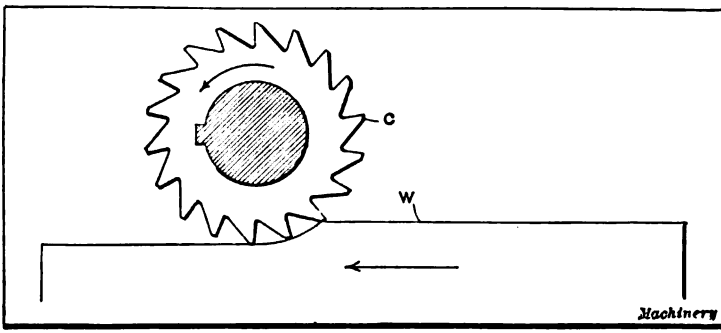

Fig. 1. End View of Cylindrical Cutter Milling Flat Surface

S through gearing, and, by varying the combination of this gearing, the required speed changes are obtained. Knee *K* is free to slide vertically on the front face of the column, and it carries saddle *Z* and the table *T*. The saddle has an in-and-out or cross movement on the knee, and the table can be traversed at right-angles to the axis of the spindle. Either of these three movements, that is, the longitudinal, cross, and vertical movements, can be effected by hand or power. The hand movements are used principally for adjusting the table and work to the required position when starting a cut, whereas the automatic power feed is employed when milling. The handcrank *D* is used for raising or lowering the knee with its attached parts, handwheel *E* is for the cross feed of the saddle and table, and handle *F* is for the longitudinal adjustment of the table. The table can also be traversed rapidly by the large handwheel *N* at the front of the machine.

The work to be milled is held either in a vise *V*, or it is attached to the table by other means. When duplicate parts are to be milled in quantity, they are usually held in a special fixture bolted to the table in place of the vise. Some pieces are also clamped directly to the table. The milling cutter is ordinarily mounted on an arbor which is driven by spindle *S* and is rigidly supported by the bearing *I* and arbor-brace *J* which is attached to a clamp on the knee. Many machines do not have the extra bearing *I*, but this is desirable for many classes of work, as it can be adjusted along the overhanging arm and provides a support for the arbor close to the cutter.

The speed of the spindle is varied by changing the positions of the levers *L*, L_1, and the handwheel *W*. Each lever has two positions, making four in all, which are marked with the letters A, B, C and D,

Fig. 2. Cincinnati Plain Milling Machine

and the positions for the handwheel are numbered 1, 2, 3, and 4. An index-plate or table attached to the casing shows just what the speed will be for any position of the levers. For example, to obtain 115 revolutions per minute, the positions given on the index-plate under 115 are 3—BC, which means that the handwheel is set to position 3, one lever is engaged with hole B and the other with hole C. This particular machine has a total of sixteen speed changes. If there is any interference between the gears when changing the speeds, they can readily be engaged by pressing foot-lever *O*, which operates an auxiliary disk clutch and revolves the gears slightly.

The power-feed mechanism at *B* transmits its movement to the front of the machine by shaft *U* equipped with universal joints and a telescopic connection to permit raising or lowering the knee on the column. Shaft *U* drives gearing in the feed-tripping and reversing box *G*, and from this point the power is transmitted to the knee, saddle or table, as may be required. The table feed is engaged or disengaged by lever *Y* and it is controlled by another lever located at *Q*, but not seen in the illustration. The direction in which lever *Q* is inclined from the vertical, determines the direction of the table feed. For instance, if it is shifted to the right the table will travel toward the right, and *vice versa*. This lever *Q* also controls any feed that happens to be engaged, as well as the table feed. Lever *X* engages either the vertical or cross feeds, and all of the feeding movements can be controlled by lever *R* by means of which they are reversed.

The rate or amount of feed per revolution of the cutter can be varied by the levers and handwheel on case *B*. There are 16 changes, and an index-plate shows what the rate of feed is for any position of the levers. The longitudinal, cross or vertical feeding movements can be automatically stopped at any predetermined point by the trip-plungers *l*, *c*, and *v*, respectively. These plungers are operated by dogs which can be adjusted so that the automatic trip will operate after the cut is completed. The dogs *H* and H_1, for the table feed, are clamped to the front of the table as shown. One of these dogs trips the feed by lifting the plunger and the other by depressing it. A movement of the plunger in either direction disengages a clutch at *G* and places it in a neutral position. This is the same clutch that is operated by feed-reverse lever *R*. The automatic trip mechanism is a very convenient feature, as it prevents feeding too far, and makes the machine more independent of the operator.

The principal features of a plain milling machine, so far as the operation of the machine is concerned, have now been described, but it should be remembered that while plain machines of other makes have the speed- and feed-changing mechanisms, the automatic trips, etc., the arrangement of these parts varies in different designs. When the construction of one machine is thoroughly understood, however, the changes in other designs in the location of the speed- and feed-control levers, and the functions of the different parts, can readily be understood.

CHAPTER II

ADJUSTING AND OPERATING A MILLING MACHINE

Before a milling machine can be used, it is necessary, of course, to arrange it for doing the work in hand, which includes mounting the cutter in position, and adjusting the driving and feed mechanisms for giving the proper speed to the cutter and feed to the work. The part to be milled must also be securely attached to the machine, so that it can be fed against the revolving cutter by moving the table in whatever direction may be required. The way a milling machine

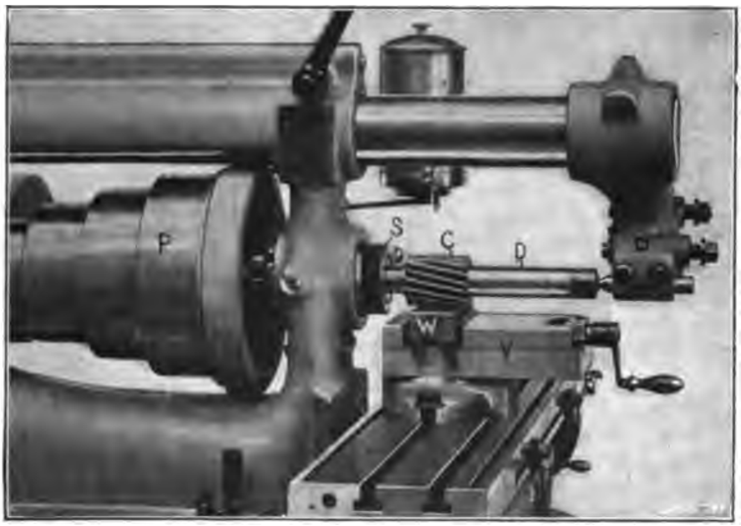

Fig. 3. Milling a Small Rectangular Block

is arranged, and the kind of cutter used, depends on the nature of the milling operation. The character of the work, and other considerations which will be referred to later, also affect the speed and feed, as well as the method of clamping the work to the table; hence, judgment and experience are needed to properly decide the questions that arise in connection with milling practice, and no definite rules or methods of procedure can be given. We shall explain, however, in a general way, how milling machines are arranged and used under varying conditions, by giving illustrated descriptions covering typical examples of work representing the various classes that are machined by the milling process.

A very simple example of milling is shown in Fig. 3, the operation being that of milling a flat surface on top of a steel block *W*.

Before referring to this work, it might be well to explain that the spindle of the machine shown in this illustration, is driven by a stepped or cone pulley *P*, instead of by a single, constant-speed pulley as in Fig. 2. Speed changes are obtained by shifting the driving belt to different steps of the cone, and the number of changes secured in this way can be doubled by the engagement of back-gears located at the side of the cone, the arrangement being the same as the back-gearing on an engine lathe.

Method of Holding and Driving the Cutter

The first thing to be done in connection with milling block *W*, is to select the cutter. As a flat surface is to be milled, a plain cylindrical cutter *C* would be used (in a machine of this type), having a width somewhat greater than the surface to be milled. This cutter

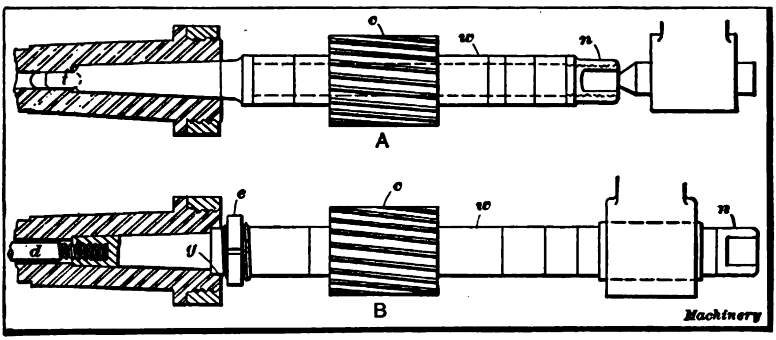

Fig. 4. Cutter Arbors

is mounted on an arbor *D* which is rotated by the spindle and is supported at its outer end by arm *B*. This is the usual method of mounting and driving the cutter, when a horizontal milling machine of the column-and-knee type is used, although some cutters or mills are made with a taper shank which is inserted directly in the spindle *S*. When an arbor is placed in the machine, its outer end, in some instances, is supported by a center (similar to a lathe center), which is inserted in the centered end of the arbor as shown at *A* in Fig. 4. Another method of supporting the arbor, which is very common, is shown at *B*. In this case, the arbor passes through a bearing in the arm. The particular machine shown in Fig. 3 has an arm containing a center and also a bearing, so that the arbor can be supported in whichever way is most convenient. The inner end of the arbor has a taper shank which fits the spindle hole, and it is usually locked with the spindle, either by a flat tang at the end or by a draw-in bolt which passes through the spindle and holds the arbor tightly in the taper hole. An arbor having a tang *t* is shown at *A*, Fig. 4, and the style having a draw-in bolt *d* is illustrated at *B*. The latter form also has a collar *g* with flattened sides which engage a slot cut in the end of the spindle, thus giving a strong, positive drive. This particular style of arbor is removed by forcing nut *e* against the end of the spindle.

The cutter *c* is clamped between cylindrical bushings *w* which are placed on the arbor and tightened by nut *n*. These bushings are of different lengths, so that the lateral position of the cutter can be varied. Many small cutters are driven simply by friction, but medium and large sizes, especially when used for taking deep roughing cuts, are mounted on splined arbors, and keys are used to give a positive drive and prevent the cutter from slipping. The cutter should always

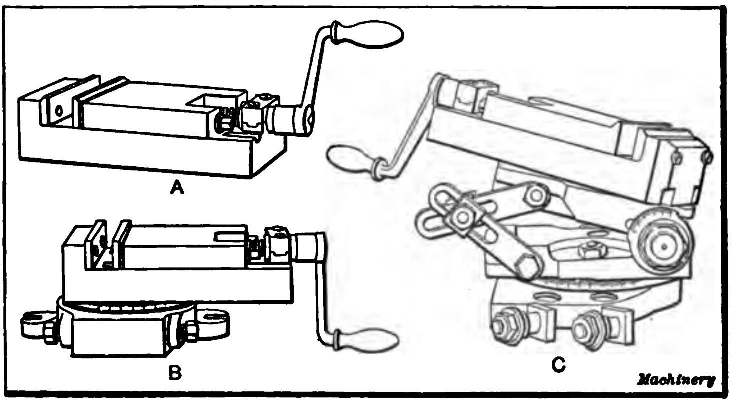

Fig. 5. Milling Machine Vises

be placed as near the spindle as circumstances will permit, in order to give a strong drive and reduce the torsional strain on the arbor.

Holding Work on the Milling Machine

The next thing to consider is the method of holding or fastening the part while it is being milled. In this case, the block is clamped between the jaws of a vise *V* (see Fig. 3), which, in turn, is bolted to the table of the machine. Vises are frequently used for holding small pieces, but are not suitable for many classes of work. The proper method of clamping, in any case, is governed by the size of the work, its shape, and the nature of the milling operation. The number of duplicate parts required should also be taken into consideration. Some pieces are clamped directly to the machine table which has T-slots for receiving the clamping bolts. It is necessary, of course, that the work be held securely enough to prevent its shifting when a cut is being taken, and it is equally important that it should be supported so as to overcome any springing action due either to its own weight or to the pressure of the cut Some parts are also sprung out of shape by applying the clamps improperly or by omitting to place supports under some weak or flexible section; as a result, the milled surface is not true after the clamps are removed and the casting springs back to its natural shape. Generally speaking, work should be clamped more securely for milling than for planing, because the pressure of the cut, when milling, is usually greater than when planing, although this depends altogether upon the depth of the cut and the size of the cutter.

Three types of milling machine vises which are commonly used, are shown in Fig. 5. The one illustrated at *A* is called a plain vise. It is held to the table by a screw which passes through the vise bed and threads into a nut inserted into one of the table T-slots. This same style is also made with flanges so that it can be secured by ordinary clamps. The vise shown at *B* has a swiveling base and it can be adjusted to any angle in a horizontal plane, the posisition being shown by graduations. This adjustment is used for angular milling. The vise shown at *C* is known as the universal type. It can be swiveled in a horizontal plane and can be set at any angle up to 90 degrees in a vertical plane, the position, in either case,

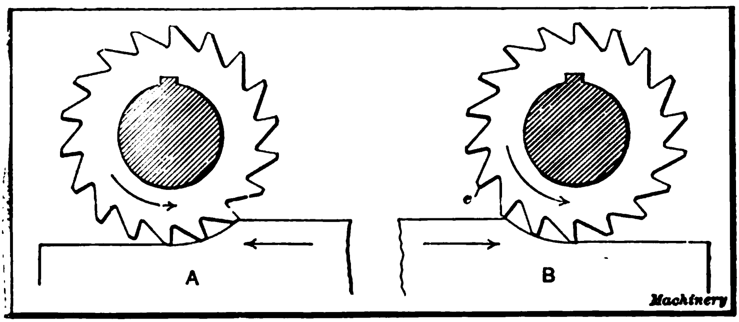

Fig. 6. (A) Work feeding against Rotation of Cutter. (B) Work feeding with Rotation of Cutter

being shown by graduations. The hinged knee which gives the vertical adjustment, can be clamped rigidly by the nut on the end of the bolt forming the hinge, and by bracing levers at the left which are fastened by the bolts shown. This style of vise is used principally by die- and tool-makers, and, owing to its universal adjustment, can often be utilized in place of a jig or fixture. When large quantities of duplicate pieces are to be milled, they are usually held in special fixtures which are so designed that the work can quickly be clamped in position for milling. The arrangement or form of a fixture depends, of course, on the shape of the part for which it is intended and the nature of the milling operation. A number of different fixtures will be shown in connection with the examples of milling given in succeeding chapters.

Direction of Feeding Movement and Relative Rotation of Cutter

After the cutter is mounted on the arbor and the part is clamped to the table, we are ready to begin milling. Before starting a cut, the table is shifted lengthwise and crosswise, if necessary, until the cutter is at one end of the work. The knee *K*, (Fig. 2) with the table, is then raised sufficiently to give the required depth of cut, and the trip-dog at the front of the table is set to disengage the power feed after the cut is completed. The longitudinal power feed for the table is then engaged, and the part *W* feeds beneath the revolving cutter *C*, which mills a flat surface.

By referring to Fig. 6, it will be seen that the direction of the feeding movement might be either to the right or left, as indicated at *A* and *B*. When the cutter rotates as shown at *A*, the part being milled feeds *against* the direction of rotation, whereas at *B*, the movement is *with* the cutter rotation. In the first case, the cutter tends to push the work away, but when the relative movements are as at *B*, the cutter tends to draw the part forward, and if there is any backlash or lost motion between the table feed-screw and nut, this actually occurs when starting a cut; consequently, the cutter teeth which happen to be in engagement, take deeper cuts than they should, which may result in breaking the cutter or damaging the work. Therefore, the work should ordinarily feed *against the rotation of the cutter.* When milling castings which have a hard sandy scale, the cutting edges of the teeth will also remain sharp for a longer period when feeding against the rotation, as at *A*. This is because the teeth move up through the metal and pry off the scale from beneath, whereas at *B*, the sharp edges *e* strike the hard scale each revolution, which dulls them in a comparatively short time. Occasionally, a part can be milled to better advantage by feeding it with the cutter. This is especially true when the work is frail and cannot be held very securely, because a cutter rotating as at *B* tends to keep the work down, whereas the upward movement at *A* tends to lift it. When the work moves with the cutter, the table gib-screws should be set up tighter than usual to prevent a free movement of the table, because this would allow the cutter teeth to "dig in" at the beginning of the cut. Some machines are designed to prevent this, and counterweights are sometimes used to hold the table back.

It should be mentioned that a cutter does not always rotate in the direction shown at *A* and *B*. If it were turned end for end on the arbor, thus reversing the position of the teeth, the rotation would have to be in a clockwise direction, and the feeding movement to the right. A cutter which rotates to the right (clockwise), as viewed from the spindle side, is said to be right-hand, and, inversely, a left-hand cutter is one that turns to the left (counter-clockwise) when milling.

The Cutting Speed and Feed

The proper speed for the cutter, and the feeding movement of the work for each revolution of the cutter, are governed by so many different things that no definite rule can be given to determine just what the speed and feed should be unless the conditions are known. The speed of the cutter depends partly on the kind of material being milled. Tool steel cannot be cut as fast as soft machine steel or cast iron, and brass can be milled at much higher speed. The condition of the cutter also affects the speed, it being possible to operate a sharp cutter faster than a dull one, because the dull edges generate an excessive amount of heat. When milling steel or wrought iron, the application of a lubricant to the cutter enables higher speeds to be used. Lard oil or any animal or fish oil is used as a lubricant, and some manufacturers mix mineral oil with lard or fish oil. The lubricant is usually applied to the cutter through a pipe or spout which can be adjusted to the proper position. Some machines have a special pump for supplying the lubricant, and others are equipped with a can from which the lubricant flows to the cutter by gravity. Cast iron and brass are milled dry.

A general idea of the speeds that are feasible when using carbon steel cutters may be obtained from the following figures which repre-

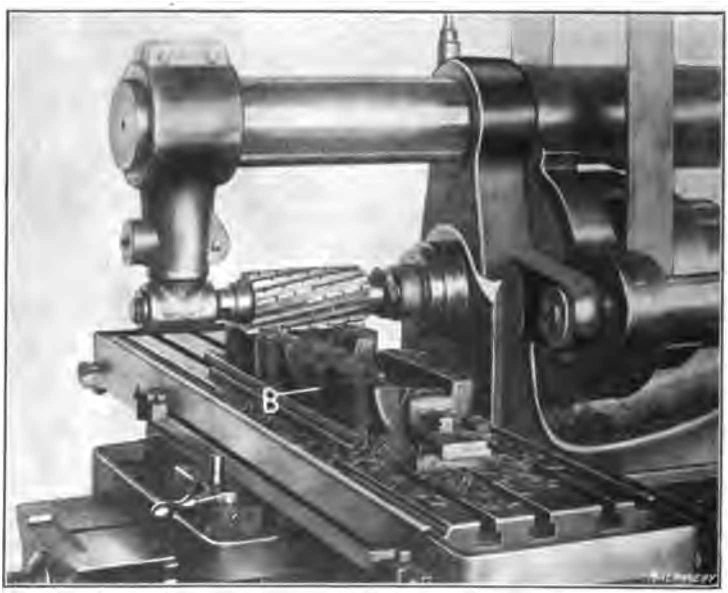

Fig. 7. Milling Cast-iron Bearing Caps

sent the velocity (in feet per minute) at the circumference of the cutter. For taking roughing cuts: for cast iron, 40 feet per minute; for machine steel, 60 feet per minute; for tool steel, 25 feet per minute; and for brass, 75 feet per minute. Finishing cuts are to be taken at speeds varying from 50 to 55 feet for cast iron; 75 to 80 feet for machine steel; 30 to 35 feet for tool steel; and 95 to 100 feet for brass. These figures are not given as representing the maximum speeds that can be used successfully, even with ordinary carbon cutters, and with high-speed steel cutters they can be doubled, owing to the superior cutting qualities of high-speed steel.

The distance that the work feeds per revolution of the cutter must also be varied to suit conditions. When milling cutters were first made, they had fine, closely-spaced teeth between which the chips clogged, thus preventing any cutting action except with fine feeds. Modern cutters, however, have much coarser teeth and, consequently, deeper cuts and heavier feeds can be used. Aside from the question of cutter design, the feed is affected by the depth of the cut, the kind of material being milled, the quality of the finish required, and the rigidity of the work. As a general rule, a relatively low cutting speed and a heavy feed is used for roughing, whereas for finishing, the speed is increased and the feed diminished. The data given in connection with some of the examples of milling referred to in this treatise, will show, in a general way, what speeds and feeds are practicable when using a well-built machine and modern cutters.

Milling Cast-iron Bearing Caps

Another example of milling which is similar in principle to the one illustrated in Fig 3, is shown in Fig. 7. The operation is that of milling flat surfaces on the edges of cast-iron bearing caps *B*. Two of these caps are placed in line and milled by one passage of the cutter. They are mounted on parallel strips placed under the bolt lugs on the side and are held by ordinary clamps as shown. The cutter used is cylindrical in form and has helical or "spiral" teeth which are nicked at intervals along the cutting edges in order to break up the chips and reduce the power required for driving. The proper depth of cut is obtained by adjusting the knee vertically, and then the edges are milled by traversing the castings beneath the revolving cutter. By clamping two of the castings in line and milling them together, they are finished, of course, more quickly than if one were machined at a time. The following figures will give a general idea of the feeds and speeds used for this particular operation. The cutter is 3 inches in diameter and rotates 53 revolutions per minute. The average depth of cut is about 1/8 inch and the table feeds 0.250 inch per revolution of the cutter or over 13 inches per minute. This cutter is made of high-speed steel and, therefore, can be run faster without injuring the cutting edges, than if made of ordinary carbon steel.

CHAPTER III

DIFFERENT TYPES OF MILLING CUTTERS

As the processes of milling can be applied to an almost unlimited range of work, the cutters used on milling machines are made in a great variety of forms. Some of the different types can be used for general work of a certain class, whereas other cutters are made especially for milling one particular part. Of course, the number of different types that are used on any one machine, depends altogether on the variety of milling operations done on that machine. When

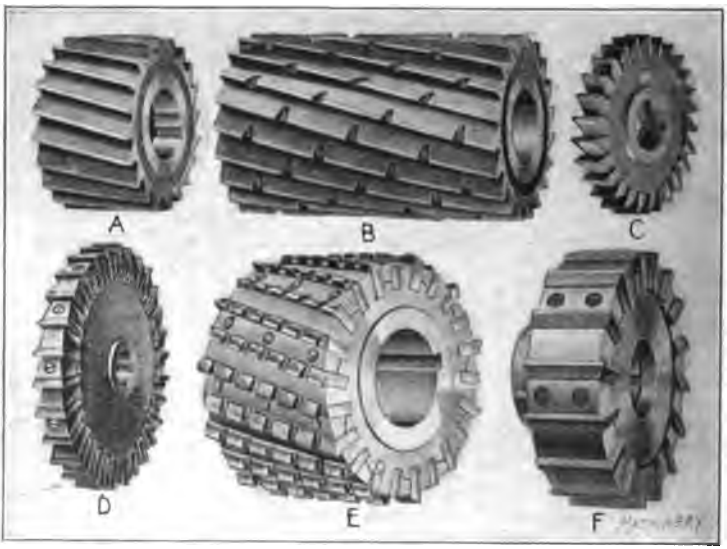

Fig. 8. Cylindrical, Side, and Face Milling Cutters

the nature of the work varies widely, the stock of cutters must be comparatively large, and, inversely, when a machine is used for milling only a few parts, a large cutter equipment is not necessary.

A number of different types of cutters in common use are shown in Figs. 8, 9, and 10. The form illustrated at *A*, Fig. 8, is called a cylindrical or plain cutter. This form is used for producing flat surfaces and it is made in various diameters and lengths. Another cutter of the cylindrical type is shown at *B*. This differs from cutter *A* in that the teeth are nicked at intervals along the cutting edges. The idea in nicking the teeth is to break up the chips, as previously mentioned. This enables heavier or deeper cuts to be taken with the same expenditure of power; hence, the nicked cutter is extensively used for roughing cuts. It will be noted that the teeth of these two cutters are not parallel with the axis, but are helical or "spiral."

Cutters having helical teeth are generally used in preference to the type with straight or parallel teeth, especially for milling comparatively wide surfaces, because the former cut more smoothly. When teeth are parallel to the axis, each tooth begins to cut along its entire width at the same time; consequently, if a wide surface is being milled, a shock is produced as each tooth engages the metal. This difficulty is not experienced with helical teeth which, being at an angle, begin to cut at one side and continue across the work with a smooth shaving action. Helical cutters also require less power for driving and produce smoother surfaces.

A side milling cutter is shown at *C*. This type has teeth on both sides, as well as on the periphery, and it is used for cutting grooves

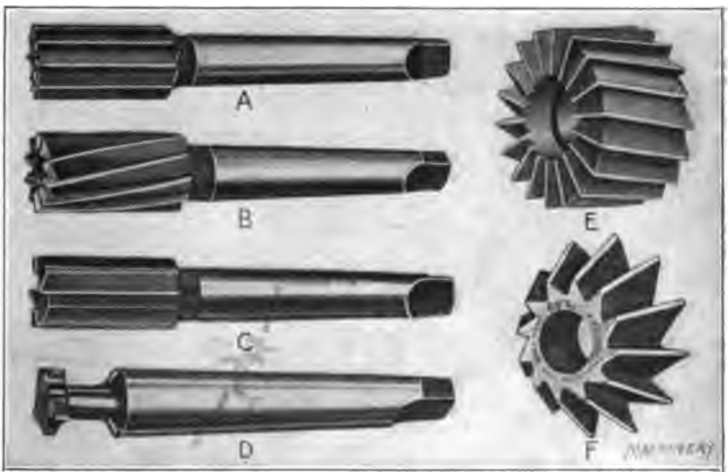

Fig. 9. End Mills, T-slot Cutter, Shell End Mill, and Angular Cutter

or slots and for other operations, examples of which will be shown subsequently. The sides of this form of cutter are recessed between the hub and inner ends of the teeth, in order that they will clear a surface being milled. Two side mills are often mounted on the same arbor and used in pairs for milling both sides of a part at the same time. This type of cutter is also employed in conjunction with other forms for milling special shapes, as will be shown later. Another side milling cutter is shown at *D*. This mill, instead of being made of one solid piece of steel, has a cast-iron body into which tool steel teeth are inserted. These teeth fit into slots and they are held in place by flat-sided bushings which are forced against them by the screws shown. There are many different methods of holding teeth in cutters of this type. The inserted-tooth construction is ordinarily used for large cutters, in preference to the solid form, because it is cheaper, and the inserted teeth can readily be replaced when necessary. When solid cutters are made in large sizes, there is danger of their cracking while being hardened, but with the inserted-tooth type, this is eliminated. A large cylindrical cutter with inserted teeth is shown at *E*. The cutter illustrated at *F* also has inserted teeth and is called a face milling cutter. This form is especially adapted to end or face milling operations. When in use, the cutter is mounted on a short arbor which is inserted in the milling machine spindle.

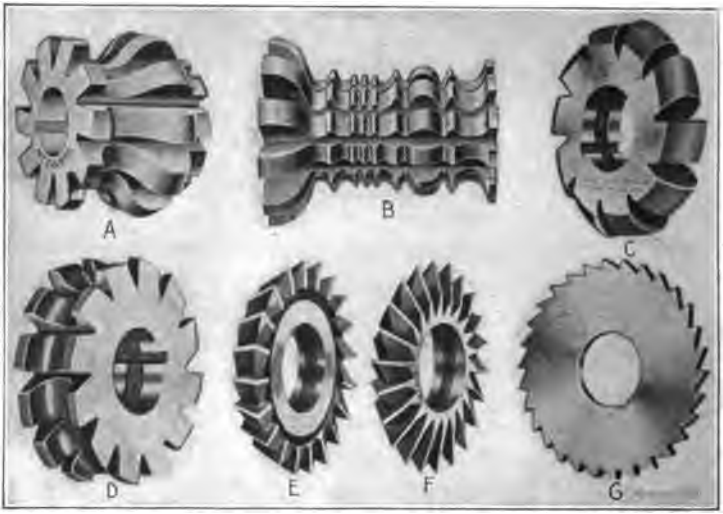

Fig. 10. Formed Cutters, Angular Cutters, and Slitting Saw

The three cutters, *A*, *B*, and *C*, Fig. 9, are called end mills because they have teeth on the end as well as on the periphery or body; hence, they can cut in an endwise as well as a sidewise direction. These mills, instead of being mounted on an arbor, have taper shanks which are driven into a hole of corresponding taper in the machine

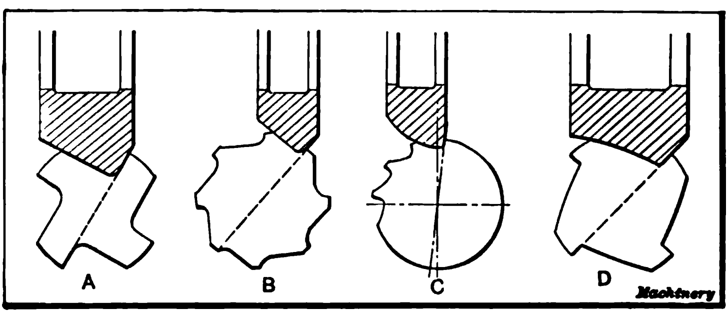

Fig. 11. Diagrams illustrating use of Formed Cutters for fluting Taps, Reamers, etc.

spindle. The shanks have a flat end or tang which engages a slot in the spindle and prevents the mill from slipping when taking a cut. The mill shown at *A* has straight teeth, whereas the form *B* has spiral teeth. The type shown at *C* is adapted to slot milling, especially when it is necessary to cut in to the required depth with the end of the mill, because the inner ends of the teeth are sharp, and can more readily cut a path from the starting point.

The cutter illustrated at *D* is a special form used for cutting T-slots, after the central groove has been milled. The larger sizes of end mills do not have solid taper shanks, but are made in the form of shells (as at *E*) which are fastened to an arbor that serves as a shank.

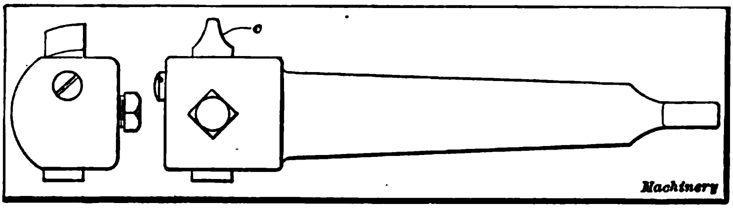

Fig. 12. Fly-cutter and Arbor

This arbor has a taper end that fits the machine spindle, and the mill is attached to the outer end which is equipped with a driving key that engages a slot cut across the inner end of the mill. This type of cutter can often be used when a long arbor with an outboard support would be in the way. The angular cutter *F* has teeth which are at an angle of 60 degrees with the axis. This form is used for milling dovetailed slots and for similar work. The particular style shown has a threaded hole and it is screwed onto an arbor.

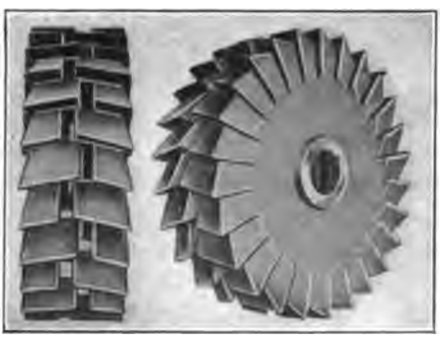

Fig. 13. Interlocking Side Milling Cutter

The two cutters illustrated at *A* and *B*, Fig. 10, are examples of formed milling cutters. The cutting edges of this type are made to the same shape as the profile of the piece to be milled. The small parts of sewing machines, guns, typewriters and other pieces having an irregular and intricate shape, are milled with formed cutters. The teeth of these cutters are "backed off" so that they can be sharpened without changing the profile, provided the front faces are ground radial. The convex and concave cutters, *C* and *D*, which are also of the formed type, are for milling half-circles, one cutting half-round grooves and the other, forming half-round edges. Formed cutters are made in a great variety of shapes and they are used for many different purposes. The diagrams, Fig. 11, illustrate how formed cutters are used for fluting taps, reamers, and four-lipped drills. Sketch *A* shows how the grooves or flutes are cut in a tap. As will be seen, the groove is milled to the same shape as the cutter. The sketches at *B* and *C* show cutters of different shapes for fluting reamers, and *D* illustrates how the grooves are cut in four-lipped twist drills, of the type used in screw and chucking machines for roughing out holes prior to reaming. The angular cutters, *E* and *F* (Fig. 10), are used extensively for forming teeth on milling cutters. The style *E* is employed for cutting straight teeth, whereas the double-angle cutter *F* is especially adapted to milling spiral grooves. The thin cutter illustrated at *G* is known as a slitting saw, and it is used for milling narrow slots, cutting off stock, and for similar purposes.

Fig. 12 shows a simple type of cutter that is often used for operations that will not warrant the expense of a regular formed cutter. This is called a fly-cutter. The milling is done by a single tool *c* which has the required outline. This tool is held in an arbor having

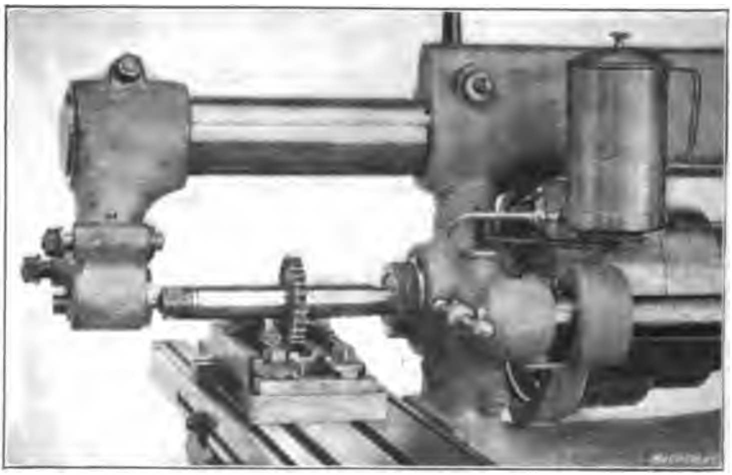

Fig. 14. Milling Groove with Interlocking Cutter

a taper shank the same as an end mill. The advantage of the fly-cutter is that a single tool can be formed to the desired shape, at a comparatively small expense.

The milling cutter shown in Fig. 13 is similar to a side mill, but it is composed of two units instead of being made of one solid piece of steel. These two sections are joined as shown by the view to the left, there being projections on each half which engage corresponding slots in the other half, thus locking both parts together. This type of cutter is largely used for milling grooves or slots, because as the side teeth wear or are ground away, the two sections of the mill can be spread apart by washers in order to maintain a standard width. An example of slot milling with an interlocking cutter is shown in Fig. 14. The cutter is mounted on an arbor the same as a regular side mill, and the part to be grooved is bolted directly to the table, one end being supported on parallel strips. When it is necessary to mill a large number of grooves to a standard size, the interlocking cutter is the best type to use, owing to its adjustment for width.

CHAPTER IV

FORM MILLING—STRADDLE AND GANG MILLING—END MILLING

One of the great advantages of the milling process is that duplicate parts having intricate shapes can be finished within such close limits as to be interchangeable. Because of this fact, milling machines are widely used for manufacturing a great variety of small machine parts having an irregular outline. The improved high-speed steel cutters now used, and the powerful machines which have been de-

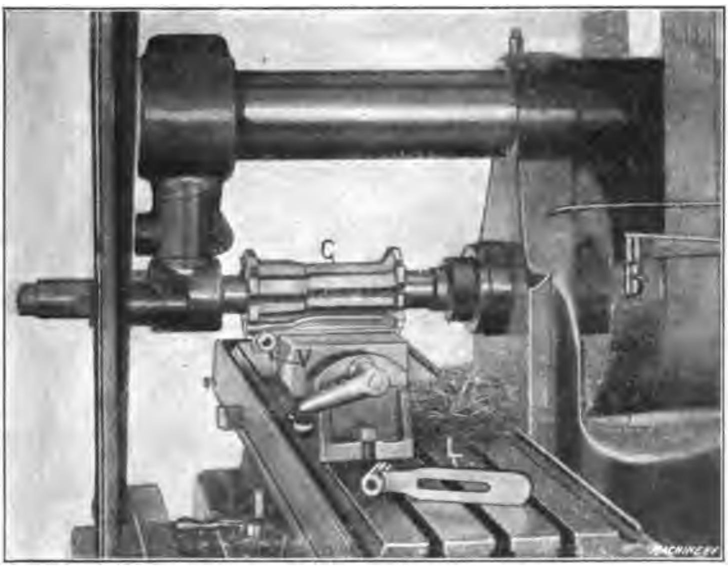

Fig. 15. Example of Form Milling

veloped for driving these cutters, also make it possible to machine many heavy parts more rapidly by milling than in any other way.

When pieces having an irregular outline are to be milled, it is necessary to use a cutter having edges which conform to the profile of the work. Such a cutter is called a form or formed cutter, as explained in Chapter III. There is a distinction between a *form* cutter and a *formed* cutter, which according to the common use of these terms is as follows: A formed cutter has teeth which are so relieved or "backed off" that they can be sharpened by grinding, without changing the tooth outline, whereas the term form cutter may be applied to any cutter for form milling, regardless of the manner in which the teeth are relieved.

An example of form milling is illustrated in Fig. 16, which shows a steel piece *W* having an irregular edge which is milled by form cutter *C*. The part *W* is held in a vise which is equipped with special false jaws having the same outline as the work, to provide a more rigid support. These special jaws are attached to the vise in place of the regular jaws, which are removable. When the cutter feeds across the work, its form is reproduced. A large number of duplicate parts can be milled in a comparatively short time, in this way.

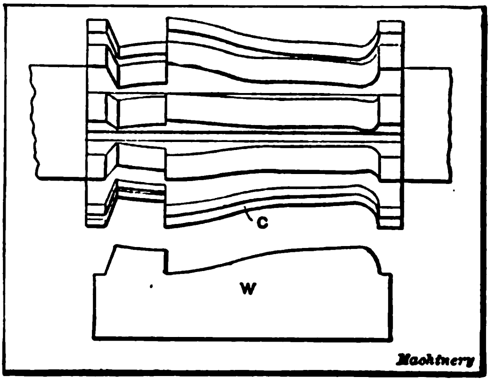

Fig. 16. Formed Cutter for Milling Part W

Of course, form milling is not economical, unless the number of parts wanted is sufficient to warrant the expense of the formed cutter. Another form milling operation is shown in Fig. 15. The small levers *L* are finished on the edges to the required outline by cutter *C*. These levers are malleable castings and they are held in a vise *V* attached

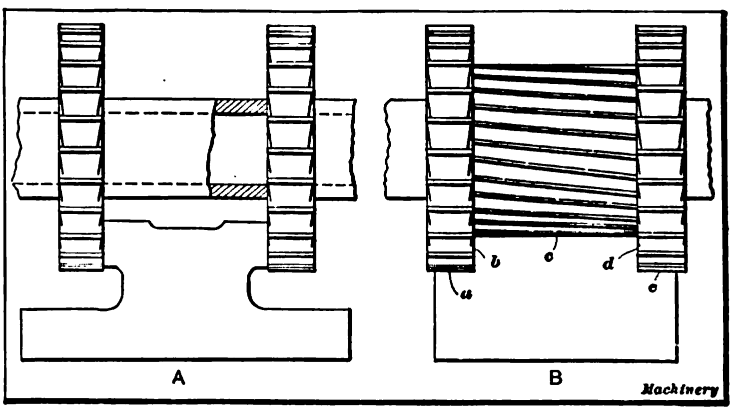

Fig. 17. (A) Straddle Milling. (B) Gang Milling

to the table. When milling, the cutter makes 50 R. P. M. and the feed is 0.053 inch, giving a table travel of 2.65 inches per minute.

Straddle and Gang Milling

When it is necessary to mill opposite sides of duplicate parts so that the surfaces will be parallel, two cutters can often be used simultaneously. This is referred to as straddle milling. The two cutters which form the straddle mill, are mounted on one arbor, as shown at *A*, Fig. 17, and they are held the right distance apart by one or more collars and washers. Side mills which have teeth on the sides as well as on the periphery (as shown at *C* and *D*, Fig. 8), are used for work of this kind. Duplicate pieces can be milled very accurately by this method, the finished surfaces being parallel and

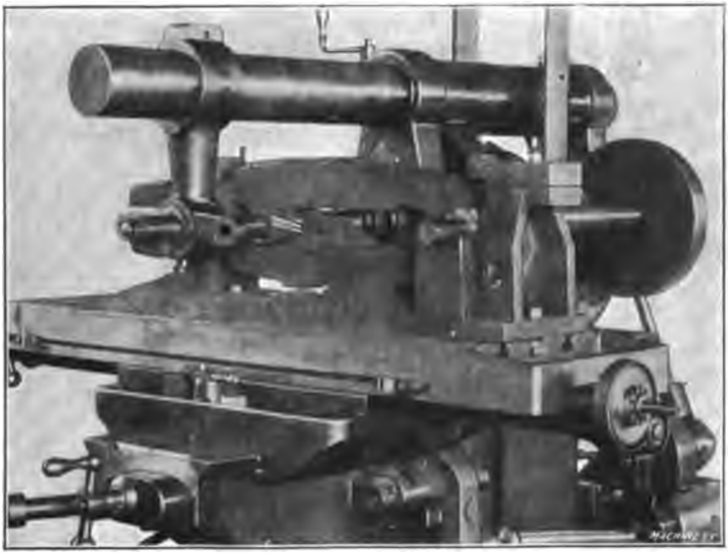

Fig. 18. Milling Slot of Crank-shaper Rocker-arm

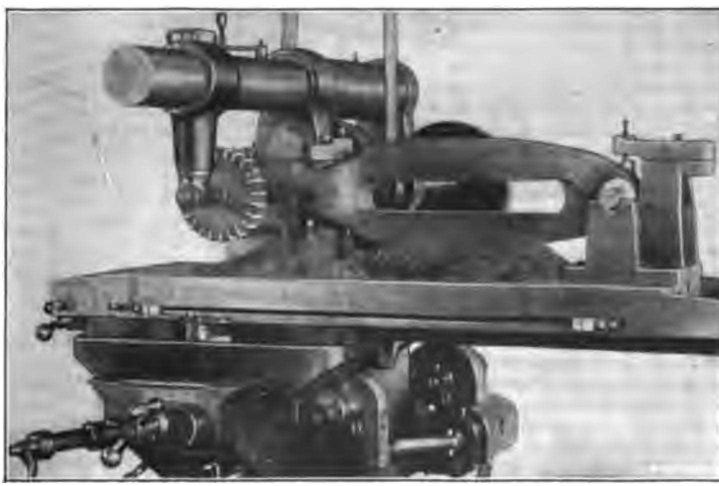

Fig. 19. Finishing End of Rocker-arm with Straddle Mill

to a given width within close limits. If the proper distance between the cutters cannot be obtained with the arbor collars available, fine adjustments are made by using metal or paper washers. When considerable accuracy is necessary, the final test for width should be made by taking a trial cut and measuring the finished surface. When the teeth on one side of each mill become dull, the opposite sides can be used by placing the right-hand cutter on the left-hand side and *vice versa;* that is by exchanging the positions of the mills on the arbor.

Figs. 18 and 19 show how the rocker-arm of a crank-shaper is finished by milling. This work requires two operations, one of which is a good example of straddle milling. A cylindrical cutter is used to mill both sides of the central slot, as shown in Fig. 18. The short slot at the left end of the rocker-arm is also milled by this same

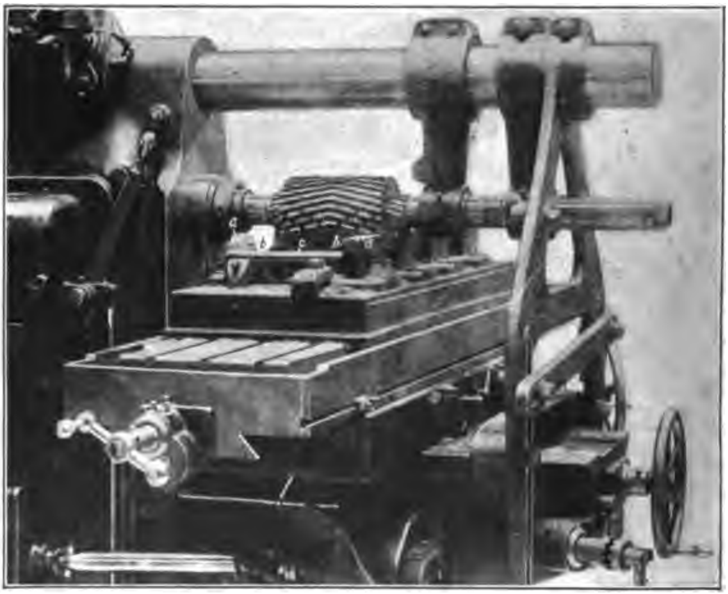

Fig. 20. Example of Gang Milling

cutter, as well as the raised pads on the top and bottom of the arm. This cutter is 2¾ inches in diameter, and when milling the long central slot, a 1/16 inch cut is taken at the top and bottom with a feed of 3 inches per minute. The second operation consists in milling the sides of the slotted end, as shown in Fig. 19. Two 8½-inch cutters of the inserted-tooth type, are used to form a straddle mill, which machines both sides at the same time. The time required for milling each arm is 2¼ hours. The casting is held in a special two-part fixture which is bolted to the table. That section of the fixture which supports the right-hand end, has V-shaped notches which receive a trunnion as shown, thus setting the casting vertically, whereas the left-hand end is clamped between setscrews that are adjusted to locate the casting horizontally. After this fixture is once set up and adjusted, very little time is required for setting one of these rocker-arms in position for milling, but it would be rather difficult to hold a casting of this shape by the use of ordinary clamps.

A great deal of the work done in a milling machine (especially of the plain horizontal type), is machined by a combination or "gang" of two or more cutters mounted on one arbor. This is known as gang milling. If a plain cylindrical cutter were placed between the side mills shown at *A* in Fig. 17, a gang cutter *B* would be formed for milling the five surfaces *a*, *b*, *c*, *d*, and *e*, simultaneously. This would not only be a rapid method, but one conducive to uniformity when milling duplicate parts.

An example of gang milling is shown in Fig. 20. Four castings are clamped to a fixture and are machined at one time by a gang-

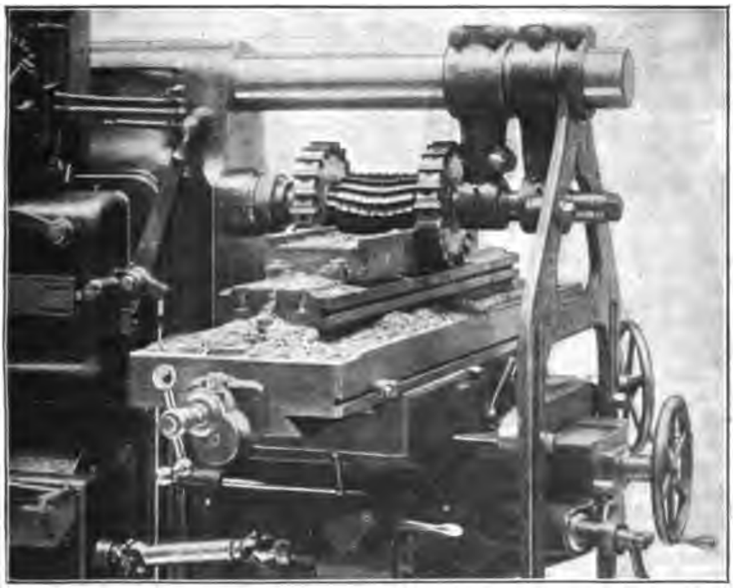

Fig. 21. Milling Top and Sides of Casting with Gang Mill

cutter which mills the top edges *a*, the inner sides *b*, and also the top surfaces *c* between the projecting ends. This cutter is formed of four independent units. The surfaces *c* are milled by two cutters of the same size, which have right- and left-hand spiral teeth, as shown, and the tops *a* of the end flanges are finished by two narrower cutters of smaller diameter. The two central cutters have a combined width of 9⅜ inches and they are 6 inches in diameter. The speed of the cutter is 32 revolutions per minute and the greatest depth of cut about 3/16 inch.

Another gang milling operation is shown in Fig. 21. The cutter, in this case, is similar to the one illustrated in Fig. 20, except that large side mills are employed for finishing the sides of the castings while the top surfaces are being milled. These side mills are 10½ inches in diameter and have inserted teeth or blades. The speed of a gang-mill which is composed of cutters that vary considerably in diameter, must be regulated to suit the largest cutters. In this instance, the cutter only makes 21 revolutions per minute, a comparatively slow speed being necessary owing to the large side mills.

Gang milling is usually employed when duplicate pieces are milled in large quantities, and the application of this method is almost unlimited. Obviously, the form of a gang-cutter and the number of cutters used, depends altogether on the shape of the part to be milled. Gang-cutters are sometimes made by combining cylindrical and formed cutters, for producing an irregular or intricate profile.

Fig. 22 shows an example of gang milling in which two castings are placed side by side and rough milled simultaneously. The gang-

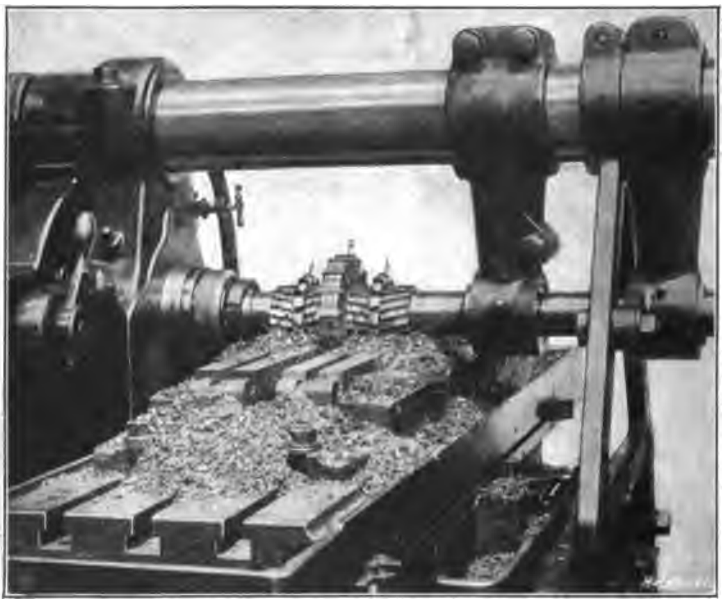

Fig. 22. Milling Two Parts Simultaneously

cutter is composed of seven units, as the illustration shows. The large inserted-tooth cutter *a* in the center mills the inner sides of each casting, while the top surfaces are machined by the four cylindrical cutters shown. The cutters *b*, placed between the cylindrical cutters, mill channels or grooves which, by another operation, are formed into T-slots. All of these cutters are made of high-speed steel and the speed is 36 revolutions per minute. The work table feeds 0.112 inch per revolution, thus giving a travel of 4 inches per minute. Two of these castings are milled in 18 minutes, which includes the time required for clamping them to the machine.

It should be noted that when more than one spiral toothed cylindrical cutter is mounted on one arbor, for forming a gang-mill, cutters having both right- and left-hand spirals are used. For example the central part of the cutter shown in Fig. 20 is composed of two cutters having teeth which incline in opposite directions; that is the teeth of one cutter form a right-hand spiral and the teeth of the other cutter, a left-hand spiral. The reason why cutters of opposite hand are used, is to equalize the end thrust, the axial pressure caused by the angular position of the teeth of one cutter being counteracted by a pressure in the opposite direction from the other cutter.

Still another gang milling operation is shown in Fig. 23. In this instance, the top surface of the casting is milled and two tongue-pieces are formed by the central gang of five cutters, which are of the straight-tooth type and vary in diameter to give the required outline. The large angular mills at the ends finish the sloping sides

Fig. 23. Another Gang Milling Operation

of the casting, as the illustration indicates. The speed of rotation is 33 revolutions per minute, and the table travel, 6⅛ inches per minute. The feeding movement is to the left or against the rotation of the cutters, which is also true of Figs. 20, 21 and 22.

End and Face Milling

All of the milling operations referred to so far have been performed with cutters mounted on an arbor, the latter being driven by the spindle and supported by an out-board bearing. For some classes of work, the cutter, instead of being placed on an arbor, is attached directly to the machine spindle. End mills, for instance, are driven in this way, as previously mentioned, and large face milling cutters are also fastened to the end of the spindle. Surfaces are frequently machined by end mills, when using a horizontal milling machine, because it would not be feasible to use a cutter mounted on an arbor.

Sketch *A*, Fig. 24, illustrates how a pad or raised part on the side of a casting would be machined by an end mill. The surface is milled by the radial teeth on the end as well as by the axial teeth, as the work is traversed at right-angles to the cutter. Occasionally, an end mill is used in this way, after the top surface of a casting has been milled with one or more cutters mounted on an arbor, in order to finish the work at one setting, which not only saves time, but insures accuracy of alignment between the finished parts.

Sketch *B* indicates how an end mill is used for cutting grooves in a vertical surface. The cutter is set to the required depth by moving the table inward, and then the longitudinal feed is engaged, which causes a groove to be milled equal in width to the diameter of the

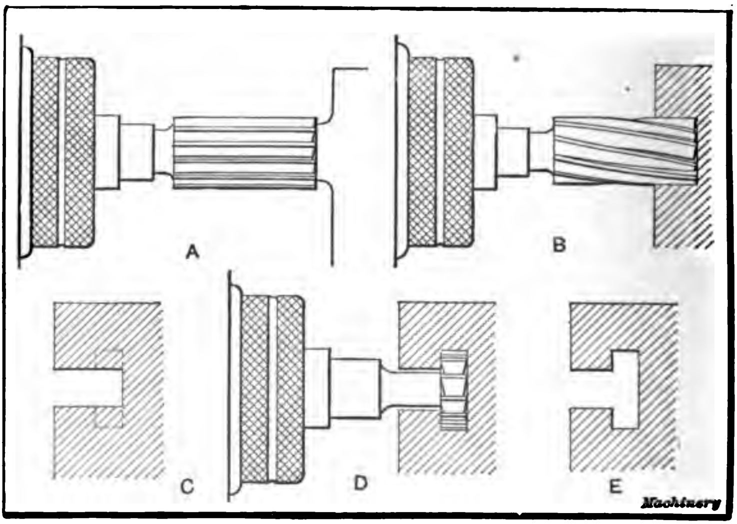

Fig. 24. End Milling—Diagrams illustrating use of T-slot Cutter

cutter. As mentioned in Chapter III, if it is necessary to start a groove by sinking the cutter in to depth, without first drilling a hole as a starting place, the form of mill shown at *C*, Fig. 9, is preferable, as the radial end-teeth have cutting edges on the inside so that they can more readily cut a path from the starting point, when the work is fed laterally. An end mill should not be used for cutting grooves or slots if a regular cutter mounted on an arbor can be employed.

When milling T-slots such as are cut in the tables of machine tools for receiving clamping bolts, a plain slot is first milled to the depth of the T-slot as shown by sketch *C*, Fig. 24. This preliminary operation is usually done with a side mill of the proper width, while the work is clamped in a horizontal position. The enlarged or T-section is then milled as shown by sketch *D*, the casting being clamped in a vertical position, provided a horizontal milling machine is employed. The T-slot cutter enlarges the bottom of the straight groove, as indicated at *E*, which shows the finished slot.

Fig. 25 shows how an end mill is used for cutting an elongated slot in a link *L*. Prior to milling, holes are drilled at each end of the slot, one of which forms a starting place for the milling cutter. The link is held in a vise and the metal between the two holes is

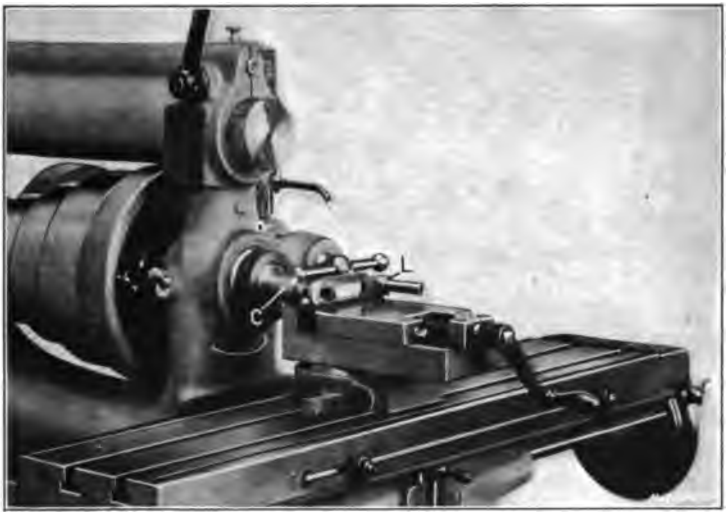

Fig. 25. Milling Slot with End Mill

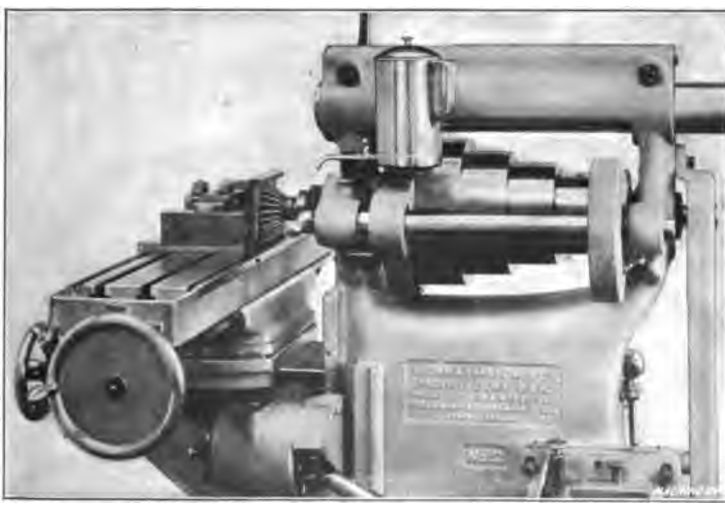

Fig. 26. Milling a Dovetail Groove

cut away to form the slot, by feeding the table lengthwise. By means of the automatic stop, the feed is disengaged when the cutter has reached the end of the slot. The shank of the end mill is not inserted directly into the spindle of the machine, but into a reducing collet *C*. This collet fits into the taper hole of the spindle and is bored out to receive the end mill, the shank of which is too small to be placed directly in the spindle.

One method of machining a dovetail groove for a slide is shown in Fig. 26, which illustrates another end milling operation. The cutter used for this work has radial teeth on the end, and also angular teeth which incline 30 degrees with the axis of the cutter. The radial end teeth mill the bottom or flat surface of the groove and the angular teeth finish the sides and form the dovetail. The way the casting is clamped to the table is plainly shown by the illustration. The cutter is mounted on an arbor which is inserted in the spindle.

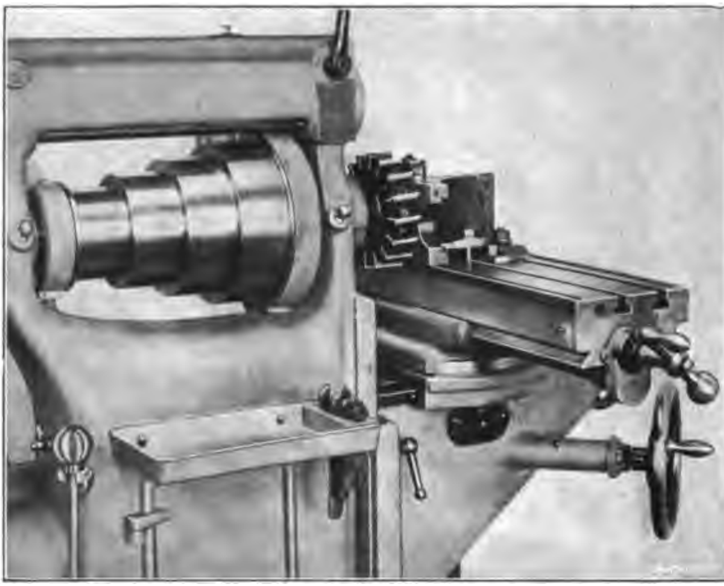

Fig. 27. Finishing Vertical Surface with Face Mill

An end milling operation is shown in Fig. 27, which differs from those previously referred to, in that a large face cutter is used, which, in this instance, is screwed onto the end of the spindle. Large face mills are employed on horizontal machines for milling flat surfaces that lie in a vertical plane. Some cutters of this type, instead of being threaded directly to the spindle, are mounted on a short arbor, whereas other designs fit over interchangeable sleeves threaded to the spindle. The casting illustrated in Fig. 27 is clamped against an angle-plate to hold it securely, and a strap at the rear prevents it from shifting backward when a cut is being taken. The surface is milled by feeding the table longitudinally, and only one cut is necessary, as the work is finished afterward by a surface grinder. The number of cuts required, when milling, is governed by the amount of metal to be removed and also by the accuracy of the work, as well as the quality of finish desired.

CHAPTER V

UNIVERSAL MILLING MACHINE

The milling machine illustrated in Fig. 28 is referred to as a universal type, because it is adapted to such a wide variety of milling operations. The general construction is similar to that of a plain milling machine, although the universal type has certain adjustments and attachments which make it possible to mill a greater variety of work. On the other hand, the plain machine is more simple, and, for a given size, more rigid in construction; hence, it is better adapted for milling large numbers of duplicate parts in connection with manufacturing operations.

The universal machine has a column *C*, a knee *K* which can be moved vertically on the column, and a table with cross and longitudinal adjustments the same as a machine of the plain type. There is a difference, however, in the method of mounting the table on the knee. As explained in Chapter I, the table of a plain machine is carried by a saddle *Z* (see Fig. 2), which is free to move in a crosswise direction, whereas, the table"s line of motion is at right angles to the spindle. The table of a universal machine also has these movements, and, in addition, it can be fed at an angle to the spindle by swiveling saddle *Z*, Fig. 28, on clamp-bed *B*, which is interposed between the saddle and knee. The circular base of the saddle has degree graduations which show the angle at which the table is set. When the zero mark of these graduations coincides with the zero mark on the clamp-bed, the table is at right angles to the spindle. The saddle is held rigidly to the clamp-bed, in whatever position it may be set, by bolts which must be loosened before making an adjustment. The utility of this angular adjustment will be explained later in connection with examples of universal milling operations.

The feed motion is derived from the main spindle, which is connected with the feed change mechanism enclosed at *F* by a chain and sprockets located inside of the column. The power is transmitted from *F* to gear-case *A* containing the reverse mechanism operated by lever *R*, which serves to start, stop, or reverse all feeds. Levers *T* and *V* control the automatic transverse and vertical feeds, respectively, and the longitudinal feed to the table is controlled or reversed by lever *L*. The longitudinal feed is automatically tripped by the adjustable dogs or tappets *D*. The vertical feed also has an automatic trip mechanism operated by dogs D_1. The table can be traversed by handles at each end and the cross movement is effected by wheel *E*. The vertical hand adjustment for the knee is controlled by handwheel *G*, which operates a telescopic elevating screw *H*. Adjustable dials, graduated to thousandths of an inch, indicate the longitudinal, traverse and vertical movements of the table. The spindle on this machine is driven by pulley *P*. Speed changes are obtained by shifting levers *O*, *Q* and *S*, and the speed obtained for any position of the levers is shown by a table or plate attached to the column. The machine is started or stopped by lever *U* which operates a clutch that engages or disengages belt pulley *P*. There is an outboard support for the arbors, having a bronzed-bush bearing and also an ad-

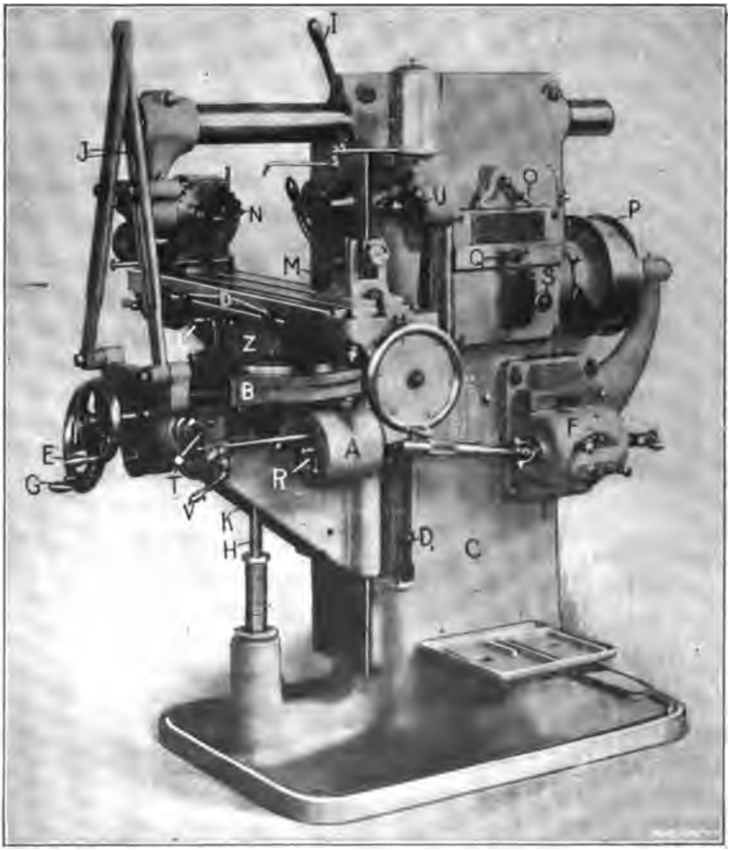

Fig. 28. Brown & Sharpe Universal Milling Machine

justable center (similar to a lathe center), which is inserted in the centered end of the arbor when in use. The overhanging arm is rigidly clamped in any position by lever *I*, and it can be pushed back out of the way when the arbor support is not needed. The arm braces *J* are attached to a clamp fastened to the top of the knee.

Indexing or Spiral Head

We have now considered, in a general way, the principal features of a universal machine, so far as the machine itself is concerned, but before referring to its practical application, the construction and use of the attachment seen at *N* should be explained. This attachment is called the spiral or indexing head and it forms a part of the equipment of all milling machines of the universal type. The spiral head, when in use, is bolted to the table of the machine. It is employed in connection with the foot-stock *M*, when milling work that must be supported between the centers. The spiral head is also used independently, that is, without the foot-stock, in which case the work is usually held in a chuck attached to the spindle. By means of the spiral head, the circumference of a cylindrical part can be divided into almost any number of equal spaces, as, for example, when it is necessary to cut a certain number of teeth in a gear. It is also used for imparting a rotary motion to work, in addition to the longitudinal feeding movement of the table, for milling helical or spiral grooves.

As a great deal of the work done in a universal milling machine requires a spiral head, its construction and operation should be thoroughly understood. The general arrangement of the design used on Brown & Sharpe machines is shown in Fig. 29. The main spindle *S* has attached to it a worm-gear *B* (see the cross-sectional view) which meshes with the worm *A* on shaft *O*, and the outer end of this shaft carries a crank *J* which is used for rotating the spindle when indexing. Worm-wheel *B* has forty teeth and a single-threaded worm *A* is used, so that forty turns of the crank are required to turn spindle *S* one complete revolution; hence, the required number of turns to index a fractional part of a revolution is found by simply dividing forty by the number of divisions desired. (As there are different methods of indexing, this subject is referred to separately to avoid confusion). In order to turn crank *J* a definite amount, a plate *I* is used, having several concentric rows of holes that are spaced equidistant in each separate row. When indexing, spring-plunger *P* is withdrawn by pulling out knob *J* and the crank is rotated as many holes as may be required. The number of holes in each circle of the index plate varies, and the plunger is set in line with any circle by adjusting the crank radially. One index plate can be replaced by another having a different series of holes, when this is necessary in order to obtain a certain division.

Sometimes it is desirable to rotate the spindle *S* independently of crank *J* and the worm gearing; then worm *A* is disengaged from worm-wheel *B*. This disengagement is effected by turning knob *E* about one-quarter of a revolution in a reverse direction to that indicated by the arrow stamped on it, thus loosening nut *G* which holds eccentric bushing *H*. Both knobs *E* and *F* are then turned at the same time, which rotates bushing *H* and throws worm *A* out of mesh. The worm is re-engaged by turning knobs *E* and *F* in the direction of the arrow; knob *E* should then be tightened with a pin wrench. The worm is disengaged in this way when it is desired to index rapidly by hand, and when the number of divisions required can be obtained by using plate *C*. This plate is attached to the spindle and contains a circle of holes which are engaged by pin *D*, operated by lever D_1, (see cross-section). This direct method of indexing can often be employed to advantage when milling flutes, reamers, taps, etc., but, as only a limited number of divisions can be obtained by this method, it is necessary to use crank *J* and index plate *I* for most of the work requiring indexing.

When the spiral head is used in connection with the milling of helical grooves (which are commonly but erroneously called spiral grooves), the main spindle *S* is rotated slowly by change gears as

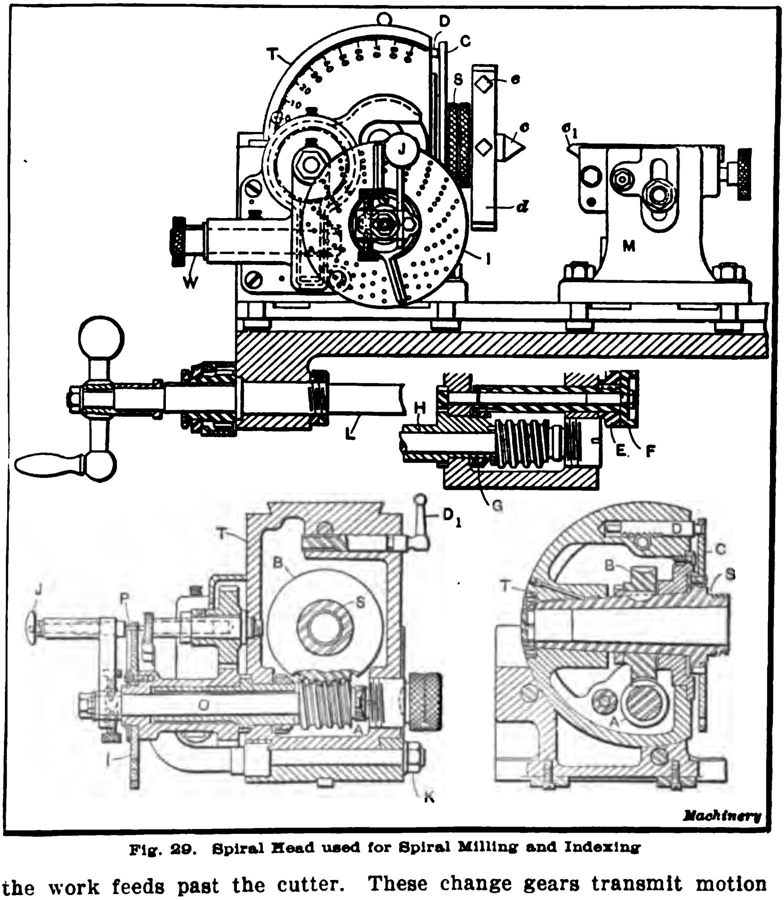

Fig. 29. Spiral Head used for Spiral Milling and Indexing

the work feeds past the cutter. These change gears transmit motion from the table feed-screw *L* to shaft *W*, which, in turn, drives spindle *S* through spiral gears, spur gears and the worm-gearing *A* and *B*. The method of determining what size gears to use for milling a helix of given lead is explained in Part II of this treatise.

There is one other feature of the spiral head which should be referred to, and that is the angular adjustment of the main spindle. It is necessary for some classes of taper work to set the spindle at an angle with the table, and this adjustment is made by loosening bolts *K* and turning the circular body *T* in its base. The angle to which the head is set, is shown by graduations reading to ½ a degree. The spindle of this particular head can be set to any angle between 10 degrees below the horiontal and 5 degrees beyond the perpendicular. This adjustment is needed when milling taper work which must be set at an angle with the table.

The footstock *M*, which is used in connection with the spiral head when milling parts that are supported between centers, is also adjustable so that the centers c and c_1 can be aligned when milling flutes in taper reamers, etc. The foot stock center is set in line with center c, when the latter is in a horizontal position, by two taper pins on the rear side. When it is desired to set the center at an angle, these pins are removed and the nuts shown are loosened; the center can then be elevated or depressed by turning a nut at the rear, which moves the center through a rack and pinion.

Work mounted between the centers is caused to rotate with the spindle, either when indexing or when cutting helical grooves, by a dog which engages driver plate *d*. The tail of the dog should be confined by a set-screw *e*, to prevent any rocking movement of the work.

Spiral heads of different makes vary more or less in their arrangement, which is also true of milling machines, or, in fact, of any other kinds of machine tools. Machines or attachments of a given type, however, usually have the same general features, and if one or two typical designs are understood, it is comparatively easy to become familiar with other makes. Of course, the operator of any machine tool should be acquainted with its general construction, but it is even more important to have a clear understanding of its appplication to various kinds of work.

CHAPTER VI

USE OF THE SPIRAL HEAD—SIMPLE INDEXING

The spiral head is ordinarily used for such work as milling the teeth in milling cutters, fluting reamers and taps, cutting teeth in small gears, or for holding any part which must be rotated either at the time it is being milled or between successive cuts. As an example of the work that requires indexing between successive cuts, suppose we have a cylindrical milling cutter blank which requires 18 equally-spaced teeth to be cut across the circumference parallel to the axis and with the front face of each tooth on a radial line. The first step would be to press the blank on an arbor, assuming that it has previously been bored and turned to the proper diameter. The arbor and work is then placed between the centers of the spiral head and footstock, as shown in Fig. 30. After attaching a dog to the left-hand end, set-screw *e* is set against the dog to take up any play between these parts, and the footstock center is adjusted rather tightly into the center of the arbor to hold the latter securely.

The form of cutter to use is the next thing to consider. As the grooves which form the teeth are angular, the cutter must have teeth which incline to the axis a corresponding amount. A cutter of this type which is largely used for milling straight teeth, is shown at *E* in Fig. 10. The cutting edges (in this instance) have an inclination of 60 degrees with the side, and the cutter is known as a 60-degree, single-angle cutter, to distinguish it from the double-angle type, the use of which will be mentioned later. After the cutter is mounted on an arbor *b*, as indicated in Fig. 30, the straight side or vertical face is set in line with the center of the arbor as shown by the detail end-view *A*. There are several ways of doing this: A simple method is to draw a horizontal line across the end of the blank with an ordinary surface gage (the pointer of which should be set to the height of the spiral head center) and then rotate the work one-quarter of a revolution to place the line in a vertical position, after which the side of the cutter is set to coincide with this line. The side of the cutter can also be set directly by the centers. The table is first adjusted vertically and horizontally until the cutter is opposite the spiral head center. A scale or straightedge held against the side of the cutter is then aligned with the point of the center, by shifting the table laterally.

The next step is to set the cutter to the right depth for milling the grooves. The depth is regulated according to the width which the tooth must have at the top, this width being known as the land. The usual method is to raise the knee, table and blank far enough to take a cut, which is known to be somewhat less than the required depth. The blank is then indexed or turned 1/18 of a revolution (as there are to be 18 teeth) in the direction shown by arrow *a*, and a second groove is started as at *B*. Before taking this cut, the blank is raised until the required width of land is obtained. The second groove is then milled, after which the blank is again indexed 1/18 of a revolution, thus locating it as at *C*. This operation of cutting a groove and indexing is repeated, without disturbing the position of the cutter, until all the teeth are formed as shown at *D*.

Plain or Simple Indexing

The dividing of a cylindrical part into an equal number of divisions by using the spiral head, is called indexing. The work is rotated

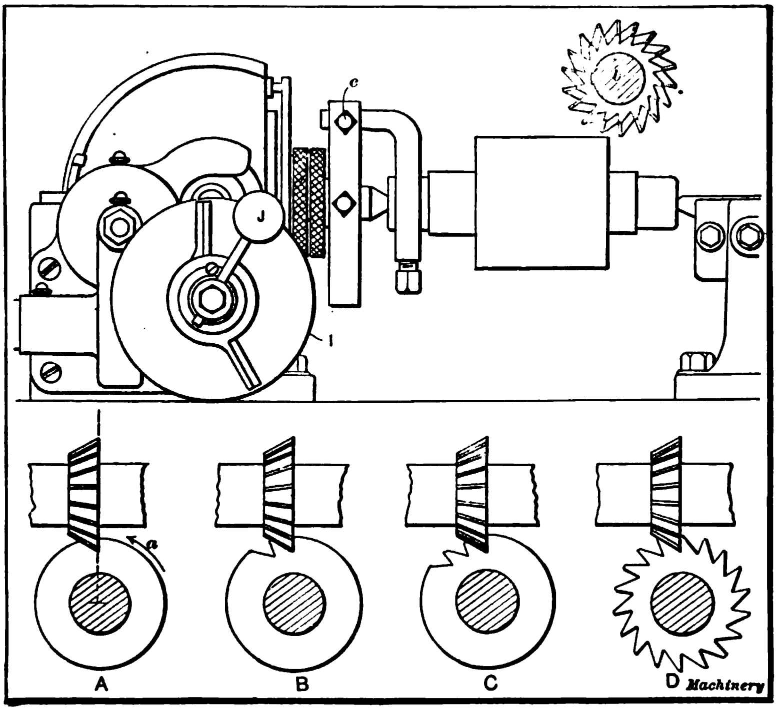

Fig. 30. Views illustrating use of Spiral Head for Indexing

whatever part of a revolution is required, by turning crank *J*. As previously explained, the shaft carrying this crank has a worm which meshes with a worm-wheel on the spiral-head spindle. As the worm is single-threaded, and as there are 40 teeth in the worm-wheel, 40 turns of the crank are necessary to rotate the spindle one complete revolution. If only a half revolution were wanted, the number of turns would equal 40 ÷ 2, or 20, and for 1/12 of a revolution, the turns would equal 40 ÷ 12, or 3-1/3, and so on. In each case, the number of turns the index crank must make, is obtained by dividing the number of turns required for one revolution of the index-head spindle, by the number of divisions wanted. As the number of turns for one revolution is always 40, the rule then is as follows: Divide 40 by the number of divisions into which the periphery of the work is to be divided, to obtain the number of turns for the index crank.

By applying this rule to the job illustrated in Fig. 30, we find that the crank *J* must be turned 2-2/9 times to index the cutter from one tooth to the next, because there are 18 teeth, or divisions, and 40 ÷ 18 = 2-2/9. The next question that naturally arises is, how is the crank to be rotated exactly 2/9 of a turn? This is done by means of the index plate *I*, which has six concentric circles of holes. These holes have been omitted in this illustration owing to its reduced scale, but are shown in the detail view, Fig. 31. The number of holes in the different circles of this particular plate are 33, 31, 29, 27, 23, and 21. Now, in order to turn crank *J* 2/9 of a revolution, it is first necessary to adjust the crank radially until the latch-pin is opposite a circle having a number of holes exactly divisible by the denominator of the fraction (when reduced to its lowest terms) representing the part of a turn required. As the denominator of the fraction in this case is 9, there is only one circle on this plate that can be used, namely, the 27-hole circle. In case none of the circles have a number which is exactly divisible by the denominator of the fractional turn required, the index plate is replaced by another having a different series of holes. The number of holes that the latch-pin would have to move for 2/9 of a turn equals 27 × 2/9, or 6 holes. After the latch-pin is adjusted to the 27-hole circle, the indexing of the cutter 1/18 of a revolution is accomplished by pulling out the latch-pin and turning the crank 2 complete turns, and then 2/9 of a turn, or what is the same thing, 6 holes in a 27-hole circle. After each tooth groove is milled in the cutter, this indexing operation is repeated, the latch-pin being moved each time 2-2/9 of a turn from the position it last occupied, until the work has been indexed one complete revolution and all the teeth are milled.

Use of the Sector

After withdrawing the latch-pin, one might easily forget which hole it occupied, or become confused when counting the number of holes for the fractional turn, and to avoid mistakes of this kind, as well as to make it unnecessary to count, a device called a sector is used. The sector has two radial arms *A* and *B* (Fig. 31), which have an independent angular adjustment for varying the distance between them. The sector is used by so adjusting these arms that when the latch-pin is moved from one to the other, it will traverse the required number of holes for whatever fractional turn is necessary. Arm *A* is first set against the left side of the latch-pin, and then arm *B* is shifted to the right until there are 6 holes between it and the latch-pin, as shown in the illustration. When indexing, the latch-pin is withdrawn from hole *a* and the crank is first given two complete turns and then 2/9 of a turn by moving the crank until the latch-pin enters hole *b* adjacent to the arm *B* of the sector. The sector is then revolved until arm *A* again rests against the pin, as shown by the dotted lines. After the next groove is milled, the crank is turned two complete revolutions as before, with hole *b* as a starting point, and then 2/9 of a revolution, by swinging the latch-pin around to arm *B* and into engagement with hole *c*. This operation of indexing and then moving the sector is repeated after each tooth is milled, until the work has made one complete revolution.

When setting the sector arms, the hole occupied by the latch-pin should not be counted or, in other words, the arms should span one

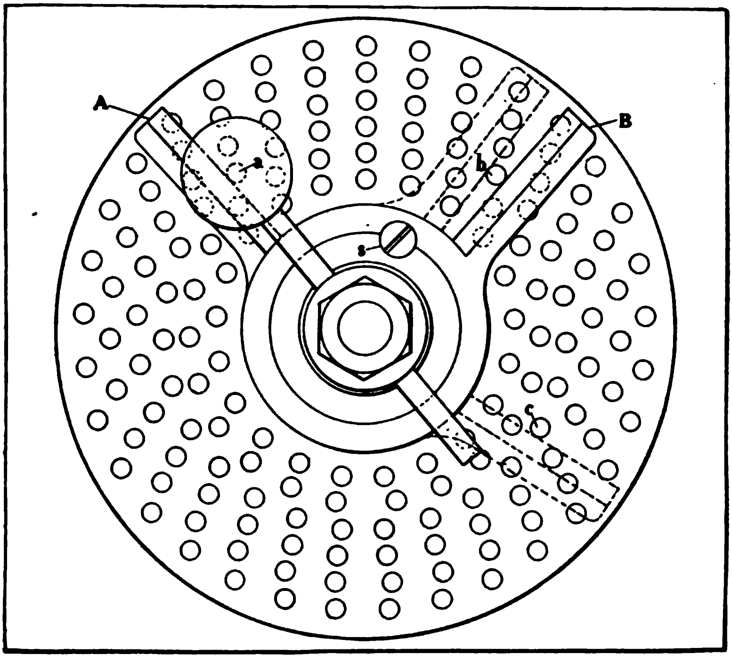

Fig. 31. Diagram showing how Sector is used when Indexing

more hole than the number needed to give the required fractional turn. In the example referred to, 6 holes in the 27-hole circle are required, but the sector arms are adjusted to span 7 holes or 6 spaces, as shown in the illustration. The two arms are locked in any position by tightening the small screw *s*. The sectors now applied to spiral heads made by the Brown & Sharpe Mfg. Co., have graduations which make it unnecessary to count the holes when adjusting the sector arms. The setting is taken directly from the index table accompanying the machine, the sector being adjusted to whatever number is given in the column headed "Graduation."

In actual practice, the number of turns of the index crank for obtaining different divisions, is determined by referring to index tables. These tables give the numbers of divisions and show what circle of holes in the index plate should be used, and also the turns or fractional part of a turn (when less than one revolution is necessary) for the index crank. The fractional part of a turn is usually given as a fraction having a denominator which equals the number of holes in the index circle to be used, whereas the numerator denotes the number of holes the latch-pin should be moved, in addition to the complete revolutions, if one or more whole turns are required. For example: the movement for indexing 24 divisions would be given as 1-26/39 of a turn, instead of 1-2/3, the denominator 39 representing the number of holes in the index circle, and 26 the number of holes that the crank must be moved for obtaining 2/3 of a revolution, after making one complete turn.

Indexing for Angles

Sometimes it is desirable to index a certain number of degrees instead of a fractional part of a revolution. As there are 360 degrees in a circle and 40 turns of the index crank are required for one revolution of the spiral-head spindle, one turn of the crank must equal $\frac{360}{40} = 9$ degrees. Therefore, two holes in an 18-hole circle, or three holes in a 27-hole circle, is equivalent to a one-degree movement, as this is 1/9 of a turn. If we want to index 35 degrees, the number of turns the crank must make equals $35 \div 9 = 3\text{-}8/9$, or three complete turns and 8 degrees. As a movement of two holes in an 18-hole circle equals one degree, a movement of 16 holes is required for 8 degrees. If we want to index 11½ degrees, the one-half degree movement is obtained by turning the crank one hole in the 18-hole circle, after the 11 degrees have been indexed by making one complete revolution (9 degrees), and four holes (2 degrees). Similarly, one and one-third degree can be indexed by using the 27-hole circle, three holes being required to index one degree, and one hole, one-third degree.

When it is necessary to index to minutes, the required movement can be determined by dividing the total number of minutes represented by one turn of the index crank or 540 ($9 \times 60 = 540$), by the number of minutes to be indexed. For example, to index 16 minutes requires approximately 1/34 turn ($540 \div 16 = 34$, nearly), or a movement of one hole in a 34-hole circle. As the 33-hole circle is the one nearest to 34, this could be used and the error would be very small.

The following is a general rule for the approximate indexing of angles, assuming that forty revolutions of the index crank are required for one turn of the spiral-head spindle:

Divide 540 by the number of minutes to be indexed. If the quotient is nearly equal to the number of holes in any index circle available, the angular movement is obtained by turning the crank one hole in this circle; but, if the quotient is not approximately equal, multiply it by any trial number which will give a product equal to the number of holes in one of the index circles, and move the crank in the circle as many holes as are represented by the trial number.

If the quotient of 540 divided by the number of minutes to be indexed, is greater than the largest indexing circle, it is not possible to obtain the movement by the ordinary method of simple indexing.

Use of Chuck on the Spiral Head

It is often necessary to use a spiral head in connection with milling of parts which cannot be held between centers and must be attached directly to the spiral head spindle. A common method of holding work of this kind is to place it in a chuck which is screwed onto the spiral head spindle. An example of chuck work is shown in Fig. 32. The operation is that of milling a square head on bolt *B*. As the illustration shows, the spiral head spindle is set in a vertical position. This is done by loosening the clamp bolts *C* and turning the head 90 degrees, as shown by the graduations on the front side.

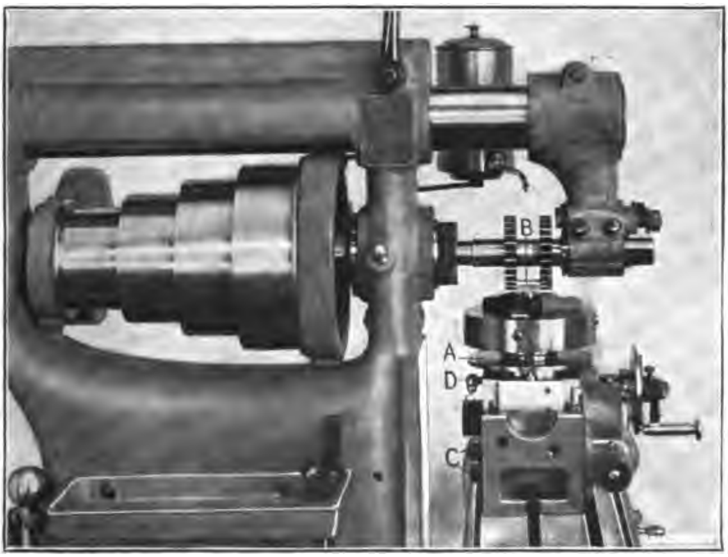

Fig. 32. Straddle Milling a Square Bolt-head

These clamp bolts should be tightened after the adjustment is made. The bolt is held in a three-jawed chuck and the body of the bolt extends into the hollow spindle of the spiral head. The square bolt head is machined to the required width by a straddle mill. One passage of this mill finishes two sides and then the spiral head spindle is indexed ¼ of a turn for milling the remaining sides. This indexing is done by using plate *A* which is attached directly to the spindle. The latch-pin engaging this plate is withdrawn by lever *D* and then the spindle and chuck are turned ¼ of a revolution, after which the latch-pin is again moved into engagement. This direct method of indexing requires little time and is used for simple operations of this kind, whenever the required movement can be obtained.

There is quite a variety of work which is milled either while held in a chuck or on some form of arbor inserted in the spiral head spindle. Whether a chuck or arbor is used, depends on the shape of the work, and, in some instances, on the nature of the milling operation. Chucks are frequently employed for holding cylindrical parts that are too long to go between the centers, but are small enough to pass through the hole in the spiral head spindle. The foot-stock

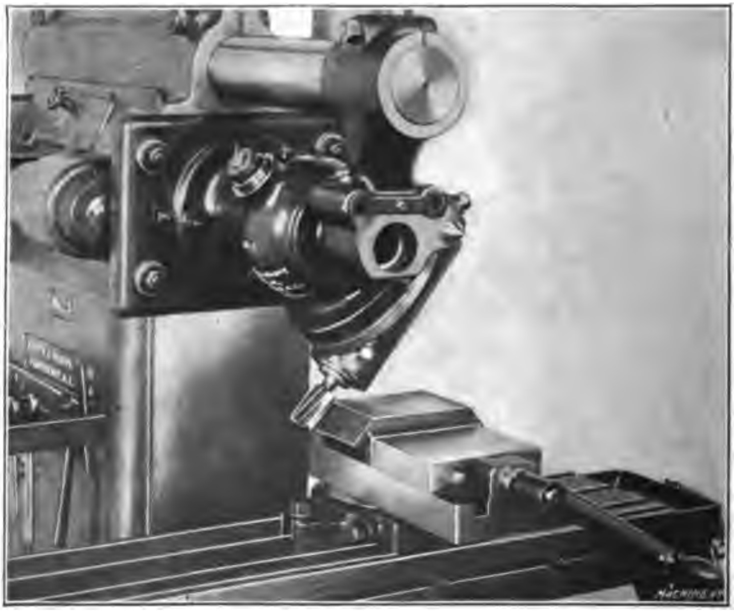

Fig. 33. Vertical Attachment applied to a Horizontal Milling Machine

center is used to support work of this class whenever feasible. When it is necessary to hold a part true with a bored hole, arbors of the expanding type are often used. These have a taper shank which fits the taper hole in the spindle, and the outer end is so arranged that it can be expanded tightly into the hole in the work. Small chucks of the collet type are sometimes used for holding small parts, instead of a jaw chuck.

CHAPTER VII

ATTACHMENTS FOR THE MILLING MACHINE

The range of a milling machine or the variety of work it is capable of doing, can be greatly extended by the use of special attachments. Many of these are designed to enable a certain type of milling machine to perform operations that ordinarily would be done on a different machine; in other words, the attachment temporarily converts one type of machine into another. There are quite a number

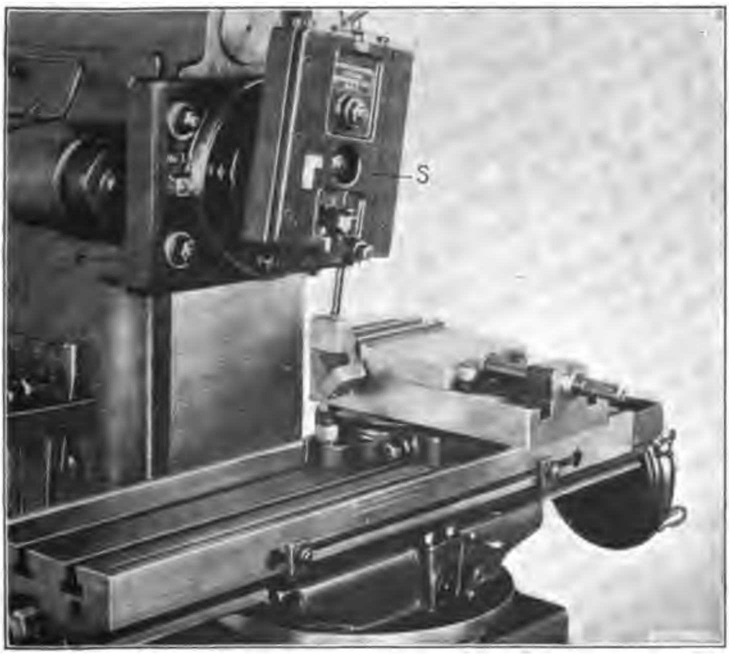

Fig. 34. Slotting Attachment applied to a Milling Machine

of different attachments for the milling machine, some of which are rarely used in the average shop. There are, however, three types that are quite common; namely, the vertical spindle milling attachment; the slotting attachment; and the circular milling and dividing attachment.

Vertical Milling Attachment

The way a vertical spindle milling attachment is applied to a horizontal milling machine is shown in Fig. 33. The base of the attachment is securely clamped to the column of the machine by four bolts and the outer end is inserted in the regular arbor support. The spindle is driven through bevel gears connecting with a horizontal shaft inserted in the main spindle of the machine. The spindle of this particular attachment can be set at any angle in a vertical or horizontal plane, and its position is shown by graduations reading to degrees. For the operation illustrated, which is that of milling the edge of the steel block shown, the spindle is set at an angle of 45 degrees from the vertical. The block is held in an ordinary vise and it is fed past the cutter by using the cross feed. The opposite edge

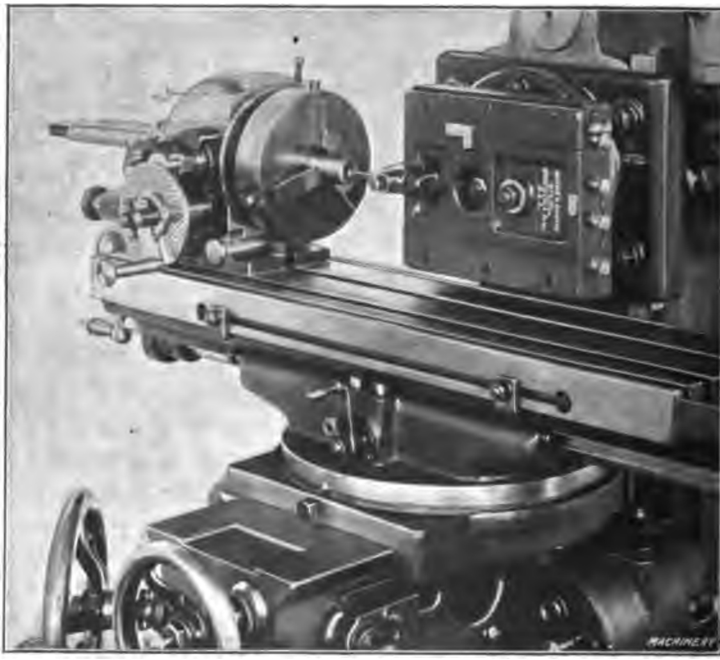

Fig. 35. Slotting Attachment finishing Square Hole in Long Rod held in Spiral Head

is milled by simply swinging the spindle 45 degrees to the right of the vertical. Vertical attachments are used in connection with horizontal machines whenever it is desirable to have the cutter in a vertical or angular position. There are several different types designed for different classes of work. The style shown in the illustration is referred to as a universal attachment because of its two-way adjustment, and it can be used for a variety of purposes, such as drilling, milling angular slots or surfaces, cutting racks, milling keyseats, etc.

Slotting Attachment

The slotting attachment, as its name implies, is used for converting a milling machine into a slotter. The base *B* is clamped to the column of the machine as shown in Fig. 34. The tool slide *S*, which has a reciprocating movement like the ram of a slotter, is driven from the main spindle of the machine by an adjustable crank which enables the stroke to be varied. The tool slide can be set in any position from the vertical to the horizontal, in either direction, the angle being indicated by graduations on the base. When the attachment is in use, a slotting tool of the required shape is clamped to the end of the slide by the bolt shown, and it is prevented from being pushed upward by a stop that is swung over the top of the tool shank. Fig. 34 shows the attachment slotting a rectangular opening in a screw machine tool which is held in the vise. As this open-

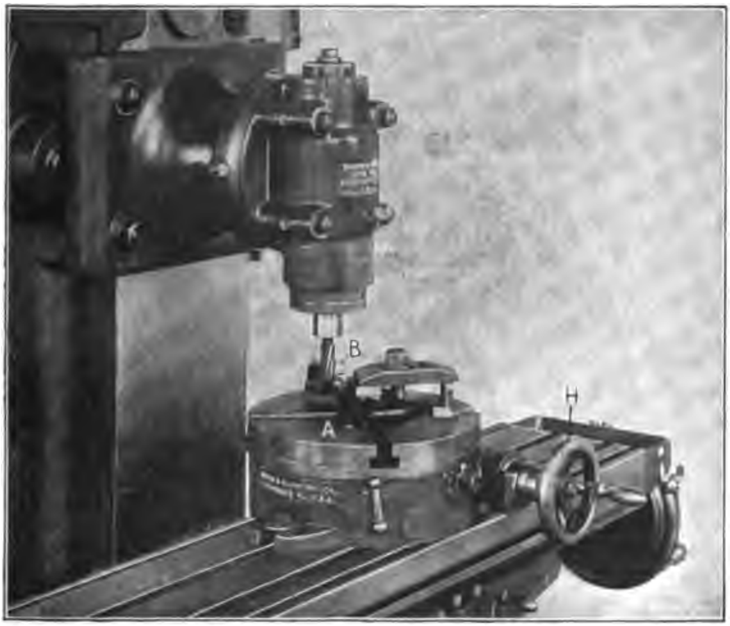

Fig. 36. Combined use of Vertical and Circular Milling Attachments

ing must be at an angle, the tool slide is inclined to the vertical, as shown. A previously drilled hole forms a starting place for the slotting tool.

Fig. 35 shows another application of the slotting attachment. The operation in this case is that of cutting a square hole in the end of a rod. As this rod is too long to be placed in a vertical position, it is inserted through the hollow spindle of the spiral head and is held in a three-jaw chuck as shown. The slotting attachment is swung around to the horizontal position, and after one side of the opening is finished, the rod is indexed ¼ of a turn by using the direct indexing plate attached to the spindle back of the chuck.

Circular Milling Attachment

A circular milling attachment is shown in Fig. 36. It is bolted to the machine and has a round table *A* which can be rotated for milling circular parts. This attachment is generally used in connection with the vertical spindle attachment, as shown in this illustration. The operation is that of milling a segment-shaped end on a small casting *B*. The bored hub of this casting is placed over a bushing in the center of the table, and is held by a clamp. The top or flat surface of the outer end is first milled, and then the table is raised for finishing the circular part as shown. The table of the attachment is given a circular feeding movement by turning hand-wheel *H*. Incidentally this view shows another type of vertical attachment which differs from the one illustrated in Fig. 33 in that it can only be adjusted at right-angles to the axis of the spindle. This type is designed for comparatively heavy vertical milling operations.

CHAPTER VIII

GASHING AND HOBBING A WORM-WHEEL IN A MILLING MACHINE

The universal milling machine is sometimes used for cutting the teeth in worm-wheels, although when there is much of this work to be done, regular gear-cutting machines are generally used. The worm itself should be finished first, as it can be used advantageously for testing the center distance when hobbing the worm-wheel. We shall assume that the worm has been made, and that the wheel blank has been turned to the required size.

The teeth of the worm-wheel are formed by two operations, which are illustrated in Figs. 37 and 38. First it is necessary to gash the blank and then the teeth are finished by hobbing. Gashing consists in cutting teeth around the periphery of the blank, which are approximately the shape of the finished teeth. This is done, preferably, by the use of an involute gear cutter of a number and pitch corresponding to the number and pitch of the teeth in the wheel. If a gear cutter is not available, a plain milling cutter, the thickness of which should not exceed three-tenths of the circular pitch, may be used. The corners of the teeth of the cutter should be rounded, as otherwise the fillets of the finished teeth will be partly removed.

As the worm which meshes with and drives the worm-wheel is simply a short screw, it will be apparent that if the axes of the worm-wheel and worm are to be at right angles to each other, the teeth of the wheel must be cut at an angle to its axis, in order to mesh with the threads of the worm. The method of setting the work and obtaining this angle will first be considered.

After the dividing head and tailstock have been clamped to the table and the cutter has been fastened on its arbor, the table is adjusted until the centers of the dividing head and the center of the cutter lie in the same vertical plane. If the cutter used has a center-line around its periphery, the table can be set by raising it high enough to bring the index head center in line with the cutter; the table can then be adjusted laterally until the center coincides with the center-line on the cutter. When the table is set, it should be clamped to the knee slide.

The blank to be gashed is pressed on a true-running arbor which is mounted between the centers of the dividing head and tailstock as illus-

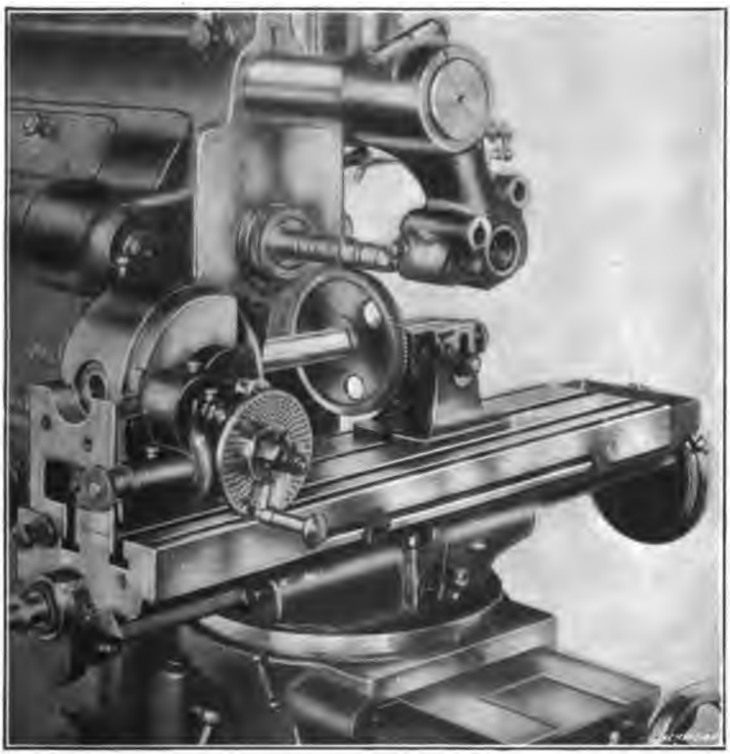

Fig. 37. Gashing a Worm-wheel in a Universal Milling Machine

trated in Fig. 37, and the driving dog is secured, to prevent any vibration of the work. The table is next moved longitudinally until a point midway between the sides of the blank is directly beneath the center of the cutter arbor. To set the blank in this position, place a square blade or straightedge against it first on one side and then on the other and adjust the table longitudinally until the distances between the blade and arbor are the same on both sides.

Angular Position of Table for Gashing

The table should now be set to the proper angle for gashing the teeth. This angle, if not given on the drawing, may be determined either graphically or by calculation. The first method is illustrated in

Fig. 39. Some smooth surface should be selected, having a straight edge as at *A*. A line having a length *B* equal to the lead of the worm thread, is drawn at right angles to the edge *A*, and a distance *C* is laid off equal to the circumference of the pitch circle of the worm. If the diameter of the pitch circle is not given on the drawing, it may be

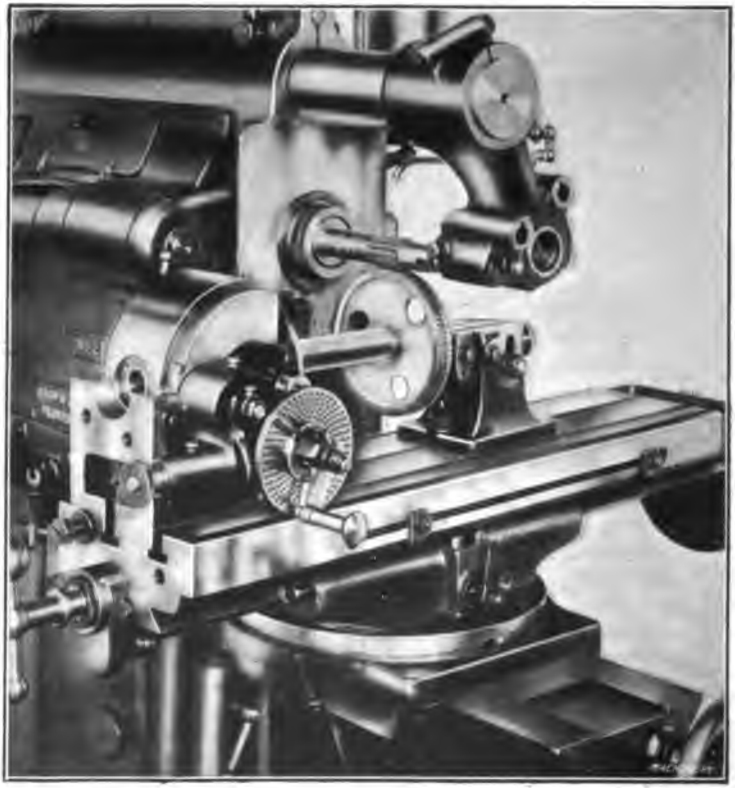

Fig. 38. Hobbing the Teeth of a Worm-wheel

found by subtracting twice the addendum of the teeth from the outside diameter of the worm. The addendum equals the linear pitch × 0.3183. The angle x is next measured with a protractor, as shown in the illustration. The table of the machine is then swiveled to a corresponding angle, as shown by the graduations provided on all universal milling machines. If the front of the table is represented by the edge *A*, and the worm has a right-hand thread, the table should be swiveled as indicated by the line *ab*; whereas if the worm has a left-hand thread, the table should be turned in an opposite direction.

The angle that the teeth of the worm-wheel make with its axis, or the angle to which the table is to be swiveled, may also be found by dividing the lead of the worm thread by the circumference of the pitch circle; the quotient will equal the tangent of the desired angle. This angle is then found by referring to a table of natural tangents.

Milling the Gashes in a Worm-wheel

When the table is set and clamped in place, as many gashes are cut in the periphery of the wheel as there are to be teeth. If the diameter of the cutter is no larger than the diameter of the hob to be used, the depth of the gashes should be slightly less than the whole depth of the tooth. This whole depth may be found by multiplying the linear pitch by 0.6866. Before starting a cut, bring the cutter into contact with the wheel blank, set the dial on the elevating screw at zero, and sink the cutter to the proper depth as indicated by the dial. The blank is then lowered to clear the cutter and indexed for gashing the next tooth.

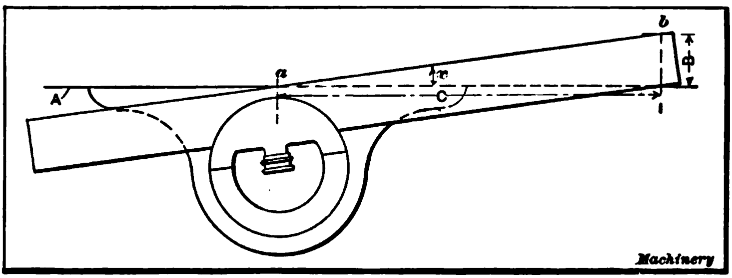

Fig. 39. Method of obtaining Helix Angle of Worm

When the cutter is larger than the hob, the whole depth of tooth should be laid off on the side of the blank, and a gash cut in to this line. The depth as indicated on the dial should then be noted and all the gashes cut to a corresponding depth.

Hobbing the Teeth of a Worm-wheel

When the gashing is finished, the table is set at right angles with the spindle of the machine, and the cutter is replaced with a hob, as shown in Fig. 38. The latter is practically a milling cutter shaped like the worm with which the wheel is to mesh, except that the thread on the hob has several lengthwise flutes or gashes to form cutting edges. The outside diameter of the hob and the diameter at the bottom of the teeth, are slightly greater than the corresponding dimensions of the worm, to provide clearance between the worm and worm-wheel. Before hobbing, the dog is removed from the arbor to permit the latter to turn freely on its centers. The hob is then placed in mesh with the gashed blank, and the teeth of the worm-wheel are finished by revolving the blank and hob together. As the two rotate, the blank is gradually raised until the body of the hob between the teeth just grazes the throat of the blank. The latter is then allowed to make a few revolutions to insure well-formed teeth.

If the center-to-center distance between the worm and worm-wheel must be accurate, this dimension can be tested by placing the finished worm in mesh with the wheel (after the latter has been hobbed), and measuring the center distance directly. The worm is placed on top of the wheel, after removing the chips from the teeth, and it is turned along until its axis is parallel with the top of the table. It can be set in this position by testing the threads at each end with a surface gage. The distance from the top of the worm to the top of the arbor is then measured, and the *difference* between the radii of the arbor and worm is either added to or subtracted from this dimension, to obtain the center-to-center distance.

If the worm is accurately made and the worm-wheel blank of the correct size, this center distance should be very close to the dimension required. If necessary, the hob may be again engaged with the wheel and another light cut taken. When testing the center distance, as explained in the foregoing, it is better to lower the knee sufficiently to make room for the worm beneath the hob, and not disturb the longitudinal setting of the table. The relation between the wheel and hob will then be maintained, which is desirable in case it is necessary to re-hob the wheel to reduce the center distance.

The center-to-center distance can also be measured with a fair degree of accuracy (when using the machine in Figs. 37 and 38) at the time the wheel is being hobbed. This is done by elevating the knee and blank until the distance from the top of the column knee-slide to the line on the column marked *center*, equals the required center-to-center distance. When the knee coincides with this line, the index centers are at the same height as the spindle; hence the position of the knee with relation to this mark, shows the distance betweeen the centers of the arbor on which the worm-wheel is mounted, and the hob.

When worm-wheels are cut in machines especially designed for this purpose, the wheel blanks, instead of being mounted on a free-running arbor, are driven by gearing at the proper speed. This makes gashing the blank previous to hobbing unnecessary, as the change gears insure a correct spacing of the worm-wheel teeth.

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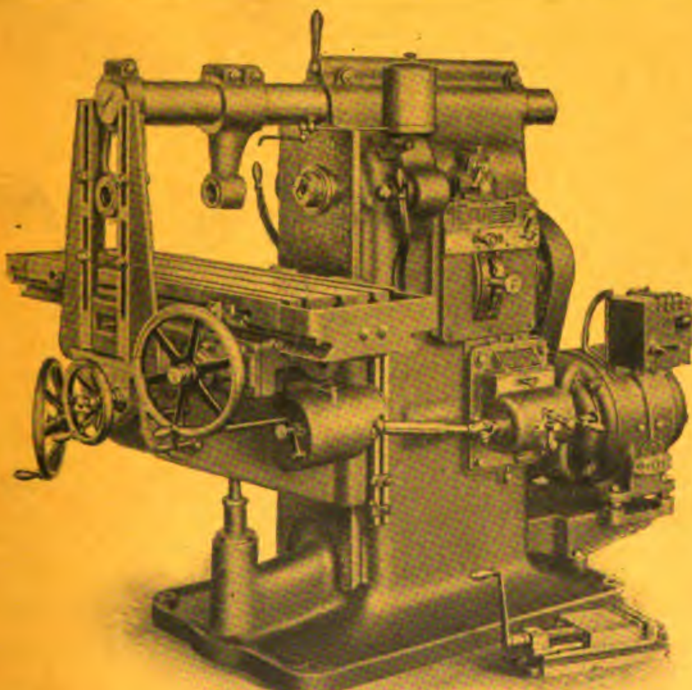

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NUMBER 97

OPERATION OF MACHINE TOOLS

By FRANKLIN D. JONES

MILLING MACHINES—PART II

CONTENTS

CHAPTER I

COMPOUND INDEXING—DIFFERENTIAL INDEXING

Ordinarily, the index crank of a spiral head must be rotated a fractional part of a revolution, when indexing, even though one or more complete turns are required. As explained in Part I of this treatise, this fractional part of a turn is measured by moving the latch-pin a certain number of holes in one of the index circles; but occasionally, none of the index plates furnished with the machine, has circles of holes containing the necessary number for obtaining a certain division. One method of indexing for divisions which are beyond the range of those secured by the direct method, is to first turn the crank a definite amount in the regular way, and then the index plate itself, in order to locate the crank in the proper position. This is known as compound indexing, because there are two separate movements which are, in reality, two simple indexing operations. The index plate is normally kept from turning, by a stationary stop-pin at the rear, which engages one of the index holes, the same as the latch-pin. When this stop-pin is withdrawn, the index plate can be turned.

To illustrate the principle of the compound method, suppose the latch-pin is turned one hole in the 19-hole circle and the index plate is also moved one hole in the 20-hole circle and in the same direction that the crank is turned. These combined movements will cause the worm (which engages the worm-wheel on the spiral head spindle) to rotate a distance equal to $\frac{1}{19} + \frac{1}{20} = \frac{39}{380}$ of a revolution. On the other hand, if the crank is moved one hole in the 19-hole circle, as before, and the index plate is moved one hole in the 20-hole circle, ***but in the opposite direction***, the rotation of the worm will equal $\frac{1}{19} - \frac{1}{20} = \frac{1}{380}$ revolution. By the simple method of indexing, it would be necessary to use a circle having 380 holes to obtain these movements, but by rotating both the index plate and crank the proper amount, either in the same or opposite directions, as may be required, it is possible to secure divisions beyond the range of the simple or direct system.

To illustrate the use of the compound method, suppose 69 divisions were required. In order to index the work $\frac{1}{69}$ revolution, it is necessary to move the crank $\frac{40}{69}$ of a turn $(40 \div 69 = \frac{40}{1} \times \frac{1}{69} = \frac{40}{69})$, and this would require a circle having 69 holes, if the simple method of indexing were employed, but by the compound system, this division can be

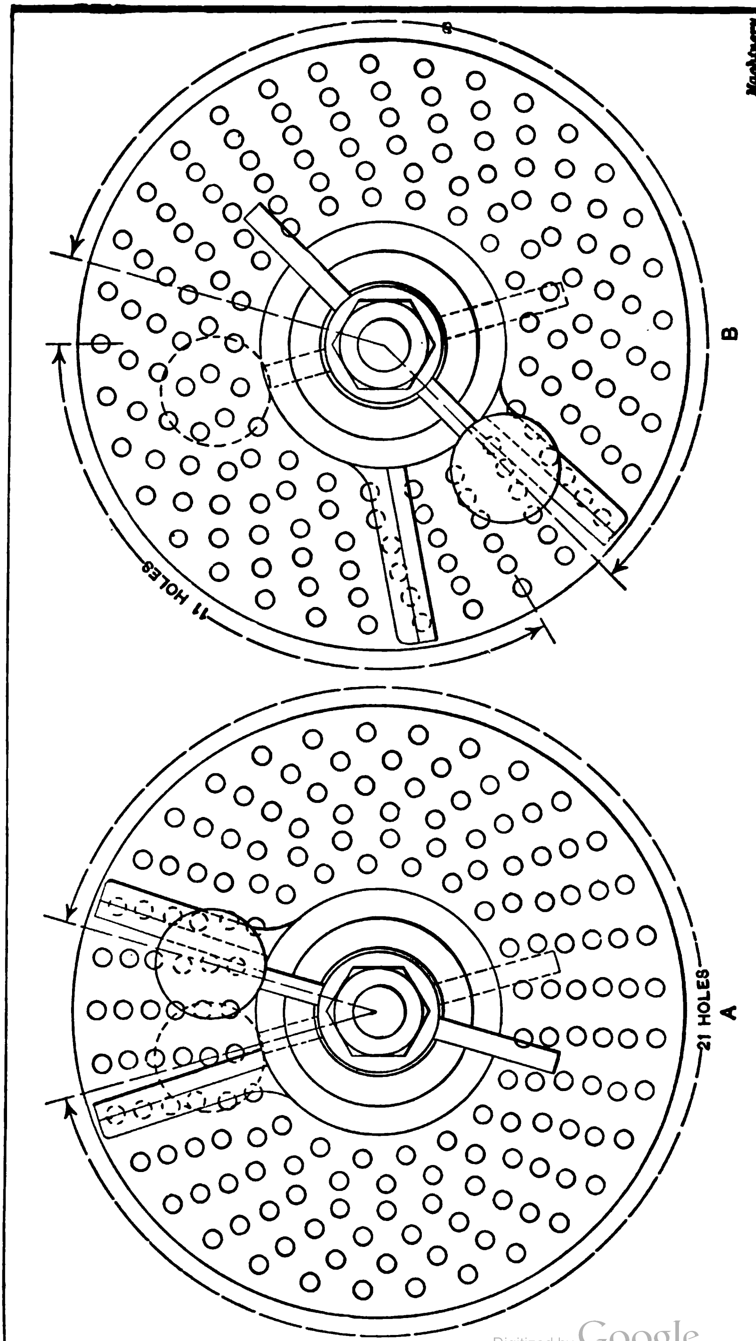

Fig. 1. Diagrams illustrating the Principle of Compound Indexing

obtained by using the 23- and 33-hole circles, which are found on one of the three standard plates furnished with Brown & Sharpe spiral heads. The method of indexing $\frac{1}{69}$ revolution by the compound system is as follows: The crank is first moved to the right 21 holes in the 23-hole circle, as indicated at *A* in Fig. 1 and it is left in this position; then the stop-pin at the rear, which engages the 33-hole circle of the index plate, is withdrawn, and the plate is turned backward, or to the left, 11 holes in the 33-hole circle. This rotation of the plate also carries the crank to the left, or from the position shown by the dotted lines at *B*, to that shown by the full lines, so that after turning the plate backward, the crank is moved from its original position a distance x which is equal to $\frac{21}{23}-\frac{11}{33}=\frac{40}{69}$ which is the fractional part of a turn the crank must make, in order to index the work $\frac{1}{69}$ of a revolution.

One rule for determining what index circles can be used for indexing by the compound method, is as follows: Resolve into its factors the number of divisions required; then choose at random two circles of holes, subtract one from the other, and factor the difference. Place the two sets of factors thus obtained above a horizontal line. Next factor the number of turns of the crank required for one revolution of the spindle (or 40) and also the number of holes in each of the chosen circles. Place the three sets of factors thus obtained below the horizontal line. If all the factors above the line can be cancelled by those below, the two circles chosen will give the required number of divisions; if not, other circles are chosen and another trial made.

To illustrate this rule by using the example given in the foregoing, we have:

$$\begin{array}{rl} 69 = & \not{3} \times \not{23} \\ 33 - 23 = 10 = & \not{2} \times \not{5} \\ \hline 40 = & \not{2} \times 2 \times 2 \times \not{5} \\ 33 = & \not{3} \times 11 \\ 23 = & \not{23} \times 1 \end{array}$$

As all the factors above the line cancel, we know that the index plate having 23- and 33-hole circles can be used. The next thing to determine is how far to move the crank and the index plate. This is found by multiplying together all the uncancelled factors below the line; thus: $2 \times 2 \times 11 = 44$. This means that to index $\frac{1}{69}$ of a revolution, the crank is turned *forward* 44 holes in the 23-hole circle, and the index plate is moved *backward* 44 holes in the 33-hole circle. The movement can also be forward 44 holes in the 33-hole circle and backward 44 holes in the 23-hole circle, without affecting the result. The movements obtained by the foregoing rule are expressed in compound indexing tables in the form of fractions, as for example: $+\frac{44}{23}-\frac{44}{33}$. The numerators represent the number of holes indexed and the denominators the circles used, whereas, the + and — signs show that the movements of the crank and index plate are opposite in direction. These fractions can often be reduced and simplified so that it will not be necessary to move so many holes, by adding some number to them algebraically. The number is chosen by trial, and its sign should be opposite that of the fraction to which it is added. Suppose, for example, we add a fraction representing one complete turn, to each of the fractions referred to; we then have:

$$
\begin{array}{r}
+\frac{44}{23}-\frac{44}{33} \\
-\frac{23}{23}+\frac{33}{33} \\
\hline
+\frac{21}{23}-\frac{11}{33}
\end{array}
$$

If the indexing is governed by these simplified fractions, the crank is moved forward 21 holes in the 23-hole circle and the plate is turned backward 11 holes in the 33-hole circle, instead of moving 44 holes, as stated. The result is the same in each case, but the smaller movements are desirable, especially for the index plate, because it is easier to count 11 holes than 44 holes. For this reason, the fractions given in index tables are simplified in this way. Ordinarily, the number of circles to use and the required number of movements to make when indexing, is determined by referring to a table as this eliminates all calculations, and lessens the chance of error.

Sometimes the simple method of indexing can be used to advantage in conjunction with the compound system. For example, if we want to cut a 96-tooth gear, every other tooth can be cut first by using the simple method and indexing for 48 teeth, which would require a movement of 15 holes in an 18-hole circle. When half of the tooth spaces have been cut, the work is indexed $\frac{1}{96}$ of a revolution by the compound method, for locating the cutter midway between the spaces previously milled. The remaining spaces are then finished by again indexing for 48 divisions by the simple system.

Compound indexing should only be used when necessary, because of the chances of error, owing to the fact that the holes must be counted when moving the index plate. As previously explained, the number of holes that the crank is turned, is gaged by a sector. This counting also requires considerable time and, because of these disadvantages, the compound system is not used to any great extent; in fact, the more modern spiral heads are so arranged that divisions formerly obtained by this system, can now be secured in a more simple and direct way.

Differential Indexing

One of the improved indexing systems, which is applied to the universal milling machines built by the Brown & Sharpe Mfg. Co., is known as the differential method. This system is the same in principle as compound indexing, but differs from the latter in that the index plate is rotated by suitable gearing which connects it to the spiral-head spindle, as shown in Figs. 2 and 3. This rotation or differential motion of the index plate takes place when the crank is turned, the plate moving either in the same direction as the crank or opposite to it, as may be required. The result is that the *actual* movement of the crank, at every indexing, is either greater or less than its movement with relation to the index plate. This method of turning the index plate by gearing instead of by hand, makes it possible to obtain any division liable to arise in practice, by using one circle of holes and simply turning the index crank in one direction, the same as for plain indexing. As the hand movement of the plate and the counting of holes is eliminated, the chances of error are also greatly reduced.

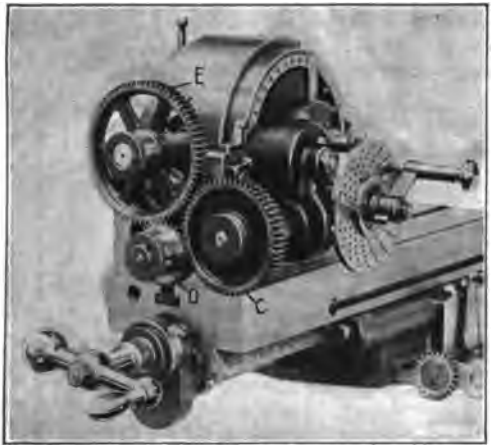

Fig. 2. Index Head geared for Differential Indexing

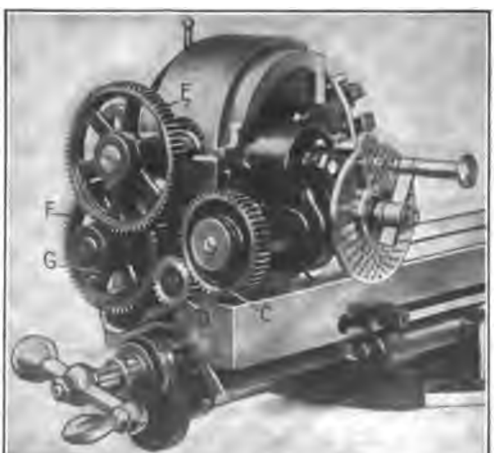

Fig. 3. Index Head equipped with Compound Gearing for Differential Indexing

The proper sized gears to use for moving the index plate the required amount, would ordinarily be determined by referring to a table which accompanies the machine. This table (a small part of which is illustrated in Fig. 4) gives all divisions from 1 to 382 and includes both plain and differential indexing; that is, it shows what divisions can be obtained by plain indexing, and also when it is necessary to use gears and the differential system. For example, if 130 divisions are required, the 39-hole index circle is used and the crank is moved 12 holes (see fourth column of table) but no gears are required. For 131 divisions, a 40-tooth gear is placed on the worm-shaft and a 28-tooth gear is mounted on the spindle. These two gears are connected by the 44-tooth idler gear, which serves to rotate the plate in the same direction as the crank. To obtain some divisions, it is necessary to

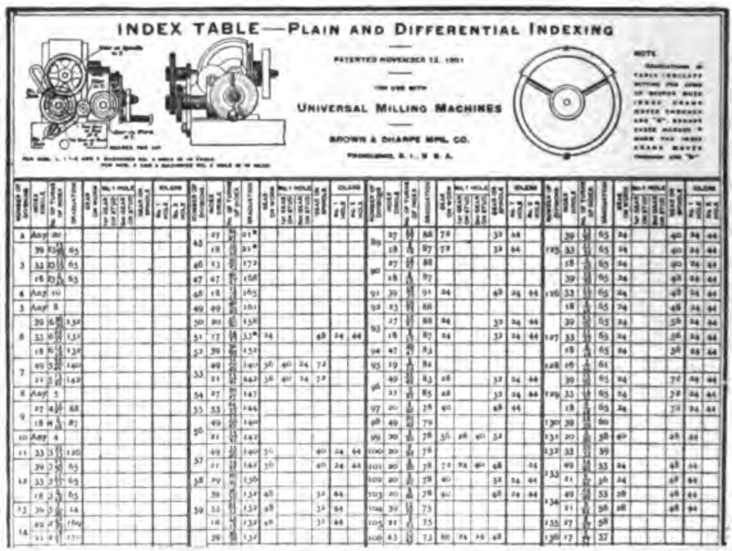

Fig. 4. Part of Index Table for Plain and Differential Indexing

rotate the plate and crank in opposite directions, and then two idler gears are interposed between the spindle and wormshaft gears.

Fig. 2 shows a spiral head geared for 271 divisions. The table calls for a gear *C* having 56 teeth; a spindle gear *E* with 72 teeth and one idler *D*. The sector should be set for giving the crank a movement of 7 holes in the 49-hole circle or 3 holes in the 21-hole circle, either of which equals $\frac{1}{7}$ of a turn. If an index plate having a 49-hole circle happens to be on the spindle head, this would be used. Now if the spindle and index plate were not connected through gearing, 280 divisions would be obtained by successively moving the crank 7 holes in the 49-hole circle, but the gears *E*, *D*, and *C* cause the index plate to turn in the same direction as the crank at such a rate that when 271 indexings have been made, the work is turned one complete revolution; therefore, we have 271 divisions instead of 280, the number being reduced because the total movement of the crank, for each indexing, is equal to its movement relative to the index plate, *plus* the movement of the plate itself when (as in this case) the crank and plate rotate in the same direction. If they were rotated in opposite directions, the crank would have a total movement equal to the amount it turned relative to the plate, *minus* the plate's movement.

Sometimes it is necessary to use compound gearing, in order to move the index plate the required amount for each turn of the crank. Fig. 3 shows a spiral head equipped with compound gearing for obtaining 319 divisions. The gears given in the table are as follows: Gear *C* on the worm, 48 teeth; first gear *F* placed on the stud, 64 teeth; second gear *G* on the stud, 24 teeth; gear *E* on the spindle, 72 teeth; and one idler gear *D*, having 24 teeth.

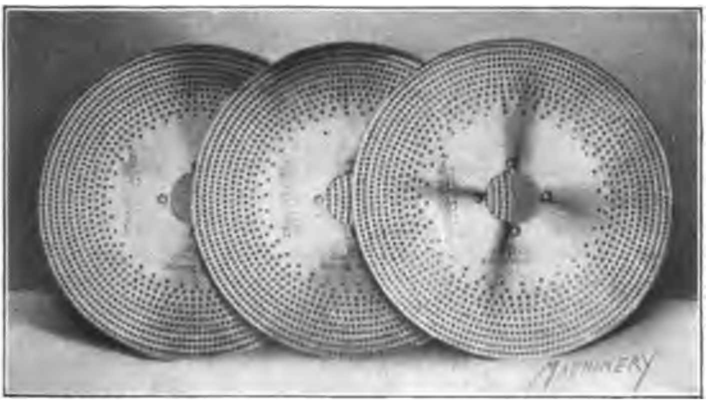

Fig. 5. Index Plates for obtaining a Large Number of Divisions by Simple Indexing

The following example is given to illustrate the method of determining the index movements and change gears to use for differential indexing: Suppose 59 divisions were required, what circle of holes and gears should be used? First assume that we are to index for 60 divisions by the simple method, which would require a $\frac{2}{3}$ movement of the crank. Now, if the crank is indexed $\frac{2}{3}$ of a revolution, 59 times, it will rotate in all, $59 \times \frac{2}{3}$ or 39 1/3 revolutions, which is $\frac{2}{3}$ of a revolution less than the 40 required for one complete revolution of the work. Therefore, the index plate must be geared so that it will move forward $\frac{2}{3}$ of a turn, while the work is revolving once. Hence, the ratio of the gearing must be $\frac{2}{3}$ to 1. Gears are next selected from those provided with the machine, which will give this ratio, as for example, gears having 32 and 48 teeth, respectively. The small gear is placed on the spindle, in this case, because the index plate is to make only $\frac{2}{3}$ of a turn, while the spindle makes one complete revolution. One idler gear is also interposed between the gears, because it is necessary for the plate to gain $\frac{2}{3}$ of a turn with respect to the crank; therefore, the movements of the index plate and crank must be in the same direction.

The differential method cannot be used for helical or spiral milling, because the spiral-head is then geared to the lead-screw of the machine, as explained in Chapter III.

High-number, Reversible Index Plates

The dividing heads furnished with Cincinnati milling machines, are equipped with comparatively large index plates. This increase in diameter gives room for more circles and a larger number of holes than the smaller plates, and the range is further increased by making the plate reversible, each side having different series of holes. Therefore, the number of divisions that can be obtained directly from one of these plates is greatly increased. The standard plate regularly supplied can be used for indexing all numbers up to 60; all even numbers and those divisible by 5 up to 120, and many other divisions between 120 and 400. If it should be necessary to index high numbers not obtainable with the standard plate, a high number indexing attachment can be supplied. This consists of three special plates (see Fig. 5), which have large numbers of holes and different series on each side. They can be used for indexing all numbers up to and including 200; all even numbers and those divisible by 5 up to and including 400. Owing to the range of the standard plate, the high-number attachment is only needed in rare instances, for ordinary milling machine work.

CHAPTER II

CUTTING SPUR GEARS IN A MILLING MACHINE

Spur gears are ordinarily cut in special gear-cutting machines, but the milling machine is often used in shops not equipped with special machines, or for cutting gears of odd sizes, especially when only a small number are required. Fig. 6 illustrates how a small spur gear is cut in the milling machine. The gear blank is first bored and turned to the correct outside diameter and then it is mounted on an arbor which is placed between the centers of the dividing head. An arbor having a taper shank which fits the dividing-head spindle, is a good form to use for gear work. If an ordinary arbor with centers in both ends is employed, all play between the driving dog and faceplate should be taken up to insure accurate indexing.

Cutter for Spur Gears

The type of cutter that is used for milling the teeth of spur gears, is shown in Fig. 7. This style of cutter is manufactured in various sizes for gears of different pitch. The teeth of these cutters have the same shape or profile as the tooth spaces of a gear of corresponding pitch; therefore, the cutter to use depends upon the pitch of the gear to be cut. The number of teeth in the gear must also be considered, because the shape or profile of the teeth of a small gear is not exactly the same as that of the teeth of a large gear of corresponding pitch.

The cutters manufactured by the Brown & Sharpe Mfg. Co. for cutting gears according to the involute system, are made in eight different sizes for each pitch. These cutters are numbered from 1 to 8 and the different numbers are adapted for gears of the following sizes. Cutter No. 1, for gears having teeth varying from 135 to a rack; No. 2, gears with from 55 to 134 teeth; No. 3, from 35 to 54 teeth; No. 4, from 26 to 34 teeth; No. 5, from 21 to 25 teeth; No. 6, from 17 to 20 teeth; No. 7, from 14 to 16 teeth; and No. 8, from 12 to 13 teeth.

If we assume that the diametral pitch of the gear illustrated in Fig. 6 is 12 and the required number of teeth, 90, a No. 2 cutter of 12 diametral pitch would be used, the No. 2 shape being selected because it is intended for all gears having teeth varying from 55 to 134.

Setting the Cutter Central

After the cutter is mounted on an arbor, it must be set over the center of the gear blank, as otherwise the teeth will not be milled to the correct form. One method of centering the cutter is illustrated by the diagram, Fig. 8. A true arbor is placed between the dividing head and foot-stock centers, and the table of the machine is first adjusted to locate the arbor in any convenient position outside of and somewhat below the cutter as at *A*. The graduated dial of the cross-feed screw is next set to zero. The arbor is then moved to position *B* and it is adjusted to barely touch or pinch a thin tissue paper "feeler" *f* held between the arbor and the corner of the cutter. The dial of the elevating screw is now set at zero, and the horizontal distance between positions *A* and *B* should be noted by referring to the cross-feed dial. For convenience, this will be called dimension No. 1, as indicated by the illustration. The arbor is next lowered and returned to position *A*, horizontally, the vertical position not being particular. The arbor is then raised until the elevating screw dial is again at zero, after

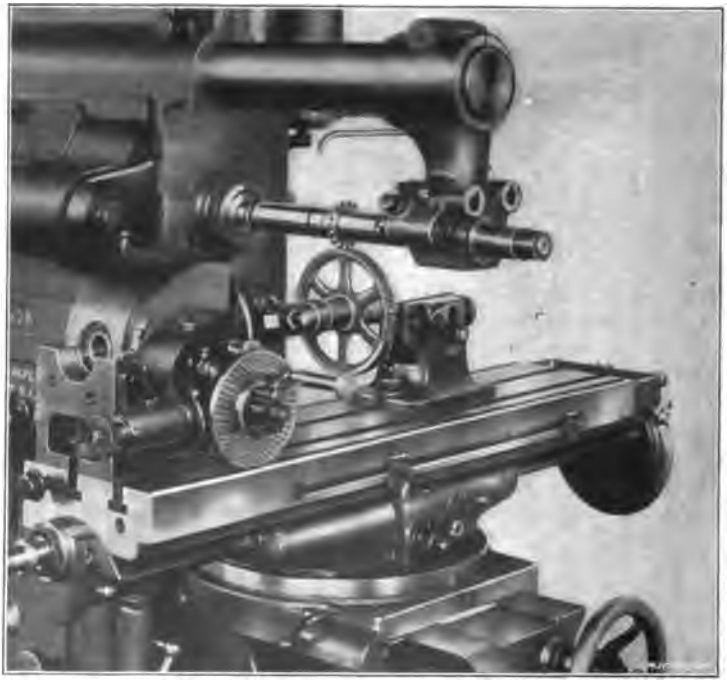

Fig. 6. Cutting the Teeth of a Spur Gear in a Universal Milling Machine

which it is moved to position *C*, or until it just touches a tissue paper "feeler" as before. The horizontal dimension No. 2 is next noted by referring to the cross-feed dial; this is added to dimension No. 1 and the sum is divided by 2 to get dimension No. 3. The arbor is then returned to position *A* (as far as the horizontal location is concerned) after which it is lowered far enough to clear the cutter and then moved inward a distance equal to dimension No. 3, which is the central position. This operation can be performed more quickly than described. When making the adjustments, all dial readings should be taken at the end of the inward or upward movements, to avoid errors due to backlash or lost motion in the elevating or feed screws.

A method of testing the location of a gear cutter, when considerable accuracy is required, is as follows: First mill a tooth space in a trial blank having the same diameter as the gear blank, and then, without changing the position of the cutter, remove the blank from the work arbor and turn it end for end. The blank should be loose on the arbor to permit feeding it back so that the cutter will enter the tooth space previously milled. The cutter is then revolved slowly by hand, in order to mark its position in the slot. If it is set exactly central, the second cut will follow the first, but if it is not central, some metal will be removed from the top of the space on one side and the bottom on the other. In order to center the cutter, it should be moved laterally toward that side of the tooth from which stock was milled at the top. Another trial cut is then taken and the test repeated.

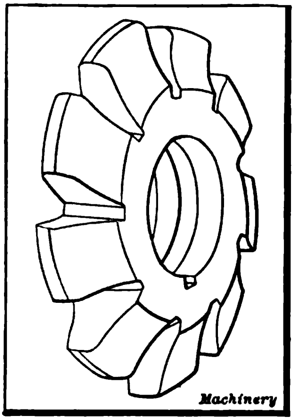

Fig. 7. Cutter for Milling the Teeth of Spur Gears

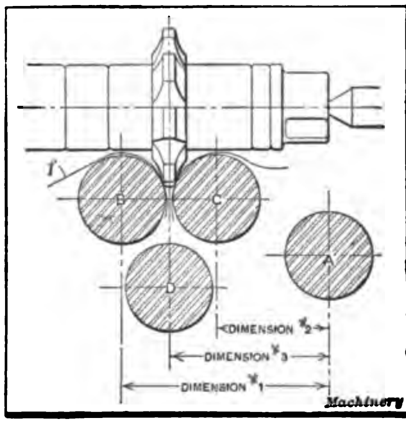

Fig. 8. Method of setting Cutter Central with Arbor

When the cutter is centrally located, the saddle should be clamped to the knee to hold it rigidly in position.

Setting the Cutter to Depth—Milling the Teeth

The next step is to set the cutter for milling tooth spaces of the proper depth. If the outside diameter of the gear blank is accurate, this can be done by first adjusting the blank upward until the revolving cutter just grazes its surface. The dial of the elevating screw is then set at zero, after which the blank is moved horizontally, to clear the cutter, and then vertically the required amount, as shown by the micrometer dial. This vertical adjustment should equal the total depth of the tooth space, which can be found by dividing the constant 2.157 by the diametral pitch of the gear. For example, if the diametral pitch is 12, the depth of the tooth space $= \frac{2.157}{12} = 0.179$ inch. After the blank has been raised this amount, the gear teeth are formed by feeding the blank horizontally and indexing after each tooth space is milled. About one quarter of the teeth have been milled in the gear blank shown in Fig. 6. The accuracy of the gear, assuming that the cutter is properly made, will depend largely upon setting the cutter central and to the proper depth. When the depth is gaged from the outside of the blank, the diameter of the latter should be accurate, as otherwise the teeth will not have the correct thickness. This diameter can be found by adding 2 to the number of teeth and dividing by the diametral pitch. The special vernier, gear-tooth caliper shown in Fig. 9, is sometimes used for testing the thickness of the first tooth milled. This test is especially desirable if there is any doubt about the accuracy of the outside diameter. A trial cut is taken at one side of the blank and then the work is indexed for the next space, after

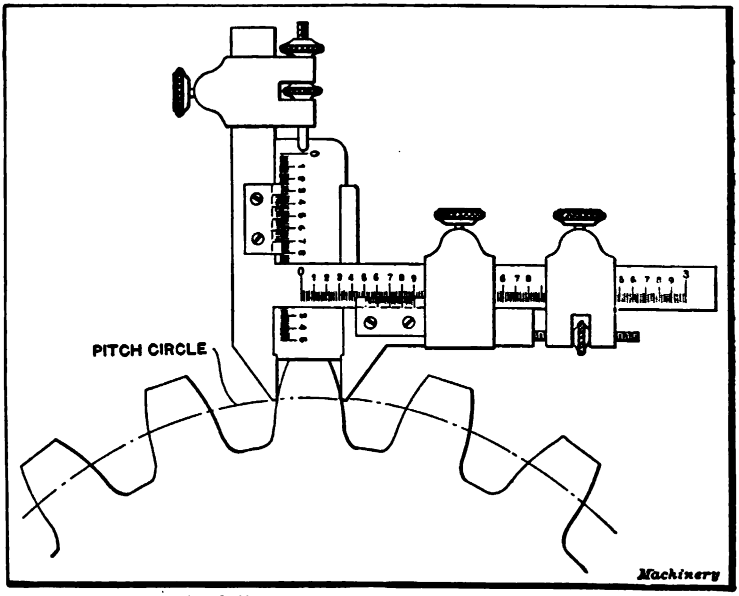

Fig. 9. Vernier Caliper for measuring the Thickness of Gear Tooth at the Pitch Circle

which another trial cut is taken part way across the gear. The vertical scale of the caliper is then set so that when it rests on top of the tooth (as shown in the illustration), the lower ends of the caliper jaws will be at the height of the pitch line. The horizontal scale then shows the thickness of the tooth at this point. The height from the top of the tooth to the pitch line equals the circular pitch multiplied by the constant 0.3183. The thickness of the tooth at the pitch line, for any gear, can be determined by dividing the circular pitch by 2, or the constant 1.57 by the diametral pitch. With a diametral pitch of 12, the thickness would equal $\frac{1.57}{12} = 0.131$ inch. The two trial cuts for determining the tooth thickness, should not extend across the blank, as it is better to simply gash one side; then if an adjustment is necessary, all the tooth spaces will be milled from the solid; whereas, if trial cuts were taken clear across the blank, very little metal would be removed from these spaces by the final cut and the thickness of the tooth between them would differ somewhat from the other teeth in the gear.

When a gear tooth is measured as shown in Fig. 9 it is the chordal thickness T (see Fig. 9a) that is obtained, instead of the thickness along the pitch circle; hence when measuring teeth of coarse pitch, especially if the diameter of the gear is quite small, dimension T should be obtained if accuracy is required. It is also necessary to find the height x of the arc and add it to the addendum H to get the corrected height H_1, in order to measure the chordal thickness T at the proper point on the sides of the tooth. To determine dimension T, multiply the pitch diameter of the gear by the sine of the angle a between the center and radial lines shown. Expressing this as a formula we have $T = D \sin a$, in which D equals the pitch diameter. To find angle a, divide 90 degrees by the number of teeth in the gear. The height x of the arc is found as follows: $x = R\ (1 - \cos a)$, in which R equals the pitch radius. That is, x equals 1 minus the cosine of angle a multiplied by the pitch radius of the gear. The corrected height H_1 is found by adding x to the distance H from the top of the tooth to the pitch circle. If much gear cutting is done, it is well to secure a table giving the chordal thickness T and the corrected height H_1, for various pitches and numbers of teeth.

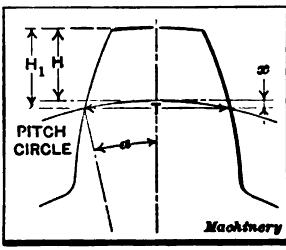

Fig. 9a. When measuring Large Gear Teeth, the Chordal Thickness T should be determined

When milling the teeth, a space is cut by feeding the blank in such a direction that it moves against the rotation of the cutter. After a space is milled, the cutter is returned to its starting point and the blank is indexed $\frac{1}{90}$ of a revolution (as the gear is to have 90 teeth) for milling the next space. This operation is repeated until all the teeth are milled.

When milling gear teeth that are coarser than 6 or 7 diametral pitch, it is advisable to first rough mill all the teeth and then take finishing cuts. Special "stocking" cutters are often used for rough milling very coarse gears, preparatory to finishing by a regular cutter. The speed for cutting gear teeth depends on the pitch of the teeth, the kind of material being milled, and the rigidity of the work and machine.

When the diameter of a gear is referred to, it is understood to mean the pitch diameter or diameter of the pitch circle, and not the outside diameter. The diametral pitch is the number of teeth to each inch of pitch diameter, and the circular pitch is the distance from the center of one tooth to the center of the next, measured along the pitch line.

CHAPTER III

HELICAL OR SPIRAL MILLING

The spiral head is not only used for indexing or dividing, but also in connection with the milling of spiral grooves. When a spiral is being milled, the work is turned slowly by the dividing head as the table of the machine feeds lengthwise. As the result of these combined movements, a spiral groove is generated by the milling cutter. The principle of spiral milling, is illustrated by the diagrams shown in Fig. 10. If a cylindrical part mounted between centers, as at *A*, is rotated and, at the same time, moved longitudinally at a constant rate, past a revolving cutter *c*, a helical or spiral groove will be milled as indicated by the curved line. Strictly speaking, a curve generated in this way upon a cylindrical surface, is a helix and not a spiral, although such curves will be referred to as spirals in this treatise, because of the universal use of this term at the present time.

Evidently, the lead *l* or distance that this spiral advances in one revolution, will depend upon the ratio between the speed of rotation and the longitudinal feeding movement. If the speed of rotation is increased, the lead of the spiral will be diminished, and *vice versa*, provided the rate of the lengthwise travel remains the same. If the cylinder traverses a distance equal to its length while making one revolution, the dimension *l* (sketch *A*) would equal the lead of the spiral generated, but, if the speed of rotation were doubled, the lead *l*, (sketch *B*), would be reduced one-half (assuming that the rate of lengthwise movement is the same in each case), because the cylinder would then make two revolutions while traversing a distance equal to its length.

Change Gears for Spiral Milling

The method of varying the speed of rotation on a milling machine, for obtaining spirals of different leads, will be seen by referring to Fig. 11 which shows an end and side view of a spiral head mounted on the table of the machine and arranged for spiral milling. The rotary movement of the spindle *S* and the work, is obtained from the feed-screw *L*, which also moves the table longitudinally. This feed-screw is connected to shaft *W* by a compound train of gears; *a*, *b*, *c* and *d*, and the movement is transmitted from shaft *W* to the worm-shaft (which carries the indexing crank) through the spiral gears *e*, *f*. and spur gearing (not shown) which drives the index plate, crank, and worm-shaft. When a spiral is to be milled, the work is usually placed between the centers of the spiral head and foot stock, and change gears *a*. *b*, *c* and *d* are selected to rotate the work at whatever speed is needed to produce a spiral of the required lead. The proper gears to use for obtaining a spiral of given lead, are ordinarily determined by referring to a table which accompanies the machine, although the gear sizes can easily be calculated, as will be explained later.

As an example of spiral milling, suppose we have a cylindrical cutter blank 3¼ inches in diameter in which right-hand spiral teeth are to be milled, as indicated in Fig. 12, which shows the cutter after the teeth have been milled. The blank is first mounted on an arbor which is placed between the centers with a driving dog attached. The arbor should fit tightly into the hole of the blank so that both will rotate as one piece, and it is also necessary to take up all play between the driving dog and faceplate. The spiral head is next geared to the feed-screw. If a table of change gears is available, it will show what gears

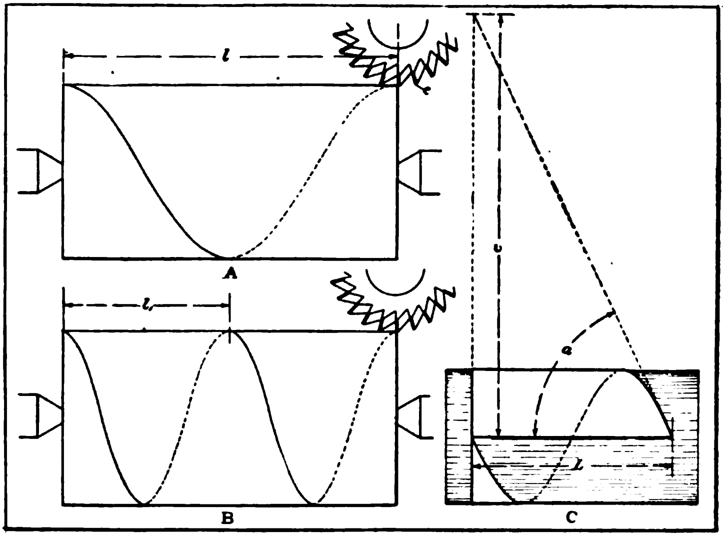

Fig. 10. Diagrams illustrating the Principle of Helical or Spiral Milling

are needed, provided the lead of the spiral is known. A small section of one of these tables is reproduced herewith (see Fig. 13) to illustrate the arrangement. Suppose the lead given on the drawing is 48 inches; then this figure (or the nearest one to it) is found in the column headed, "Lead in Inches," and the four numbers to the right of and in line with 48, indicate the number of teeth in the four gears to be used. The numbers opposite 48 are 72, 24, 64 and 40, respectively, and the position for each of these gears is shown by the headings above the columns. As 72 is in the column headed "Gear on Worm," a gear *d* (see also Fig. 11) of this size is placed on shaft *W*. The latter is referred to as the "worm-shaft," although, strictly speaking, the worm-shaft W_1 is the one which carries the indexing crank and worm. The first gear *c* placed on the stud *E*, has 24 teeth, as shown by the table, and the second gear *b* on the same stud has 64 teeth, whereas gear *a* on the screw has 40 teeth.

After these gears are placed in their respective positions, the first

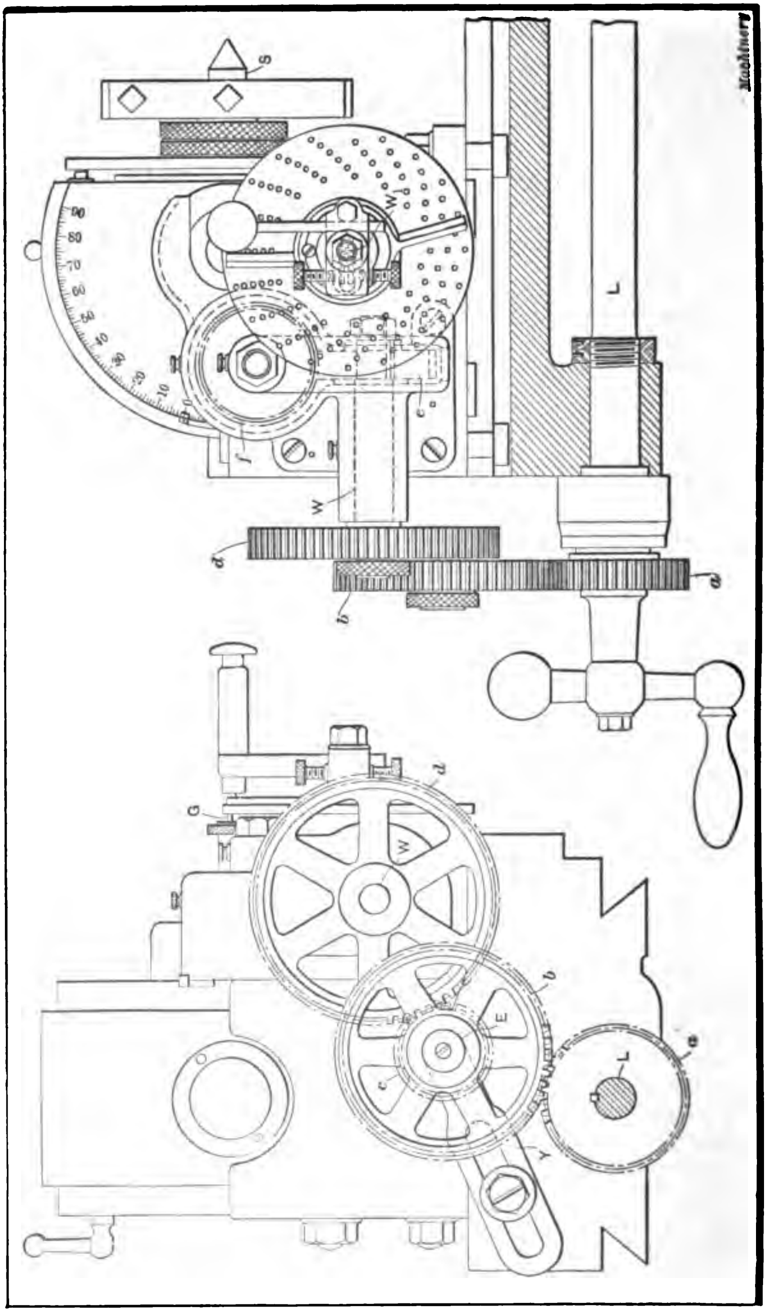

Fig. 11. The Indexing or Spiral Head of a Universal Milling Machine

and second gears *c* and *b* on stud *E* are adjusted to mesh properly with gears *a* and *d* by changing the position of the supporting yoke *Y*. As a right-hand spiral is to be milled, which means that it advances by twisting or turning to the right, an idler gear is not used with the design of spiral head shown. When milling a left-hand spiral, it is necessary to insert an idler gear in the train of gears (as at *j* in Fig. 17) in order to rotate the work in a reverse direction; this idler has no effect, however, on the ratio of the gearing. When the change gears are in place, evidently any longitudinal movement of the table effected by turning feed-screw *L*, will be accompanied by a rotary movement of the spiral head spindle. As connection is made with the worm-shaft W_1, Fig. 11, through the index plate and crank, the stop-pin *G* at the rear must be withdrawn for spiral milling, so that the index plate will be free to turn.

Form of Cutter Used and its Position

The next thing to consider is the kind of cutter to use. If we assume that the grooves are to have an angle of 60 degrees, evidently the cutter must have teeth which conform to this angle. The type used for forming teeth of spiral mills, is shown at *A* in Fig. 14. The teeth have an inclination with the axis, of 48 degrees on one side and 12 degrees on the other, thus giving an included angle of 60 degrees for the tooth spaces. This form of cutter is used in preference to the single-angle type shown at *B*, for milling spiral teeth, because the 12-degree side will clear the radial faces of the teeth and produce a smooth surface. The single-angle cutter *B* is used for milling grooves that are parallel with the axis. The cutter is mounted on an arbor, and it is set in such a position that when the groove is cut to the required depth, the 12-degree side will be on a radial line, as shown by the sketch; in other words, it should be set so that the front faces of the teeth to be milled, will be radial.

Setting the Cutter

A method of setting a double-angle cutter, for milling the teeth in spiral mills, which is simple and does not require any calculations, is, as follows: The pointer of a surface gage is first set to the height of the index head center and then the work is placed in the machine. The cutter is next centered with the blank, laterally, which can be done with a fair degree of accuracy by setting the knee to the lowest position at which the cutter will just graze the blank. The blank is then adjusted endwise until the axis of the cutter is in line with the end of the work, as shown by the side and plan views at *A*, Fig. 15. One method of locating the cutter in this position (after it has been set approximately) is to scribe a line on the blank, a distance from the end equal to the radius of the cutter. The blade of a square is then set to this line, and the table is adjusted lengthwise until the cutter just touches the edge of the blade. The cutter can also be centered with end (after it is set laterally) by first moving the blank endwise from beneath the cutter, and then feeding it back slowly until a tissue paper "feeler" shows that it just touches the corner of the blank. The relation between the cutter and blank will then be as shown at *A*.

The table is next set to the angle of the spiral (as explained later) but its lengthwise position should not be changed. The surface gage, set as previously described, is then used to scribe lines which represent one of the tooth spaces on the end of the blank where the cut is to start. This is done by first drawing a horizontal line as at *B*. This line is then indexed downward an amount equal to one of the tooth

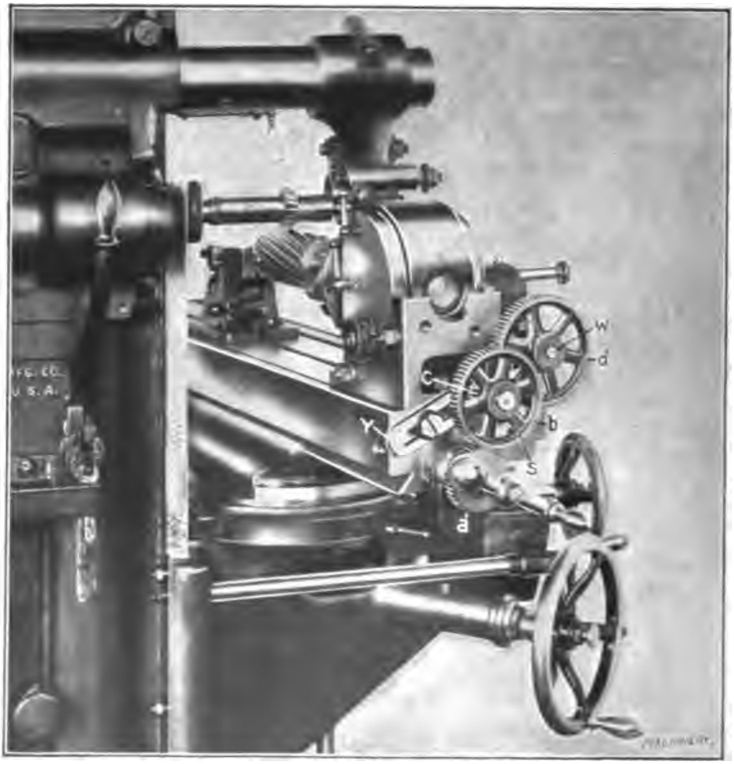

Fig. 12. Universal Machine arranged for Spiral Milling

spaces, and another horizontal line is drawn as at *C*. The last line scribed is then indexed 90 + 12 degrees, which locates it parallel with the 12-degree side of the cutter, as at *D*. The work is then adjusted laterally, and vertically by elevating the knee, until the cutter is so located that the 12-degree side cuts close to the scribed line, and, at the same time, the required width of land *w* (see sketch *E*) is left between the top edge of the groove and the line representing the front face of the next tooth. After the cutter is centered, as at *A*, the longitudinal position of the blank should not be changed until the cutter is set as at *E*, because any lengthwise adjustment of the work would be accompanied by a rotary movement (as the spiral head is geared to the table feed-screw) and the position of the lines on the end would be changed.

Setting the Table to Angle of Spiral and Milling the Grooves

The table of the machine must also be set to the same angle that the spiral grooves will make with the axis of the work. This is done by loosening the bolts which normally hold the saddle to the clamp-bed, and swinging the table around to the right position, as shown by the degree graduations on the base of the saddle. The reason for setting the work to this angle is to locate the cutter in line with the spiral grooves which are to be milled by it. If the cutter were not in line with the spiral, the shape of the grooves would not correspond with

	DRIVEN	DRIVER	DRIVEN	DRIVER		DRIVEN	DRIVER	DRIVEN	DRIVER		DRIVEN	DRIVER	DRIVEN	DRIVER
LEAD IN INCHES	GEAR ON WORM	1ST GEAR ON STUD	2ND GEAR ON STUD	GEAR ON SCREW	LEAD IN INCHES	GEAR ON WORM	1ST GEAR ON STUD	2ND GEAR ON STUD	GEAR ON SCREW	LEAD IN INCHES	GEAR ON WORM	1ST GEAR ON STUD	2ND GEAR ON STUD	GEAR ON SCREW
42.00	72	24	56	40	48.00	72	24	64	40	56.31	86	24	44	28
					48.38	86	32	72	40	57.14	100	28	64	40
42.23	86	28	44	32	48.61	100	24	56	48	57.30	100	24	44	32
42.66	100	28	86	72	48.61	100	24	28	24	57.33	86	24	64	40
42.78	56	24	44	24	48.86	100	40	86	44	58.33	100	24	56	40
42.86	100	28	48	40	48.89	64	24	44	24	58.44	100	28	72	44
42.86	72	24	40	28	49.11	100	28	44	32	58.64	86	24	72	44
43.00	86	32	64	40	49.14	86	28	64	40	59.53	100	24	40	28
43.00	86	28	56	40	49.27	86	24	44	32	59.72	86	24	40	24
43.00	86	24	48	40	49.77	100	24	86	72	60.00	72	24	64	32
43.64	72	24	64	44	50.00	100	28	56	40	60.00	72	24	56	28
43.75	100	32	56	40	50.00	100	24	48	40	60.00	72	24	48	24
43.98	86	32	72	44	50.00	72	24	40	24	60.61	100	24	64	44
44.44	64	24	40	24	50.00	100	32	64	40	61.08	100	32	86	44
44.64	100	28	40	32	50.17	86	24	56	40	61.43	86	28	64	32
44.68	86	28	64	44	50.26	86	28	72	44	61.43	86	24	48	28

Fig. 13. Part of Table showing Gear Combinations to use for obtaining Spirals of Different Lead

the shape of the cutter. The angle to which the table should be set, or the spiral angle, varies according to the diameter of the work and lead of the spiral. As the diameter, in this case, is 3¼ inches and the lead of the spiral is 48 inches, the angle is 12 degrees. The direction in which the table is turned, depends upon whether the spiral is right- or left-hand. For a right-hand spiral the right-hand end of the table should be moved toward the rear, whereas if the spiral is left-hand, the left-hand end of the table is moved toward the rear.

After the table of the machine is set to the required angle and the saddle is clamped in position, the work is ready to be milled. The actual milling of the spiral grooves is practically the same as though they were straight or parallel to the axis. When a groove is milled, it is well to either lower the table slightly or turn the cutter to such a position that the teeth will not drag over the work, when returning for another cut, to prevent scoring or marring the finished groove. If the work-table is lowered, it is returned to its original position by referring to the dial on the elevating screw. After each successive groove is cut, the work is indexed by turning the indexing crank in the regular way. This operation of milling a groove and indexing, is repeated until all the teeth are finished. It should be mentioned that the differential method of indexing cannot be employed in connection with spiral work, because with this system of indexing, the worm-shaft of the spiral head is geared to the spindle. When milling spiral grooves, the position of the cutter with relation to the work, should be such that the rotary movement for producing the spiral, will be toward that side of the cutter which has the greater angle. To illustrate, the blank *A*, Fig. 14, should turn (as shown by the arrow) toward the 48-degree side of the cutter, as this tends to produce a smoother groove.

Calculating Change-gears for Spiral Milling

As was explained in connection with Fig. 10, the lead of a spiral cut in a milling machine depends on the relation between the rotary speed

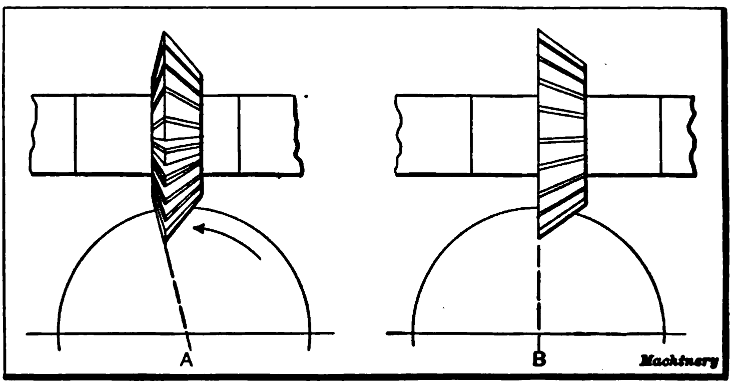

Fig. 14. Double- and Single-angle Cutters

of the work and its longitudinal movement, and these relative speeds are controlled by the change-gears *a*, *b*, *c* and *d*, Fig. 11, which connect the table feed-screw *L* with shaft *W*. If the combination of change-gears is such that 20 turns of screw *L* are required for one revolution of spindle *S*, and the screw has four threads per inch, the table will advance a distance equal to $20 \div 4 = 5$ inches, which is the lead of the spiral obtained with that particular gearing. Now the proper gears to use for producing a spiral of any given lead, can easily be determined if we know what lead will be obtained when change-gears of equal diameter are used. Suppose gears of the same size are employed, so that feed-screw *L* and shaft *W* rotate at the same speed; then the feed-screw and worm-shaft W_1 will also rotate at the same speed, if the gearing which forms a part of the spiral head and connects shafts *W* and W_1 is in the ratio of one to one, which is the usual construction. As will be recalled, 40 turns of the worm-shaft are required for each revolution of spindle *S*; therefore with change-gears of the same diameter, the feed-screw will also make 40 turns, and assuming that it has four threads per inch, the table movement will equal 40 ÷ 4 = 10 inches. This movement, then, of 10 inches, equals the lead of the spiral that would be obtained by using change-gears of the same size, and it is known as the *lead of the machine.*

If we wanted to mill a spiral having a lead of 12 inches and the lead of the machine is 10, the compound ratio of the gears required would be $\frac{12}{10}$ or $\frac{\text{lead of spiral}}{\text{lead of machine}}$. The compound ratio, then, may be represented by a fraction having the lead of the required spiral as its numerator and the lead of the machine or 10 as its denominator. In

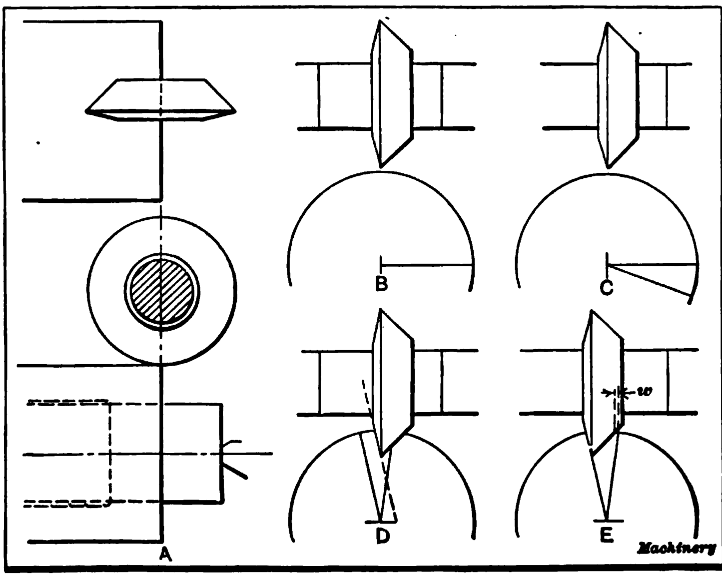

Fig. 15. Setting a Double-angle Cutter for Milling Teeth of a Spiral Mill

order to find what size gears to use, this ratio is revolved into two factors as follows:

$$\frac{12}{10} = \frac{3}{2} \times \frac{4}{5}$$

Each factor is then multiplied by some number which will give a numerator and denominator that corresponds to numbers of teeth on change-gears furnished with the machine. Suppose both terms of the first factor are multiplied by 24; we would then have,

$$\frac{3}{2} \times \frac{24}{24} = \frac{72}{48}$$

The second factor is also raised to higher terms in the same way; that is by using some multiplier which will give a new fraction, the numerator and denominator of which equals the numbers of teeth in available gears. Suppose 8 is chosen for the second multiplier; we then have,

$$\frac{4}{5} \times \frac{8}{8} = \frac{32}{40}$$

The set of fractions obtained in this way, that is $\frac{72}{48}$ and $\frac{32}{40}$, represent the gears to use for milling a spiral having a lead of 12 inches. The numerators equal the number of teeth in the driven gears, and the denominators the number of teeth in the driving gears. If numbers occurred in either fraction which did not correspond with the number of teeth in any of the change-gears available, the fraction should be multiplied by some other trial number until the desired result is obtained.

Relative Positions of the Change-gears

When the gears for cutting a given spiral are known, it remains to place them in the proper place on the machine, and in order to do this, the distinction between *driving* and *driven* gears should be understood. The gear *a* (Fig. 11) on the feed-screw is a driver and gear *b*, which is rotated by it, is driven. Similarly, gear *c* is a driver and gear *d* is driven. As the numerators of the fractions represent driven gears, one having either 72 or 32 teeth (in this instance) should be placed on shaft *W*. Then a driving gear with either 40 or 48 teeth is placed on stud *E* and the remaining driven gear is afterwards mounted on the same stud. The other driving gear is next placed on the screw *L* and yoke *Y* is adjusted until the gears mesh properly. The spiral head will then be geared for a lead of 12 inches, the gear on the worm having 72 teeth, the first gear on the stud having 40 teeth, the second gear having 32 teeth, and the gear on the screw having 48 teeth. Either the driving or driven gears could be transposed without changing the lead of the spiral. For example, the driven gear with 32 teeth could be placed on shaft *W* and the one having 72 teeth could be used as a second gear on the stud, if such an arrangement were more convenient. As previously stated, a reverse or idler gear is inserted in the train when cutting left-hand spirals, but it does not affect the ratio of the gearing.

Determining the Angle of the Helix or Spiral

When the change-gears for a given spiral have been selected, the next step is to determine the angle to which the table of the machine must be set in order to bring the milling cutter in line with the spiral. This angle equals the angle that the spiral makes with its axis and it depends upon the lead of the spiral and the diameter of the cylindrical part to be milled. The angle of a spiral can be determined graphically by drawing a right-angle triangle as shown by sketch *C*, Fig. 10. If the length *e* of one side equals the circumference of the cylinder on which the spiral is to be generated, and the base *L* equals the lead, the angle *a* will be the spiral angle. If such a triangle is wrapped around the cylinder, the hypothenuse will follow a helical curve, as the illustration indicates.

Another way of determining the angle of a spiral is to first get the tangent of the angle by dividing the circumference of the work by the lead of the spiral. When the tangent is known, the corresponding angle is found by referring to a table of natural tangents. For example, if the circumference e is 12 inches, and the lead L is 48 inches, the tangent equals $\frac{12}{48} = 0.25$ and the angle a corresponding to this tangent is about 14 degrees. Evidently, if the circumference is increased or

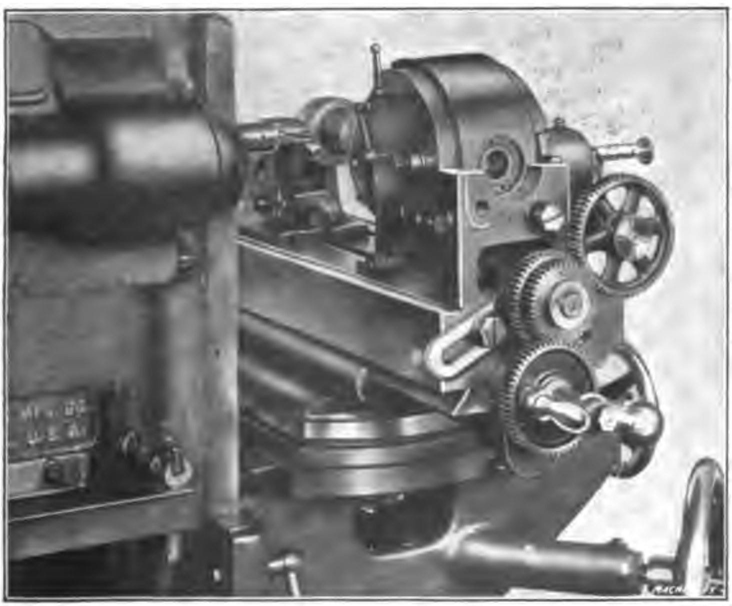

Fig. 16. Milling a Spiral Groove with an End Mill

diminished, there will be a corresponding change in angle a provided the lead L remains the same. For that reason, the outer circumference is not always taken when calculating the spiral angle. The angle for setting the table when cutting spiral gears in a milling machine, is determined by taking the diameter either at the pitch circle, or at some point between the pitch circle and the bottoms of the teeth, rather than the outside diameter, in order to secure teeth of the proper shape.

Cutting Spiral Grooves with an End Mill

When a spiral groove having parallel sides is required it should be cut with an end mill as illustrated in Fig. 16. If an attempt were made to mill a groove of this kind by using a side mill mounted on an arbor, the groove would not have parallel sides, because the side teeth of the mill would not clear the groove; in other words, they would cut away the sides owing to the rotary movement of the work and form a groove having a greater width at the top than at the bottom. This can be overcome, however, by using an end mill. The machine is geared for the required lead of spiral, as previously explained, and the work is adjusted vertically until its axis is in the same horizontal plane as the center of the end mill. With the machine illustrated, this vertical adjustment can be obtained by moving the knee up until its top surface coincides

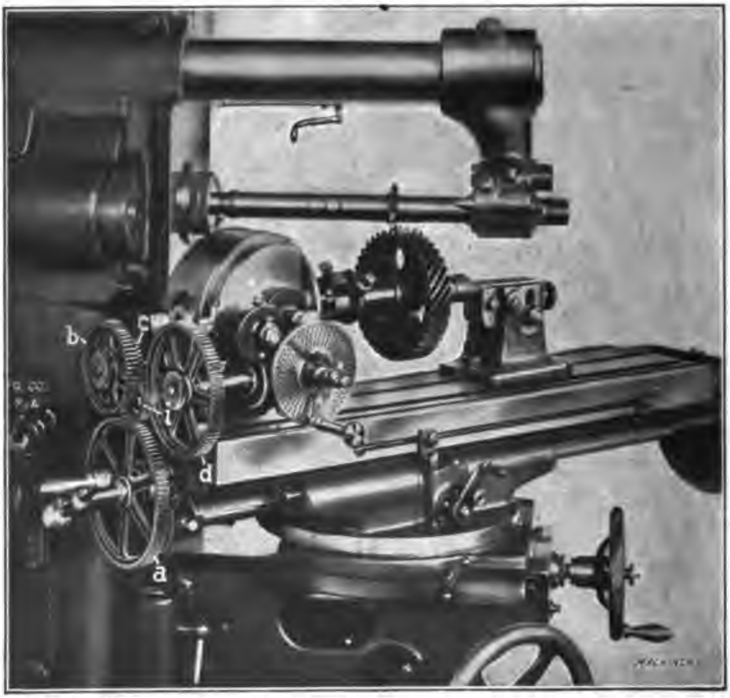

Fig. 17. Cutting the Teeth of a Spiral Gear in a Universal Milling Machine

with a line on the column marked *center*; the index head centers will then be at the same height as the axis of the machine spindle.

Cutting a Spiral Gear in a Universal Milling Machine

The teeth of spiral gears are often cut in universal milling machines, as indicated in Fig. 17, although special gear-cutting machines are used ordinarily where spiral gears are constantly being made, because the special machines are more efficient. As the teeth of a spiral gear are inclined to the axis and follow helical or "spiral" curves, they are formed by milling equally-spaced spiral grooves around the periphery of the blank, the number of the grooves corresponding, of course, to the number of teeth in the gear. From this it will be seen that a spiral gear is similar to a multiple-threaded screw, except that the teeth do not correspond in shape to screw threads; in fact, this type of gearing is sometimes referred to as screw gearing.

Cutter to Use for Spiral Gears

Because of the inclination of the teeth, the cutting of spiral gears is quite different from the method followed for spur gears, as far as the arrangement of the machine and the selection of the cutter is concerned. The spiral head must be connected to the table feed-screw by change gears that will give a spiral of the required lead, and the proper cutter to use depends upon the number of teeth in the gear, their pitch and the spiral angle. Just why the inclination of the teeth to the axis of the gear is considered when selecting a cutter will be more clearly understood by referring to the diagrammatical view of a spiral gear shown in Fig. 18. The circular pitch of the teeth is the distance c measured along the pitch circle at one end of the gear, or in a plane at right angles to the axis.

As will be seen, the circular pitch in the case of a spiral gear is not the shortest distance between the adjacent teeth, as this minimum distance n is along a line at right angles to the teeth. Hence, if a cutter is used having a thickness at the pitch line equal to one-half the circular pitch, as for spur gearing, the spaces between the teeth would be cut too wide and the teeth would be too thin. The distance n is referred to as the normal circular pitch, and the thickness of the cutter at the pitch line should equal one-half this pitch. Now, the normal pitch varies with the angle of the spiral, which is equal to angle a; consequently, the spiral angle must be considered when selecting a cutter.

If a gear has thirty teeth and a pitch diameter of 6 inches, what is sometimes referred to as the *real* diametral pitch is 5 ($30 \div 6 = 5$) and in the case of a spur gear, a cutter corresponding to this pitch would be used; but if a 5-pitch cutter were used for a spiral gear, the tooth spaces would be cut too wide. In order to secure teeth of the proper shape when milling spiral gears, it is necessary to use a cutter of the same pitch as the normal diametral pitch.

The normal diametral pitch can be found by dividing the real diametral pitch by the cosine of the spiral angle. To illustrate, if the pitch diameter of the gear shown in Fig. 17 is 6.718 and there are 38 teeth having a spiral angle of 45 degrees, the real diametral pitch equals $38 \div 6.718 = 5.656$; then the normal diametral pitch equals 5.656 divided by the cosine of 45 degrees, or $5.656 \div 0.707 = 8$. A cutter, then, of 8-diametral pitch is the one to use for this particular gear.

This same result could also be obtained as follows: If the circular pitch c is 0.5554 inch, the normal circular pitch n can be found by multiplying the circular pitch by the cosine of the spiral angle. For example, $0.5554 \times 0.707 = 0.3927$. The normal diametral pitch is next found by dividing 3.1416 by the normal circular pitch To illustrate,

$$\frac{3.1416}{0.3927} = 8,$$ which is the diametral pitch of the cutter.

Of course, in actual practice, it is not generally necessary to make such calculations, as the pitch of the gear, the lead and angle of the spiral, etc., is given on the drawing, and the work of the machinist is confined to setting up the machine and cutting the gear according to specifications. It is much easier, however, to do work of this kind when the fundamental principles are understood.

As previously explained in Chap. II, the proper cutter to use for spur gears depends not only upon the pitch of the teeth, but also upon the number of teeth in a gear, because the teeth of a small gear do not have the same shape as those of a much larger size of the same pitch. Therefore, according to the Brown & Sharpe system for spur gears having involute teeth, eight different shapes of cutters (marked by numbers) are used for cutting all sizes of gears of any one pitch. from a 12-tooth pinion to a rack. The same style of cutter can be used

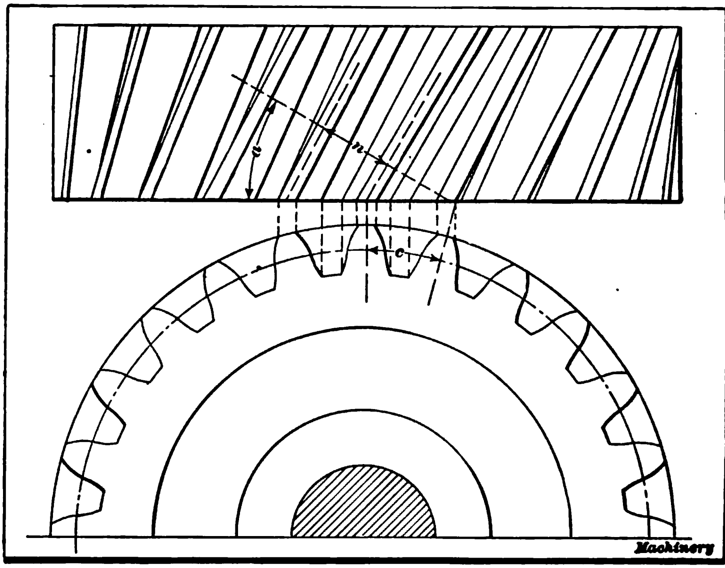

Fig. 18. The Circular Pitch of a Spiral Gear is the Distance c and the Normal Pitch, Distance n

for spiral gearing, but the cutter is not selected with reference to the actual number of teeth in the gear, as with spur gearing.

By referring to the list of cutters given on page 11, Chapter II, it will be seen that a No. 3 would be used for a spur gear having 38 teeth. A spiral gear with 38 teeth, however, might require a cutter of some other number, because of the angular position of the teeth. If the actual number of teeth in a spiral gear is divided by the cube of the cosine of the tooth angle, the quotient will represent the number of teeth for which the cutter should be selected, according to the system for spur gears. If we assume that a gear is to have 38 teeth cut at an angle of 45 degrees, then the cutter to use would be determined as follows: The cosine of 45 degrees is 0.7071 and $38 \div 0.7071^3 = \frac{38}{0.3535} = 107$. The list of cutters previously referred to calls for a No. 2 cutter for spur gears having any number of teeth between 55 and

134; hence, that is the cutter to use for a spiral gear having 38 teeth and a tooth angle of 45 degrees. It will be understood that this number has nothing to do with the pitch of the cutter, which is determined as previously explained; it is simply that one of the eight cutters (according to the B. & S. system) which is made for milling gears having numbers of teeth between 55 and 134.

The number obtained by the foregoing rule is much larger than the actual number of teeth in the spiral gear. This is because a line at right-angles to the teeth, along which the normal pitch is measured, has a larger radius of curvature than the pitch circle of the gear (although, strictly speaking, the term radius is incorrectly used, as this line is a helix and not a circle) and the curvature increases or diminishes for corresponding changes in the spiral angle. Therefore, the number of teeth for which the cutter is selected depends upon the angle of the spiral, as well as the actual number of teeth in the gear. As the angle becomes smaller, the difference between the normal and circular pitches also diminishes until, in the case of spur gears, the normal and circular pitches are equal.

Gearing Machine—Position of Table

The change gears *a*, *b*, *c* and *d*, Fig. 17, connect the spiral head and table feed-screw and rotate the gear blank as the table feeds lengthwise, in order to produce the spiral teeth. The relative sizes of these gears depend upon the lead of the spiral or the distance that any one tooth would advance if it made a complete turn around the gear. When calculating the sizes of spiral gears, the diameter and angle of the teeth is usually made to suit conditions; consequently, the lead of the spiral is sometimes an odd dimension that cannot be obtained exactly with any available combination of change gears, although some combination of the gears furnished with a universal milling machine will generally give a lead which is close enough for all practical purposes.

The gear shown in Fig. 17 has left-hand spiral teeth. Therefore it is necessary to place an idler gear *I* in the train of gears in order to reverse the rotation of the gear blank. Without this idler, the rotation would be in the opposite direction and a right-hand spiral would be milled.

Before the teeth of a spiral gear can be milled the table of the machine must be set to the spiral angle. This is done so that the cutter will produce grooves and teeth of the proper shape. As previously explained, the angle of a spiral depends upon the lead *L* (see Fig 10), and the circumference *e* of the cylindrical surface (which may be either real or imaginary) around which the spiral is formed. The smaller the circumference, the smaller the angle *a*, assuming that the lead *L* remains the same. The angle, then, that the teeth of a spiral gear make with the axis, gradually diminishes from the tops to the bottoms of the teeth, and if it were possible to cut a groove right down to the center or axis, its angle would become zero. Hence, if the table of the machine is set to the angle at the top of a tooth, the cutter will not be in line with the bottom of the groove, and, consequenly, the teeth will not be milled to the correct shape. It is a common practice to set the table to the angle at the pitch line, which is nearly halfway between the top and bottom of the tooth, although some contend that if the angle near the bottom of the groove is taken, teeth of better shape will be obtained.

Whatever the practice may be the angle is determined by first getting the tangent and then the corresponding angle from a table of tangents. For example, if the pitch diameter of the gear is 4.46 and the lead of the spiral is 20 inches, the tangent will equal $\frac{4.46 \times 3.1416}{20}$ $= 0.700$, and 0.700 is the tangent of 35 degrees, which is the angle to which the table is set from the normal position at right angles to the spindle.

The table is adjusted by loosening the bolts which ordinarily hold it to the clamp-bed and swiveling it around until the 35-degree graduation on the circular base coincides with the stationary zero mark. Before setting the table to the spiral angle, the cutter should be located directly over the center of the gear blank. An accurate method of centering a cutter of this kind was described in connection with Fig. 8, Chapter II.

Milling the Spiral Teeth

The teeth of a spiral gear are proportioned from the normal pitch and not the circular pitch. The whole depth of the tooth, that is the depth of each cut, can be found by dividing the constant 2.157 by the normal diametral pitch of the gear; the latter, as will be recalled, corresponds to the pitch of the cutter. The thickness of the gear at the pitch line equals 1.571 divided by the normal diametral pitch. After a cut is completed the cutter should be prevented from dragging over the teeth when being returned for another cut. This can be done by lowering the blank slightly or by stopping the machine and turning the cutter to such a position that the teeth will not touch the work. If the gear has teeth coarser than 10 or 12 diametral pitch, it is well to cut twice around; that is, take a roughing and a finishing cut.

When pressing a spiral gear blank on the arbor, it should be remembered that spiral gears are more likely to slip when being cut than spur gears. This is because the tooth grooves are at an angle and the pressure of the cut tends to rotate the blank on the arbor.

CHAPTER IV

THE VERTICAL MILLING MACHINE

When an end mill is driven directly by inserting it in the spindle of a milling machine of the horizontal type it is often difficult to do satisfactory work, especially if much hand manipulation is required, because the mill operates on the rear side where it cannot readily be seen when one is in the required position for controlling the machine. Moreover, it is frequently necessary to clamp the work against an angle-plate to locate it in a vertical position or at right-angles to the end mill, when the latter is driven by a horizontal spindle. In order to overcome these objectionable features special vertical milling attachments are used to convert a horizontal machine temporarily into a vertical type. These vertical attachments are very useful, especially when the shop equipment is comparatively small and a horizontal machine must be employed for milling a great many different parts, but where there is a great deal of work that requires end milling, it is better to use a machine having a vertical spindle.

A vertical milling machine is shown in Fig. 19. The part to be milled is attached to table *T* and the cutter is driven by the vertical spindle *S*, so that it is always in plain view. This is particularly desirable when milling an irregular outline, or any part that requires close attention.

The table of this machine has longitudinal, crosswise, and vertical movements, all of which can be effected either by hand or by the automatic power feeds. The spindle and the slide which supports the lower end can also be fed vertically, within certain limits, by hand or power. It should be mentioned that milling machines of this type do not always have vertical movements for both the spindle and table. In some designs the table, instead of being carried by a sliding knee *K*, is mounted on a fixed part of the base which extends forward beneath it; whereas other machines have a table that can be moved vertically, but a spindle that remains fixed, as far as vertical movement is concerned.

The particular machine shown in Fig. 19 is driven by a belt pulley *P*, which transmits power through gears and shafts to spindle *S*. This belt pulley is connected or disconnected with the driving shaft by vertical lever *M*, which serves to start and stop the machine. The speed of the spindle is varied by levers *A*, *B*, *C*, and *D*. Levers *A* and *B* operate a tumbler-gear through which four speeds are obtained. This number is doubled by lever *C*, and lever *D* doubles it again, thus giving a total of sixteen speeds. The direction of rotation is reversed by lever *H*.

The power feeds for the table are varied by the levers seen attached to the feed-box *F*. The feed motion is transmitted to a reversing box on the side of the knee, by a telescoping shaft, the same as with a horizontal machine. Lever *R* may be used to start, stop or reverse the automatic table feeds; lever *V* controls the vertical movement of the knee and table; and lever *N* the cross-movement. The table is reversed by lever *L* at the front, the reversing lever *R* not being used for this

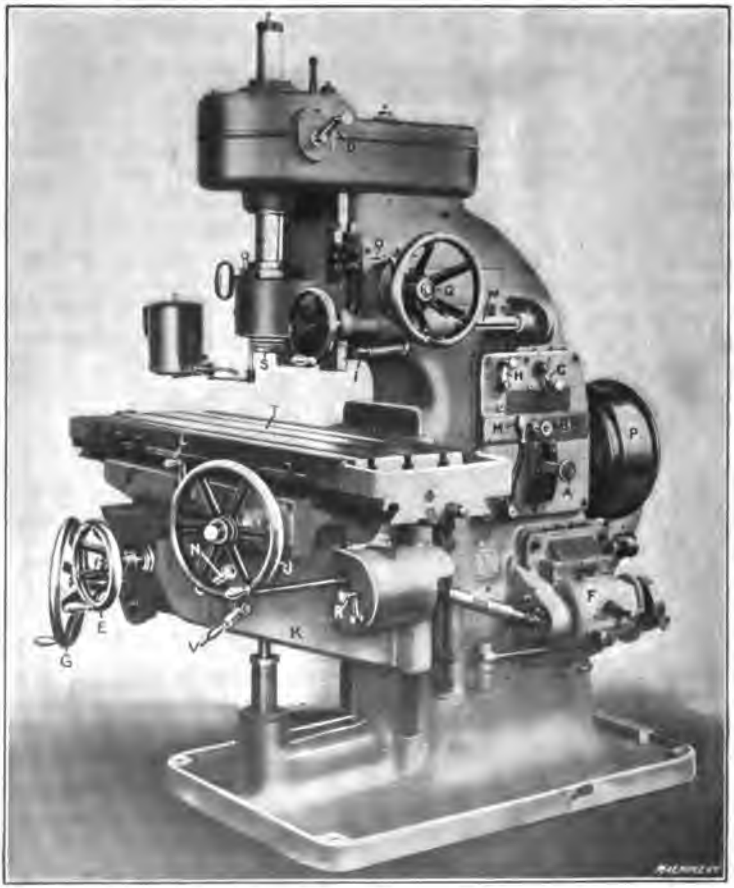

Fig. 19. Brown & Sharpe Vertical-spindle Milling Machine

purpose. The handwheel *G* is for raising and lowering the table, and the smaller wheel *E* is for the transverse adjustment. By means of handwheel *J* the table can be given a fast or slow movement, or the wheel can be disconnected entirely, a clutch in the center of the hub being used to make these changes. The handwheels *E* and *G* can also be disengaged from their shafts by knobs in the center of each wheel. This is done to prevent the table from being shifted after an adjustment is made, in case the workman should accidentally turn one of the wheels.

The vertical feed for the spindle head is also varied by the mechanism at *F*, the required motion being transmitted to the top of the machine by a chain and sprockets which drive worm-shaft *W*. This worm-shaft is connected with the upper sprocket through a clutch controlled by lever *I*. This same clutch is also operated by adjustable stops clamped into T-slots in the side of the spindle-head, for automatically disengaging the vertical feed at any predetermined point. Shaft *W* transmits the feeding movement to the spindle, through worm gearing, and a pinion shaft *Q*, and lever *O* engages or disengages the worm-wheel with this pinion shaft. When the worm-wheel is disengaged, the large handwheel at the side of the column may be used to raise or lower the spindle rapidly, and, at other times, the small hand-wheel at the front gives a slow feeding movement.

Circular Milling Attachment

The vertical milling machine is often used for milling circular surfaces or slots. In order to do this it is necessary to impart a rotary movement to the piece being milled. This is done by means of a circular milling attachment which is bolted to the main table of the machine, as shown in Fig. 21. The table of the attachment can be revolved by handwheel *A* or automatically. The power feed is derived from the splined shaft which drives the longitudinal feed-screw of the table, this shaft being connected by a chain and sprockets to shaft *B* which transmits the movement to the attachment. When the attachment is in use the table feed-screw is disconnected from the splined shaft, so that the feeding movement is transmitted to the circular table only. For adjusting the longitudinal table, when using the circular attachment, a crank is applied to the squared end of the screw at the left end of the table. The circular attachment has automatic stops for disengaging the feed at any point, which are held in a circular T-slot cut in the periphery of the table. The circumference of the table is also graduated in degrees, so that angular adjustments can be made when necessary.

Vertical Milling Operations

The vertical milling machine illustrated in Fig. 19 is shown at work in Fig. 20. The casting *C*, which is being milled, is the saddle of a milling machine, and the operation is that of finishing the dovetail ways for the table. The ways on the under side have already been milled and this finished part is placed against a plate or fixture *F*, having a slide similar to the knee upon which the saddle will be mounted when assembled.

The cutter used for this job has radial end teeth for milling the flat or bottom surfaces, and angular teeth for finishing the dovetail. The cutter revolves in a fixed position, and the slide is milled by feeding the table endwise after it is adjusted to the proper vertical and crosswise positions. The fixture is made in two parts, and the top section can be swiveled slightly so that the dovetail can be milled tapering on one side for the gib which is afterward inserted. The top part of the fixture is located in the proper position when milling either the straight or taper side, by a pin which passes through the upper and lower plates.

Milling a Circular T-slot

The operation illustrated in Fig. 21, as previously intimated, requires the use of a circular attachment, as it is necessary to mill a circular T-slot. The casting in which this slot is being cut, is the wheel-stand slide of a cylindrical grinder and the slot receives the

Fig. 20. Example of Milling on Vertical Milling Machine

heads of clamping bolts. As the T-slot must be concentric with a hole previously bored in the casting, it is necessary to locate this hole in the center of the circular table. This is done by placing an arbor in the central hole of the table, having a bushing which just fits the hole in the casting. The latter is held to the circular table by a clamp and the bolts shown.

The T-slot is formed by two operations: A plain, rectangular slot is cut first by using an ordinary end-mill, and then the enlarged T-section at the bottom is milled by a special T-slot cutter. This particular view was taken after the T-slot cutter had completed about one-quarter of the groove. The cutter rotates in one position and the circular groove is milled as the casting is slowly fed around by the circular attachment. The shape of the finished slot is clearly shown to the left, and the plain rectangular slot cut by the first operation is shown to the right.

Examples of End and Edge Milling

Fig. 22 shows how a vertical machine is used for milling the bearing brasses of an engine connecting-rod. These brasses are cast with

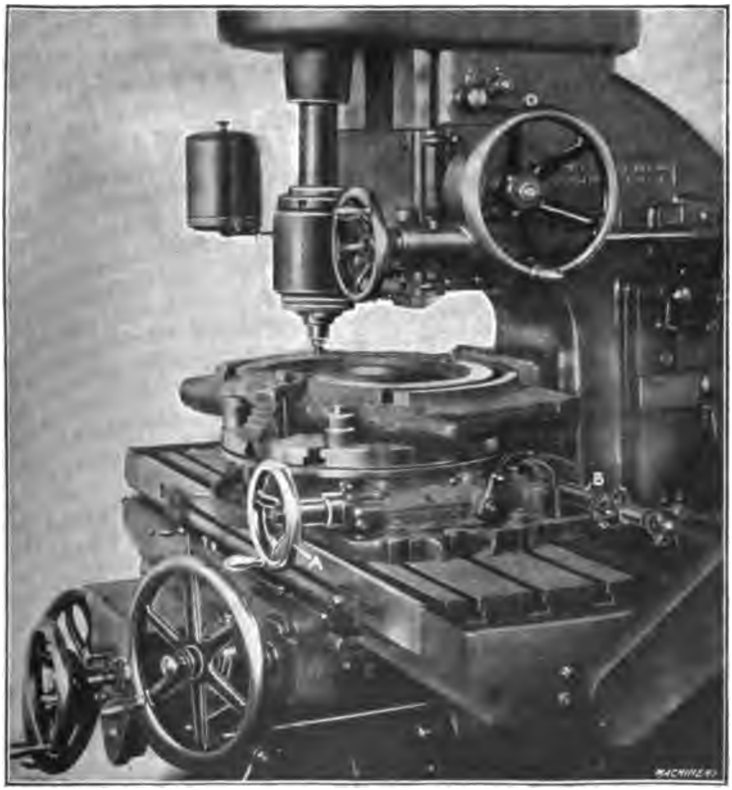

Fig. 21. Milling a Circular T-slot on a Vertical Machine

flanged sides which must be finished to fit the strap which holds the brasses in position on the rod. An end-mill is used for this work. The end or radial teeth finish the bottom of the groove, while the cylindrical part of the mill finishes the groove to the required width. The brasses are clamped to a special box-shaped angle-plate, and four sets are milled at one passage of the tool. For finishing the opposite sides, the milled surfaces are "bedded" on a cylindrical rod to align them with the table. In this way both sides are finished parallel.

Work of this kind is often done in the shaper, but these small brasses can be finished more rapidly by milling, as the bottom of the grooves and the sides of the flanges are milled simultaneously, whereas, with the shaper it would be necessary (with a single-pointed tool) to cut down each side and plane the horizontal surface at the bottom of the groove, separately. Furthermore, it is easier to mill these brasses to a uniform size than to plane them in a shaper. When milling, the width between the flanges is governed by the diameter of the cutter, but if a shaper were used, this width would depend on the adjustment of the tool, which might not always be set in exactly the

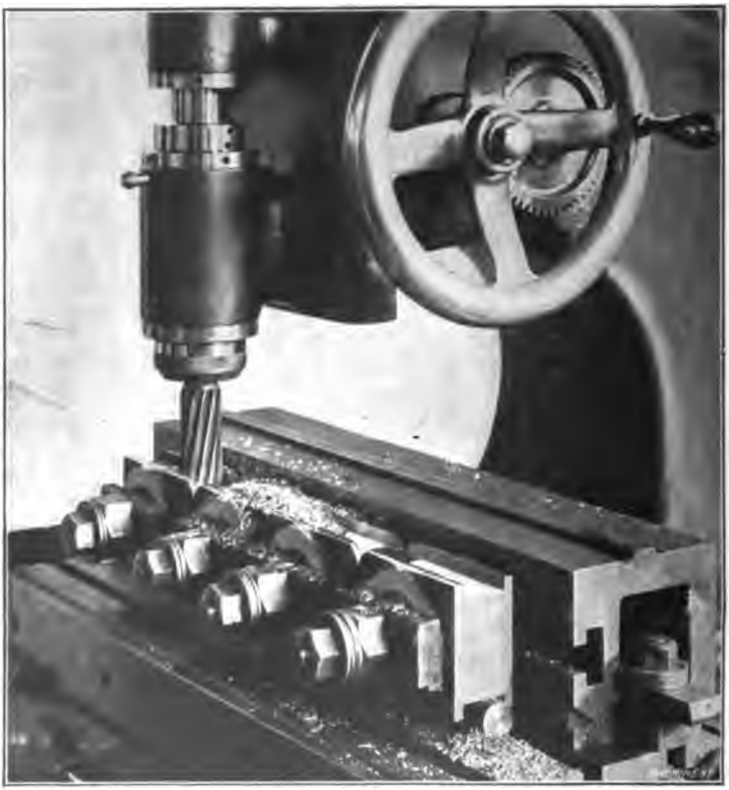

Fig. 22. Milling Connecting-rod Bearing Brasses on Becker Vertical Machine

same position. The vertical milling machine used for this operation, is not the same as the one previously illustrated, although its construction is very similar and it is used for the same class of work.

The vertical milling machine is often used for finishing the edges of straight or circular parts, and irregular shapes can also be worked out by using the longitudinal and cross feeds alternately, as may be required. Of course, if an irregular outline is to be followed, the machine is fed by hand. At *A*, Fig. 23, is shown an odd-shaped steel forging, the rough end and sides of which are finished by milling, as indicated at *B*. The straight sides and part of the circular hub are first milled as shown in this illustration. As the hole through the hub has already been bored, this is used for locating the forging in a central position, the bored hub being placed over a close-fitting cylindrical piece that is clamped to the table as shown. The work is held by a bolt and heavy washer at the top, and it is kept from turning by a small angle-plate which is set against the flanged end.

As the illustration shows, the edge is finished by a spirally-fluted end-

Fig. 23. Milling the Edge of a Steel Forging

mill. The table of the machine is fed longitudinally for milling the straight part, and then the circular attachment is used for finishing the circular hub, around as far as the projecting flanged end will permit. The circular end of the hub is then completed (as shown in Fig. 24) by using a different type of cutter which rounds that part of the hub next to the projecting end and gives a finished appearance to the work. This cutter, which is called a "rose mill," has a spherical end that forms a fillet as it feeds around.

This particular forging may require a little handwork for finishing one or two rough, uneven spots left by milling, but this is very slight at the most. Without a milling machine, however, it would be necessary to trim up this part by hand, and to make a neat job of it would require considerable time. In fact, before the milling machine came into use, vise or handwork was done on a much more extensive scale than at the present time, and, incidentally, the amount of handwork in connection with the fitting and erecting of machinery, is gradually

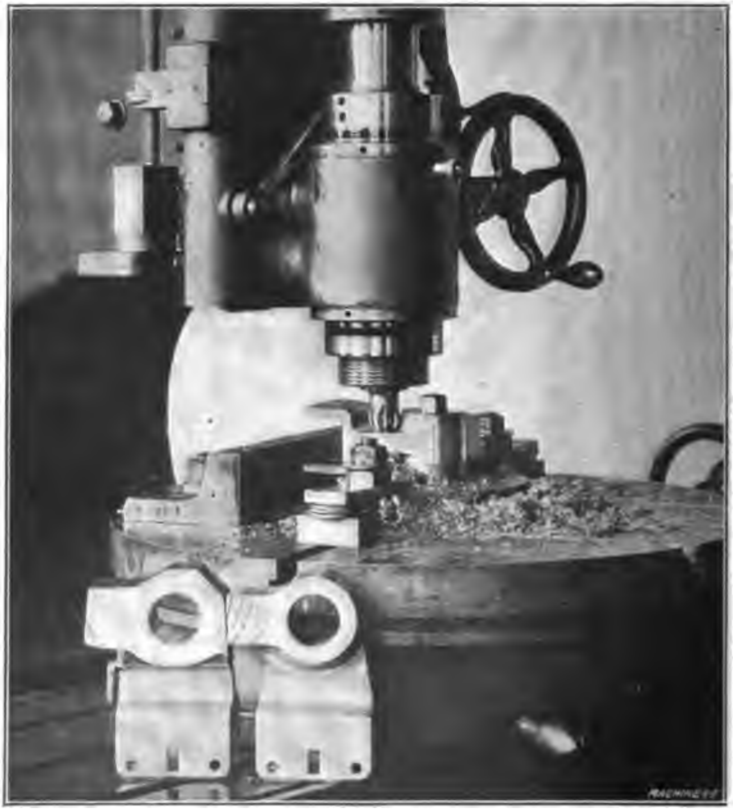

Fig. 24. Finishing a Circular Fillet with a Rose Milling Cutter

diminishing, owing to the high degree of accuracy with which parts can be finished, not only by milling but by modern machines and methods generally.

When milling edges in the vertical machine, the depth of the cut is sometimes limited by the spring of the cutter arbor, although when quite wide edges have to be milled, the arbor is sometimes supported at the lower end by a bracket which is attached to the column of the machine. This prevents the cutter from springing away from the work, and enables fairly heavy cuts to be taken.

Surface Milling in the Vertical Machine

While the vertical milling machine is especially adapted for milling straight or curved edges or surfaces of irregular shape, it is also very efficient for finishing plain, flat surfaces on certain classes of work. Frequently the top of a casting or forging and its sides or edges, can be milled at one setting, which not only saves time but insures accuracy. When a flat, horizontal surface is milled in a vertical machine,

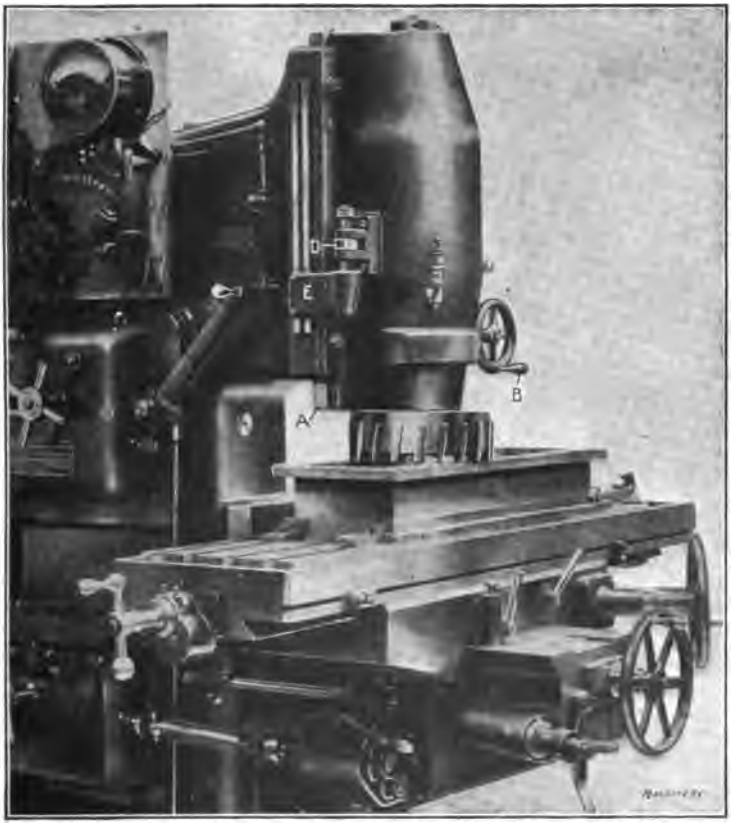

Fig. 25. Finishing Top Surface of a Casting on a Cincinnati Vertical Machine

a face cutter is used, as shown in Fig. 25. This cutter, which is over 12 inches in diameter, is screwed to the end of the spindle and the flange around the casting *C* is milled by the ends of the inserted teeth or blades. This cutter is large enough to mill both sides of the casting in one cut. The over-all dimensions of this part are 12 by 36 inches, and the width of the flanges on each side is 2 inches.

The machine shown in this illustration is a powerful, rigid design especially adapted for work of this kind. It is similar in many respects to the plain horizontal machine described in Chapter I, Part I, of this treatise, excepting, of course, the changes necessary on account of the vertical location of the spindle. The part to be milled is bolted directly to the table, and, before milling the first casting, the knee is elevated, so that the spindle slide *A* will not need to extend much below its bearing when the cutter is at work. The spindle and cutter are then lowered for the right depth of cut by using the fine hand-feed which is operated by the small wheel *B* at the right of the spindle. After rough milling the surface by traversing the table longitudinally, the feed is reversed and a finishing cut 0.010 of an inch deep is taken, as the table feeds in the opposite direction.

Fig. 26. Machine equipped with Two Work-holding Fixtures so that One Casting can be chucked while the Other is being Milled

The micrometer stop *D* which engages an arm *E* bolted to the side of the column, makes it possible to set the cutter to the same vertical position, when milling a number of castings of the same height. This same casting can also be milled by using a smaller cutter which covers a flange on one side only, instead of the entire casting. When the smaller cutter is employed, it is made to follow the rectangular flange by using the longitudinal and cross feeds, alternately.

The example of vertical face milling shown in Fig. 26 illustrates a modern method of chucking castings and operating the machine, when large numbers of duplicate parts have to be milled. There are two independent work-holding fixtures mounted on the table, and the cutter moves from one casting to another. First a roughing cut is taken about 3/16 inch deep, with the table feeding 7¾ inches per minute. When the working side of the cutter reaches the end of the casting, the feed is reversed and increased to 20 inches per minute for the return or finishing cut. Meanwhile, another casting is placed in the other fixture, and when the cutter reaches it, the feed is reduced to 7¾ inches. While this roughing cut is being taken, a new piece is chucked in the other fixture, and so on, one casting being chucked while the other is being milled, so that the milling operation is practically continuous. Of course, this method of handling the work, cannot be employed unless it is possible to clamp the part in the proper position in a comparatively short time. The fixtures shown in this illustration are made like milling machine vises and have special jaws

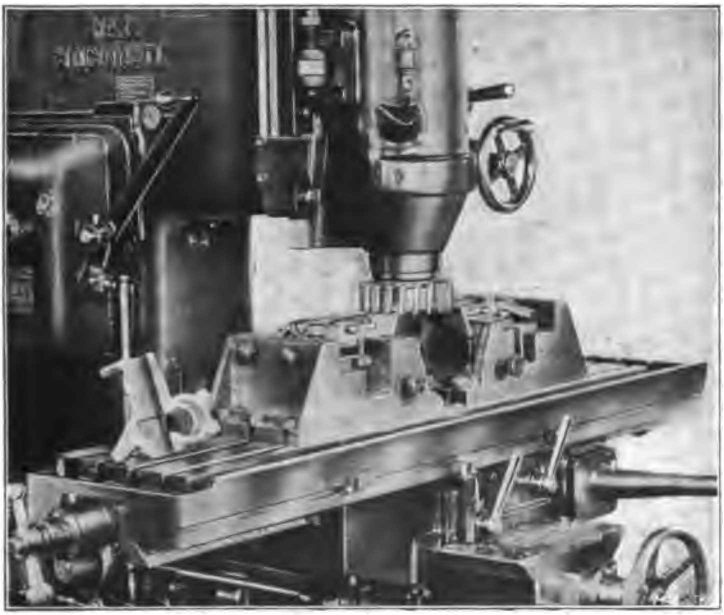

Fig. 27. Another Milling Operation Employing Two Fixtures

with angular faces which hold a casting firmly against the base of the vise.

Fig. 27 shows a continuous milling operation similar to the one just referred to, as far as the method of chucking the work is concerned. There are two independent fixtures, as before, and the castings are inserted in each fixture alternately; that is, one is being chucked while the other is being milled. The machine is fitted with an automatic reverse, and the table travels back and forth without stopping. Two cuts are taken across each piece; first a roughing cut and then a finishing cut on the return movement of the table. One of the finished castings is shown on the left end of the table. The material is malleable iron and the milled surface has an over-all dimension of 6 by 7 inches. From 1/16 to 3/32 inch metal is removed, and the table feeds 12½ inches per minute.

Continuous Circular Milling

The continuous method of face milling is also done in connection with a circular attachment. The parts to be milled are held in a fixture near the edge of the table, and, as the latter revolves, one casting after another is fed beneath the revolving cutter. An example of continuous circular milling is shown in Fig. 28. The operation is that of milling sad-irons These are held in a fixture having a capacity for fourteen castings. The table makes one revolution in from three to four minutes when doing this particular work. As the finished cast-

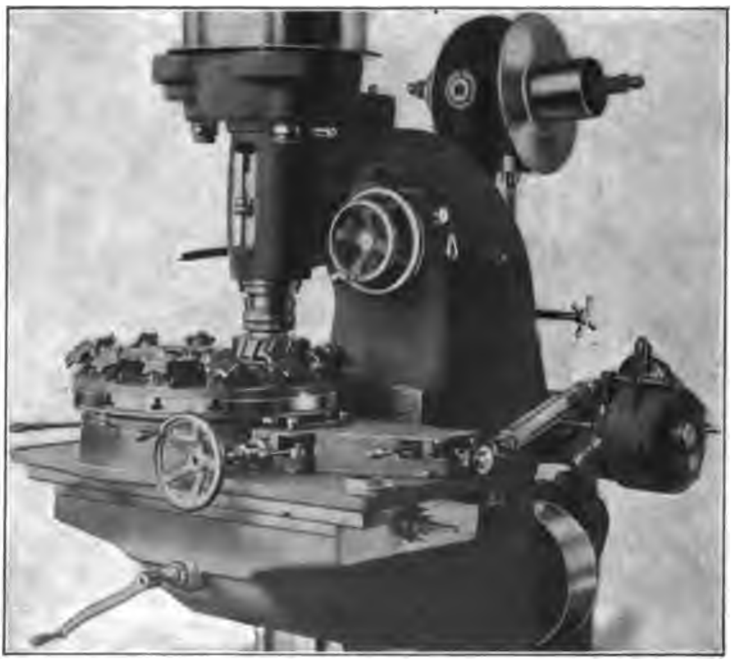

Fig. 28. Becker Vertical-spindle Machine for Continuous Circular Milling

ings come around to the front they are removed and replaced by rough ones, without stopping the machine so that the milling operation is continuous. From two thousand to three thousand castings can be milled per day by this method, the number depending on the kind of material. The fixture has star-shaped clamping nuts which make it possible to quickly release a finished casting or clamp a rough one in position. This machine is not a regular vertical milling machine of the standard type, but is especially designed for continuous circular milling. The table is without cross adjustment but can be fed longitudinally for straight surface milling. Continuous circular milling is also done on standard vertical machines by using the circular milling attachment, as previously mentioned.

CHAPTER V

LINCOLN AND PLANER-TYPE MILLING MACHINES

The milling machine shown in Fig. 29 is intended especially for manufacturing; that is, it is not adapted to a great variety of milling operations but is designed for machining large numbers of duplicate parts. The construction is very rigid but comparatively simple; and,

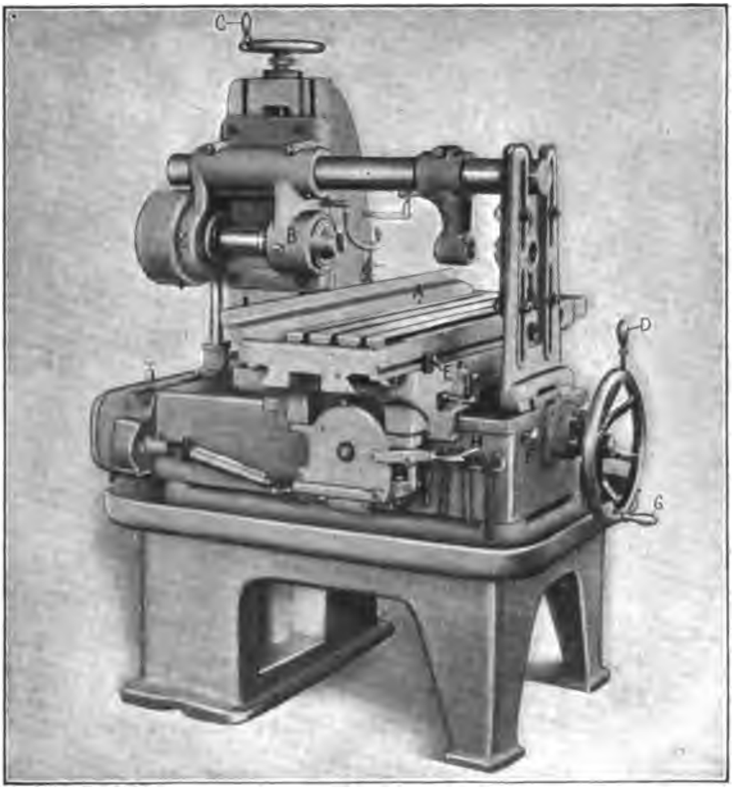

Fig. 29. Brown & Sharpe Plain Milling Machine of the Lincoln Type

therefore, this style of machine is preferable to the more complicated designs for work within its range. Milling machines having the same general construction as the one illustrated, are often referred to as the Lincoln type. As will be noted, the work-table *A*, instead of being carried by an adjustable knee, is mounted on the solid bed of the machine and the outer arbor-support is also bolted directly to the bed. This connection gives a very rigid support both for the work and cutter. The work is usually held in a fixture or vise attached to the table, and the milling is done as the table feeds longitudinally.

The table is not adjustable vertically, but the spindle-head *B* with the spindle, can be raised or lowered as may be required. This vertical adjustment of the spindle-head is effected by turning handwheel *C* which has a graduated collar reading to thousandths of an inch. After the spindle has been adjusted vertically, the head is clamped to the upright by the four bolts shown. The spindle is driven from a pulley at the rear which transmits the motion through shafting and gearing.

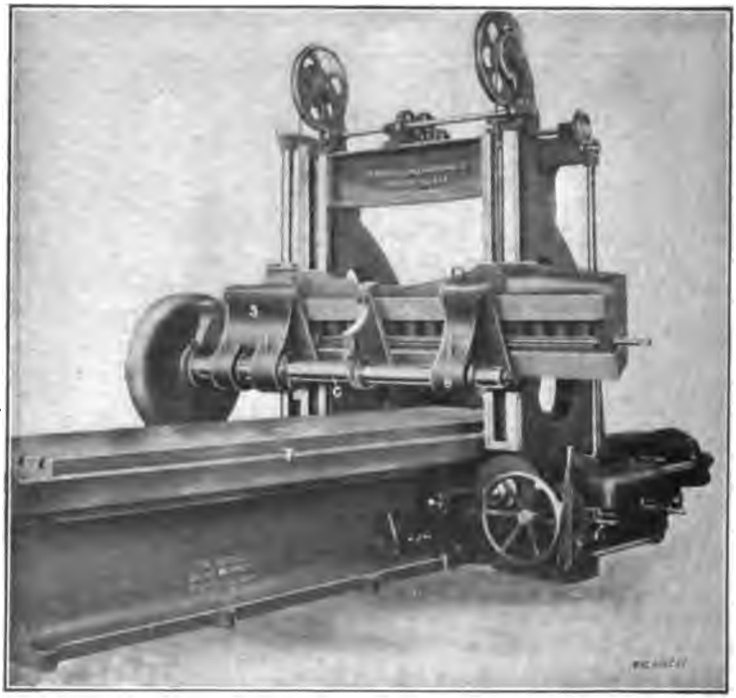

Fig. 30. Ingersoll Horizontal or Planer-type Milling Machine

A friction clutch is located in this driving pulley and provides means for starting and stopping the machine. This clutch is operated by the hand-lever *D*.

The table has a longitudinal power feed in either direction, which can be varied to suit requirements. This power feed can be automatically disengaged at any point by setting the adjustable stops *E* in the proper position. The direction of the feed can also be reversed by operating reverse-rod *F*. The large handwheel *G* can be used for adjusting the table lengthwise or crosswise. Normally this handwheel is in position for traversing the table lengthwise. When a transverse movement is required in order to locate the work with reference to the cutter, the handwheel is pushed inward, which engages it with the cross-feed screw. Before using the hand traverse, the worm-gearing of the power feed mechanism should be disengaged by operating lever *H*. The variations in both spindle speeds and table feeds are obtained, on this particular machine, by means of change gears. As machines of this kind are frequently used for a long time on one class of work, it is not necessary to make speed or feed changes very often.

This machine has a maximum longitudinal feed for the table of 34 inches; a transverse adjustment of 6 inches, and a vertical adjustment for the spindle of 12 inches. The variety of milling that can be done on a machine of this type is small as compared with the column-and-knee machines, but it is intended for milling operations that are of the

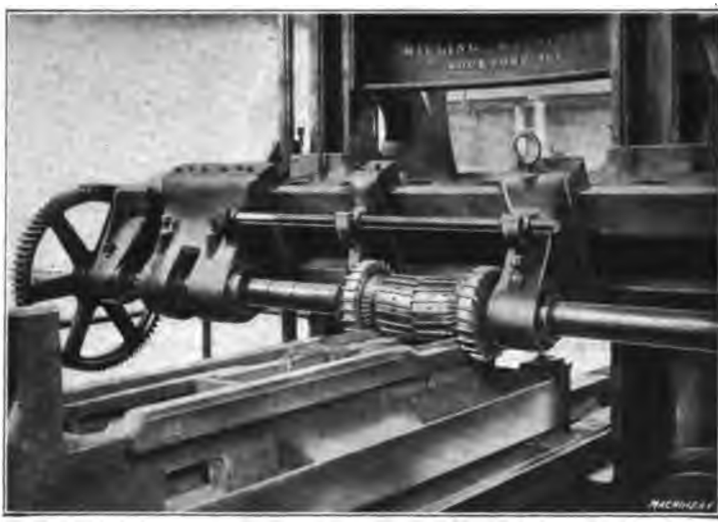

Fig. 31. Milling the Ways of a Turret Lathe Bed on a Horizontal Machine

same general character, so that a great capacity or "range" is not needed. The Lincoln type is used very effectively in connection with the manufacture of firearms, sewing machines, electrical instruments and many other kinds of machinery.

Horizontal Milling Machines of the Planer Type

The machine illustrated in Fig. 30 is designed for heavy milling operations. This style of milling machine is sometimes referred to as a planer or slab type; as the illustration shows, it is built somewhat like a planer. The work-table *T* is mounted on a long bed, and the cutter arbor *C* is carried by a cross-rail *A* which, in turn, is attached to vertical housings. The cutter arbor is driven by gearing at the left end, and it can be adjusted longitudinally by traversing the main saddle *S* along the cross-rail. The outer end of the arbor is supported by a bearing *B*, and there is also an intermediate support. The work-table has an automatic feeding movement along the bed, and it can be traversed rapidly by power, in either direction, when the position needs to be changed considerably. The power feed can be automatically disengaged at the end of the cut by a tappet which is shifted along the side of the bed to the required position. The cross-rail can be raised or lowered to locate the cutter at the required height, and

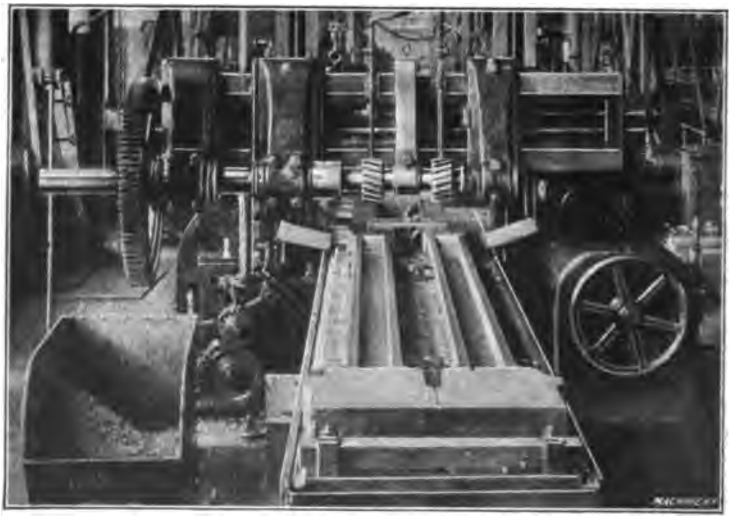

Fig. 32. Channeling the Sides of Locomotive Main-rods on Horizontal Machine

it is counterbalanced by weights attached to wire ropes that pass over the pulleys at the top of the housings.

Fig. 31 shows how a horizontal machine of this kind is used for milling a large casting. The particular part illustrated is the bed of a turret lathe, and the operation is that of milling the V-shaped ways,

Fig. 33. Cutters used for Channeling Main-rods

the flat surfaces inside these ways and the outer sides or edges. The arrangement of the gang of eight cutters is clearly shown by the illustration. The bed has been moved away from the cutters somewhat, in order to show the shape of the milled surfaces. The V-shaped ways are milled by angular cutters and the flat inner surfaces by cylindrical cutters, while the edges are trued by large side mills. This gang of cutters rotates to the right, as viewed from the operating side of the machine, and the table feeds toward the rear or against the cutter rotation.

The great advantage of machining a casting in this way is that all the surfaces are milled to shape at one passage of the work. This same casting could be machined in a planer, which is true of practically all work done on large horizontal milling machines, but whether a planer or a milling machine should be used is a question that is often difficult to decide. The number of parts to be milled and the general character of the work, must be considered. To illustrate, it

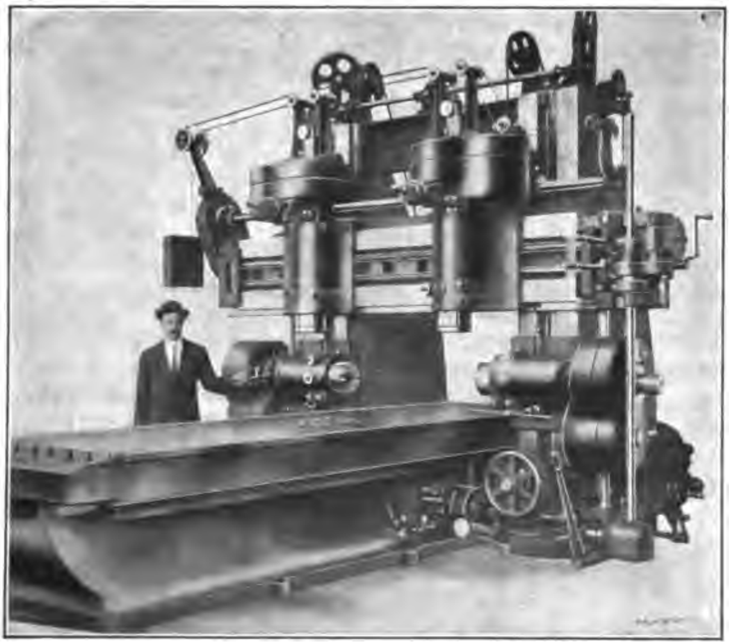

Fig. 34. Ingersoll Four-head Milling Machine

might be possible to finish a casting by milling much more rapidly than by planing. It does not necessarily follow, however, that milling will be more economical than planing. In the first place, milling cutters are much more expensive than the single-pointed planer tools which can be forged to shape by a blacksmith or toolsmith, and more time is also required to set up a milling machine than a planer, especially when a gang of cutters must be arranged for milling several surfaces simultaneously. Hence, if only a few parts are required and the necessary milling cutters are not in stock, the cost of the cutters, and the time for arranging the machine, might much more than offset the time gained by the milling process. On the other hand, when a large number of duplicate parts are required, milling is often much more economical than planing. It must not be inferred from this that the planer should always be used for small quantities of work, and the milling machine when there is a large number of parts, although the quantity of work to be done; frequently decides the question. Sometimes planing is preferred to milling, because the surface left by a planing tool is more desirable, in certain cases, than a milled surface.

When castings or forgings are quite long and narrow, two parts are sometimes clamped side by side on the bed and milled at the same time by separate cutters. Fig. 32 illustrates a job of this kind. The two steel forgings on the machine are the main rods of a locomotive, the sides of which have been channeled or grooved to form an I-beam section. This lightens the rod considerabbly but leaves it strong enough to resist the various stresses to which it is subjected. This view was taken after the channels on one side were milled. These channels are milled from the solid, and the cutters used for this work are shown on an enlarged scale in Fig. 33. They have inserted spiral teeth which incline in opposite directions to neutralize the endwise thrust. They are 8¼ inches in diameter and their width is 4½ inches, which corresponds to the width of the channel. When milling, these cutters revolve 36 revolutions per minute, giving a peripheral speed of 82 feet per minute. The channel or groove is 1¾ inches deep, and it is milled in two cuts, each having a depth of ⅞ inch. A constant stream of lubricant pours on each cutter through the hose and vertical pipes seen attached to the cross-rail. When setting up work for an operation of this kind, it must be held securely against endwise movement, because the pressure of such heavy milling cuts is very great. In this case, the rods rest against a heavy steel block which is fastened across the end of the table to resist the endwise thrust of the cut.

Multiple-head Milling Machine

Horizontal machines are built in many different designs which are modified to suit different classes of work. Fig. 34 shows a machine which, instead of having a single cutter-arbor, is equipped with four heads. Two of these heads are carried by the cross-rail and the other two are attached to the right and left housings. The cross-rail heads have vertical spindles and the side-heads, horizontal spindles, so that the sides and top surfaces of castings can be milled simultaneously. The side-heads can be adjusted vertically on the housings, and the vertical heads laterally along the cross-rail. This particular machine will drive face mills up to 20 inches in diameter.

Machines of the same general design are also built with three heads, one being on the cross-rail and two on the housings, and there are various other modifications. With the multiple-spindle machines, the number of spindles used at one time depends, of course, on the nature of the work. For some jobs it is necessary to use the horizontal spindles, whereas other parts are milled by using the horizontal and vertical spindles in combination. This type of machine is very efficient for certain kinds of milling.

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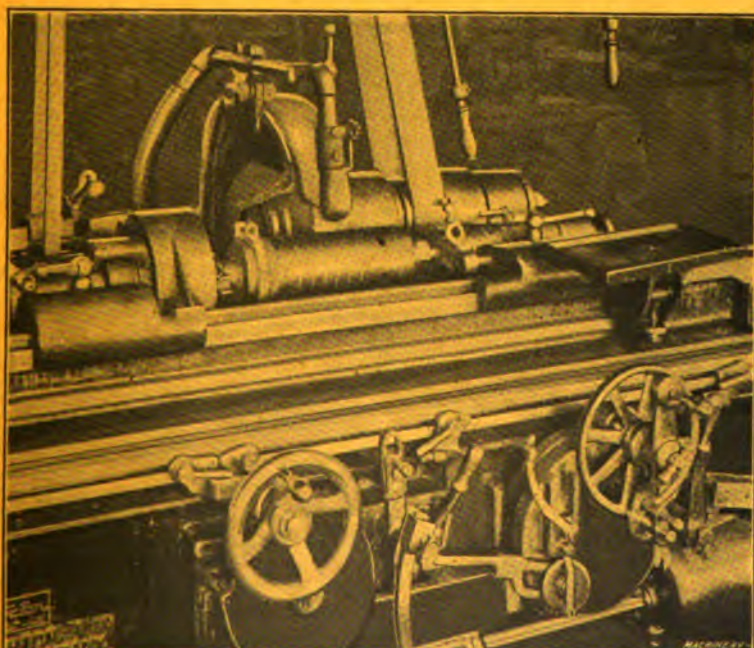

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OPERATION OF MACHINE TOOLS

By FRANKLIN D. JONES

GRINDING AND GRINDING MACHINES

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CHAPTER I

CYLINDRICAL GRINDING MACHINES

Grinding machines were originally used almost exclusively for truing tool steel parts which had been distorted by hardening, and they are still indispensable for work of this class. The great improvements which have been made, both in grinding machines and abrasive wheels, however, have resulted in the application of the grinding process to the finishing of a great many unhardened parts. In either case, the work, as a rule, is first reduced to within a few thousandths inch of the required size by turning in some form of lathe, and then it is ground to the finished dimension. After a part has been hardened, grinding is the only practicable method of truing it. On the other hand, unhardened pieces can be finished by other means, but grinding is preferable for most cylindrical work, because it enables parts to be finished accurately to a given diameter, in less time than would be required by any other known method.

Several different types of grinding machines have been developed for handling the various kinds of work to which the grinding process is applicable. The machines used for grinding cylindrical parts such as shafts, piston-rods, etc., are called cylindrical grinders whereas the type used for grinding holes in bushings, gears, milling cutters, etc., are known as internal grinders. There are also surface grinders for finishing flat or plane surfaces, and, in addition, types that are specially designed for sharpening cutters, reamers, etc. As cylindrical grinders are the type most commonly used, they will be considered first.

When grinding a cylindrical part such as a rod or shaft, it is mounted between the conical centers of the grinder (as shown by the diagrams, Fig. 1), just as it would be placed between the centers of a lathe for turning; in fact, the same center holes upon which the shaft was rough turned are used when grinding. The work is rotated rather slowly upon these centers *c* and c_1 by a driving dog *d*, which engages a pin in the driver plate at the left, and the surface is ground cylindrical by a disk-shaped wheel *g*. This wheel rotates rapidly (a 14-inch wheel would run about 1600 revolutions per minute), and the grinding is done either by traversing the rotating part past the face of the wheel or by traversing the wheel along the work. Some cylindrical grinders operate in one way, and some the other. The diagram *A*, Fig. 1, illustrates the method of grinding by traversing the work, the reciprocating movement past the wheel face being indicated by the full and dotted lines which show the position of the shaft at each end of the stroke. The revolving wheel *g* is fed inward a slight amount at each end of the work and the latter is accurately ground to the required diameter. The wheel can be fed by hand or automatically, the latter method being generally employed, except when adjusting the wheel or starting a cut. The amount that the shaft moves endwise while making one revolution, is always somewhat less than the full width of the grinding wheel face in order to secure a smooth surface free from ridges. This side traverse, as well as the rotative speed of the work, is varied to suit conditions. The operation of a machine having a traversing wheel is shown by diagram *B*. In this case, the work, instead of moving back and forth past the wheel, rotates in one position while the grinding wheel, which is mounted on a suitable carriage, moves from one end to the other, as indicated by the full and dotted lines.

The grinding wheels are composed of innumerable grains of some hard abrasive material which is held together by an adhesive bond. These grains or cutters, as they might properly be called, have sharp

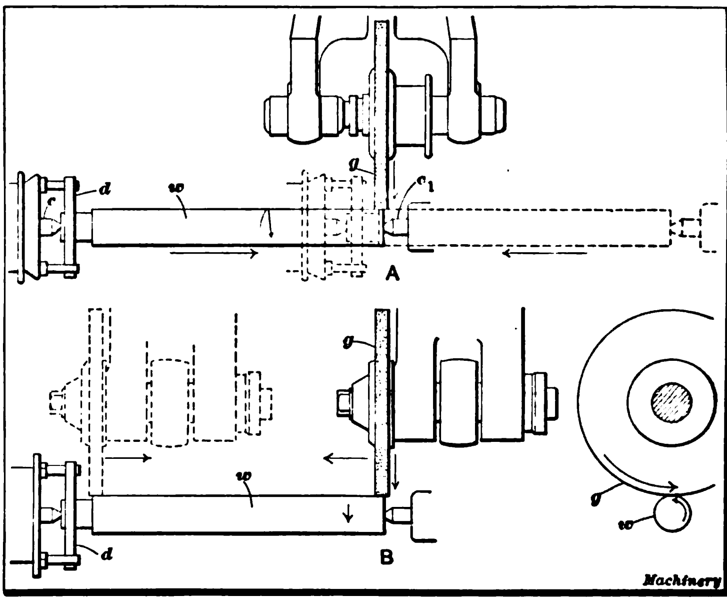

Fig. 1. (A) Diagram illustrating Method of Grinding by traversing Work past Face of Grinding Wheel. (B) Grinding by Traversing the Wheel

corners or edges which cut away the metal as the work traverses past the wheel face, or *vice versa*. The relative rotation of the wheel and the part being ground should always be as shown by the end view (diagram *B*), for cylindrical grinding. As the arrows indicate, the grinding side of the wheel *g* moves downward, and that side of the work *w* being ground, moves upward or in the opposite direction.

From the foregoing, it will be seen that a cylindrical grinding machine must be arranged to rotate both the grinding wheel and work. In addition, either the work or the wheel must be traversed longitudinally. The wheel must also be fed in automatically for taking successive cuts, and provision must be made for varying the traversing movement and the rotative speed of the work to suit different conditions. The way these various movements and adjustments are obtained with the type of cylindrical grinder illustrated in Fig. 2, will be explained. It should be understood, however, that the mechanical details vary with grinders of different makes, although all cylindrical grinding machines operate on the same general principle.

Cylindrical Grinding Machine of the Universal Type

The machine shown in Fig. 2 operates by traversing the work past the grinding wheel *G*, as illustrated by the diagram *A*, Fig. 1. The grinding wheel is revolved by a belt that passes over a pulley at the side of the wheel and connects with an overhead countershaft. The table *A*, which moves back and forth when the machine is in operation, carries a headstock *H* and a footstock *F* in which conical centers *C* and

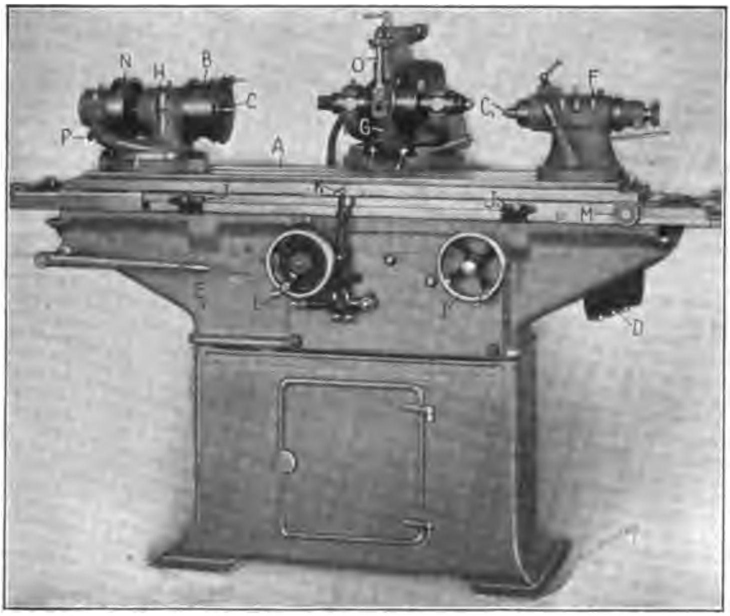

Fig. 2. Brown & Sharpe Universal Cylindrical Grinding Machine

C_1 are inserted. When a cylindrical part such as a shaft or rod is to be ground, it is placed between these centers and is rotated upon them by a belt passing over pulley *B* and connecting with a long cylindrical drum, which forms part of the overhead works for driving the machine. This long drum is used instead of a narrow pulley, so that the belt can shift along as the table moves to and fro.

The power for moving the table along the ways of the bed is obtained from a belt connecting with cone-pulley *D* which transmits motion to the table through suitable shafts and gearing located inside the bed. The traverse of the table and rotation of the work-spindle, can be started or stopped by lever *E* to the left. The wheel *I* to the right is used for moving the table by hand. When operating the table in this way, the knob in the center of this wheel is pushed inward, and when the table is to be traversed automatically, this knob is pulled out. The travel of the table or the length of its stroke is controlled by the position of the adjustable dogs *J* and J_1 which operate the reversing lever *K*. Lever *K* connects with a clutch inside the base and this clutch, through gearing, reverses the movement of the table whenever lever *K* is thrown to the right or left. The length of the stroke is changed by varying the distance between dogs *J*. These dogs slide upon a rack attached to the front of the table and are held in position by a spring-latch that engages the rack teeth.

The Automatic Cross Feed

The grinding wheel can be moved to or from the work by rotating handwheel *L*, and it is fed inward automatically by the mechanism

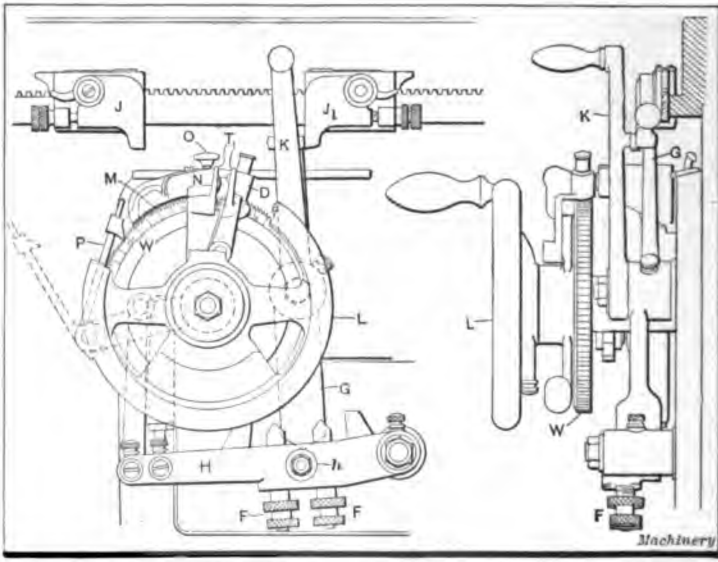

Fig. 3. Mechanism which feeds the Grinding Wheel forward at each Reversal of the Work and automatically disengages the Feed when a Predetermined Amount has been ground away

located just back of this wheel. This mechanism is so arranged that it can be set to stop the feed when the diameter has been ground to a predetermined size. The way in which this automatic feed operates will be more clearly understood by referring to the detail drawing, Fig. 3. When the dogs *J* strike lever *K*, thus reversing the table movement, the lever *G* is also actuated, and it has a V-shaped end which engages roll *h*, and operates lever *H* and pawl *P*. If this pawl is in mesh with the ratchet wheel *W*, the grinding wheel will be fed forward an amount depending upon the position of the screws *F*, which come against a surface on lever *G*, thus regulating the upward movement of lever *H* and, consequently, the movement of the pawl at the end of each stroke. The automatic feed will continue at each reversal until the shield *M* (which is attached to head *N*) intercepts pawl *P* and prevents it from engaging the ratchet wheel *W*. The feed then stops automatically.

The amount that the grinding wheel moves inward before the feed is automatically disengaged, depends upon the distance between the end of shield *M* and the tooth of pawl *P*. Each time the table reverses, this pawl rotates ratchet *W* one or more teeth and this feeding movement continues until shield *M* moves around and disengages the pawl, as previously mentioned. As a movement of one tooth represents a reduction in the diameter of the work of 0.00025 inch, the automatic feed can be set for grinding very close to a given size by varying the distance between the disengaging shield and the pawl. The feed can be set to give the full amount at each end of the stroke or any part of the full amount at either end, by adjusting the regulating screws *F*. The feed on this particular machine can be varied from 0.00025 inch to 0.004 inch at each reversal of the table. These feeds seem like very small amounts, especially when compared with the cuts taken on turning or planing machines, but the grinder is a precision machine used for producing fine, accurate surfaces and it is not adapted to taking deep cuts. With a modern high-power machine, however, metal can be removed with considerable rapidity.

The automatic cross feed is a great advantage, especially when grinding a large number of duplicate parts, as it prevents grinding them too small, and makes it unnecessary for the operator to be continually measuring the diameter of the work. The automatic feed is also desirable because it moves the wheel inward an unvarying amount at each reversal. This regularity of the feeding movement increases the "sizing power" of the grinding wheel. In other words, the wheel maintains its size for a longer period and the wear is more uniform. Of course, all grinding operations are accompanied by more or less wheel wear which has to be compensated for (as will be described later), although the amount of wear is surprisingly small when the wheel and work rotate at the proper speeds.

Miscellaneous Features

The headstock *H* (Fig. 2) is held to the table by bolts which slide in a T-slot, and the footstock *F* is clamped by the lever shown, so that the distance between the centers can be varied to suit the length of the work. The spindle and upper part of the headstock can be swiveled about a vertical axis for grinding flat disks or taper work, and the angular position is shown by degree graduations on the circular base. The spindle of the footstock is not screwed rigidly against the end of the work, as in the case of a lathe, but it is held in position by a strong spring. By means of this spring, a firm, even pressure is applied to the center, and, in case the work expands from the heat developed in grinding, the center yields and the part being ground is not distorted.

The usual method of grinding a cylindrical part is to rotate it on two "dead centers," both centers remaining stationary. The object of grinding work while it revolves on stationary centers is to secure accuracy, for then any slight error which may be in the spindle bearings is not reproduced in the work. If center *C* were rotated with the work, as in the case of a lathe, any eccentricity of the center would result in inaccurate grinding. Therefore, when grinding cylindrical parts on centers, the spindle is locked by a pin *P* which engages a hole in the flange of pulley *N*. Pulley *B*, which rotates freely around the spindle, carries a driving dog and rotates the work. For some classes of grinding, as, for example, when grinding parts held in a chuck attached to the spindle, it is necessary to rotate the spindle. Lock-pin *P* is then withdrawn and a belt from the overhead driving drum is connected with pulley *N*.

The upper part of the work-table can be set at an angle for taper grinding. This upper swiveling table is normally held to the lower member by bolts at each end. When these are loosened, the table can be turned a limited extent about a central stud, by means of adjusting

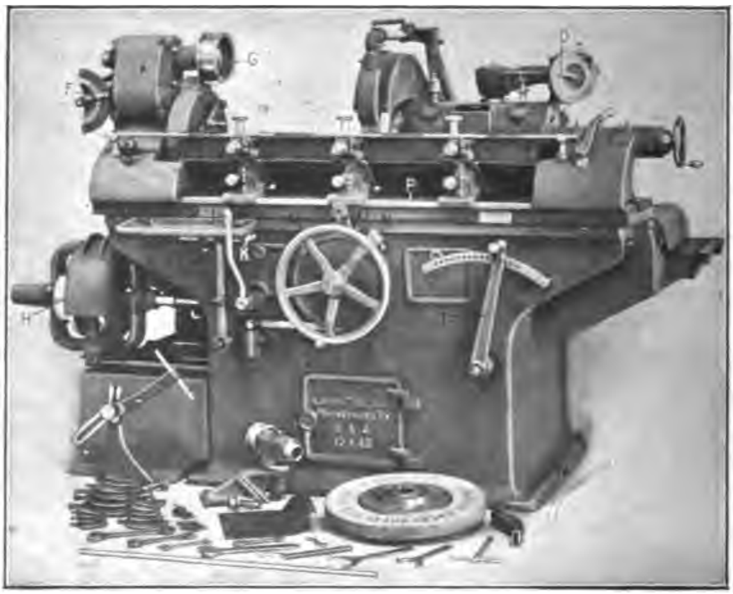

Fig. 4. Landis Plain Grinding Machine

screw *M*. There are two sets of graduations on the end of the swiveling table, one reading to degrees and the other giving the taper in inches per foot. When the swivel table is set at an angle, the headstock and footstock centers remain in line but are at an angle with the ways of the bed or the line of motion. For ordinary cylindrical grinding, the wheel-stand slide is set at right angles to the ways. On a grinder of this type, the wheel slide can also be set at an angle when necessary for grinding parts having a steep or abrupt taper.

Another feature of the cylindrical grinder which should be referred to is the provision made for supplying cooling water to the wheel when grinding. At the point where the wheel is in contact with the work there is considerable heat generated; consequently a cooling medium is very essential when grinding parts which revolve upon the centers, in order to maintain an even temperature. When water is not used, the part being ground tends to bend towards the wheel owing to the higher degree of heat and resulting elongation on the grinding side; in other words, its axis will be continually changing, and, obviously, inaccuracy will be the result. The apparatus for supplying the water consists of a small pump of the fan type which operates in a tank at the rear. The water is conveyed to the grinding wheel through a hose and pipe *O*, and plays on that part of the work being ground.

Cylindrical Grinding Machine of the Plain Type

Cylindrical grinding machines, like milling machines, are divided into two general classes, known as plain and universal grinders. The first type is used for grinding work in large quantities, which varies comparatively little in form, which means that it is essentially a machine for manufacturing purposes. The general construction of the universal grinder is similar to that of the plain grinder, but it differs

Fig. 5. End View of Landis Grinder, showing Automatic Cross-feed Mechanism

from the latter in having certain special features and auxiliary attachments which adapt it to a more general or universal class of work. The principal difference between the universal and plain types, as far as the construction of the machine itself is concerned, is as follows: The wheel slide of a universal machine can be swiveled with relation to the travel of the table; the headstock can also be set at an angle, and provision is made for revolving the spindle for grinding parts that are held in a chuck or otherwise. With a plain machine the wheel slide is permanently set at right angles to the table travel and the headstock cannot be swiveled. The machine shown in Fig. 2 is a universal type, whereas a plain grinder is shown in Fig. 4. These machines differ considerably in their construction because they are different makes. Plain and universal machines of the same make, however, are practically the same except for the changes referred to, unless one is much larger than the other.

The machine illustrated in Fig. 4 operates by traversing the grinding wheel along the work which rotates in a fixed position, as indicated by the diagram *B*, Fig. 1. The travel of the wheel carriage is regulated,

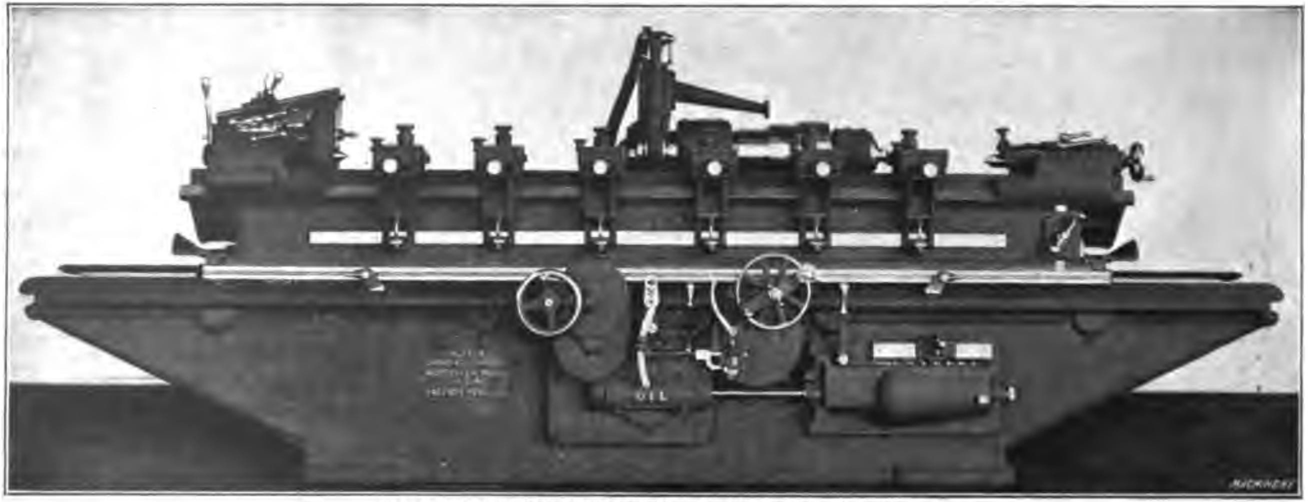

Fig. 6. Norton Cylindrical Grinding Machine of the Plain Type

for work of different lengths, by varying the position of the dogs *N*, which are mounted on a wheel or circular rack. On the periphery of this wheel worm-teeth are cut, and the dogs are held in any desired position by worms which may be lifted out of engagement when the dogs are to be moved a considerable distance. The tappet *O* against which these dogs strike, thus reversing the movement of the carriage, can be swung out of the way when it is desired to let the wheel travel beyond the reversing points. The amount that the wheel carriage moves longitudinally per revolution of the work, or its side traverse, is regulated by changing the position of lever *I*. The lever *J* is used for reversing the carriage travel at any point, by hand, while the traverse movement is started or stopped by lever *K*. When it is desired to move the carriage longitudinally by hand, the wheel *L* is used. The platen *P* can be swiveled for grinding taper work, the same as with a universal machine. The power for traversing the wheel carriage is obtained from a belt operating on pulley *H*, and the work is rotated by a belt connecting with pulley *G*. The work speeds are varied by shifting lever *F*.

The grinding wheel is moved to or from the work by the handwheel *D*. In conjunction with this handwheel there is an automatic cross feed which may be set to advance the wheel at each reversal of the carriage on which the wheel is mounted. This feed is effected by the pawl *A* (Fig. 5) which meshes with ratchet teeth in the periphery of the wheel *D*. Provision is made for automatically disengaging this feed when the wheel has ground any predetermined amount from the work. This is accomplished by a movable ring *B*, mounted on the handwheel and having a knock-out cam *C*, which engages a pin on the feed pawl *A*. When setting this feed to grind a given amount, the wheel is first brought into contact with the work, by turning the handwheel *D*; the ring *B* is then moved around until the cam *C* is against the pin on pawl *A*. When the machine makes its first stroke, the pawl is disengaged from the ratchet. The wheel should then be allowed to pass over the work until it has practically ceased cutting, when the traverse should be stopped, say at the footstock end. The diameter of the work is next measured carefully with a micrometer. The thumb-latch *E* is then pressed against its stop four times for each 0.001 inch reduction in diameter required. As this thumb-latch has attached to it a spring pawl engaging the ratchet teeth on the wheel *D*, the ring *B*, with its knock-out cam, is moved away from the feed pawl *A* an amount equivalent to one ratchet tooth each time the latch is pressed. When the grinding is continued, the cam gradually moves backward and finally disengages the feed pawl. The amount of feed is regulated by adjusting screw *F*.

Large Grinding Machine of the Plain Type

Fig. 6 shows a large grinding machine of the plain type which will grind work up to 96 inches in length. This machine has a moving work-table and the grinding wheel revolves in a fixed position, except for the crosswise feeding movement at each end of the stroke. The wheels used in this machine are 24 inches in diameter and have a width of 2 inches. The wheel slide is fed forward either by a handwheel or automatically, and the automatic feed can be set for grinding a given amount. The rotative speed of the work can be changed by shifting the belt on the driving cone pulley of the headstock. The rate of table traverse can also be regulated to give a coarse feed for removing stock rapidly or a finer feed for finishing. The mechanism seen at the front of the machine includes the automatic cross feed, and the table speed-changing mechanism. There are also hand-wheels for adjusting the table longitudinally and the grinding wheel in a crosswise direction. The particular machine illustrated is equipped with six steadyrests which are used for supporting the work and to prevent vibration. The number of rests used in any case depends upon the length of the part being ground.

CHAPTER II

CYLINDRICAL GRINDING OPERATIONS

As an example of grinding, suppose a rather short shaft is to be ground cylindrical and to a diameter somewhere between 2.050 and 2.0495 inches, there being an allowable variation in size of 0.0005 inch. Before beginning to grind, a wheel should be selected that is suitable for the part to be ground. When grinding, the work must also be rotated at the proper speed in order to minimize the wheel wear and secure a well finished surface. The points to be considered when selecting the wheel and adjusting the work speed, have been referred to separately in Chapter III, to avoid confusion. We shall assume that a wheel of the proper grade and grain has been mounted on the spindle of the grinder and that a machine similar to the one shown in Fig. 2 is to be used. We shall also assume that the work has been rough turned in a lathe to within about 0.010 inch of the required size.

The headstock *H* and footstock *F* are first set the required distance apart and then the work is placed between the centers with a driving dog attached to the headstock end, as illustrated in Fig. 7. The same center holes upon which the part was turned, are also used when grinding, and they should be carefully cleaned before placing the shaft in the machine. The centers should also be oiled, because, as previously mentioned, work of this kind rotates upon the "dead" centers of the machine, which remain stationary in order to secure greater accuracy. When the shaft is in place, the reversing dogs *J* and J_1 are set to give the table the right length of stroke. The travel should be reversed when a small part of the wheel face has passed the end of the piece being ground. If the stroke is too long, more time will be required for taking a cut than is necessary.

As the part is to be ground cylindrical or straight, the swivel table *A* should be set to the zero position. The headstock *H* must also be set to zero, as otherwise the centers will not be in alignment. It should be remembered that the graduations are only intended to give an approximate setting, and when accuracy is required, it is necessary to test the work by using a micrometer or gages. This test is made by first taking a trial cut and then measuring the diameter of the work at each end. If there is any variation, the table is turned slightly in whatever direction may be required to produce a cylindrical surface, by using the fine adjusting screw *M*, Fig. 2.

Setting the Automatic Feed

When starting a cut and setting the automatic feed, the grinding wheel is moved in by hand until it is almost in contact with the work. The stroke of the table is then stopped by pushing in knob *Q*, (with this particular machine) and pawl *P* is placed into engagement with the

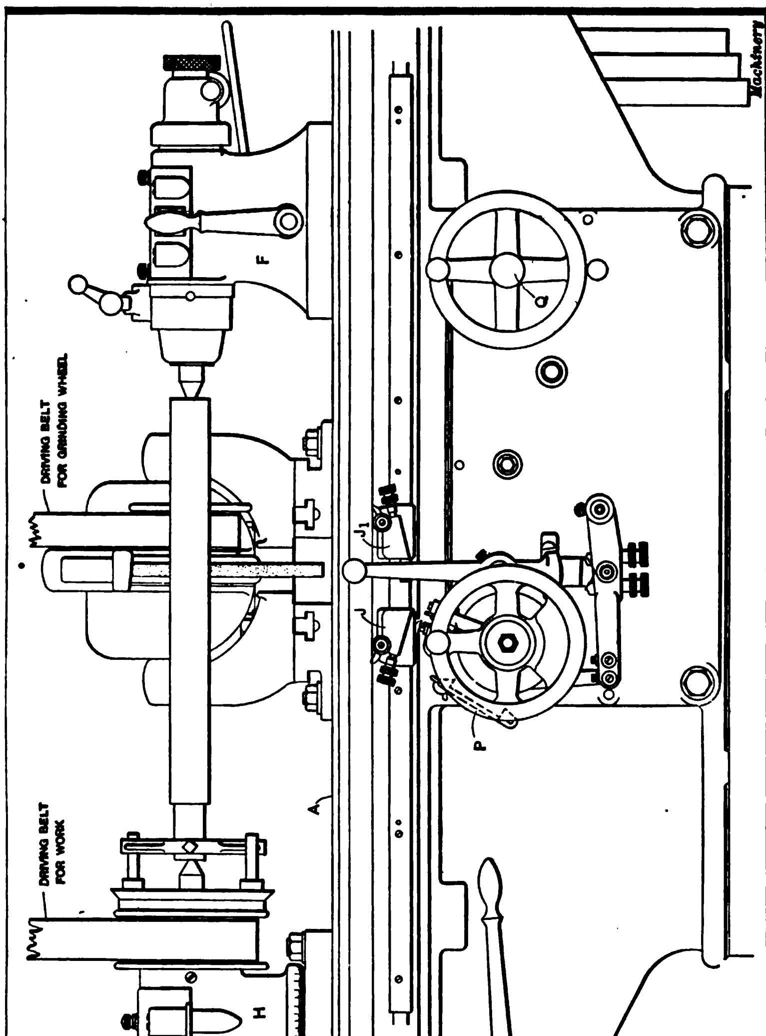

Fig. 7. Type of Machine illustrated in Fig. 2, arranged for Grinding a Cylindrical Shaft

ratchet wheel. The latch *O* (see Fig. 3) is then raised and the head *N* moved around the periphery of the ratchet wheel until the point of shield *M* has just passed the tooth occupied by the pawl, so that the latter rests upon the shield. After the table stroke is again started, thumb-latch *T* is pressed until the grinding wheel begins to cut. When the surface is ground true, the table is stopped when the grinding wheel is at the footstock end, and the diameter of the part ground is measured with a micrometer. The thumb latch *T* of the automatic feed is then pressed once for each quarter of a thousandth to be removed. To illustrate, suppose the diameter, after the surface has been trued, is 2.057 inch. Then there would be 0.007 inch stock to remove ($2.057 - 2.050 = 0.007$; hence, the latch would be pressed twenty-eight times, thus moving shield *M* far enough away from the feed pawl to allow the latter to continue feeding until 0.007 inch has been ground away.

When the feed has been set, the table traverse is again started and the grinding continued until the feed is disengaged. The wheel should then be stopped at the footstock end, as before, when the density of the sparks thrown off by the wheel have diminished somewhat and are about the same as for the final cut taken prior to the first measurement. If a suitable wheel has been used and the work rotated at the proper speed, the diameter should be very close to 2.050 inch, because, in this case, a comparatively small amount has been ground away, and, consequently, the wheel wear would be almost negligible. On the other hand, where it is necessary to remove considerable stock, the diameter of the work might be somewhat above the size for which the automatic feed was set, owing to the wear of the grinding wheel. After the amount of wheel wear for removing a given amount of stock is determined, the automatic feed can be set to compensate for this wear, when grinding a duplicate part. For example, if the diameter of the work were 0.001 inch over size, the latch *P* would be pressed four times or once for each quarter thousandth reduction required, and the grinding continued until the feed was again automatically disengaged. After this disengagement takes place, the traversing movement of the work should be continued until the wheel has practically ceased cutting, as shown by the decrease in the shower of sparks.

By noting the sparks and then stopping the machine when the volume or density is practically the same for the final cut, duplicate parts can be ground to a given diameter within close limit; in fact the shower of sparks thrown off by the grinding wheel is a very convenient and sensitive indication of the depth of the cut, and, with a little practice, it is possible to gage the cut to within very close limits by this method. An interesting experiment was made to determine what the depth of a cut would be when the sparks were just visible. A hardened steel gage was ground very carefully and, when taking the final cut, the work was traversed past the wheel until no sparks were visible. The exact diameter of the gage was then found by using a measuring machine, after which the gage was again placed in the grinder and the wheel was fed forward very slowly until sparks were just visible. The gage was then traversed past the wheel, as before, until all the sparks had disappeared. Then by again measuring the diameter, it was found that a reduction of 0.00001 inch had been made.

One not experienced in grinding machine operation should become familiar with the relation between the shower of sparks thrown off by the wheel and the depth of the cut, so that a given amount of stock can be ground away without wasting too much time in measuring. It is well for the inexperienced operator to note the density of the sparks when cuts of a known depth are being taken. With a little practice, one can judge the depth of a cut by this method with considerable accuracy.

When one shaft is ground and another is to be inserted in the machine, pawl *P* is disengaged and handwheel *L* is turned to the right about one revolution (without changing the position of shield *M*) in order to move the wheel away from the work. The latter is then removed and replaced by a rough shaft. When the new blank is in position, wheel *L* is turned to the left until the grinding wheel begins to cut. Then pawl *P* is again placed in mesh with the ratchet wheel, which causes the automatic feed to operate as previously described.

While the automatic feed will enable parts to be ground to a given diameter within close limits, this diameter should, of course, always be measured either with a micrometer or by the use of a fixed gage. As previously intimated, the accuracy of the automatic feed for grinding to the diameter for which it is set, depends upon the amount the wheel wears, and the wheel wear, in turn, is governed by the "grade" of the wheel and the surface speed of the work. When a wheel of the proper grade is used and surface speeds of the wheel and work are correct, the wear is surprisingly small and, in some instances, quite a number of duplicate parts can be ground without compensating for the wheel wear.

Taking Roughing and Finishing Cuts

The exact method of procedure when grinding cylindrical parts often depends on the number of pieces to be ground and their shape. A single shaft having a diameter of, say, 2 inches and a length of 12 inches, could be ground by simply placing it between the centers with a dog attached and proceeding as described in the foregoing. On the other hand, if the shaft were long and flexible, it would have to be supported by work-rests to prevent deflection and vibration. A single shaft might also be finished by taking a number of light cuts which would be, practically, a succession of finishing cuts, whereas a number of pieces would be first "rough" ground and then finished.

The difference between roughing and finishing in the grinder is as follows: For roughing, a fast side traversing movement is used that is almost equal to the face width of the wheel, and comparatively deep cuts are taken, whereas, for finishing, the side feed and depth of cut are reduced in order to obtain a fine, smooth finish. The rotative speed of the work is also changed for finishing; in some shops the speed is increased, whereas in others it is diminished. This variation in practice is doubtless due to the use of different machines and grinding wheels. The method commonly employed for ordinary machine grinding is to use a coarse, free-cutting wheel and a work speed that is fast enough to keep the wheel "sharp" and permit rapid grinding. The same wheel is then used for finishing after it has been trued with the diamond, and the work speed is reduced to get a finer finish than would be possible with the higher speed used for roughing. The advantage of rough grinding and then finishing by a separate operation, is that the stock can be removed more rapidly by the roughing operation. It is necessary, however, to true the wheel face before taking the finishing cut and when grinding a single part, it might be better to simply take a number of light cuts in order to keep the face of the wheel true.

The following example will serve to illustrate one method of handling a grinding machine when the parts are first rough ground close to size and then finished by light cuts. Suppose there are a number of cylin-

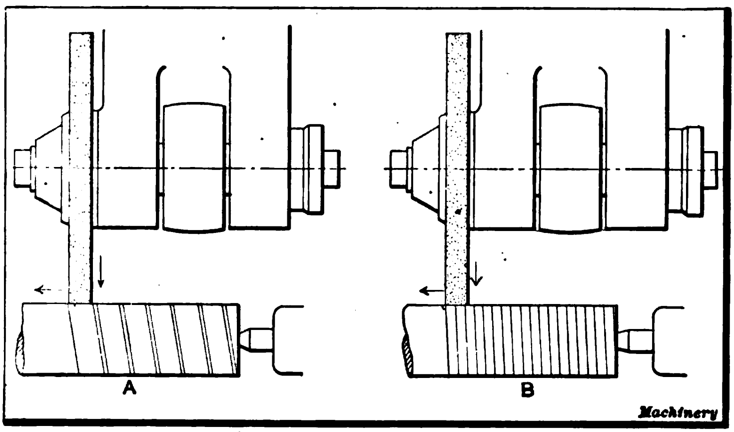

Fig. 8. (A) Wheel with Excessive Side Traverse or Feed. (B) Wheel feeding laterally a Fraction of its Width for each Revolution of the Work

drical rods which have been rough turned in the lathe to within 0.020 inch of the finish size, and are to be ground to a diameter of 2 inches and be given a good finish. Before beginning to grind, a number of steadyrests should be clamped to the table of the machine and adjusted against the work to prevent the latter from springing and vibrating. These rests are made in several different styles and the number that should be used depends on the length of the work. This matter of supporting the work is very important, and will be referred to subsequently. The grinder is next set to the right length of stroke, and the feed of the table (or side traverse of the wheel) as well as the work speed, should also be properly adjusted.

The wear of a grinding wheel, as previously mentioned, depends very much on the surface speed of the work, the wear increasing as the work speed is increased. Hence it is the modern practice to use a comparatively slow work speed in conjunction with a coarse side feed of the wheel when it is important to grind rapidly; that is, instead of feeding the wheel a distance equal to only ⅛ or ¼ its width per revolution of the work, it is given a side feed that is only a little less than the full width of the wheel face. Comparatively wide wheels are also used in modern machines, so that the surface being ground is covered quite rapidly.

Suppose the work is rotated fast enough to give a surface speed of 25 feet per minute and the fastest side feed is engaged in order to determine by trial what combination will give the best results. When the wheel is brought into contact with the work, if it leaves coarse, spiral feed lines (as shown at *A*, Fig. 8) having a greater pitch than the width of the wheel, the side feed should be reduced until the wheel does not leave any unground surface. In other words, the side feed should be somewhat less than the wheel width in order to grind a

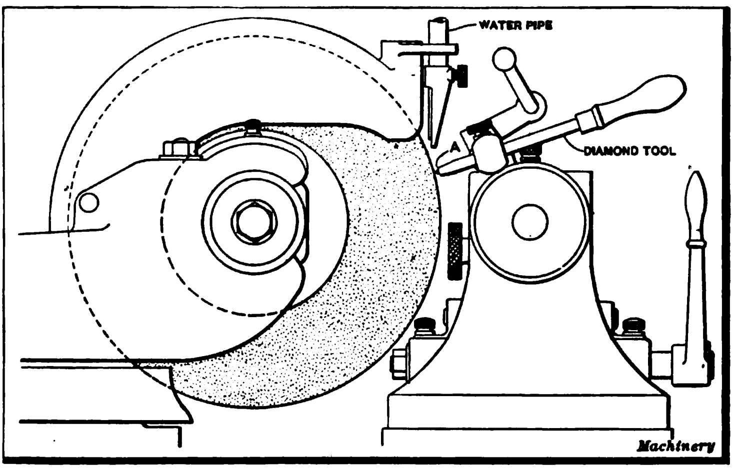

Fig. 9. Truing Face of Grinding Wheel by use of Diamond Tool

smooth surface, free from ridges. On the contrary, if the fastest side feed only moves the wheel laterally a fraction of its full width (as indicated by the narrow feed lines at *B*) the work speed should be reduced until the side feed is nearly equal to the wheel width. Owing to the rapid side feed, the wheel will pass over the surface being ground in a comparatively short time, and by using a rather slow work speed, the wear of the wheel is minimized. This method of grinding is employed when using large machines, which have sufficient driving power to enable such broad cuts to be taken and are rigid enough to prevent excessive vibration. When a small light grinder is employed, it is not always feasible to take such wide cuts, owing to the lack of rigidity and driving power. The depth of the cut or the amount that the wheel feeds inward at each reversal, is also controlled by the power and rigidity of the machine used.

After the stroke, side feed and work speed have been properly adjusted, the feed mechanism is set to give the desired depth of cut. We shall assume that in this case a cut of 0.001 inch is to be taken at each reversal, which would reduce the diameter 0.002 inch for each passage of the wheel. As soon as the rough turned surface has been ground true, the wheel should be allowed to pass across the work without feeding it inward, until the sparks diminish somewhat thus showing that the wheel has practically ceased cutting. The diameter is then measured to find out how much stock must be removed by roughing. Suppose the diameter is 2.016 inch and we want to rough grind to within about 0.002 inch of the finish size or to a diameter of 2.002 inches; there would then be 0.014 inch to be removed by rough grinding, and the automatic feed would be set for this amount. The machine is then started and the grinding continued until the feed is disengaged and the wheel has practically ceased cutting as before. The diameter is then

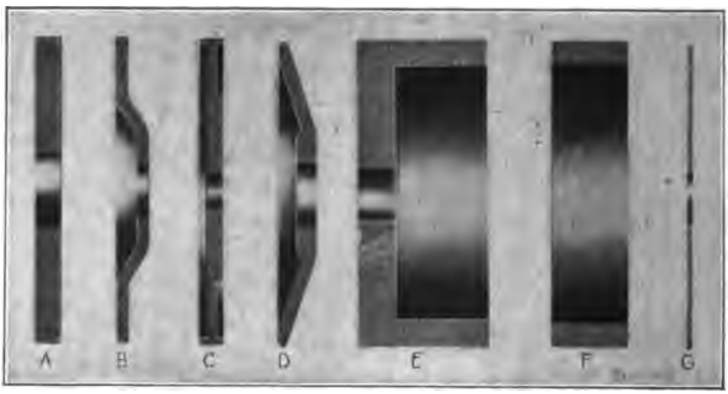

Fig. 10. Grinding Wheels of Different Shape

again measured and the difference between this measurement and 2.002 inch will show how much the wheel has worn. If the wheel wear should be excessive, it would be well to try a finer feed when grinding the next piece.

We shall assume that the rods are to be rough ground to a diameter somewhere between the limits of 2.0015 and 2.0025 inch, and that the diameter of the first piece was 0.002 or 0.003 inch over the maximum size when the automatic feed tripped. This stock should first be removed by putting on additional feed and then another blank should be placed in the machine and the roughing operation repeated, but with a reduced feed in order to diminish the wheel wear. By a little experimenting we should be able to find what combination would give the best results. All parts are then rough ground, and whenever the wheel has worn to such an extent that the diameter is greater than the maximum limit of 2.0025 inches, enough additional feed is "put on" to grind the next blank to the minimum roughing limit of 2.0015 inches. After all of the pieces have been roughed out, in this way, the wheel should be trued for finishing, as explained in the next paragraph. The finishing cuts are then taken after the side feed of the wheel and the surface speed of the work have been reduced, to obtain a smoother finish.

As little stock is removed when finishing, it should be possible to grind a number of parts without compensating for wheel wear.

Truing a Grinding Wheel

The grinding wheel should never be used unless it runs true and has an even bearing on the surface of the work. In other words, the face of the wheel should be parallel with the surface being ground, and it is especially important to have a true, even wheel face when taking a finishing cut. The only satisfactory method of truing a wheel is by the use of a diamond tool. This tool is clamped to the footstock of the machine (as shown in Fig. 9), or in a special holder attached to the table, and the stroke is adjusted so that the diamond point *A* will just clear the wheel face on each side. The wheel, which should revolve at the speed required for grinding, is then trued by bringing it into contact with the diamond as the latter travels back and forth. Very light cuts should be taken and water used to keep the diamond cool. The diamond tool should be held with the point quite close to the clamp or point of support in order to reduce vibration and give a smooth accurate wheel surface. Diamond tools usually have round shanks to permit clamping them in different positions so that the wear on the diamond will not be confined to one to two points. When truing the wheel, light cuts should be taken and the diamond traversed across the face with a uniform speed. The number of times that the wheel has to be trued depends upon the character of the work and the kind of wheel used. If it is necessary to remove considerable stock, the wheel may have to be trued before taking each finishing cut, provivded the roughing and finishing operations are performed successively. When a number of duplicate parts are ground, this is avovided by first rough grinding them all and then truing the wheel once for finishing the entire lot, or as many parts as the wheel will grind satisfactorily.

Shapes of Grinding Wheels

Grinding wheels are made in a great many different shapes and sizes for use in different types of grinding machines, and on different classes of work. A plain disk-shaped wheel *A*, Fig. 10, is used for most cylindrical grinding. The diameter and width of the wheel, for ordinary work, depends, principally, upon the size and power of the machine. The type of wheel shown at *B* is intended for grinding up to a large shoulder. It is mounted on the end of the spindle and is dished at the center, so that the retaining nut on the spindle will not project beyond the side of the wheel and strike the shoulder. Wheel *C* is especially adapted for facing the ends of bushings or small shoulders. When the wheel is used for end facing, the grinding is done by the side, which is recessed to reduce the contact area. The saucer-shaped wheel *D* is extensively used for grinding formed milling cutters, etc., especially on regular tool- and cutter-grinding machines. The cup wheel *E* is used for grinding flat surfaces by traversing the work past the end or face of the wheel. The cylindrical or ring-wheel *F* is also used for producing flat surfaces and grinds on the end or face. The cup wheel is attached directly to the spindle but the ring-wheel is held in a special chuck.

Thin wheels *G* are used for sharpening cutters, reamers, etc., or for cutting off stock. Grinding wheels are made in many other shapes, but most of them are modifications of the few styles referred to.

Rests or Supports for the Work

Practically all parts that are ground on centers should be supported by suitable work-rests or "steadies," as their use will permit taking deeper cuts with coarser feeds and also increase the "sizing power" of the wheel. When grinding long and slender parts, such supports are indispensable, and even for work which is short and rigid, rests are desirable to prevent vibration, which increases wheel wear and affects the quality of the ground surface. These rests or supports are fastened to the table of the machine and are equipped with shoes of hard

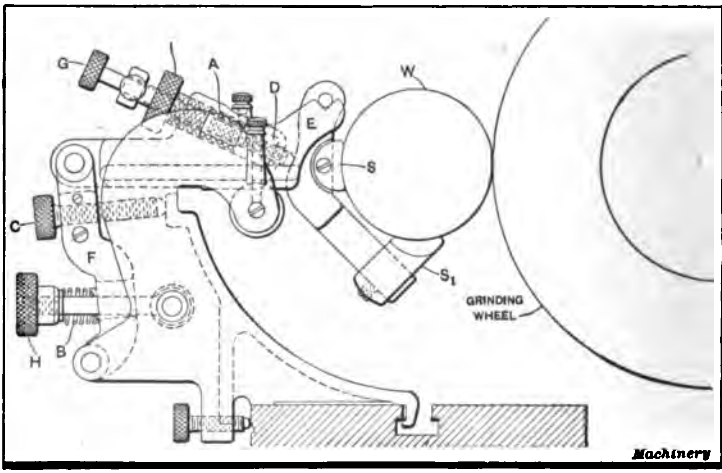

Fig. 11. Universal Back-rest for Supporting Work being Ground

wood or soft metal which bear against the piece being ground. The number of rests used, depends on the form and diameter of the work. According to a commonly accepted rule, the distance between each rest should be from six to ten times the diameter of the part being ground.

Work-rests are made in several different styles, and they may be divided into two general classes which differ in that one type is rigid and the other flexible. The rigid rest gives a positive unyielding support, whereas the flexible rest, as the name implies, can yield more or less, the supporting shoe being held against the work by springs. Most rigid rests must be readjusted by hand as the diameter of the work is reduced by grinding, whereas the shoes of the flexible type adjust themselves automatically after the rest is properly set. Then there is another form of rest which has spring tension but can be made rigid when desirable, and still another type is so designed, that the supporting shoes are adjusted automatically but the support is unyielding.

A design of work-rest that has been extensively used, is shown in Fig. 11. This is a spring or flexible type and is called a universal back-rest. The work *W* is supported by the shoes *S* and S_1 which are held yieldingly but quite firmly in position, by means of springs located at *A* and *B*. Adjustable stops *C* and *D* are provided to prevent the springs from forcing the work against the wheel after the part has been ground to the required diameter. When these stops are correctly set, no pressure is exerted by the springs upon the shoe after the work has been reduced to the finished size. Provision is also made for regulating the pressure of the springs to adapt the rest to either light or heavy work. After the stops are once set, duplicate parts can be ground to the same diameter without readjusting the rests.

Fig. 12 shows how four of these back-rests are used for supporting a long shaft which is being ground. After they are clamped to the table

Fig. 12. Grinding Machine equipped with Four Universal Back-rests

of the machine, the shoes of each rest are adjusted, independently, to bear properly against the shaft. The way this adjustment is made will be more clearly understood by again referring to Fig. 11. The holder for the shoes has trunnions at the top which rest in V-shaped notches formed at the front end of frame *E*. The latter is connected at the rear with a link *F* which is pivoted at its lower end. Spring *B* tends to push frame *E* forward, and the extent of this forward movement is regulated by stop-screw *C*. In addition to this motion, the shoe holder can also be swiveled about its supporting trunnions by spring *A*. This spring forces screw *G* against the holder, and the movement of the screw is regulated by stop *D*. From the foregoing, it will be seen that spring *B* forces shoe *S* against the rear side of the work, whereas spring *A* forces shoe S_1 in an upward direction. Moreover, the pressure of the shoes can be arrested (after the work has been ground to a given diameter) by setting stops *C* and *D* in the proper position.

In adjusting a back rest, screw *G* is turned out far enough to allow the shoe to clear the work, and nut *H* is loosened to entirely relieve the tension of spring *B*. Stop screw *C* is also turned back, and nut *I* is screwed in to slightly compress spring *A*. Screw *G* is next turned forward to bring the shoes into contact with the work. The shoes are then held lightly in position and screw *C* is turned until the end just touches its stop or seat. With screw *C* in this position, both shoes should bear evenly against the work. Spring *B* is next compressed somewhat by turning nut *H*. The combined pressure of screws *A* and *B* should be only sufficient to resist the wheel pressure when taking the final cut, and also to prevent vibration.

When grinding the trial piece for adjusting the work-rests, the screws *G* on the different rests are used to keep the shoes in contact with the

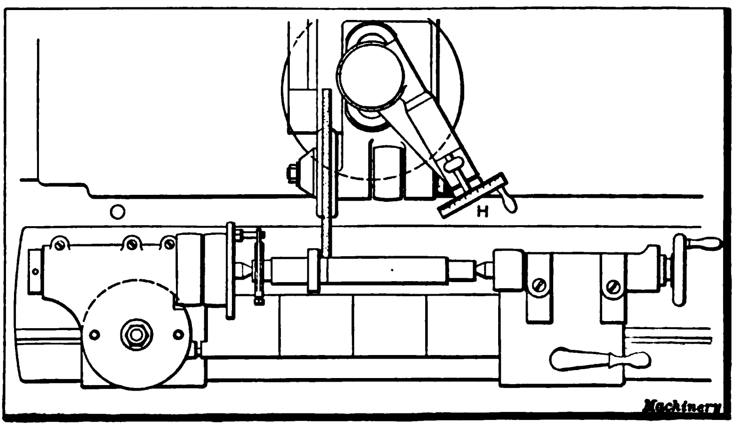

Fig. 18. Grinding Close to a Shoulder—Plan View

work, and the diameter at various points is regulated by adjusting stop-screws *C*. When the rests are correctly set, screws *G* are only adjusted to compensate for the wear of the shoes, and screws *C* are used for the delicate diameter adjustments. When short stiff pieces are being ground, the cylindrical form is obtained from the machine centers, but when the work is long and flexible, the control of the cenetrs is limited and they only steady the ends; consequently, in order to grind a slender shaft or rod cylindrical from one end to the other, it is necessary to rely on the adjustment of the work-rests.

Before adjusting the rests it is the practice in some shops to grind true "spots" for each of the supporting shoes. In order to do this, the rests are first placed in their respective positions and then the machine table is moved by hand until one of the rests is opposite the grinding wheel. The work is next "spotted" or trued by feeding the wheel in against the revolving work, while the table remains stationary. The diameter of the surface ground in this way should be within, say 0.002 inch of the finished size, although a larger allowance may be needed in certain cases. This "spotting" operation is repeated by successively placing each work-rest in front of the grinding wheel and proceeding as described. When spotting a very flexible shaft, it is well to first grind a spot for the work-rest nearest the footstock and then place this rest in position. The rest nearest the headstock is then located in the same manner and in this way a support is provided for the work, while spotting for the rests in the center of the shaft. The practice of grinding spots is not to be recommended for ordinary work, and, in many shops, parts are never "spotted" prior to grinding, even when they are ground from the rough.

There is a difference of opinion among grinding machine operators and manufacturers regarding the relative merits of the rigid work-rest and the flexible or spring type. Some advise the use of spring-rests for supporting light slender work, and the fixed or rigid form when grinding heavy stiff parts, whereas others advocate the use of rigid rests for

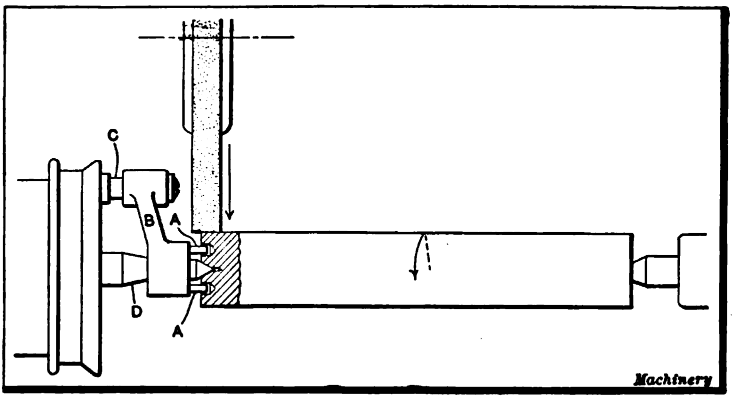

Fig. 14. Special End-driving Dog applied to Shaft for Grinding entire Length in One Operation

light as well as heavy work. It is also the practice in some shops to use spring-rests almost exclusively. Satisfactory results can doubtless be obtained with each type, under favorable conditions. When the work is light and flexible, spring-rests are often used in preference to the fixed form. On the other hand, when a heavy rigid piece is being ground, solid unyielding rests are commonly employed to provide as solid a support as possible in order to absorb vibration and prevent chattering.

When chattering is caused by vibration of the work, owing to improper supports, the surface left by the grinding wheel has minute, parallel ridges which spoil the finish; moreover the vibration which produces the chatter marks causes excessive wheel wear and greatly affects the efficiency of the grinding operation. Chatter marks are also caused by defects in the machine itself, in which case they have a spiral form. Sometimes the wheel spindle vibrates either because it is too light or the bearings are too loosely adjusted. Chattering is also produced by an unbalanced or improperly trued wheel, and the jar from a large stiff belt-joint will also set up vibrations that are copied on the work in the form of chatter marks. In some instances, chattering can be eliminated by a slight change in the work speed or by using a wheel of different grade; but, in other cases, the remedy is not so simple, especially when the trouble is caused by the design, construction or mounting of the machine.

Grinding Close to a Shoulder

Occasionally it is necessary to grind close to a shoulder, as indicated, in the plan view, Fig. 13. This can be done by setting the wheel close to the shoulder with the hand adjustment and then feeding it straight in until the diameter next to the shoulder is reduced to the finished size or slightly above it; the remaining surface between the shoulder and the end of the work is then ground by using the power traverse movement in the usual way. The object in first grinding close to the shoulder is to provide a clearance space so that the wheel does not have

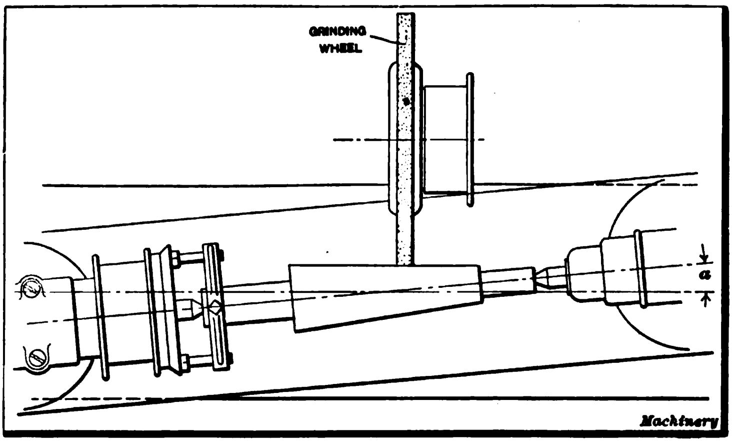

Fig. 15. Taper Grinding by Swiveling Platen to Required Angle

to travel close up to the shoulder. It is also possible to grind close to a shoulder without providing a clearance space, by carefully adjusting the stroke dogs to reverse the table when the wheel is almost against the shoulder. When this method is employed, the dog which controls the reversal at the shoulder end of the travel, must be accurately located to prevent the wheel from striking, and it may be necessary to adjust this dog for each piece ground, because the center holes usually vary more or less in depth and any such variation would change the position of the shoulder with relation to the wheel. The result is that considerable time is wasted in adjusting the stroke, and for that reason the first method referred to is preferable. With the second method, the surface next to a shoulder is also likely to be left a little large unless the wheel is allowed to dwell for a short time at the extreme end of the stroke. With the machine illustrated in Fig. 2 this dwell can be obtained by pushing in the knob located in the center of the handwheel *I*. The table traverse is again started by pulling out this knob. The machine shown in Fig. 13 is similar to the one shown in Fig. 4, but differs in that it is a universal type.

Special End-driving Dog

Sometimes it is desirable to grind a straight cylindrical shaft from one end to the other at one setting. Of course this cannot be done when a regular driving dog is used, because the latter will interfere with the movement of the grinding wheel. Fig. 14 illustrates a special end-driving dog which is sometimes used in cases of this kind. This dog has pins *A* which engage holes drilled in the end of the work. The arm *B* swings freely on pin *C* and has a hole which is larger than the machine

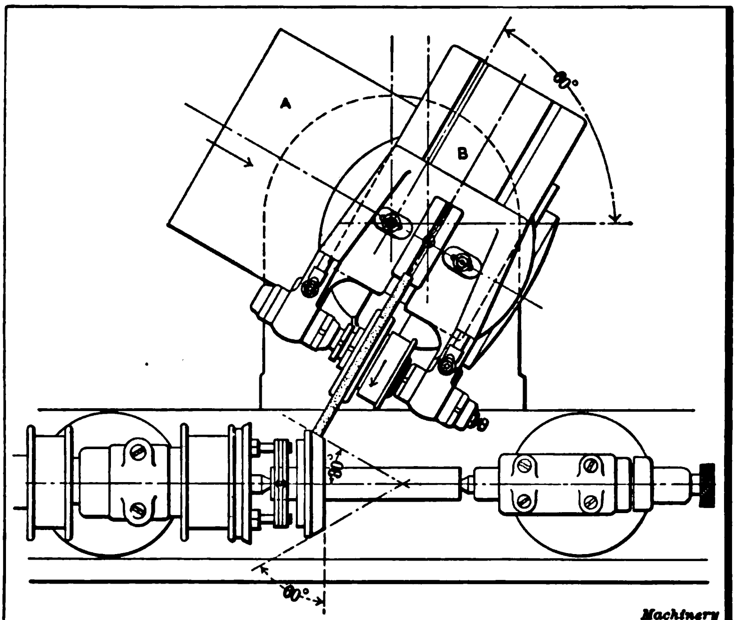

Fig. 16. Grinding Abrupt Taper by Setting Wheel-slide to Required Angle

center *D*, thus allowing it to turn on pin *C* until the driving pins *A* engage the holes on both sides. With this arrangement, the grinding wheel can move across the entire shaft, thus permitting the latter to be ground in one operation, instead of reversing it on the centers for grinding the driving or "dogged" end.

Taper Grinding

Taper parts are ground practically the same as those that are straight or cylindrical, provided the taper is not too steep or abrupt. The work is placed between the centers, as illustrated in Fig. 15, and the table is set to the required angle *a*, as shown by the graduations at one end. This adjustment locates the axis of the work at an angle with the table's line of motion; hence a taper is produced, the angle of which depends upon the amount that the swivel table is turned from its central or parallel position. There are usually two sets of graduations for the swivel table, one reading to degrees and the other giving the taper in inches per foot. The taper should be tested before the part is ground to the finished size, by using a gage or in any other available way.

The plan view, Fig. 16, shows how a taper surface is ground when the angle is beyond the range of the swivel table. The wheel slide *A* (which is normally at right angles to the table) is set to bring its line of motion parallel with the taper to be ground. The upper wheel stand *B* is also set at right angles to slide *A*, to locate the wheel face parallel with the taper surface. The table of the machine should be set in the zero position, so that the angular graduations on the wheel slide base will give correct readings with relation to the axis of the work. After adjusting

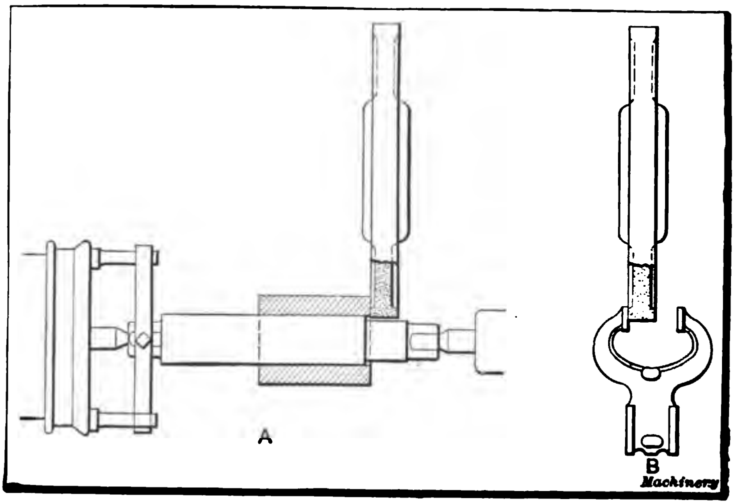

Fig. 17. Grinding with Side of a Recessed Wheel

the table to the proper longitudinal position, the grinding is done by moving the wheel across the taper surface by using the hand cross-feed, and the depth of each cut is regulated by slight longitudinal adjustments of the table. When the taper is tested, if any adjustment is necessary, this can be made by the table adjusting screw. Evidently an operation of this kind must be done on a universal machine, because the wheel slide of a plain type does not have the angular adjustment.

Parts having a double or compound taper can be ground at one setting, provided one taper is within the range of the swivel table. The latter is set for the smaller angle and the wheel slide for the greater angle, as indicated by the sketch *A*, Fig. 18. The wheel is set at right angles to the longest surface and one corner is beveled to suit the other surface. One part is then ground by traversing the table, and the other by moving the wheel slide. The wheel base, in this instance, should be set to an angle corresponding to the sum of the angles of both tapers, as measured from the axis. The sum of both angles, in the example illustrated, is 50 degrees.

Grinding with Side of Wheel

When it is necessary to grind bushings or sleeves, they are sometimes mounted on a mandrel as shown at *A*, Fig. 17. This view illustrates how the end of a bushing is finished by grinding with the side of the wheel. A wheel for end facing should be soft and porous and it should also be recessed on the sides (as shown by the sectional view) to reduce the working area. The grinding should be done by moving the work

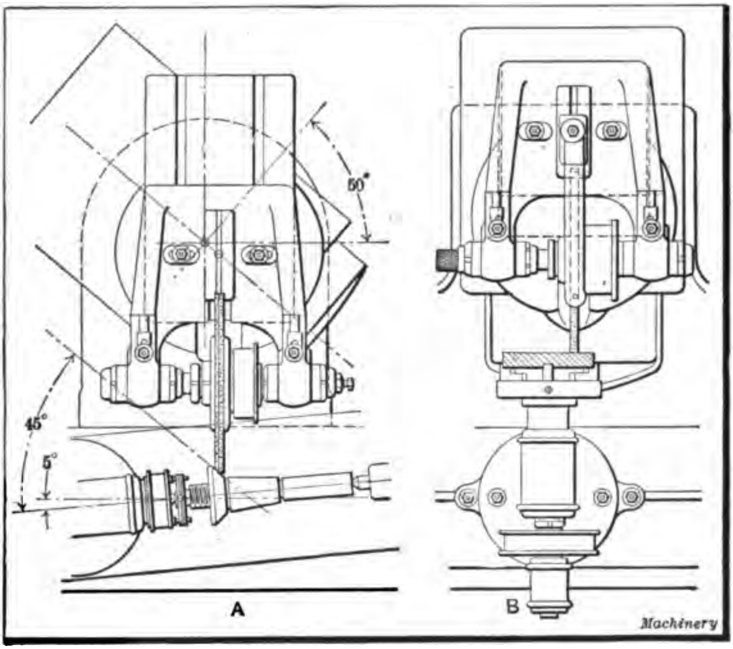

Fig. 18. (A) Grinding a Double Taper by Traversing both Platen and Wheel Slide. (B) Grinding the Side of a Disk

endwise against the side of the wheel, instead of traversing the wheel laterally. This method of facing the ends of cylindrical parts is only employed when the surfaces are quite narrow. Sketch *B* indicates how the jaws of a caliper gage are ground by the side of the wheel. The gage is held in a fixture attached to the table of the machine and the wheel is traversed across the face of the jaw being ground. It is necessary to traverse the wheel in this instance because the work is not revolving.

Use of the Universal Head

The headstock of the universal grinder is used for holding and revolving many parts, such as saws, milling cutters, and other pieces that cannot be revolved between the centers. Sometimes the work is held in an ordinary chuck screwed to the headstock spindle, and special collet chucks or fixtures are also employed, as well as magnetic chucks, where electric power is available. Sketch *B*, Fig. 18, illustrates how the side of a plain, flat disk is ground. The headstock spindle is set at right angles to the table, and the work, in this case, is held in a four-jawed chuck. When grinding, the wheel operates on only one side of the disk, and the automatic table traverse is used. If the surface must be flat it can be tested with a straightedge or by allowing the wheel to pass clear across the face and noting the density of the sparks on both sides. When the sparks show the same at all points the surface is flat within close limits. The fine adjusting screw for the table should be used for making adjustments. Obviously, concave or convex surfaces can be ground by setting the headstock to the required angle.

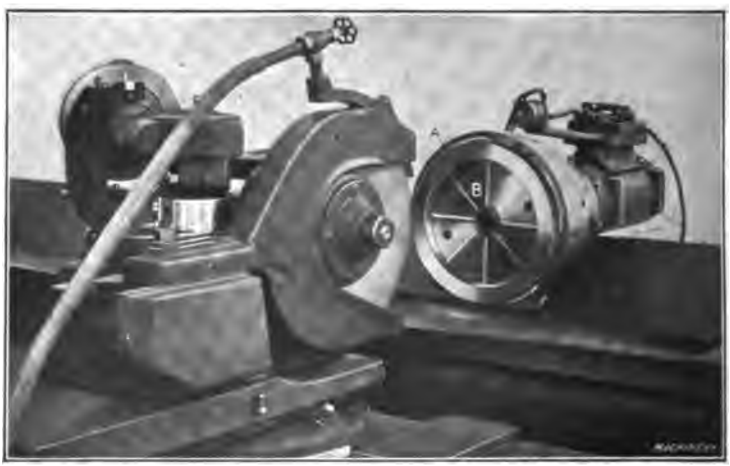

Fig. 19. Grinding Side of Steel Ring which is held by a Magnetic Chuck

Fig. 19 illustrates the use of a magnetic chuck attachment for face grinding. The operation is that of grinding the sides of a steel ring *A*. As these sides must be flat, the headstock spindle is set at right angles to the wheel spindle. The work is rotated by a belt (not in place) which passes over a pulley located just back of the magnetic chuck *B*. The current for magnetizing the chuck is conveyed through the wires and brushes shown. The wheels used for grinding flat surfaces should be of a softer grade than for cylindrical work, owing to the greater contact area.

Truing Grinding Machine Centers

Fig. 20 illustrates how a universal grinding machine is used to true its own centers. The headstock is set to an angle of 30 degrees, giving an included standard angle of 60 degrees, and the grinding is done by traversing the wheel across the conical surface. The tailstock center is ground first by inserting it in the headstock spindle, these centers being interchangeable. The table stroke should be adjusted so that the wheel overlaps the taper surface slightly on each side, and a copious supply of water should be used, when grinding, to prevent drawing the temper of the hardened centers. The centers of a plain grinder are inserted in a special fixture while being trued. This fixture is clamped to the table and holds the center at an angle of 30 degrees. It is very important to keep the centers in good condition, as otherwise parts ground upon them will not be accurate.

Preparation of Work for Grinding

The amount of stock that can economically be removed by grinding depends largely on the size and power of the grinding machine. The modern practice, when using heavy machines, is to reduce the work in a lathe to within somewhere between 0.015 and 0.030 inch of the required diameter and then finish by grinding. The lathe is simply used for roughing, and the stock is removed by taking one or more coarse

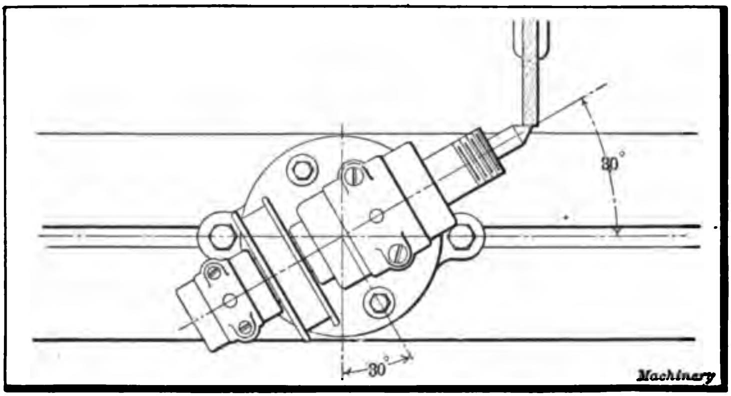

Fig. 20. Truing Conical Center of a Universal Grinder

cuts, leaving a rough surface on the work. When the diameter has been reduced to within say 0.025 inch of the finished size by turning, it is more economical to remove this stock by grinding than by taking a light finishing cut in the lathe. It is also practicable, in some cases, to grind bar stock from the rough without any preliminary turning operation, although most work is first turned. When using a light grinder the allowance for grinding must be comparatively small and is governed more or less, in any case, by the size and character of the work, as well as by the power and stock-removing capacity of the grinding machine.

Parts which have been hardened are occasionally so distorted by the hardening process that they cannot be finished to the required size. Straightening can then be resorted to, but this should not be done while the work is cold, as there is always a tendency for the piece to resume its original shape owing to internal strains, and even if properly heated, there is more or less danger of such distortion. When a hardened part must be straightened it should first be heated (though not enough to anneal it) and then straightened in a press. By proper annealing prior to the hardening process, this tendency to spring out of shape is often overcome. The annealing, which releases the internal strains incident to the rolling or forging operations, should take place after the outer surface has been removed in the lathe; then if the work runs practically true when tested, it can be machined to the grinding size, but if the piece is badly warped, it should be heated to a cherry red, straightened, and then annealed as before. Whenever possible, grinding should be done last, so that the work will not be marred or sprung out of true by other machining operations that may be performed later. Keyways in shafts, etc., should invariably be finished prior to grinding, as the removal of metal for the keyway from one side of the shaft will often distort the latter.

The machine itself should be carefully examined frequently, as its efficiency often depends upon a little intelligent care. The bearings, particularly of the wheel spindle, should be carefully adjusted to eliminate all lost motion, and the cross-slide for the grinding wheel should be thoroughly oiled so that it moves freely. The centers in the work should correspond to the angle of the machine centers and be carefully cleaned and oiled before the work is placed in position. When a grinding wheel is being mounted on the spindle, see that the central hole is a close but easy fit. If the diameter of the hole is about 0.005 inch large, the wheel will slide on without cramping, and it will not only have a good fit on the spindle, but an even bearing against the inside flange. Soft washers of blotter or rubber should be placed between the wheel and flanges on each side, as they compensate for any roughness in the wheel and distribute the clamping pressure evenly. The flanges should be tightened just enough to hold the wheel firmly, to avoid any unnecessary strain.

CHAPTER III

GRINDING WHEELS—WORK SPEEDS

If satisfactory work is to be done in the grinder it is absolutely essential that the grinding wheel be of a grade and grain which is adapted for the material to be ground. Grinding wheels are composed of a large number of grains or kernels of some suitable abrasive material, such as alundum, corundum or carborundum, which are held together by what is known as a bond. By varying the amount and composition of this bond, wheels of different grades are obtained. The term grade does not refer to the degree of hardness of the abrasive, but to the tenacity with which the bond holds the grit in place. A wheel from which the grit or cutting particles can easily be dislodged is called soft, and one which holds the particles securely is referred to as a hard wheel.

The degree of hardness or grade of a wheel is commonly denoted by the letters of the alphabet. According to one system the letter *M* represents a medium grade and the successive order of letters preceding and following *M* denote softer and harder wheels. For example, grade *E* is soft; grade *I*, medium soft; *M*, medium; *Q*, medium hard; *U*, hard; *Y*, extremely hard; whereas the intermediate letters indicate grades between those mentioned. Thus wheel *L* is one grade softer than *M*, and *N* one grade or degree harder. This method of grading wheels is not universal, as a standard system has never been adopted by the different manufacturers.

The grain or coarseness of a wheel is designated by numbers which indicate the number of meshes to the square inch through which the kernels of grit will pass. To illustrate, a 36 grain means that the grains or cutting particles will pass through a sieve having 36 meshes to the linear inch. The combination of grade and grain is marked on the side of the wheel by using the letter for the grade and the number for the grain; thus a 36-M wheel is one having cutting material of No. 36 grain and a medium degree of hardness.

Selection of Wheel for Grinding

When selecting a grinding wheel there are several factors which must be considered. The grade and grain depend largely upon the character of the material to be ground and its degree of hardness. For example, machinery steel requires a harder wheel than hardened tool steel. The reason for this will perhaps be better understood if we think of a grinding wheel as a cutter having attached to its periphery an innumerable number of small teeth, for this is literally what the thousands of small grains of abrasive are. When the wheel is of the proper grade these small teeth or cutting particles are held in place by the bond until they become too dull to cut effectively, when they are torn out of place by the increased friction. Obviously these grains or cutters will become dulled sooner when grinding hard than when grinding soft steel; hence, as a general rule, the harder the material, the softer the wheel, and *vice versa.*

When a hard wheel is used for grinding hard material, the grit becomes dulled, but it is not dislodged as rapidly as it should be, with the result that the periphery of the wheel is worn smooth or glazed, so that grinding is impossible without excessive wheel pressure. Any undue pressure tends to distort the work, and this tendency is still further increased by the excessive heat generated. If the surface of the wheel becomes "loaded" with chips and burns the work, even when plenty of water is used, it is too hard.

Soft materials, such as brass, are ground with a soft wheel, which crumbles easily, thus preventing the wheel from becoming loaded or clogged with metal, as would be the case if a hard-bonded wheel were used. When a wheel is used which is too soft, the wear is, of course, greatly increased, as the particles of grit are dislodged too rapidly, and, consequently, the wheel is always "sharp." This means that the abrasive has not done sufficient work to become even slightly dulled, and the result is a rough surface on the work.

The area of the surface which is in contact with the wheel should also be considered when selecting the proper grade. For a given material the wheel should be softer as the area increases. To illustrate, a wheel of grade *N* might be suitable for grinding cylindrical pieces 2 inches in diameter, but not suitable for a diameter of 4 inches, because of the increased contact area, owing to the increase in diameter.

The grain or degree of coarseness of the wheel is another point to be considered when making a selection. Generally speaking, coarse wheels are better adapted to most work because the larger grains permit deeper cuts to be taken. When a very fine finish is required, particularly on a number of duplicate pieces, fine wheels are sometimes used for finishing, after the work has been ground to within, say, 0.002 inch of the required size with a coarse wheel. It is not necessary, however, to use a fine wheel in order to obtain a smooth surface, as a wheel of comparatively coarse grain will produce a finish fine enough for most purposes, if the work speed is reduced somewhat and the wheel is trued with a diamond just before taking the finishing cut; in fact, very fine surfaces can be obtained with a comparatively coarse wheel, provided there is the proper relation between the surface speeds of the wheel and work. When roughing cuts are being taken, the cutting particles are constantly worn away or dislodged so that the face of the wheel is kept rough or "sharp," and the ground surface is also comparatively rough. After the wheel face has been trued with a diamonod, however, light finishing cuts, in conjunction with a reduced work speed, will give a finish which is smooth enough for all practical purposes, even though a fairly coarse wheel is used.

Incidentally, it is not always the highly polished surface which represents the most accurate work, because this finish is sometimes obtained at the expenes of accuracy, by using hard wheels that require so much pressure to make them grind that the work is distorted. In order to secure accuracy, the wheel must cut freely and without perceptible pressure. Sometimes a coarse wheel refuses to cut after a surface has been finished to a certain point, because the cutting particles wear off somewhat and the ends become too large and blunt to enter the smooth surface. If this occurs, the wheel should be trued with a diamond or be replaced with one of finer grain. When grinding brass or soft bronze the grain of the wheel must be as fine as the finish desired; in other words, it is not practicable to use a coarse wheel for finishing these metals.

Peripheral Speed of Work and Grinding Wheel

A wheel which is perfectly adapted to grinding a certain kind of material will not work satisfactorily if the relative surface speeds of the wheel and work are not approximately correct. The work speed affects the wear of the wheel, which, when excessive, also affects the finish of the surface being ground. The amount of stock that the wheel removes for a given amount of wear can be increased or diminished by varying the work speed, the wheel wear being excessive when the speed is too high. This close relation between the work speed and the wheel wear makes it possible to use a wheel which is somewhat harder than it should be for a given piece of work, by increasing the work speed, with the result that the grit is dislodged more easily, and, consequently, does not remain long enough to cause glazing, which would otherwise take place; this practice, however, is not to be recommended.

As there are a number of factors, such as kind of material, finish desired, etc., which determine the proper work speed, it is impractical to say just what this speed should be unless the conditions are known. A speed of twenty-five feet per minute might be correct for grinding a certain piece of steel, and not correct for another steel part having a different carbon content. The finish of a ground surface, as previously stated, is also affected by the work speed. It is possible to grind a very rough or smooth surface by simply varying the speed, depth of cut and side feed of wheel, the surface becoming smoother as these are diminished. For this reason the speed and feeds (when within, say, 0.002 inch of the finish size) are often reduced before taking the finishing cuts. The best method of ascertaining the proper speed for a given piece of work, and, incidentally, of determining the best wheel to use, is by experimenting until the desired results are obtained. This does not necessarily mean that whenever a new piece of work is to be ground considerable time must be wasted, as the speed adjustments are easily made, and besides, experience will soon teach what combinations of speed will give the best results.

The peripheral or surface speed of a grinding wheel is usually somewhere between 5500 and 6000 feet per minute, although speeds between 5000 and 6500 feet per minute are employed. As the wheel diminishes in size, it appears to get softer, even though the peripheral or surface speed is maintained. This increase in wear is due to the fact that the grit of a small wheel is in contact with the work oftener owing to the increased number of revolutions necessary for the same surface speed.

It should always be remembered that the thing to be sought after is maximum production. When choosing a grinding wheel, for example, if one too hard for the work is selected with the idea of reducing the wheel wear, the corresponding reduction in the output will much more than off-set the increased expense incurred by using a softer and more rapidly wearing wheel. The wheel wear, however, should be considered, and, as it is dependent upon the work speed, the vibration of the work, and depth of cut, these should receive careful attention. When certain combinations of speed, feed, etc., have been found correct for a certain kind and size of material, it is advisable to record this information for future reference, for while such data may not always be applicable, owing to a difference in the grade of the material, it will, in many instances, enable one to save considerable time.

Composition of Grinding Wheels

There are several kinds of abrasive materials used in the manufacture of grinding wheels, and the composition of the bond for holding the abrasive grains together in the form of a wheel is also varied to produce wheels adapted to different purposes. At one time practically all grinding wheels were made of emery, but other materials possessing superior cutting qualities are now largely employed for machine grinding. Three of the abrasives commonly used in modern grinding wheels are corundum carborundum and alundum. Both emery and corundum are natural abrasives, whereas the other materials mentioned are produced artificially. Corundum is much purer than emery and contains a much larger percentage of crystalline alumina, which is the element in both abrasives that does the cutting.

Carborundum, which is a trade name for carbide of silicon, is a product of the electric furnace. The principal materials used in the manufacture of carborundum are coke and sand. The coke is used to supply the carbon, and the sand the silicon. These elements are placed in an electric furnace, where they are subjected to a temperature ranging between 7000 and 7500 degrees F., for a period of thirty-six hours. In this terrific heat all impurities in the coke and sand are destroyed and the carbon and silicon unite to form masses of carborundum crystals. These crystals are only inferior to the diamond in hardness. After the furnace is cooled the masses of crystalline carborundum are crushed to grains which are subjected to various forms of treatment and are finely graded. Alundum is also made in the electric furnace by the fusion of a mineral called Bauxite, which was considered infusible until the invention of the electric process. The chemical composition of alundum is similar to the ruby and sapphire which are the hardest natural minerals, except the diamond.

In the manufacture of grinding wheels the abrasive grains are bound together by mixing them with an adhesive substance or "bond." which is usually composed either of clays and fluxes, silicate of soda, or shellac.

The Vitrified Process

When clays are used they are thoroughly mixed with the abrasive in large power-driven mixing kettles. This mixture is then drawn off into molds and dried. The wheels are then shaved off to the proper shape in a special machine, after which they are baked or burned continuously for a period of 100 hours or more, the time depending upon the size of the wheels. During this baking process the temperature is gradually raised until the clay is partially melted and vitrified. The wheels are then allowed to cool slowly for a week, and great care must be taken to maintain uniform temperatures and prevent sudden changes. As the cooling takes place the clay crystallizes and binds the abrasive grains firmly together. This is known as the vitrified process and is the method employed for making most grinding wheels.

The Silicate and Elastic Processes

There are two other common methods of making grinding wheels, one of which is known as the silicate, and the other as the elastic process. With the silicate process, silicate of soda is the principal ingredient of the bond. The abrasive grains are first mixed with the bond in special machines, and the mixture is then tamped into molds. After the wheels are molded they are dried and baked in special ovens. The temperature of these ovens is much lower than is requird in connection with the vitrified process.

Wheels made by the elastic process have shellac as the principal ingredient of the bond. They are also molded and then baked at a comparatively low temperature to set the shellac. Wheels made by this process have great tensile strength and also a certain amount of elasticity so that very thin wheels can be safely used; in fact elastic wheels only 1/32 inch thick are manufactured. Elastic wheels are also made by what is known as the Vulcanite process, in which case the bond is composed of vulcanized rubber. Tough, thin wheels can be produced by this method, but they are very expensive.

The vitrified wheel is generally considered superior for most grinding operations, as it is very porous and free cutting. It is adapted to cylindrical and surface grinding, and for a variety of other operations. Vitrified wheels are difficult to make in large sizes as they are liable to crank in the kiln, and the process requires about four weeks, which is sometimes a decided disadvantage. Silicate wheels are recommended for wet tool grinding, wet surface grinding (especially when cup wheels are used), and whenever accuracy of grading is required. Silicate wheels can be made in large sizes and the process only requires a few days, which is an advantage, particularly when special shapes are needed.

CHAPTER IV

INTERNAL GRINDING

The grinding of holes is known as internal grinding. This class of work is done on universal machines and also on special types designed exclusively for internal grinding. When a universal cylindrical grinder is employed for internal work it is equipped with an internal grinding attachment. Fig. 21 shows how an internal attachment is applied to a Landis machine. The regular wheel head is turned half way around on its slide, and the internal fixture *A* is bolted to the front of the slide after the wheel-guard has been removed. The spindle of the internal

Fig. 21. Landis Universal Grinder equipped with Internal Grinding Attachment

fixture is driven by a short belt *B* connecting with a pulley which replaces the regular grinding wheel. The work is held in a chuck mounted on the headstock spindle, and the grinding is done by a wheel *C*. The wheel to use in any case must, of course, be somewhat smaller than the hole to be ground, and the grinding is done by traversing the wheel through the hole. The work is rotated rather slowly when grinding, and the wheel cuts along one side as it passes through.

The wheels used for internal grinding should generally be softer than those employed for other grinding operations, because the contact area between the wheel and work is comparatively large. The wheel spindle is also rather weak so that a soft wheel that will cut with little pressure, should be used to prevent springing the spindle. The grade of the wheel depends on the character of the work and the stiffness of the machine, and where a large variety of work is being ground, it may not be practicable to have an assortment of wheels adapted to all conditions. By adjusting the speed, however, a wheel not exactly suited to the work in hand can often be used. If the wheel wears too rapidly, it should be run faster, and if it tends to glaze, the speed should be diminished.

When adjusting the machine for grinding a hole, the length of the stroke should be regulated so that the wheel will only travel beyond the ends of the hole, one-fourth or one-half its width, because if it is allowed to pass clear through the hole, the spring of the spindle will cause the hole to be ground "bell-mouthed" or large at the ends.

When a hole is to be ground straight or cylindrical, the head can be accurately set by the following method: Before attaching the internal fixture a cylindrical piece is gripped in the chuck and ground

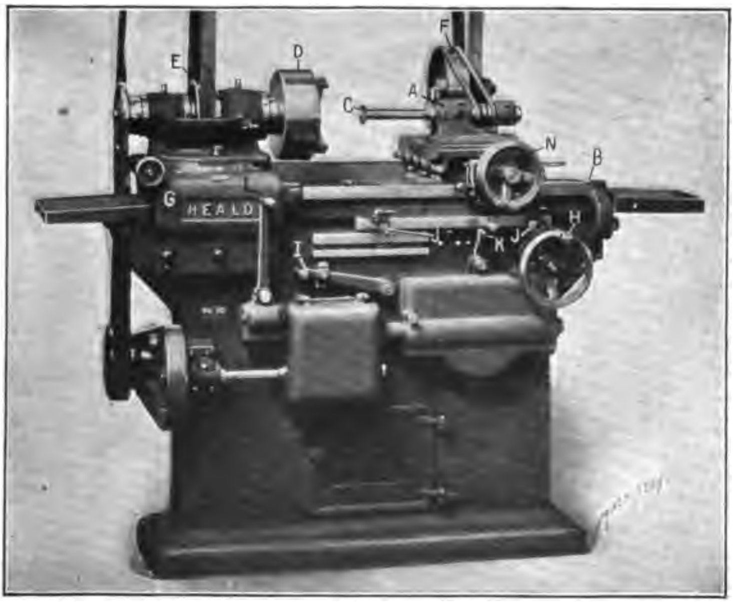

Fig. 22. Heald Internal Grinding Machine

externally with the regular wheel. When the head is adjusted so that this test piece is ground straight, then it is properly set for grinding a straight or cylindrical hole. The straightness of a hole can also be tested when grinding it, by the following method: First grind the hole true with the wheel operating in its normal position on the rear side; then bring the wheel into contact with the opposite side of the hole and, as it passes through, note the density of the sparks in order to determine whether the hole is straight or tapering. If the wheel cuts heavier as it approaches the back end of the hole the latter is smaller at that end, but if the density of the sparks becomes less, the hole is smaller in front. When the sparking is even on both sides the hole is straight or cylindrical.

The work shown in Fig. 21 is held in an ordinary three-jawed chuck. but draw-in collets and special fixtures are often used for internal grinding. When gripping frail parts in a chuck, care should be taken to prevent springing them out of shape. As the pressure of grinding is comparatively light, it is not necessary to clamp the work very tightly, although if a part is held insecurely, it may be shifted when testing the diameter of the hole with a plug gage, especially if the gage sticks in the hole. Therefore, a greater clamping pressure than is necessary for grinding is often required. In the case of thin bushings and similar work, this matter of distortion is very important; for work of this class, the Heald Machine Co. recommends the use of a special chuck which clamps endwise, thus avoiding all radial pressure and distortion.

Internal grinding is often done dry, although cooling water should be used whenever practicable, as it not only keeps the work cool but washes away the chips and abrasive. When a part that has been ground dry, is being measured with a plug gage, the latter may stick or "freeze" in the hole, unless the work is cooled somewhat before inserting the gage. This sticking is due to the fact that the hole being ground is expanded by the frictional heat of grinding and when the cold plug gage is inserted, the hole contracts and grips the gage. Internal grinding wheels should be kept true in order to secure smooth accurately finished holes. A diamond tool is preferable for truing the wheel face, although a piece of some hard abrasive such as carborundum can be substituted. The diamond tool or carborundum "rub," as the case may be, should be held in a fixed position when in use.

Heald Internal Grinder

A machine that is designed especially for internal grinding is shown in Fig. 22. The grinding wheel head *A* is mounted on a cross-slide which is carried by the table *B*. The latter has a reciprocating movement on the bed for traversing the grinding wheel *C* through the hole. The work is held in some form of chuck *D*, or in a special fixture, and it is rotated by a belt operating on pulley *E*. This belt connects with a pulley overhead, the speed of which can be varied by a change gear box forming part of the countershaft. This feature enables the work speed to be varied for grinding holes of different diameter. The pulley *F* for driving the wheel spindle, is driven by belt from an overhead drum which allows the table to move longitudinally. The headstock is mounted on a base *G* which forms a bridge over the table so that the latter can pass beneath it. The headstock can be set to an angle of 45 degrees either side of the center-line, for grinding taper holes. The table can be operated by handwheel *H* or by power. Lever *I* engages the power feed clutch, and the stroke of the table and grinding wheel is controlled by the position of dogs *J* which engage reverse lever *K*. The travel of the table per revolution of the work is controlled by lever *L*. By means of this lever three rates of feed are obtained for each work speed, a coarse feed being used for rough grinding and finer feeds for finishing. The cross feed for the wheel slide can be operated either by hand or automatically. The automatic feed mechanism is located just back of wheel *N* which is used for the hand movement.

CHAPTER V

SURFACE GRINDING

The grinding of plane or flat surfaces is called surface grinding. There are several different types of surface grinders, some of which are adapted principally to tool-room work, and others to general manufacturing. A common method of grinding a flat surface is indicated by the diagram *A*, Fig. 23. The work *w* is traversed to and fro beneath the grinding wheel *G* (as indicated by the dotted lines), and either the wheel or work is fed laterally (see end view) at each end of the stroke, so that the periphery of the wheel gradually grinds the entire surface. Another method of producing flat surfaces is illustrated at *B*. The wheel *g*, in this instance, is a cup type, and the vertical surface *a* is ground by being traversed past the face of the wheel; hence this is often called face grinding.

Diagram *C* illustrates the operation of a vertical surface grinder. The grinding is done by either a cup or ring wheel *g*, which revolves about a vertical axis. The work *w* is attached to a reciprocating table and is traversed beneath the grinding wheel. This type of machine is used quite extensively, at the present time, and it has proved very efficient for work within its range. Diagram *D* illustrates the operation of another vertical-spindle machine. In this case the work table has a rotary instead of a reciprocating movement. This type is especially adapted to grinding the sides of flat disk-shaped parts, such as saws, etc., and for a variety of other work. For example, to finish the side of a circular plate *w*, wheel *g* is placed in the position shown by the plan view, and the surface is ground as the table and work revolve in the directions indicated by the arrows. The grinding is done by the lower edge or face of the wheel, and the latter is slowly fed downward until the part has been ground to the required thickness.

The surface grinder is indispensable in the tool-room for truing parts that have been distorted by hardening and for producing fine accurate surfaces. Many of the machines built at the present time are also efficient for producing flat surfaces in connection with manufacturing operations. Ordinarily the surface grinder is used for finishing parts which have been milled or planed approximately to size, although many pieces are ground from the rough on the large machines used for manufacturing purposes.

Fig. 24 shows a plain surface grinder of medium size which operates on the principle illustrated by diagram *A*, Fig. 23. The part to be ground is attached to table *A*, and the grinding is done by wheel *G* which can be adjusted to the proper height by handwheel *B*. The stroke of the table is controlled by the position of dogs *D* and D_1 which operate the reverse lever *C*. As the table reciprocates, the wheel with the column which supports it, feeds laterally at each end of the stroke.

The movement of the table and the lateral feeding movement of the wheel are automatic when grinding, but they can be effected by hand for making adjustments. Crank *E* is for traversing the table, and wheel *F* operates the hand cross feed.

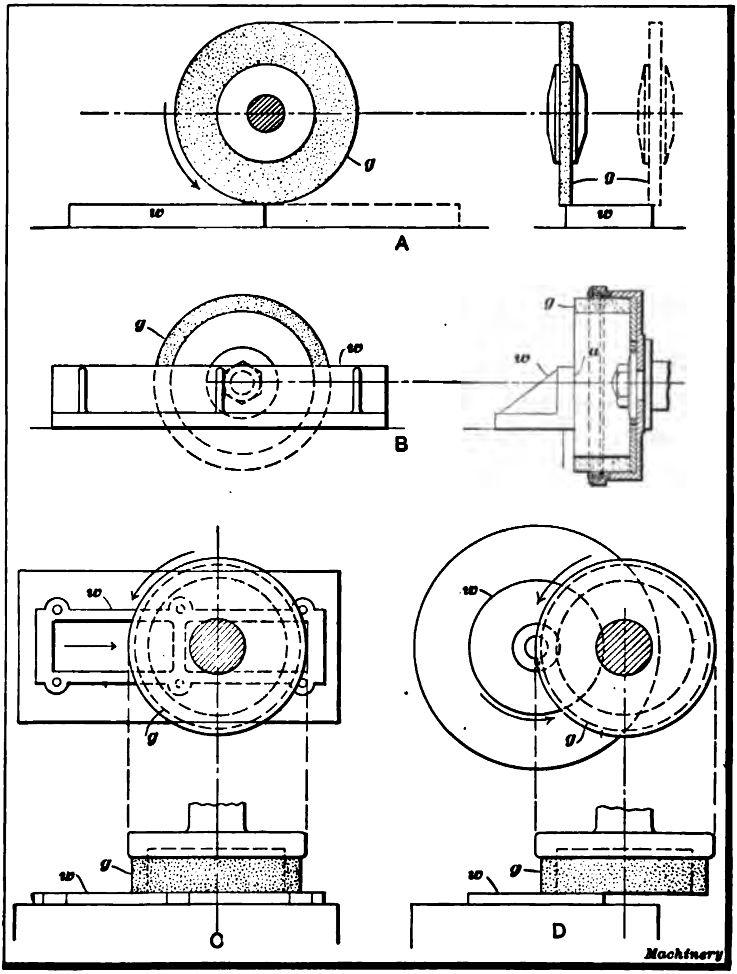

Fig. 28. Diagrams illustrating Four Methods of Surface Grinding

The belt which drives the grinding wheel connects with pulley *H* and the latter is driven by belt *I* from an overhead shaft. The reciprocating movement of the work table is derived from the belts *J* and *K*. One of these belts is open and the other crossed, so that the pulleys which they engage rotate in opposite directions. Interposed between these pulleys there is a clutch which is splined to a shaft that operates the table driving mechanism. This clutch is engaged with first one pulley and then the other, whenever the dogs *D* strike lever *C*, thus reversing the direction of the table's movement. The motion of lever *C* is transmitted to the clutch at the rear, by means of suitable links and levers. This movement of lever *C* (which is caused by engagement with dogs *D*), not only operates the table, but also operates the mechanism for feeding the grinding wheel laterally.

The traversing motion of the work table can be stopped automatically when the wheel has fed across the part being ground, by means of a

Fig. 24. Walker Surface Grinder of Reciprocating Type

trip mechanism. In connection with this mechanism there are two adjustable collars mounted on a horizontal rod located on the left side of the machine. There is also a trip-finger attached to the wheel housing, and whenever this finger engages one of the collars, the horizontal rod is shifted slightly, which makes it impossible for the reverse clutch at the rear to engage the driving pulleys; consequently, the reciprocating motion of the table is stopped. The point at which the trip mechanism operates, depends upon the position of the stop-collars which are adjusted so that the table will stop after the wheel has passed across the surface to be ground.

Some surface grinders which grind with the periphery of the wheel like the machine illustrated in Fig. 24, are designed along the lines of an ordinary planer; in fact the construction is almost identical except that a grinding wheel is mounted on the crossrail, instead of a toolhead. When this type of machine is in operation, the work table reciprocates and the wheel feeds laterally across the surface to be ground.

Horizontal Face Grinding Machine

A face grinding machine is illustrated in Fig. 25. This type operates by traversing the work past the face of ring-wheel *G*, as previously explained in connection with diagram *B*, Fig. 23. The part being ground is clamped to table *A* which has an automatic reciprocating movement.

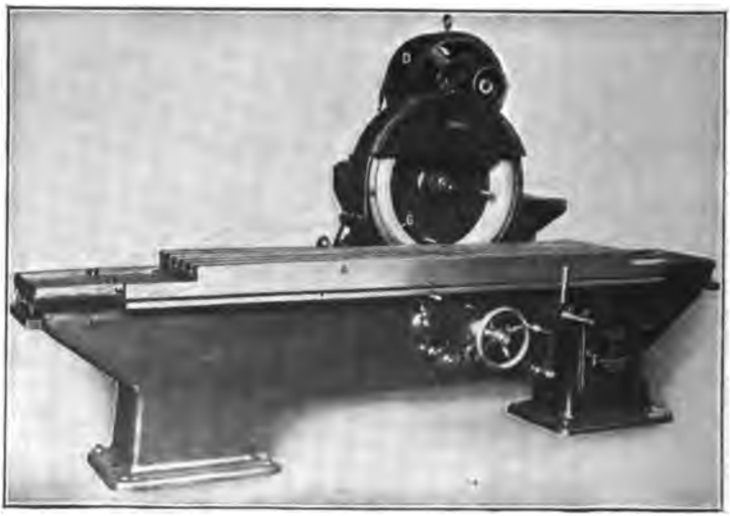

Fig. 25. Diamond Motor-driven Face Grinder

The length of the stroke is regulated by dogs (not in place) which engage reverse lever *C*. The wheel has an adjustable automatic power feed, and both the wheel and work table can be moved by hand. This particular machine is driven by a motor *D* which is connected to the wheel spindle by a belt.

The face grinder has some advantages over the type of machine using a wheel that grinds on the periphery. In fact, the advantages are similar to those which a face milling cutter has over an axial milling cutter. In the first place, the power consumption is less and plane surfaces are produced with fewer passes of the grinding wheel. The radius of a cup wheel also remains the same until it is worn out, instead of changing constantly, as with a disk wheel. The type of face grinder shown in Fig. 25, is generally used for grinding quite heavy parts and it is especially adapted to that class of work which can be held to better advantage when the surface to be finished is in a vertical plane. For example, the ends of rather long castings, such as machine legs, etc., can easily be ground on this style of grinder, because the work can be clamped to the table of the machine, in a horizontal position. Evidently it would be impracticable to grind work of this class on a machine having a vertical spindle, because the castings would have to be held in an upright position. The horizontal face grinder is often used in locomotive shops for truing or finishing the

Fig. 26. Pratt & Whitney Vertical Surface Grinder

bearing surfaces of guide-bars, and it can be employed to advantage for many other grinding operations.

Vertical Surface Grinder

Fig. 26 shows a surface grinder of the vertical type. The grinding is done by ring or cup wheel *G* which covers the full width of the work. With this machine, the work can be given either a reciprocating or rotary motion, depending upon the shape of the part being ground. For grinding rectangular surfaces, or parts that should move in a straight line beneath the wheel, the table *A* is given a reciprocating movement, the length of which is controlled by dogs in the usual manner. On the other hand, the sides of saws, rings or flat disk-shaped parts are rotated while being ground, by placing them on a rotary chuck which is mounted on the grinder table. When the rotary chuck is in use, the table remains stationary.

It will be seen from the foregoing that this machine operates either as illustrated by diagram *C*, Fig. 23, or as shown by diagram *D*. The grinding wheel and its spindle is carried by a head *B* which can be fed vertically on the face of the column. The vertical feed can be operated automatically or by hand, and be disengaged automatically at any predetermined point. The reciprocating table has two rates of feed or travel and it can be moved by hand, if desired. This grinder is equipped with a pump for supplying cooling water to the wheel. The water is pumped into the hollow spindle, at the top, and passes down to the inside of the grinding wheel, after which it is driven outward by centrifugal force between the wheel and the work. An outside stream of cooling water is also provided and the table is surrounded by a water guard *C* which prevents the water from flying about.

The vertical type of grinder can be used advantageously for grinding long rectangular surfaces, disk-shaped parts (by using the circular attachment) and it is very efficient for grinding a number of small castings simultaneously. When several parts are to be ground at the same time, they are grouped on the table of the machine or on a magnetic chuck, so that the wheel will grind each casting as the table feeds along. It is comparatively easy to hold several small castings on a grinder of this type, because they are placed horizontally on the machine, and, as the wheel operates on the top surfaces, the pressure of grinding is mostly downward against the table and bed, which provide a solid unyielding support. This type of machine is used extensively for grinding from the rough; that is, castings or forgings are finished by grinding without any preliminary machining operation, such as planing or milling. This practice is followed when it is not necessary to remove very much metal.

Rotary Surface Grinder

Still another type of surface grinder is shown in Fig. 27. This machine is designed for rotary grinding exclusively, the principle of its operation being indicated by diagram *D*, Fig. 23. A cup wheel *G* is carried by an upper slide *B* and the work is held on a rotary magnetic chuck *C* mounted on lower slide *D*. The wheel spindle is driven from a horizontal shaft at the rear by a quarter-turn belt, as shown, whereas the work table is driven from drum pulley *E*. When the machine is in operation, the wheel is fed down against the work until the latter is finished to the required thickness, by operating hand-lever *F*. The wheel slide is fed against a positive stop, and the thickness of the work is varied by adjusting the lower slide which is equipped with a vertical feed screw. This screw is operated by handwheel *H* which is graduated to thousandths of an inch. When the lower slide has been set, its position is not changed for successive operations except to compensate for wheel wear.

The link-and-lever mechanism seen at the side of the column, connects the wheel slide with a jaw clutch inside the work-table driving drum, and disconnects this drum from the shaft on which it is mounted, when the wheel slide is in the upper position. By this means, the work spindle is automatically stopped whenever the wheel is raised from the work. As the wheel is moved vertically by lever *F*, it will be seen that the latter controls the starting and stopping of the work-table. This lever also controls the magnetizing current for the chuck, and the demagnetizing current for neutralizing the residual magnetism

Fig. 27. Walker Rotary Surface Grinder

always found in a magnetic chuck after the electric current has been switched off. If desired, the drum-clutch operating mechanism can be disengaged, and the motion of the work-table be controlled independently by means of the foot lever seen at the base of the machine.

This machine can be used for concave grinding, in which case the knee supporting the work-table is tilted to the required angle. Work having a concave surface is not held directly against the magnetic chuck, but on an auxiliary plate. The magnetic power of the main chuck is transmitted through this auxiliary plate, the upper surface of which is shaped to suit the surface of the work. The use of an auxiliary plate in connection with the grinding of a milling saw is illustrated in Fig. 28. After the saw is ground concave on one side, it is held for grinding the opposite side on a plate *A* having a convex face. If the saw were held for grinding the last side against the flat face of the regular chuck, it would be sprung down in the middle, so that both sides would not be finished alike, or to the same concavity. Fig. 29 shows how a number of parts can be ground simultaneously on a rotary surface grinder. In this instance, three castings are arranged in a group on the magnetic chuck, in such a way that they support each other to some extent, while the top surfaces are being ground flat.

Fig. 28. Grinding Side of Saw Concave

Fig. 29. Grinding Three Castings Simultaneously

These views indicate, in a general way, the kind of work that is grouna on a machine of this type.

Use of Magnetic Chucks

The method of holding work to the table of a surface grinder depends, of course, more or less on the shape of the part to be ground. Ordinary clamps and bolts are sometimes used, but where electric power is available, magnetic chucks are preferable for most work. The magnetic chuck is a special form of electro magnet which is connected by wires and a control switch, with the electric power circuit. The top surface against which the parts are held, has a series of positive and negative holes which are separated by an insulating material. When in use, the chuck is clamped onto the table of the surface grinder, and the work is held by magnetic force when the current is turned on.

A rectangular magnetic chuck is illustrated in Fig. 30. This is the form used on surface grinders of the reciprocating type, whereas for rotary grinders, round chucks are employed. The control switch is located at *D*, and the work is held against surface *A* which has a number of positive and negative poles, as the engraving shows. There is a thin steel aligning strip *B* attached to the rear side of the chuck and also a vertically adjustable back-rest *C* which is used to support parts

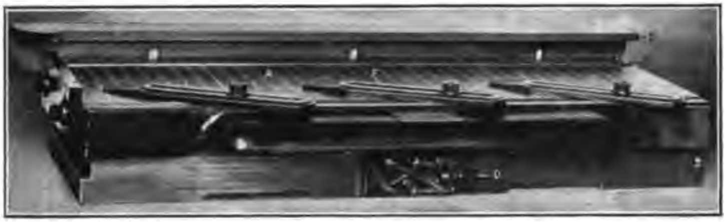

Fig. 30. Walker Magnetic Chuck

that are high in proportion to their width. In addition, there is an end-stop *E* having vertical adjustment. The work to be ground is simply laid on the chuck face, against end-stop *E* and the back-rest *C*. The slotted fingers *E* which are provided on this particular chuck, are also used, in some cases, to stay the work edgewise and prevent it from shifting. Magnetic chucks are sometimes used on planers, as well as surface grinders, in which case fingers *E* are of especial value.

This chuck is equipped with a duplex switch which enables the chuck

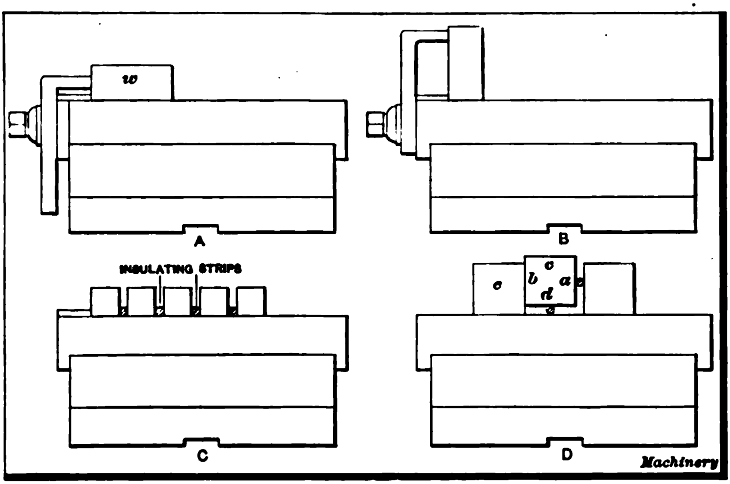

Fig. 31. End Views illustrating Different Methods of holding Work on Magnetic Chuck

face to be demagnetized so that work can easily be removed after the grinding operation. This demagnetizing is accomplished by simply reversing the current through the chuck coils, momentarily, until the residual magnetism is removed. In order to do this, the switch is opened and moved until the switch bars are nearly in contact with the posts at the opposite end of the switch. The handle is then gripped tightly with the tips of the fingers, and the bars are quickly moved in and out of contact with the posts. This movement, when timed correctly, will remove the magnetism lift by the previous charge. When demagnetizing, if the contact should be for too long a period, the chuck will simply become oppositely charged, and in such a case it can be discharged again by making quick contact with the posts on the opposite side. It should be mentioned that this switch does not demagnetize the work itself. This is necessary, however, for certain classes of work, because some materials become more or less permanently magnetized and this causes them to attract small particles, which is sometimes quite objectionable. When the work must be demagnetized, a special apparatus called a demagnetizer is used.

The way the back-rest *C* of the magnetic chuck shown in Fig. 30, is used is illustrated by the diagrams *A* and *B*, Fig. 31, which represent end views of the chuck. The operation is that of grinding a true rectangular block *w*. While the sides are being ground, the block is held as indicated at *A*. The edges are then ground square with the sides by holding the block against the aligning strip and back-rest, as shown at *B*. Sketch *C* shows how a number of strips are held on the chuck and ground simultaneously. When parts are arranged in this way, it is sometimes advisable to place magnetic insulating strips of brass or paste-board between them, so that the magnetism will get an independent grip on each piece and hold it firmly against the face of the chuck.

Sketch *D*, shows how a piece is sometimes held for grinding the sides square to each other. Two of the sides, as at *a* and *b*, are first ground by holding the work directly against the face of the magnetic chuck. One of these finished sides, as at *b*, is then held against the vertical surface of an accurately finished square block *e*, while the upper side is ground. The lower side, instead of resting directly on the chuck face, is placed upon a piece of drill rod to reduce the contact area. In this way, the work is held more securely against block *e*, than against the chuck face, because the holding power depends upon the area of the surface in contact with the magnetized part. If the side *d* were in direct contact with the chuck face, side *b* might not be held evenly against block *e*, in which case the work would not be ground square. In this instance, the work is further secured by a block on the right side which is separated by drill rod to reduce the contact area.

Magnetic chucks are made in many different styles and shapes. Some are so arranged that the clamping face can be set at any angle for taper grinding and others have faces that are vertical. There is also the rotary type which has previously been referred to, and other special designs. The rotary form is used when a continuous rotary movement is required, instead of a reciprocating motion.

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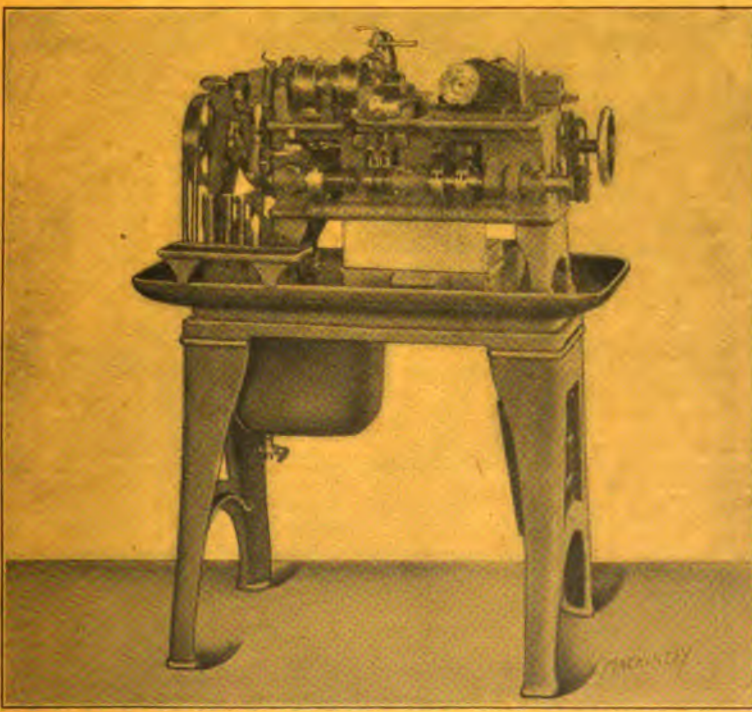
OPERATION OF THE BROWN & SHARPE AUTOMATIC SCREW MACHINES

BY DOUGLAS T. HAMILTON



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NUMBER 99

AUTOMATIC SCREW MACHINE PRACTICE

PART I

OPERATION OF THE BROWN & SHARPE AUTOMATIC SCREW MACHINES

By DOUGLAS T. HAMILTON

CONTENTS

49-55 Lafayette Street, New York City

Automatic Screw Machine Practice for the Brown & Sharpe automatic screw machines is covered in eight Reference Books, Nos. 99 to 106, inclusive. Reference Book No. 99, "Operation of the Brown & Sharpe Automatic Screw Machines," deals with the construction of these machines and the setting-up of the tools. No. 100, "Designing and Cutting Cams for Automatic Screw Machines," gives detailed instruction on cam design, and describes a simplified method for milling cams. No. 101, "Circular Form and Cut-off Tools for the Automatic Screw Machine," deals with the general arrangement and the calculations of these tools, and describes the different methods employed in their making. No. 102, "External Cutting Tools for the Automatic Screw Machine," deals with the design and construction of box-tools, taper turning tools, hollow mills, and shaving tools. No. 103, "Internal Cutting Tools for the Automatic Screw Machine," deals with centering tools, cross-slide drilling attachments, counterbores, reamers, and recessing tools. No. 104, "Threading Operations on the Automatic Screw Machine," treats on cam design for threading operations, threading dies, taps and tap drills, die and tap holders, and thread rolling. No. 105, "Knurling Operations on the Automatic Screw Machine," describes the construction of knurling holders, and gives directions for the making of knurls and the design of tools and cams used in connection with knurling operations. No. 106, "Milling, Cross-drilling and Burring Operations on the Automatic Screw Machine," describes screw-slotting attachments, index drilling attachments, and burring attachments, giving directions for their use and for the design of cams for them.

CHAPTER I

CONSTRUCTION OF THE BROWN & SHARPE AUTOMATIC SCREW MACHINES

The object of this treatise is to give the operator a clear idea of the construction of the Brown & Sharpe automatic screw machines, so as to enable him to operate these machines to the best advantage. The various mechanisms, together with their functions and operation, will be dealt with in detail, and the procedure to follow in setting the tools held in the turret and on the cross-slide will be illustrated and described. The No. 00 Brown & Sharpe automatic screw machine, front, rear and plan views of which are shown in Figs. 1, 2 and 3, is made the main subject of this treatise, but wherever the Nos. 0 and 2 machines differ in construction, these differences will be explained. A brief description of the principal features of automatic turret forming and cutting-off machines will also be included, together with tabular and other data of value to the operator.

Principles of Operation

Before proceeding with the description of the construction of the Brown & Sharpe automatic screw machines, the general principles of operation will be briefly outlined. The work spindle is driven from the overhead works by friction pulleys *A* and *B*, see Figs. 1 and 2, by open and cross belts, thus providing for the rotation of the work in either direction. The other operating mechanisms receive their motion from the driving shaft *O*, at the rear (see Fig. 7), which is driven by pulley *C* from the over-head works. The driving shaft carries all the clutches and tripping mechanisms for starting the machine, indexing the turret, reversing the spindle, feeding the stock, and opening and closing the collet, and also drives the front camshaft *D*, and the lead camshaft through a worm and worm-wheel and spur and bevel gearing.

The camshafts, which carry plate cams for operating the front and rear cross-slides *E* and *F* and turret slide *G*, are driven at the required speed for the different jobs by means of change gears *H*. A set of plate cams is made up for each job; the cams are held on the shafts in their correct relation to each other by means of locating pins. The turret *I*, which carries the end-working tools, is provided with six holes, and is indexed by means of tripping levers operated by adjustable dogs held on drum *J*. Drum *K* carries dogs for operating the collet opening and closing and feeding mechanisms. The spindle is reversed when cutting a thread by adjustable dogs held on drum *L*, which can be detached from camshaft *D* by separating coupling *M*. The length of feed is controlled by rotating crank *N*; turning it to the right increases the length of feed, and turning it to the left shortens it. The machine is started and stopped by throwing the clutch O in or out by means of handle P. When the bar is exhausted a bell R is rung to notify the operator.

Construction of the Spindle

The spindle A_1, see Fig. 4, runs in phosphor-bronze bearings B_1 and C_1. The front bearing B_1 is split and tapered, and is adjusted by means of nuts D_1 and E_1, in case of wear. A brass liner is placed in the slot in the bearing, and when the latter is worn, this liner should be removed, reduced to the required thickness, and replaced. When the liner is replaced, nut D_1 should be tightened. This bearing is also pro-

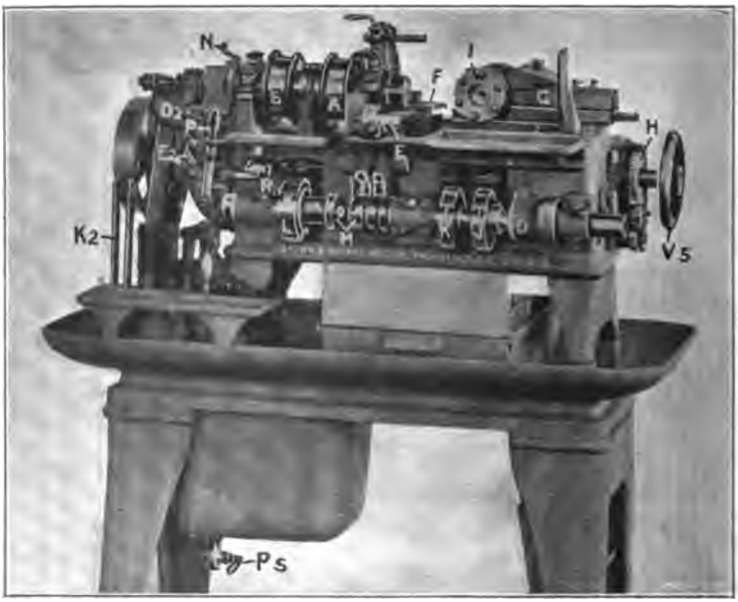


Fig. 1. Front View of No. 00 Brown & Sharpe Automatic Screw Machine

vided with saw slots around its circumference, in which strips of wood are inserted, so that the bearing will have more flexibility and yield more easily to the adjusting nuts.

The rear bearing C_1 is made straight, and is held in the box by nuts F_1 and G_1. The thrust is taken at the rear of the spindle, the thrust bearing consisting of a hardened steel washer H_1 and a bronze washer I_1. Washer H_1 is held against a shoulder on the end of the spindle by nut G_1 and loose washer I_1, the latter running against the hardened and ground inside face of nut G_1. To take up the end play of the spindle, loosen nut F_1 and tighten nut G_1, locking them in place again after adjusting.

The pulleys A and B which drive spindle A_1 through friction clutch S, are driven by open and cross belts from the countershafting. The pulleys rotate freely on the spindle, being provided with steel bushings

J_1 and rollers K_1 which are held in bronze cages L_1. The rollers run on the hardened and ground part of the spindle. The pulleys are oiled from oil reservoirs, the latter being filled by removing screws M_1. Any good machine oil is suitable for oiling these pulleys.

Friction Clutches

The friction clutch body S is tapered to an angle of 12 degrees at each end, and comes in contact with the driving pulleys A or B, when shifted in either the one or the other direction. It is made from phosphor-bronze, turned cone-shaped on each end, and slotted to hold clutch levers N_1, which are made from double-shear steel. These clutch levers are held in the clutch body by screws, and are fulcrumed in notches cut in the spindle. The clutch sleeve O_1 which operates on these levers

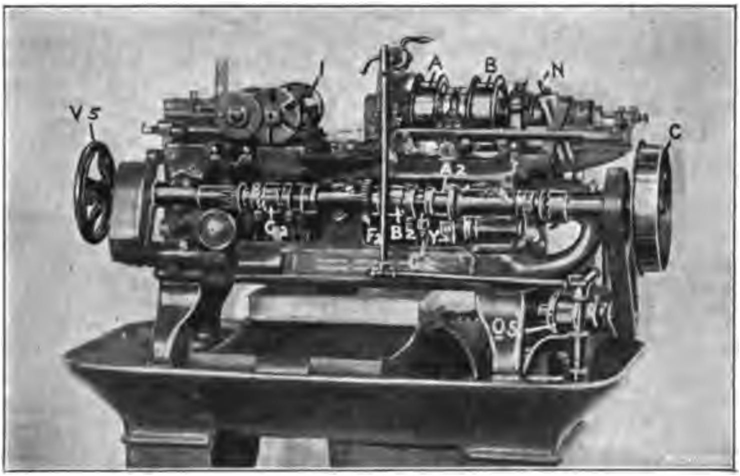


Fig. 2. Rear View of No. 00 Brown & Sharpe Automatic Screw Machine

is slotted to hold hardened steel shoes P_1 which bear on the hardened ends of the clutch levers.

The coned ends of the clutch body are forced into the pulleys by sliding sleeve O_1 over levers N_1. When sleeve O_1 is forced to the right it depresses the right-hand end of levers N_1, and as the lower portion of these levers are fulcrumed in the spindle, which cannot move longitudinally, it is evident that this action must move the clutch body, because the levers are held to it by screws. When the sleeve O_1 is forced in the opposite direction, the same action takes place, the cone-end of the clutch body engaging with the pulley to the left. To adjust the clutches to provide for wear, pulleys A and B are moved in towards the cones of the clutch body by loosening set-screws Q_1 and adjusting the nuts R_1.

The clutch sleeve O_1 is set central by means of screws T, Fig. 3. In making this adjustment a slight play should be allowed in the clutch fork U to avoid friction, except at the point of reversal. Care should also be taken not to run in the screws V too far into the clutch ring W, so as to split it. This clutch is made in halves and held together by pins.

On the No. 00 machine, the spindle is reversed to run backwards by means of the spring plunger *Y*, Fig. 2, and on the Nos. 0 and 2 machines by the cam A_2. The spring plunger on the No. 00 machine, when released, instantly engages the cone of the clutch with the pulley nearest the collet, and rotates the spindle backwards. To run forward, the clutch is operated by the cam A_2 to engage pulley *B*. Cam A_2, in turn, is operated by clutch B_2, and is released by lever C_2, one revolution of the driving shaft being required for the No. 00, and ½ revolution for the Nos. 0 and 2 machines. Lever C_2, again, is operated by a dog held on drum *L* on the front camshaft, see Figs. 1 and 6.

Operation of the Spring Collet

The spring collet S_1, Fig. 4, which holds the work, is held in sleeve T_1 in the front end of the spindle. This sleeve is driven by a pin in

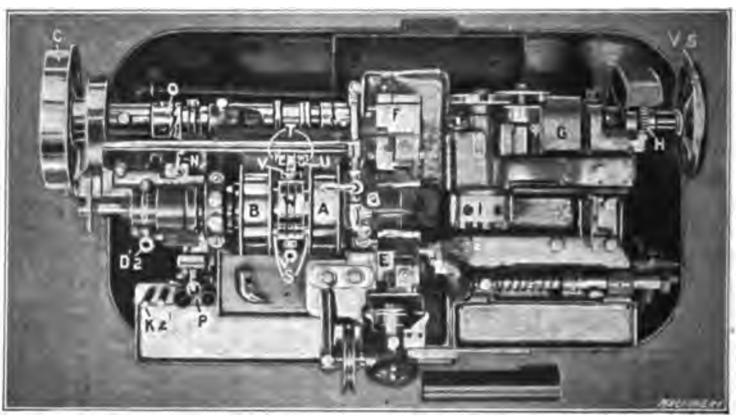


Fig. 3. Plan View of No. 00 Brown & Sharpe Automatic Screw Machine

the spindle, which fits in a slot cut in the sleeve. The front end of the sleeve is ground tapered and fits over the collet S_1. The collet has no end play, being held tightly against the inside ground face of the cap U_1, thus insuring accurate feeding of the stock regardless of any slight variation in size. Spring collet S_1 is closed by means of sleeve T_1, which slides over it and is operated by tube V_1. This tube, on the Nos. 00 and 0 machines, extends through the spindle to the levers W_1, which, in turn, are acted upon by sleeve *Y* through lever D_2 and cam E_2, Figs. 1 and 6.

The collet closing and stock feeding mechanism are operated by the same cam E_2 (on the Nos. 00 and 0 machines), which is driven through spur gears F_2 and positive clutch G_2, Figs. 2 and 7. Clutch G_2 is engaged by depressing lever H_2 by a dog held on drum *K* (see Figs. 1 and 6). The driving shaft makes one revolution, whereupon the clutch is disengaged by the pin lever H_2, Fig. 7, acting upon the cam surface of the clutch, returning it to its original position—out of mesh.

To adjust spring collet S_1, Fig. 4, loosen nut I_2 and turn nut J_2 until the holding capacity of the clutch is properly regulated; then re-tighten nut I_2 and lock both nuts by means of the spanner wrenches provided for this purpose. Great care should be exercised in adjusting these nuts. If they are so adjusted that the collet S_1 bears too tightly on the work, either the collet or closing levers W_1 will be broken. A good

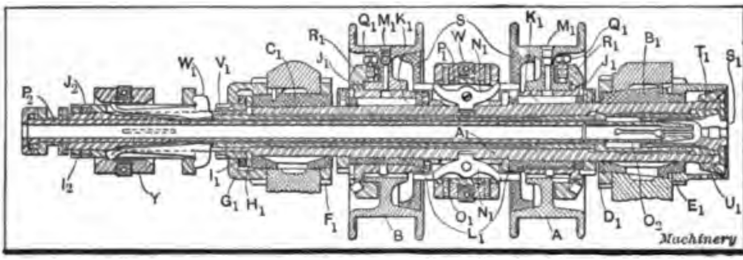


Fig. 4. Section through Spindle, Boxes, Pulleys, etc., of the No. 00 Brown & Sharpe Automatic Screw Machine

method to follow in regulating the proper grip of the collet upon the work is to adjust nuts I_2 and J_2, and then test the grip of the collet by operating fork D_2 by means of the handle K_2 (see Figs. 1 and 3). In this way the proper grip can be secured without difficulty.

On the No. 2 machine the sleeve T_1 (see Fig. 5) is forced over the collet S_1 directly by the levers W_1, the latter being operated by sleeve Y_1 and a cam on the intermediate shaft directly under the spindle.

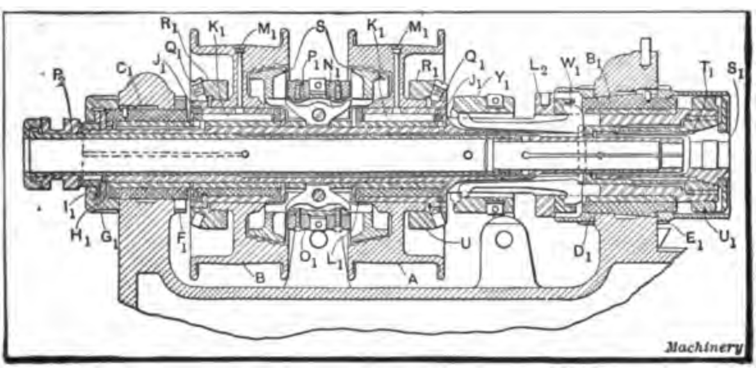


Fig. 5. Section through Spindle, Boxes, Pulleys, etc., of the No. 2 Brown & Sharpe Automatic Screw Machine

To adjust the grip of the collet on the stock, loosen the clamp screw in nut L_2, and turn the knurled nut toward the front of the machine to tighten the collet, reversing the direction of the nut to loosen it.

Operation of the Feeding Mechanism

The feeding mechanism derives its motion from pulley C through spur gear F_2 (Fig. 2) to gear M_2 on central shaft N_2 (Fig. 10). Pulley C is engaged by a positive clutch O (Fig. 7), which is brought into action by means of the starting lever P; in this way the feed is always

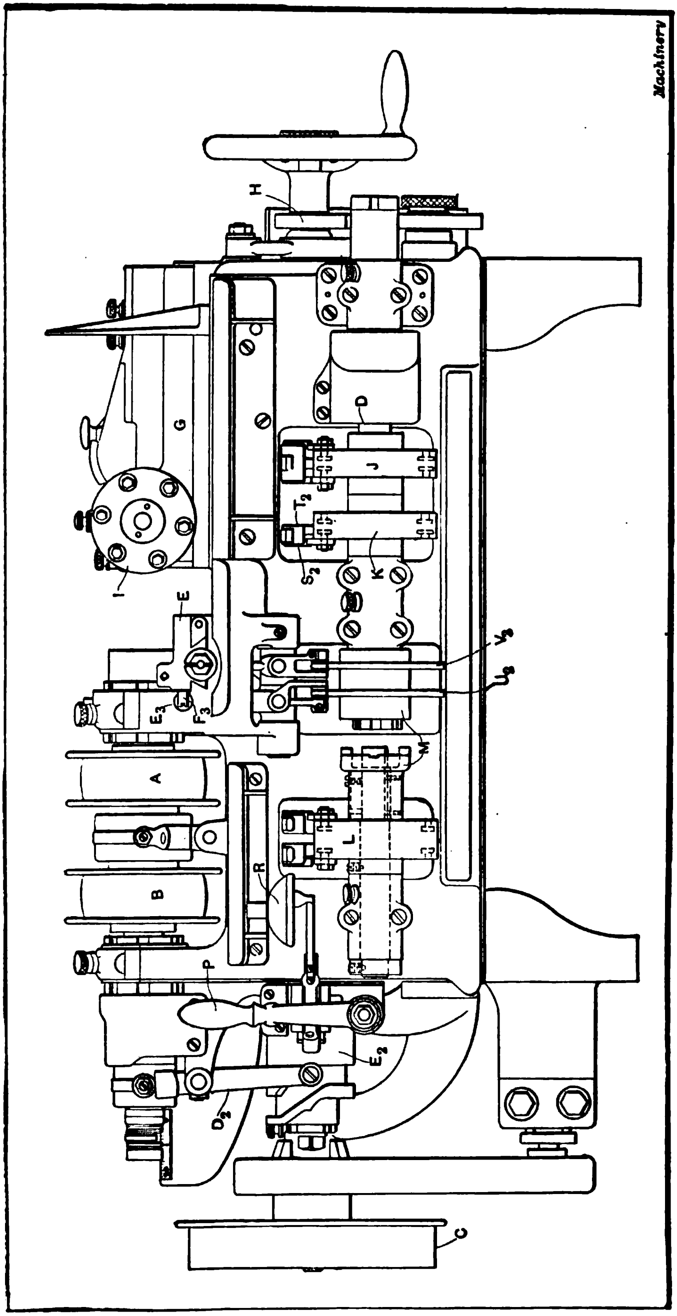


Fig. 6. Front Elevation of the No. 00 Brown & Sharpe Automatic Screw Machine

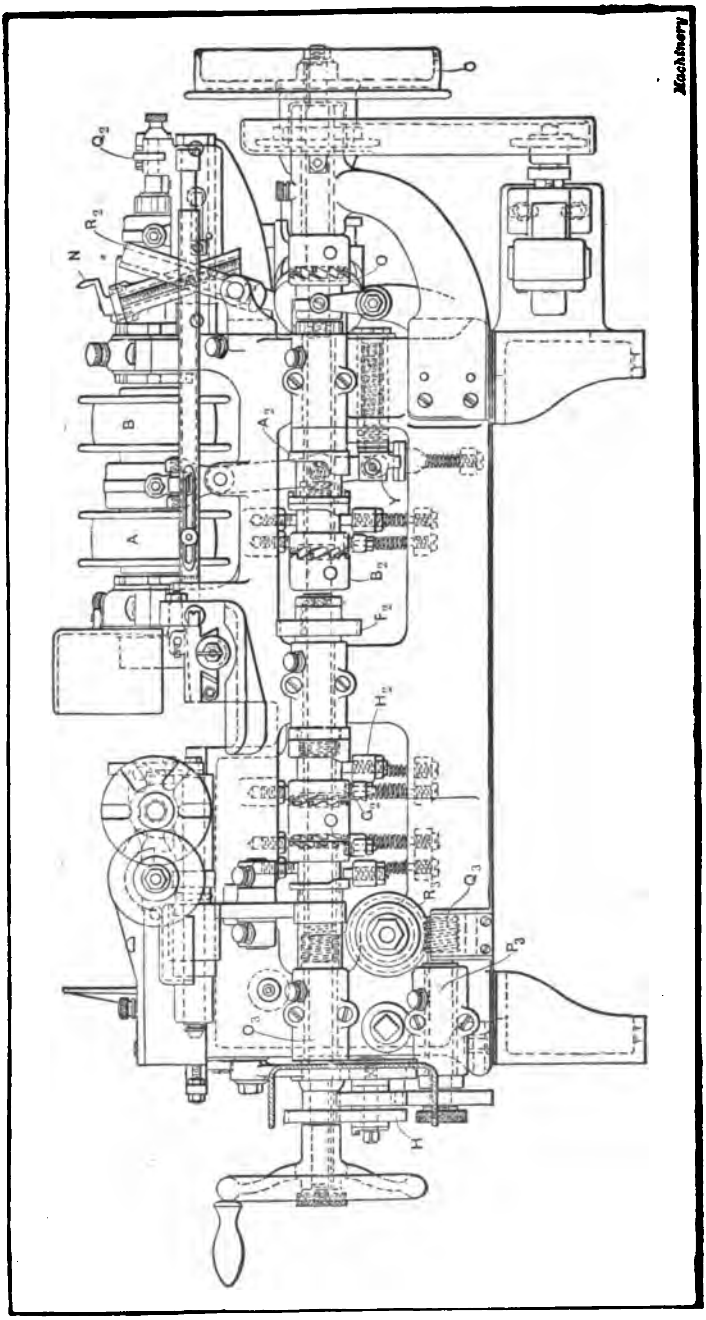


Fig. 7. Rear Elevation of the No. 00 Brown & Sharpe Automatic Screw Machine

under complete control. The stock is fed out by means of a feed finger O_2 (Fig. 4), which is provided with a left-hand thread, and is screwed into the feed tube P_2, the latter passing completely through the spindle. The outer end of the feed tube is connected to the feeding mechanism or slide by means of a latch Q_2, Figs. 7 and 8. The feed slide carrying the latch has a slot cut in it, in which is a sliding block connected to arm R_2, the latter being operated by cam E_2. The sliding block is adjusted in the feed lever by means of a screw and crank N, and as the arm R_2 always moves a fixed distance, the length

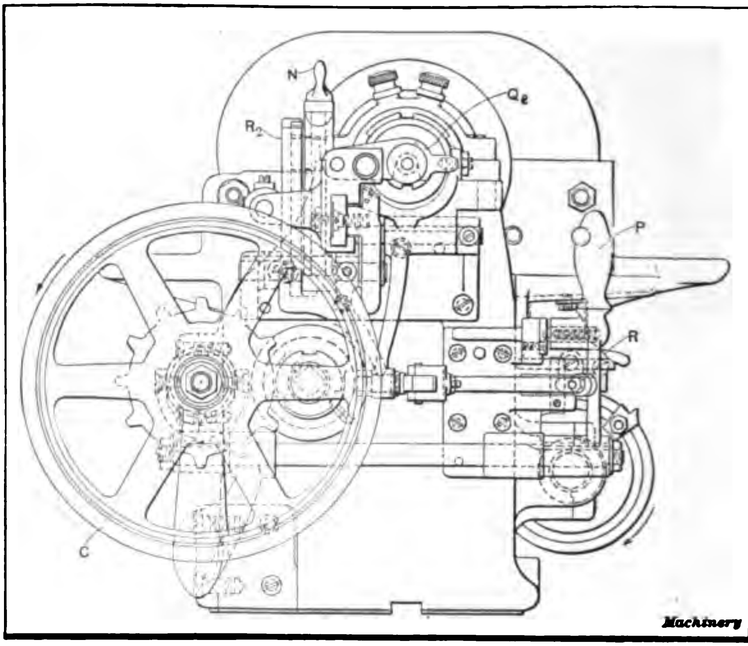


Fig. 8. End Elevation of the No. 00 Machine showing Collet Operating Mechanism

of the feed is obtained by varying the position of the block. A graduated scale which indicates the length to which the stock is fed, is mounted on the feed slide.

When it is desired to change the feeding finger, the feed tube can be withdrawn by lifting the latch. The feeding of the stock can be discontinued by turning up dog S_2, Fig. 6, attached to lever T_2, thus allowing the trip dogs on the drum K to pass by without raising the lever. When it is desired to feed stock more than the usual capacity of the machine, two or more dogs can be placed on the left side of the drum, and the feeding mechanism operated several times.

Operation of the Cross-slides

The front and rear cross-slides E and F are operated by plate cams U_2 and V_2 held on the front camshaft D, Figs. 6 and 9. The front cross-slide is operated by a direct lever or segment gear W_2 that has teeth cut in its upper end meshing in a rack Y_2, which, in turn, fits in a slot in the base of the cross-slide. This rack is threaded on one end and is provided with a split adjusting nut A_3 which is used for changing the position of the cross-slide relative to the center of the spindle. The screw binding these nuts should always be tightened after the cross-slide has been set to travel the required distance. The rear cross-slide is fitted up in the same manner, but is operated through an intermediate lever or segment gear B_3 to reverse the motion, thus bringing the cams for operating both slides in a convenient position.

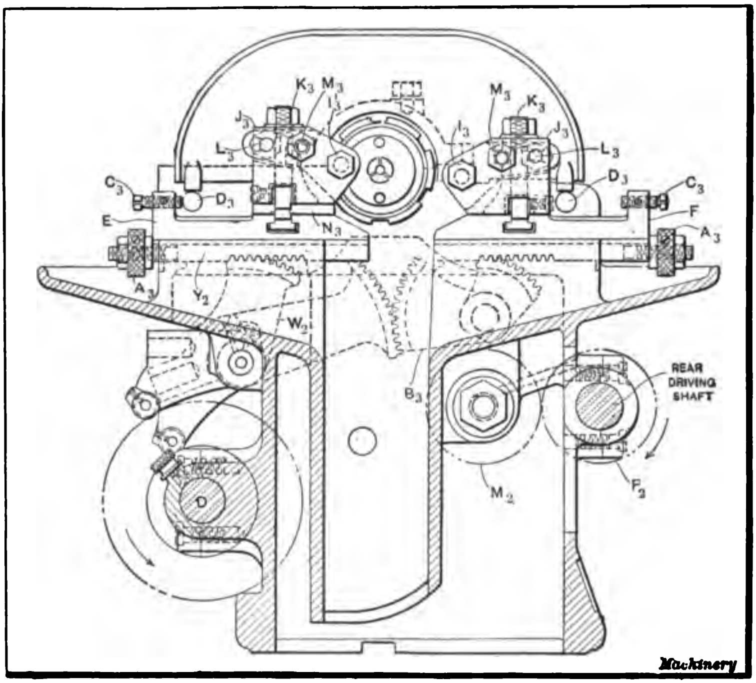


Fig. 9. Partial Section of No. 00 Machine showing Operation of Cross-slides

The cross-slides are made to travel to exactly the same point by set-screw C_3 which comes in contact with stop D_3. The cross-slides E and F are returned to their "back" position by means of coil springs and plungers E_3, the latter coming in contact with plugs F_3 screwed into the cross-slides. When setting the circular form and cut-off tools, the slides can be operated by hand by means of a rod inserted into holes provided for that purpose in the ends of the slide-operating segment gears.

The cross-slide tools are circular in form, and are held by screws I_3 to the toolposts J_3, the latter being retained on the cross-slides by T-bolts and nuts K_3. Eccentric nuts are provided on the screws L_3 at the rear of the toolpost, which make it possible to easily and quickly

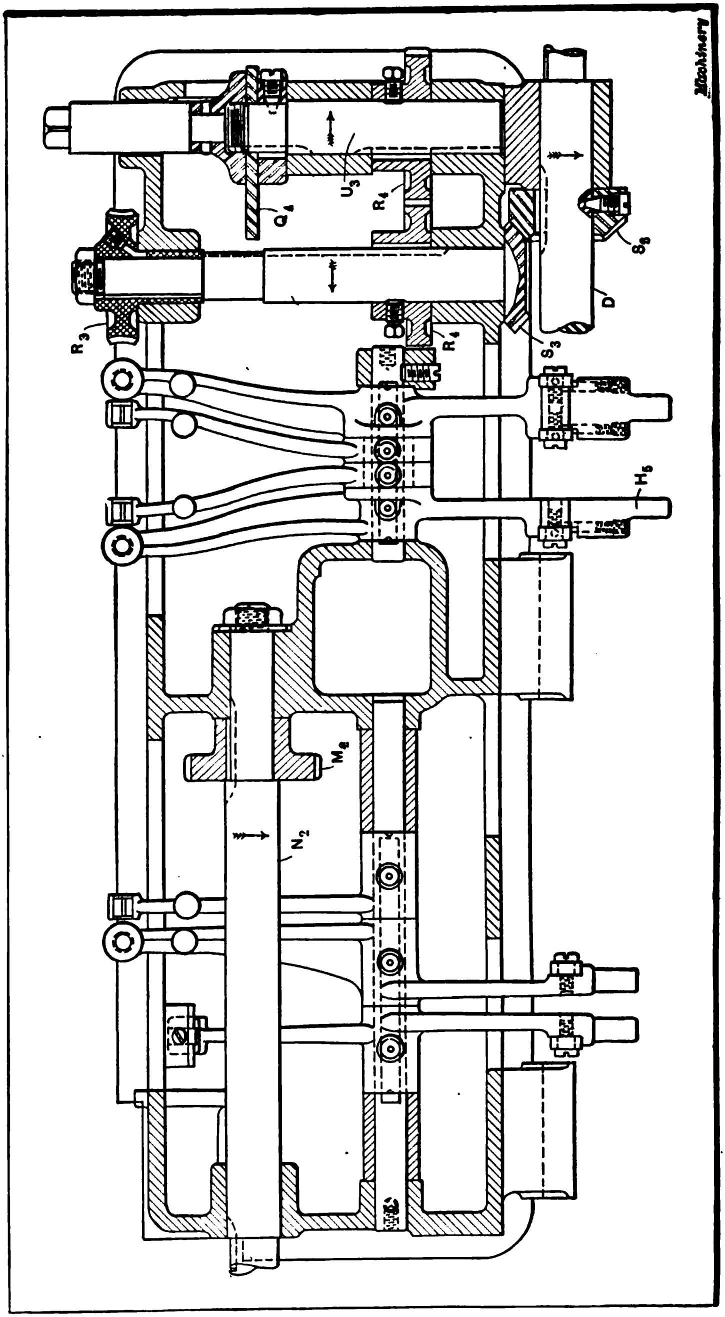


Fig. 10. Partial Section of No. 00 Machine showing Operation of the Front and Lead Cam-shafts, Tripping Levers, etc.

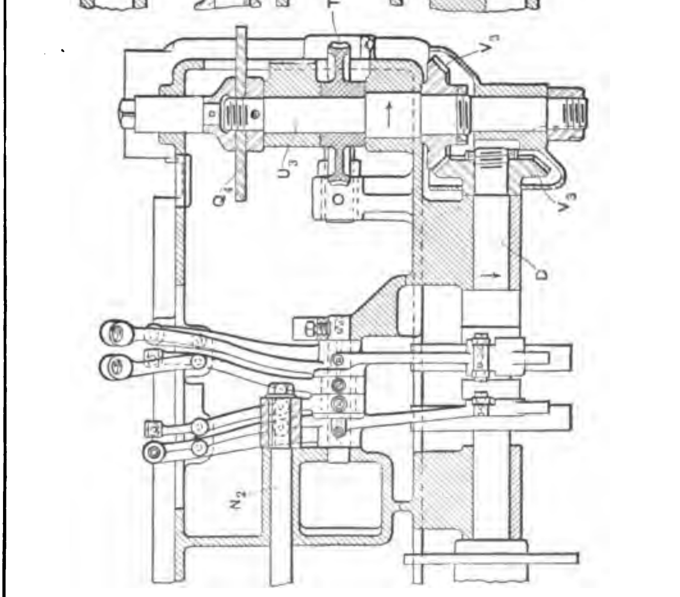


Fig. 11. Partial Section showing how the Front and Lead Camshafts are operated on the No. 0 Machine

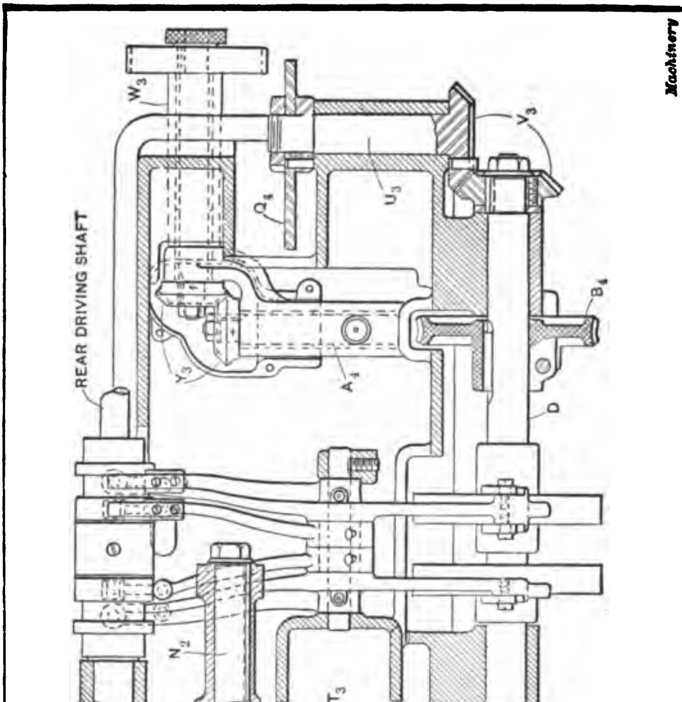


Fig. 12. Partial Section showing how the Front and Lead Camshafts are operated on the No. 2 Machine

adjust the circular tools to the proper height. Additional clamping means for the circular tools are provided for by hook-bolts and nuts M_3. The circular tools are ground on the face for sharpening without changing their outline. The block N_3 is provided for raising or lowering the toolposts, so that the circular tools can be ground below center to give sufficient rake.

The manner in which the front camshaft is driven is illustrated in Figs. 7 and 10. Power is transmitted from the rear driving shaft O_3

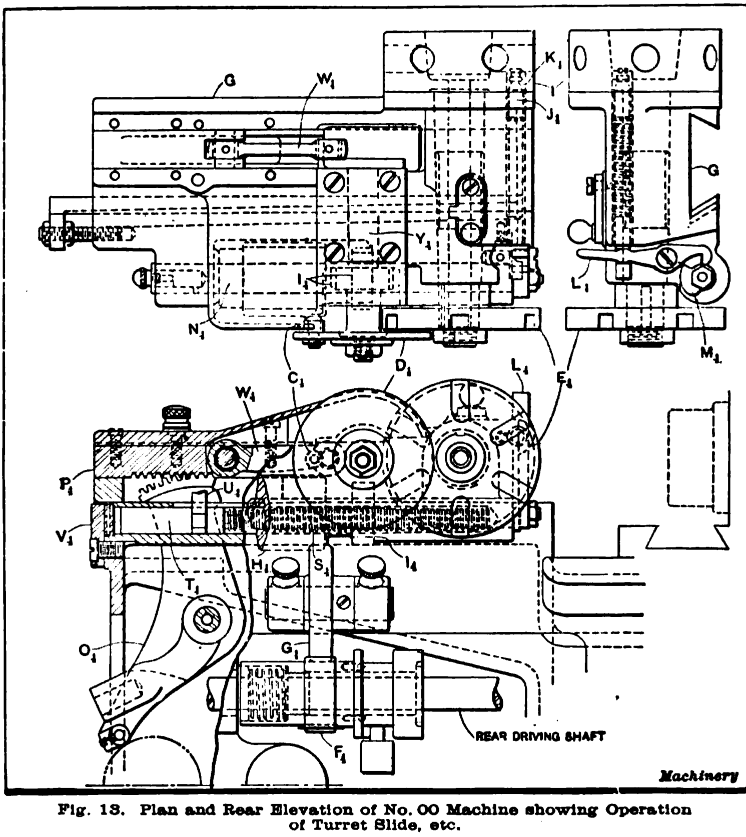


Fig. 13. Plan and Rear Elevation of No. 00 Machine showing Operation of Turret Slide, etc.

through the change gearing *H* to the worm-shaft P_3. Double-pitch worm Q_3 drives worm-wheel R_3, which through bevel gears S_3 rotates front camshaft *D*. On the Nos. 0 and 2 machines, the power is transmitted differently as can be seen in Figs. 11 and 12. On the No. 0 machine the power is transmitted from the rear driving shaft through the change gearing to a single-pitch worm, the latter driving the worm-wheel T_3 on the lead camshaft U_3, which furnishes power to the camshaft *D* through bevel gears V_3. The arrangement is slightly different on the No. 2 machine. The power in this case comes from the rear driving shaft through the change gearing to the so-called "worm-shaft" W_3, which through bevel gears Y_3 drives the single-pitch worm on shaft A_4 and the worm-wheel B_4 on front cam-shaft D.

Operation of the Turret Slide

The turret I, Fig. 13, which holds the working tools, is mounted vertically on the side of the turret slide G. The turret has a long tapered shank which forms the bearing in the turret slide. It is rotated by means of a hardened roll C_4 on a disk D_4, which engages in radial grooves in the disk E_4. Disk D_4 is driven from the rear driving shaft through spur gears F_4, G_4, and H_4, and helical gears I_4. There are six

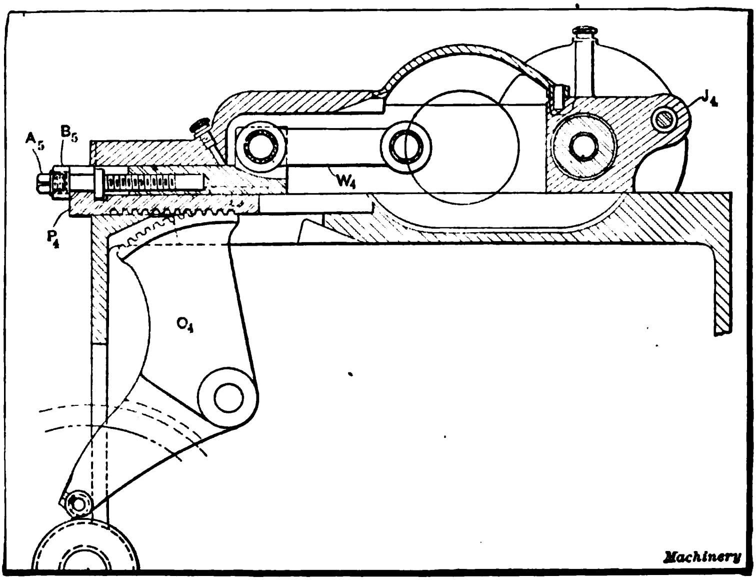


Fig. 14. Partial Section of No. 2 Machine showing Operation of Turret Slide

holes in the turret, disk D_4 making six revolutions for every complete revolution of the turret. The turret is locked in position by the hardened tapered plug J_4 which fits in a hardened bushing K_4 in the turret. This plug is operated by a trip latch L_4, which is withdrawn by a cam M_4 on one end of the shaft N_4. The locking pin or plug is withdrawn from the turret by hand by pushing back latch L_4.

Slide G upon which the turret I is mounted receives its forward movement from the lead cam Q_4 (Fig. 10) through the bell crank lever O_4 and rack block P_4. The lead camshaft (Fig. 10) is driven from the rear driving shaft through worm-wheel R_3 and spur gears R_4. The turret slide is returned by a coil spring S_4, plunger T_4 and pin U_4, shown in Fig. 13, the plunger is located in its "back" position by a stop-block V_4.

The quick return and advance of the turret slide and the revolving of the turret are controlled independently of the lead cam by the crank

W_4, which is connected eccentrically to the turret revolving shaft Y_4. This crank indexes the turret while the roll on the bell crank lever O_4 is passing from the highest point of the lead cam to the starting point of the lobe for the next cut. Crank W_4 is driven from the rear driving shaft, as previously described, by a positive clutch, the latter being operated by tripping levers and dogs on drum J, Fig. 6.

As the crank revolves it allows spring S_4, Fig. 13, to return the turret slide. The turret is then revolved, as described, and when the crank comes to rest after making one complete revolution, the machine is

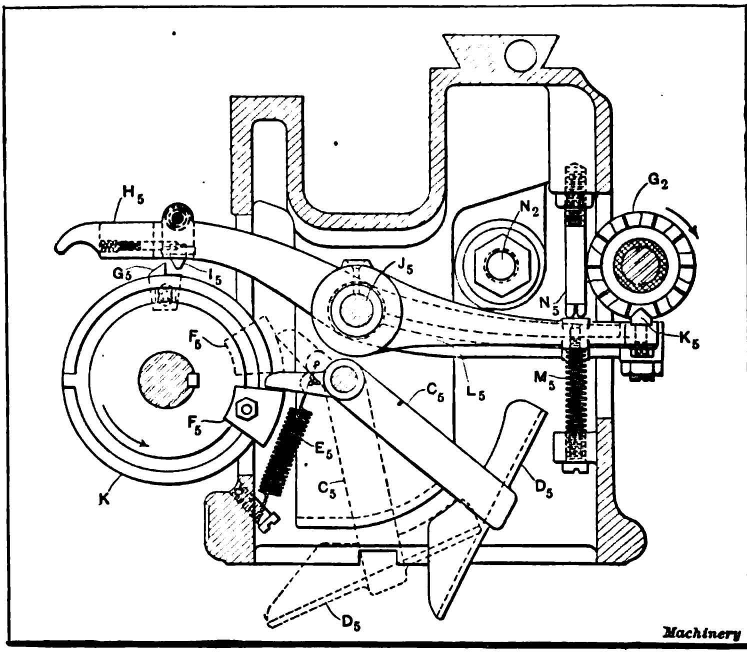


Fig. 15. Partial Section of No. 00 Machine showing Operation of Deflector, Tripping Levers, etc.

ready for the next operation. The bell crank lever O_4 bears against the bed at the extreme forward movement and insures the positive return of the turret slide should the spring fail, owing to the binding of the turret tools on the work. The turret slide is not adjustable lengthwise on the Nos. 00 and 0, but on the No. 2 machine an adjustment of 1 inch is provided for by a screw A_5 and lock nut B_5, Fig. 14.

On the No. 0 machine the indexing disk D_4, Fig. 13, is driven as before described from the rear driving shaft through spur gears, but the turret revolving shaft Y_4 receives its motion from shaft N_4 through bevel gears. The lead camshaft U_3 is driven from front camshaft D through bevel gears V_3.

The indexing disk D_4 on the No. 2 machine (see Fig. 13) is driven in a manner similar to that of the No. 0 machine, but in this case D_4

is a spur gear. The latch L_4 on the No. 0 and 2 machines is operated by a cam on indexing disk D_4. The lead camshaft U_2 is driven from the front camshaft D through bevel gears V_3, as shown in Fig. 12.

Operation of the Deflector

To separate the chips and oil from the work which is cut off, a deflector is provided, as shown in Fig. 15. This deflector consists of a bell-crank C_5 to which a pan or chute D_5 is integrally cast. The crank is operated by spring E_5 and cam block F_5 on drum K, which lifts up the forward end of the crank, moving the deflector into the position shown by the dotted lines. This brings it directly under the fixed

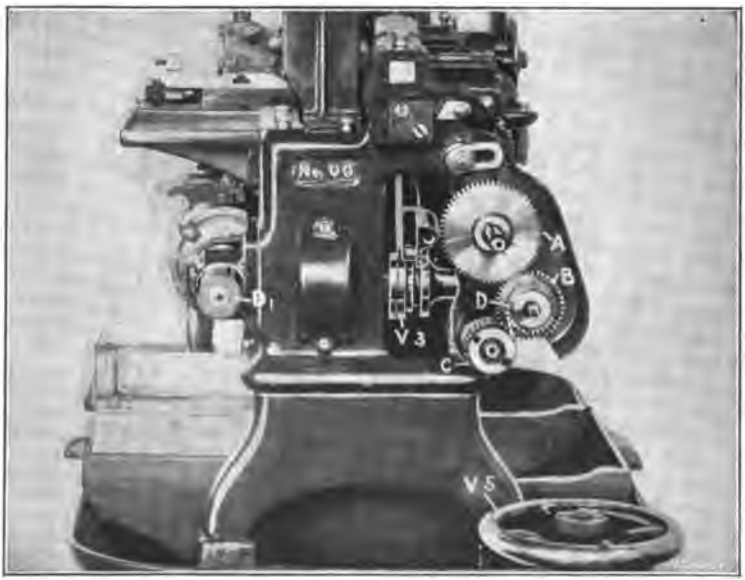


Fig. 16. End View of No. 00 Machine showing Arrangement of Change Gears

chute of the machine, so that the work is deflected from the pan for the chips into the pan provided for holding the work. The cam block is adjustably mounted on the drum so that it can be moved into the desired position for operating the deflector. On work requiring a small amount of machining, the deflector must remain under the chute for a longer period than is required on longer operations; therefore, cam blocks having different lengths of arcs are provided, to allow the deflector to remain under the chute for a greater or less time.

Fig. 15 illustrates clearly the construction and action of the tripping lever for operating clutch G_2, Fig. 2. The operation is as follows: A dog G_5 on drum K lifts tripping lever H_5 by means of the block I_5, and as H_5 is fulcrumed on shaft J_5, this action lowers the rear end of the lever. A pin held in the rear end of the lever by adjusting nuts, fits in a recess in the cam which forms one jaw of the clutch G_2, and as the

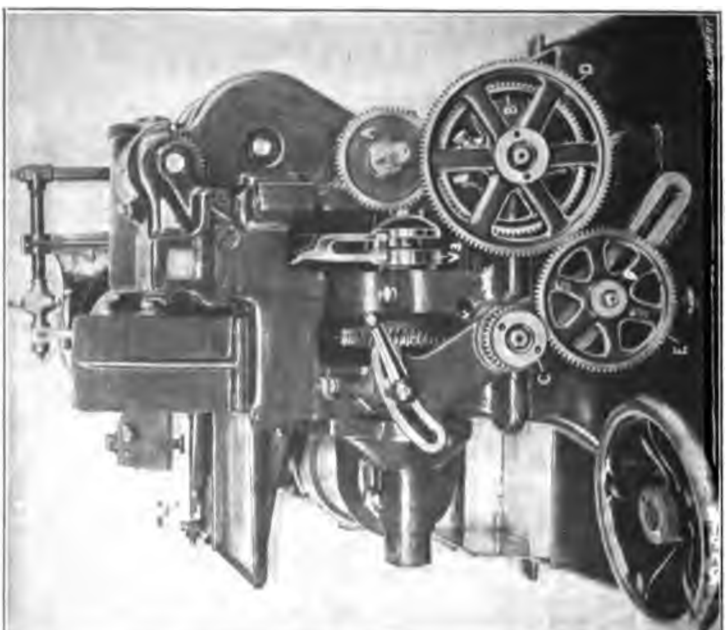


Fig. 17. End View of No. 0 Machine showing Arrangement of Change Gears

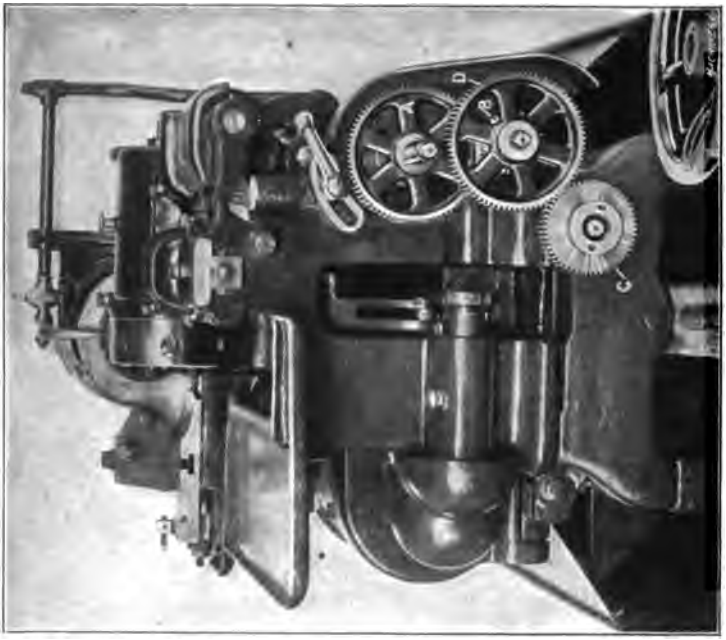


Fig. 18. End View of No. 2 Machine showing Arrangement of Change Gears

pin is withdrawn, the cam is forced out into engagement with the driving part of the clutch by a spring. The cam G_2 is located in the correct relation (each time it is disengaged from the driving clutch) to the collet closing mechanism by a V-groove in the cam body in which a stop K_8 in the lever L_8 fits. The stop is kept in contact with the cam body by a spring M_8 and is stopped in its "up position" by a stud N_8. All the tripping levers and clutches for the feeding, spindle reversing and turret indexing mechanisms are operated in a similar manner.

Operation of Oil Pump—Arrangement of Change Gears

The oil pump O_8, Fig. 2, is driven from the driving shaft by means of a chain and sprockets, which are shown guarded, and is provided

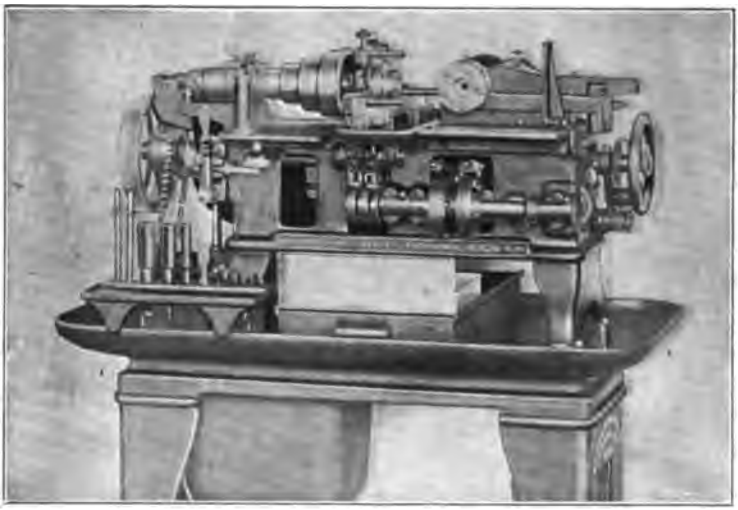


Fig. 19. No. 00 Brown & Sharpe Automatic Turret Forming Machine, Front View

with suitable piping. The pump is not stopped when the feed is disengaged, but continues in operation, thus insuring a steady stream of oil as soon as the tools commence to cut. Care should be taken to see that the pipe is not blocked up and that the oil pan is filled with oil. The oil is removed from the pan by opening the cock P_5, Fig. 1.

The speed of the front and lead camshafts is changed for the different jobs by means of change gears, as shown in Figs. 16, 17 and 18. Fig. 16 shows the arrangement of gearing for the No. 00 machine, where *A* is the gear on the driving shaft; *B*, the idler gear; and *C* the gear on the worm shaft. When it is desired to compound the gearing on this machine, another gear *D* is placed on the idler stud and a gear not shown is placed on the driving shaft. When the gearing is compounded, *B* becomes "first gear on stud," and *D*, "second gear on stud." The arrangement of the gearing for the No. 0 machine is shown in Fig. 17. Here *A* is the gear on the driving shaft; *B*, "first gear on stud"; *D*, "second gear on stud"; *E*, an intermediate gear; and *C* the gear on the worm-shaft. On the No. 2 machine the gearing is arranged as shown in Fig. 18, where *A* is the gear on the driving shaft; *B*, "first gear on stud"; *D*, "second gear on stud"; and *C* the gear on the worm-shaft.

Automatic Turret Forming and Cutting-off Machines

The automatic turret forming machine, the No. 00 size of which is shown in Fig. 19, is intended for work not requiring the reversal of the spindle. It is practically of the same design and capacity as the regular automatic screw machine, except that it is driven by a four-step cone pulley. The preceding description applies to these machines in general, and the collets, cams, tools, etc., are all interchangeable with the regular "automatics" of the same size.

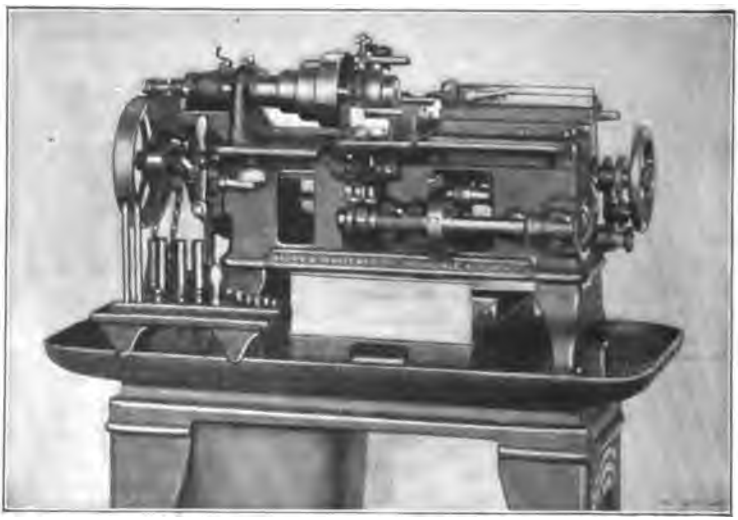


Fig. 20. No. 00 Brown & Sharpe Automatic Cutting-off Machine, Front View

The automatic cutting-off machine, size No. 00 of which is shown in Fig. 20, is driven by cone pulleys in the same manner as the turret forming machines and at the same speed. It has no turret, but is provided with a tool-slide for carrying a stop hollow-mill, box-tool or drill. It is of the same chuck capacity as the regular automatics, but the tool-holder is adjustable so that much longer work can be accommodated. The tool-slide on the No. 00 machine has a movement of 1¼ inch. The shortest distance (approximately) between the face of the tool-holder and the face of the collet when the lead lever roll is on the largest diameter of the cam, is 1¾ inch on the No. 00, 2 inches on the No. 0, and 2½ inches on the No. 2 machine. The greatest distance obtainable, approximately, with the lead lever roll on the smallest diameter of the cam, is 10 inches on the No. 00, 14 inches on the No. 0, and 17 inches on the No. 2 machine. The tools, cams, collet, etc., are interchangeable with the regular automatic screw machines of the same size.

CHAPTER II

SETTING THE TOOLS AND OPERATING AUTOMATIC SCREW MACHINES

In "setting-up" the Brown & Sharpe automatic screw machines, the most simple tools should, generally, be set first. As a rule these are the circular form and cut-off tools which are held on the cross-slides. Before any of the tools are set, however, the collet and feed finger should be changed for the size of work required, the proper change gears put on, and the driving belt placed on the required step.

Setting the Circular Form and Cut-off Tools

After the feed finger and spring collet have been put in place, the stock is inserted and pushed out far enough so that it can be faced off with the circular cut-off tool. The cut-off tool is then clamped to the toolpost and set with its cutting edge as close as possible to the height of the center of the work. The spindle is rotated and the end of the stock faced off, using lever K_2, Fig. 21, to operate the cross-slide. This procedure is followed until the cut-off tool is set correctly. The circular form tool is then clamped to the toolpost and the same procedure followed.

Fig. 21 shows an operator setting the cutting edge of a circular form tool to the height of the center of the work by means of the adjusting nut L_3. Care should be taken in setting the circular form and cut-off tools so that they will form the work parallel, and cut it off with a square face. This is accomplished by means of the adjusting screws *a* in the rear of the toolpost, which can be adjusted when nut K_3 is slackened slightly. When a circular form tool is placed on the front cross-slide, it is necessary to put the rising block N_3 under the toolpost. All dirt and oil should be removed from the surfaces of the rising block, toolpost and cross-slide, so that the cutting edge of the circular form tool, which should be ground at right angles to the side face, can be set parallel with the center line of the work. If this is not done, it will be found that the work will be slightly tapered.

The rolls in the cam levers require careful attention. If the pin in these rolls are not a good running fit, the roll will stick and wear out of round. This will result in the production of pieces which vary in diameter, due to the changes of position of the roll for the different pieces.

In setting the tool on the front cross-slide, the cutting edge should never be below the center of the work, but should be set preferably above or at the height of the center. The cutting edge of the tool on the rear cross-slide should be set just the reverse in reference to the center of the work, when the latter is running forward. When the work is running backward, the position of the cutting edges of the tools on the front and rear cross-slide should be reversed from that for the forward rotation of the work. If the cutting edges of the circular tools are not set in the positions described, the work, when rotating, has a tendency to pull them around, thus increasing the diameter of the work, and causing chattering.

When the circular form tool is used for finishing the work to an exact diameter, the set-screw C_3, Fig. 21, should always be set so that it will come in contact with the stop D_3 when the work is turned to the desired diameter. In setting this stop it should be so adjusted that it will put a slight strain on the cross-slide operating lever. The

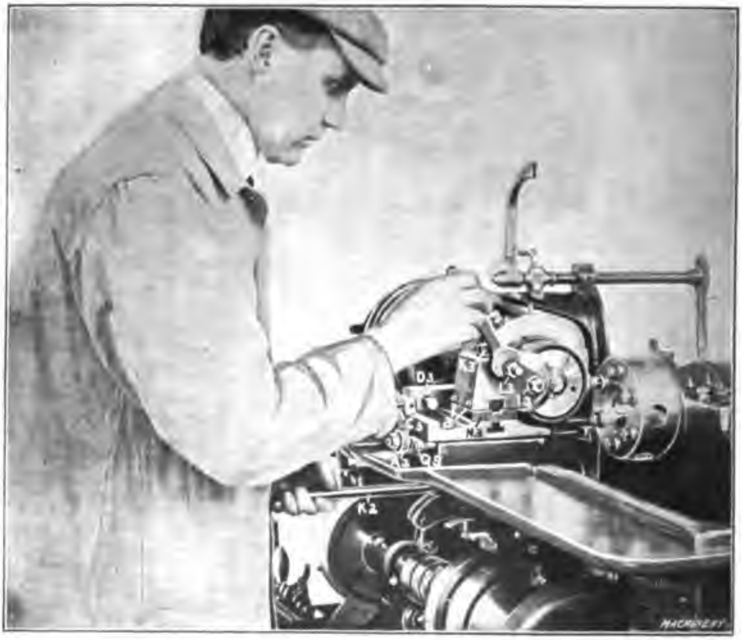


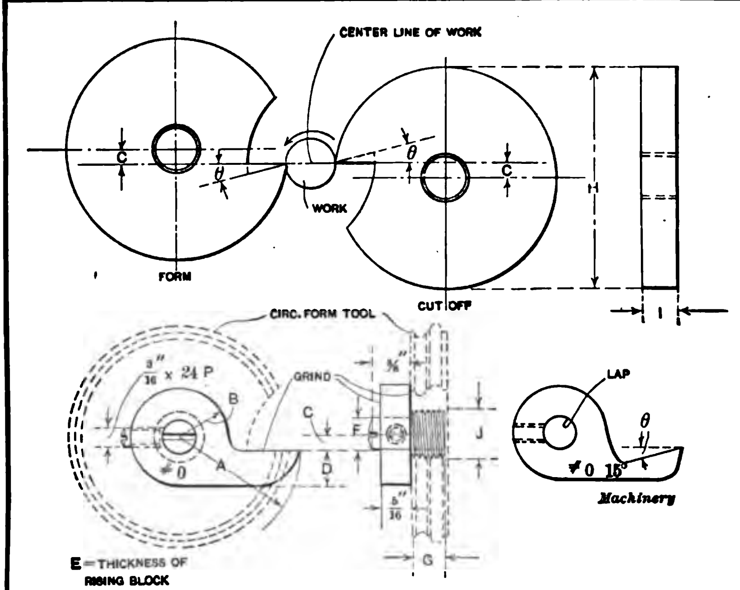
Fig. 21. Operator setting a Circular Form Tool

resulting action keeps the roll in close contact with the cam, and thus assures the parts formed being of the same diameter. When the circular form tool wears slightly, the set-screw C_3 can be adjusted back a slight amount, and the strain which has been set up in the lever will allow the tool to turn the work to the desired diameter. The cross-slide is adjusted back and forth to bring the cross-slide tools in contact with the work by means of split nut A_3, which is locked by means of a screw. Gib Q_5 should be adjusted so that there will be no unnecessary side play of the cross-slide in the bed.

Sharpening Circular Form and Cut-off Tools

The circular form and cut-off tools should be carefully sharpened when they become dull. If the cutting edge is not ground at right angles to the side face of the circular tool, the work produced will be slightly tapered. For this reason the circular tool when being sharpened should be held on a table, the top surface of which is at right angles to the side face of the emery wheel. The cutting edge is then brought up against the side face of the emery wheel, and the tool ground. To insure that the tool is ground correctly, a templet similar to that shown in the illustration accompanying Table I is made for

TABLE I. PROPORTIONS FOR TEMPLETS AND CIRCULAR TOOLS



Number of Machine	Dimensions in Inches									
	A	B	C	D	E	F	G	H	I	J
00	1	7/16	1/8	5/16	1/4	1/4	7/32	1 3/4	1/4	3/8–16 P. R. H.
0	1 1/4	1/2	5/32	11/32	5/16	5/16	5/32	2 1/4	5/16	1/2–14 P. R. H.
2	1 5/8	5/8	1/4	3/8	3/8	3/8	11/32	3	3/8	5/8–12 P. R. H.

the circular tools used on each size of machine. The dimensions of this templet for the various sizes of machines are given in this table. The distance *G* is made less than the thinnest tool, so that the screw will not prevent the tool from lying flat on the table when grinding.

These templets should preferably be made of tool steel, hardened and ground as indicated. The hole should be lapped and the plug made a good fit for it. To the right of the illustration a templet is shown with its top face ground at an angle *θ*, and the size of the machine and angle stamped on it. Circular tools are ground with top rake for cutting machine steel, tool steel, etc. The cutting angles for the various materials are as follows:

ANGLE OF TOP RAKE ON CIRCULAR TOOLS

Material	Angle θ, in Degrees
Brass rod	0
Drill rod and tool steel	8 to 10
Gun-screw iron	12
Machine steel	15
Norway iron	18

The sizes and pitches of the tapped holes in the circular tools are listed in column *J* of Table I, where the thread is given as right-hand. Sometimes the tools are tapped left-hand, especially in the case of wide

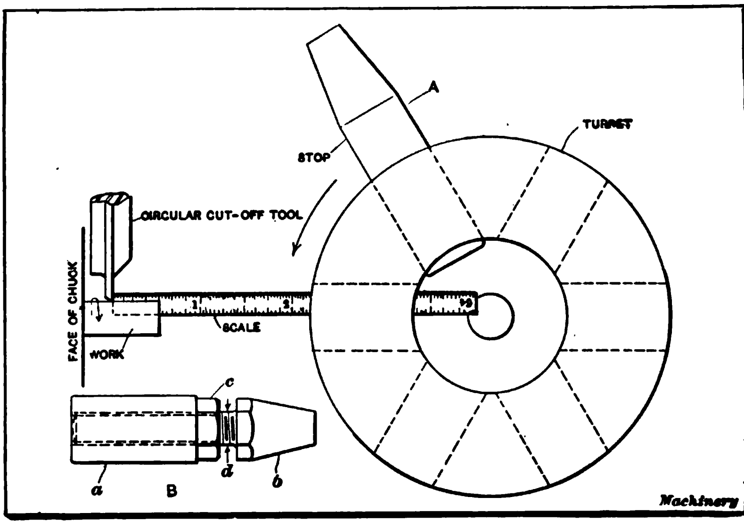


Fig. 22. Simple Method for setting a Stop

forming tools; they are then set on the front cross-slide, with the work running forward. As a rule, the tools are tapped right-hand and the hook bolt M_1 and bolt I_3, Fig. 9, tightly clamped, thus holding the circular tool securely.

Setting the Stop

When the circular cut-off tool has been set correctly, the chuck is opened by lifting the tripping lever, and the stock is fed out the desired length by hand; this length can be easily measured off by the method shown in Fig. 22. A flexible scale, the length of which depends on the size of the machine, is placed in an empty hole in the turret and brought up against the inside face of the circular cut-off tool. The cut-off tool is now brought up against the work by means of the handle operating the cross-slide. It is then an easy matter to set the stock to the desired length. When this has been done, the chuck is closed and the turret swung around so that the stop comes in line with the stock.

When the stop is in this position, the roll should be on the quick rise of the lead-cam so that by rotating the cam, the roll will rise up onto the lobe, thus forcing the stop back into the turret the required amount, where it can be locked with the lock-screw provided for that purpose.

When it is necessary to have the length of the piece to within a limit of 0.010 inch or less, the stop *A* in Fig. 22 gives considerable trouble, because the only way in which it can be set is by tapping it in or out, which is a rather difficult matter. A stop which gives better results is shown at *B*. The parts *a*, *b* and *c* are made from machine steel and casehardened. The body *a* is drilled and tapped for a screw the diameter of which is made in accordance with the size of the machine in which the stop is to be used: For the No. 00, $d = 5/16$ inch; for the No. 0, $d = 3/8$ inch; and for the No. 2, $d = 1/2$ inch.

For the No. 00 machine the number of threads per inch of the screw should be thirty-two, which would mean that one revolution would give

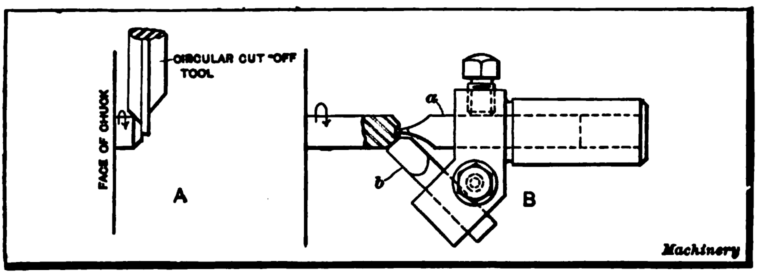


Fig. 23. Chamfering the End of the Work

an adjustment of 0.03125 inch. For the other machines, the screw should have twenty threads per inch. The stop proper, *b*, is made of hexagonal stock to fit the standard wrenches supplied with the machines. The nut *c* is made of the same shape and from the same size of stock as *b*. By having the stop hexagonal, as shown, it is an easy matter to set it within 0.005 inch, by means of the faces on stop *b*, as the relation of these to the nut can be noted, provided the latter is held with a wrench while part *b* is rotated.

Setting a Hollow-mill or Box-tool

Before reducing the diameter of the work by means of a hollow-mill or box-tool, it is necessary to chamfer the front end of the work to facilitate the starting of the cutter on a light cut until the tool is properly supported. One method of pointing the end of the work is shown at *A* in Fig. 23. Here the circular cut-off tool has an angular projection on its face next to the chuck, which points the bar before it is fed out for the next piece. This method is generally used when the work is not very long and runs practically true. It is sometimes impossible, however, to point the bar with a cut-off tool, and in that case the bar is usually pointed by a combination centering and pointing tool, as shown at *B*. This tool can be used when the bar does not project more than $3\frac{1}{2}$ times its diameter from the face of the chuck, and when it is unfinished or of irregular shape. Tool *a* is used for centering the work, thus preparing it for drilling a hole, while tool *b* is used for pointing the end of the bar.

In setting a box-tool, the bar should project out of the spring collet only far enough to allow it to be turned down for a short distance; otherwise the work will not be held rigidly, and will spring away from the cutting tool. The cutting tool is first set to turn the work to within about 0.0005 or 0.001 inch of the finished diameter; then the supports are forced up tightly into contact with the work and clamped. It will be found that when the stock is fed out to the desired length, the supports bearing against the work tightly, the tool turns it slightly

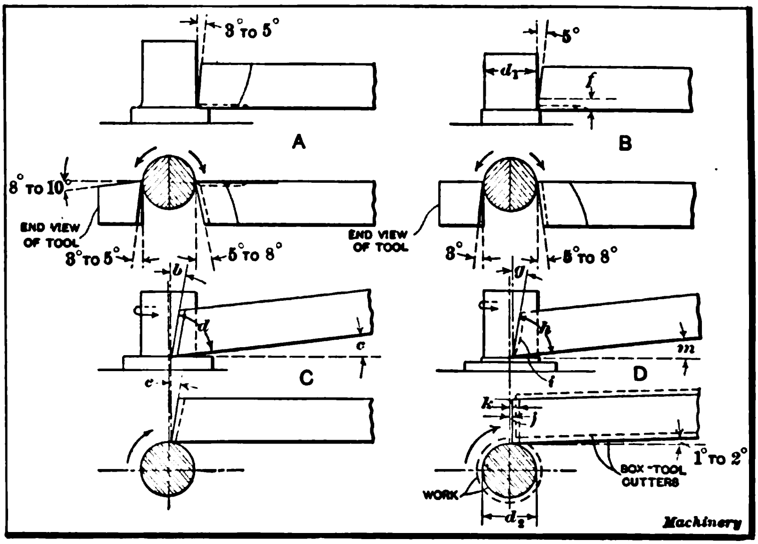


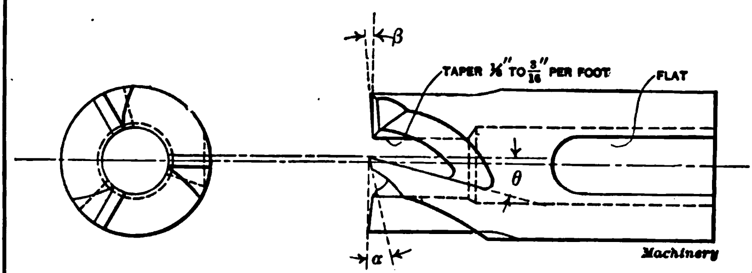
Fig. 24. Cutting-angles for Box Tool Cutters

smaller in diameter. The box-tool cutter is brought in contact with the work by means of the handle K_3, Fig. 21, on the No. 00 machine, which is inserted in the lead lever O_4, Fig. 13, and by the lever R_8 on the Nos. 0 and 2 machines, as shown in Fig. 33. These levers should always be removed before engaging the driving clutch. For additional information regarding the application of external tools to the work, see MACHINERY'S Reference Book No. 102, "Automatic Screw Machine Practice—External Cutting Tools."

Cutting-angles for Box-tool Cutters

The cutting angle on a box-tool cutter depends largely on the method used in holding it, and on how it is applied to the work. In Fig. 24 a few methods of the application of box-tool cutters to the work are shown, and the angles at which they should be ground for various materials. A box-tool cutter, to give good results, should have sufficient clearance and rake so that it will remove the metal with the least possible resistance. Generally, in automatic screw machine work, the box-tool cutter is set radially to the work, for cutting brass, as shown at *A*. When held in this manner the cutting angles are approximately as given in the illustration. This type of tool is used particularly for roughing work. For finishing work on brass, the tool is set as indicated at *B*, and the cutting face is ground parallel for a short distance *f*, which for usual conditions equals one-fifth of the smallest diameter of the work being turned. For steel, the box-tool cutter should be set tangentially to the work, as shown at *C* and *D*.

TABLE II. CUTTING ANGLES FOR HOLLOW-MILLS



Angle	Material to be Cut		
	Brass Rod	Machine Steel	Tool Steel
	Cutting Angle in Degrees		
α	8	15	10
β	8	5	3
θ	0	15	10

The angles on the box-tool cutter shown at *C* for cutting various materials is as follows:

Cutting-angles for Tool Steel
b = 8 deg.
c = 8 to 10 deg.
d = 72 to 74 deg.
e = 8 deg.

Cutting-angles for Machine Steel
c = 8 to 10 deg.
e = 10 deg.
d = 70 to 72 deg.
b = 10 deg.

The method of grinding the tools shown at *C* is commonly used for roughing purposes on steel, but will not produce an absolutely square shoulder on the work. For finishing cuts, the box-tool cutter is ground as shown at *D*.

The cutting angles for this type of tool are as follows:

Cutting-angles for Tool Steel
m = 8 to 10 deg.
g = 8 to 10 deg.
h = 72 to 74 deg.

Cutting- angles for Machine Steel
m = 10 to 12 deg.
g = 15 to 18 deg.
h = 60 to 65 deg.

While the cutting face on the tool shown at *D* is straight, it is usually advisable, especially when cutting machine steel and Norway iron to give it more "lip," and is indicated by the dotted line *i*. This produces a curling chip, and is conducive to better and more efficient cutting. It is not advisable in most cases to make the box-tool cutters for finishing from high-speed steel for cutting steel and Norway iron, if an exceptionally good finish is desired.

At *D* in Fig. 24 is shown the method used in adjusting the tangent cutter. The face of the cutter should be set at a distance *j* back from the center of the work. This gives the tool more clearance on the periphery of the work. The distance *j* should equal (for Norway iron and machine steel) one-tenth of the smallest diameter of the work being turned. When the tangent cutter is adjusted in a vertical direction, it should also be moved back an amount equal to *k*, as shown by the dotted lines in the illustration, so that *k* bears the same relation to the larger diameter as *j* does to the smaller.

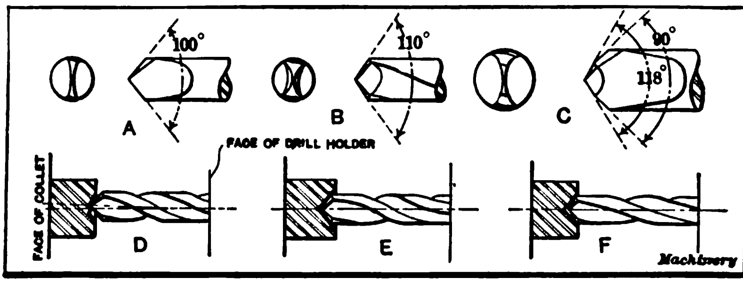


Fig. 25. Centering Tools—Incorrect and Correct Methods of Centering

Sometimes, when cutting machine steel, it is advisable to set the tool at an angle of from 1 to 2 degrees from the horizontal plane. This increases the clearance between the periphery of the work and the cutting face of the tool, and is accomplished by means of adjusting screws in the box-tool.

Cutting-angles for Hollow-mills

The illustration accompanying Table II shows a type of hollow-mill which is used on the automatic screw machine in cases where it is necessary to remove a large amount of material. The cutting angles for the lips of the hollow-mill are given in this table for various materials. Unless the operator has equipment sufficiently accurate to grind hollow-mills, he should not attempt to do so, as unsatisfactory results will be obtained if all the prongs or teeth do not do their share of the cutting. Preferably hollow-mills should be sharpened in the tool-room on an ordinary cutter grinder.

Setting Centering Tools and Drills

When the drill used is less than 1/8 inch in diameter, and is to pass entirely through the work, a centering or spotting drill should always be used. The centering tool should be ground and set so that it will not leave a teat in the work. It also should have an included angle less than that used on the drill. In Fig. 25, three types of centering tools are shown at *A*, *B* and *C*. The tool shown at *A* is used principally for brass work, while that shown at *B* is used for steel work, and is made similar to an ordinary twist drill. The tool shown at *C* is used when a large center is to be "spotted" in steel.

At *D* is shown the effect of using a centering tool with an included angle greater than that used on the drill, and also by having it set so that it leaves a teat in the hole. It is evident that when the drill is projecting out of the holder for a considerable distance (because it is to pass entirely through the work) it will not enter concentrically, but

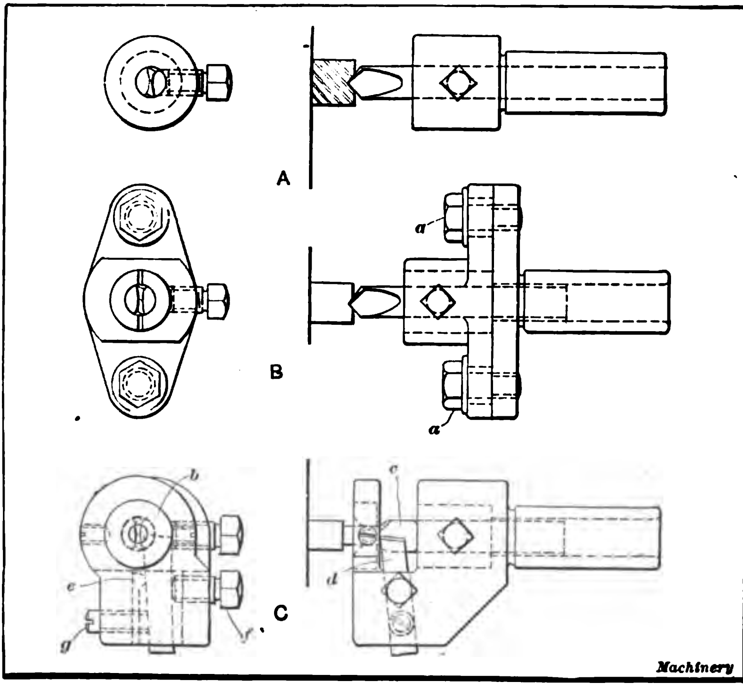


Fig. 26. Various Types of Centering Tool Holders

will be deflected by the teat. If the centering tool is made with an included angle less than that used on the drill, the result will be as shown at *F*, even if a teat has been left in the hole. Here the drill is well supported before its point would touch the teat; hence it would not be deflected. At *E* is shown the position that a drill should take in a correctly centered hole.

Holders for centering tools are illustrated at *A*, *B* and *C* in Fig. 26. The type of holder shown at *A* is frequently used, but is not recommended, owing to the difficulty of setting the centering tool concentric with the work. Preferably the floating holder shown at *B* should be used, as the centering tool can then be set concentric, after which the screws *a* are tightened. The holder shown at *C* is used when the work projects to a considerable distance out of the collet, and the center is to be concentric with the part already turned. This holder carries a bushing *b*, held by a screw in the front part of the holder, a centering tool *c*, and facing tool *d*. The centering tool *c* is retained in a bushing by a set-screw, while the facing tool *d* is held down on block *e* by another set-screw. The headless screw *g* is used for adjusting.

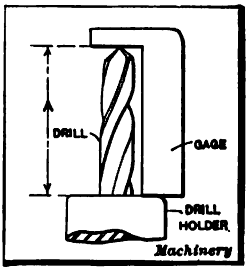


Fig. 27. Gage for setting a Drill

To set the centering tool *B*, the holder carrying it is placed in the turret, the latter swung down, the spindle stopped, and the centering tool brought in contact with the work. The screws *a* are then loosened, the tool set concentrically, and the screws tightened. The lead cam is then rotated by handwheel V_8, Fig. 29, until the roll rises up onto the starting point of the lobe for feeding the centering tool into the work. The holder is tapped back into the turret so that the point of the tool just clears the end of the work; then the holder is clamped in the turret. If upon trial it is found that the centering tool does not project in to the required distance, it is a simple matter to bring it out.

Before setting the drill, see that it is ground correctly for the material upon which it is to work, that is, to the desired angle and lip clearance. For brass work, the lip should be almost ground off, especially when a broken chip and not a curling one is desired. For steel the drill should be given a fairly good lip. The procedure given for

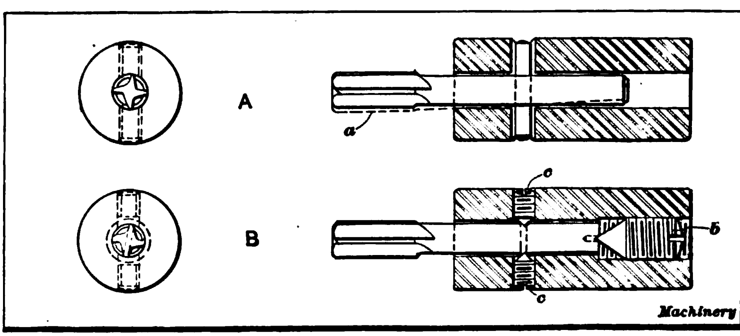


Fig. 28. Floating Reamer Holders

setting the centering tool also applies to setting a drill. For information regarding drill grinding see Chapter IV of Machinery's Reference Book No. 94, "Operation of Machine Tools—Drilling Machines."

Prepare in time for the failure of a drill, as considerable time is lost in regrinding and resetting. A good idea is to have a number of drills lying on the tray already ground, and to use a gage for setting the drills as shown in Fig. 27. This gage is made from sheet steel about 1/16 inch thick. The dimension *A* is made equal to the distance that the drill is required to extend out of the holder. If there is more than one drill in the turret, which would be necessary when a deep hole is to be produced, a gage of this description should be made for setting each drill. These gages should be marked according to the position that the drill for which they are used takes in relation to the other drills; that is, "1st," "2nd," etc., and kept in the same box as the other tools used on the job. If this precaution is taken, no time will be lost in setting a drill, because the machine need not be stopped. The clamping screw holding the drill can be released, the drill pulled out and a fresh one inserted while the machine is running.

Setting Counterbores and Reamers

A counterbore provided with a leader should always be held in a floating holder. Before setting the counterbore, of course, the hole should be drilled; then the procedure for setting centering tools

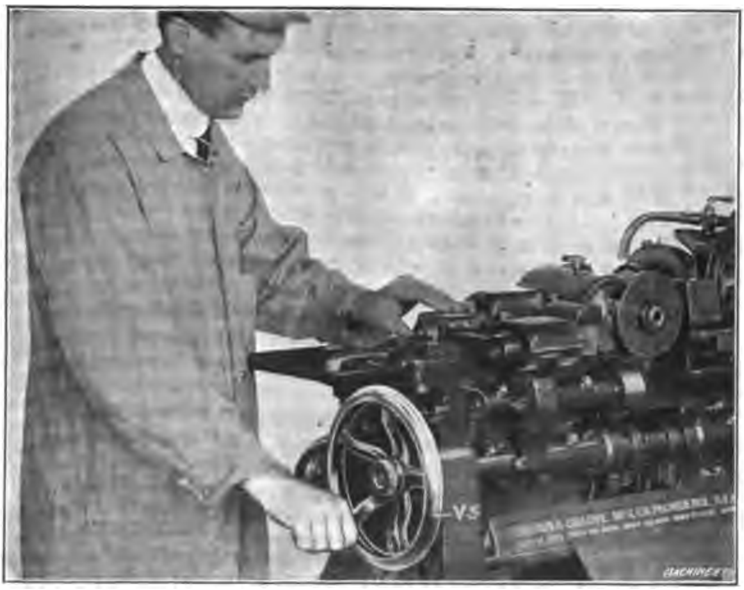


Fig. 29. Operator setting the Spindle Reversing Dogs for Threading

should be followed, except that the leader is inserted, bringing the face of the counterbore in contact with the end of the work. When the counterbore is not provided with a leader, a floating holder similar to that shown at *B* in Fig. 26 should be used.

Reamers which are to produce deep holes should be held in floating holders. Two types of floating holders are shown at *A* and *B* in Fig. 28. The one shown at *A*, however, is not recommended for automatic screw machine work, because the reamer drops down as shown at *a* if too much clearance is allowed between the hole in the holder and the reamer shank, thus preventing the reamer from centering easily into the work, and sometimes breaking it. The holder at *B* should be used in preference, because the reamer is guided by means of the screws *b* and *c*, and can be given the desired amount of "float" by screws *e*. When a reamer is only to project a short distance into the work, the holder shown at *B* in Fig. 26, can be used.

Setting Dies and Taps

Before a die or tap and its holder are placed in the turret, the dogs should be set in position to reverse the spindle in the correct relation to the threading lobe on the lead cam. The two parts of clutch *M* (see Figs. 1 and 6) should first be engaged, so that the shaft carrying the disk on which the dogs are located will be rotated in step with the other driving mechanism of the machine. Then the shifter is pulled over and the main spindle started. The lead-cam is now rotated by means

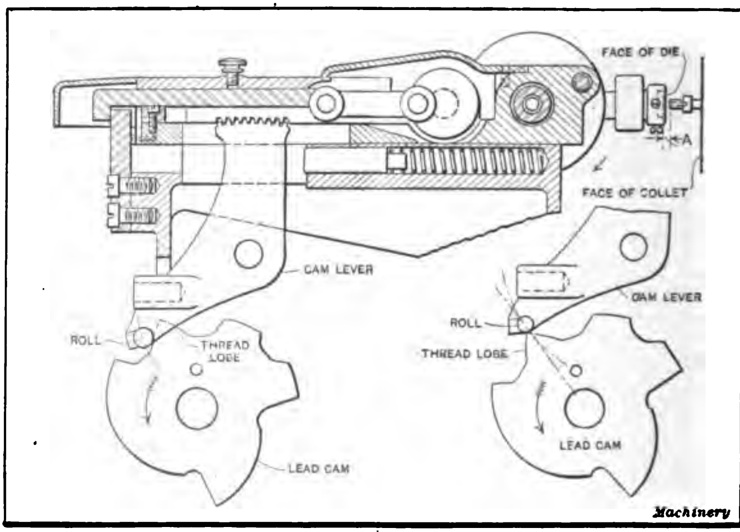


Fig. 30 Fig. 31

Showing the Position of the Roll on the Cam Lobe Relative to the Reversal of the Spindle

of hand-wheel V_5, Fig. 29, the operator also pressing his thumb against the turret slide and bearing on the turret base. While rotating the hand-wheel V_5, he watches to see when the spindle reverses; and by keeping his thumb in contact with the turret slide he can tell when the roll drops over the highest point of the lobe on the cam. When the spindle reverses at the same instant that the roll drops over the highest point of the lobe on the cam, the dog is set in the desired position. This is illustrated graphically, for setting a die, in Figs. 30 and 31. In Fig. 30 a button die is shown, held in a holder, in position ready to start on the work. The face of the die should be set the distance *A* from the end of the work. This distance varies from 1/16 to 3/16 inch, depending on the pitch of the thread and the length of the threaded portion. In Fig. 31 the cam roll is set just back of the highest point of the lobe; when the roll is at this point, the spindle should reverse.

After the first setting, if it is found that the die does not travel onto the work far enough, the holder is brought further out of the turret. The same procedure is followed in setting a tap, except that it should be set more carefully, only going into the work a slight distance when starting, and the holder moved out of the turret until the desired depth is reached. It is sometimes found necessary, after setting the tripping dogs, to adjust them slightly, especially when using the draw-out type of die or tap-holder. The turret should not be indexed until the die or tap is clear of the work.

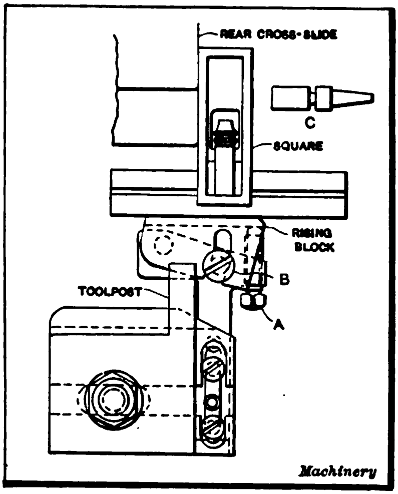


Fig. 32. Setting a Rising Block with a Square

Setting Swing Tools and Taper-turning Tools

Swing tools are used for both internal and external cutting, and are operated under three different conditions: first, the cutting tool is fed into the work from the cross-slide alone; second, the cutting tool is fed longitudinally by the turret; third, the cutting tool is fed inward by the cross-slide and longitudinally by the turret. For the first condition, the rising block need not be set in any particular relation to the axis of the spindle. When straight turning is to be produced under the second condition, the face of the rising block should be set parallel with the axis of the spindle. For the third condition, when the work is to be turned taper, the face of the rising block should be set at an angle with the axis of the spindle.

In Fig. 32 is shown a simple method of setting the face of the rising block parallel with the axis of the spindle. An ordinary adjustable square is held against the face of the rear cross-slide, and screw *A* is adjusted until the block is set correctly, after which screw *B* is tightened. This method can be used when it is not necessary to have the rising block set exactly parallel with the axis of the spindle.

A better and more accurate method is shown in Fig. 33. Here a Brown & Sharpe dial test indicator *B* is used. A split bushing is inserted in one of the holes in the turret, and a bent rod with the indicator is held in it. The finger of the indicator is brought to bear against the face of the rising block *C*, and the turret is traversed by handle R_5 on the No. 0 and 2 machines, and by using handle K_2, Fig. 21, on the No. 00 machine, inserting it in the turret traversing lever. While the turret is being traversed back and forth, the movement of the needle on the dial is noted, and the screw *A* adjusted until no movement is transmitted to the needle.

The setting of the rising block for operating a taper turning tool or a swing tool for taper turning is generally accomplished by the cut and try method, the first time the tools are set up. Most operators, when setting up a job for the second time, use what is called a "set piece" to set the tools by. This is a piece of work which has been made correctly to size, but which is not entirely cut off, as shown at *C* in Fig. 32. It is gripped in the collet, and the turning tool as well as the circular form and cut-off tools are set to it.

Setting Shaving Tools

There are two distinct types of shaving tools employed on the automatic screw machines, each type requiring the use of a different holder. Fig. 34 shows a shaving tool holder and shaving tool which

Fig. 33. Setting the Rising Block with the Aid of a Brown & Sharpe Dial Test Indicator

is used without a support for the work. This type of tool is used when the work is large enough in diameter to withstand the cutting pressure. The angles on the shaving tools shown to the right of the illustration for the different materials are as follows:

Material	Cutting-angle in Degrees
Brass rod	$A = 20$, $B = 30$, $C = 10$.
Machine steel	$A = 30$, $B = 40$, $C = 15$.
Tool steel	$A = 40$, $B = 50$, $C = 15$.

These angles need only be approximated, but the table gives a fair idea of preferable angles to which a shaving tool should be ground for shaving long work. Another type of shaving tool-holder and shaving tool is shown in Fig. 35. This type is used principally on steel work which is long in proportion to the diameter. It consists of a shaving tool *A* and support *B*. The support *B* is made an exact duplicate of the shaving tool *A*, except that it is not backed off for cutting, and is slightly rounded on the front end. It should always be set a slight amount back of the cutting edge of the shaving tool. At *C* and *D* is shown the way in which these shaving tools should be made. At *C* the tool is shown machined and ready for hardening, and at *D* the front part, shown partially separated at *C*, is removed and the tool ground ready for work. The cutting angles for this tool are as follows:

Material	Cutting-angle in Degrees
Brass rod	$a = 10$, $b = 10$.
Machine steel	$a = 15$, $b = 15$.
Tool steel	$a = 20$, $b = 15$.

Setting the Belt-shifting Attachment

The belt shifting attachment on the Nos. 0 and 2 machines, which is used for changing the spindle from a fast to a slow speed or *vice*

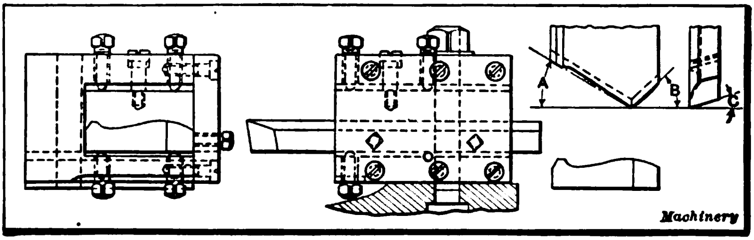


Fig. 34. Shaving Tool and Holder for Long Work

versa, is shown set up on a No. 0 machine in Fig. 36. This attachment is driven from the rear driving shaft through gears *A* and *B*, which rotate disk *C*, carrying rod *D*, the latter being connected eccentrically to the disk and operating the shifter on the countershafting, as illustrated in Figs. 42 and 43 and Figs. 44 and 45. Gear *A* has half as many teeth as gear *B*, so that for every revolution of the driving shaft the belt is shifted once. This attachment is operated by clutch *E*, which is brought into and out of engagement by a tripping lever

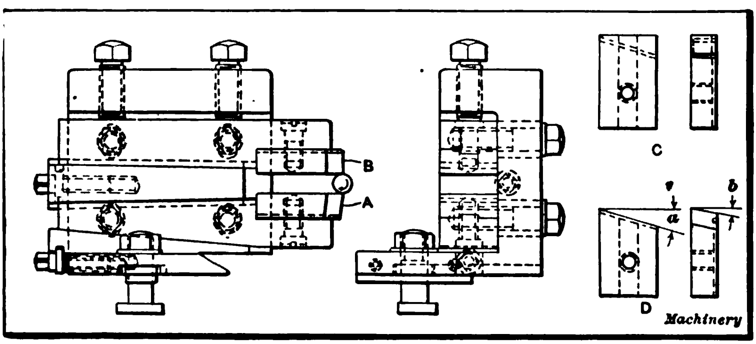


Fig. 35. Shaving Tool and Holder provided with a Support for the Work

and dog carried on the drum on the front camshaft. It is not advisable to shift the belt when a tap is in or a die on the work, but the spindle should rather be rotated at the lowest speed when the tap or die engages or disengages the work.

The No. 00 machine is not equipped with this belt shifting device, but for steel work a threading attachment as shown at *A* in Fig. 37 is used. This attachment is also supplied for the Nos. 0 and 2 machines, but its driving capacity is limited to the following sizes of taps or dies. For the No. 00, the maximum diameter of tap or die that can be driven by this device is 1/8, 40 threads; on the No. 0 machine 3/16, 32 threads; and on the No. 2 machine 1/4, 22 threads. When a larger diameter tap or die and a coarser thread than this is to be cut in the No. 00 machine, the two speeds of the spindle are employed, which, of course, necessitates the using of left-hand turning

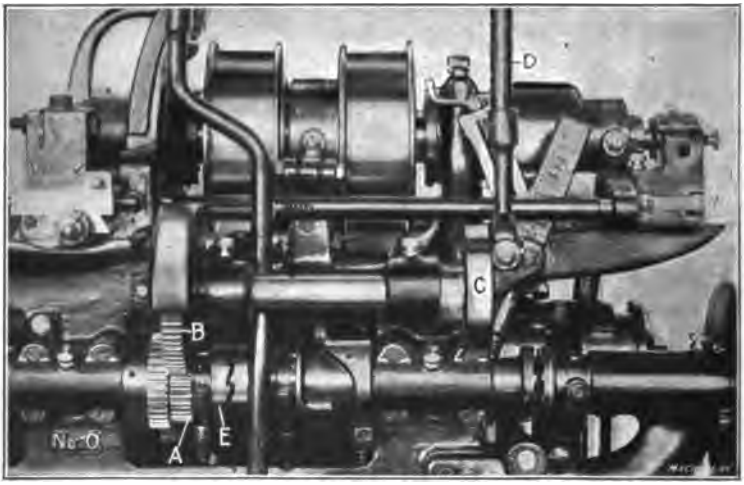


Fig. 36. The Belt-shifting Attachment used for Threading

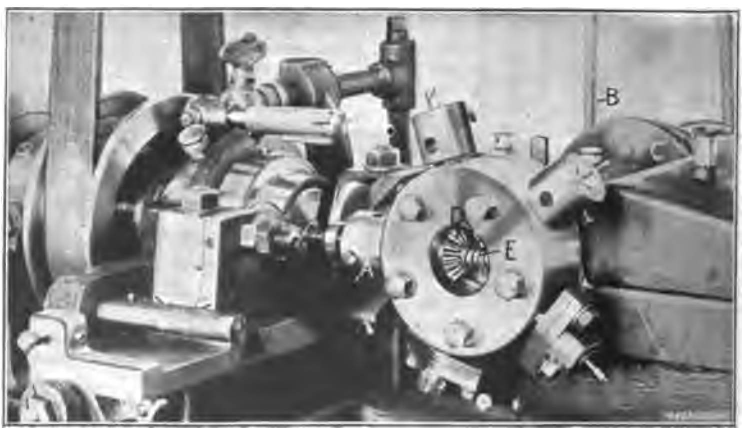


Fig. 37. Ratio Threading Attachment

tools in the turret. On the Nos. 0 and 2 machines, the belt shifting arrangement, previously described, should be used.

The ratio threading attachment shown at *A* in Fig. 37 is held in the turret and driven by a belt *B* from the countershaft, through pulley *C* and bevel gears *D*. The spring *E* acts in the same manner as the spring in the ordinary draw-out die or tap holder.

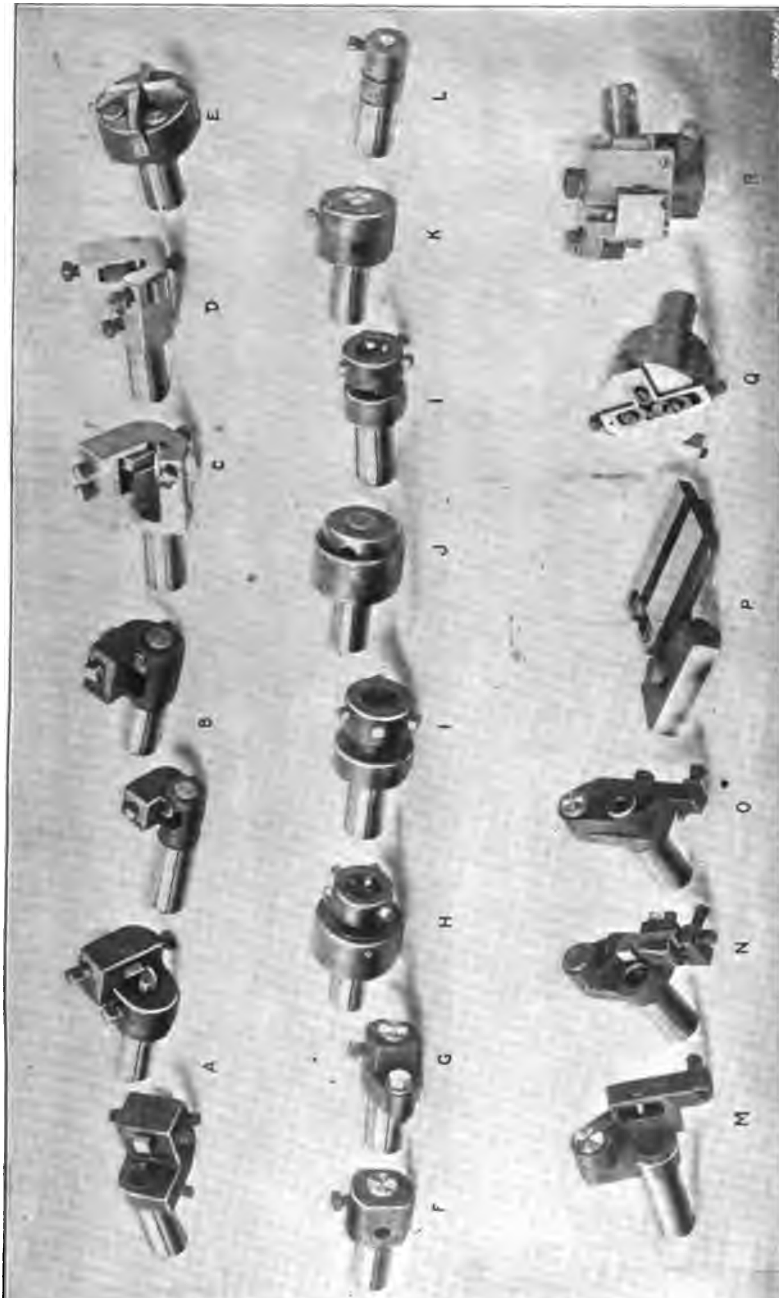


Fig. 38. Representative Group of Standard Tools for Brown & Sharpe Automatic Screw Machines

There are a number of special cross-slide and turret attachments which can be obtained for the Brown & Sharpe automatic screw machines for various operations. The method of setting these attachments, of course, is entirely governed by the work and the construction of the attachment itself. Figs. 38 and 39 show groups of standard tools which are used on the Brown & Sharpe automatic screw machines. The names of the tools shown in Fig. 38 are:

Knee tool, and centering and facing tools.	*A*,
Box-pointing tools.	*B*,
Box-tool (two cutters).	*C*,
Box-tool (one cutter).	*D*,
Adjustable hollow mill (finishing).	*E*,
Drill holder.	*F*,
Floating holder.	*G*,
Button die holder (releasing).	*H*,
Button die holder (draw-out).	*I*,
Tap holder (releasing).	*J*,
Tap holder (draw-out).	*K*,
Small tap holder (draw-out).	*L*,
Swing knurl or thread roll-holder.	*M*,
Swing turning tool.	*N*,
Recessing tool holder.	*O*,
Rising block with adjustable guide.	*P*,
Taper turning tool.	*Q*,
Angular cutting-off tool.	*R*,

The names of the standard tools shown in Fig. 39 are:

Turret knurl holder.	A_1,
Cross-slide knurl holder (side).	B_1,
Cross-slide knurl holder (top).	C_1,
Spring collet.	D_1,
Feed finger.	E_1,
Centering tool and turret back rests.	F_1,
Auxiliary work support.	G_1,
Double-throw cross-slide attachment.	H_1,
Slabbing attachment.	I_1,
Cross-slide cutting-off tool post (high).	J_1,
Cross-slide cutting-off tool post (low).	K_1,
Tool post for straight forming tools.	L_1,
Cross-slide drilling attachment.	M_1,
Brake for spindle.	N_1,

With the exception of the auxiliary work support shown at G_1 in Fig. 39, all of the standard tools and attachments illustrated are dealt within detail in MACHINERY'S Reference Books, Nos. 99 to 106, inclusive, on "Automatic Screw Machine Practice." The attachment G_1 is used for steadying the work and making it run "dead" true when it is desired to turn down a portion of the work perfectly concentric with the remainder of the piece, which is not to be operated on. This device is fastened over the hood enveloping the spring collet and ex-

Fig. 39. Representative Group of Standard Tools and Attachments for the Brown & Sharpe Automatic Screw Machines

tends in front of the latter. The bushing *a*, shown solid, is then drilled and reamed out from the turret, after which it is hardened, inserted again and lapped.

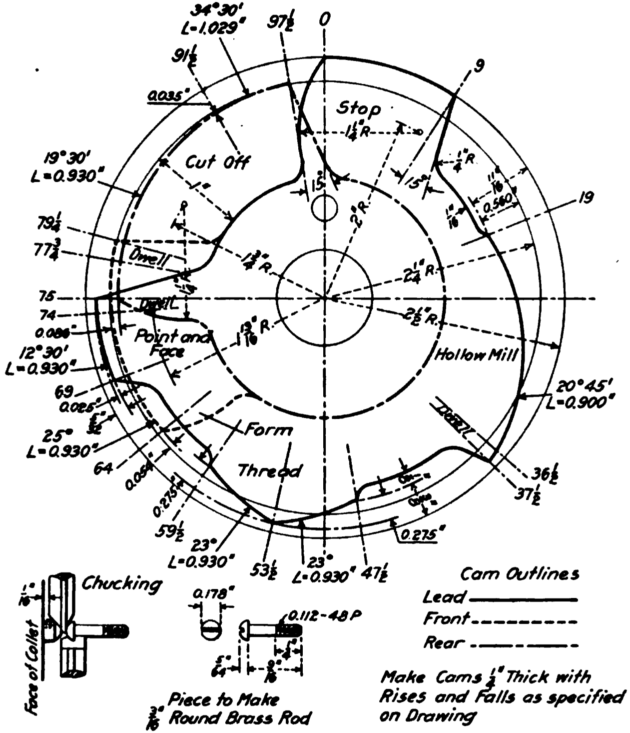
Instructions for Setting-up a Job on the Automatic Screw Machine

To illustrate the method followed in setting-up a job on the Brown & Sharp automatic screw machines, we will assume that a set of cams as illustrated in Fig. 40 have been designed and made for producing a button-head screw on the No. 00 machine. These came, together with the special and standard tools which are numbered, are turned over to the operator. He also receives a drawing similar to that shown in Fig. 40. We will assume that the machine has been set up for another piece of work, so that it is necessary to dismantle it. The first thing the operator does is to remove all the tools from the turret and the cams from the front and rear end shafts. He also removes the spring collet by removing the cap, and the feed tube by lifting the latch; then he unscrews the feed finger, which is threaded left-hand. The change gears are now removed, leaving the machine dismantled ready for the new job.

To proceed, the operator first inserts the spring collet, puts on the cap, and then screws the new feeding finger into the feed tube, and inserts the latter into the spindle. He then puts the stock into the feed tube, and places a suitable pipe in the stand in which the stock is to revolve. This pipe should be central with the feed tubes, thus reducing the wear in the hole of the latter. The belts are now placed on their proper cones, as illustrated in Fig. 41, to give the desired spindle speeds for the job. All belts should be without rivets, and preferably should be laced with wire, as this gives a smoother running belt. Now oil all the bearings with good machinery oil, and also the friction clutch. The latter should be oiled at least twice a day. Then see that the reservoir in the tank is filled with good lard oil, the latter being absolutely necessary if the machine is to be run economically and to its full capacity.

After the belts have been placed on the proper cones, the collet, feed finger, etc., having been inserted, the change gears should be put on as illustrated in Fig. 16. These gears are held by thumb nuts which should be tightened with the pin wrench supplied for that purpose. The handwheel V_8 is next put on for operating the machine by hand.

Before putting on the cams, set the collet so that it has the proper grip on the stock. The method for doing this has been described in Chapter I. Now open the collet again and push the stock out far enough to be faced off by the cut-off tool. Close the collet by means of the handle and start the spindle. Now set the cross-slide circular form and cut-off tools directly at the height of the center of the work, and in their proper relation to each other. Next put on the front and rear cross-slide cams; and if the job, as this one does, requires a threading operation, the shaft with the drum carrying the tripping dogs for reversing the spindle, should be connected with the front camshaft.



Name of Piece: Button Head Screw

Gears		Time to Make 1 Piece 6½ Seconds	Spindle Speeds	
No. 52	On Drive Shaft	Gross Production 10 hours = 5538	Forward	Backward
No. 34	On Worm Shaft	Made on No. 00 B.&S. Auto. Scr. Mach.	2400 R.P.M.	2400 R.P.M.
No.	On 1st Stud	Material Used: 3/16" Round Brass Rod	R.P.M.	R.P.M.
No.	On 2nd Stud	Remarks: Use 6 hole Turret	Surface Speeds	
		Machine, and Tool Numbers	For Stock	117.81 F.P.M.
		as specified	For Thread	70.37 F.P.M.
			For Drilling	F.P.M.

Revs.	Hunds.	Start	Finish	Rise	Feed	Operations
23.4	9	0	9			Feed stock to stop and chuck
26.0	10	9	19			Revolve Turret
48.1	18½	19	37½	0.560"	0.0123"	Turn (Hollow Mill) Dwell 0.10
26.0	10	37½	47½			Revolve Turret
15.6	6	47½	53½	0.275"	0.122"-48	Die on } Reverse Spindle
15.6	6	53½	59½	0.275"	0.122"-48	Die off }
11.7	4½	59½	64			Clearance and Revolve Turret
38.65	15½	64	79½	0.054"	0.00155"	Form (Circular Tool) Dwell 0.15
15.6	6	69	75	0.025"	0.00192"	Point and Face Dwell 0.10
42.9	16½	75	91½	0.051"	0.00119"	Start Cut-off } Circular Tool
15.6	6	91½	97½	0.035"	0.00224"	Finish Cut-off }
6.5	2½	97½	100			Clearance

Special Tools	Tool No.	Dwg. No.	Standard Tools	Tool No.	Dwg. No.
Circular Form Tool	1678	L.7218	Stop	1368	T.S. 50
Circular Cut-off Tool	1679	L.7218	Floating Holder	1472	L.7685
Cams. Lead, Front, Rear	1680	L.7219	Hollow Mill	1763	T.S.100
Slotting Bushing	1681	L.6301	Button Die Holder	1875	L.7860
			0.112-48P Button Die	1673	T.S.150
			Pointing and Facing Tool	1520	L.7679

Remarks:

Fig. 40. Setting-up Chart for making a Button Head Screw on the No. 00 Brown & Sharpe Automatic Screw Machine

Next, set in the cross-slides by adjusting nuts A_3, Fig. 21, so that the circular form and cut-off tools travel in to the required distance. Place the hollow-mill in the turret, set it correctly, and also set the tripping dog so as to revolve the turret. Put the box-tool in the turret, set it, and also set the dog for indexing the turret. The die is then set as previouslyy described, and all the tripping dogs are set to index the turret completely around. . After all the tools have been set in their proper relation, make a piece, except threading, by turning the handwheel; at the threading operations drop down the die so that it does not pass onto the work. Gage the piece thus made; if it is correctly to size, and the tripping dogs for reversing the spindle and the die have been properly set, throw the feed clutch by means of handle *P*, Fig. 1, and start the machine.

When the bar is all used up, the chuck should be opened by tripping the lever, and the turret revolved by withdrawing the locking pin, so that it will not interfere with the short piece left in the chuck, which should be driven out for the insertion of a new bar. To insert the new bar, turn the handwheel sufficiently to bring the shoulder of the feed tube against the end of the spindle, and push out the bar just far enough so that its front end can be faced off with the cut-off tool. Now turn the turret back into position and start the machine by throwing in the clutch. The ends of the rods of stock should be ground to remove the burrs, thus insuring their entering and feeding freely and evenly through the feed tube.

The work should always be tested after the insertion of a new bar of stock. If the parts made are short or thin, the tools will become dull much more quickly; consequently the work should be tested more frequently in that case, so that any errors may be corrected as soon as possible.

CHAPTER III

COUNTERSHAFT ARRANGEMENT AND SPINDLE SPEEDS

The arrangement of the spindle speeds for the No. 00 automatic screw machine, as well as the spindle speeds of the No. 00 automatic turret forming and the No. 00 automatic cutting-off machines, are shown in Fig. 41. The spindle speeds obtainable on the No. 0 automatic screw machine, as well as the arrangement of the countershaft with respect to the main shaft, is shown in Figs. 42 and 43. The spindle speeds obtainable on the No. 0 automatic turret forming machine and on the No. 0 automatic cutting-off machine are also given. The arrangement of the spindle speeds for the No. 2 automatic screw machines are shown in Figs. 44 and 45, where the spindls speeds for the No. 2 automatic turret forming and automatic cutting-off machines are also given.

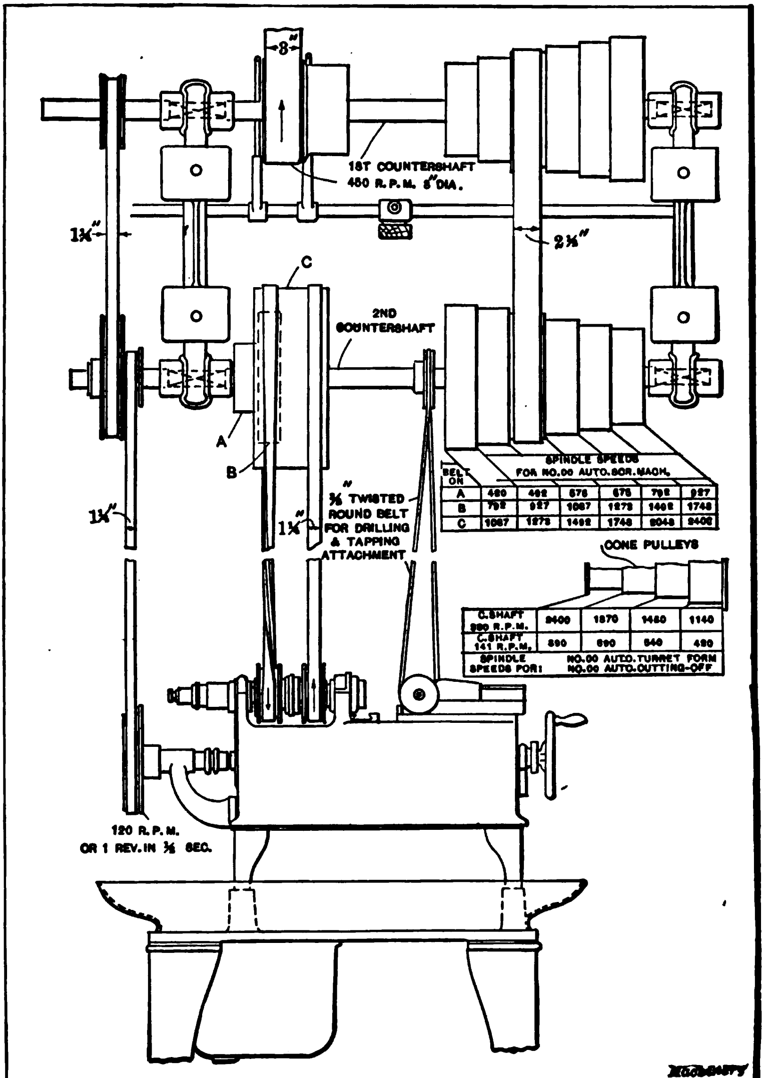
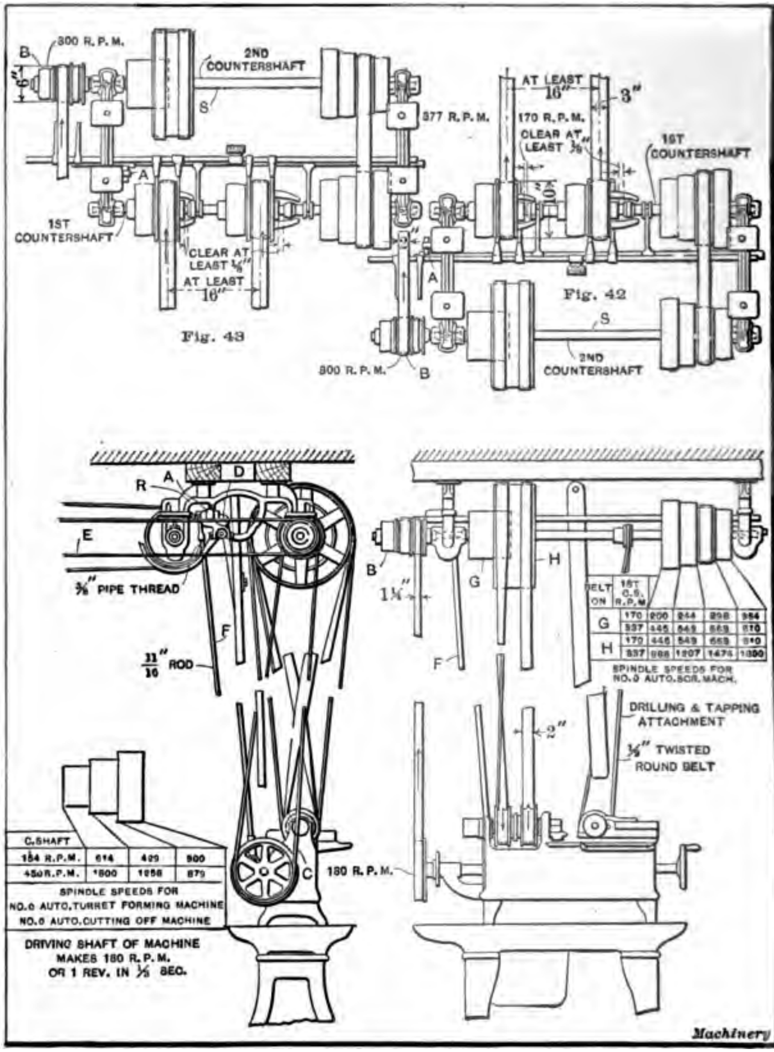


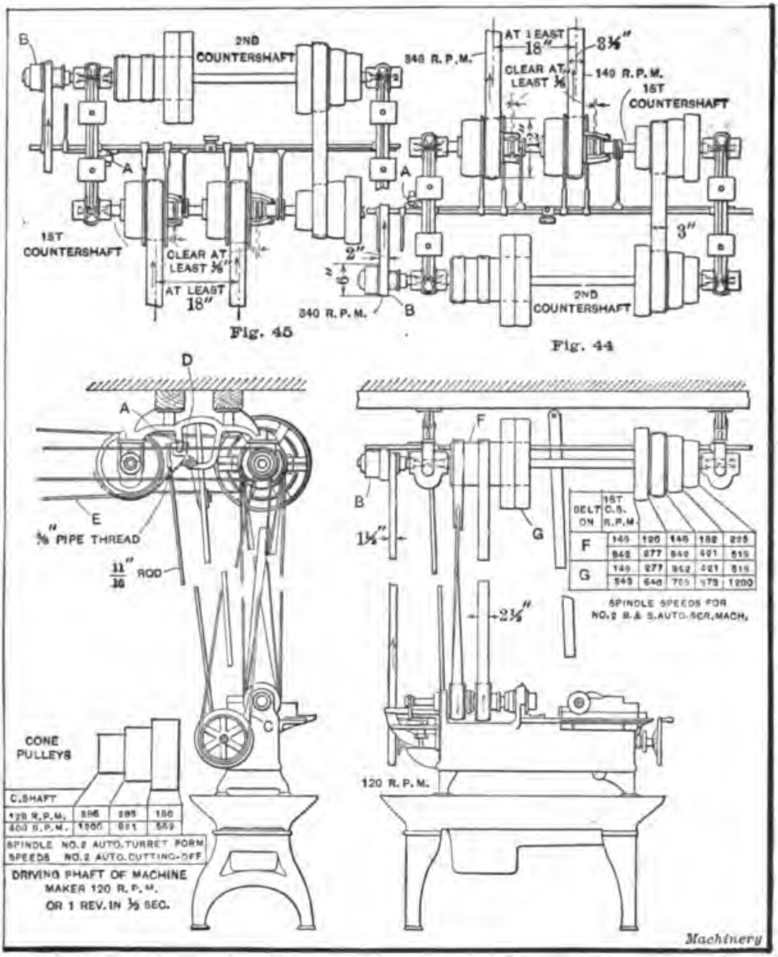
Fig. 41. Arrangement of Spindle Speeds for No. 00 Brown & Sharpe Automatic Screw Machines

The counter-shaft arrangement shown in Figs. 41 to 45 drives, both the main spindle and the rear driving shaft. The rear driving shaft is driven independently of the cone pulleys by a double loose pulley mounted on the end of the second countershaft. This pulley acts as an intermediate between the main line and the feed mechanism, driving the latter at a constant speed. The belts are all controlled by means of one shifter handle.



Figs. 42 and 43. Arrangement of Spindle Speeds for No. 0 Brown & Sharpe Automatic Screw Machines

For the No. 0 machine, the countershafting may be set up as in Fig. 42 or as in Fig. 43, to suit the location of the main line-shaft. In Fig. 42, *A* is on the outside of the hanger, and in Fig. 43, on the inside. The first countershaft is always nearest the main line-shaft, and the sides *R* of the hangers are always its support. The long shaft *S* with pulley *B* may be placed in either pair of boxes, so that belt *C* will clear the feed-slide of the machine. If belt *E* interferes with the shifter-rod at *D*, belts *E* and *C* may be crossed. The belts will gen-



Figs. 44 and 45. Arrangement of Spindle Speeds for No. 2 Brown & Sharpe Automatic Screw Machines

erally clear, as the main line-shaft is usually lower than the countershaft. Rod *F* can be nearly vertical when the drilling attachment is not used.

For the No. 2 machine, the countershaft can be set up as in Fig. 44, or as in Fig. 45, to suit the location of the main line-shaft. In Fig. 44, *A* is on the outside of the hanger, and in Fig. 45, on the inside. The long shaft with pulley *B* can be placed in either pair of boxes, so that belt *C* will clear the feed-slide of the machine. If belt *E* should interfere with the shifter-rod at *D*, belts *E* and *C* may be crossed. Belt *E* will generally clear, as the main line-shaft is, as a rule, lower than the countershaft.

TABLE II. SURFACE SPEED OF STOCK

Diameter of Stock	Decimal Equivalent	Revolutions Per Minute															
		2400	2048	1800	1748	1492	1474	1273	1200	1087	988	978	927	810	792	675	640
		Surface Speed in Feet per Minute															
1/16	0.062	39.3	33.5	29.4	28.6	24.4	24.1	20.8	19.6	17.9	16.2	15.9	15.2	13.2	12.9	11.0	10.5
5/64	0.078	49.1	41.9	36.8	35.7	30.5	30.1	26.0	24.5	22.2	20.2	19.9	18.9	16.9	16.2	13.8	13.1
3/32	0.094	61.4	52.4	46.1	44.7	38.1	37.7	32.6	30.7	27.8	24.2	24.9	22.7	20.7	20.3	16.6	16.4
7/64	0.109	68.5	58.4	51.8	49.9	42.6	42.0	36.3	34.2	31.0	28.3	27.8	26.5	23.1	22.6	19.3	18.3
1/8	0.125	78.5	67.0	58.9	57.2	48.8	48.2	41.6	39.3	35.6	32.3	31.8	30.3	26.5	25.9	22.1	20.9
9/64	0.141	88.6	75.6	66.4	64.5	55.1	54.4	47.0	44.3	40.1	36.4	35.9	34.1	29.9	29.2	24.9	23.6
5/32	0.156	98.0	83.6	73.5	71.4	60.9	60.2	52.0	49.0	44.4	40.4	39.7	37.9	33.1	32.4	27.6	26.1
11/64	0.172	107.9	92.1	81.0	78.6	67.1	66.3	57.3	54.0	48.9	44.4	43.8	41.7	36.4	35.6	30.4	28.8
3/16	0.187	117.8	100.5	88.8	85.8	73.2	72.3	62.5	58.9	53.3	48.5	47.8	45.5	39.8	38.9	33.1	31.4
13/64	0.203	127.6	108.9	95.7	93.0	79.3	78.4	67.7	63.8	57.8	52.5	51.7	49.3	43.1	42.1	35.9	34.0
7/32	0.219	137.6	117.3	103.1	100.1	85.4	84.4	72.9	68.7	62.2	56.6	55.7	53.1	46.4	45.3	38.6	36.6
15/64	0.234	147.3	125.7	110.4	107.2	91.5	90.4	78.1	73.6	66.7	60.6	59.7	56.9	49.7	48.6	41.4	39.3
1/4	0.250	157.1	134.0	117.8	114.4	97.6	96.5	83.3	78.5	71.1	64.7	63.7	60.7	53.0	51.8	44.2	41.9
9/32	0.281	176.7	150.8	132.5	128.7	109.8	108.5	93.7	88.3	80.0	72.7	71.6	68.2	59.7	58.2	49.7	47.1
5/16	0.312	196.3	167.5	147.3	143.0	122.0	120.6	104.1	98.2	88.9	80.8	79.6	75.8	66.3	64.7	55.2	52.4
11/32	0.344	215.9	184.3	161.9	157.3	134.2	132.6	114.6	107.9	97.8	88.9	87.6	83.4	73.0	71.2	60.7	57.6
3/8	0.375	235.6	201.0	176.7	171.6	146.4	144.7	125.0	117.8	106.7	97.0	95.5	91.0	79.6	77.6	66.3	62.9
13/32	0.406	255.2	217.8	191.4	185.9	158.5	156.8	135.4	127.6	115.6	105.1	103.5	98.6	86.3	84.1	71.8	68.1
7/16	0.437	274.9	234.5	206.2	200.2	170.7	168.8	145.8	137.4	124.5	113.2	111.4	106.2	92.9	90.6	77.3	73.3
15/32	0.469	294.5	251.3	220.9	214.5	183.0	180.9	156.2	147.3	133.4	121.2	119 4	113.8	99.6	97.0	82.8	78.5
1/2	0.500	314.2	268.1	235.6	228.8	195.1	192.9	166.6	157.1	142.3	129.3	127.4	121.3	106.2	103.5	88.3	83.8
17/32	0.531	333.8	284.8	250.3	243.1	207.3	205.0	177.0	166.9	151.2	137.4	135 8	128.9	112.9	109.9	93.9	89.0
9/16	0.562	353.4	301.6	265.1	257.4	219.5	217.1	187.5	176.7	160.1	145.5	143.3	136.5	119.5	116.4	99.4	94.2
19/32	0.594	373.1	318.3	279.8	271.7	231.7	229.1	197.9	186.5	168.9	153.6	151.2	144.1	126.2	122.9	104.9	99.5

TABLE III. SURFACE SPEED OF STOCK

Diameter of Stock	Decimal Equivalent	Revolutions per Minute															
		576	543	519	492	445	420	364	342	298	277	244	225	200	182	148	120
		Surface Feet in Inches per Minute															
9/32	0.281	42.6	40.0	38.2	36.2	32.7	31.7	26.8	25.2	21.9	20.4	18.0	16.9	14.7	13.4	10.8	8.8
5/16	0.312	47.1	44.4	42.4	40.2	36.4	34.4	29.8	28.0	24.9	22.7	20.1	18.4	16.4	14.5	12.1	9.8
11/32	0.344	51.8	48.9	46.7	44.3	40.0	37.8	32.7	30.8	26.8	24.9	21.9	20.2	18.0	16.4	13.3	10.8
3/8	0.375	56.5	53.3	50.9	48.3	43.8	41.2	35.7	33.6	29.3	27.2	23.9	22.1	19.6	17.9	14.5	11.8
13/32	0.406	61.2	57.7	55.2	52.3	47.3	44.7	38.7	36.4	31.7	29.5	25.9	23.9	21.3	19.4	15.7	12.8
7/16	0.437	66.0	62.2	59.4	56.4	51.0	48.1	42.6	39.2	34.1	31.7	27.9	25.8	23.0	20.8	16.9	13.7
15/32	0.469	70.7	66.6	63.7	60.4	54.6	51.5	44.6	42.0	36.6	34.0	29.9	27.6	24.5	22.3	18.6	14.7
1/2	0.500	75.4	71.1	67.9	64.4	58.2	55.0	47.6	44.8	39.0	36.3	31.9	29.5	26.2	23.8	19.4	15.7
17/32	0.531	80.1	75.5	72.2	68.4	61.9	58.4	50.6	47.6	41.4	38.5	33.9	31.3	27.8	25.3	20.6	16.7
9/16	0.562	84.8	80.0	76.4	72.5	65.5	61.8	53.6	50.4	43.9	40.8	35.9	33.1	29.5	26.8	21.8	17.7
19/32	0.594	89.5	84.4	80.7	76.5	69.2	65.3	56.6	53.2	46.3	43.1	37.9	35.0	31.1	28.3	23.0	18.6
5/8	0.625	94.2	88.8	84.9	80.5	72.8	68.7	59.5	55.9	48.7	45.3	39.9	36.8	32.7	29.8	24.2	19.6
21/32	0.656	98.9	93.3	89.2	84.5	76.4	72.1	62.5	58.7	51.2	47.6	41.9	38.7	34.4	31.3	25.4	20.6
11/16	0.687	103.7	97.7	93.4	88.5	80.1	75.6	65.5	61.5	53.6	49.9	43.9	40.5	36.0	32.8	26.6	21.6
23/32	0.719	108.4	102.1	97.6	92.6	83.7	79.0	68.5	64.3	56.1	52.1	45.9	42.3	37.6	34.2	27.8	22.6
3/4	0.750	113.1	106.6	101.9	96.6	87.3	82.4	71.4	67.1	58.5	54.4	48.0	44.2	39.3	35.7	29.0	23.6
25/32	0.781	117.8	111.0	106.1	100.6	91.0	85.9	74.4	69.9	60.9	56.7	50.0	46.0	40.9	37.2	30.3	24.5
13/16	0.812	122.5	115.5	110.4	104.6	94.6	89.3	77.4	72.7	63.4	58.9	52.0	47.9	42.5	38.7	31.5	25.5
27/32	0.844	127.2	119.9	114.6	108.6	98.3	92.7	80.4	75.5	65.8	61.2	54.0	49.7	44.2	40.2	32.7	26.5
7/8	0.875	131.9	124.3	118.8	112.7	101.9	96.2	83.3	78.3	68.2	63.5	56.0	51.6	45.8	41.7	33.9	27.5
29/32	0.906	136.6	128.8	123.1	116.7	105.5	99.6	86.3	81.1	70.7	65.8	58.0	53.4	47.5	43.2	35.1	28.5
15/16	0.937	141.3	133.2	127.3	120.7	109.2	103.0	89.3	83.9	73.1	68.0	60.0	55.2	49.1	44.7	36.3	29.4
31/32	0.969	146.0	137.6	131.6	124.7	112.8	106.5	92.3	86.7	75.5	70.3	62.0	57.1	50.8	46.2	37.5	30.4
1	1.000	150.7	142.1	135.8	128.7	116.4	109.9	95.2	89.5	78.0	72.6	64.0	58.9	52.4	47.7	38.7	31.4

Surface Speed of Stock

Tables II and III give surface speeds of stock varying in diameter from 1/64 to 1 inch. All the spindle speeds obtainable on the various sizes of automatic screw machines are included, except a few spindle speeds which are so near to those listed that the variation in the sur-

TABLE IV. PRINCIPAL DIMENSIONS OF AUTOMATIC SCREW MACHINES

No. of Machine	00	0	2
No. of changes of spindle speeds	12	12	12
Dia. of hole through largest feed finger	5/16"	1/2"	7/8"
Dia. of hole through feed tube	21/64"	17/32"	1 1/32"
Extreme length of feed	2"	3"	4"
Extreme length that can be turned	1 1/4"	1 3/4"	2 1/2"
No. of holes in turret	6	6	6
Dia. of holes in turret	5/8"	3/4"	1"
Dia. of turret	3 5/8"	4"	5"
Greatest length of tool that turret will swing	2 1/4"	3 1/4"	3 7/8"
Least distance bet. turret and collet face	1 5/8"	2 1/2"	2 1/2"
Greatest distance bet. turret and collet face	3"	4 1/2"	6 1/4"
Greatest dia. that turret will swing and clear turret slide	1 5/8"	2 5/8"	2 7/8"
Adjustment of turret	..	..	1"
Movement of cross-slides	1"	1 1/4"	1 3/4"
Distance from center of spindle to floor	46"	46"	46"
Floor space	22" x 40"	23" x 51"	26" x 60"

face speed of the stock would be very slight. For diameters and spindle speeds not listed in the table, it will be an easy matter to find the equivalent surface speed in feet per minute by simple proportion.

In Table IV are given the principal dimensions of the Brown & Sharpe automatic screw machines. The dimensions here given will be found useful both by the operator of the machine and the designer of cams and tools for automatic screw machine work.

No. 50. Principles and Practice of Assembling Machine Tools, Part I.

No. 51. Principles and Practice of Assembling Machine Tools, Part II.

No. 52. Advanced Shop Arithmetic for the Machinist.

No. 53. Use of Logarithms and Logarithmic Tables.

No. 54. Solution of Triangles, Part I.—Methods, Rules and Examples.

No. 55. Solution of Triangles, Part II.—Tables of Natural Functions.

No. 56. Ball Bearings.—Principles of Design and Construction.

No. 57. Metal Spinning.—Machines, Tools and Methods Used.

No. 58. Helical and Elliptic Springs.—Calculation and Design.

No. 59. Machines, Tools and Methods of Automobile Manufacture.

No. 60. Construction and Manufacture of Automobiles.

No. 61. Blacksmith Shop Practice.—Model Blacksmith Shop; Welding; Forging of Hooks and Chains; Miscellaneous.

No. 62. Hardness and Durability Testing of Metals.

No. 63. Heat Treatment of Steel.—Hardening, Tempering, Case-Hardening.

No. 64. Gage Making and Lapping.

No. 65. Formulas and Constants for Gas Engine Design.

No. 66. Heating and Ventilation of Shops and Offices.

No. 67. Boilers.

No. 68. Boiler Furnaces and Chimneys.

No. 69. Feed Water Appliances.

No. 70. Steam Engines.

No. 71. Steam Turbines.

No. 72. Pumps, Condensers, Steam and Water Piping.

No. 73. Principles and Applications of Electricity, Part I.—Static Electricity; Electrical Measurements; Batteries.

No. 74. Principles and Applications of Electricity, Part II.—Magnetism; Electro-Magnetism; Electro-Plating.

No. 75. Principles and Applications of Electricity, Part III.—Dynamos; Motors; Electric Railways.

No. 76. Principles and Applications of Electricity, Part IV.—Electric Lighting.

No. 77. Principles and Applications of Electricity, Part V.—Telegraph and Telephone.

No. 78. Principles and Applications of Electricity, Part VI.—Transmission of Power.

No. 79. Locomotive Building, Part I.—Main and Side Rods.

No. 80. Locomotive Building, Part II.—Wheels; Axles; Driving Boxes.

No. 81. Locomotive Building, Part III.—Cylinders and Frames.

No. 82. Locomotive Building, Part IV.—Valve Motion.

No. 83. Locomotive Building, Part V—Boiler Shop Practice.

No. 84. Locomotive Building, Part VI.—Erecting.

No. 85. Mechanical Drawing, Part I.—Instruments; Materials; Geometrical Problems.

No. 86. Mechanical Drawing, Part II.—Projection.

No. 87. Mechanical Drawing, Part III.—Machine Details.

No. 88. Mechanical Drawing, Part IV.—Machine Details.

No. 89. The Theory of Shrinkage and Forced Fits.

No. 90. Railway Repair Shop Practice.

No. 91. Operation of Machine Tools.—The Lathe, Part I.

No. 92. Operation of Machine Tools.—The Lathe, Part II.

No. 93. Operation of Machine Tools.—Planer, Shaper, Slotter.

No. 94. Operation of Machine Tools.—Drilling Machines.

No. 95. Operation of Machine Tools.—Boring Machines.

No. 96. Operation of Machine Tools.—Milling Machines, Part I.

No. 97. Operation of Machine Tools.—Milling Machines, Part II.

No. 98. Operation of Machine Tools.—Grinding Machines.

No. 99. Automatic Screw Machine Practice, Part I.—Operation of the Brown & Sharpe Automatic Screw Machine.

No. 100. Automatic Screw Machine Practice, Part II.—Designing and Cutting Cams for the Automatic Screw Machine.

No. 101. Automatic Screw Machine Practice, Part III.—Circular Forming and Cut-off Tools.

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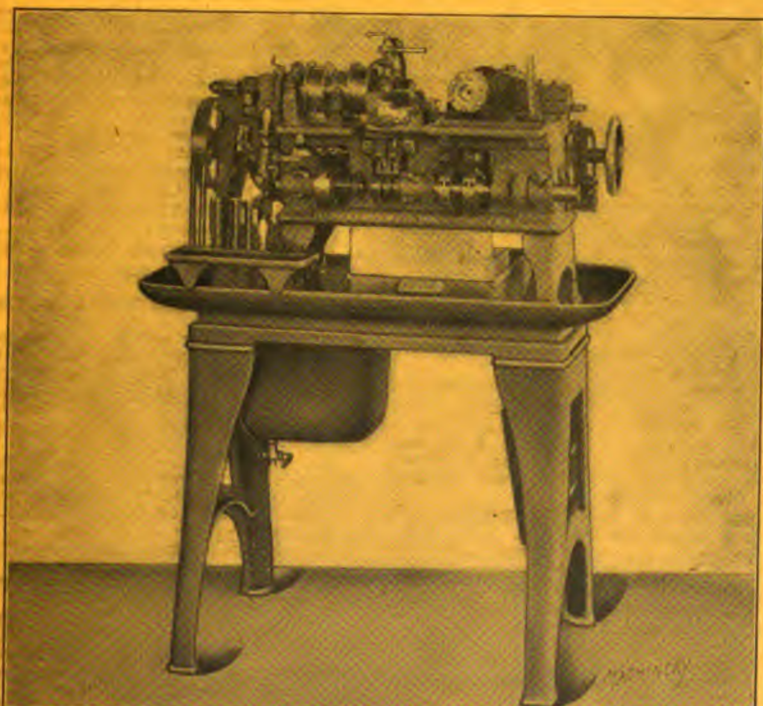
DESIGNING CAMS FOR THE BROWN & SHARPE AUTOMATIC SCREW MACHINES

BY DOUGLAS T. HAMILTON



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NUMBER 100

AUTOMATIC SCREW MACHINE PRACTICE

PART II

DESIGNING AND CUTTING CAMS FOR BROWN & SHARPE AUTOMATIC SCREW MACHINES

By DOUGLAS T. HAMILTON

CONTENTS

49-55 Lafayette Street, New York City

Automatic Screw Machine Practice for the Brown & Sharpe automatic screw machines is covered in eight Reference Books, Nos. 99 to 106, inclusive. Reference Book No. 99, "Operation of the Brown & Sharpe Automatic Screw Machines," deals with the construction of these machines and the setting-up of the tools. No. 100, "Designing and Cutting Cams for Automatic Screw Machines," gives detailed instruction on cam design, and describes a simplified method for milling cams. No. 101, "Circular Form and Cut-off Tools for the Automatic Screw Machine," deals with the general arrangement and the calculations of these tools, and describes the different methods employed in their making. No. 102, "External Cutting Tools for the Automatic Screw Machine," deals with the design and construction of box-tools, taper turning tools, hollow mills, and shaving tools. No. 103, "Internal Cutting Tools for the Automatic Screw Machine," deals with centering tools, cross-slide drilling attachments, counterbores, reamers, and recessing tools. No. 104, "Threading Operations on the Automatic Screw Machine," treats on cam design for threading operations, threading dies, taps and tap drills, die and tap holders, and thread rolling. No. 105, "Knurling Operations on the Automatic Screw Machine," describes the construction of knurling holders, and gives directions for the making of knurls and the design of tools and cams used in connection with knurling operations. No. 106, "Milling, Cross-drilling and Burring Operations on the Automatic Screw Machine," describes screw-slotting attachments, index drilling attachments, and burring attachments, giving directions for their use and for the design of cams for them.

CHAPTER I

DESIGNING SCREW MACHINE CAMS

The object of the present chapter is to give the average mechanic and draftsman a clear idea of the methods employed when designing special tools and cams for the Brown & Sharpe automatic screw machine. The first thing to be explained is the change-gear mechanism, as on this are based the fundamental principles used in the construction of the tables for laying out cams. Following this, the construction of the rise and drop on the cams, which is governed by the amount of clearance necessary for one tool to pass another will be treated. Then

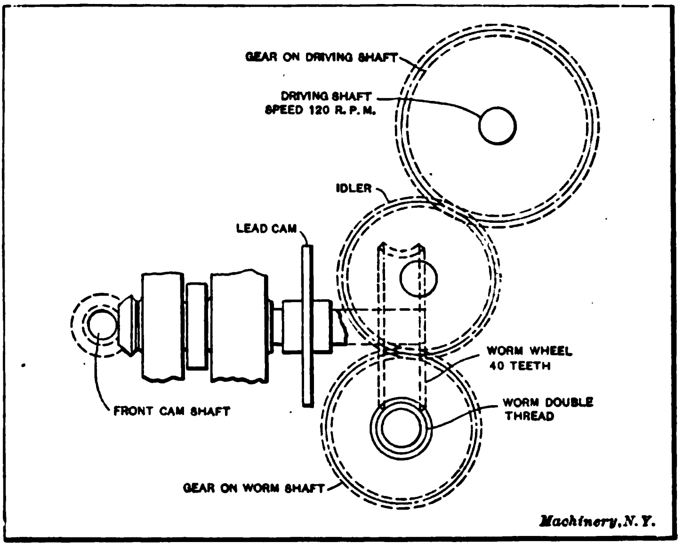


Fig. 1. Diagram of Gearing on the No. 00 Brown & Sharpe Automatic Screw Machine

a number of general points which should be of value especially to those who are not experienced in this class of work, are given.

Change-gear Mechanism

A system of simple gearing is used on the No. 00 Brown & Sharpe automatic screw machine, as clearly shown in Fig. 1. The worm has a double thread; hence for every revolution of the worm, the worm-wheel travels through a distance of two teeth. To find the change gears, assume that it is required to make one piece in 12 seconds. This necessitates that the worm-wheel make one revolution in 12 seconds. As there are 40 teeth in the worm-wheel and the worm has a double thread, the worm shaft will make 40 ÷ 2 or 20 revolutions in 12 seconds. The driving shaft runs constantly at 120 R. P. M. or 2 revolutions per second. Then the driving shaft will make 12 × 2 or 24 revolutions in 12 seconds. As, in this case, the driving shaft is required to run the faster, we will put the gear with the smaller number of teeth on that shaft. Now if we have gears having 20 and 24 teeth, respectively, they will "do the trick," but after referring to the gears supplied with the machine we find that a gear with 24 teeth is not available, so multiplying the number of teeth in each by two (which does not change the ratio) the gears will be: 40-tooth gear on driving shaft; 48-tooth gear on worm shaft.

On the No. 0 Brown & Sharpe automatic screw machine there is also one driving and one driven gear, but on this machine the gear

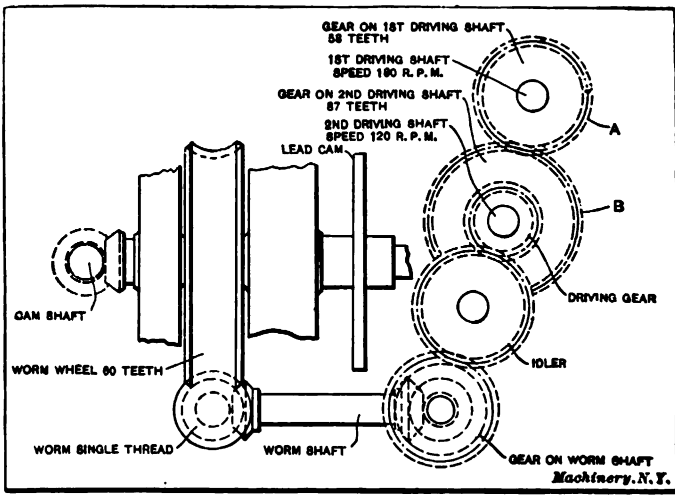


Fig. 2. Diagram of Gearing on the No. 0 Brown & Sharpe Automatic Screw Machine

which is called the driver is placed on the second driving shaft as shown in Fig. 2. Then, before finding the change gears it is necessary to find the speed of the gear on this second driving shaft. The first driving shaft runs constantly at a speed of 180 R. P. M. Then the speed of the second driving shaft $= \dfrac{180 \times 58}{87} = 120$ R. P. M. To find the change gears, assume that it is required to make one piece in 36 seconds. (To obviate confusion, we will call the second driving shaft, which runs at 120 R. P. M., the main driving shaft). Since the cam shaft is to make one revolution in 36 seconds and as there are 60 teeth in the worm-wheel and the worm has a single thead, the worm shaft will make 60 revolutions in 36 seconds. The driving shaft which runs at 120 R. P. M., or two revolutions per second, will make 72 revolutions in 36 seconds. From this we see that the driving shaft is required to run the faster of the two, and, hence, the smaller gear will be put on this shaft. The gears to use could have 60 and 72 teeth, respectively; or, by dividing the number of teeth in each by two, we have 30 and 36 teeth, respectively.

The gears can also be found directly by the formula:

$$\frac{120 \times D}{W} = \frac{3600}{S} \qquad (1)$$

where D = number of teeth in gear on driving shaft,
W = number of teeth in gear on worm shaft,
S = time in seconds to make one piece.

Then, $\frac{120 \times D}{W} = \frac{3600}{36}$ or $120\ D = 100\ W$; $W = 1.2\ D$.

Let $D = 30$. Then $W = 30 \times 1.2 = 36$.

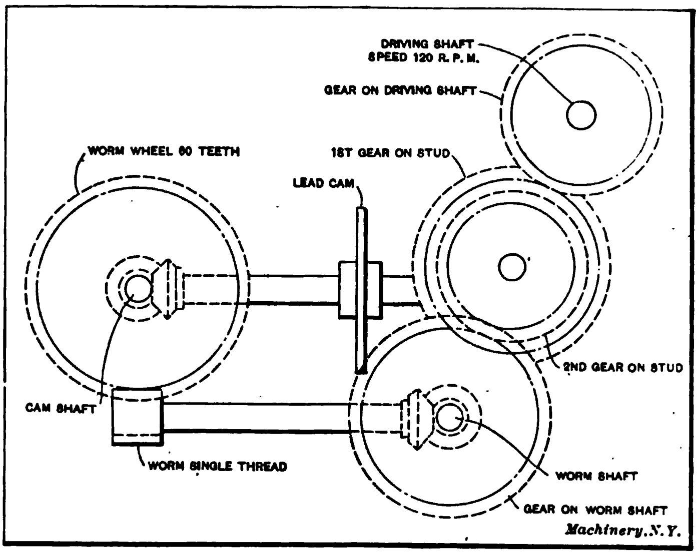


Fig. 3. Diagram of Gearing on the No. 2 Brown & Sharpe Automatic Screw Machine

A system of compound gearing is used on the No. 2 Brown & Sharpe automatic screw machine making it necessary to find the various gears by factoring. To explain the method of finding the gears we will take a practical example. Let it be required to find the gears to make one piece in 28 seconds. Referring to Fig. 3 we find that the speed of the driving shaft is 120 R. P. M. There are 60 teeth in the worm-wheel and the driving worm has a single thread. Thus the cam shaft must make one revolution in 28 seconds. The worm shaft will make 60 revolutions in 28 seconds as the worm has a single thread. The driving shaft makes 2 revolutions per second or 56 revolutions in 28 seconds. It will thus be seen that the worm shaft (or driven shaft) is required to run the faster of the two. Therefore, the product of the number of teeth in the driven gears should be smaller than the product of the number of teeth in the driving gears. The ratio of the gearing equals $\frac{60}{56}$. By dividing the numerator and denominator into factors and multiplying each pair of factors by the same number we find the gears:

$$\frac{60}{56}=\frac{10\times 6}{4\times 14}=\frac{(10\times 8)\times(6\times 6)}{(4\times 8)\times(14\times 6)}=\frac{80\times 36}{32\times 84}.$$

Then the gears are as follows:

80, gear on driving shaft; 36, second gear on stud; 32, first gear on stud; 84, gear on worm shaft.

How Tables for Laying out Cams are Constructed

Before a table can be constructed it is necessary to know the range of spindle speeds obtainable and also the speed of the driving shaft. Then the number of seconds to make one piece is placed in the first column of the table, and the number of revolutions to complete one piece is placed under the various spindle speeds as shown in Table I. The total number of revolutions to make one piece is found by the following formula: $r=\frac{R\times S}{60}$, where R = revolutions of spindle per minute (R. P. M.), S = time in seconds to make one piece, and r = total number of revolutions to make one piece. The total number of revolutions to complete one piece can also be found by adding together the number of revolutions required for each operation plus the revolutions required for clearance, feeding the stock, and revolving the turret. The number of seconds to make one piece is found by the following formula:

$$S=\frac{r\times 60}{R}. \qquad (2)$$

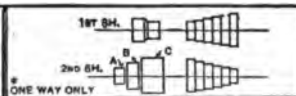
The time required to feed stock and revolve the turret on the various Brown & Sharpe automatic screw machines is as follows: No. 2 machine, 1 second; No. 0 machine, 2/3 seconds; No. 00 machine, 1/2 second. The revolutions of the spindle required to feed stock and revolve the turret on the various machines are found by the following formulas:

No. 2 machine, $r_1=R\div 60$ (3)
No. 0 machine, $r_1=R\div 90$ (4)
No. 00 machine, $r_1=R\div 120$ (5)

where r_1 = revolutions of spindle to feed stock and revolve turret,
R = speed of spindle in revolutions per minute.

Now, to convert the revolutions required to feed stock into hundredths of the cam surface, it is necessary to know the time in seconds required to make one piece and the speed of the spindle. For example, let it be required to construct a table for laying out cams

TABLE I. CHANGE GEARS AND DATA FOR LAYING OUT CAMS.
No. 00 BROWN & SHARPE AUTOMATIC SCREW MACHINE



SPINDLE SPEEDS			
BELT ON	*A	B	C
	420	792	1087
	492	927	1273
	576	1087	1492
	675	1273	1748
	792	1492	2048
	927	1748	2400

TIME IN SECONDS TO MAKE ONE PIECE.	GROSS PRODUCT IN TEN HOURS	NET PRODUCT IN TEN HOURS GROSS MINUS 10%	GEARS ON DRIVING SHAFT.	1ST GEAR ON STUD.	2ND GEAR ON STUD.	GEAR ON WORM SHAFT.	HUNDREDTHS OF CAM SURFACE TO FEED STOCK	SPINDLE SPEEDS: MIN. 420 / SEC. 7 / ½ SEC. 3.5	492 / 8.2 / 4.1	576 / 9.6 / 4.8	675 / 11.2 / 5.6	792 / 13.2 / 6.6	927 / 15.4 / 7.7	1087 / 18.1 / 9.1	1273 / 21.2 / 10.6	1492 / 24.8 / 12.4	1748 / 29.1 / 14.6	2048 / 34.1 / 17.1	2400 / 40. / 20.
								NUMBER OF REVOLUTIONS TO MAKE ONE PIECE.											
3	12000	10800	70			21	17	21	25	29	34	40	46	54	64	75	87	102	120
4	9000	8100	50			20	13	28	33	38	45	53	62	72	85	99	117	137	160
5	7200	6400	60			30	10	35	41	48	56	66	77	91	106	124	146	171	200
6	6000	5400	50			30	9	42	49	58	67	79	93	109	127	149	175	205	240
7	5142	4600	60			42	8	49	57	67	79	92	108	127	149	174	204	239	280
8	4500	4000	60			48	7	56	66	77	90	106	124	145	170	199	233	273	320
9	4000	3600	60			54	6	63	74	86	101	119	139	163	191	224	262	307	360
10	3600	3200	40			40	5	70	82	96	112	132	154	181	212	249	291	341	400
11	3272	2900	40			44	5	77	90	106	124	145	170	199	233	274	320	375	440
12	3000	2700	40			48	5	84	98	115	135	158	185	217	255	298	350	410	480
13	2769	2400	40			52	4	91	107	125	146	172	201	236	276	323	379	444	520
14	2571	2300	30			42	4	98	115	134	157	185	216	254	297	348	408	478	560
15	2400	2100	40			60	4	105	123	144	169	198	232	272	318	373	437	512	600
16	2250	2000	30			48	4	112	131	154	180	211	247	290	339	398	466	546	640
17	2117	1900	20			34	3	119	139	163	191	224	263	308	361	423	495	580	680
18	2000	1800	30			54	3	126	148	173	202	238	278	326	382	448	524	614	720
19	1894	1700	20			38	3	133	156	182	214	251	294	344	403	472	554	649	760
20	1800	1600	20			40	3	140	164	192	225	264	309	362	424	497	583	683	800
21	1714	1500	20			42	3	147	172	202	236	277	324	380	446	522	612	717	840
22	1636	1450	20			44	3	154	180	211	247	290	340	399	467	547	641	751	880
23	1565	1400	20			46	3	161	189	221	259	304	355	417	488	572	670	785	920
24	1500	1350	20			48	3	168	197	230	270	317	371	435	509	597	699	819	960
25	1440	1300	20			50	3	175	205	240	281	330	386	453	530	622	728	853	1000
26	1384	1250	20			52	3	182	213	250	292	343	402	471	552	647	757	887	1040
27	1333	1200	20			54	3	189	221	259	304	356	417	489	573	671	787	922	1080
28	1285	1150	20			56	3	196	230	269	315	370	433	507	594	696	816	956	1120
29	1241	1100	20			58	3	203	238	278	326	383	448	525	615	721	845	990	1160
30	1200	1050	20			60	3	210	246	288	337	396	463	543	636	746	874	1024	1200
32	1125	1000	30	30	48	60	3	224	262	307	360	422	494	580	679	796	932	1092	1280
34	1050	950	20	44	50	60	3	238	279	326	383	449	525	616	721	846	990	1161	1360
36	1000	900	30	30	54	60	3	252	295	346	405	475	556	652	764	895	1049	1229	1440
38	947	850	20	30	38	60	3	266	312	365	428	502	587	688	806	945	1107	1297	1520
40	900	800	20	30	40	60	3	280	328	384	450	528	618	724	849	995	1165	1365	1600
42	857	775	20	30	42	60	3	294	344	403	473	554	649	761	891	1045	1224	1434	1680
44	818	725	20	30	44	60	3	308	361	422	495	581	680	797	934	1094	1282	1502	1760
46	782	700	20	30	46	60	3	322	377	442	518	607	711	833	976	1144	1340	1570	1840
48	750	675	20	30	48	60	3	336	394	461	540	634	742	870	1018	1194	1398	1638	1920
50	720	650	20	30	50	60	3	350	410	480	563	660	773	906	1061	1243	1457	1707	2000
52	692	620	20	30	52	60	3	364	426	499	585	686	803	942	1103	1293	1515	1775	2080
54	666	600	20	30	54	60	3	378	443	518	608	713	834	978	1146	1343	1573	1843	2160
56	642	575	20	30	56	60	3	392	459	538	630	739	865	1015	1188	1393	1631	1911	2240
58	620	550	20	30	58	60	3	406	476	557	653	766	896	1051	1231	1442	1690	1980	2320
60	600	525	30	21	54	70	3	420	492	576	675	792	927	1087	1273	1492	1748	2048	2400
63	571	500	30	20	54	70	3	441	517	605	709	832	973	1141	1337	1567	1835	2150	2520
70	514	450	20	20	40	70	3	490	574	672	788	924	1082	1268	1485	1741	2039	2389	2800
77	467	420	20	20	44	70	3	539	631	739	866	1016	1190	1395	1634	1915	2243	2628	3080
84	428	385	20	20	48	70	3	588	689	806	945	1109	1298	1522	1782	2089	2447	2867	3360
91	395	355	20	20	52	70	3	637	746	871	1024	1201	1406	1649	1931	2263	2651	3106	3640

The number of hundredths given is always sufficient for feeding stock, but it is usually best to add 1-100 for revolving the Turret.

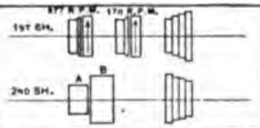
for the No. 2 Brown & Sharpe automatic screw machine. For a spindle speed of 182 R. P. M., as shown in Table III (assuming that it takes 10 seconds to make one piece), we find:

$$r = \frac{R \times S}{60} = \frac{182 \times 10}{60} = 30.3$$

or approximately 30 revolutions. We now put 30 revolutions in the

TABLE II. CHANGE GEARS AND DATA FOR LAYING OUT CAMS.
No. 0 BROWN & SHARPE AUTOMATIC SCREW MACHINE

FEED GEARS



SPINDLE SPEEDS								
BELT TO MACH. ON PULLEY	A				B			
FAST	445	543	663	810	988	1207	1474	1800
SLOW	200	244	298	364	445	543	663	810

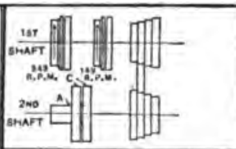
TIME IN SECONDS TO MAKE ONE PIECE	GROSS PRODUCT IN TEN HOURS	NET PRODUCT IN TEN HOURS GROSS MINUS 10%	GEAR ON A	1ST GEAR ON B	2ND GEAR ON B	GEAR ON C	HUNDREDTHS OF CAM SURFACE TO FEED STOCK	SPINDLE SPEEDS MIN.	200	244	298	364	445	543	663	810	988	1207	1474	1800
								SEC.	3.3	4.1	4.9	6.1	7.4	9.1	11.1	13.5	16.4	20.1	24.5	30
								⅔ SEC	2.2	2.7	3.3	4.	4.9	6.	7.3	9.	10.9	13.4	16.3	20.
								NUMBER OF REVOLUTIONS TO MAKE ONE PIECE												
5	7200	6400	58	86	120	20	14		17	20	25	30	37	45	55	67	82	101	123	150
6	6000	5400	58	86	120	24	12		20	24	30	36	44	54	66	81	99	121	147	180
7	5142	4600	58	86	120	28	10		23	28	35	42	52	63	77	94	115	141	172	210
8	4500	4000	58	86	120	32	9		27	33	40	49	59	72	88	108	132	161	197	240
9	4000	3600	58	86	80	24	8		30	37	45	55	67	81	99	121	148	181	221	270
10	3600	3200	58	86	120	40	7		33	41	50	61	74	90	110	135	165	201	246	300
11	3272	2900	58	86	60	22	7		37	45	55	67	82	100	122	148	181	221	270	330
12	3000	2700	58	86	60	24	6		40	49	60	73	89	109	133	162	198	241	295	360
13	2769	2400	34	110	120	24	6		43	53	65	79	96	118	144	175	214	262	319	390
14	2571	2300	58	86	60	28	5		47	57	70	85	104	127	155	189	231	282	344	420
15	2400	2100	58	86	60	30	5		50	61	74	91	111	136	166	202	247	302	368	450
16	2250	2000	58	86	60	32	5		53	65	79	97	119	145	177	216	263	322	393	480
17	2117	1900	58	86	60	34	4		57	69	84	103	126	154	188	229	280	342	418	510
18	2000	1800	58	86	40	24	4		60	73	89	109	133	163	199	243	296	362	442	540
19	1894	1700	58	86	60	38	4		63	77	94	115	141	172	210	256	313	382	467	570
20	1800	1600	58	86	60	40	4		67	81	99	121	148	181	221	270	329	402	491	600
22	1636	1450	58	86	30	22	4		73	89	109	133	163	199	243	297	362	443	540	660
24	1500	1350	58	86	40	32	3		80	98	119	146	178	217	265	324	395	483	590	720
26	1384	1250	34	110	60	24	3		87	106	129	158	193	235	287	351	428	523	639	780
28	1285	1150	58	86	30	28	3		93	114	139	170	208	253	309	378	461	563	688	840
30	1200	1050	58	86	60	60	3		100	122	149	182	222	271	331	405	494	603	737	900
32	1125	1000	58	86	30	32	3		107	130	159	194	237	290	354	432	527	644	786	960
34	1059	950	58	86	30	34	3		113	138	169	206	252	308	376	459	560	684	835	1020
36	1000	900	58	86	20	24	3		120	146	179	218	267	326	398	486	593	724	884	1080
38	947	850	58	86	30	38	3		127	155	189	231	282	344	420	513	626	764	934	1140
40	900	800	58	86	30	40	3		133	163	199	243	297	362	442	540	659	805	983	1200
44	818	725	34	110	32	22	3		147	179	218	267	326	398	486	594	725	885	1081	1320
48	750	675	58	86	20	32	3		160	195	238	291	356	434	530	648	790	966	1179	1440
52	692	620	34	110	30	24	3		173	211	258	315	385	471	575	702	856	1046	1277	1560
56	642	575	58	86	32	60	3		187	228	278	340	415	507	619	756	922	1127	1376	1680
60	600	525	58	86	30	60	3		200	244	298	364	445	543	663	810	988	1207	1474	1800
65	553	490	34	110	60	60	3		217	264	323	394	482	588	718	877	1070	1308	1597	1950
70	514	450	34	110	80	86	3		233	285	348	424	519	633	773	945	1153	1408	1720	2100
75	480	430	58	86	24	60	3		250	305	372	455	556	679	829	1012	1235	1509	1842	2250
80	450	400	58	86	30	80	3		267	325	397	485	593	724	884	1080	1317	1609	1965	2400
90	400	360	58	86	20	60	3		300	366	447	546	667	814	994	1215	1482	1810	2211	2700
100	360	320	58	86	24	80	3		333	407	497	607	742	905	1105	1350	1647	2012	2457	3000
110	327	290	58	86	30	110	3		367	447	546	667	816	995	1215	1485	1811	2213	2702	3300
120	300	270	58	86	20	80	3		400	488	596	728	890	1086	1326	1620	1976	2414	2948	3600
135	266	235	58	86	20	90	3		450	549	670	819	1001	1722	1492	1823	2223	2716	3316	4050
150	240	215	58	86	24	120	3		500	610	745	910	1112	1358	1658	2025	2470	3017	3685	4500
165	218	195	58	86	20	110	3		550	671	819	1001	1224	1493	1823	2228	2717	3319	4053	4950
180	200	180	58	86	20	120	3		600	732	894	1092	1335	1629	1989	2430	2964	3621	4422	5400
195	184	165	34	110	30	90	3		650	793	968	1183	1446	1765	2155	2633	3211	3923	4790	5850
210	171	150	34	110	28	90	3		700	854	1043	1274	1557	1901	2321	2835	3458	4224	5159	6300
225	160	140	34	110	26	90	3		750	915	1117	1365	1669	2036	2486	3038	3705	4526	5527	6750
240	150	135	34	110	24	90	3		800	976	1192	1456	1780	2172	2652	3240	3952	4828	5896	7200
270	133	120	34	110	22	90	3		900	1098	1341	1638	2002	2444	2984	3645	4446	5431	6633	8100
300	120	105	34	110	26	120	3		1000	1220	1490	1820	2225	2715	3315	4050	4940	6035	7370	9000
330	109	100	34	110	24	120	3		1100	1342	1639	2002	2447	2987	3647	4455	5434	6638	8107	9900
360	100	90	34	110	22	120	3		1200	1464	1788	2184	2670	3258	3978	4860	5928	7242	8844	10800
390	92	80	34	110	20	120	3		1300	1586	1937	2366	2892	3530	4310	5265	6422	7845	9581	11700

column under 182 as shown, and proceed to find the revolutions to feed stock, which according to Formula (3) equals:

$$R \div 60 = 182 \div 60 = 3.03 \quad \text{revolutions.}$$

Now, to find the hundredths of the cam surface to feed stock, divide the revolutions to feed stock by the total revolutions of the spindle required to make one piece. In this case we find that it requires $\frac{3.03}{30.3} = 0.099$ or approximately 10 hundredths. It is always advisable

TABLE III. CHANGE GEARS AND DATA FOR LAYING OUT CAMS. No. 2 BROWN & SHARPE AUTOMATIC SCREW MACHINE



SPINDLE SPEEDS	Belt to mach. on pulley A				Belt to mach. on pulley C			
FAST	277	342	421	519	640	789	973	1200
SLOW	120	148	182	225	277	342	421	519

Time in seconds to make one piece	Gross product in 10 hours	Net product in 10 hours gross minus 10%	Gear on driving shaft	1st gear on stud	2nd gear on stud	Gear on worm shaft	Hundredths of cam surface to feed stock	Spindle speeds pulley: Sec. 2 / Min. 120	Sec. 2.467 / Min. 148	Sec. 3.033 / Min. 182	Sec. 3.75 / Min. 225	Sec. 4.617 / Min. 277	Sec. 5.7 / Min. 342	Sec. 7.017 / Min. 421	Sec. 8.65 / Min. 519	Sec. 10.667 / Min. 640	Sec. 13.15 / Min. 789	Sec. 16.217 / Min. 973	Sec. 20 / Min. 1200
								Number of revolutions to make one piece											
6	6000	5400	80	32	80	40	17	12	15	18	22	28	34	42	52	64	79	97	120
7	5142	4600	80	32	72	42	15	14	17	21	26	32	40	49	61	75	92	114	140
8	4500	4000	80	32	72	48	13	16	20	24	30	37	46	56	69	85	105	130	160
9	4000	3600	80	32	72	54	12	18	22	27	34	42	51	63	78	96	118	146	180
10	3600	3200	80	32	72	60	10	20	25	30	37	46	57	70	86	107	131	162	200
11	3272	2900	80	32	84	77	10	22	27	33	41	51	63	77	95	117	145	178	220
12	3000	2700	80	32	60	60	9	24	30	36	45	55	68	84	104	128	158	195	240
13	2769	2400	80	32	72	78	9	26	32	39	49	60	74	91	112	139	171	211	260
14	2571	2300	80	32	60	70	8	28	35	42	52	65	80	98	121	149	184	227	280
16	2250	2000	80	32	60	80	7	32	39	49	60	74	91	112	138	171	210	259	320
18	2000	1800	80	32	48	72	6	36	44	55	67	84	103	126	156	192	237	292	360
20	1800	1600	80	32	48	80	5	40	49	61	75	92	114	140	173	213	263	324	400
22	1636	1450	80	32	42	77	5	44	54	67	82	102	125	154	190	235	289	357	440
24	1500	1350	80	32	40	80	5	48	59	73	90	111	137	168	208	256	116	389	480
26	1384	1250	80	32	36	78	4	52	64	79	97	120	148	182	225	277	342	422	520
28	1285	1150	80	32	36	84	4	56	69	85	105	129	160	196	242	299	368	454	560
30	1200	1050	60	60	80	80	4	60	74	91	112	138	171	210	259	320	394	486	600
35	1028	925	60	60	72	84	3	70	87	106	131	162	199	246	303	373	460	568	700
40	900	800	60	60	54	72	3	80	99	121	150	185	228	281	346	427	526	649	800
45	800	700	60	60	48	72	3	90	111	136	169	208	256	316	389	480	592	730	900
50	720	625	60	60	48	80	3	100	124	152	187	231	285	351	432	533	657	811	1000
55	654	575	60	60	42	77	3	110	136	167	206	254	313	386	476	587	723	892	1100
60	600	525	40	80	60	60	3	120	148	182	225	277	342	421	519	640	789	973	1200
70	514	450	40	80	60	70	3	140	173	212	262	323	399	491	605	747	920	1135	1400
80	450	400	40	80	54	72	3	160	198	243	300	369	456	561	692	853	1052	1297	1600
90	400	350	40	80	48	72	3	180	222	273	337	415	513	631	778	960	1183	1459	1800
100	360	300	40	80	48	80	3	200	247	303	375	462	570	702	865	1067	1315	1622	2000
110	327	290	40	80	42	77	3	220	272	334	412	508	627	772	951	1173	1446	1784	2200
120	300	270	40	80	40	80	3	240	296	364	450	554	684	842	1038	1280	1578	1946	2400
135	266	240	36	72	40	90	3	270	333	409	506	623	769	947	1168	1440	1775	2189	2700
150	240	210	36	80	40	90	3	300	370	455	562	692	855	1052	1297	1600	1972	2432	3000
165	218	190	36	77	35	90	3	330	407	500	619	752	940	1158	1427	1760	2170	2675	3300
180	200	180	36	84	35	90	3	360	444	546	675	831	1026	1263	1557	1920	2367	2919	3600
195	184	160	32	78	36	96	3	390	481	591	731	900	1112	1368	1687	2080	2564	3162	3900
210	171	150	24	80	40	84	3	420	518	637	788	970	1197	1474	1817	2240	2762	3406	4200
225	160	140	32	90	36	96	3	450	555	682	844	1039	1283	1579	1946	2400	2959	3649	4500
240	150	135	24	80	40	96	3	480	592	728	900	1108	1368	1684	2076	2560	3156	3892	4800
270	133	120	32	72	24	96	3	540	666	819	1013	1247	1539	1895	2336	2880	3551	4379	5400
300	120	105	24	80	32	96	3	600	740	910	1125	1385	1710	2105	2595	3200	3945	4865	6000
330	109	95	24	88	32	96	3	660	814	1001	1238	1524	1881	2316	2855	3520	4340	5352	6600
360	100	90	22	88	32	96	3	720	888	1092	1350	1662	2052	2526	3114	3840	4734	5838	7200
390	92	80	24	78	24	96	3	780	962	1183	1463	1801	2223	2737	3374	4160	5129	6325	7800
420	85	75	24	84	24	96	3	840	1036	1274	1575	1939	2394	2947	3633	4480	5523	6811	8400
450	80	70	24	90	24	96	3	900	1110	1365	1688	2078	2565	3158	3893	4800	5918	7298	9000
480	75	65	24	88	22	96	3	960	1184	1456	1800	2216	2736	3368	4152	5120	6312	7784	9600

to add one hundredth for revolving the turret so that it will be securely locked in position before the tools advance on the work; then in this case it will require 11 hundredths to revolve the turret. Owing to the diameter of the cam roll there should never be less than three hundredths allowed for revolving the turret, irrespective of the speed at which the cam shaft is running.

Tables I to III give the change gears and data for laying out cams for the Nos. 00, 0 and 2 automatic screw machines. When the speed at

TABLE IV. CHANGE GEARS AND DATA FOR LAYING OUT CAMS. No. 00 TURRET FORMING AND CUTTING-OFF MACHINE

Time in Seconds to Make One Piece	Gross Product in Ten Hours	Net Product in Ten Hours, Gross Minus 10%	Gear on Driving Shaft	1st Gear on Stud	2nd Gear on Stud	Gear on Worm Shaft	Hundredths of Cam Surface to Feed Stock	Number of Revolutions to Make One Piece — Spindle Speeds: Min. 420, Sec. 7, ½ Sec. 3½	Min. 540, Sec. 9, ½ Sec. 4½	Min. 690, Sec. 11½, ½ Sec. 6	Min. 890, Sec. 15, ½ Sec. 7½	Min. 1140, Sec. 19, ½ Sec. 9½	Min. 1460, Sec. 24⅓, ½ Sec. 12	Min. 1870, Sec. 31, ½ Sec. 15½	Min. 2400, Sec. 40, ½ Sec. 20
3	12000	10800	70			21	17	21	27	34	44	57	73	93	120
4	9000	8100	50			20	13	28	36	46	59	76	97	125	160
5	7200	6400	60			30	10	35	45	58	74	95	122	156	200
6	6000	5400	50			30	9	42	54	69	89	114	146	187	240
7	5142	4600	60			42	8	49	63	81	104	133	170	218	280
8	4500	4000	60			48	7	56	72	92	119	152	195	249	320
9	4000	3600	60			54	6	63	81	104	134	171	219	280	360
10	3600	3200	40			40	5	70	90	115	148	190	243	312	400
11	3272	2900	40			44	5	77	99	127	163	209	268	343	440
12	3000	2700	40			48	5	84	108	138	178	228	292	374	480
13	2769	2400	40			52	4	91	117	150	193	247	316	405	520
14	2571	2300	30			42	4	98	126	161	208	266	341	436	560
15	2400	2100	40			60	4	105	135	173	222	285	365	467	600
16	2250	2000	30			48	4	112	144	184	237	304	389	499	640
17	2117	1900	20			34	3	119	153	196	252	323	414	530	680
18	2000	1800	30			54	3	126	162	207	267	342	438	561	720
19	1894	1700	20			38	3	133	171	219	282	361	462	592	760
20	1800	1600	20			40	3	140	180	230	297	380	487	623	800
21	1714	1500	20			42	3	147	189	242	311	399	511	654	840
22	1636	1450	20			44	3	154	198	253	326	418	535	686	880
23	1565	1400	20			46	3	161	207	265	341	437	560	717	920
24	1500	1350	20			48	3	168	216	276	356	456	584	748	960
25	1440	1300	20			50	3	175	225	288	371	475	608	779	1000
26	1384	1250	20			52	3	182	234	299	386	494	633	810	1040
27	1333	1200	20			54	3	189	243	311	400	513	657	841	1080
28	1285	1150	20			56	3	196	252	322	415	532	681	872	1120
29	1241	1100	20			58	3	203	261	334	430	551	706	904	1160
30	1200	1050	20			60	3	210	270	345	445	570	730	935	1200
32	1125	1000	30	30	48	60	3	224	288	368	475	608	779	997	1280
34	1050	950	20	44	50	60	3	238	306	391	504	646	827	1060	1360
36	1000	900	30	30	54	60	3	252	324	414	534	684	876	1122	1440
38	947	850	20	30	38	60	3	266	342	437	564	722	925	1184	1520
40	900	800	20	30	40	60	3	280	360	460	593	760	973	1247	1600
42	857	775	20	30	42	60	3	294	378	483	623	798	1022	1309	1680
44	818	725	20	30	44	60	3	308	396	506	653	836	1071	1371	1760
46	782	700	20	30	46	60	3	322	414	529	682	874	1119	1434	1840
48	750	675	20	30	48	60	3	336	432	552	712	912	1168	1496	1920
50	720	650	20	30	50	60	3	350	450	575	742	950	1217	1558	2000
52	692	620	20	30	52	60	3	364	468	598	771	998	1265	1621	2080
54	656	600	20	30	54	60	3	378	486	621	801	1026	1314	1683	2160
56	642	575	20	30	56	60	3	392	504	644	831	1064	1363	1745	2240
58	620	550	20	30	58	60	3	406	522	667	860	1102	1411	1808	2320
60	600	525	30	21	54	70	3	420	540	690	890	1140	1460	1870	2400
63	571	500	30	20	54	70	3	441	567	725	935	1197	1533	1963	2520
70	514	450	20	20	40	70	3	490	630	805	1038	1330	1703	2182	2800
77	467	420	20	20	44	70	3	539	693	886	1142	1463	1874	2400	3080
84	428	385	20	20	48	70	3	588	756	966	1246	1596	2044	2618	3360
91	395	355	20	20	52	70	3	637	819	1047	1350	1729	2214	2836	3640

which the spindle is to be run for any certain job, and the number of revolutions required to complete one piece, are known, the gears, product in ten hours and the time in seconds to make one piece as well as the number of hundredths of the cam surface required to feed the stock and revolve the turret, are found in the left-hand columns of the table, the total revolutions required to make one piece being given in the.

TABLE V. CHANGE GEARS AND DATA FOR LAYING OUT CAMS. No. 0 TURRET FORMING AND CUTTING-OFF MACHINE

Time in Seconds to Make One Piece	Gross Product in Ten Hours.	Net Product in Ten Hours. Gross Minus 10%	Gear on Driving Shaft.	1st Gear on Stud	2nd Gear on Stud	Gear on Worm Shaft	Hundredths of Cam Surface to Feed Stock.	Spindle Speeds. Min. 300 / Sec. 5. / ⅔ Sec. 3.3	Min. 429 / Sec. 7.2 / ⅔ Sec. 4.8	Min. 614 / Sec. 10.2 / ⅔ Sec. 6.8	Min. 879 / Sec. 14.7 / ⅔ Sec. 9.8	Min. 1258 / Sec. 21. / ⅔ Sec. 14.	Min. 1800 / Sec. 30. / ⅔ Sec. 20.
								Number of Revolutions to Make One Piece					
5	7200	6400	58	86	120	20	14	25	36	51	73	105	150
6	6000	5400	58	86	120	24	12	30	43	61	88	126	180
7	5142	4600	58	86	120	28	10	35	50	72	103	147	210
8	4500	4000	58	86	120	32	9	40	57	82	117	168	240
9	4000	3600	58	86	80	24	8	45	64	92	132	189	270
10	3600	3200	58	86	120	40	7	50	72	102	147	210	300
11	3272	2900	58	86	60	22	7	55	79	113	161	231	330
12	3000	2700	58	86	60	24	6	60	86	123	176	252	360
13	2769	2400	34	110	120	24	6	65	93	133	190	273	390
14	2571	2300	58	86	60	28	5	70	100	143	205	294	420
15	2400	2100	58	86	60	30	5	75	107	153	220	315	450
16	2250	2000	58	86	60	32	5	80	114	164	234	335	480
17	2117	1900	58	86	60	34	4	85	122	174	249	356	510
18	2000	1800	58	86	40	24	4	90	129	184	264	377	540
19	1894	1700	58	86	60	38	4	95	136	194	278	398	570
20	1800	1600	58	86	60	40	4	100	143	205	293	419	600
22	1636	1450	58	86	30	22	4	110	157	225	322	461	660
24	1500	1350	58	86	40	32	3	120	172	246	352	503	720
26	1384	1250	34	110	60	24	3	130	186	266	381	545	780
28	1285	1150	58	86	30	28	3	140	200	287	410	587	840
30	1200	1050	58	86	60	60	3	150	215	307	440	629	900
32	1125	1000	58	86	30	32	3	160	229	327	469	671	960
34	1059	950	58	86	30	34	3	170	243	348	498	713	1020
36	1000	900	58	86	20	24	3	180	257	368	527	755	1080
38	947	850	58	86	30	38	3	190	272	389	557	797	1140
40	900	800	58	86	30	40	3	200	286	409	586	839	1200
44	818	725	34	110	32	22	3	220	315	450	645	923	1320
48	750	675	58	86	20	32	3	240	343	491	703	1006	1440
52	692	620	34	110	30	24	3	260	372	532	762	1090	1560
56	642	575	58	86	32	60	3	280	400	573	820	1174	1680
60	600	525	58	86	30	60	3	300	429	614	879	1258	1800
65	553	490	34	110	60	60	3	325	465	665	952	1363	1950
70	514	450	34	110	80	86	3	350	501	716	1026	1468	2100
75	480	430	58	86	24	60	3	375	536	767	1099	1573	2250
80	450	400	58	86	30	80	3	400	572	819	1172	1677	2400
90	400	360	58	86	20	60	3	450	644	921	1319	1887	2700
100	360	320	58	86	24	80	3	500	715	1023	1465	2097	3000
110	327	290	58	86	30	110	3	550	787	1126	1612	2306	3300
120	300	270	58	86	20	80	3	600	858	1228	1758	2516	3600
135	266	235	58	86	20	90	3	675	965	1381	1978	2831	4050
150	240	215	58	86	24	120	3	750	1073	1535	2198	3145	4500
165	218	195	58	86	20	110	3	825	1180	1688	2417	3460	4950
180	200	180	58	86	20	120	3	900	1287	1842	2637	3774	5400
195	184	165	34	110	30	90	3	975	1394	1995	2857	4089	5850
210	171	150	34	110	28	90	3	1050	1502	2149	3077	4403	6300
225	160	140	34	110	26	90	3	1125	1609	2302	3296	4718	6750
240	150	135	34	110	24	90	3	1200	1716	2456	3516	5032	7200
270	133	120	34	110	22	90	3	1350	1931	2763	3956	5661	8100
300	120	105	34	110	26	120	3	1500	2145	3070	4395	6290	9000
330	109	100	34	110	24	120	3	1650	2360	3377	4835	6919	9900
360	100	90	34	110	22	120	3	1800	2574	3684	5274	7548	10800
390	92	80	34	110	20	120	3	1950	2789	3991	5714	8177	11700

right-hand columns. Tables IV to VI give the change gears and data for laying out cams for the Nos. 00, 0 and 2 turret forming and cutting-off machines. The same remarks apply to these as to the preceding tables.

The principal dimensions for the plate cams and the radii of the cross-slide and lead levers on the Nos. 00, 0 and 2 automatic screw machines, are given in Table VII. For notation see the illustration accompanying the table.

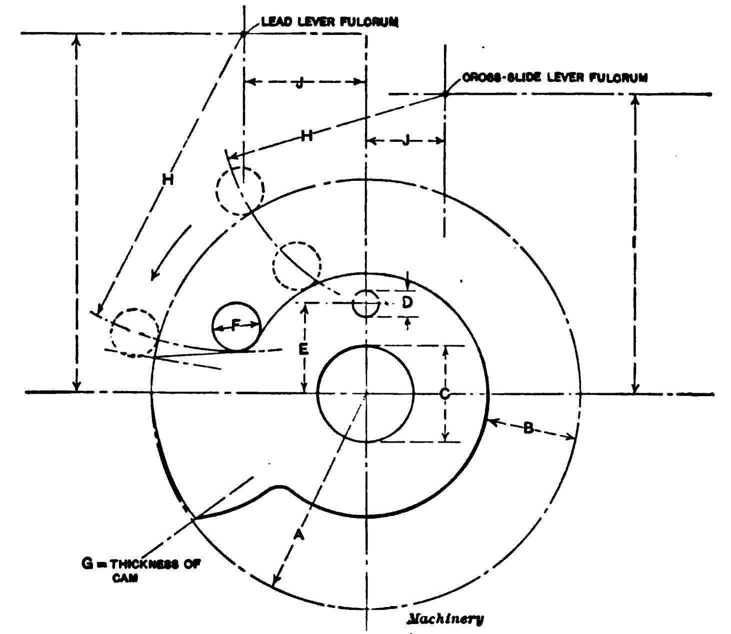
TABLE VI. CHANGE GEARS AND DATA FOR LAYING OUT CAMS.
No. 2 TURRET FORMING AND CUTTING-OFF MACHINE

Time in Seconds to Make One Piece.	Gross Product in 10 Hours.	Net Product in 10 Hours-Gross Minus 10%	Gear on Driving Shaft.	1st Gear on Stud.	2nd Gear on Stud.	Gear on Worm Shaft	Hundredths of Cam Surface to Feed Stock.	Spindle Speeds.								
								Sec.			3	4.38	6.42	9.37	13.68	20
								Min.			180	263	385	562	821	1200
6	6000	5400	80	32	80	40	17	Number of Revolutions to Make One Piece.			18	26	39	56	82	120
7	5142	4600	80	32	72	42	15				21	31	45	66	96	140
8	4500	4000	80	32	72	48	13				24	35	51	75	109	160
9	4000	3600	80	32	72	54	12				27	39	58	84	123	180
10	3600	3200	80	32	72	60	10				30	44	64	94	137	200
11	3272	2900	80	32	84	77	10				33	48	71	103	151	220
12	3000	2700	80	32	60	60	9				36	53	77	112	164	240
13	2769	2400	80	32	72	78	9				39	57	83	122	178	260
14	2571	2300	80	32	60	70	8				42	61	90	131	192	280
16	2250	2000	80	32	60	80	7				48	70	103	150	219	320
18	2000	1800	80	32	48	72	6				54	79	116	169	246	360
20	1800	1600	80	32	48	80	5				60	88	128	187	274	400
22	1636	1450	80	32	42	77	5				66	96	141	206	301	440
24	1500	1350	80	32	40	80	5				72	105	154	225	328	480
26	1384	1250	80	32	36	78	4				78	114	167	244	356	520
28	1285	1150	80	32	36	84	4				84	123	180	262	383	560
30	1200	1050	60	60	80	80	4				90	131	193	281	410	600
35	1028	925	60	60	72	84	3				105	153	225	328	479	700
40	900	800	60	60	54	72	3				120	175	257	375	547	800
45	800	700	60	60	48	72	3				135	197	289	422	616	900
50	720	625	60	60	48	80	3				150	219	321	468	684	1000
55	654	575	60	60	42	77	3				165	241	353	515	753	1100
60	600	525	40	80	60	60	3				180	263	385	562	821	1200
70	514	450	40	80	60	70	3				210	307	449	656	958	1400
80	450	400	40	80	54	72	3				240	351	513	749	1095	1600
90	400	350	40	80	48	72	3				270	394	577	843	1231	1800
100	360	300	40	80	48	80	3				300	438	642	937	1368	2000
110	327	290	40	80	42	77	3				330	482	706	1030	1505	2200
120	300	270	40	80	40	80	3				360	526	770	1124	1642	2400
135	266	240	36	72	40	90	3				405	592	866	1265	1847	2700
150	240	210	36	80	40	90	3				450	657	963	1405	2052	3000
165	218	190	36	77	35	90	3				495	723	1059	1546	2258	3300
180	200	180	36	84	35	90	3				540	789	1155	1686	2463	3600
195	184	160	32	78	36	96	3				585	855	1251	1827	2668	3900
210	171	150	24	80	40	84	3				630	920	1348	1967	2873	4200
225	160	140	32	90	36	96	3				675	986	1444	2108	3079	4500
240	150	135	24	80	40	96	3				720	1052	1540	2248	3284	4800
270	133	120	32	72	24	96	3				810	1183	1733	2529	3694	5400
300	120	105	24	80	32	96	3				900	1315	1925	2810	4105	6000
330	109	95	24	88	32	96	3				990	1446	2118	3091	4515	6600
360	100	90	22	88	32	96	3				1080	1578	2310	3372	4926	7200
390	92	80	24	78	24	96	3				1170	1709	2503	3653	5336	7800
420	85	75	24	84	24	96	3				1260	1841	2695	3934	5747	8400
450	80	70	24	90	24	96	3				1350	1972	2888	4215	6157	9000
480	75	65	24	88	22	96	3				1440	2104	3080	4496	6568	9600

Constructing the Rise on Cams

The rise on the cam should be such that the tools will gradually slow up as they approach the work. It is not necessary to lay out a uniform curve for the rise, as in most cases the cam rotates slowly, but when the cam is required to make one revolution in less than 5 seconds on the No. 0 or No. 2 screw machine, a curve for a more uniform speed should be constructed.

TABLE VII. DIMENSIONS OF CAMS AND CAM LEVERS



No. of Machine	00		0		2	
Principal Dimensions	Lead	Cross-slide	Lead	Cross-slide	Lead	Cross-slide
	Dimensions in Inches					
A	2 1/2	2 1/4	3 1/4	3	4	3 1/2
B	1 3/8	1	2	1 1/4	2 3/4	1 3/4
C	1	1	1 1/8	1 1/8	1 1/4	1 1/4
D	1/4	1/4	5/16	5/16	5/16	5/16
E	15/16	15/16	1	1	1 1/16	1 1/16
F	1/2	1/2	9/16	9/16	5/8	5/8
G	1/4	1/4	5/16	5/16	3/8	3/8
H	3 5/16	2 3/8	3 3/4	2 3/4	4.5	3.083
I	3 13/16	3 1/8	4 3/4	3 11/16	4.208	4 1/4
J	1 1/4	7/8	1/2	1 3/4	3 1/2	1 5/8

Generally the rise can be abrupt for about three-quarters of the way, and then gradually slow down as the tool approaches the work. A good method of laying out a curve of this form is shown in Fig. 4. The reason for making a curve of this form is that less time is necessary for one tool to clear another, which sometimes makes quite a considerable difference in the time required to produce one piece

To construct the rise, proceed as follows: Lay off on line *H* a distance *D* from the point *a*. Distance *D* varies with the clearance necessary between the turret and cross-slide tools. Then draw line *BC* at right angles to *H*. With *a* as a center, and a radius *R* describe an arc intersecting line *BC* at point *b*; again with *R* as a radius, and a center at *b*, describe the rise. Join the rise and the small diameter dwell of

TABLE VIII. DIMENSIONS FOR LAYING OUT CAM RISE FOR No. 00 BROWN & SHARPE AUTOMATIC SCREW MACHINE

Number of Seconds to make one Piece	Lead	Front and Back Cams
	D	R
From 3 to 5 seconds............	11/32	1 1/8
From 6 to 12 seconds............	3/4	1 1/4
From 13 to 30 seconds............	5/8	1 1/4

the cam with a circle having a diameter equal to the diameter of the roll. The distance *r* should then be measured off and recorded on the drawing to be used by the toolmaker when laying out the cams. The various values for the dimensions given in Fig. 4 for the rise, that have been found suitable, are specified in Tables VIII, IX and X.

Constructing Drop on Cams

The drop on the cams should be such that the cross-slides will drop back without shock. The turret slide drops back on a cushion spring,

TABLE IX. DIMENSIONS FOR LAYING OUT CAM RISE FOR No. 0 BROWN & SHARPE AUTOMATIC SCREW MACHINE

Number of Seconds to make one Piece	Lead		Front and Back Cams	
	D	R	D	R
From 5 to 12 seconds....	1 1/8	15/16	7/8	1 1/2
From 13 to 30 seconds....	1 1/8	2 3/8	7/8	2
From 32 to 60 seconds....	1	3 1/4	13/16	3

thus allowing the drop on the lead cam to be more abrupt, on the No. 0 and No. 2 screw machines, than it is on the front and rear cams. This is also true of the No. 00 machine, but as the drop is not great, very little time would be saved by using a smaller angle of drop for the lead than for the cross-slide cams. Referring to Fig. 4, it can be seen that the lever arm swings about a pivot, so that, to have a uniform drop, a special curve should be constructed. But, as this drop would be more difficult to make than a straight drop, a straight or angular drop is adopted. This gives the drop of the arm a variable motion, as can be seen by referring to Fig. 4; the roll will drop quickly to about the point *e*, then slow up and then increase in speed as it approaches the bottom. The cross-slides are forced back by a spring which serves to keep the roll in contact with the cam. The drop on

TABLE X. DIMENSIONS FOR LAYING OUT CAM RISE FOR No. 2 BROWN & SHARPE AUTOMATIC SCREW MACHINE

Number of Seconds to make one Piece	Lead		Front and Back Cams	
	D	R	D	R
From 6 to 14 seconds..	$1\frac{7}{8}$	$2\frac{7}{16}$	$1\frac{1}{2}$	$1\frac{3}{4}$
From 15 to 40 seconds..	$1\frac{3}{4}$	$2\frac{3}{8}$	$1\frac{1}{4}$	$1\frac{13}{16}$
From 45 to 90 seconds..	$1\frac{1}{2}$	$2\frac{1}{2}$	$1\frac{1}{16}$	$1\frac{15}{16}$
From 100 to 180 seconds.	$1\frac{3}{8}$	$3\frac{1}{4}$	$\frac{15}{16}$	$2\frac{1}{16}$

the cam should not be laid off from a circle as shown by the dotted lines at *c*. This would mean that the roll would drop slower when dropping a short distance than when dropping a greater distance. The drop should be laid off from the hundredth line where the operation

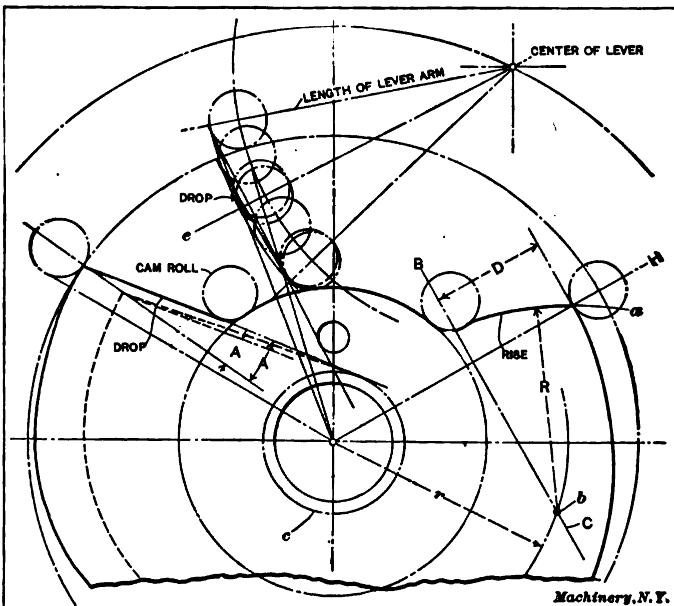


Fig. 4. Method of Laying out Rise and Fall on Cams

finishes as shown by the angle *A*. This assures the drop always being of the same speed, irrespective of the distance through which it has to drop. The following angles of drop have been found suitable for the given number of seconds required to make one piece.

DROP ON CAMS FOR No. 00 BROWN & SHARPE AUTOMATIC SCREW MACHINE

Number of Seconds to make One Piece	Lead, Front and Back
From 3 to 5 seconds	$A = 20$ degrees
From 6 to 12 seconds	$A = 15$ degrees
From 13 to 30 seconds	$A = 10$ degrees

DROP ON CAMS FOR No. 0 BROWN & SHARPE AUTOMATIC SCREW MACHINE

Number of Seconds to make One Piece	Lead	Front and Back
From 5 to 12 seconds	$A = 17$ degrees	16 degrees
From 13 to 30 seconds	$A = 14$ degrees	13 degrees
From 32 to 60 seconds	$A = 10$ degrees	9 degrees

DROP ON CAMS FOR No. 2 BROWN & SHARPE AUTOMATIC SCREW MACHINE

Number of Seconds to make One Piece	Lead	Front and Back
From 6 to 14 seconds	$A = 16$ degrees	22 degrees
From 15 to 40 seconds	$A = 14$ degrees	19 degrees
From 45 to 90 seconds	$A = 12$ degrees	16 degrees
From 90 to 180 seconds	$A = 10$ degrees	13 degrees

Clearance for Tools

In laying out a set of cams it is sometimes found necessary to make allowance for one tool to clear another, the amount of clearance necessary being determined by the diameter or width of tool used in the turret and the position of the cross-slide tools relative to the work. When determining the amount of clearance necessary, the rise and drop on the lead cam is disregarded and the rises and drops on the front and rear cams are taken into consideration. To determine the rise and drop to use, make a rough lay-out of the various operations to be performed and also settle upon the approximate number of revolutions to complete one piece. The revolutions are then converted into seconds as was previously explained. To explain clearly the method used, we will take a practical example. Assume that it is required to make a brass screw as shown in Fig. 5. This screw is made from ¼-inch round brass rod, and can be made to advantage on the No. 00 Brown & Sharpe automatic screw machine, using a spindle speed of 2400 R. P. M. backward and forward. Assume that it is required to find the amount of clearance necessary for the die holder to pass the circular form and cut-off tools. Draw in the form tool in position on the screw as shown to the left in Fig. 5, and also an outline of the toolpost. Then lay out the die holder in position to start on the screw, as shown by the dotted lines. If a releasing die holder is used, take the diameter over the heads of the screws in the holder, but if a "draw-out" type is used, the diameter of the cap is taken. In this case, as the screw is threaded up to the shoulder, a releasing die holder will be used. In Fig. 5 it can be seen that the die holder cannot advance on the screw until the form tool drops back a distance *B*, but as *B* is the actual distance, it will be necessary to add an extra amount to insure that the die holder can advance without coming in contact with the circular form tool. The extra amount of clearance necessary varies with the type of tool used. The following dimensions give the approximate amounts that should be added to tne actual clearance for the type of tools specified:

Type of Tool	Extra Amount of Clearance
Drill holders	from 1/8 to 3/16 inch
Box-tools (with V-supports)	from 1/8 to 1/4 inch
Box-tools (with supporting bushing)	from 3/16 to 5/16 inch
Button die holders (draw-out type)	from 3/16 to 5/16 inch
Button die holders (releasing type)	from 1/4 to 1/2 inch

To find the amount necessary for clearance, make a diagram as shown in Fig. 6, laying out the drop on the front cam as shown. Then add, say, ¼ inch, to dimension *B* and measure down from the point where the lobe finishes, scribing an arc of a circle through the point

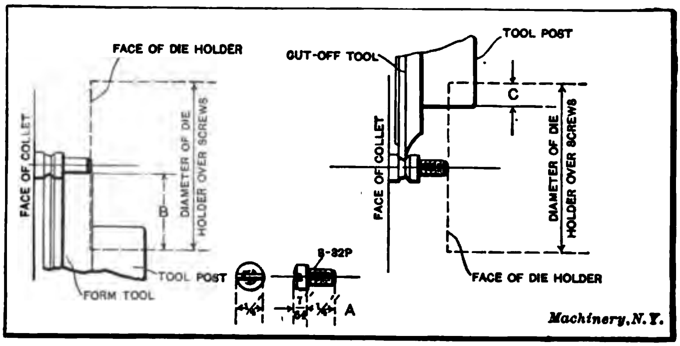


Fig. 5. Diagram illustrating Method of Finding Clearance for Die Holder

thus located, as shown. Then with a radius equal to the radius of the cam roll, describe a circle touching the arc drawn and the drop on the cam. Join the center of the roll with the center of the cam circle by a straight line. The clearance is then measured off in hundredths as shown by dimension *H*. The starting point of the lobe on the lead cam for threading will be at the hundredth line *D* and the intervening space between the lines *D* and *E* will be the amount necessary for clearance.

When the cutting-off operation follows the threading operation it will also be necessary to allow for clearance. To find the amount of clearance necessary for the die holder to clear the circular cut-off tool, proceed as follows: Make a lay-out as shown to the right in Fig. 5 and measure off the distance C. Add ¼ inch to this and lay off this dimension from the starting point *A* of the rear cam as shown in Fig. 6, drawing an arc of a circle as before. Then draw a circle the diameter of which is equal to the diameter of the roll, touching the arc drawn and the rise on the cam, and measure off the clearance *H* as was previously explained. The thread lobe would finish at the hundredth line *F* and the cut-off tool start at the line *A*. Clearance should also be allowed between the dropping back of the cut-off tool and the feeding of the stock. To find the amount of clearance necessary add 1/8 inch to the largest radius of the stock used and proceed as previously explained.

To make this explanation more complete, the various steps followed when designing a set of cams will be given.

Designing and Laying out Cams

When designing a set of cams the speed of the spindle best suited for the size of stock and nature of material should first be decided upon.

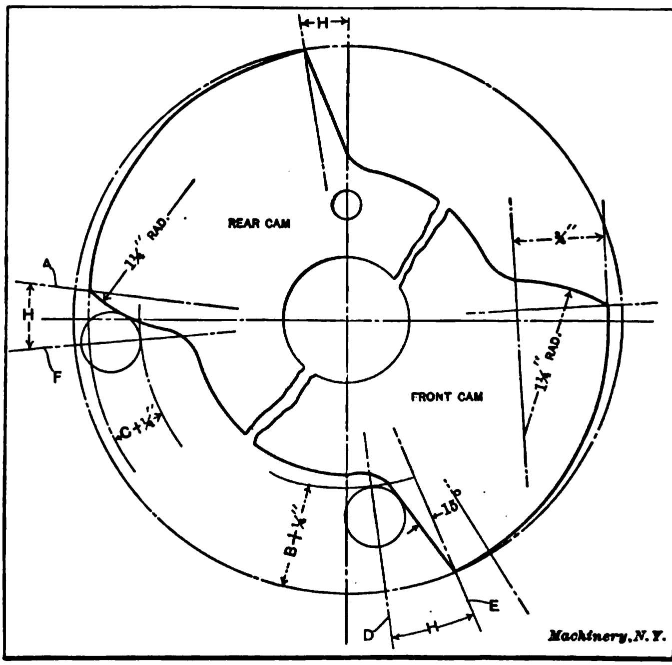


Fig. 6. Method of Determining Clearance on Cross-slide Cams

The tables for surface speeds given in MACHINERY's Reference Book No. 99, "Automatic Screw Machine Practice—Operation of the Brown & Sharpe Automatic Screw Machine," will be found convenient for this purpose. The quickest and best method of making the piece should next be considered, and a diagram made of the tools to be used in the turret as shown at *A*, Fig. 7, leaving from 1/8 to 3/16 inch clearance between the rear face of the tool-holder and the face of the turret. This amount, of course, varies to a considerable extent, depending on the length of the shank and body of the tool, and also on the distance that the work projects from the chuck. When the shank of the tool is short, care should be taken to see that the clamping devices in the turret have a good grip on the shank of the tool. The diagram of the circular tools applied to the work should also be made as shown at *B*, Fig. 7. The feeds for the various operations are then decided upon and divided into the length of cut which will give the number of revolutions required for the various operations. The total number of revolutions to complete one piece is found by adding together the number of revolutions for each cut, for revolving the turret, feeding the stock and, in some cases, reversing the spindle; an approximate number of revolutions should also be added for clearance. When the approximate number of seconds to complete one piece has been obtained we make a diagram of the rise and drop on the cam as shown in Fig. 6. To ascertain the exact number of revolutions required for clearance, if the approximate number of revolutions as allowed for

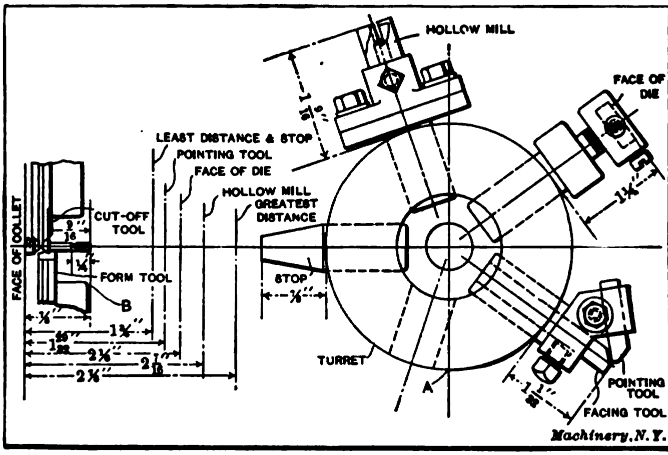


Fig. 7. Position of Tools in Turret, and Forming Tools applied to Work

clearance is not sufficient, the feed on some of the tools is increased, but if the maximum feed that the tools will stand has been used, the number of seconds to make one piece has to be increased. When the actual number of seconds has been obtained, we then convert the revolutions for each operation into hundredths of cam circumference, and proportion the different lobes on the cam to the number of revolutions for each operation. To explain the method adopted in laying out the cams, we will take a practical example.

Assume that it is required to make a screw as shown at *B*, Fig. 7. We first make the diagrams of the circular tools and the tools used in the turret as shown. Then to find the amount that the lead cam is to be cut down below the outer cam circle, measure the distance that the tools project out of the turret and add this amount to the distance that the piece projects from the face of the chuck. Then the least distance between the turret and the face of the chuck subtracted from this amount would give the distance down from the outer circle to where the lobe on the cam starts. For example, take the lobe for the hollow mill.

1 9/16 + 7/8 = 2 7/16 inch.

2 7/16 inch — 1 3/4 inch = 11/16 inch.

In Fig. 8 is given a method of laying out the cams for the screw shown in Fig. 7. This method is commendable, as it can be seen whether the tools will clear one another better than if the cams were drawn separately instead of one on top of the other. If the foregoing suggestions are followed, very little trouble will be encountered in designing a set of cams. The example as given is for making screws, but the same method can be followed in making any other class of work. After the cams have been designed, a tracing should be made and kept

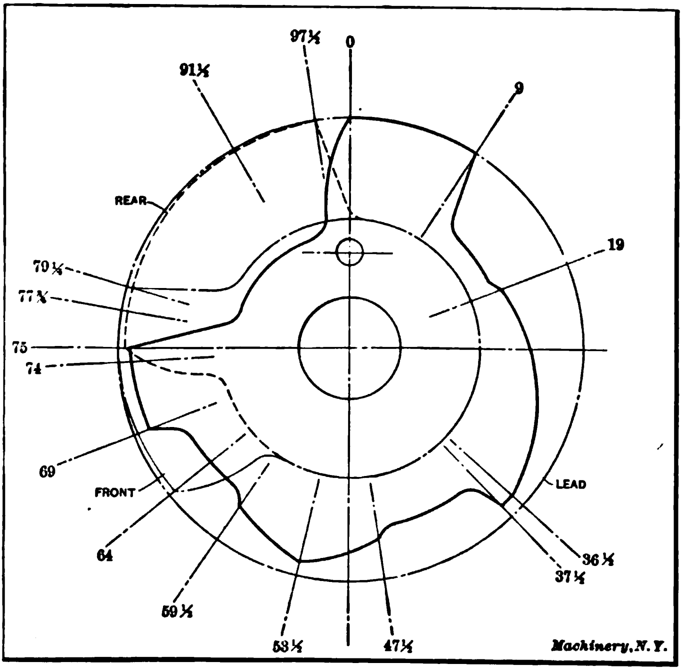


Fig. 8. Commendable Method of Laying out Cams

for reference. (See Fig. 40, Part I of this treatise, MACHINERY'S Reference Book No. 99.)

Practical Points in Designing Cams and Special Tools

1. Use the highest spindle speeds that the various tools will stand.

2. Use the arrangement of circular tools best suited for the class of work. (See Reference Book No. 101.)

3. Decide on the quickest and best method of arranging the operations before designing the cams.

4. Do not use turret tools for forming when the cross-slide tools can be used to better advantage.

5. Do not use a circular cut-off tool without top rake when cutting Norway iron, machine steel, etc.

6. Make the shoulder on the circular cut-off tool large enough so that the clamping screw will grip firmly.

7. When chips clinging to the work are objectionable, the circular form tool should be turned up-side-down and placed on the rear cross-slide.

8. Do not use too narrow a cut-off blade.

9. Allow 0.005 to 0.010 inch for the circular tools to approach the work and 0.003 to 0.005 inch for the cut-off tool to pass the center.

10. When cutting off work large in diameter, the feed on the cut-off tool should be increased until near the end of the cut where the piece breaks off. After it breaks off, the feed should again be increased until the tool has passed the center.

11. When a thread is cut up to a shoulder, the piece should be grooved or necked to make allowance for the lead on the die. This requires an extra projection on the form tool and also an extra amount of rise on the cam.

12. Use circular form and cut-off tools made from high-speed steel when cutting Norway iron, machine steel, etc.

13. Use a fine feed and high spindle speed for all cutting tools.

14. Allow sufficient clearance for tools to pass one another.

15. Always make a diagram of the cross-slide tools in position on the work when difficult operations are to be performed; it is also necessary to make a diagram of the tools held in the turret.

16. Do not drill a hole the depth of which is more than 2½ times the diameter of the drill, but use two or more drills as required. If there are not sufficient holes in the turret, drop the drill back clear of the hole, and advance it into the hole again.

17. Do not run a drill at a slow speed.

18. When the turret tools operate further in than the face of the chuck, see that they will clear the chute when revolving the turret.

19. See that the body of all turret tools will clear the side of the chute when revolving the turret.

20. Do not use a box-tool for a roughing cut. Use a hollow mill.

21. Do not use a box-tool with soft supports. Use solid supports only on cold-drawn or finished stock.

22. The rise on the thread lobe should be reduced so that the spindle will reverse when the die or tap holder is drawn out.

23. When threading Norway iron, machine steel, etc., if the spindle speed used for the other tools is too high for threading, use a special threading attachment. (See MACHINERY's Reference Book No. 104.)

24. When bringing another tool into position after a threading operation, allow clearance before revolving the turret.

25. Make provision to revolve the turret rapidly, especially when pieces are being made in from three to five seconds and when only a few tools are used in the turret. It is sometimes convenient to use two sets of tools.

26. When using a belt-shifting attachment for threading, clearance should be allowed, as it requires extra time to shift the belt.

27. When laying out a set of cams for operating on a piece which requires to be slotted, cross-drilled or burred, allowance should be made on the lead cam so that the transferring arm can descend and ascend to and from the work without coming in contact with any of the turret tools.

28. Always allow a vacant hole in the turret when it is necessary to use the transferring arm.

29. Use standard tools whenever possible.

30. When designing special tools allow as much clearance as possible. Do not make them so that they will just clear, as errors sometimes turn up, causing trouble.

31. When designing special tools having intricate movements, avoid springs as much as possible, and use positive actions.

CHAPTER II

CAMS FOR SCREW-SLOTTING ATTACHMENTS

The Brown & Sharpe Mfg. Co., Providence, R. I., has designed a number of standard and special attachments for its automatic screw machines. These attachments are used for performing various second operations on a piece of work, such as slotting, milling, cross-drilling and burring, at the same time that another piece is being operated on by the cross-slide and turret tools. Thus extra operations are performed without taking additional time.

While the attachments—as such—are widely known, the methods of laying out the cams for operating them are no doubt unfamiliar to a large number of operators and mechanics in general, and, therefore, a description of the methods of laying out the cams for one of these attachments should be of general interest. The best known attachment designed by the Brown & Sharpe Mfg. Co. is its screw-slotting attachment, which is shown in Fig. 9.

Screw-slotting Attachment for the No. 00 Machine

The screw-slotting attachment is fastened to a boss, provided for this purpose on the machine, by two cap-screws. An apron, which is also an additional part, carries the arbor *C* to which the transferring arm *F* is attached. The transferring and advancing cam levers *D* and *E* are also fastened to bosses on this apron by cap-screws. These levers are operated by the advancing and transferring cams *J* and *K*. A block *H* is fastened to the arm *F*, and a slotting bushing or carrier for the screw is driven into it. This bushing grips the screw and holds it while the slotting saw, held on an arbor and driven by a pulley through bevel gears, mills the slot in the head.

The design and action of the device is, in detail, as follows: The transferring lever *D* is kept in contact with the cam by means of two

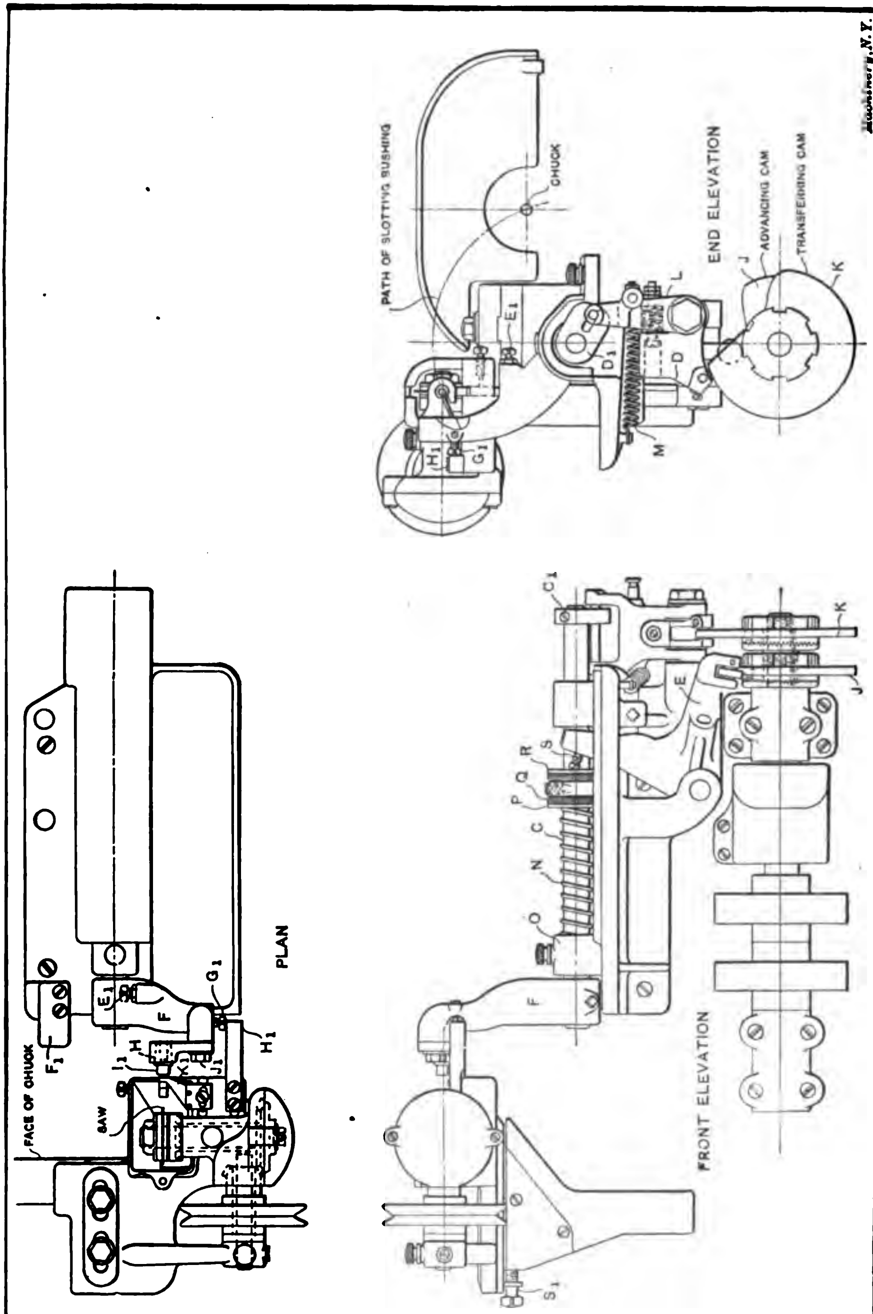


Fig. 9. Assembly Views of Screw-slotting Attachment for the No. OO Brown & Sharpe Automatic Screw Machine

springs *L* and *M*. The advancing lever *E* is kept in contact with the advancing cam by the spring *N*, located on the transferring-arm rod *C*. This open-wound spring presses against the boss *O* on the attachment and the washer *P*, this latter being held up against a ball retainer *Q* which, in turn, is forced against a washer held to the arbor *C* by a cone-pointed screw. The lever *E* does not bear directly against the thrust-washer *R* to advance the arm, but holds a set-screw *S* which can be adjusted in and out and locked with a headless screw. This screw *S*, in conjunction with the screw S_1, is used for varying the depth of the slot in the head of the screw.

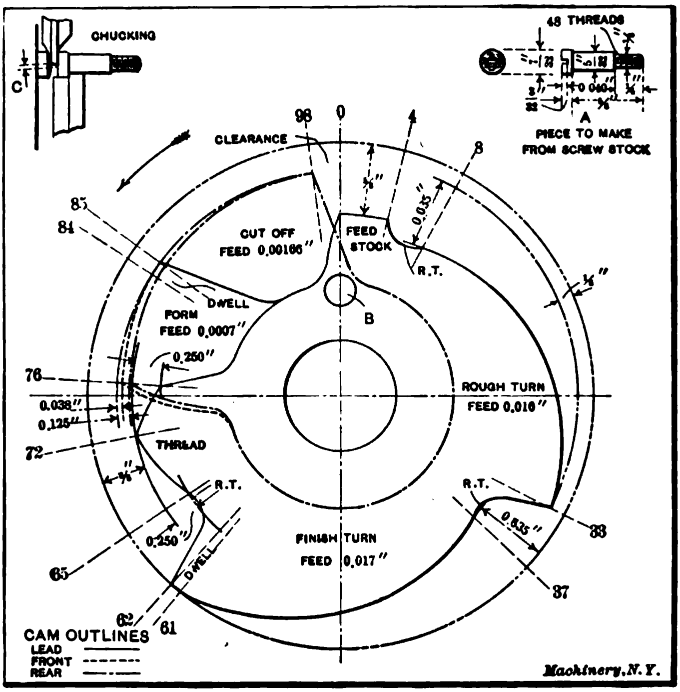


Fig. 10. Turret and Cross-slide Cams for Making a Steel Screw

The transferring lever *D* is connected to a block D_1, which is fastened to the rod *C* by a screw C_1. This block connects arm *F* with lever *D*. The arms of lever *D* and the arm *F* are so proportioned that a small rise of about 1⅛ inch on the cam in this case is sufficient to carry the slotting bushing from the chuck up to the saw through the path indicated in the engraving. When arm *F* drops down into a position in front of the chuck, it is stopped at the desired point by a set-screw E_1, which rests on a block F_1, attached to the machine. When the arm moves up into a position in front of the saw, it is stopped by a set-screw G_1, which bears against a block H_1, fastened to the attachment. The set-screws G_1 and E_1 are used for setting the slotting bushing accurately. The slotting bushing is shown at I_1 in position in block H. The shank of this bushing is tapered one-half inch to the foot and is driven into the block. Block H is held to the arm by a cap-screw J_1. When the slot in the screw has been cut and arm F drops back, the screw is removed from the bushing, which has a slot cut in it, by the ejector K_1, which is simply a piece of sheet steel fastened to the attachment.

Laying out a Set of Cams for a Screw-slotting Operation

Undoubtedly the method of setting and operating this screw-slotting attachment can best be described by taking a practical example. Suppose it is necessary to make the shouldered steel screw shown at A in Fig. 10 on a No. 00 Brown & Sharpe automatic screw machine. To pro-

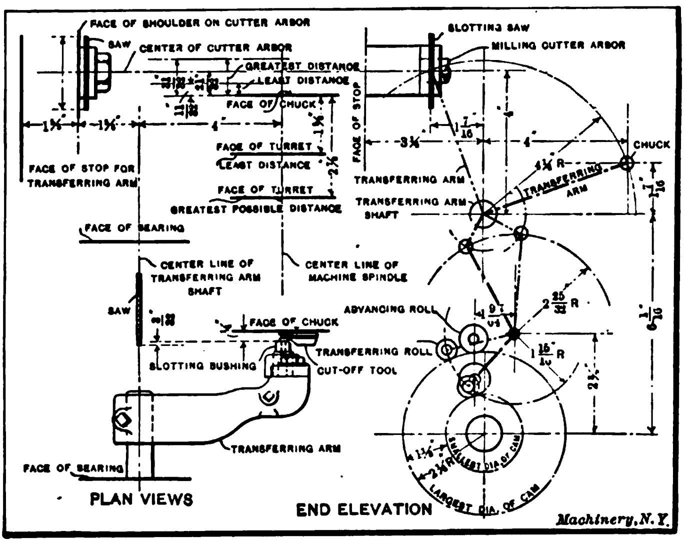


Fig. 11. Diagram used in determining the Rises on the Transferring and Advancing Cams

ceed: First design the cross-slide and turret cams, making allowance for one empty hole in the turret, thus enabling the transferring arm to drop down and pick up the screw while it is being cut off. It will not be necessary to describe the method of laying out the turret and cross-slide cams, as this has been described in the previous chapter, so we will confine our attention to the calculations necessary in laying out the transferring and advancing cams for removing and slotting the screw.

Before proceeding with the laying out of these cams, it is necessary to make a diagram such as is shown in Fig. 11. Here a diagrammatical view of the necessary movement of the transferring and advancing levers is shown. To the right of the illustration is a diagram of the movement of the transferring arm and lever. For the slotting attachment, the transferring arm does not have to dwell at any intermediate point between the chuck and the slotting saw, so that no calculation is necessary to find the rise on the cam—the full rise or 1⅛ inch being sufficient to lift the slotting bushing from the chuck to the slotting saw. To the left of the illustration is a diagram in which is indicated the least and greatest possible distances between the face of the turret and the chuck, and also the position of the screw-slotting arbor relative to the chuck. Below this, the transferring arm is shown in position on the screw. Here it can be seen that the lobes for placing the bushing on the work and advancing it to the saw will be of the same height, as the distance 3/32 inch is considerably less than the adjustment provided for the screw-slotting attachment; this adjustment is equal to 5/16 inch on each side of the center line.

When the rises or the heights of the various lobes on the cams have been determined, the next problem is to determine their relative positions, or, in other words, the starting and finishing points of the lobes on the transferring and advancing cams, respectively.

Laying out the Transferring and Advancing Cams

The location hole *B* in the cam shown in Fig. 10 is not used in the transferring and advancing cams, so that these cams, when made, can be shifted around to the desired position. However, it is best to start from some predetermined point when laying out the cams. The least confusion will result if the point at which the piece breaks off is used for the point at which the bushing is located on the work. This point, of course, cannot be determined exactly, but it is easy to locate it approximately.

The method of determining this is as follows: Taking the screw shown at *A*, in Fig. 10, as an example, we will assume that it will break off when the teat is 0.010 inch in diameter. (This screw is made in 9 seconds and requires 360 revolutions of the work spindle, which in this case is rotated at 2400 R. P. M.) Then assuming that the length of the bevel on the cut-off tool, or distance *C*, Fig. 3, equals 0.010 inch, and that the amount to pass the center of the work equals 0.005 inch, we find that the distance the point of the cut-off tool will have to travel after the piece breaks off equals $0.010 + 0.005 + 0.005 = 0.020$ inch. To find the hundredth line on the cam circle where the screw is supposed to break off, divide the travel (in inches) of the cut-off tool, still to be completed after the piece is cut-off, by the feed of the cut-off tool per revolution of the work. (See cut-off cam, Fig. 10.) Thus,

$$\frac{0.020}{0.00166} = 12.05 \text{ revolutions.}$$

In other words, it requires 12 revolutions of the spindle after the piece is cut off before the cut-off tool reaches the end of its travel. The hundredths of cam surface equivalent to 12 revolutions of the spindle are $\frac{12 \times 100}{360} = 3\frac{1}{2}$ hundredths, approximately. Therefore we assume that the screw will break off when the center of the cross-slide roll is at 94½ hundredths. As this is where the screw will break off, it is necessary to have the bushing on the work a moment previous to this. In this case we will allow 1/2 hundredth, but it is usually best to allow one hundredth of the cam surface to give the arm time to steady itself after forcing the bushing onto the work.

Having determined the point where the slotting bushing should be located on the work we can proceed to lay out the transferring and advancing cams. The method of laying out these cams is shown in Fig. 12. As previously determined, the advancing cam is not cut down below the outer circumference except for the rise for feeding the screw to the saw and dropping back, so a circle is drawn with a 2¼-inch radius as shown, which represents the largest diameter of the cams. A circle *A*, representing the path of the center of the transferring lever, is next drawn. Then a vertical line *B*, representing the path of the center of the advancing cam, is drawn. When this line and circle have been drawn, we have the relative positions of the transferring and advancing rolls. The transferring roll is ½ inch in diameter, while the advancing roll is ¾ inch, on the No. 00 machine only.

To find the starting and finishing points on the cams, proceed as follows: Draw a circle *C* representing the advancing roll on the hundredth line marked 94; then draw a quick-rise on the cam with a 1½-inch radius. As the screw will be severed from the bar at 97¼ hundredths, this is the finishing point of the lobe for placing the screw in the slotting bushing. Next construct the quick-drop on the cam and draw another circle *D*, 1/16 inch below the largest diameter of the cam, so that the arm will drop back from the chuck before it begins to rise.

Now, to determine the position of the transferring roll, draw two circles *E* and *F* of such diameters that the distance *G* equals the relative distance between the center of the transferring arm lever and the path of the center of the advancing lever; these levers swing through arcs in planes at right angles to each other.

To obtain the center of the transferring lever, relative to the path of the advancing lever, draw a line through the center of the circle *D* and tangent to the circle *F*. Then draw another line tangent to the circle *E* and parallel to the line which is tangent to the circle *F* and passes through the center of the circle *D*. The point where the last drawn line cuts the circle *A* will be the center of the transferring lever. With this point as center and the compasses set to the radius of the transferring lever, strike an arc, and with its center on this arc draw the transferring roll circle *H*, touching the smallest diameter of the cam. The quick-rise on the transferring cam is then constructed, and the finishing point of this rise is made with a ¼-inch radius, so that the speed at which the arm is traveling will be decreased as it approaches the top of its travel. If this is not done, the arm will hit the stop and rebound, which will have a tendency to knock the screw out of the slotting bushing. When the transferring roll is on the highest point of the cam, the advancing roll should be at the bottom. A clearance of

1/100 is allowed between the point when the transferring roll is on the top of the cam, and the point when the advancing roll begins to advance the screw to the saw. The starting and finishing points of the lobes on the advancing cam for advancing the screw to the saw are constructed in a manner similar to that just described.

Nothing will be gained by dropping the arm down to pick up another screw before the teat has been reduced sufficiently so that the screw can be removed; hence as much of the cam surface as possible is used for slotting, thus preventing forcing the feed too much. To find the

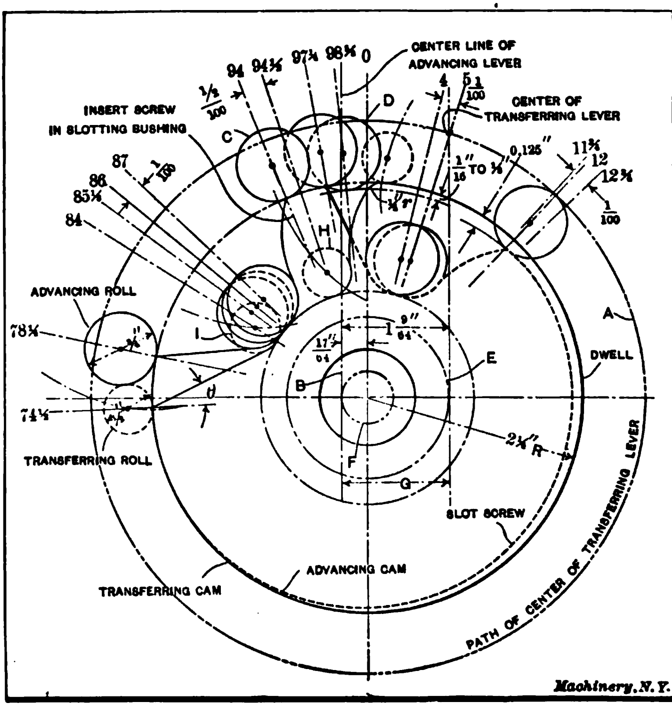


Fig. 12. Illustration showing Method of laying out Transferring and Advancing Cams

finishing point, we work backward, as it were, and locate the transferring roll at the base of the cam, as shown at *I*; then draw the quick-rise at an angle θ, which should be from 15 to 20 degrees for the No. 00 automatic screw machine. When this angle is drawn, we then have the finishing point on the transferring cam. The finishing point of the advancing cam is found by laying out the rolls in their respective positions, in the same manner as before, care being taken to retain the correct relations between the center of the transferring lever and the path of the advancing lever. This problem may seem to be rather complicated at first, but after some practice it will be found to be simple enough. A rise of 0.125 inch is generally allowed on the advancing

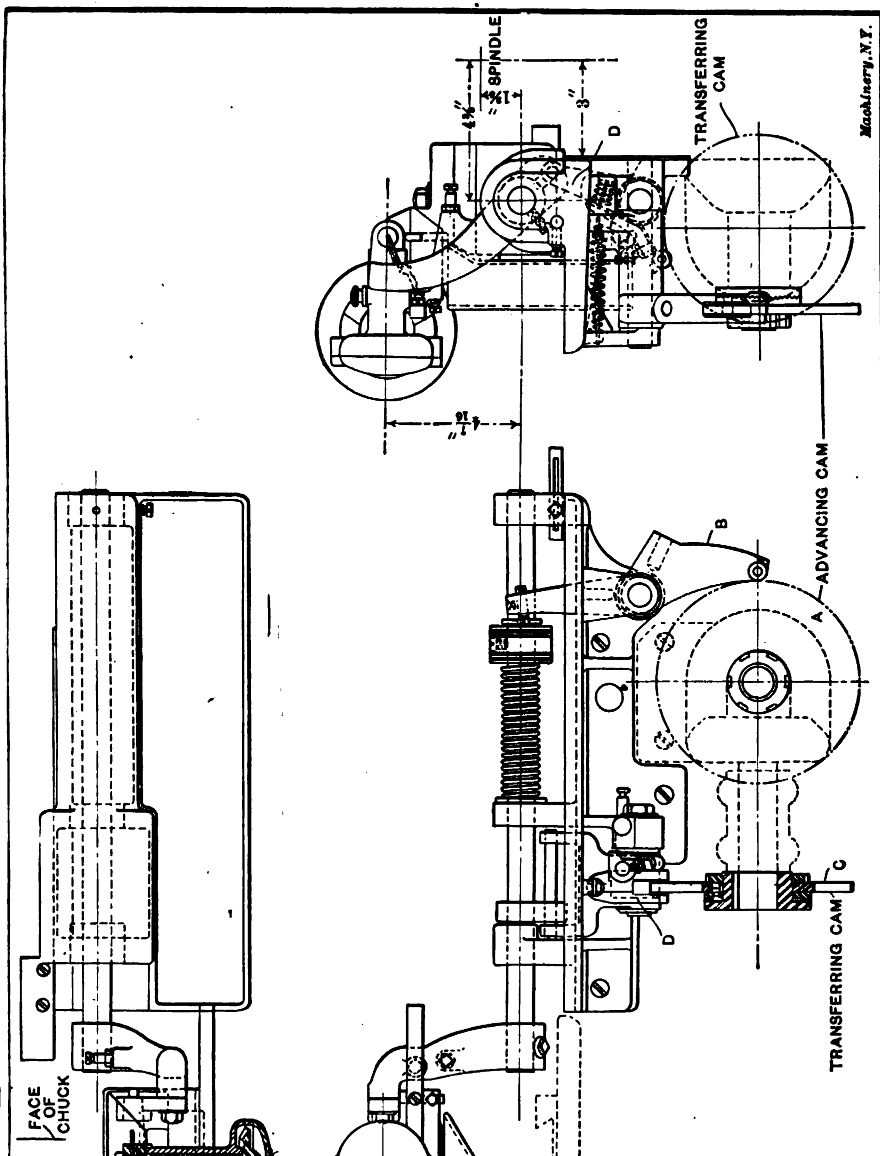


Fig. 18. Screw-slotting Attachment for the No. O Brown & Sharpe Automatic Screw Machine

cam, so that all sizes of screws within the range of the machine can be slotted with this same set of cams.

Screw-slotting Attachment for the No. 0 and No. 2 Machines

The principle on which the screw-slotting attachment for the No. 0 and No. 2 machines works does not vary from that used on the No. 00

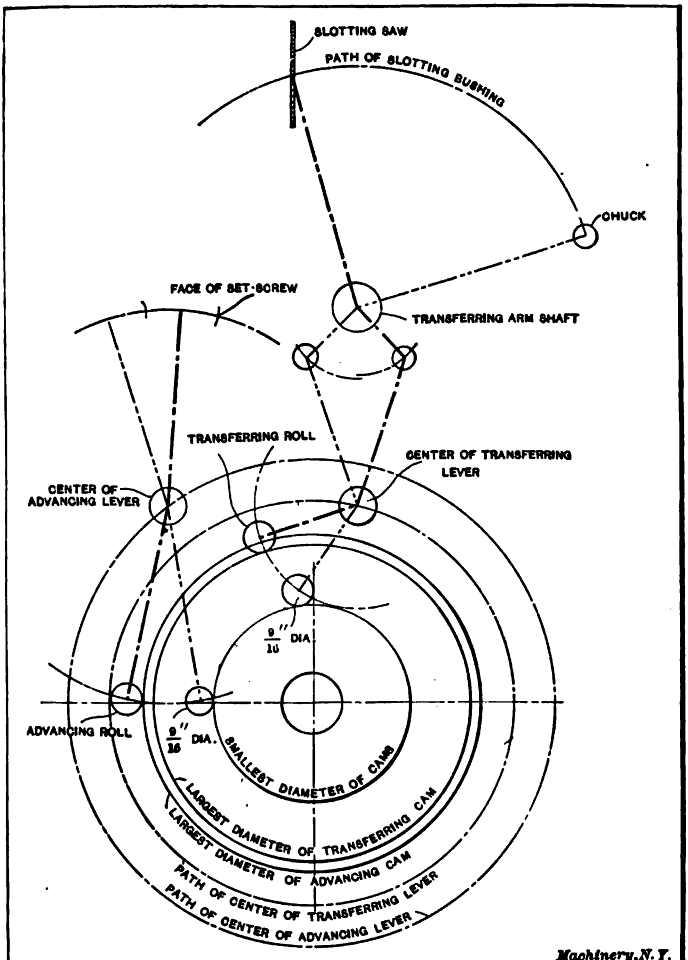


Fig. 14. Diagram used in laying out Transferring and Advancing Cams for the No. 0 Brown & Sharpe Automatic Screw Machine

machine, but the advancing and transferring cams are located differently. On the No. 00 machine, these cams are held side by side on the front cam-shaft, while in the No. 0 and No. 2 machines, the advancing cam is held on the stud which holds the lead cam, while the transferring cam is held on the front cam-shaft. The movement of the levers, of course, in this case differs from that on the No. 00 machine. Referring to the illustration Fig. 13, which shows the attachment used on the No. 0 machine, *A* is the advancing cam and *B* the advancing cam lever; *C* is the transferring cam, and *D* the transferring lever. The method of carrying the screw to the saw is similar to that on the No. 00 machine, as are also the other movements, so that this will not need further description. It is, however, necessary to describe the method of laying out the transferring and advancing cams,

The method of laying out the transferring and advancing cams is illustrated diagrammatically in Fig. 14 where the advancing and transferring levers, as well as the cams, are shown in the same plane. The method of finding the starting and finishing points of the lobes on the transferring and advancing cams is the same as that used for the ordinary cross-slide and lead cams. The only point to remember is to retain the proper distances between the centers of the levers, and to swing them into their proper positions. A templet could be made for these cams, which would simplify the problem of laying out the starting and finishing points. When a templet is not available, the method previously described for the No. 00 machine can be used; that is, keeping the center distances in the same relation, in their respective paths, and swinging the rolls into the desired position.

The screw-slotting attachment for the No. 2 Brown & Sharpe automatic screw machine does not differ from that for the No. 0 machine. The transferring cams in both these machines are made in two pieces, as it would be impossible otherwise to assemble them on the front camshaft. As there are no intermediate points at which the transferring arm is to dwell between the chuck and slotting saw, there are no calculations necessary for determining different heights on the transferring cam, the rise from the lowest to the highest point of the cam being sufficient to lift the screw from the chuck to the slotting saw.

The diagram shown in Fig. 11 should be laid out so that all the dimensions required for laying out the height of the lobes on the cams can be found. It is always advisable to allow at least one-hundredth of the cam surface for clearance, between the starting or finishing points of the lobes on the transferring or advancing cams. This allows the transferring arm to stop for a brief interval before the direction of its motion is changed.

APPENDIX

MILLING SCREW MACHINE CAMS

There are several methods used for finishing plate cams. Most methods require that the outline be accurately laid out, after which the stock is removed, generally by drilling a series of holes around the outline and breaking away the outer part. The cam is then finished to the scribed lines by milling and filing. This method, however, is slow, and the highest accuracy is not obtainable in this way.

Another method which is applicable to all cams with a constant rise is illustrated and described in the following: A diagrammatical view of the relative positions of the compound vertical milling attachment and the index head used in this method, is shown in Fig. 15. By this method constant-rise cams may be milled, so to speak, automatically, by placing the cam blank on the index head spindle, and gearing the head for spiral milling. An end-mill is held in the compound vertical milling attachment, which is adjustable to any angle in the vertical plane, as indicated. The milling attachment and the spiral head are set at a certain angle with the table surface, this angle being determined by the rise of the cam and the forward feed of the milling machine table for one turn of the index head spindle; this forward feed is usually called the spiral lead for which the machine is geared. It will be clear even to persons unfamiliar with this method, that when the table is feeding forward, the slowly revolving cam blank is fed against the cutting edge of the end-mill, and as this latter is stationary, the radius of the cam will be constantly decreased. It is the object of this article to describe a method for finding the angle to which the spiral head is to be set, and the lead for which the spiral head is to be geared, so as to obtain very accurate results when milling constant-rise cams. The formulas given below and the accompanying tables of leads obtainable on the Brown & Sharpe milling machines, and their logarithms, are used for facilitating the necessary calculations. In order to carry out the calculations by the method outlined, a table of logarithms of numbers (MACHINERY'S Reference Book No. 53) and a table of logarithms of angular functions (MACHINERY'S Reference Book No. 55) are required. In order to find the gears to be used for any spiral lead obtainable on the machine, a book entitled "Tables of Leads for Use with Universal Milling Machines," published by the Brown & Sharpe Mfg. Co., Providence, R. I., should be used.

General Formulas for the Calculations

In the following formulas let

l = lead of the cam lobe to be milled; the lead of the cam lobe is the rise of the cam if the given rate of rise were continued for one whole revolution or 360 degrees

R = rise of the cam in a given part N of the circumference,
N = the part of the circumference in which a given rise takes place; N is expressed as a decimal in hundredth of the cam circumference,
L = spiral lead for which the milling machine is geared,
α = angle to which the index head and milling attachment are to be set.

The finding of the angle α to which the index head is to be set for any specific case is most easily explained by reference to Fig. 16. In the right-angle triangle shown, the hypotenuse L represents the distance that the milling machine table will be fed forward while the

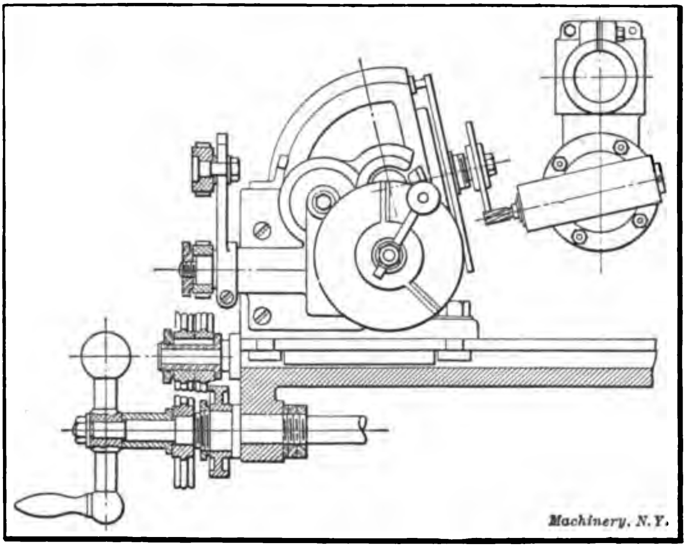


Fig. 15. Diagrammatical View showing Method of Milling Cams on the Milling Machine

index head spindle makes one complete revolution, or, in other words, L is the spiral lead for which the machine is geared. The side l in the triangle represents the rise that the cam to be milled would have in 360 degrees, or in one complete revolution; hence, this side represents the lead of the cam. It is then clear that

$$\sin = \frac{l}{L} \qquad (1)$$

$$\text{But } l = \frac{R}{N}\text{, hence: } \sin \alpha = \frac{R}{N \times L} \qquad (2)$$

It is apparent from Formula (2) that when R, N and L are known angle α can be determined. As it is not practicable, however, to set either the index head or the vertical milling attachment closer than to whole or half degrees, the lead L must be so selected that the angle

a will be within 5 minutes either way of a whole or a half degree. Hence trial calculations must be made, and it is for the purpose of facilitating these calculations that the tables on pages 36 to 38 have been prepared.

Practical Use of Tables and Formulas

The practical use of the formulas given and of the tables can be best explained by means of an example. Assume that a set of cams is designed and drawn as shown in Fig. 17, and that the toolmaker is to be given the necessary data for milling the lobes on these cams. The milling is to be done according to the method illustrated in Fig. 15. The calculations should be made by the draftsman or whoever designs the cams, and it is recommended that the results of the calculations

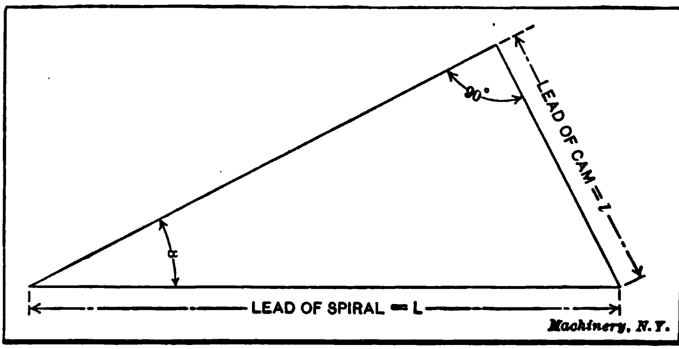


Fig. 16. Relation between Setting Angle of Index Head, Spiral Lead and Lead of Cam Lobe

be tabulated as shown in the table. Referring to the cam drawings in Fig. 17, let us first take the first lobe on the front-slide cam. Here the rise $R = 0.155$ inch and this rise takes place in 0.24 of the whole cam circumference. Hence $N = 0.24$. We have further:

$$l = \frac{R}{N} = \frac{0.155}{0.24} = 0.6458$$

and, from Formula (1):

$$\sin a = \frac{l}{L} = \frac{0.6458}{L} \qquad (3)$$

As already mentioned we must now find a lead L so selected that angle a will be within 5 minutes either way of a whole or half degree. In order to accomplish this result proceed as follows:

First find the logarithm of 0.6458:

$$\log 0.6458 = \bar{1}.81010$$

Now turn to the accompanying tables on pages 36 to 38 (Tables XI to XII). Beginning with any lead L that is *larger* than the numerator 0.6458, subtract the logarithms of the leads, as found in the tables, from the logarithm of the numerator 0.6458 until, by repeated trials,

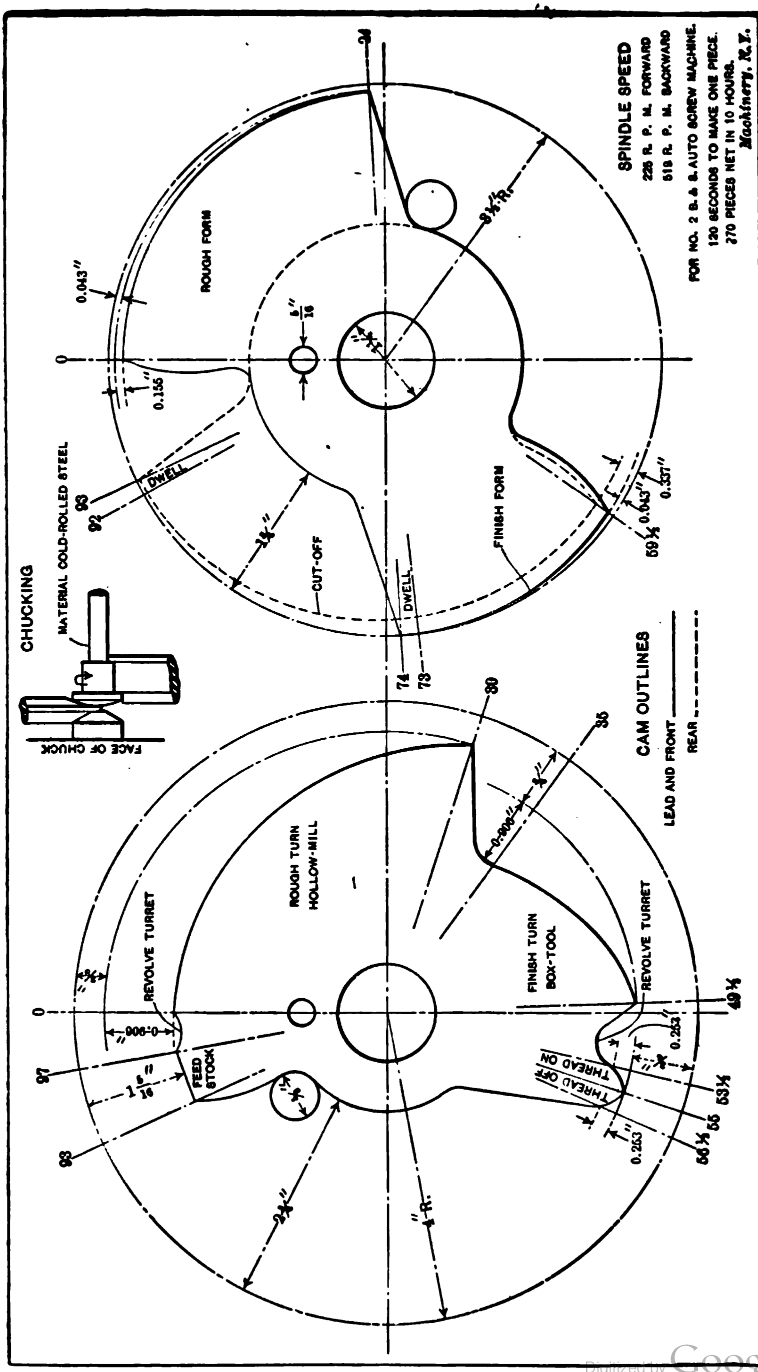


Fig. 17. Cams used as Examples in the Calculations

TABLE XI. DATA FOR MILLING SCREW MACHINE CAMS

Spiral Lead	Logarithm	Spiral Lead	Logarithm	Spiral Lead	Logarithm	Spiral Lead	Logarithm	Spiral Lead	Logarithm
0.900	$\bar{1}$.95424	1.776	0.24944	2.333	0.36791	2.894	0.46150	3.429	0.53517
0.930	$\bar{1}$.96848	1.778	0.24993	2.338	0.36884	2.909	0.46374	3.438	0.53631
0.933	$\bar{1}$.96988	1.786	0.25188	2.344	0.36996	2.917	0.46494	3.488	0.54258
1.029	0.01242	1.800	0.25527	2.368	0.37438	2.924	0.46598	3.491	0.54295
1.042	0.01787	1.809	0.25744	2.381	0.37676	2.933	0.46731	3.492	0.54307
1.047	0.01995	1.818	0.25959	2.386	0.37767	2.934	0.46746	3.500	0.54407
1.050	0.02119	1.823	0.26079	2.392	0.37876	2.946	0.46923	3.520	0.54654
1.067	0.02816	1.860	0.26951	2.400	0.38021	2.950	0.46982	3.535	0.54839
1.085	0.03543	1.861	0.26975	2.424	0.38453	2.977	0.47378	3.552	0.55047
1.116	0.04766	1.867	0.27114	2.431	0.38578	2.984	0.47480	3.556	0.55096
1.196	0.07773	1.875	0.27300	2.442	0.38775	3.000	0.47712	3.564	0.55194
1.200	0.07918	1.886	0.27554	2.445	0.38828	3.030	0.48144	3.565	0.55206
1.221	0.08672	1.905	0.27989	2.450	0.38917	3.044	0.48344	3.571	0.55279
1.228	0.08920	1.919	0.28307	2.456	0.39023	3.055	0.48501	3.572	0.55291
1.240	0.09342	1.920	0.28330	2.481	0.39463	3.056	0.48515	3.582	0.55413
1.244	0.09482	1.925	0.28443	2.489	0.39602	3.070	0.48714	3.588	0.55485
1.250	0.09691	1.944	0.28870	2.500	0.39794	3.080	0.48855	3.600	0.55630
1.302	0.11461	1.954	0.29092	2.514	0.40037	3.086	0.48940	3.618	0.55847
1.309	0.11694	1.956	0.29137	2.532	0.40346	3.101	0.49150	3.636	0.56062
1.333	0.12483	1.990	0.29885	2.537	0.40432	3.111	0.49290	3.637	0.56074
1.340	0.12710	1.993	0.29950	2.546	0.40586	3.117	0.49374	3.646	0.56182
1.371	0.13704	2.000	0.30103	2.558	0.40790	3.125	0.49485	3.655	0.56289
1.395	0.14457	2.009	0.30298	2.567	0.40943	3.126	0.49499	3.657	0.56312
1.400	0.14613	2.030	0.30750	2.571	0.41010	3.140	0.49693	3.663	0.56384
1.429	0.15503	2.035	0.30856	2.593	0.41380	3.143	0.49734	3.667	0.56431
1.433	0.15625	2.036	0.30878	2.605	0.41581	3.150	0.49831	3.673	0.56502
1.440	0.15836	2.045	0.31069	2.618	0.41797	3.175	0.50174	3.684	0.56632
1.447	0.16047	2.047	0.31112	2.619	0.41814	3.182	0.50270	3.686	0.56656
1.458	0.16376	2.057	0.31323	2.625	0.41913	3.189	0.50365	3.704	0.56867
1.467	0.16643	2.067	0.31534	2.640	0.42160	3.190	0.50379	3.721	0.57066
1.488	0.17260	2.083	0.31869	2.658	0.42455	3.198	0.50488	3.733	0.57206
1.500	0.17609	2.084	0.31890	2.667	0.42602	3.200	0.50515	3.750	0.57403
1.522	0.18241	2.093	0.32077	2.674	0.42716	3.214	0.50705	3.763	0.57553
1.527	0.18384	2.100	0.32222	2.678	0.42781	3.225	0.50853	3.771	0.57646
1.550	0.19033	2.121	0.32654	2.679	0.42797	3.241	0.51068	3.772	0.57657
1.556	0.19201	2.133	0.32899	2.700	0.43136	3.256	0.51268	3.799	0.57967
1.563	0.19396	2.143	0.33102	2.713	0.43345	3.267	0.51415	3.809	0.58081
1.595	0.20276	2.171	0.33666	2.727	0.43569	3.273	0.51495	3.810	0.58092
1.600	0.20412	2.178	0.33806	2.743	0.43823	3.275	0.51521	3.818	0.58184
1.607	0.20602	2.182	0.33885	2.750	0.43933	3.281	0.51601	3.819	0.58195
1.628	0.21165	2.188	0.34005	2.778	0.44373	3.300	0.51851	3.822	0.58229
1.637	0.21405	2.193	0.34104	2.791	0.44576	3.308	0.51957	3.837	0.58399
1.650	0.21748	2.200	0.34242	2.800	0.44716	3.333	0.52284	3.840	0.58433
1.667	0.22194	2.222	0.34674	2.812	0.44902	3.345	0.52440	3.850	0.58546
1.674	0.22376	2.233	0.34889	2.828	0.45148	3.349	0.52492	3.876	0.58838
1.680	0.22531	2.238	0.34986	2.843	0.45378	3.360	0.52634	3.889	0.58984
1.706	0.23198	2.240	0.35025	2.845	0.45408	3.383	0.52930	3.896	0.59062
1.711	0.23325	2.250	0.35218	2.849	0.45469	3.403	0.53186	3.907	0.59184
1.714	0.23401	2.274	0.35679	2.857	0.45591	3.409	0.53263	3.911	0.59229
1.744	0.24155	2.286	0.35908	2.865	0.45712	3.411	0.53288	3.920	0.59329
1.745	0.24180	2.292	0.36021	2.867	0.45743	3.422	0.53428	3.927	0.59406
1.750	0.24304	2.326	0.36661	2.880	0.45939	3.428	0.53504	3.929	0.59428

TABLE XII. DATA FOR MILLING SCREW MACHINE CAMS

Spiral Lead	Logarithm	Spiral Lead	Logarithm	Spiral Lead	Logarithm	Spiral Lead	Logarithm	Spiral Lead	Logarithm
3.977	0.59956	4.572	0.66011	5.160	0.71265	5.848	0.76701	6.548	0.81611
3.979	0.59977	4.582	0.66106	5.168	0.71332	5.861	0.76797	6.563	0.81710
3.987	0.60065	4.583	0.66115	5.185	0.71475	5.867	0.76842	6.578	0.81809
4.000	0.60206	4.584	0.66124	5.186	0.71483	5.893	0.77034	6.600	0.81954
4.011	0.60325	4.651	0.66755	5.195	0.71559	5.912	0.77173	6.645	0.82249
4.019	0.60412	4.655	0.66792	5.209	0.71675	5.920	0.77232	6.667	0.82393
4.040	0.60638	4.667	0.66904	5.210	0.71684	5.926	0.77276	6.689	0.82536
4.059	0.60842	4.675	0.66978	5.226	0.71817	5.952	0.77466	6.697	0.82588
4.060	0.60853	4.687	0.67089	5.233	0.71875	5.954	0.77481	6.698	0.82595
4.070	0.60959	4.688	0.67099	5.236	0.71900	5.969	0.77590	6.719	0.82730
4.073	0.60991	4.691	0.67127	5.238	0.71917	5.972	0.77612	6.720	0.82737
4.074	0.61002	4.714	0.67339	5.250	0.72016	5.980	0.77670	6.735	0.82834
4.091	0.61183	4.736	0.67541	5.256	0.72066	6.000	0.77815	6.750	0.82930
4.093	0.61204	4.762	0.67779	5.280	0.72263	6.016	0.77931	6.757	0.82975
4.114	0.61426	4.773	0.67879	5.303	0.72452	6.020	0.77960	6.766	0.83033
4.125	0.61542	4.778	0.67925	5.316	0.72558	6.061	0.78254	6.784	0.83149
4.135	0.61648	4.784	0.67979	5.328	0.72656	6.077	0.78369	6.806	0.83289
4.144	0.61742	4.785	0.67988	5.333	0.72697	6.089	0.78455	6.818	0.83366
4.167	0.61982	4.800	0.68124	5.347	0.72811	6.109	0.78597	6.822	0.83391
4.186	0.62180	4.813	0.68242	5.348	0.72819	6.112	0.78618	6.825	0.83410
4.200	0.62325	4.821	0.68314	5.357	0.72892	6.122	0.78689	6.857	0.83613
4.242	0.62757	4.849	0.68565	5.358	0.72900	6.125	0.78711	6.875	0.83727
4.253	0.62870	4.861	0.68673	5.375	0.73038	6.137	0.78796	6.880	0.83759
4.264	0.62982	4.884	0.68878	5.400	0.73239	6.140	0.78817	6.944	0.84161
4.267	0.63012	4.889	0.68922	5.413	0.73344	6.143	0.78838	6.945	0.84167
4.278	0.63124	4.898	0.69002	5.426	0.73448	6.160	0.78958	6.952	0.84211
4.286	0.63205	4.900	0.69020	5.427	0.73456	6.171	0.79036	6.977	0.84367
4.300	0.63347	4.911	0.69117	5.444	0.73592	6.172	0.79043	6.982	0.84398
4.320	0.63548	4.914	0.69144	5.455	0.73679	6.202	0.79253	6.984	0.84410
4.341	0.63759	4.950	0.69461	5.469	0.73791	6.222	0.79393	7.000	0.84510
4.342	0.63769	4.961	0.69557	5.473	0.73823	6.234	0.79477	7.013	0.84590
4.361	0.63959	4.978	0.69705	5.486	0.73926	6.250	0.79588	7.040	0.84757
4.363	0.63979	4.984	0.69758	5.500	0.74036	6.255	0.79623	7.071	0.84948
4.364	0.63988	5.000	0.69897	5.556	0.74476	6.279	0.79789	7.104	0.85150
4.365	0.63998	5.017	0.70044	5.568	0.74570	6.286	0.79837	7.106	0.85163
4.375	0.64098	5.023	0.70096	5.581	0.74671	6.300	0.79934	7.111	0.85193
4.386	0.64207	5.029	0.70148	5.582	0.74679	6.343	0.80229	7.130	0.85309
4.400	0.64345	5.040	0.70243	5.600	0.74819	6.350	0.80277	7.143	0.85388
4.444	0.64777	5.074	0.70535	5.625	0.75012	6.364	0.80373	7.159	0.85485
4.465	0.64982	5.080	0.70586	5.657	0.75259	6.379	0.80475	7.163	0.85509
4.466	0.64992	5.088	0.70655	5.698	0.75572	6.396	0.80591	7.167	0.85534
4.477	0.65099	5.091	0.70680	5.714	0.75694	6.400	0.80618	7.176	0.85588
4.479	0.65118	5.093	0.70697	5.730	0.75815	6.417	0.80733	7.200	0.85733
4.480	0.65128	5.105	0.70800	5.733	0.75838	6.429	0.80814	7.268	0.86141
4.500	0.65321	5.116	0.70893	5.756	0.76012	6.450	0.80956	7.272	0.86165
4.522	0.65533	5.119	0.70919	5.759	0.76035	6.460	0.81023	7.273	0.86171
4.537	0.65677	5.120	0.70927	5.760	0.76042	6.465	0.81057	7.292	0.86285
4.545	0.65753	5.133	0.71037	5.788	0.76253	6.482	0.81171	7.310	0.86392
4.546	0.65763	5.134	0.71046	5.814	0.76448	6.512	0.81371	7.314	0.86415
4.548	0.65782	5.142	0.71113	5.818	0.76477	6.515	0.81391	7.326	0.86487
4.558	0.65877	5.143	0.71122	5.833	0.76589	6.534	0.81518	7.330	0.86510
4.567	0.65963	5.156	0.71231	5.847	0.76693	6.545	0.81591	7.333	0.86528

TABLE XIII. DATA FOR MILLING SCREW MACHINE CAMS

Spiral Lead	Logarithm	Spiral Lead	Logarithm	Spiral Lead	Logarithm	Spiral Lead	Logarithm	Spiral Lead	Logarithm
7.334	0.86534	8.081	0.90747	8.953	0.95197	9.828	0.99247	10.800	1.03342
7.347	0.86611	8.103	0.90859	8.959	0.95226	9.844	0.99317	10.853	1.03555
7.371	0.86753	8.119	0.90950	8.960	0.95231	9.900	0.99564	10.859	1.03579
7.372	0.86759	8.140	0.91062	8.980	0.95328	9.921	0.99656	10.909	1.03778
7.400	0.86923	8.145	0.91089	9.000	0.95424	9.923	0.99664	10.913	1.03794
7.408	0.86970	8.148	0.91105	9.044	0.95636	9.943	0.99752	10.937	1.03890
7.424	0.87064	8.149	0.91110	9.074	0.95780	9.954	0.99800	10.945	1.03922
7.442	0.87169	8.163	0.91185	9.091	0.95861	9.967	0.99856	10.949	1.03937
7.465	0.87303	8.167	0.91206	9.115	0.95976	9.968	0.99861	10.972	1.04029
7.467	0.87315	8.182	0.91286	9.134	0.96066	10.000	1.00000	11.000	1.04139
7.500	0.87506	8.186	0.91307	9.137	0.96080	10.033	1.00143	11.021	1.04222
7.525	0.87651	8.212	0.91445	9.143	0.96109	10.046	1.00199	11.057	1.04364
7.543	0.87754	8.239	0.91585	9.164	0.96209	10.057	1.00247	11.111	1.04575
7.576	0.87944	8.250	0.91645	9.167	0.96223	10.078	1.00337	11.137	1.04677
7.597	0.88064	8.306	0.91939	9.210	0.96426	10.080	1.00346	11.160	1.04766
7.601	0.88087	8.312	0.91971	9.214	0.96445	10.101	1.00436	11.163	1.04778
7.611	0.88144	8.333	0.92080	9.260	0.96661	10.159	1.00685	11.169	1.04801
7.619	0.88190	8.334	0.92085	9.302	0.96858	10.175	1.00753	11.198	1.04914
7.620	0.88195	8.361	0.92226	9.303	0.96862	10.182	1.00783	11.200	1.04922
7.636	0.88287	8.372	0.92283	9.333	0.97002	10.186	1.00800	11.225	1.05019
7.639	0.88304	8.377	0.92309	9.334	0.97007	10.209	1.00898	11.250	1.05115
7.644	0.88332	8.400	0.92428	9.351	0.97086	10.228	1.00979	11.313	1.05358
7.657	0.88406	8.437	0.92619	9.375	0.97197	10.233	1.01000	11.314	1.05362
7.674	0.88502	8.457	0.92722	9.382	0.97230	10.238	1.01022	11.363	1.05549
7.675	0.88508	8.484	0.92860	9.385	0.97243	10.267	1.01144	11.401	1.05694
7.679	0.88530	8.485	0.92865	9.406	0.97340	10.286	1.01225	11.429	1.05801
7.680	0.88536	8.506	0.92973	9.428	0.97442	10.312	1.01334	11.454	1.05896
7.700	0.88649	8.523	0.93059	9.429	0.97447	10.313	1.01338	11.459	1.05915
7.714	0.88728	8.527	0.93080	9.460	0.97589	10.320	1.01368	11.467	1.05945
7.752	0.88941	8.532	0.93105	9.472	0.97644	10.336	1.01435	11.512	1.06115
7.778	0.89087	8.534	0.93115	9.524	0.97882	10.370	1.01578	11.518	1.06138
7.792	0.89165	8.552	0.93207	9.545	0.97978	10.371	1.01582	11.520	1.06145
7.813	0.89282	8.556	0.93227	9.546	0.97982	10.390	1.01662	11.574	1.06348
7.815	0.89293	8.572	0.93308	9.547	0.97987	10.417	1.01774	11.629	1.06554
7.818	0.89310	8.594	0.93420	9.549	0.97996	10.419	1.01783	11.638	1.06588
7.838	0.89421	8.600	0.93450	9.556	0.98028	10.451	1.01916	11.667	1.06696
7.855	0.89515	8.640	0.93651	9.569	0.98087	10.467	1.01982	11.688	1.06774
7.857	0.89526	8.681	0.93857	9.598	0.98218	10.473	1.02007	11.695	1.06800
7.872	0.89609	8.682	0.93862	9.600	0.98227	10.476	1.02020	11.719	1.06889
7.875	0.89625	8.687	0.93887	9.625	0.98340	10.477	1.02024	11.721	1.06896
7.883	0.89669	8.721	0.94057	9.643	0.98421	10.500	1.02119	11.728	1.06922
7.920	0.89873	8.727	0.94086	9.675	0.98565	10.558	1.02358	11.733	1.06941
7.936	0.89960	8.730	0.94101	9.690	0.98632	10.571	1.02412	11.757	1.07030
7.954	0.90059	8.750	0.94201	9.697	0.98664	10.606	1.02555	11.785	1.07133
7.955	0.90064	8.772	0 94310	9.723	0.98780	10.631	1.02657	11.786	1.07137
7.963	0.90108	8.800	0.94448	9.741	0.98860	10.655	1.02755	11.825	1.07280
7.974	0.90168	8.838	0.94635	9.768	0.98981	10.659	1.02772	11.852	1.07379
7.994	0.90276	8.839	0.94640	9.773	0.99003	10.667	1.02804	11.905	1.07573
8.000	0.90309	8.889	0.94885	9.778	0.99025	10.694	1.02914	11.938	1.07693
8.021	0.90423	8.909	0.94983	9.796	0.99105	10.713	1.02991	11.944	1.07715
8.035	0.90499	8.929	0.95080	9.818	0.99203	10.714	1.02995	11.960	1.07773
8.063	0.90650	8.930	0.95085	9.822	0.99220	10.750	1.03141	12.000	1.07918

a remainder is obtained which is the logarithm of the sine of an angle which is within 5 minutes of a whole or a half degree. The angle thus found is the setting angle for the index head and the lead giving this angle is the one for which the head is to be geared. Proceeding according to the directions given above we have:

$$\begin{array}{rl} & \log 0.6458 = \bar{1}.81010 \\ \text{(Subtract)} & \log 0.900 \;\; = \bar{1}.95424 \\ \hline & \log \sin a = \bar{1}.85586 \end{array}$$

From a table of logarithms of sines we find that a = 45 degrees 51 minutes. As this angle is not within 5 minutes of a whole or a half degree, try the next lead in Table XI, as follows:

$$\begin{array}{rl} & \log 0.6458 = \bar{1}.81010 \\ \text{(Subtract)} & \log 0.930 \;\; = \bar{1}.96848 \\ \hline & \log \sin a = \bar{1}.84162 \end{array}$$

Hence a = 43 degrees 59 minutes.

This angle fills the requirements. No more trials are, therefore, required, and the index head and the compound vertical milling attachment are to be set to 44 degrees; the gears to use for gearing the spiral head for 0.930 inch lead are found from Brown & Sharpe Mfg. Co.'s book "Table of Leads for Use with Universal Miling Machines," as aready mentioned.

In using this method, the following conditions must be taken into consideration:

If a spiral lead can be found in the accompanying tables which is exactly equal to the numerator l in the fraction giving sin a in Formula (1), then this lead is the lead for which the spiral head is to be geared. It will be seen that sin a in this case becomes equal to 1, which is the sine of 90 degrees. This indicates that the compound vertical milling attachment and the index head are to be set in a vertical position. The calculations required for this case then become very simple, as no further trials are necessary.

Especial attention should be given to the fact that the spiral leads L used in the trial calculations must be larger than the numerator l in the fraction giving sin a in Equation (1). If the number expressing the lead were not greater than the numerator, the value of the fraction would be greater than 1, but as the sines of all angles are smaller than 1, this would be an impossible condition.

In finding the lead corresponding to a suitable angle, a simple way is to write the logarithm of the lead L on the upper edge of a second sheet of paper and to hold this under the originally written value of the logarithm of the numerator l in Formula (1), putting the difference on the second sheet of paper until a logarithm of sin a is found, giving a suitable angle, as explained above. This saves repeating the writing down of the logarithm of the numerator l for each trial subtraction.

As another example illustrating what has been said, we may calculate the first lobe on the lead cam. Here $L = 0.906$, $N = 0.30$. Hence

$$l = \frac{0.906}{0.30} = 3.02.$$

It is found by repeated trials, starting with $L = 3.03$, that no lead gives an angle α even approximately within the given requirements, before we come to the lead 3.111:

$$\log 3.02 = 0.48001$$
(Subtract) $$\log 3.111 = 0.49290$$
$$\log \sin \alpha = \bar{1}.98711$$

Hence α = 76 degrees 6 minutes.

TABLE XIV. RESULTS OBTAINED BY THE CALCULATIONS FOR ANGLE AND LEAD

Piece No. 4-817
Computed by H. W. E.
Checked by W. W. J.
Date: Nov. 17, 1910

Name of Cam	Rise on Cam in Inches	Number of Hundredths	Angle α in Degrees	Lead in Inches	Gear on Worm	First Gear on Stud	Second Gear on Stud	Gear on Screw
Lead cam	0.906	30	76	3.111	40	72	56	100
Lead cam	0.906	14½	80	6.343	100	44	24	86
Front cam	0.155	24	44	0.930	24	72	24	86
Front cam	0.043	18½	20	0.930	24	72	24	86
Rear cam	0.337	32½	82	1.047	24	64	24	86

While the angle 76 degrees 6 minutes is not quite within the limits that we have specified, it is so nearly so that it is safe enough to assume the setting angle to be 76 degrees, the corresponding lead being 3.111. We can calculate the actual rise of the cam with this lead and angle and compute the error resulting in the rise. From Formula (2) we have:

$$R = \sin \alpha \times N \times L \qquad (4)$$

Inserting $\alpha = 76$ degrees, $N = 0.30$, and $L = 3.111$, we obtain $R = 0.9056$ inch.

The error in the rise thus is 0.0004 inch, which for all practical purposes can be disregarded. The same method is employed for the other lobes. With a little practice, the work can be carried on rapidly, and the method is very simple to remember.

While it is the best practice always to use a spiral lead which corresponds to an angle within 5 minutes of a whole or half degree, as stated, yet a considerable amount of time may be saved in milling cam lobes with several leads, when the greatest accuracy may not be required, by gearing the machine for the greatest lead of lobe and changing the setting angle of the head for the other leads.

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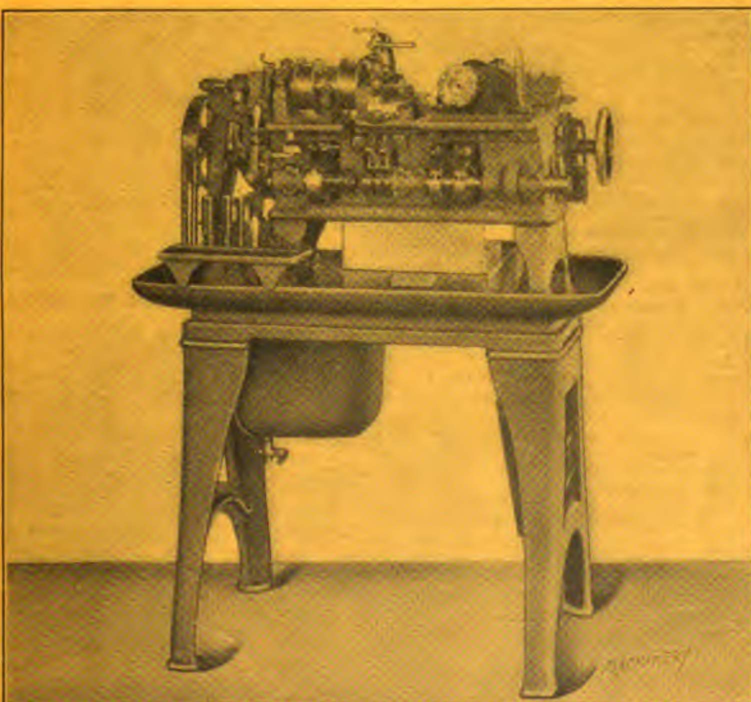

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PART III

CIRCULAR FORM AND CUT-OFF TOOLS FOR THE BROWN & SHARPE AUTOMATIC SCREW MACHINE

By DOUGLAS T. HAMILTON

CONTENTS

APPENDIX

Automatic Screw Machine Practice for the Brown & Sharpe automatic screw machines is covered in eight Reference Books, Nos. 99 to 106, inclusive. Reference Book No. 99, "Operation of the Brown & Sharpe Automatic Screw Machines," deals with the construction of these machines and the setting-up of the tools. No. 100, "Designing and Cutting Cams for Automatic Screw Machines," gives detailed instruction on cam design, and describes a simplified method for milling cams. No. 101, "Circular Form and Cut-off Tools for the Automatic Screw Machine," deals with the general arrangement and the calculations of these tools, and describes the different methods employed in their making. No. 102, "External Cutting Tools for the Automatic Screw Machine," deals with the design and construction of box-tools, taper turning tools, hollow mills, and shaving tools. No. 103, "Internal Cutting Tools for the Automatic Screw Machine," deals with centering tools, cross-slide drilling attachments, counterbores, reamers, and recessing tools. No. 104, "Threading Operations on the Automatic Screw Machine," treats on cam design for threading operations, threading dies, taps and tap drills, die and tap holders, and thread rolling. No. 105, "Knurling Operations on the Automatic Screw Machine," describes the construction of knurling holders, and gives directions for the making of knurls and the design of tools and cams used in connection with knurling operations. No. 106, "Milling, Cross-drilling and Burring Operations on the Automatic Screw Machine," describes screw-slotting attachments, index drilling attachments, and burring attachments, giving directions for their use and for the design of cams for them.

CHAPTER I

GENERAL ARRANGEMENT OF CIRCULAR FORM AND CUT-OFF TOOLS

When any given piece of work is to be made on the screw machine, the methods of arranging the operations and the tools to be used should be decided upon before designing the cams. One of the first things to consider is the method of applying the circular form and cut-off tools. The methods, of course, will vary to a considerable extent, according to the shape of the piece to be made.

Forming with circular tools as shown in Fig. 1, when the piece permits, is usually the best and quickest method; it is quicker than using the turret tools, on account of eliminating the necessity of revolving the turret. The tools can also be easily and quickly changed when setting up for another piece. This method is recommended when the length of the work is not more than 2½ times the smallest diameter of the piece when finished. For example, when the smallest diameter *a* in Fig. 1 is ¼ inch and dimension *b* not more than ⅝ inch, it is most economical to use the form and cut-off tool method. The operations for making the piece would be as follows: The stock is first fed out to the stop, then the form tool *A* is brought in, forming the body *a*, and just as the tool *A* is finishing, the tool *B* is brought in and severs the piece from the bar. Another example is shown in Fig. 2 where a shouldered screw is being made; here the tool *C* is brought in and forms the part *c* and the neck *e;* then the die threads the screw, and the tool *D* is brought in and severs the piece from the bar, and forms the part *d* for the next screw at the same time; the stock is then fed out to the stop and the operations continued. This order of operations necessitates one complete revolution of the turret, for each screw, and if the time utilized by the tools *C* and *D* is not long enough to allow the turret to be revolved, so as to bring the stop into position for the next piece, additional time would have to be allowed for revolving the turret.

Applications of Circular Tools

When making short screws similar to that shown at *A*, Fig. 3, where the circular form and cut-off tools finish the screw, except for the threading, it is good practice to apply the circular tools as shown, and if the time utilized by the tools is not long enough so that the turret can be revolved to bring the stop into position for the next piece, two sets of tools, *viz.*, two stops and two die holders, should be used in the turret. The method shown at *B*, Fig. 3, is not commendable, inasmuch as the feeding of the stock varies to such an extent that the form tool will break off the screw when the latter is much reduced at *a*, in case there be an excessive amount to face off the end of the screw. The turret would also require to be indexed, to clear the slotting arm, so that very little time could be saved by adopting a method of this description, except when the part *a* is large in diameter and the screw is short in length.

When a box-tool or hollow-mill follows the forming operation, the forming tool should be beveled, as shown at *e* in *C*; this leaves a beveled shoulder on the pieces, so that when the box-tool or hollow-mill is fed as shown at C_1, it completely removes the superfluous material without leaving the objectionable ring which would be produced if the face of the form tool were square, as shown at *b* in C_2. This ring of metal is shown at *c* in C_2; it prevents the finishing box-tool or die from being fed up to the shoulder. It is clearly seen that the ring would have to be removed in any case. The cut-off tool should bevel the end of the stock, as shown at *d* in *C*, in order to permit the starting of the box-tool on a light cut, until the back rests have a good support; the bevel also locates the hollow-mill and equalizes the cutting

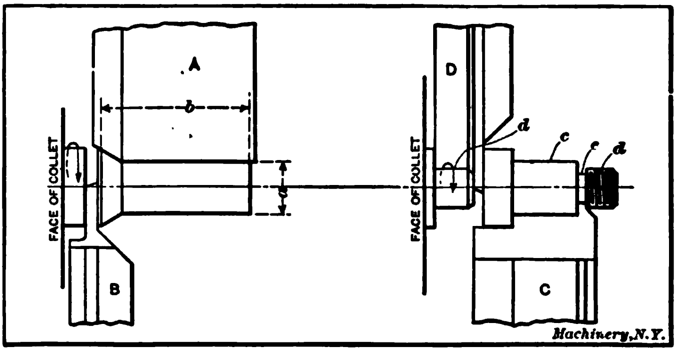


Fig. 1. Illustration showing Relation between Smallest Diameter of Work and Length of Forming Tool

Fig. 2. Illustration showing a Case where the Cut-off Tool forms Part of the Piece

pressure on the teeth. The previous examples apply to the making of screws, but the principles involved are also, of course, applicable to the forming of other parts.

It is obvious that, as the conditions under which the work is done and the limits allowed on it vary widely, it would be impracticable to lay down hard and fast rules in regard to the application of circular tools, but the following suggestions will be found applicable to general conditions. At *D*, Fig. 3, is shown a method sometimes used to advantage in making shouldered screws or other pieces of a similar character. This forming operation is not recommended when the piece to be made is required to be very accurate, as a slight eccentricity in the spring collet would cause the part *f* to be out of true with the part *g*. In cases where accuracy is required, the part *g* could be roughed down with the cut-off tool and a light finishing cut taken with a box-tool. At D_1 is shown an improved method of forming the same piece, as the form tool here removes the burr from the head.

In applying circular tools, the question of gaging the pieces must be carefully considered, as in some cases, when difficult shapes are to be

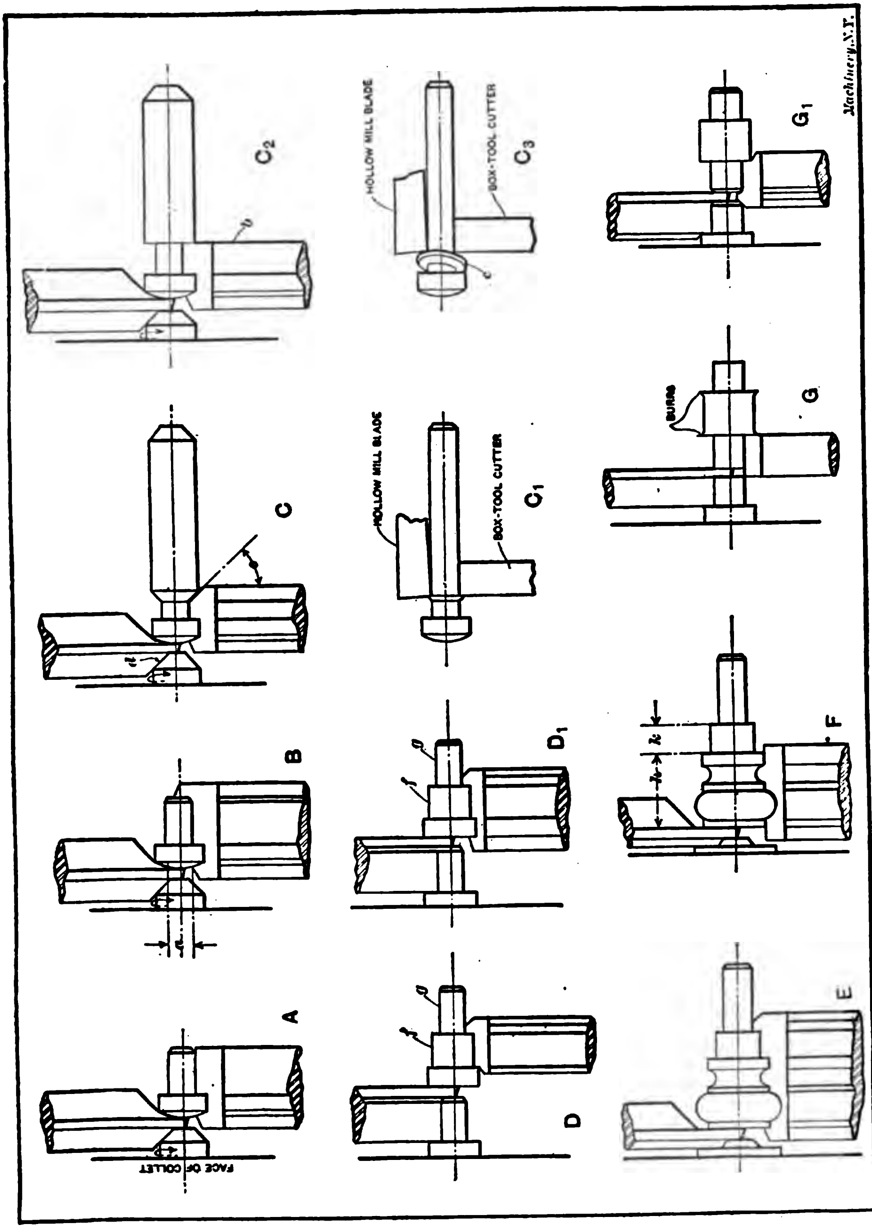


Fig. 3. Examples of Applications of Circular Form and Cut-off Tools

formed, it is advisable, if possible, to use the forming tool for this purpose, thus avoiding the making of expensive gages, which is usually necessary when more than one tool is used. The piece shown at *E*, Fig. 3, will require a box-tool, forming tool and cut-off tool; if made as shown, it will be seen that no gaging is necessary, except for diameters and over-all length, the latter not being required to be very accurate. At *F*, a piece of the same shape is shown; three tools are used as before, but the cut-off tool is used to finish part *h* to the required length and the box-tool to finish the shoulder *k* to correct length. It will readily be seen that a more expensive gage will be

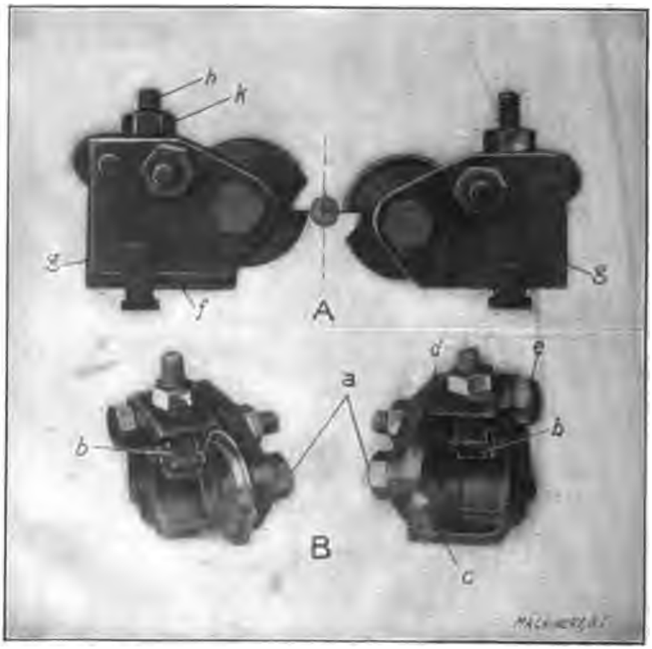


Fig. 4. Holders for Circular Form and Cut-off Tools

required for gaging the parts *h* and *k*, and considerable time will be lost in setting up the tools, after grinding, in their correct relation to each other, so as to insure that the part *h* of the piece to be made be formed the correct length.

It is generally necessary to provide means for removing the objectionable burrs thrown up by the forming tools, as shown at *G*, Fig. 3. The burrs are caused by the tools becoming dull and by the rubbing of the forming tools on the sides of the cut, due to lack of side clearance on the side of the forming tools. By adding a beveled edge to the tools as shown at G_1, the burrs are removed; this adds slightly to the cost of the tools, but in the majority of cases the results produced warrant the extra expense.

Holding Circular Form and Cut-off Tools

The method by which circular tools are held should be carefully considered, otherwise satisfactory results will not be obtained. If, for instance, the tool-holder is light and improperly supported, chattering will result when long work is formed. To prevent this, the tool-holder should be well proportioned and held rigidly upon the cross-slide. The half-tones *A* and *B*, Fig. 4, illustrate a suitable holder for general work, which is supplied by the Brown & Sharpe Mfg. Co. with their various types of automatic screw machines. This holder embodies all the essential features necessary for obtaining good results, *viz.*: rigidity, means to prevent the tool from rotating while cutting, suitable adjustment, provision for periphery clearance, means for adjusting the tool at right angles to the work, and means for the securing of the holder to the cross-slide.

The form tool is firmly clamped against the face of the holder by means of cap-screw *a* and clamping bolt *b*; the latter is used to keep the tool from turning while cutting. Care should be taken when

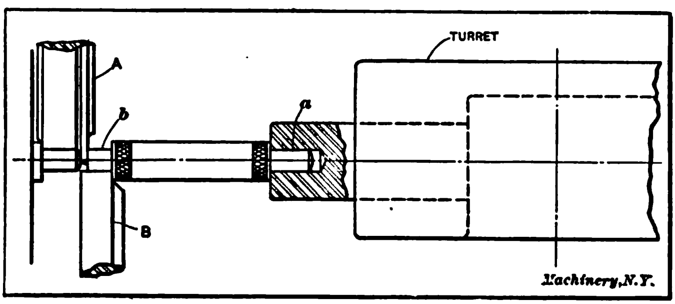


Fig. 5. Method of Supporting Long Work

designing the circular tools, so that the clamping bolt *b* gets an ample bearing on the side of the tool as otherwise the clamping bolt will in time become bent, as shown by the dotted lines in the half-tone *B*, which would impair its efficiency as a clamping device. Plate *d* and eccentric bolt *e* are provided for obtaining a slight adjustment when setting the cutting-edge of the tool in the correct relation to the center of the work. The block *f* is used for raising the tool when the cutting edge is cut below the center. At *g* are two screws, not shown in the half-tone, by means of which the tool can be set at right angles to the work. The holder is clamped to the cross-slide by the bolt *h* and nut *k*. Numerous types of holders for holding circular tools have been designed, the principles involved being in most cases similar to those of the one described.

Supporting Long Work while Forming

It is sometimes found necessary to support long work while forming, especially when the piece being formed is turned down on both ends. The work is generally supported by a support held in the turret, which, in the majority of cases, can also be used as a stop. In Fig. 5

is shown a piece which is being supported in this manner. The part *a* is formed by the tool *A* and the stock is then fed out into the support which in this case also acts as a stop; the tool *B* then forms the part *b*. This kind of a support works satisfactorily on work which is not required to be very accurate and which is left plain, *i. e.*, not threaded on part *a*. In some cases both ends are to be knurled; then a support of this description cannot be used to advantage.

In Fig. 6 is shown a method which will work satisfactorily when the piece is threaded or knurled. The work operated on is shown in position, supported by a movable slide *A* held in a holder *B;* slide *A* carries two hardened and ground supporting rollers *C*. It is forced

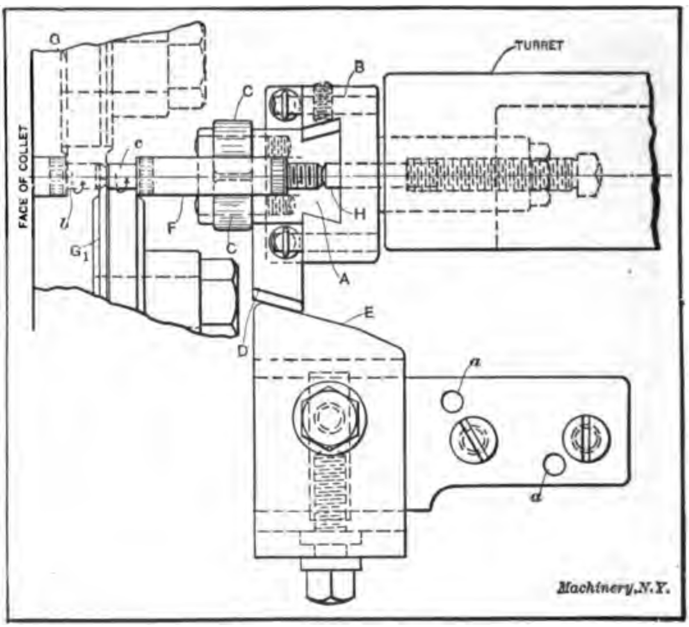


Fig. 6. Improved Method of Supporting Long Work

up against the work by cam *D*, which in turn is operated by the cam attachment *E*. To fasten the cam attachment to the machine, as shown in Fig. 6, the stop which is used for locating the slotting arm when it is in position to travel onto the work, is removed, and the cam attachment is screwed down in its place. Two dowel pins *a* have been added to the cam attachment to hold it rigid.

A detailed view of the cam attachment is shown in Fig. 7, from which the operating parts can be clearly understood; the combination stop and support is shown in Fig. 8. The operations to produce the piece *F*, Fig. 6, would be as follows: The part *b* is left to project out of the chuck far enough so as to allow it to be threaded. To start the operations, the part *b* is formed and threaded; then, after the die leaves the work, the turret is revolved, the support is brought into position and the stock is fed out and gaged to length by the stop *H*. The spindle is left running backwards and the tool G_1 forms the part

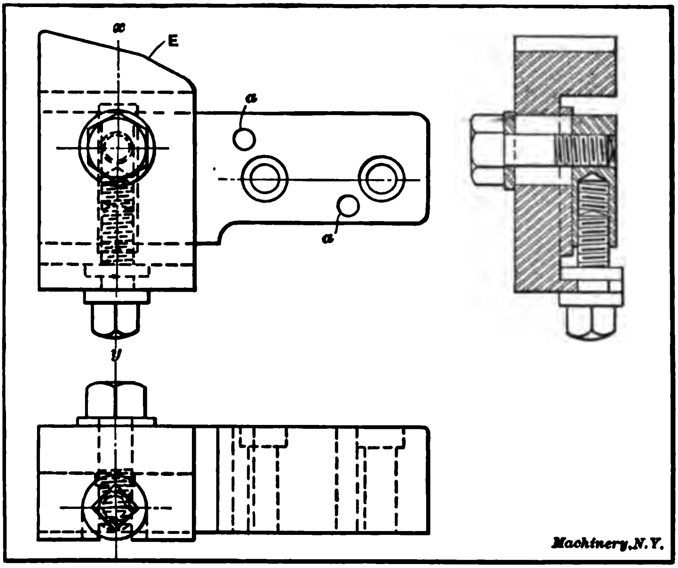


Fig. 7. Cam Attachment used in Connection with the Arrangement for Supporting Long Work shown in Fig. 6

c. After the form tool G_1 has finished its work, a knurl-holder, not shown in the illustration, travels over the work and knurls the ends. The cut-off tool *G* severs the finished piece from the bar, at the same

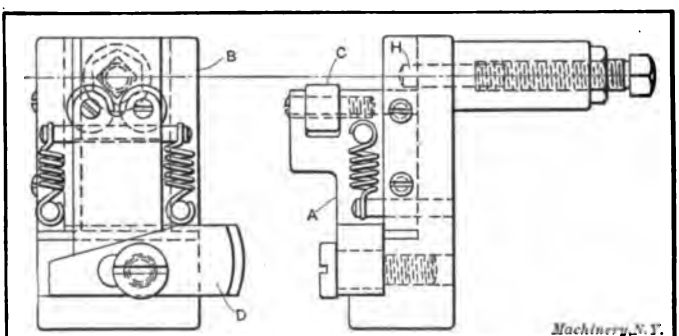


Fig. 8. Combination Stop and Support used in Arrangement for Supporting Long Work shown in Fig. 6

time forming the part *b* of the next piece. The support can be withdrawn after knurling, or left in position until the piece is cut off, when the turret is revolved and the piece drops out.

Arrangement of Circular Tools

When applying circular tools to the Brown & Sharpe automatic screw machines, the arrangement of the tools has an important bearing on the results obtained. The various ways of arranging the circular tools, with relation to the rotation of the spindle, are shown at *A*, *B*, *C*, and *D*, Fig. 9. These diagrammatical views are to be considered as being seen looking from the turret towards the face of the chuck. The arrangement at *A* gives good results for long forming on brass, steel or gun-screw iron, for the reason that the pressure of the cut is downward and hence the work is supported and held more rigidly than when the form tool is turned upside down on the front slide as shown at *B*; here the stock turning up towards the tool has a tendency to lift the cross-slide, causing chattering; therefore, the

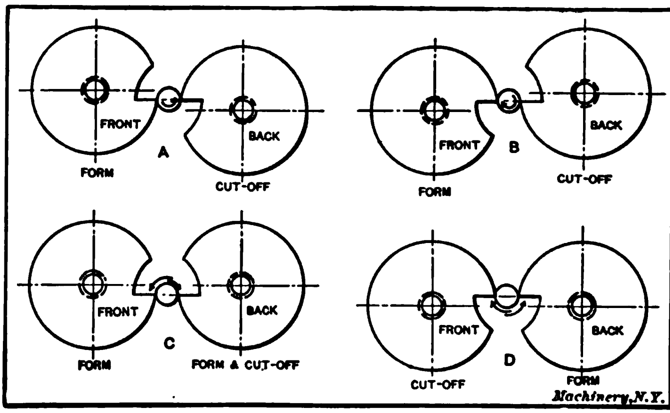


Fig. 9. Different Arrangements of Circular Tools

arrangement shown at *A* is recommended when a high finish is desired. The arrangement at *B* works satisfactorily when forming short steel pieces which do not require a high finish, as it allows the cuttings to drop clear of the work, and also allows a good supply of oil to reach the tools. This arrangement gives good results when making screws when the form and cut-off tools operate after the die, as no time is lost in reversing the spindle. The arrangement at *C* is recommended for heavy cutting on large work, when both tools are used for forming the piece; a rigid support is then necessary for both tools and a good supply of oil is also required. The arrangement at *D* is objectionable, and should be avoided, being used only when a left-hand thread is cut on the piece, and when the cut-off tool is used on the front slide, leaving the heavy cutting to be performed from the rear slide. In all "cross-forming" work, it is essential that the spindle be kept in good condition, and that the collet or chuck have a parallel contact upon the bar which is being formed.

CHAPTER II

CALCULATIONS FOR FORMING TOOLS

In the making of spherical head screws or other spherical work, the circular form tool is generally used for forming part of the head, leaving the part attached to the bar to be finished by the cut-off tool. This method has become general practice on the Brown & Sharpe automatic screw machines and has proved, without a doubt, to be the most economical and efficient method of performing operations of this description. In order to produce the best results by the above method, the radius of the cut-off tool should be struck off in "advance" of the edge of the tool, as will be described later; otherwise a result will be produced as shown at *a*, Fig. 12, a ridge being formed on the head. The circular form tool should be designed first, and should be made so that the circular cut-off tool will have as little as possible to form when cutting the piece from the bar. The amount that the form tool reduces the bar, as shown at *b*, Fig. 12, is governed by the operations following the forming cut. If heavy cuts are taken, the part *b* should be strong enough to resist the twisting action produced; therefore, it is not always advisable to cut a thread (especially if it be of coarse pitch) after the piece has been considerably reduced by the form tool.

In designing the form tool, there are certain dimensions which must be derived by calculation. Referring to Fig. 10:

Let $r = \text{radius of stock} = \frac{D}{2}$,

R = radius of head of screw or piece,
D_1 = distance from axis of head to point of tool,
D = diameter of head of piece,
T = thickness of head,
r_1 = radius of body of screw or piece,
O = the dimension required to be found by calculation.

Then $O = \sqrt{R^2 - D_1^2} - (R - T)$.

For example, let $r = 0.175$ inch, $R = 0.178$ inch, $D_1 = 0.062$ inch, $T = 0.156$ inch.

Then $O = \sqrt{0.178^2 - 0.062^2} - (0.178 - 0.156) = 0.145$ inch.

Assume further that a form tool is to be made to form a piece as shown in Fig. 10; $r = 0.175$ inch; $r_1 = 0.043$ inch; then assume the largest diameter A of the form tool to be 1.750 inch; the diameter B will then be:

$A - 2(D_1 - r_1) = 1.750 - 2(0.062 - 0.043) = 1.712$ inch, and the diameter C will be:

$A - 2(r - r_1) = 1.750 - 2(0.175 - 0.043) = 1.486$ inch.

In the above calculations the "cut-down" below the horizontal center line is not taken into consideration when finding the various diameters, but if the forms produced require to be accurate, the differences should be calculated. This question will be treated further on in this chapter.

The feed of the circular cut-off tool should be decreased at the end of the cut, so as to leave as small a teat as possible on the work. The teat varies according to the radius of the formed piece, the size of the piece, and the nature of the material. It is, therefore, impossible to specify any exact size of teat, but the results of a few experiments would not be out of place here, as they will give a fair idea of the sizes of teats left on various classes of work. The teat left on small brass screws varies from 0.010 inch to 0.025 inch in diameter; on

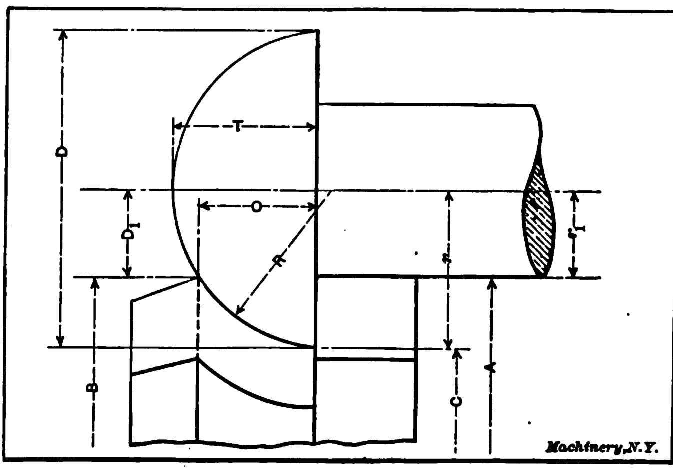


Fig. 10. Diagram for Calculating Dimensions of Circular Tools forming Spherical Screw Heads

small screws made from gun-screw iron from 0.012 inch to 0.030 inch; on small steel screws from 0.015 inch to 0.035 inch. A good method of overcoming great variations in the size of the teat, is to make the angle of the cut-off tool similar to the enlarged view shown at *b*, Fig. 11, where the flat portion should be half the thickness of the cut-off tool blade. This method tends to decrease the pressure on the piece, thus preventing it from breaking off too soon.

As previously stated, the radius on the cut-off tool, if not struck off in "advance" of the edge of the tool, will give a result as shown at *a*, Fig. 12. There will be a mark left on the head where the form tool finishes cutting, because the screw breaks off from the bar before the point of the tool has reached the center, and consequently the correct form on the piece has not been obtained. It is therefore necessary (especially for small radii) to use the method termed "laying off the radius in advance" of the cutting edge of the tool. This method is clearly shown in Fig. 11, where *d* is the distance the center is in advance of the point of the tool. Then, to determine the dimensions of the tool, take any approximate dimension D as required, and also take any angle which will suit the radius of the tool, and cut away that portion of the tool which is not required for forming. In order to determine the dimension X (see Fig. 11) it will be necessary to make the following calculations:

$$A = \frac{180 \text{ deg.} - \theta}{2}$$

$$\phi = 90 \text{ deg.} - \theta$$

$$\beta = A - \phi$$

Then $a = r \times \cos\phi$; $H = a \times \tan\beta$; $B = D - H$;
$Y = B \times \cot\theta$; $X = Y + a - d$; $C = D - h$;
$h = r - \sqrt{r^2 - d^2}$.

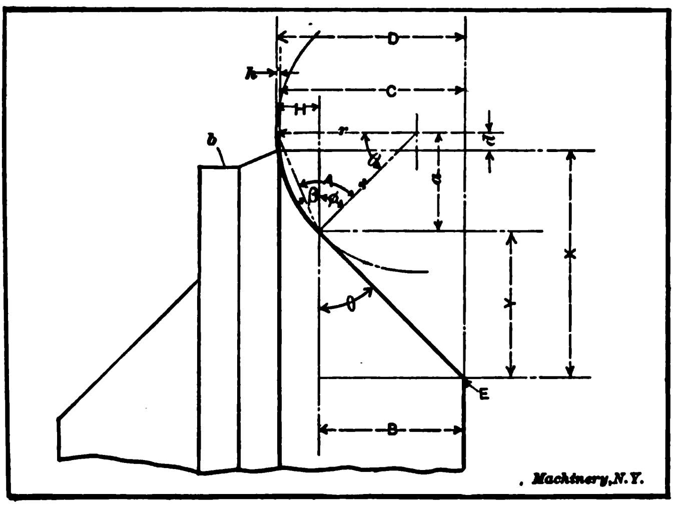


Fig. 11. Diagram for Determining Dimensions of Circular Cut-off Tool which forms Part of a Spherical Screw Head

Where h works out to less than 0.002 inch, it can be disregarded for all practical purposes.

For example, let $D = 0.2343$ inch; $r = 0.175$ inch; $\theta = 45$ deg.; $d = 0.021$ inch.

$$\text{Then } A = \frac{180° - 45°}{2} = 67° \; 30'.$$

$$\phi = 90° - \theta = 45°.$$

$$\beta = 67° \; 30' - 45° = 22° \; 30'.$$

$$a = 0.175 \times \cos 45° = 0.1237.$$

$$H = a \times \tan 22° \; 30' = 0.0512.$$

$$B = 0.2343 - 0.0512 = 0.1831.$$

$$Y = 0.1831 \times \cot 45° = 0.1831.$$

$$X = 0.1831 + 0.1237 - 0.021 = 0.2858.$$

$$h = r - \sqrt{r^2 - d^2} = 0.175 - 0.1737 = 0.0013.$$

Therefore, in this case, for all practical purposes, the dimension *C* would equal the dimension *D*. When the largest diameter of the circular tool is 2.250 inch, the diameter of the tool at point *E* will be $2.250 - (0.2858 \times 2) = 1.6784$ inch.

Angle on Blade for Cutting-off Various Materials

The object of the angle at the point of a cut-off tool (see angle *a*, Fig. 13) is to reduce the teat on the end of the work by minimizing the cutting pressure which becomes greater as the angle that the tool edge makes with the work decreases. Therefore, as the material becomes harder, the angle on the tool may decrease, since the material

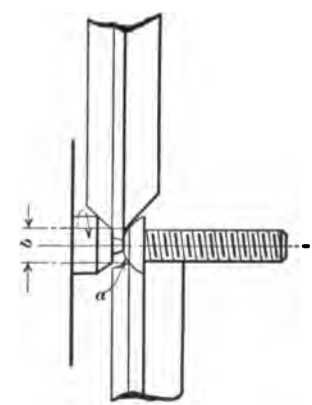


Fig. 12. Spherical Screw Head formed by Combination of Forming and Cut-off Tools

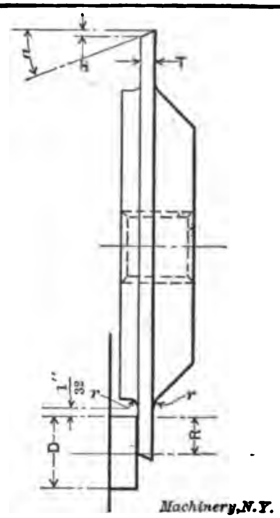


Fig. 13. Diagram showing Dimensions of Circular Cut-off Tools

will stand more pressure before breaking. It is obvious, therefore, that certain angles are better suited for the various kinds of materials than others. The values given in Table I have been found to give good results on the materials specified.

Thickness of Blade on Cut-off Tools

The thickness of the blade is an important point in the design of circular cut-off tools. It is governed by the angle on the edge of the tool and also by the diameter and hardness of the material being operated upon. It is obvious that a circular tool with an acute angle (about 23 degrees) and a narrow blade would not work satisfactorily on hard material, as the blade would not stand the cutting pressure and would bend, producing a concave surface on one end of the piece

TABLE I. DIMENSIONS FOR CIRCULAR CUT-OFF TOOLS (For Notation See Fig. 13)

Diameter of Stock	Soft Brass and Copper			Hard B ass			Gun Screw Iron			Norway Iron and Mach. Steel			Drill Rod and Tool Steel		
	Angle a = 23 Deg.			Angle a = 20 Deg.			Angle a = 18 Deg.			Angle a = 15 Deg.			Angle a = 10 Deg.		
	T	x	2x	T	x	2x	T	x	2x	T	x	2x	T	x	2x
1/16	0.031	0.013	0.026	0.033	0.012	0.024	0.035	0.011	0.023	0.039	0.010	0.021	0.043	0.009	0.018
1/8	0.044	0.019	0.038	0.047	0.017	0.034	0.050	0.016	0.032	0.055	0.015	0.030	0.062	0.013	0.026
3/16	0.052	0.022	0.044	0.058	0.021	0.042	0.061	0.020	0.040	0.068	0.018	0.036	0.076	0.016	0.032
1/4	0.062	0.026	0.053	0.067	0.024	0.049	0.071	0.023	0.046	0.078	0.021	0.042	0.088	0.019	0.038
5/16	0.069	0.029	0.059	0.075	0.027	0.055	0.079	0.026	0.052	0.087	0.023	0.047	0.098	0.021	0.042
3/8	0.076	0.032	0.065	0.082	0.030	0.060	0.087	0.028	0.057	0.095	0.025	0.051	0.107	0.023	0.046
7/16	0.082	0.035	0.070	0.088	0.032	0.064	0.094	0.031	0.062	0.103	0.028	0.056	0.116	0.025	0.050
1/2	0.088	0.037	0.075	0.095	0.035	0.070	0.100	0.033	0.066	0.110	0.029	0.059	0.124	0.026	0.052
9/16	0.093	0.039	0.079	0.100	0.036	0.073	0.106	0.034	0.069	0.117	0.031	0.063	0.131	0.028	0.056
5/8	0.098	0.042	0.084	0.105	0.038	0.076	0.112	0.036	0.073	0.123	0.033	0.066	0.137	0.029	0.058
11/16	0.103	0.044	0.088	0.111	0.040	0.081	0.118	0.038	0.077	0.129	0.035	0.070	0.145	0.031	0.062
3/4	0.107	0.045	0.091	0.116	0.042	0.084	0.123	0.040	0.080	0.134	0.036	0.072	0.152	0.032	0.064
13/16	0.112	0.047	0.095	0.121	0.044	0.088	0.127	0.041	0.082	0.141	0.038	0.076	0.158	0.033	0.067
7/8	0.116	0.049	0.098	0.125	0.046	0.092	0.133	0.043	0.086	0.146	0.039	0.078	0.164	0.035	0.070
15/16	0.120	0.051	0.102	0.130	0.047	0.095	0.137	0.045	0.090	0.151	0.040	0.081	0.170	0.036	0.072
1	0.124	0.053	0.106	0.134	0.049	0.098	0.141	0.046	0.092	0.156	0.042	0.084	0.175	0.037	0.074

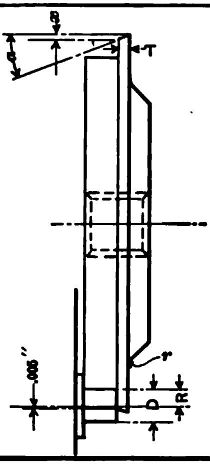
and a convex surface on the other. This has been thoroughly experimented with by the writer and an empirical formula has been derived which has given good results. For standard circular cut-off tools, as shown in Fig. 13, where the tool is not required to form part of the work, the formula is as follows:

$$T = \sqrt{\frac{D \times \cot a}{3}} \times 0.14,$$

in which T = thickness of blade in inches,
D = the diameter of the stock in inches,
a = the angle on the edge of cut-off blade.

The value of r (the radius to obviate cracking in hardening) for standard circular cut-off tools for cutting off various diameters of stock is as follows:

From 1/8 to 3/8 inch diameter = 1/32 inch,
From 3/8 to 3/4 inch diameter = 1/16 inch,
From 3/4 to 1 inch diameter = 3/32 inch.



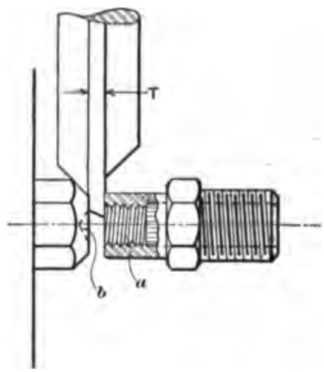


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Fig. 14. Diagram showing Dimensions of Circular Cut-off Tool when it is used both for cutting-off and forming part of the Work

Fig. 15. Illustration showing a Case where a Cut-off Tool with Increased Thickness of Blade is required

The actual length of the blade on cut-off tools is found by the formula:

$$L = R + x + r + 1/32,$$

where L = actual length of blade in inches,
R = radius of stock in inches,
x = dimension as shown in Fig. 13,
r = radius to obviate cracking while hardening, as shown in Fig. 13.

For example, let D = 3/8 inch; a = 20 degrees.

$$\text{Then } T = \sqrt{\frac{D \times \cot a}{8}} \times 0.14 = \sqrt{\frac{0.375 \times 2.747}{8}} \times 0.14 = 0.082 \text{ inch.}$$

$L = R + x + r + 1/32$, where $R = 0.1875$; $x = \tan 20° \times 0.082 = 0.364 \times 0.082 = 0.0298$; $r = 1/32$ inch.

Therefore, $L = 0.1875 + 0.0298 + 0.0312 + 0.0312 = 0.2797$ inch.

The thickness of the cut-off tool blade, and the value of x and $2x$ are tabulated in Table I. The above formula is applicable when the cut-off tool does not form the stock. It will be necessary to change the formula somewhat when calculating the thickness of blade when the tool is used for partly forming the work, as shown in Fig. 14.

When Cut-off Tool Forms Stock

When the cut-off tool is used to form the end of the stock, as shown at Fig. 14, the following formula is used for finding the thickness of the blade:

$$T = \sqrt{\frac{D \times \cot a}{5}} \times 0.17,$$

in which T = thickness of blade on cut-off tool in inches,
D = diameter of end of piece in inches,
a = angle on edge of tool blade (see Fig. 14).

The actual length of the cut-off tool blade $= R + x + 0.005$ inch,
in which R = radius on end of piece in inches,
x = dimension as shown in Fig. 14.

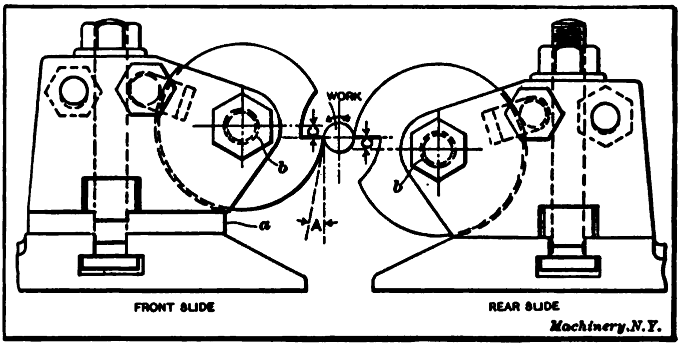


Fig. 16. Circular Form Tools and Holders showing Location of Center of Tool in Relation to Center of Piece being formed

The dimension 0.005 inch is the clearance to pass the center.

To find the value of x multiply T by tan a as before.

For example, let $D = 0.250$ inch, $a = 20$ degrees.

$$\text{Then } T = \sqrt{\frac{0.250 \times \cot 20^\circ}{5}} \times 0.17 = \sqrt{0.1373} \times 0.17 = 0.063$$

$L = R + x + 0.005$, where $R = 0.125$ inch; $x = 0.063 \times \tan 20^\circ = 0.023$ inch.

Then $L = 0.125 + 0.023 + 0.005 = 0.153$ inch.

In cases where pieces are being made similar to that shown in Fig. 15, in which the tapped hole *a* passes through the piece, the blade on the cut-off tool should be of sufficient width to remove the portion taken up by the chamfer on the tap. Otherwise, if the blade is too narrow, the hole *b* will extend part way into the next piece to be made. Then, if the drill had a tendency to run eccentric, the centering tool would not remove the eccentric hole thus formed by the drill, which would result in the drill running out, and finally in the breaking of the tap before many pieces would be completed.

The amount of chamfer required on taps for various pitches is as follows:

From 14 to 24 threads	2½ threads.
From 26 to 32 threads	3 threads.
From 36 to 48 threads	4 threads.
From 56 to 80 threads	5 threads.

When the thickness of the blade as derived by the formulas is not equal to the amount required for the chamfer on the tap, the thickness of the blade must be increased.

Periphery Clearance

To provide for sufficient periphery clearance on circular tools, the center of the tool is located a certain amount above or below the cut-

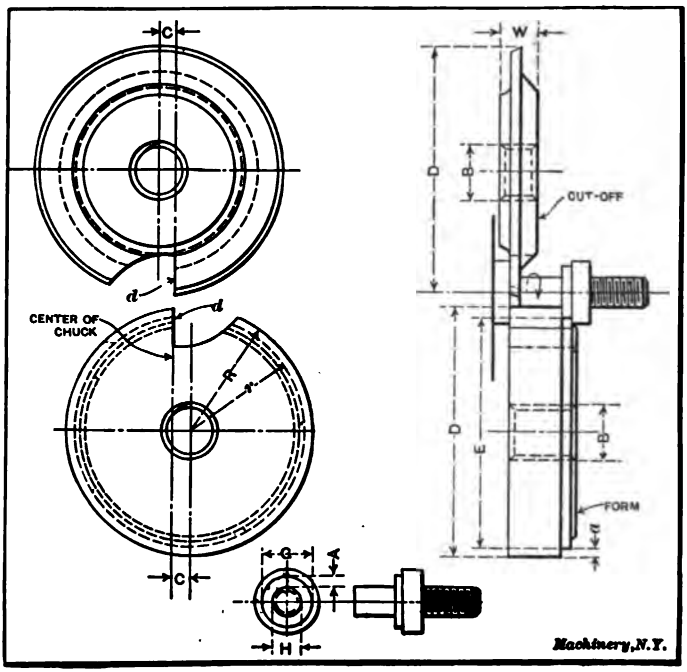


Fig. 17. Diagram showing Principal Dimensions of Circular Form Tools

ting edge, as shown in Fig. 16. The hole *b* in the tool holders is raised or lowered, depending on the position of the tools and the direction in which the spindle is rotating. The block *a* is provided for raising or lowering the hole in the tool holder. Raising or lowering the cutting edge of the tool relative to its center, changes the clearance angle *A* and also changes the form produced with the same tool. Clearance angles and the relation of the holes in the toolposts to the center of the spindle are, therefore, points which require careful consideration. With a given material, the larger the diameter of the work, the greater the clearance angle required. With the same dimension *C*, Fig. 16, a small tool diameter causes a greater clearance angle than a large diameter. The maximum diameter, *D*, the cut-down below the center, *C*, the width of the cut-off tool, *W*, and the size of tapped hole, *B*, as shown in Fig. 17, are tabulated in Table II, for the various sizes of Brown & Sharpe automatic screw machines.

Calculating the Diameter of Circular Tools

Locating the cutting edge of the tool below the center changes the form produced on the work. On account of this, the actual difference of diameters on the piece of work cannot be used for the measurements on the forming tool. If the dimension *A*, shown in Fig. 17, on the piece to be formed, is transferred to the form tool and then the tool cut below the horizontal center line, as shown at *C*, it would make the dimension *A* on the piece greater than required. Therefore, it is evident that a certain amount must be subtracted from the dimension *A* on the work to find dimension *a* on the circular tool. A general

TABLE II. DIMENSIONS REQUIRED FOR DESIGNING FORMING TOOLS FOR B. & S. AUTOMATIC SCREW MACHINES (See Fig. 17 for Notation Used)

No. of Machine	D	C	B	W
00	1¾	1/8	3/8–16	1/4
0	2¼	5/32	1/2–14	5/16
2	3	1/4	5/8–12	3/8

formula may be deduced by the aid of geometry, by which the various diameters on the forming tool can be determined, when the largest or smallest diameter of the tool, the amount that the cutting edge is below the center, and the diameter on the piece to be formed, are known.

Let R = largest radius of tool in inches,
A = difference in radii of steps on the work,
C = amount cutting edge is below the center in inches,
r = required radius in inches.

Then:

$$r = \sqrt{(\sqrt{R^2 - C^2} - A)^2 + C^2} \qquad (1)$$

If the smaller radius r is given and the larger radius R is required, the formula would be:

$$R = \sqrt{(\sqrt{r^2 - C^2} + A)^2 + C^2} \qquad (2)$$

Assume that it is required to make a circular form tool to be used on the No. 0 Brown & Sharpe automatic screw machine for forming the piece shown in the lower view in Fig. 17, the diameters *G* and *H* to be formed by the tool. By referring to Table II it will be seen that the largest diameter should be 2¼ inches, and that the cutting edge is 5/32 inch below the horizontal center line. Half the diameter

E, Fig. 17 (or radius *r*), is then found from Formula (1), by inserting the given values.

$R = 1\,1/8$; $C = 5/32$; assume that $A = 1/8$.

Then

$$r = \sqrt{\left(\sqrt{(1\tfrac{1}{8})^2 - (\tfrac{5}{32})^2} - \tfrac{1}{8}\right)^2 + (\tfrac{5}{32})^2} =$$

$$\sqrt{\left(\sqrt{\tfrac{1271}{1024}} - \tfrac{1}{8}\right)^2 + \tfrac{25}{1024}} = 1.0014 \text{ inch.}$$

The value of *r* is thus found to be 1.0014 inch and diameter *E* will then be 2 times this or 2.0028 inches instead of 2 inches exactly, as would have been the case if the cutting edge had been on the center line. The formula may seem rather complicated, but when applied to circular tools used on the Brown & Sharpe automatic screw machines it can be simplified by inserting the values for *R* and *C*, these being constant for each size of machine. The formula would then take the following form:

No. 00 Brown & Sharpe automatic screw machine:

$$r = \sqrt{(0.866 - A)^2 + 0.0156} \qquad (3)$$

No. 0 Brown & Sharpe automatic screw machine:

$$r = \sqrt{(1.114 - A)^2 + 0.0244} \qquad (4)$$

No. 2 Brown & Sharpe automatic screw machine:

$$r = \sqrt{(1.479 - A)^2 + 0.0625} \qquad (5)$$

Top Rake

Most circular form tools are made without top rake, that is, they have the cutting edge in a horizontal plane when cutting, as shown in Fig. 17; tools made in this manner are best suited for cutting brass, but do not work entirely satisfactorily on tougher and harder metals, as the chip, instead of being cut away, is scraped off, this action destroying the cutting edge very fast. Form tools for steel should, therefore, be provided with top rake, as shown in Fig. 18. The amount of top rake that should properly be used on circular tools for different materials varies from 0 to 18 degrees. Under general conditions the following angles are suggested as most suitable:

Material	Angle of Top Rake, Degrees
Rod brass	0
Drill rod and tool steel	8 to 10
Gun-screw iron	12
Machine steel	15
Norway iron	18

When top rake is ground on a circular form tool, as shown in Fig. 18, the calculations for the diameters must be accordingly changed. In Fig. 18 the case is shown exaggerated in order to be able to show clearly the various dimensions involved. To find the diameters of a form tool made in this manner, proceed as follows:

First find radius R_1 which would be the actual radius if the tool were merely cut down the required amount *C* below the center of the tool, but had no top rake. Then the radius R_2 of the tool, required when top rake is given, must be found. In order to explain the procedure clearly we will assume a practical example. Let $R = 1\frac{1}{8}$ inch, $C = 5/32$ inch, D (see Fig. 18) $= 9/16$ inch, $D_1 = 5/16$ inch. Then $A = 1/8$ inch.

First find R_1 by means of Formula (1) or (4):

$$R_1 = \sqrt{(1.114 - 0.125)^2 + 0.0244} = 1.00126 \text{ inch.}$$

The next step will be to find dimension B:

$$B = \sqrt{R^2 - C^2} - A = 1.114 - 0.125 = 0.989 \text{ inch.}$$

The next step is to find dimension h and as the tool is to cut machine steel, angle θ is 15 degrees.

Then:

$$h = A \times \tan 15 \text{ deg.} = \tfrac{1}{8} \times 0.26794 = 0.03349.$$

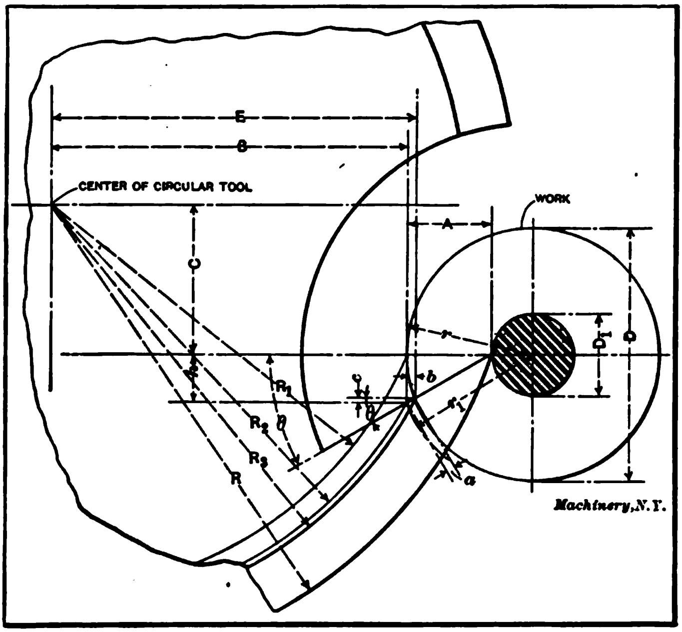


Fig. 18. Diagram for Calculating Form Tools having Top Rake

This gives us the distance from the center of the work to the point where radius R_2 intersects the face of the cutting edge. Now R_2 may be found:

$$R_2 = \sqrt{B^2 + (C + h)^2} = \sqrt{0.989^2 + 0.18974^2} = 1.007 \text{ inch.}$$

Radius R_2 would be a fairly approximate dimension for the tool when the diameters of the tool and work are nearly of the same size, and when the angle θ is comparatively small. As the difference between the diameters of the tool and work increases, the diameter of the work being small in comparison with the diameter of the tool, it is necessary to find the theoretically correct radius R_3. To do this first find r_1:

$$r_1 = \sqrt{r^2 + h^2} = \sqrt{(9/32)^2 + 0.0335^2} = 0.2832 \text{ inch.}$$

We have further that $a = r_1 - r$, and $b = a \times \cos\theta$. Also $c = a \times \sin\theta$. Then $E = B + b$. Having obtained these dimensions we have:

$$R_2 = \sqrt{(C + h - c)^2 + E^2}.$$

Inserting the actual values in the formulas just given, we have:

$$a = 0.2832 - \frac{9}{32} = 0.00195,$$

$$b = 0.00195 \times \cos 15° = 0.00188,$$

$$c = 0.00195 \times \sin 15° = 0.00051,$$

$$E = 0.989 + 0.00188 = 0.99088,$$

$$R_2 = \sqrt{0.18923^2 + 0.99088^2} = 1.0088 \text{ inch.}$$

The found value of R_2 is the required radius of the tool. This radius is about 0.0075 inch greater than the radius R_1. The procedure

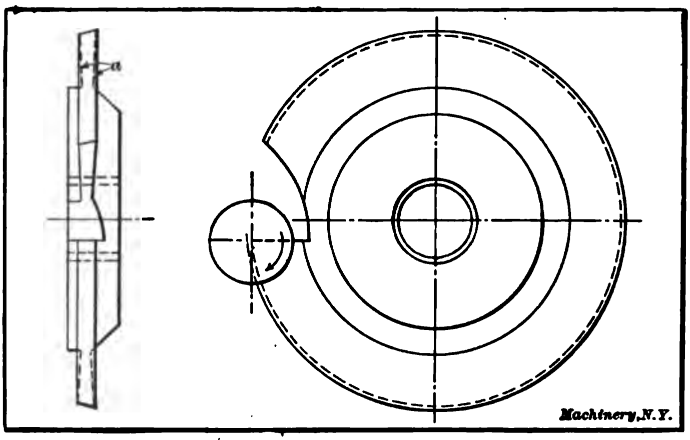


Fig. 19. Side Clearance on Circular Tools

may appear difficult at first sight, but a few examples in practice will make the user familiar with it.

While the angle of top rake as given is suitable for cutting the material specified, the distance C as given in Table II for the various machines is only suitable when cutting brass and drill rod and does not give sufficient peripheral clearance when cutting Norway iron and soft machine steel. The arrangement shown at C in Fig. 9 should be adopted when these materials are cut, as the centers of both the form and cut-off tools can then be raised as compared with the usual arrangement. This raising of the center is accomplished by putting packing strips of the required thickness under the tool-holder blocks.

Side Clearance on Circular Tools

The question of side clearance is a subject which few authorities seem to agree upon. Some advocate a great deal of side clearance, others only a slight amount, and still others, no clearance at all; in fact, some go as far as to say that a cut-off tool should be about 0.0015 inch narrower at the point than at the back. The greatest trouble with tools heating up and welding is not to be attributed to insufficient side clearance only, but to the quality of oil or other cooling lubricant used. It has been demonstrated that if a poor grade of oil is used and the tools made without side clearance, welding will surely occur; but take the same tools and use a good quality of lard oil, and the tools will run for days without welding. The writer admits that there are some cases in which side clearance is necessary, but the clearance should not be given as shown at *a*, Fig. 19, as this is not side clearance, but merely provision for pockets for the fine chips to lodge in, while the revolving stock forces the chips in and also tries to draw them out; and when a chip is drawn out, it leaves a rough finish on the end of the piece, and sometimes breaks the tool.

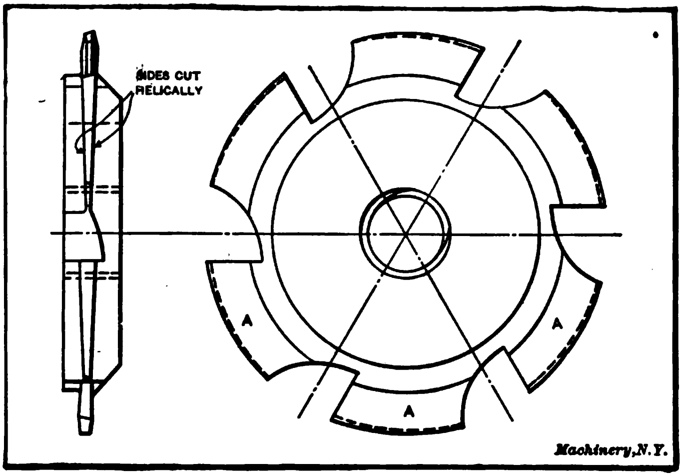


Fig. 20. Cut-off Tool with Side Clearance

When side clearance is necessary, and when the width of the slot is not important, a tool as shown in Fig. 20, where each section *A* of the tool is finished helically on each side, provides for excellent clearance. This tool is specially adapted for cutting vulcanite or fiber. It can also be used to advantage in cutting a very soft grade of iron. All the sections are ground, and when one becomes dull the following section is brought into position, and so on, until the tool requires grinding again. When a tool is made without side clearance, it should be ground smooth on the sides, as any high spots on the face of the sides would cause heating and welding. A good grade of lard oil should also be used if good results are to be expected. When pieces as shown at *A*, Fig. 21, are being made, the tools should be made without side clearance, and the faces ground and lapped as indicated. The form tool should be made in sections and straddle the thin portion of the piece; it should remain in position on the work until the angle on the edge of the cut-off tool is well into the stock as shown at *b*.

CHAPTER III

SPEEDS AND FEEDS FOR FORMING TOOLS

The conditions under which different classes of work are made and the kinds of materials used vary to such an extent that it is impossible to give any definite rules for the speed of the spindle or the feed of the tools, and whatever is said here is only by way of suggestion. The maximum speeds obtainable on the various Brown & Sharpe automatic screw machines are as follows: On the No. 00 machine the

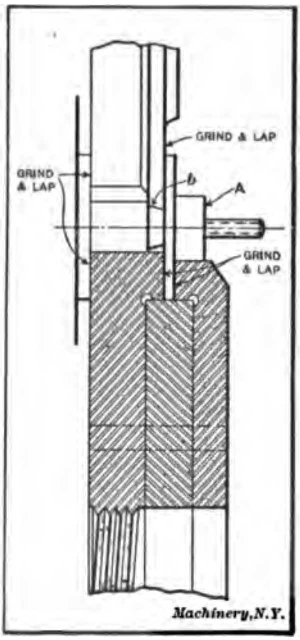


Fig. 21. Circular Form Tool without Side Clearance

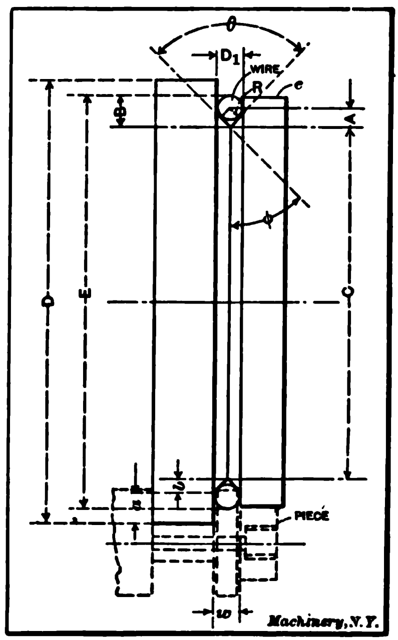


Fig. 22. Wire Method employed for Measuring Circular Form Tools

maximum spindle speed is 2400 R.P.M. and the maximum diameter of stock that can be turned is 5/16 inch; this gives a maximum surface speed of 197 feet per minute. On the No. 0 machine the maximum spindle speed is 1800 R.P.M. and the maximum diameter that can be turned is 5/8 inch, giving a maximum surface speed of 294 feet per minute. On the No. 2 machine, the maximum spindle speed is 1200 R.P.M. and the maximum diameter that can be turned is 7/8 inch, giving a maximum surface speed of 275 feet per minute. It can be easily seen that the greatest surface speed (294 feet per minute) is rather high for ordinary carbon steel tools even when working on

TABLE III. FEEDS PER REVOLUTION FOR FORMING TOOLS

Width of Form	Smallest Diameter of Form												
	1/16	3/32	1/8	5/32	3/16	7/32	1/4	5/16	3/8	1/2	5/8	3/4	7/8
1/16	0.0007	0.00075	0.0008	0.0009	0.001	0.0011	0.0012	0.0012	0.0012	0.0012	0.0012	0.0012	0.0012
3/32	0.00065	0.0007	0.0008	0.0009	0.001	0.001	0.0013	0.0014	0.0015	0.0017	0.0019	0.002	0.0021
1/8	0.0005	0.00055	0.00075	0.00085	0.001	0.00095	0.0012	0.0014	0.0016	0.002	0.0023	0.0025	0.0025
3/16	....	0.0003	0.0007	0.0008	0.00095	0.00095	0.0011	0.0015	0.0016	0.0018	0.0019	0.0021	0.0022
7/32	....	....	0.0005	0.00075	0.0009	0.0009	0.0011	0.0013	0.0015	0.0017	0.0018	0.002	0.0021
1/4	....	....	0.00025	0.0007	0.0009	0.0009	0.001	0.0012	0.0015	0.0016	0.0017	0.0018	0.002
5/16	....	....	....	0.0005	0.00085	0.00085	0.001	0.0011	0.0013	0.0015	0.0016	0.0017	0.0018
3/8	....	....	....	0.00025	0.0008	0.00085	0.00095	0.001	0.0012	0.0012	0.0014	0.0016	0.0017
1/2	....	....	....	....	0.0008	0.0008	0.00095	0.00095	0.001	0.0011	0.0013	0.0015	0.0016
5/8	....	....	....	....	0.0003	0.0005	0.0009	0.0009	0.00095	0.001	0.0012	0.0014	0.0015
3/4	....	....	....	....	....	0.0002	0.0008	0.00085	0.0009	0.00095	0.0011	0.0013	0.0014
7/8	....	....	....	....	....	....	0.0005	0.0006	0.00085	0.00095	0.001	0.0012	0.0013
1	....	....	....	....	....	....	0.0002	0.0005	0.0008	0.00085	0.00095	0.001	0.0012

brass rod. Hence, if the highest speeds obtainable on the various machines mentioned are to be taken advantage of, a suitable grade of cutting steel must be used. This matter will be discussed later.

The following surface speeds can be used when the tools are made from Bohler's Styrian steel:

Material	Surface Speed, Feet per Minute
Brass rod	200-300
Gun-screw iron	100-125
Norway iron and machine steel	80-95
Drill rod and tool steel	60-75

A good supply of lard oil should be provided, and the tools kept in good condition.

Feeds

In all cases, the feed is governed by the surface speed, the smallest diameter being formed, and the width of the form tool. Feeds for forming tools are given in Table III. The widths covered here range from 1/16 to 1 inch, and the smallest diameters formed from 1/16 to 7/8 inch. It will be seen that a tool about 1/8 inch wide is, in general, adapted to take the coarsest feed. Tools from 3/32 to 3/16 inch (such as are commonly used for cutting-off purposes) admit of coarser feeds, as a rule, than either wider or narrower tools. Thus the feed decreases as the tool decreases in thickness to 1/16 inch, except for small diameters, and increases from 3/32 to 3/16 inch. From 1/4 inch up, the feed must again be decreased to give satisfactory results. For cutting-off purposes the feed varies from 0.0008 to 0.0025 inch, depending on the nature of the material, the surface speed, and the width of the tool. The feeds for machine steel, gun-screw iron and Norway iron should be less than the feed used for brass. The feed used in cutting off Shelby steel tubing should not exceed 0.001 inch per revolution; a surface speed as high as 125 feet per minute can be used with good results, when using tools made from Styrian special steel.

Cooling and Lubricating Mediums

A proper cooling and lubricating medium is essential, if good results are to be expected. As previously stated, if a proper cooling and lubricating medium is not used, welding and excessive heating of the tools and work will result. There are various compounds on the market, some of them giving good results on certain classes of work, depending on the conditions under which they are used. Oil is used to advantage in cutting internal and external threads, where friction plays a very important part, but when cutting threads at high speeds, a cooling material largely composed of water is sometimes used. Oil will not conduct away the heat generated at high cutting speeds as rapidly as some of the special cooling compounds, because oil is more sluggish in penetrating to the point of the tool, where the chip is being cut or torn from the work. The writer would, however, advise that a good grade of lard oil be used on screw machines in preference to all other compounds or other poorer grades of screw cutting oil for the following reasons: 1. The speeds used are comparatively low. 2. A good supply can be furnished to the cutting edges of the tools. 3. Circular tools can be used without side clearance and yet give satisfactory results. 4. Good lard oil does not gum up the machines or cause rusting of the operating parts, as would be the case if cooling mediums composed of water and compounds were used. The lard oil used should be thin and not sluggish.

CHAPTER IV

MAKING CIRCULAR FORMING TOOLS

The conditions under which the work is produced should determine the steel to be used in making the circular tools, *i. e.*, if the piece to be made is of a very difficult shape, requiring sharp or thin projections on the tool, a grade of steel should be used which would not require a high heat to harden, as the thin projections are liable to become burnt or cracked while hardening. A brand of steel which has been found to give good satisfaction in such cases is Bohler's Gold Label Styrian steel; this steel holds a fine edge satisfactorily and also gives a very smooth finish to the work; it is especially adapted for cutting brass. Care should be exercised in hardening this steel, as it hardens at a very low heat. Various other grades of special carbon and high-speed steel are used on screw machines, among which are the following: Jessops steel, Novo high-speed steel, Blue-chip steel and Saben steel. Some of these kinds, especially Novo, give good results when high cutting speeds and feeds are used. Novo steel is frequently used for cutting machine steel and Norway iron, as it will stand a higher speed and a coarser feed than Styrian steel, but when a high finish is required, Styrian steel should be used in preference.

Methods of Making Circular Tools

In designing circular tools, the methods of making them should be carefully considered, and when possible, the contour of the tool should be as simple as the requirements will permit. There are various methods employed in making circular tools of irregular shape, among them being the transfer scheme, the templet system, the use of master tools, and of individual turning tools. For work requiring a fair amount of accuracy, the first two methods are not reliable. The master tool system is sometimes advisable when very difficult shapes are to be produced and when a large number of tools of the same shape are required. The writer considers that where a few tools are required, the individual turning-tool method is the cheapest and best, and that direct measurements are more reliable than either the transfer scheme or templet system.

The Transfer Method

To illustrate what is meant by the transfer scheme, refer to Fig. 23; here a circular tool and setting gage are shown on the arbor *A*. The steps 1, 2, 3, 4, on the setting gage correspond with the various diameters required on the circular tool The setting gage is turned to micrometer measurements, and then copper plated with blue vitriol. To transfer the sizes from the setting gage to the circular tool, the master tools for the various shapes are brought in until they touch the setting gage, and the reading on the micrometer collar on the feed-screw is noted. The master tool is then brought into position on the circular tool and fed in the depth required, as indicated on the micrometer collar. The succeeding operations are continued in like manner until the desired shape on the tool is obtained. As previously stated, where a fair amount of accuracy is required, this scheme is not advisable, for the reason that if the feed-screw or slide has any lost motion, as is generally the case, the same pressure could not be brought to bear on the gage, when setting the master tool, as would be exerted on the circular tool when cutting to the indicated depth; then the circular tool would be larger in diameter than the setting gage.

Templets

Some authorities advocate making templets which conform to the contour of the piece to be made. Considerable skill is required to file

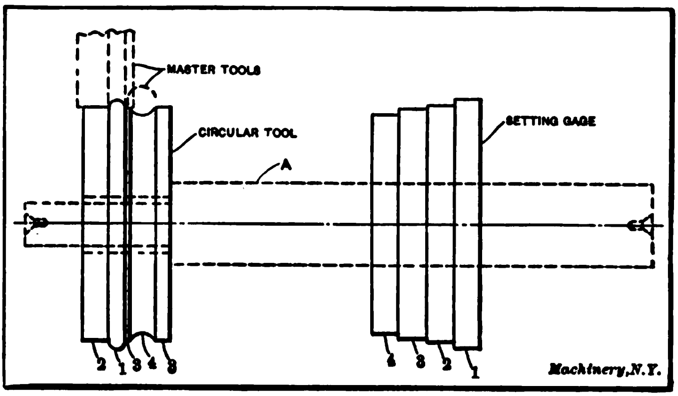


Fig. 23. Transfer Method for Making Circular Form Tools

complicated templets accurately, as any error which might occur would be doubled in the diameters of the product. It is just as easy to measure a circular tool, as it is to measure a templet, and in the first case the error would be less, as the measurement does not require to be transferred. The writer considers that when accurate tools are required, templets should be avoided and direct measurements used instead.

Master Tools

Master tools are unnecessary, unless a large number of circular tools of the same shape are required. When master tools are being made, the differences in diameters due to the cutting down below center should be calculated, and the tool made so that it can be set on the center of the work when cutting the circular form tool, instead of setting the master tool below the center the required amount, as is advocated by some authorities. It is bad practice to set the edge of a tool much below the center of the work, as it produces chattering, and the material is removed by a scraping action instead of being cut. In the majority of cases, it is preferable to make a circular master tool rather than a dove-tail tool, as the former is more easily measured and made.

Individual Turning Tools

The individual turning tool method, in conjunction with direct measurements, is preferable to all others, when only a small number of similar-shaped tools are required. In Fig. 24 is shown a tool-holder *A* and tool *B* for forming the radii for oval head screws and other shapes of a similar character, special tools being inserted in the tool holder *A*, as required. When using this tool for forming circular cut-off tools, as shown in Fig. 11, the distance *a* is set equal to the radius of the tools *B*, minus the amount that the center is ahead of the edge of the circular tool. The radius of the tool *B* is, of course, made equal to

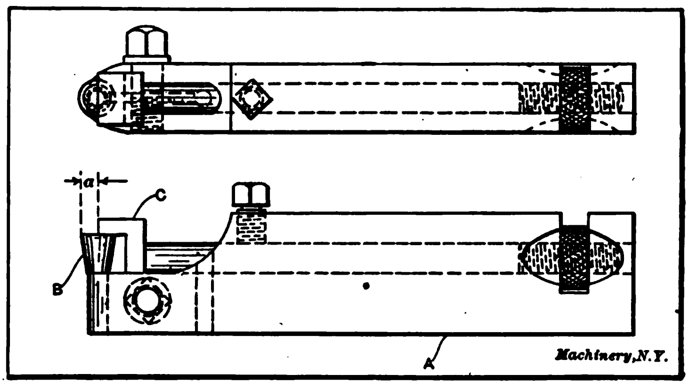


Fig. 24. Holder for Special Turning Tools

the radius required on the circular tool. The operating parts of this tool holder are clearly illustrated in Fig. 24.

The operations for making a circular tool for a round-head screw are shown at *A*, *B*, *C*, and *D*, Fig. 25. The first operation *A* consists in taking a cut (about 0.005 inch) partly across the circumference, making the distance *a* equal to the dimension *D*, shown in Fig. 11. Then a light cut is taken along the side as at *B*, making the distance *b* equal to the dimension *X*. The tool shown in Fig. 24 is then set square with the face-plate or at right angles to the centers, and the tool fed in until the gage *C* touches the largest diameter of the tool, leaving the shape of the tool as shown at *C*, Fig. 25. A square nose tool is then set tangentially to the radius, forming the angle θ, as shown in Fig. 11. This square nose tool removes the material left after the operation at *C*, Fig. 25, and leaves the tool as shown at *D*. The individual turning tools used are concave tools, round or convex tools, square nose tools, and parting tools.

Measuring Difficult Shapes

When making circular tools of irregular contour, shapes difficult to measure are sometimes encountered. There are various tools and methods employed for this. An appliance to be used in connection with a micrometer for measuring deep slots and grooves is shown in Fig. 26. The special measuring pieces *A* are fitted to the anvil and spindle of the micrometer, and when the measurement is taken, the distances *B* are subtracted, giving the actual diameter of the tool. The pieces *A* can be made so that tools of very difficult shapes can be

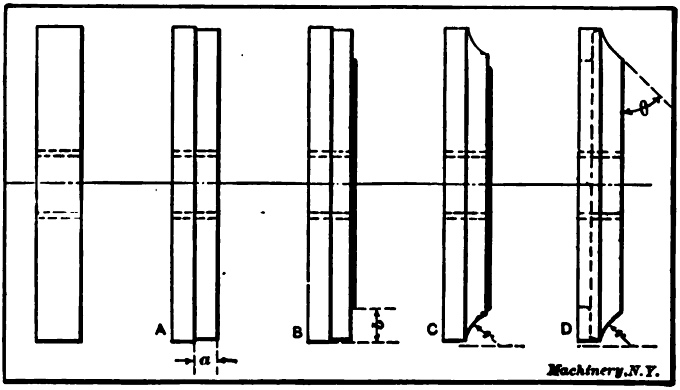


Fig. 25. Making Out-off Tools for Spherical Work

measured with accuracy. When a form tool straddles a piece, the sharp corners produced by the tool rubbing against the sides are frequently objectionable and require to be removed. A form tool similar to that shown in Fig. 22 is sometimes used for this purpose. Making a tool of this description produces a form difficult to measure accu-

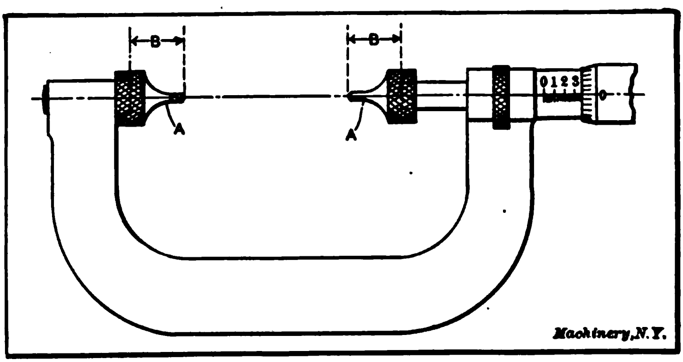


Fig. 26. Micrometer Arranged for Measuring Form Tools of Difficult Shapes

rately, but by adopting the wire method, the measuring of the tool is somewhat simplified. In Fig. 22,

Let D = the largest diameter of the tool,

a = distance from outer edge of largest diameter of tool to bottom of chamfer, on the piece,

w = the width of piece to be chamfered, .

ϕ = angle that chamfer makes with vertical line of tool,
b = distance from bottom of chamfer to apex or root of triangle,
C = the root diameter of tool,
R = the radius of wire,
A = distance from center of wire to apex or root of triangle,
E = the diameter over wires.

Then $b = \frac{w}{2} \times \cot \phi$; $C = D - 2(a + b)$

$$A = \frac{R}{\sin \phi}; \quad B = A + R; \quad E = C + 2B.$$

The dimension E can be calculated when the tool is designed, and put on the drawing, also giving the size of wire to be used. When the wires are below the part e, the pieces A shown in Fig. 26 can be used for finding dimension E.

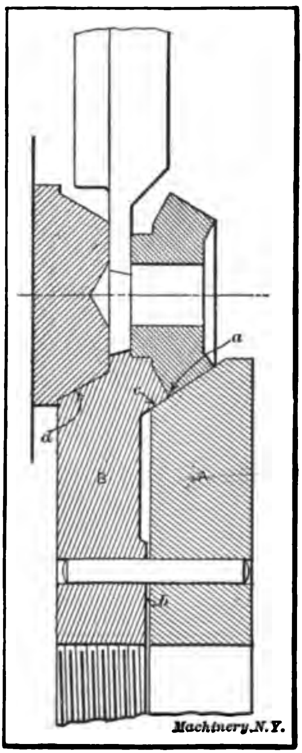


Fig. 27. Forming Tool for Bevel Gear Blanks

As an interesting example of the making of forming tools, the following case of making forming tools for forming the outside angular surfaces of small bevel gears on automatic screw machines may be cited. The forming tool can best be made as shown in Fig. 27. It consists of two sections A and B, doweled together. Two fillister head screws, not shown in the illustration, are also used for clamping the sections together. When grinding the two sections, a slight clearance of about 0.002 inch is allowed between the parallel faces at b; then, when the tool is fastened in the tool-holder, the clamping screw will entirely close up any space at point a. When grinding the inside face c of section B, the angle should be somewhat less than the corresponding angle on part A, so that the sections will fit very tightly at a. The angular surface at d takes a roughing cut on the next piece. The face of the section A, when cut down below the center, would theoretically be slightly concave, but the amount would be so slight that it would be imperceptible, and of no account in practice. When an absolutely true taper is required, a circular forming tool cut down below the center should not be used, but instead a taper turning box tool or a taper turning attachment, operated from the cross-slide. A so-called dove-tail forming tool is also sometimes found convenient.

APPENDIX

CALCULATION OF CIRCULAR FORMING TOOLS

When a large number of circular forming tools are to be designed, it involves a great deal of labor to compute the different diameters separately. The usual method is as follows (see Fig. 28):

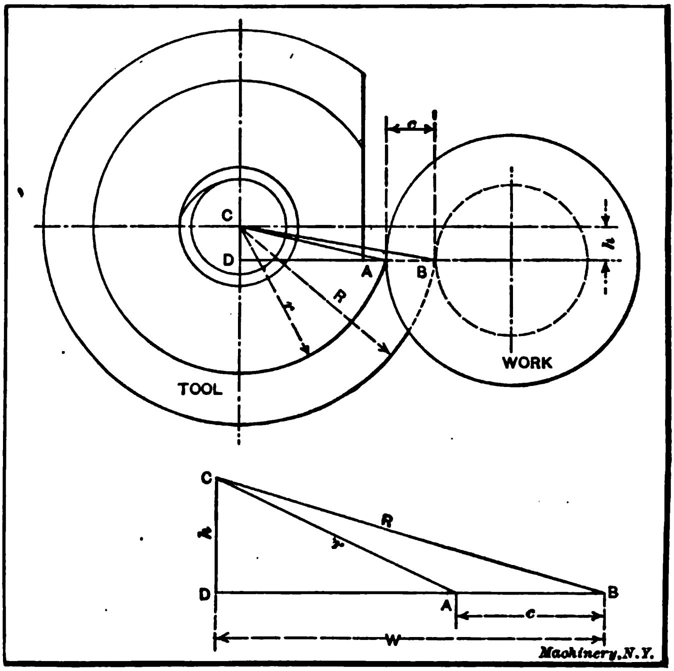


Fig. 28. Notation used in Formulas for Forming Tool Calculations

First find the value of W in the right-angle triangle BCD:

$$W = \sqrt{R^2 - h^2}$$

in which

R = radius of largest diameter of circular tool,

h = distance which the center of the tool is set either above or below the center line of the work.

Now, find the value of r in the right-angled triangle ACD:

$$r = \sqrt{(W - c)^2 + h^2}$$

in which

c = one-half the difference between the required diameters of the work,

r = the required radius of the circular tool.

This method is quite long and cannot be materially shortened by using a table of squares. Therefore, anything that can be done to aid in computing the different diameters of circular forming tools will no doubt be appreciated. The purpose of this chapter is to show how to compute tables giving the diameters of circular tools corresponding to

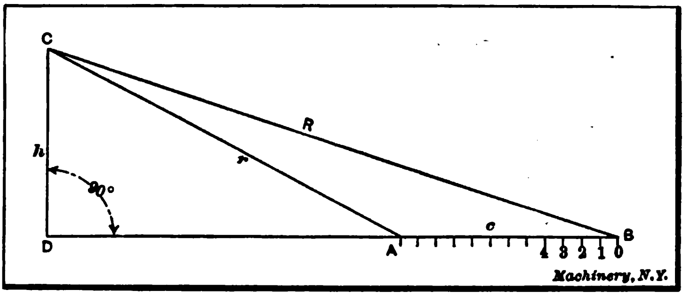


Fig. 29. Notation used in Formulas for Calculating Table IV

differences of one-thousandth inch in the radius of the work. Such tables are given on pages 34 to 37, inclusive.

In Table II, Chapter II, are given the dimensions required for designing circular forming tools for Brown & Sharpe automatic screw machines. (See Fig. 17 for notation used.) For the purpose of illustration, a table of diameters for circular forming tools for the No. 2

TABLE IV. VALUES OF r FOR DIFFERENT VALUES OF n

n	r	Difference between Radii for n = 50	Corresponding Difference for n = 1	2 r	Double Difference (n = 1)
0	1.500000	0.049277	0.0009855	3.000000	0.001971
50	1.450723	0.049225	0.0009845	2.901446	0.001969
100	1.401498	0.049169	0.0009834	2.802996	0.001967
150	1.352329	0.049105	0.0009821	2.704658	0.001964
200	1.303224	0.049035	0.0009807	2.606448	0.001961
250	1.254189	0.048955	0.0009791	2.508278	0.001958
300	1.205234	0.048866	0.0009773	2.400468	0.001955
350	1.156368	0.048765	0.0009753	2.312736	0.001951
400	1.107603	0.048650	0.0009730	2.215206	0.001946
450	1.058953	0.048517	0.0009703	2.117906	0.001941
500	1.010436			2.020872	

machine will be computed. The method can be applied universally, however, provided the tools have no top rake. The conditions of the problem are shown diagrammatically in Fig. 29. The notation is the same as that used in Fig. 28.

Let

n = the numbers 1, 2, 3, 4, etc., successively,

$c = 0.001\,n$.

TABLE V. CALCULATING CIRCULAR FORMING TOOLS

Length c on Tool	Number of B. & S. Auto. Screw Machine			Length c on Tool	Number of B. & S. Auto. Screw Machine		
	No. 00	No. 0	No. 2		No. 00	No. 0	No. 2
0.001	1.7480	2.2480	2.9980	0.051	1.6491	2.1490	2.8995
0.002	1.7460	2.2460	2.9961	0.052	1.6471	2.1470	2.8975
0.003	1.7441	2.2441	2.9941	0.053	1.6452	2.1451	2.8955
0.004	1.7421	2.2421	2.9921	0.054	1.6432	2.1431	2.8936
0.005	1.7401	2.2401	2.9901	0.055	1.6412	2.1411	2.8916
0.006	1.7381	2.2381	2.9882	0.056	1.6392	2.1391	2.8896
0.007	1.7362	2.2361	2.9862	0.057	1.6373	2.1372	2.8877
0.008	1.7342	2.2341	2.9842	0.058	1.6353	2.1352	2.8857
0.009	1.7322	2.2321	2.9823	0.059	1.6333	2.1332	2.8837
0.010	1.7302	2.2302	2.9803	0.060	1.6313	2.1312	2.8818
0.011	1.7282	2.2282	2.9783	0.061	1.6294	2.1293	2.8798
0.012	1.7263	2.2262	2.9763	0.062	1.6274	2.1273	2.8778
0.013	1.7243	2.2243	2.9744	1/16	1.6264	2.1263	2.8768
0.014	1.7223	2.2223	2.9724	0.063	1.6254	2.1253	2.8759
0.015	1.7203	2.2203	2.9704	0.064	1.6234	2.1233	2.8739
1/64	1.7191	2.2191	2.9692	0.065	1.6215	2.1213	2.8719
0.016	1.7184	2.2183	2.9685	0.066	1.6195	2.1194	2.8699
0.017	1.7164	2.2163	2.9665	0.067	1.6175	2.1174	2.8680
0.018	1.7144	2.2143	2.9645	0.068	1.6155	2.1154	2.8660
0.019	1.7124	2.2123	2.9625	0.069	1.6136	2.1134	2.8640
0.020	1.7104	2.2004	2.9606	0.070	1.6116	2.1115	2.8621
0.021	1.7085	2.2084	2.9586	0.071	1.6096	2.1095	2.8601
0.022	1.7065	2.2064	2.9566	0.072	1.6076	2.1075	2.8581
0.023	1.7045	2.2045	2.9547	0.073	1.6057	2.1055	2.8561
0.024	1.7025	2.2025	2.9527	0.074	1.6037	2.1035	2.8542
0.025	1.7005	2.2005	2.9507	0.075	1.6017	2.1016	2.8522
0.026	1.6986	2.1985	2.9488	0.076	1.5997	2.0996	2.8503
0.027	1.6966	2.1965	2.9468	0.077	1.5978	2.0976	2.8483
0.028	1.6946	2.1945	2.9448	0.078	1.5958	2.0956	2.8463
0.029	1.6926	2.1925	2.9428	5/64	1.5955	2.0954	2.8461
0.030	1.6907	2.1906	2.9409	0.079	1.5938	2.0937	2.8443
0.031	1.6887	2.1886	2.9389	0.080	1.5918	2.0917	2.8424
1/32	1.6882	2.1881	2.9384	0.081	1.5899	2.0897	2.8404
0.032	1.6867	2.1866	2.9369	0.082	1.5879	2.0877	2.8384
0.033	1.6847	2.1847	2.9350	0.083	1.5859	2.0857	2.8365
0.034	1.6827	2.1827	2.9330	0.084	1.5839	2.0838	2.8345
0.035	1.6808	2.1807	2.9310	0.085	1.5820	2.0818	2.8325
0.036	1.6788	2.1787	2.9290	0.086	1.5800	2.0798	2.8306
0.037	1.6768	2.1767	2.9271	0.087	1.5780	2.0778	2.8286
0.038	1.6748	2.1747	2.9251	0.088	1.5760	2.0759	2.8266
0.039	1.6729	2.1727	2.9231	0.089	1.5740	2.0739	2.8247
0.040	1.6709	2.1708	2.9211	0.090	1.5721	2.0719	2.8227
0.041	1.6689	2.1688	2.9192	0.091	1.5701	2.0699	2.8207
0.042	1.6669	2.1668	2.9172	0.092	1.5681	2.0679	2.8187
0.043	1.6649	2.1649	2.9152	0.093	1.5661	2.0660	2.8168
0.044	1.6630	2.1629	2.9133	3/32	1.5647	2.0645	2.8153
0.045	1.6610	2.1609	2.9113	0.094	1.5642	2.0640	2.8148
0.046	1.6590	2.1589	2.9093	0.095	1.5622	2.0620	2.8128
3/64	1.6578	2.1572	2.9076	0.096	1.5602	2.0600	2.8109
0.047	1.6570	2.1569	2.9073	0.097	1.5582	2.0581	2.8089
0.048	1.6550	2.1549	2.9054	0.098	1.5563	2.0561	2.8069
0.049	1.6531	2.1529	2.9034	0.099	1.5543	2.0541	2.8050
0.050	1.6511	2.1510	2.9014	0.100	1.5523	2.0521	2.8030

TABLE VI. CALCULATING CIRCULAR FORMING TOOLS

Length c on Tool	Number of B. & S. Auto. Screw Machine			Length c on Tool	Number of B. & S. Auto. Screw Machine		
	No. 00	No. 0	No. 2		No. 00	No. 0	No. 2
0.100	1.5523	2.0521	2.8030	0.151	1.4517	1.9514	2.7027
0.101	1.5503	2.0502	2.8010	0.152	1.4498	1.9494	2.7007
0.102	1.5484	2.0482	2.7991	0.153	1.4478	1.9474	2.6988
0.103	1.5464	2.0462	2.7971	0.154	1.4458	1.9455	2.6968
0.104	1.5444	2.0442	2.7951	0.155	1.4439	1.9435	2.6948
0.105	1.5425	2.0423	2.7932	0.156	1.4419	1.9415	2.6929
0.106	1.5405	2.0403	2.7912	5/32	1.4414	1.9410	2.6924
0.107	1.5385	2.0383	2.7892	0.157	1.4399	1.9395	2.6909
0.108	1.5365	2.0363	2.7873	0.158	1.4380	1.9376	2.6889
0.109	1.5346	2.0343	2.7853	0.159	1.4360	1.9356	2.6870
7/64	1.5338	2.0336	2.7846	0.160	1.4340	1.9336	2.6850
0.110	1.5326	2.0324	2.7833	0.161	1.4321	1.9317	2.6830
0.111	1.5306	2.0304	2.7814	0.162	1.4301	1.9297	2.6811
0.112	1.5287	2.0284	2.7794	0.163	1.4281	1.9277	2.6791
0.113	1.5267	2.0264	2.7774	0.164	1.4262	1.9257	2.6772
0.114	1.5247	2.0245	2.7755	0.165	1.4242	1.9238	2.6752
0.115	1.5227	2.0225	2.7735	0.166	1.4222	1.9218	2.6732
0.116	1.5208	2.0205	2.7715	0.167	1.4203	1.9198	2.6713
0.117	1.5188	2.0185	2.7696	0.168	1.4183	1.9178	2.6693
0.118	1.5168	2.0166	2.7676	0.169	1.4163	1.9159	2.6673
0.119	1.5148	2.0146	2.7656	0.170	1.4144	1.9139	2.6654
0.120	1.5129	2.0126	2.7637	0.171	1.4124	1.9119	2.6634
0.121	1.5109	2.0106	2.7617	11/64	1.4107	1.9108	2.6617
0.122	1.5089	2.0087	2.7597	0.172	1.4104	1.9099	2.6614
0.123	1.5070	2.0067	2.7578	0.173	1.4084	1.9080	2.6595
0.124	1.5050	2.0047	2.7558	0.174	1.4065	1.9060	2.6575
0.125	1.5030	2.0027	2.7538	0.175	1.4045	1.9040	2.6556
0.126	1.5010	2.0008	2.7519	0.176	1.4025	1.9021	2.6536
0.127	1.4991	1.9988	2.7499	0.177	1.4006	1.9001	2.6516
0.128	1.4971	1.9968	2.7479	0.178	1.3986	1.8981	2.6497
0.129	1.4951	1.9948	2.7460	0.179	1.3966	1.8961	2.6477
0.130	1.4932	1.9929	2.7440	0.180	1.3947	1.8942	2.6457
0.131	1.4912	1.9909	2.7420	0.181	1.3927	1.8922	2.6438
0.132	1.4892	1.9889	2.7401	0.182	1.3907	1.8902	2.6418
0.133	1.4873	1.9869	2.7381	0.183	1.3888	1.8883	2.6398
0.134	1.4853	1.9850	2.7361	0.184	1.3868	1.8863	2.6379
0.135	1.4833	1.9830	2.7342	0.185	1.3848	1.8843	2.6359
0.136	1.4813	1.9810	2.7323	0.186	1.3829	1.8823	2.6339
0.137	1.4794	1.9790	2.7302	0.187	1.3809	1.8804	2.6320
0.138	1.4774	1.9771	2.7282	3/16	1.3709	1.8794	2.6310
0.139	1.4754	1.9751	2.7263	0.188	1.3789	1.8784	2.6300
0.140	1.4734	1.9731	2.7243	0.189	1.3770	1.8764	2.6281
9/64	1.4723	1.9719	2.7231	0.190	1.3750	1.8744	2.6261
0.141	1.4715	1.9711	2.7224	0.191	1.3730	1.8725	2.6241
0.142	1.4695	1.9692	2.7204	0.192	1.3711	1.8705	2.6222
0.143	1.4675	1.9672	2.7184	0.193	1.3691	1.8685	2.6202
0.144	1.4655	1.9652	2.7165	0.194	1.3671	1.8665	2.6182
0.145	1.4636	1.9633	2.7145	0.195	1.3652	1.8646	2.6163
0.146	1.4616	1.9613	2.7125	0.196	1.3632	1.8626	2.6143
0.147	1.4596	1.9593	2.7106	0.197	1.3612	1.8606	2.6123
0.148	1.4577	1.9573	2.7086	0.198	1.3592	1.8587	2.6104
0.149	1.4557	1.9553	2.7066	0.199	1.3573	1.8567	2.6084
0.150	1.4537	1.9534	2.7047	0.200	1.3553	1.8547	2.6064

TABLE VII. CALCULATING CIRCULAR FORMING TOOLS

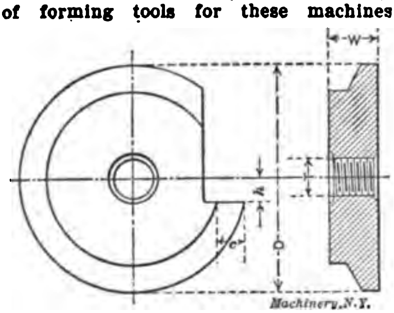
Length c on Tool	No. of B. & S. Machine		Length c on Tool	No. of B. & S. Machine		Length c on Tool	No. 2 B. & S. Machine	Length c on Tool	No. 2 B. & S. Machine
	No. 0	No. 2		No. 0	No. 2				
0.201	1.8527	2.6045	0.251	1.7543	2.5064	0.301	2.4085	0.351	2.3108
0.202	1.8508	2.6025	0.252	1.7523	2.5045	0.302	2.4066	0.352	2.3088
0.203	1.8488	2.6006	0.253	1.7503	2.5025	0.303	2.4046	0.353	2.3069
13/64	1.8486	2.6003	0.254	1.7484	2.5005	0.304	2.4026	0.354	2.3049
0.204	1.8468	2.5986	0.255	1.7464	2.4986	0.305	2.4007	0.355	2.3030
0.205	1.8449	2.5966	0.256	1.7444	2.4966	0.306	2.3987	0.356	2.3010
0.206	1.8429	2.5947	0.257	1.7425	2.4947	0.307	2.3968	0.357	2.2991
0.207	1.8409	2.5927	0.258	1.7405	2.4927	0.308	2.3948	0.358	2.2971
0.208	1.8390	2.5908	0.259	1.7385	2.4908	0.309	2.3929	0.359	2.2952
0.209	1.8370	2.5888	0.260	1.7366	2.4888	0.310	2.3909	23/64	2.2945
0.210	1.8350	2.5868	0.261	1.7346	2.4868	0.311	2.3890	0.360	2.2932
0.211	1.8330	2.5849	0.262	1.7326	2.4849	0.312	2.3870	0.361	2.2913
0.212	1.8311	2.5829	0.263	1.7306	2.4829	5/16	2.3860	0.362	2.2893
0.213	1.8291	2.5809	0.264	1.7287	2.4810	0.313	2.3851	0.363	2.2874
0.214	1.8271	2.5790	0.265	1.7267	2.4790	0.314	2.3831	0.364	2.2854
0.215	1.8252	2.5770	17/64	1.7255	2.4778	0.315	2.3811	0.365	2.2835
0.216	1.8232	2.5751	0.266	1.7248	2.4770	0.316	2.3792	0.366	2.2815
0.217	1.8212	2.5731	0.267	1.7228	2.4751	0.317	2.3772	0.367	2.2796
0.218	1.8193	2.5711	0.268	1.7208	2.4731	0.318	2.3753	0.368	2.2776
7/32	1.8178	2.5697	0.269	1.7189	2.4712	0.319	2.3733	0.369	2.2757
0.219	1.8173	2.5692	0.270	1.7169	2.4692	0.320	2.3714	0.370	2.2737
0.220	1.8153	2.5672	0.271	1.7149	2.4673	0.321	2.3694	0.371	2.2718
0.221	1.8133	2.5653	0.272	1.7130	2.4653	0.322	2.3675	0.372	2.2698
0.222	1.8114	2.5633	0.273	1.7110	2.4633	0.323	2.3655	0.373	2.2679
0.223	1.8094	2.5613	0.274	1.7090	2.4614	0.324	2.3636	0.374	2.2659
0.224	1.8074	2.5594	0.275	1.7071	2.4594	0.325	2.3616	0.375	2.2640
0.225	1.8055	2.5574	0.276	1.7051	2.4575	0.326	2.3596	0.376	2.2620
0.226	1.8035	2.5555	0.277	1.7031	2.4555	0.327	2.3577	0.377	2.2601
0.227	1.8015	2.5535	0.278	1.7012	2.4535	0.328	2.3557	0.378	2.2581
0.228	1.7996	2.5515	0.279	1.6992	2.4516	21/64	2.3555	0.379	2.2562
0.229	1.7976	2.5496	0.280	1.6972	2.4496	0.329	2.3538	0.380	2.2542
0.230	1.7956	2.5476	0.281	1.6953	2.4477	0.330	2.3518	0.381	2.2523
0.231	1.7936	2.5456	9/32	1.6948	2.4472	0.331	2.3499	0.382	2.2503
0.232	1.7917	2.5437	0.282	1.6933	2.4457	0.332	2.3479	0.383	2.2484
0.233	1.7897	2.5417	0.283	1.6913	2.4438	0.333	2.3460	0.384	2.2464
0.234	1.7877	2.5398	0.284	1.6894	2.4418	0.334	2.3440	0.385	2.2445
15/64	1.7870	2.5390	0.285	1.6874	2.4398	0.335	2.3421	0.386	2.2425
0.235	1.7858	2.5378	0.286	1.6854	2.4378	0.336	2.3401	0.387	2.2406
0.236	1.7838	2.5358	0.287	1.6835	2.4359	0.337	2.3381	0.388	2.2386
0.237	1.7818	2.5339	0.288	1.6815	2.4340	0.338	2.3362	0.389	2.2367
0.238	1.7799	2.5319	0.289	1.6795	2.4320	0.339	2.3342	0.390	2.2347
0.239	1.7779	2.5300	0.290	1.6776	2.4300	0.340	2.3323	25/64	2.2335
0.240	1.7759	2.5280	0.291	1.6756	2.4281	0.341	2.3303	0.391	2.2328
0.241	1.7739	2.5260	0.292	1.6736	2.4261	0.342	2.3284	0.392	2.2308
0.242	1.7720	2.5241	0.293	1.6717	2.4242	0.343	2.3264	0.393	2.2289
0.243	1.7700	2.5221	0.294	1.6697	2.4222	11/32	2.3250	0.394	2.2269
0.244	1.7680	2.5201	0.295	1.6677	2.4203	0.344	2.3245	0.395	2.2250
0.245	1.7661	2.5182	0.296	1.6658	2.4183	0.345	2.3225	0.396	2.2230
0.246	1.7641	2.5162	19/64	1.6641	2.4166	0.346	2.3206	0.397	2.2211
0.247	1.7621	2.5143	0.297	1.6638	2.4163	0.347	2.3186	0.398	2.2191
0.248	1.7602	2.5123	0.298	1.6618	2.4144	0.348	2.3166	0.399	2.2172
0.249	1.7582	2.5104	0.299	1.6599	2.4124	0.349	2.3147	0.400	2.2152
0.250	1.7562	2.5084	0.300	1.6579	2.4105	0.350	2.3127	0.401	2.2133

TABLE VIII. CALCULATING CIRCULAR FORMING TOOLS

Length c on Tool	No. 2 B. & S. Machine	Length c on Tool	No. 2 B. & S. Machine	Length c on Tool	No. 2 B. & S. Machine	Length c on Tool	No. 2 B. & S. Machine	Length c on Tool	No. 2 B. & S. Machine
0.402	2.2113	0.422	2.1724	0.443	2.1315	0.464	2.0907	31/64	2.0505
0.403	2.2094	0.423	2.1704	0.444	2.1296	0.465	2.0888	0.485	2.0500
0.404	2.2074	0.424	2.1685	0.445	2.1276	0.466	2.0868	0.486	2.0480
0.405	2.2055	0.425	2.1666	0.446	2.1257	0.467	2.0849	0.487	2.0461
0.406	2.2035	0.426	2.1646	0.447	2.1237	0.468	2.0830	0.488	2.0441
13/32	2.2030	0.427	2.1627	0.448	2.1218	15/32	2.0815	0.489	2.0422
0.407	2.2016	0.428	2.1607	0.449	2.1199	0.469	2.0810	0.490	2.0403
0.408	2.1996	0.429	2.1588	0.450	2.1179	0.470	2.0791	0.491	2.0383
0.409	2.1977	0.430	2.1568	0.451	2.1160	0.471	2.0771	0.492	2.0364
0.410	2.1957	0.431	2.1549	0.452	2.1140	0.472	2.0752	0.493	2.0344
0.411	2.1938	0.432	2.1529	0.453	2.1121	0.473	2.0733	0.494	2.0325
0.412	2.1919	0.433	2.1510	29/64	2.1113	0.474	2.0713	0.495	2.0306
0.413	2.1899	0.434	2.1490	0.454	2.1101	0.475	2.0694	0.496	2.0286
0.414	2.1880	0.435	2.1471	0.455	2.1082	0.476	2.0674	0.497	2.0267
0.415	2.1860	0.436	2.1452	0.456	2.1063	0.477	2.0655	0.498	2.0247
0.416	2.1841	0.437	2.1432	0.457	2.1043	0.478	2.0636	0.499	2.0228
0.417	2.1821	7/16	2.1422	0.458	2.1024	0.479	2.0616	0.500	2.0200
0.418	2.1802	0.438	2.1413	0.459	2.1004	0.480	2.0597	.....	......
0.419	2.1782	0.439	2.1393	0.460	2.0985	0.481	2.0577	.....	......
0.420	2.1763	0.440	2.1374	0.461	2.0966	0.482	2.0558	.....	......
0.421	2.1743	0.441	2.1354	0.462	2.0946	0.483	2.0538	.....	......
27/64	2.1726	0.442	2.1335	0.463	2.0927	0.484	2.0519	.....	......

METHOD OF USING TABLES

The accompanying tables have been compiled to facilitate the calculation of circular forming tools for Brown & Sharpe automatic screw machines. The maximum diameter D (see illustration) of forming tools for these machines



should be: For No. 00 machine, 1¾ inch; for No. 0 machine, 2¼ inches; for No. 2 machine, 3 inches. To find the other diameters of the tool for any piece to be formed, proceed as follows: Subtract the smallest diameter of the work from that diameter of the work which is to be formed by the required tool-diameter; divide the remainder by 2; locate the quotient obtained in the column headed "Length c on Tool," and opposite the figure thus located and in the column headed by the number of the machine used, read off directly the diameter to which the tool is to be made. (The quotient obtained, and which is located in the column headed "Length c on Tool" is the length c as shown in the illustration).

GENERAL DIMENSIONS OF FORMING TOOLS FOR B. & S. AUTOMATIC SCREW MACHINES
(See illustration for notation.)

Number of Machine	D	h	T	W
00	1¾	1/8	3/8—16	1/4
0	2¼	5/32	1/2—14	5/16
2	3	1/4	3/4—12	3/8

Example: A piece of work is to be formed on a No. 0 machine to two diameters, one being ¼ inch and one 0.550 inch; find the diameters of the tool.

The maximum tool diameter is 2¼ inches. This will be the diameter which will cut the ¼ inch diameter of the work. To find the other diameter, proceed according to the rule given.

$0.550 - \frac{1}{4} = 0.300$; $0.300 \div 2 = 0.150$.

In Table II, opposite 0.150, we find that the required tool diameter is 1.9534 inch.

From Fig. 29 we have:

$$\sin CBD = \frac{h}{R}.$$

From Table II we have $h = C = \frac{1}{4}$, and $R = \frac{1}{2} D = 1\frac{1}{2}$, and hence:

$$\sin CBD = \frac{1}{6}$$

$$\cos CBD = \sqrt{1 - \sin^2 CBD} = \sqrt{\frac{35}{36}} = 0.9860183$$

From the "law of cosines" in trigonometry, we obtain:

$$r = \sqrt{R^2 + c^2 - 2\,R\,c \times \cos\,C\,B\,D}$$

Substituting the known values, we have:

$$r = \sqrt{2.25 + 0.000001\,n^2 - 0.0029580399\,n.}$$

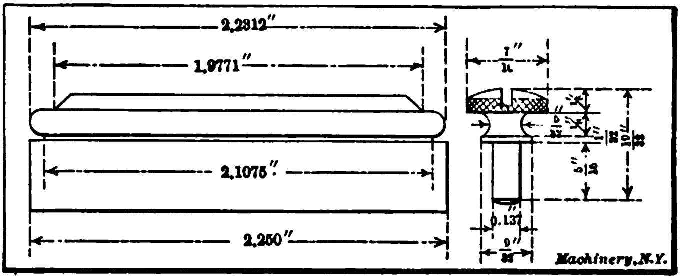


Fig. 30. Dimensions of Work and Tool in the Practical Example Given

To shorten the numerical work we can now calculate r for $n = 50$, $n = 100$, $n = 150$, etc., which is equivalent to considering the distance AB, Fig. 29, divided into a number of equal divisions, each 0.001 inch long, and computing the radius r for $AB = 0.050$, $AB = 0.100$, etc. By trial it can be determined that the values of r for other values of n can be interpolated between those calculated, so that the interpolated values will be correct to four decimal places. Henee, by computing the values of r, as stated, by the formula just given, we obtain the values in Table IV. The fourth column in this table gives the differences of radii corresponding to a difference of 0.001 inch in the length of line AB. By multiplying the values of r and the differences for 0.001 inch, by 2, we obtain the diameter and diametral differences directly, as shown in the last two columns. The tables on pages 34 to 37 are computed by simply subtracting these diametral differences, as given in Table IV, from each preceding diameter, as indicated below.

For

$n = 0,\ 2r = 3.000000$

$n = 1,\ 2r = 3.000000 - 0.001971 = 2.998029$

$n = 2,\ 2r = 2.998029 - 0.001971 = 2.996058$

and so forth to $n = 49$.

For

$n = 50,\ 2r = 2.901446$

$n = 51$, $2r = 2.901446 - 0.001969 = 2.899477$

$n = 52$, $2r = 2.899477 - 0.001969 = 2.897508$

and so forth to $n = 99$. In this way the calculations are continued until the table is completed.

The following example will illustrate the practical application of Tables V to VIII. Assume that we wish to design a circular forming tool to turn the piece shown in Fig. 30, on a No. 0 Brown & Sharpe automatic screw machine. Let the largest diameter of the circular tool correspond with the smallest diameter on the piece. Then find one-half the difference between the required diameters of the work as follows:

$$\frac{\frac{5}{32} - 0.137}{2} = \frac{0.156 - 0.137}{2} = \frac{0.019}{2} = 0.0095 \text{ inch}$$

$$\frac{\frac{9}{32} - 0.137}{2} = \frac{0.281 - 0.137}{2} = \frac{0.144}{2} = 0.072 \text{ inch}$$

$$\frac{\left(\frac{7}{16} - 0.024\right) - 0.137}{2} = \frac{0.276}{2} = 0.138 \text{ inch}$$

From Table V, we find opposite 0.0095,* in the column headed No. 0 the value 2.2312, which is the diameter to which to turn the circular tool to produce the 5/32 inch diameter on the work when the largest diameter of the circular tool turns the smallest diameter on the work to 0.137 inch diameter. The other diameters are found opposite 0.072 and 0.138, in the column headed No. 0; they are 2.1075 inches and 1.9771 inch, respectively.

* The table only reads to thousandths of an inch, but values corresponding to ten-thousandths inch can be found by interpolating.

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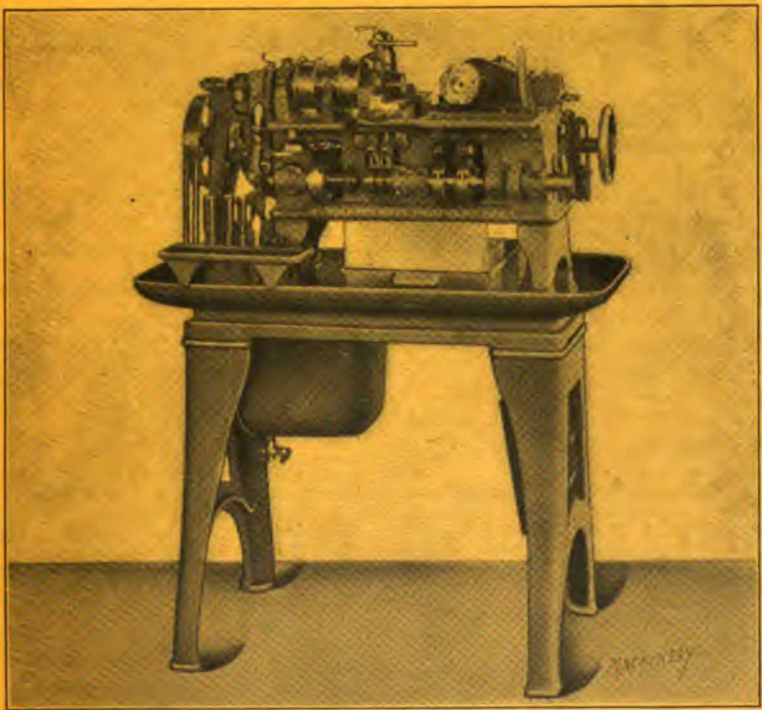

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NUMBER 102

AUTOMATIC SCREW MACHINE PRACTICE

PART IV

EXTERNAL CUTTING TOOLS FOR BROWN & SHARPE AUTOMATIC SCREW MACHINES

By DOUGLAS T. HAMILTON

CONTENTS

Automatic Screw Machine Practice for the Brown & Sharpe automatic screw machines is covered in eight Reference Books, Nos. 99 to 106, inclusive. Reference Book No. 99, "Operation of the Brown & Sharpe Automatic Screw Machines," deals with the construction of these machines and the setting-up of the tools. No. 100, "Designing and Cutting Cams for Automatic Screw Machines," gives detailed instruction on cam design, and describes a simplified method for milling cams. No. 101, "Circular Form and Cut-off Tools for the Automatic Screw Machine," deals with the general arrangement and the calculations of these tools, and describes the different methods employed in their making. No. 102, "External Cutting Tools for the Automatic Screw Machine," deals with the design and construction of box-tools, taper turning tools, hollow mills, and shaving tools. No. 103, "Internal Cutting Tools for the Automatic Screw Machine," deals with centering tools, cross-slide drilling attachments, counterbores, reamers, and recessing tools. No. 104, "Threading Operations on the Automatic Screw Machine," treats on cam design for threading operations, threading dies, taps and tap drills, die and tap holders, and thread rolling. No. 105, "Knurling Operations on the Automatic Screw Machine," describes the construction of knurling holders, and gives directions for the making of knurls and the design of tools and cams used in connection with knurling operations. No. 106, "Milling, Cross-drilling and Burring Operations on the Automatic Screw Machine," describes screw-slotting attachments, index drilling attachments, and burring attachments, giving directions for their use and for the design of cams for them.

CHAPTER I

BOX-TOOLS FOR AUTOMATIC SCREW MACHINES

The subject of external cutting tools is of wide scope, embracing all the tools which are used in removing material from the exterior of the work. The most common tools used for external work are circular forming tools, box-tools, hollow-mills, swing tools, taper-turning tools, angular cutting-off tools, and shaving tools. All the tools mentioned, with the exception of circular form and cut-off tools, which are dealt with in MACHINERY's Reference Book No. 101, "Automatic Screw Machine Practice—Part III," will be described in the following pages. External cutting tools are made of different designs to suit the conditions of the work on which they are to be used; therefore a detailed description of the construction and use of each tool will be given. As box-tools are used extensively on the automatic screw machine, and as they are the most common of all the tools used for external work, they will be considered first.

Preparing Work for Turning

Before reducing the diameter of the work by means of a box-tool or other external cutting tool of a similar type, it is necessary to chamfer the front end of the work to permit the starting of the box-tool cutter on a light cut, until the supports are in position to steady the work. Pointing or chamfering the end of the work also facilitates the setting of a hollow-mill concentric with the work.

One method of pointing the end of the work is shown at *A* in Fig. 1. Here the circular cut-off tool has an angular projection on its face next to the chuck, which points the bar before it is fed out for the next piece. This method is generally used when the work is not very long, and when it runs practically true. When it is necessary to cut a thread on a piece, the beveled end of the bar is made small enough to facilitate the starting of the die.

It is sometimes found impossible to point the bar with the cut-off tool, owing to various conditions, and in this case the bar is usually pointed by a combination centering and pointing tool as shown at *B*. This tool can be used when the bar does not project more than three and one-half times its diameter from the face of the chuck, and also when the bar is unfinished or of irregular shape. The tool *a* is used for centering the work, thus preparing it for drilling a hole, and the tool *b* is used for pointing the end of the bar.

Another condition is that shown at *C*. Here the form tool precedes the box-tool, necking the bar at *a*. Now if the face *b* of the circular tool were left square and not chamfered, as shown, a ring or washer would be formed by the box-tool cutter, as there would be no resistance to the pressure of the cut, and hence the thin ring would break off before all the material had been removed. This condition was clearly illustrated and described in Part III of this treatise, Reference Book No. 101.

When it is necessary to turn down a portion of a long cylindrical piece of cold-drawn steel or other material which has a finished surface, and have the part turned concentric with that which has not been reduced, it is usually good practice to weaken the bar with the circular cut-off tool as shown at *D*. For this class of work a supporting bushing held in the box-tool should precede the turning tool, so that the part turned will be concentric with the finished body of the work. Before turning, the bar is pointed with the circular cut-off tool as shown at *A*.

The diameter *a* of the neck should be small enough to allow the bar to be straightened with the box-tool support, so that it will run true.

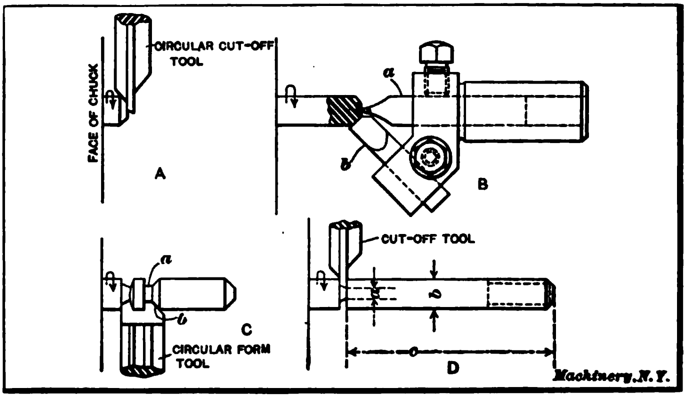


Fig. 1. Methods of Preparing Work for Turning

In the majority of cases the neck *a* may be made from 0.3 to 0.5 times *b*, but, of course, the length *c* of the work, the depth of the chip removed, and the feed used, will govern largely the diameter of the neck. The material being turned will also affect this diameter slightly, but in most cases this latter condition can be disregarded. Rods which have short bends in them should not be used, as it will be found impossible to produce a good surface on the part which is turned. The spring collet should also run perfectly true if good results are to be expected.

Application of Box-tool Cutters to the Work

Box-tool cutters are applied either radially or tangentially to the work. The radial cutter is more commonly used for brass work, while the tangential cutter is used for all classes of steel work, although it is also sometimes used for brass work.

At *A* in Fig. 2 is shown what is termed a "radial cutter." The cutting edge is set slightly above the horizontal center line of the work. The amount that it is set above the center is usually about 0.02 times the diameter to which the work is being turned. This is the preferable

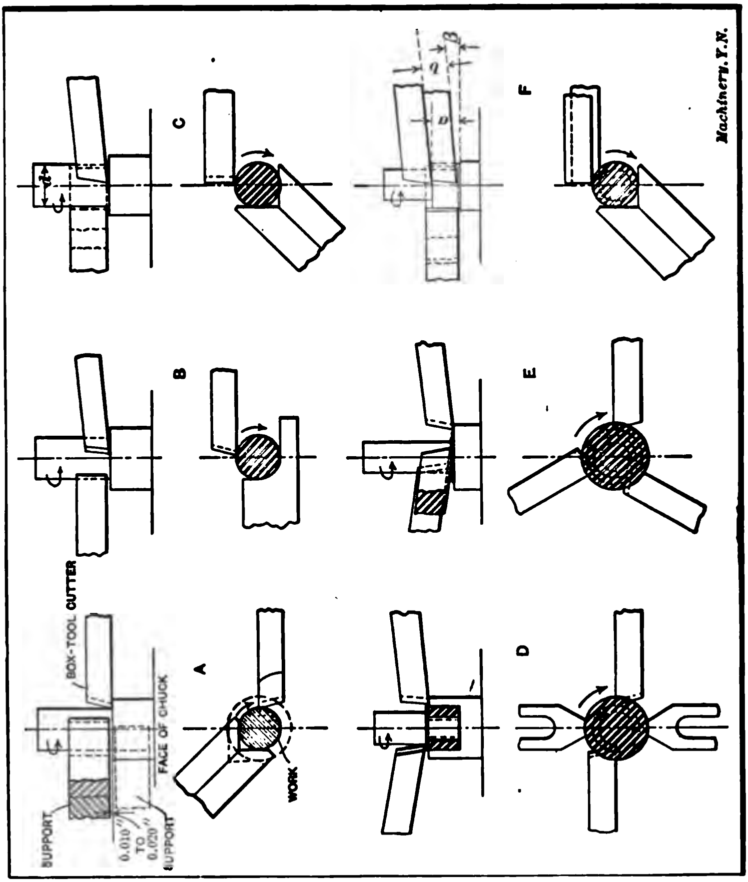


Fig. 2. Various Methods of Applying Box-tool Cutters to the Work

method of applying a turning tool for taking roughing cuts on brass rod. When the stock is rough, or of an irregular shape, the cutter should precede the support by an amount equal to from 0.010 to 0.020 inch, but when the bar is cylindrical and has a finished surface, the support for roughing cuts should precede the turning tool, as is shown by the dotted lines.

At *B* is shown what is called a tangential cutter. Here the cutter is set to take a roughing cut from a bar which is not finished, or of irregular shape. Where the bar has a finished surface and is circular in shape, the support is set in advance of the turning tool as already mentioned.

A tangential cutter set for taking a finishing cut on steel work is shown at *C*. Here the turning tool is set slightly back of the center, an amount equal to about 0.10 of the diameter *d* to which the work is being turned. For cutting brass, the tangential cutter is set in line with the center, and, in some cases, a slight amount in advance of the center.

A method of applying two turning tools for roughing down steel work is shown at *D*, and at *E* is shown a method of applying three turning tools for the same purpose. For taking roughing cuts on brass, where a great amount of material is to be removed, a hollow-mill is generally used, but the method shown at *D* can sometimes be used to advantage. In the case shown at *E* no supports are used, as the tools support the stock. These tools can either be set radially as shown. and a slight amount in advance of each other, or tangentially and at varying heights, so as to distribute the cuts equally among the tools. For taking roughing cuts on steel, it is preferable to set the cutters tangentially to the work.

At *F* is shown a method of applying two tangential turning tools for turning down two diameters on a piece of work. This method is used when the distance *a* is not much greater than from ½ to ⅝ inch. If the distance *a* is much greater than this it is generally advisable to use two separate box-tools, provided there is sufficient room in the turret. When turning tools are used in this manner it is necessary to have the thickness of the first tool, or the distance *b*, such that the second tool, when set tightly against the first one will turn the shoulder to the desired length.

To illustrate clearly how the distance *b* is obtained, we will take a practical example. Let $a = 0.375$ inch, $\beta = 10$ degrees; then $b = a \times \cos\beta = 0.375 \times 0.9848 = 0.3693$ inch. When two turning tools are used in this manner they should be ground on all surfaces and should also be made a good fit in the square or oblong hole cut in the body of the holder to receive them.

Holding and Adjusting Box-tool Cutters

It is conducive to good results to have a box-tool cutter held rigidly in the holder. It should not project any further from the holder than is absolutely necessary in order that the latter may clear the largest diameter of the bar being turned. Means for adjusting the tool to cut different diameters should also be provided. At *A* in Fig. 3 is shown a method which is commonly used for holding a box-tool cutter for brass work. In this case a square hole is cut in the body of the holder to receive the cutter, the latter being held by a set-screw *a*. The cutter is adjusted for different diameters by the collar-head set-screw *b* which bears against the rear end of the tool. It is obvious that this screw can only be used for adjusting the tool in, but by cutting a slot in the turning tool to fit the collar on the screw, this same screw may be used for adjusting the tool both in and out, thus making it more convenient.

The method shown at *B* for holding the turning tool is used particularly for brass work. In this case the turning tool is held in the block *c* by two set-screws *d*, the block being adjustable along the body of the holder. The block *c* has a projecting shank which passes through the body of the holder and is fastened to it by means of the nut and washer shown. It is evident that this method of holding the tool is very convenient for certain classes of work, especially when different

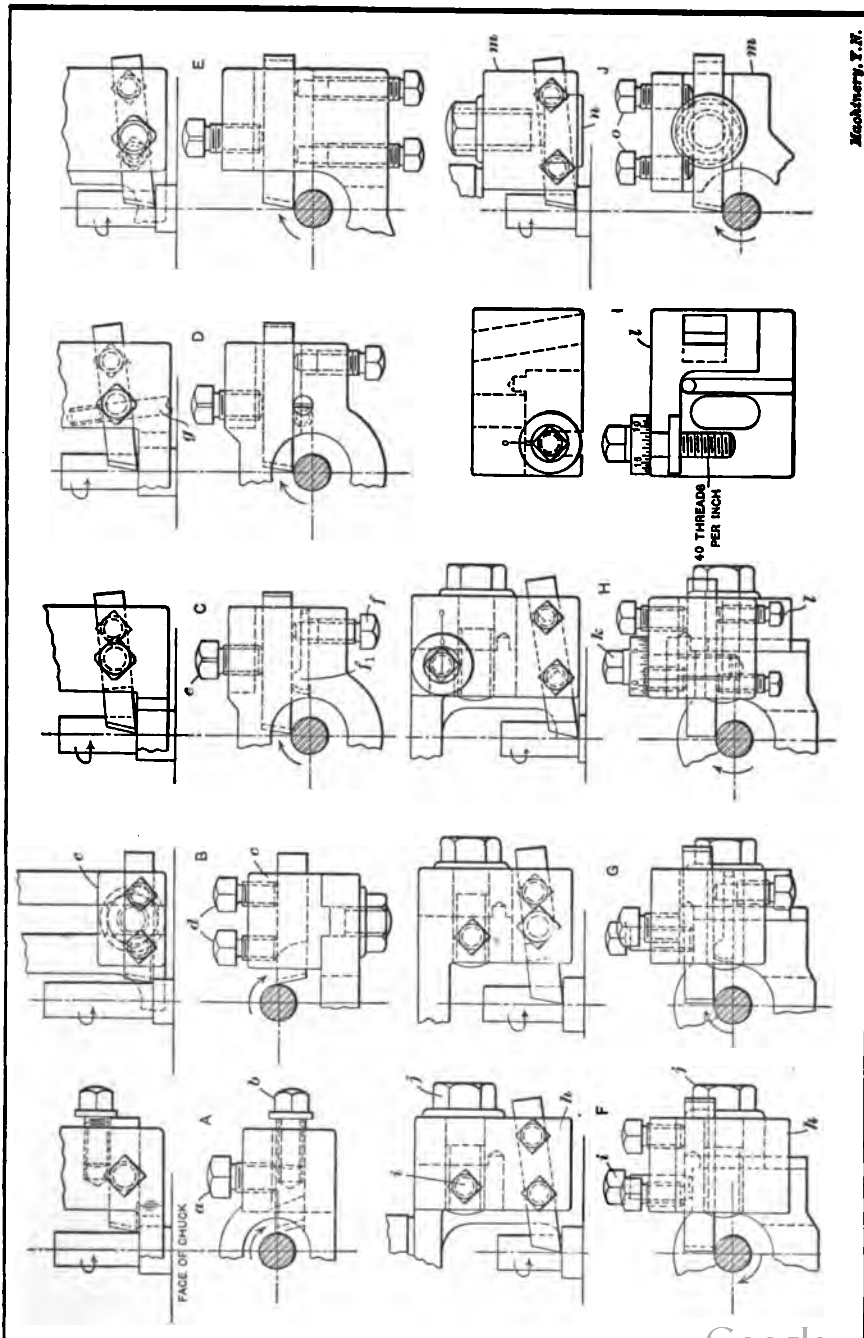


Fig. 3. Holding and Adjusting Box-tool Cutters for Various Conditions

diameters are required, as it is possible to have one or more blocks for holding the turning tools.

A method of adjusting and holding a tangential cutter is shown at *C*. Here the cutter is set off at an angle from the face of the box-tool, and is held in the body of the holder by two set-screws *e* and *f*. The tool rests on a small block f_1, thus allowing it to be adjusted for turning different diameters, the two set-screws being used in connection with this block for adjusting. This method of adjusting and holding the turning tool is limited in its range, very little adjustment being obtained by it.

A method of holding the turning tool somewhat similar to that just described is shown at *D*. Here the tool rests on the body of a screw *g* instead of on a block. These two methods of adjusting the tool can only be used for certain classes of work. A method which allows of more adjustment is shown at *E*. Here the tool is adjusted and held by three set-screws, thus allowing it to be adjusted for various diameters, with the face of the tool held in a plane parallel to the horizontal center line.

The methods shown at *C*, *D* and *E* are very seldom used for finishing box-tools; they are used principally for roughing box-tools. At *F* is shown the method of adjusting the turning tool holder which is usually applied to finishing box-tools. Here the tool is held in a block *h* which is adjusted up and down on the body of the holder by means of set-screw *i*; the block is held, when in the desired position, by cap-screw *j*. This block has a groove in it which fits on a tongue formed on the box-tool body, thus holding the tool-holder rigidly.

At *G* is shown a method similar to that just described, but the turning tool is in this case held in the holder in a manner similar to that shown at *C*. By this means the cutter may be set at a slight angle from the horizontal center line, thus giving it more clearance, as is sometimes necessary, especially when cutting steel. A slight adjustment of the tool, independently of the tool-holder is also possible.

It will be seen from a study of the various methods shown that the setting of the tool cannot be accurately known, so that a number of trial cuts have to be taken before the desired diameter is obtained. To obviate this tedious operation of setting the tool, a micrometer screw is used for setting the box-tool cutter to the correct diameter, as shown at *H* and *I*. This micrometer screw *k* has two shoulders on it and is screwed into the body of the holder, the body of the screw being made a good fit in the block shown in detail at *I*. The hole in block *l* through which screw *k* passes is slotted out to the edge as shown, to facilitate assembling the screw in the block. A 40-pitch thread is cut on this screw, so that for one revolution of the screw the turning tool is moved up or down, as the case may be, a distance equal to 0.025 inch. By making this screw a good fit in the body of the holder and the block, it is possible to get the desired diameter without much trouble. The block is held to the body of the holder in the same manner as that shown at *F* and *G*.

A good method of holding two or more turning tools for roughing is shown at *J*, the holder, of course, being made with the desired number of projecting lugs or tool-holders *m*. The tool in this case is held in a stud *n*, which has a square hole cut in it to receive the tool. This hole is cut at an angle with the face, so that the tool is set at the desired angle. Two set-screws *o* are used to prevent the tool from turning under the pressure of the cut, and also to permit of a slight adjustment of the tool. As can be seen, this tool is limited in its scope, the changes for diameter being accomplished by means of the set-screws *o*, and also by moving the turning tool in or out a slight amount. This method of holding a turning tool is used mostly for roughing work and is applied in a manner similar to that shown at *E*, Fig. 2.

Application of Box-tool Supports to the Work

The type of support to use and the method of applying it are governed largely by the following conditions:

1. Shape of the stock, whether round or otherwise;
2. Character of the cut, whether taper or otherwise;
3. Nature of the material, whether soft or hard;
4. Number of different diameters to be turned;
5. Length of the work being turned;
6. Clearance allowable between the face of the circular form tool and box-tool.

These various points should be taken into consideration before designing a box-tool.

At *A* in Fig. 4 is shown a box-tool support, which is commonly used in roughing box-tools. This support envelopes the work and precedes the turning tool. It is used mainly for turning down cylindrical work in which the finished diameter is to be concentric with the part which is not finished, that is, which has not had a cut taken from it. Where the work being turned projects more than five times its diameter from the chuck, and is of large diameter, it is not advisable to use a bushing support, unless the stock is reduced by the circular cut-off tool, as previously described.

At *B* is shown a support which is recommended by some authorities for finishing box-tools. As a rule this support should be used sparingly, and in fact, the writer would suggest that it be entirely dispensed with, particularly where the work has not been previously turned. There are several objections to this support, especially when it is made solid with the holder, among which the following might be given: As this support does not envelope the work, a bar which is larger in diameter than the hole in the support can be turned; therefore, the support throws the bar to one side, so that it is not in line with the chuck, thus producing work which is not straight, but slightly tapered. At times this is objectionable, and can be avoided if an adjustable support is used. It is also sometimes suggested to drill this support in the machine in which it is to be used, and after hardening, to lap it in the machine also. This seems a roundabout way to make a support for a box-tool, when it is a very simple matter to have the box-tool support adjustable.

The support shown at *C* has none of the objectionable features mentioned regarding that shown at *B*. This support is commonly called a V-support, and has a two-point bearing on the work. As shown in the illustration, the thrust from the tool is against both supports. As a rule, this support should not precede the cutting tool, for the reason that if the work is not cylindrical in shape, the irregularities of the bar will be reproduced on the work that is turned. Hence, when using a V-support it is always best to have the cutting tool precede the support an amount varying from 0.010 to 0.015 inch. This V-support can be used for brass, steel and similar materials, and gives satisfactory results when it does not precede the turning tool.

In turning cast iron, aluminum or materials of a similar character, difficulty is sometimes encountered in producing a finished surface on

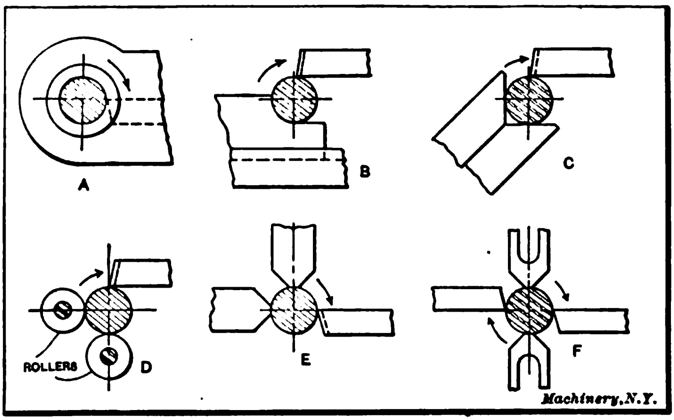


Fig. 4. Method of Applying Box-tool Supports to the Work

the work. This is usually due to fine chips or dust getting in between the supports and the work, thus causing an abrasive action which roughens the work. It is, therefore, advisable when turning aluminum, cast iron or materials of a similar character, to use roller supports. One method of applying the roller supports is shown at *D*. These rollers should be hardened and ground, and it is usually preferable to lap them also, so that they are very smooth. This support is also used when turning machine steel, and is made to bear rather hard against the work, which gives it a burnished appearance.

Another support which is sometimes used for cast iron is shown at *E*. This gives a two-point bearing, and allows the tool to be set radially to the work. This support, however, is not as good as the roller support.

At *F* is shown a method of supporting the work when applying two turning tools to it. This method is used principally for roughing down steel work. The supports, as shown, are set at right angles to the tools. This manner of turning steel work is used largely when it is necessary to rough down the work from a large to a small diameter in the least possible time.

As a rule, supports for box-tools should be made from high-carbon steel, left glass hard, and given a very smooth finish, which is one of the chief requirements of a box-tool support.

Holding and Adjusting Box-tool Supports

There are various methods used for holding and adjusting box tool supports, some of which are shown in Fig. 5. At *A* is shown a common method of holding a bushing support. The bushing is driven into the body of the holder and is held with a cone-pointed screw *a*, which is located in a spot drilled in the bushing. The bushing as shown is straight, but it is sometimes advisable to make the bushing with a shoulder on it, so that if a large piece of stock is encountered, it will not force the bushing back against the cutting tool. Of course, this is an extreme case, and where the stock varies to such an extent, the bushing support should not be used. At *B* is shown a method of holding a support similar to that shown at *B* in Fig. 4. The adjustment in this case, however, is only longitudinally along the body of the holder, there being no provision for variations in diameter. At *C* is shown one method of holding a V-support. A rectangular hole is cut in the body of the holder in which the supports fit. When in position, the supports are held by the set-screw *b*. This method of holding a V-support is commonly used for both roughing and finishing box-tools, when one cutting tool is applied to the work, and sometimes when two cutting tools are used so close together that it is only necessary to support the work at one place.

At *D* is shown a method of holding a V-support when it is necessary to apply more than one support to the work, as in the case when turning down to more than one diameter at a time. This support is held in a movable block *c*, which is adjusted along the body of the holder. This block *c* is held to the holder by the cap-screw *d*. A slot is cut in the body of the holder, in which this cap-screw is adjusted, and a groove is also cut in the holder to fit a projection formed on the base of the block *c*. The supports are held in the block by means of a set-screw, as at *C*.

These last two methods are principally for box-tools used for turning brass or a similar class of materials, in which the cutter is set radially to the work. At *E* is shown a common method of applying the V-support to a box-tool used for cutting steel and work of a similar character. This method of applying the support is used when the cutting tool is set tangentially with the work. The support is held in a rectangular hole cut in the body of the box-tool, by a set-screw, as shown.

The methods shown at *C*, *D* and *E* are limited in their scope, to a certain extent, owing to the fact that they cannot be used in conjunction with a circular form tool when it is necessary to have the tool work closer to the forming tool than the thickness of the web *e*. For this class of work the method of holding the support shown at *F* is commonly used. This support is beveled as shown, and set in a correspondingly beveled slot cut in the front end of the box-tool body. As

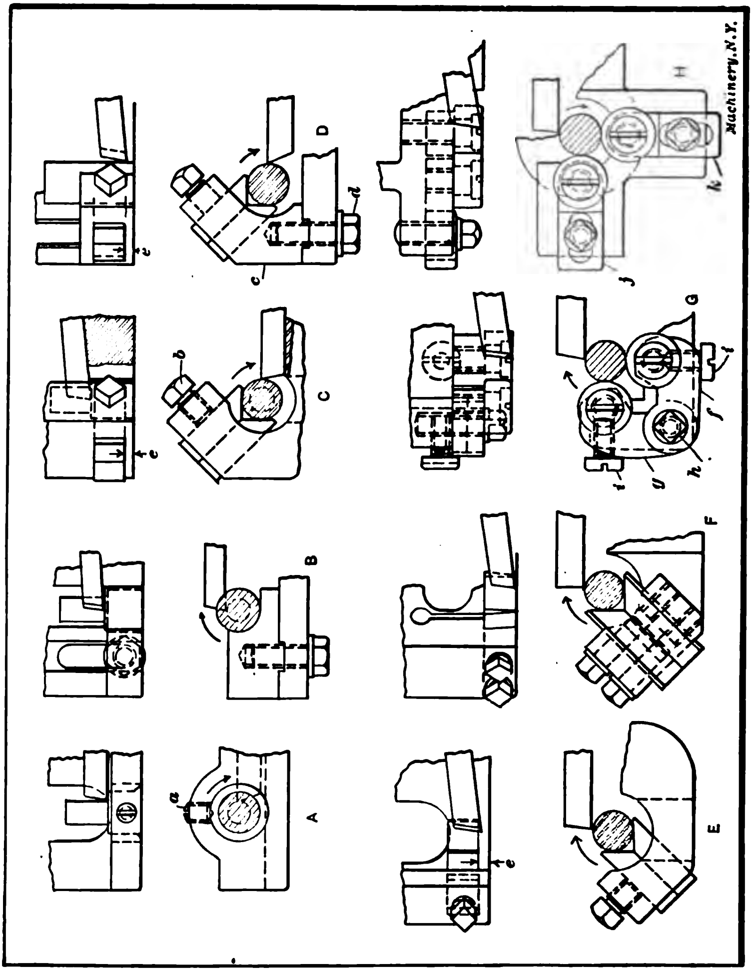


Fig. 5. Methods of Holding and Adjusting Box-tool Supports

it would be impossible to bind these supports by having a screw pressing on top of them, it is necessary to split the body of the holder, and have screws pass through the two parts, binding them together. A clearance hole for the body of the screw is drilled in the upper part, while the lower part is tapped out to fit the screw. As this method depends on the elasticity of the material, it is usually best to drill a hole of from 1/4 to 3/8 inch in diameter at the rear end of the slot, to facilitate the drawing of the two parts of the body together, which is necessary to bind the supports in a rigid manner. There is one objection to this method of holding the support, *viz.*, the difficulty of applying the turning tool (in some cases), due to the fact that it comes very close to the face of the box-tool.

As was previously mentioned, difficulty is sometimes encountered in turning cast iron, aluminum and materials of a similar character, owing to fine chips or dust getting in between the box-tool supports and the work. It was also mentioned that roller supports were advisable for this class of work. At *G* is shown a method of applying roller supports. These roller supports are held in two movable members, *f* and *g*, which, in turn, are fastened to the body of the holder by the clamping screw *h*. These members, *f* and *g*, are cut out so that they fit into each other and form a sort of "mortised" joint. As the clamping screw *h* would not be sufficient to hold these roller-support holders against the pressure of the cut, they are held in the correct position by large-headed screws *i*, which are screwed into the body of the holder.

At *H* is shown another method of applying roller supports. In this case the supports are held on two sliding holders, *j* and *k*, which slide in grooves cut in the box-tool body. They are adjusted in and out to the required diameter, and held by the clamping screws, as shown. This method of holding the supports is more rigid than that described in connection with *G*, and should in most cases be used in preference. There are numerous other methods of holding roller supports, but they are all of a somewhat similar character to those already shown. Naturally, there are various conditions which govern the method of applying these supports.

The methods of holding supports illustrated in Fig. 5 are those generally used in standard box-tools, and do not include those used for special conditions. Special applications of box-tool supports will be dealt with in a following chapter.

Cutting-angles for Box-tool Cutters

It is not sufficient to hold a box-tool cutter rigidly, and support the work well, to obtain good results, but it is also necessary to have sufficient clearance, and the correct cutting angle on the tool. That is, the tool must have sufficient clearance and rake, so as to remove the material with the least possible resistance and power. The manner in which the tool is applied to the work, and the material on which it operates, govern the cutting angle on the tool. Generally, in automatic screw machine work, for cutting brass, the box-tool cutter is set radially to the center, as shown at *A* in Fig. 6. For taking a roughing cut on brass with the turning tool set radially to the work, the tool should be ground to the shape here shown.

When taking a finishing cut on brass work, the tool is ground to the shape shown at *B*. Here a portion of the cutting surface, equal to the distance *b*, is made straight, so as to produce a smooth finish on the work. For usual conditions *b* equals 1/5 of the smallest diameter of the work being turned. It will be noticed in both these cases that the tool is not set at an angle with the face of the work, but is set parallel with it. While this method of setting the tool can be used for brass work, it is not advisable for steel work. A turning tool set tangentially with the work is shown at *C*. The angles on the tool for cutting the materials specified in the following are as follows:

Cutting-angles for Machine Steel	Cutting-angles for Tool Steel
$a = 10$ degrees,	$a = 8$ degrees,
$b = 10$ degrees,	$b = 8$ degrees,
$c = 8$ to 10 degrees,	$c = 8$ to 10 degrees,
$d = 70$ to 72 degrees.	$d = 72$ to 74 degrees.

The method of grinding the tool shown at *C* is commonly used for roughing cuts, and will not produce an absolutely square shoulder on the work. For finishing cuts the tool is ground as shown at *D*, which produces a square shoulder on the work. The cutting angles for the materials specified below are as follows:

Cutting-angles for Machine Steel	Cutting-angles for Tool Steel
$e =$ from 10 to 12 degrees,	$e =$ from 8 to 10 degrees,
$f =$ from 15 to 18 degrees,	$f =$ from 8 to 10 degrees,
$g =$ from 60 to 65 degrees.	$g =$ from 70 to 74 degrees.

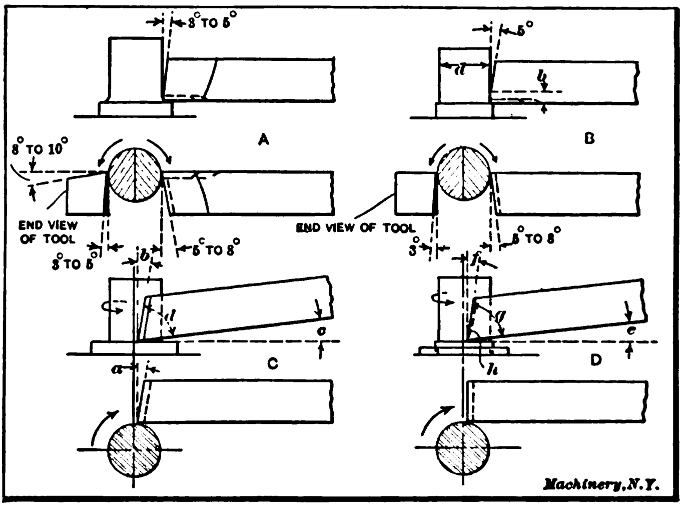


Fig. 6. Cutting-angles for Box-tool Cutters

While the cutting face on the tool shown at *D* is straight, it is usually advisable, especially when cutting machine steel and Norway iron, to give more "lip" to the tool, as is clearly shown by the dotted line *h*. This produces a curling chip and is conducive to better and more efficient cutting. It is also advisable in most cases to make the turning tools for box-tools from high-speed steel, especially for cutting machine steel, Norway iron, etc., because better results are obtained by using a high peripheral velocity and a fine feed.

Adjusting the Tangent Cutter for Turning Different Diameters

The use of the so-called "tangent" cutter has been found to be the most satisfactory method of applying a box-tool cutter for cutting machine steel, Norway iron, etc., although this method of applying the cutter is also sometimes used for cutting brass. In Fig. 7 is shown the manner of setting a tangent cutter. The face of the cutter should be set at a distance *d* back of the center. This gives the tool more clearance, and is conducive to a cleaner and better cutting action. The distance *d* should be equal to about 1/8*D* for tool steel, and 1/10*D* for Norway iron and machine steel, where *D* equals the diameter to which the work is being turned. When the tangent cutter is adjusted for a larger diameter, it should also be set back enough so that d_1 bears the same relation to the larger diameter as *d* does to the smaller. (See the dotted lines.) It is also sometimes advisable, especially when cutting machine steel, to set up the tool from the horizontal at an angle of from 1 to 2 degrees, which increases the clearance of the tool. This is accomplished by means of adjusting screws, as is clearly illustrated in Fig. 3.

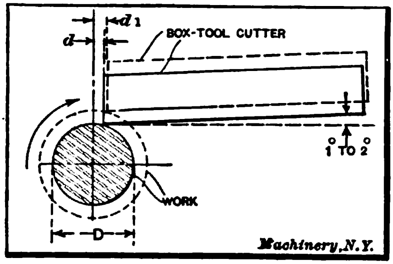


Fig. 7. Adjusting a Tangent Cutter for Turning Different Diameters

Sections of Steel used for Box-tool Cutters

Box-tool cutters should not be made of too weak a cross-section, especially for roughing, although a rigid tool is also required for finishing. The conditions under which a box-tool cutter is used govern to a large extent the cross-section of the tool. For special conditions, the tool is sometimes made of rectangular section, but for standard box-tools, it is made from square stock. The square sections recommended for box-tool cutters are as follows:

Largest Diameter of Work in Inches	Square Section of Tool in Inches	Largest Diameter of Work in Inches	Square Section of Tool in Inches
1/4	3/16	3/4	3/8
3/8	1/4	1	7/16
1/2	5/16	..	..

Where box-tools are to be used exclusively for taking light finishing cuts, the sections given above can be slightly decreased.

CHAPTER II

DESIGNING BOX-TOOLS

The designer of screw-machine tools is frequently confronted with difficulties when designing special box-tools, owing to the fact that the Brown & Sharpe automatic screw machines are very compact. This makes it necessary to design all the tools so that they will not interfere with any part of the machine or the tools which are used on the cross-slides. The following considerations must also be borne in mind:

1. Character of material, whether rough or cold-drawn.
2. Cross-section of the material, whether cylindrical, square, or hexagonal, etc.

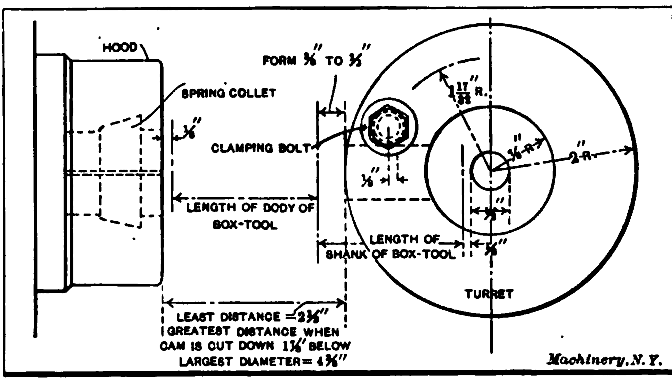


Fig. 8. Method of Determining Length of Body and Shank of Box-tool

3. Character of the longitudinal cut, whether straight, tapered or irregular.
4. Length of the work to be turned.
5. Number of different diameters to be turned.
6. Position of the box-tool in relation to the cross-slide tools, when in action on the work.
7. Amount of material to be removed from the diameter.

In addition to the factors mentioned, one of the first things to consider when designing a box-tool is the length of the body and shank of the tool. As a rule, the length of the body is governed by the length of the work to be turned, especially when the hole in the shank cannot be made large enough to let the smallest diameter of the work pass through. Another consideration to take into account is the distance from the center of the hole in the turret to the side of the chute. This limits the width of the box-tool, and is a governing factor in its design. Still another point which might be mentioned is the distance between the point where the box-tool cutter finishes on the work, and the face of the chuck. When this is less than 1/8 inch it is usually necessary to have the cutter project slightly in advance of the face of the box-tool body.

If a special box-tool is to be designed, it is advisable to make a lay-out of the machine on which this tool is to be used. A plan and side elevation of the turret and cross-slides should be drawn, and the tools used on the cross-slide should also be drawn in the positions they will occupy when the box-tool is in operation on the work.

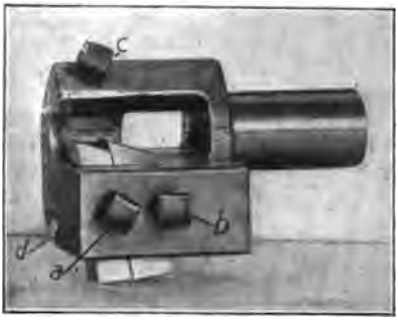


Fig. 9. Standard Box-tool made by the Brown & Sharpe Mfg. Co.

A method of laying out a box-tool for determining the length of the body and shank is shown in Fig. 8. This diagram is for a No. 0 machine, but the same principle can be used for the other sizes. When designing a standard box-tool, the body is made about 5/8 inch less than the least distance between the face of the turret and the face of the chuck. The shank is allowed to project through the turret to within 1/8 inch of the 1/2-inch hole through the turret spindle. All the other important points regarding the design and uses of supports, turning-tool holders, etc., have been dealt with in the previous chapter, so it will not be necessary to enlarge on them here.

Various Types of Box-tools

As there are so many designs of box-tools in use, it will be impossible to mention all of them, but a few of the most common designs will be described. In Fig. 9 is shown a standard box-tool, as made by the Brown & Sharpe Mfg. Co. This box-tool, as shown, carries two cutting tools. The tools rest on a pin *d* and are held by set-screws *a* and *b*, and by two other set-screws, not shown, which are on the under side of the box-tool. The support, which is of the V-type, is located at the back of the box-tool at an angle of 45 degrees with the vertical center line, and is held by the set-screw *c*. This box-tool is used for general work, for turning both one and two diameters, as required. When one diameter is being turned, the cutter in the rear is pushed back, out of action.

In Fig. 10 is shown a standard finishing box-tool which is used largely for steel work. In this box-tool the turning tool is held in an adjustable block *A* which is adjusted up and down on the body of the holder by the set-screw *B*, and held to the body by the cap-screw *C*. A projection is formed on the body of the box-tool and a corresponding groove is cut in the block to guide. The turning tool is held by means of two set-screws *D* and the headless screws *E*. These latter are for adjusting the turning tool, in order to increase the clearance between the tool and the periphery of the work.

The V-support is held in beveled grooves, cut in the body of the holder, by two screws *F* which pass through the two parts of the body separated by a saw cut, thus binding them together. The cutting edge of the turning tool is located from 0.010 to 0.012 inch in advance of the face of the supports. A hole is drilled through the shank of the

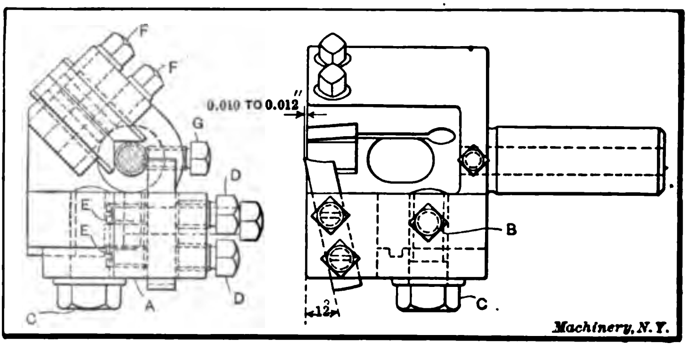


Fig. 10. Finishing Box-tool largely used for Steel Work

box-tool for holding a pointing tool or other internal cutting tool, which is held with the set-screw *G*.

The value of roller supports for turning aluminum, cast iron, etc., has been referred to, and in Fig. 12 is shown a box-tool of the roller-support type, as made by the Brown & Sharpe Mfg. Co. This box-tool, as may be seen, is provided with roller support for the front cutter, and V-support for the rear cutter.

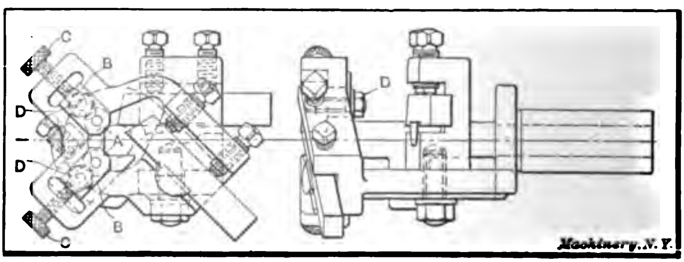


Fig. 11. Details of Box-tool shown in Fig. 12

The general design of this box-tool can be seen in Fig. 11. This illustration shows the method of holding and adjusting the roller supports. The supports *A* are held by pins in a slot cut in the two blocks *B*, which are adjusted in and out by the knurled-head screws *C*. The blocks *B* are held to the body of the box-tool by cap-screws *D* which are tapped into them. A slot is cut in the body of the holder in which the bodies of the cap-screws slide, thus providing adjustment for turning different diameters. All the other details of this box-tool can be clearly seen from the illustration.

Some interesting designs of box-tools are shown in Fig. 13. These tools are all made by the Brown & Sharpe Mfg. Co., and are used for various classes of work. At *A* is shown a box-tool which is equipped with three turning tools, and three sets of V-supports. The turning-tool and V-support holders *a*, *b* and *c* are made in one piece and are held to the body of the box-tool by cap-screws. A tongue is formed on the base of the holders, which fits in a longitudinal groove cut in the box-tool body. It will be noticed that the supports in this case are double supports, that is, they are notched on both ends, the purpose of this being to increase their range. The end of the support shown facing the turning tool is for work of small diameter, while the end projecting from the box-tool is for work of a larger diameter. This box-tool can

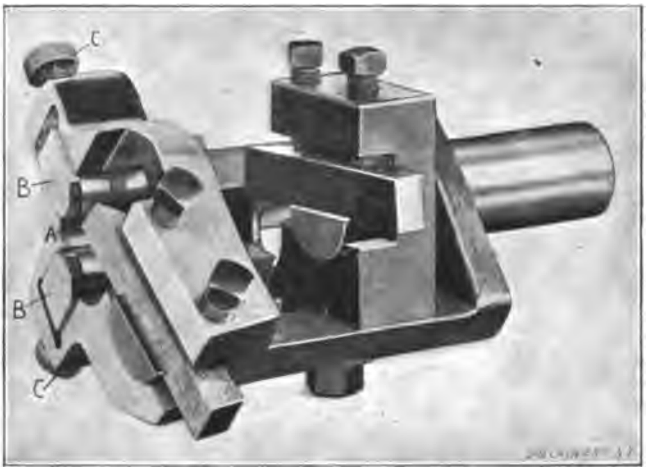
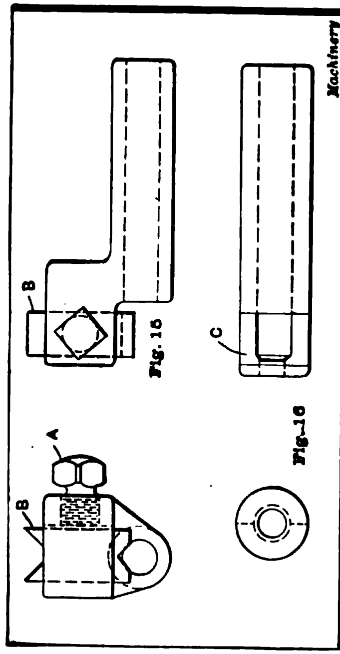


Fig. 12. Box-tool of the Roller Support Type

be used either for roughing or for finishing work, and is especially adaptable to work having three different diameters.

At *B* is shown a box-tool with two cutting tools, but with only one support. It will be noticed in this case that the holders for the turning tools are very narrow, thus permitting the tools to be set close together. The box-tool shown at *C* has two turning tools which are set close together. A hole is drilled through the shank, and a set-screw is provided for holding a centering or other internal cutting tool. At *D* is another box-tool similar to that shown at *C*, except that the supports in this case are double-ended. *E* is a finishing box-tool having two turning tools. *F* is a box-tool of similar design, but carrying only one turning tool. *G* is a pointing and centering tool, the bushing for which is shown at *H*. *I* is a pointing tool of a somewhat similar design to that shown at *G*. *J* and *K* are also pointing tools which are used largely for small work. These illustrations show clearly the design of box-tools which are used, in general, for automatic screw machine work.

Fig. 13. A Collection of Interesting Designs of Box-tools



Figs. 15 and 16. Supports used in Connection with Swing Tools

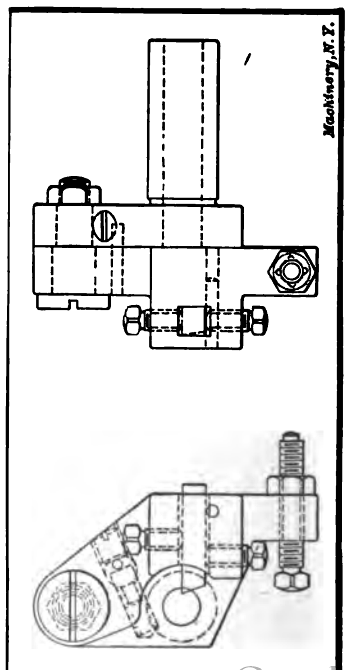


Fig. 14. Swing-tool used for External Cutting

Swing Tools for External Work

Swing tools, besides being used extensively for internal cutting, are also used for external work. There are some cases where a box-tool or a circular form tool cannot be used, owing to the irregular contour of the work, or its length in proportion to its diameter. A form tool can be used where the length of the work being turned is not more than from 2½ to 3 times its diameter, but when it exceeds this, it is necessary to use some other type. For this class of work, a swing tool such as that shown in Fig. 14 can be used to advantage. The work can be roughed down with this tool and finished with a shaving tool, which will bring it to the correct shape, and also to the desired diameter. (The use of shaving tools will be taken up in a subsequent chapter.) This tool, of course, can only be used when the diameter of the work is large enough to make a support unnecessary.

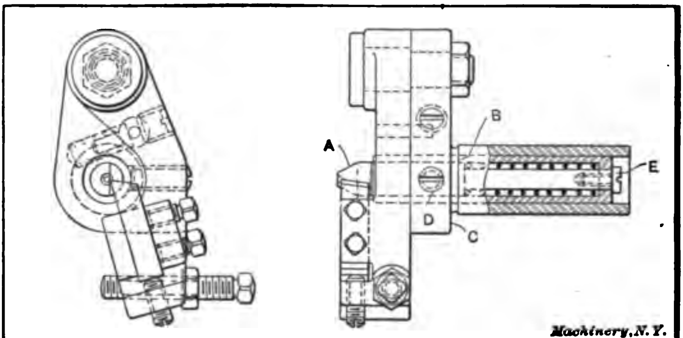


Fig. 17. Swing-tool used when the Work Turned must be Supported

The swing tool shown in Fig. 14 can be used on work of small diameter by the insertion of the support shown in Fig. 15. This support is inserted in the hole in the shank of the holder and is held by a setscrew screwed into the shank. The support *B* is of the V-type and is held by a set-screw *A*. They are set in advance of the turning tool, so that the work will be well supported while being turned. In cases where there is not sufficient room to use a support as shown in Fig. 15, a support as shown in Fig. 16 can be used. This support precedes the cutting tool, and half of the support is cut away at *C*, about ⅛ inch from the end, so that the turning tool can reach the work.

Another tool which gives very satisfactory results for this class of work is shown in Fig. 17. This tool is provided with a telescopic support which recedes into the holder as the tool advances on the work. The other features of this tool are similar in design to the standard swing tools. Mention might be made, however, of the method of holding the telescopic support *A*. A sleeve *B* is driven into the body and shank of the holder *C*, and is held by the headless screw *D*. The support proper is turned down on the shank, so that an open-wound coil spring can be inserted behind it. The support is kept from being forced out of the holder by a screw *E* which is tapped into it, and which has a head larger than the hole through the end of sleeve *B*. This method of supporting the work is found to give satisfactory results when turning work of very small diameter. It is preferable, when using this tool, to point the end of the work so that it fits snugly in the cone-pointed hole in the end of the support.

A tool for delicate turning similar to that in Fig. 17, is shown in Fig. 18, where the rising block which operates it is also shown. The only difference in this tool from that just described is that the turning tool *W* is off-set. The turning tool is held as shown in the swinging member *V*, which is pivoted to the front end of the shank *T* by a stud *U*. The tool *W* is fed in to the work by the pusher *S* pressing against the set-screw *Y*, tapped into the swinging member *V*.

Thus far we have confined our attention to tools used for straight turning; but, of course, taper work can also be done on the automatic screw machine if a suitable tool is provided. A tool which can be used for taper turning is shown in Fig. 19. This is the standard taper turning tool made by the Brown & Sharpe Mfg. Co. and is recommended for taper turning when accurate work is desired. The illustration shows the taper turning tool and the rising block for operating it. This rising block can be set at any desired angle; the angle to which the rising block is set, governs the taper on the work. When in operation, this rising block presses on the point of screw *a*, which forces the holders carrying the supports and turning tool out from the center.

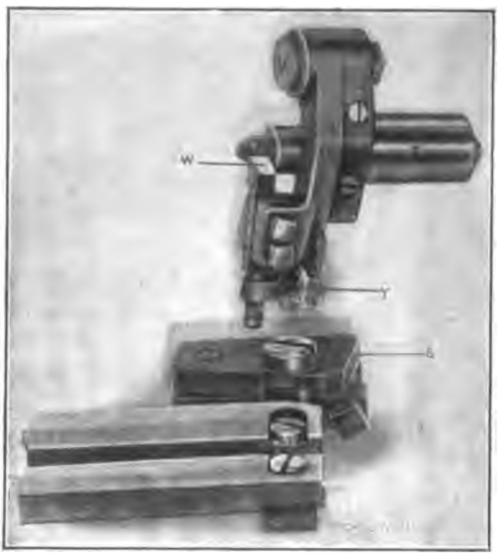


Fig. 18. Swing Tool for Delicate Turning

A clearer idea of the operation of this taper turning tool can be obtained by referring to Fig. 20. In this illustration an end view, longitudinal section and cross-section are shown at *A*, *B* and *C*, respectively, to illustrate the working mechanism of this tool. As the rising block (shown in Fig. 19) presses against the point of the screw *a*, which is tapped into sleeve *b*, it forces the latter in the direction of the arrow. Now as the sleeve *b* is forced in, it pulls on the band spring *c*, which is attached to the circular block *d*, thus turning the latter around in the direction of the arrow. The band spring is made from sheet steel, 5/16 inch wide by 0.012 inch thick, which is left soft. This spring, as shown, is fastened in a slot cut in the circular block *d*. The circular block *d* has eccentric projections *e* formed on it, which fit in slots cut in the tool-holder *f* and support-holders *g*. From a study of the illustration it can be seen that as the sleeve *b* is forced in, it carries the spring *c* forward, thus rotating the circular block *d* in the direction of the arrow and forcing the holders carrying the supports and turning tools out from the center.

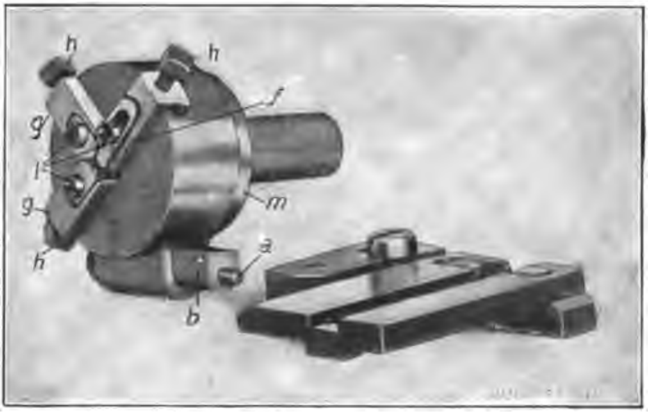


Fig. 19. Standard Taper Turning Tool

In the end view shown at *A* the turning tool and support holders are shown in the position they occupy before the rising block operates on the holder. The supports and turning tool can be adjusted independently of each other by the set-screws *h*, and are held by the fillister

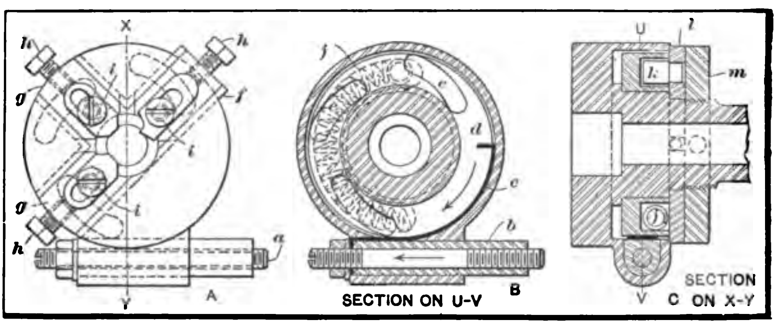


Fig. 20. Details of Taper Turning Tool shown in Fig. 19

screws *i*. After the turret drops back, disconnecting the screw *a* from the rising block, the turning tool and supports are returned to their former position by means of the coil spring *j* (shown at *B*) which is held in an annular groove cut in the rear of the circular block *d*. The spring *j* presses against a pin *k* (shown at *C*) which is riveted to a plate *l*; this plate is held to the shank of the holder by a pin fitting in a slot. Plate *l* is held up against the outer casing of the holder by the nut *m*, screwed onto the shank of the holder.

CHAPTER III

HOLLOW MILLS—SPEEDS AND FEEDS

For roughing down work, especially brass work, a hollow mill is found to give very satisfactory results. Two hollow mills of the solid type are shown in Fig. 21. These hollow mills are ground for steel work, a rake being given to the cutting edge. This is found to give better results on steel than having the cutting faces of the blades parallel with the center line.

Fig. 21. Hollow Mills of the Solid Type

The proportions for hollow mills and the cutting angles for various materials are given in Table I. The sizes from 0.065 to 0.462 inch given in column *A* are worked out for roughing mills for the A. S. M. E. standard and special machine screw sizes, an allowance of from 0.005 to 0.015 inch being made for finishing. These mills can be made to cut smaller by using a collar on them. In making these hollow mills, they should be reamed out tapering from the rear, so that the blades will clear

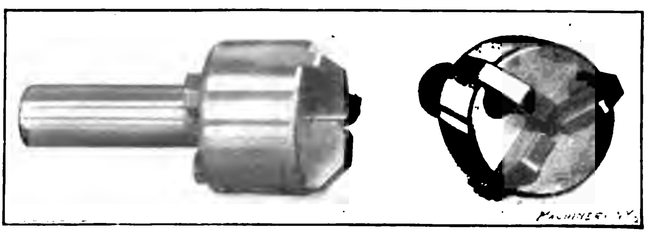
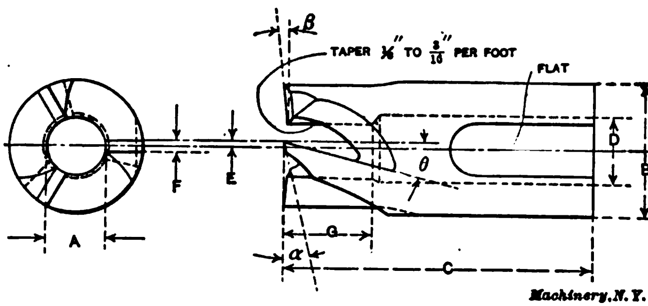


Fig. 22. Hollow Mill of the Inserted-blade Type

and not drag on the work. A taper of from about 1/8 to 3/16 inch per foot is generally satisfactory. For steel work the cutting edge is set about 1/10 of the diameter ahead of the center, but for brass work it should be on the center line. Hollow mills for cutting steel are, as a rule, made either from steel containing a very high percentage of carbon, or from high-speed steel. When high speeds are used, high-speed steel is preferable.

A hollow mill of the inserted-blade type is shown in Fig. 22. This is used extensively for screw machine work; although its use is

TABLE I. CUTTING ANGLES AND PROPORTIONS FOR HOLLOW MILLS



Machinery, N. Y.

Cutting Angles for Hollow Mills

Angle	Brass Rod	Machine Steel	Tool Steel
α	8 degrees	15 degrees	10 degrees
β	8 degrees	5 degrees	8 degrees
θ	....	15 degrees	10 degrees

Proportions for Hollow Mills

A	B	C	D	E	F	G
0.065	1/2	1 1/4	1/4	0.007	0.020	1/4
0.078	1/2	1 1/4	1/4	0.008	0.020	1/4
0.091	1/2	1 1/4	1/4	0.009	0.025	1/4
0.105	1/2	1 1/4	1/4	0.011	0.025	1/4
0.120	1/2	1 1/4	1/4	0.012	0.025	1/4
0.135	1/2	1 1/4	1/4	0.014	0.030	1/4
0.148	1/2	1 1/4	1/4	0.015	0.030	1/4
0.161	1/2	1 1/4	1/4	0.016	0.035	5/16
0.174	1/2	1 1/4	1/4	0.017	0.035	5/16
0.187	1/2	1 1/4	1/4	0.019	0.040	5/16
0.200	5/8	1 1/2	3/8	0.020	0.040	5/16
0.226	5/8	1 1/2	3/8	0.023	0.045	5/16
0.252	5/8	1 1/2	3/8	0.025	0.045	5/16
0.280	5/8	1 1/2	3/8	0.028	0.050	3/8
0.305	5/8	1 1/2	3/8	0.031	0.060	3/8
0.332	5/8	1 1/2	3/8	0.033	0.065	3/8
0.358	3/4	1 1/2	3/8	0.036	0.070	7/16
0.385	1	2 1/4	1/2	0.039	0.075	7/16
0.410	1	2 1/4	1/2	0.041	0.080	7/16
0.436	1	2 1/4	1/2	0.044	0.085	1/2
0.462	1	2 1/4	1/2	0.046	0.090	1/2
0.480	1	2 1/4	1/2	0.048	0.095	5/8
0.515	1	2 1/4	1/2	0.052	0.100	5/8
0.578	1	2 1/4	1/2	0.058	0.105	3/4
0.640	1	2 1/4	1/2	0.064	0.110	3/4
0.708	1	2 1/4	11/16	0.070	0.115	7/8
0.765	1	2 1/4	11/16	0.077	0.120	7/8

mainly confined to hand screw machines it is sometimes also applied to the automatics. This mill is provided with three cutting blades, which are held in the body of the holder by clamp-bolts fitting in beveled slots cut in the blades. The clamp-bolts are held by means of nuts located at the rear of the body. The blades are sharpened by grinding on the ends, and can be adjusted for diameter by simply releasing the nuts and moving the blades out or in by hand.

Hollow Mill Holders

When hollow mills of the solid type are used, it is necessary to have a holder which can be set so that the mill will cut concentric. A

TABLE II. FEEDS FOR ROUGHING BOX-TOOLS—CUTTERS MADE FROM HIGH-SPEED AND CARBON STEEL

1/32-inch Chip				1/8-inch Chip			
Smallest Diameter of Stock	Brass Rod, Feed per Revolution	Machine Steel, Feed per Revolution	Tool Steel, Feed per Revolution	Smallest Diameter of Stock	Brass Rod, Feed per Revolution	Machine Steel, Feed per Revolution	Tool Steel, Feed per Revolution
1/16	0.0020	0.0015	0.0010	3/8	0.0045	0.0030	0.0020
1/8	0.0030	0.0020	0.0015	7/16	0.0050	0.0035	0.0025
3/16	0.0040	0.0030	0.0020	1/2	0.0060	0.0040	0.0030
1/4	0.0050	0.0040	0.0025	9/16	0.0070	0.0050	0.0035
5/16	0.0060	0.0045	0.0030	5/8	0.0085	0.0060	0.0040
3/8	0.0075	0.0050	0.0035	3/4	0.0100	0.0070	0.0050
1/16-inch Chip				**3/16-inch Chip**			
1/4	0.0045	0.0030	0.0020	1/2	0.0040	0.0025	0.0015
5/16	0.0060	0.0040	0.0025	9/16	0.0045	0.0030	0.0018
3/8	0.0090	0.0060	0.0030	5/8	0.0050	0.0032	0.0020
7/16	0.0105	0.0070	0.0040	11/16	0.0055	0.0035	0.0023
1/2	0.0120	0.0080	0.0050	3/4	0.0060	0.0040	0.0025
9/16	0.0135	0.0090	0.0060	13/16	0.0070	0.0045	0.0028
5/8	0.0150	0.0100	0.0075	7/8	0.0075	0.0050	0.0030

holder which is used for this purpose, and which gives satisfactory results, is the standard floating holder made by the Brown & Sharpe Mfg. Co. In setting a hollow mill, the screws holding the floating part of the holder to the body proper are released and the mill is set concentric. It is desirable to turn a bevel on the end of the work to facilitate the setting of the hollow mill.

Speeds for External Cutting Tools

The following speeds are for external cutting tools such as box-tool cutters, hollow mills, etc., made from ordinary carbon and high-speed steel, but do not apply to circular cut-off or form tools. The speeds are intended for average conditions on the materials specified.

SPEEDS FOR BOX-TOOL CUTTERS AND HOLLOW MILLS MADE FROM ORDINARY CARBON STEEL

Material	Surface Speed in Feet per Minute
Brass (ordinary quality)	170 — 180
Gun screw iron	70 — 80
Norway iron and machine steel	60 — 70
Drill rod and tool steel	35 — 40

SPEEDS FOR BOX-TOOL CUTTERS AND HOLLOW MILLS MADE FROM HIGH-SPEED STEEL

Material	Surface Speed in Feet per Minute
Brass (ordinary quality)	250 — 270
Gun screw iron	100 — 120
Norway iron and machine steel	90 — 100
Drill rod and tool steel	50 — 60

TABLE III. FEEDS FOR FINISHING BOX-TOOLS—CUTTERS MADE FROM HIGH-SPEED AND CARBON STEEL

0.005-inch Chip				0.020-inch Chip			
Smallest Diameter of Stock	Brass Rod, Feed per Revolution	Machine Steel, Feed per Revolution	Tool Steel, Feed per Revolution	Smallest Diameter of Stock	Brass Rod, Feed per Revolution	Machine Steel, Feed per Revolution	Tool Steel, Feed per Revolution
1/32	0.0020	0.0020	0.0018	3/8	0.0040	0.0040	0.0025
1/16	0.0030	0.0030	0.0020	7/16	0.0045	0.0045	0.0030
3/32	0.0045	0.0045	0.0025	1/2	0.0050	0.0050	0.0035
1/8	0.0060	0.0060	0.0030	9/16	0.0060	0.0060	0.0035
3/16	0.0070	0.0070	0.0040	5/8	0.0070	0.0070	0.0040
1/4	0.0080	0.0080	0.0050	11/16	0.0075	0.0075	0.0045
5/16	0.0100	0.0100	0.0060	3/4	0.0080	0.0080	0.0050
3/8	0.0120	0.0120	0.0080	13/16	0.0090	0.0090	0.0050
0.010-inch Chip				**0.030-inch Chip**			
1/4	0.0070	0.0070	0.0035	1/2	0.0040	0.0040	0.0020
5/16	0.0080	0.0080	0.0040	9/16	0.0045	0.0045	0.0022
3/8	0.0085	0.0085	0.0045	5/8	0.0050	0.0050	0.0025
7/16	0.0090	0.0090	0.0050	11/16	0.0055	0.0055	0.0028
1/2	0.0095	0.0095	0.0055	3/4	0.0060	0.0060	0.0030
9/16	0.0100	0.0100	0.0060	13/16	0.0070	0.0070	0.0035
5/8	0.0100	0.0100	0.0065	7/8	0.0080	0.0080	0.0040

Feeds for Roughing and Finishing Box-tools

In Table II are given feeds for roughing box-tools in which the cutters are made from high-speed and carbon steel, and in Table III are given feeds for finishing box-tools in which the cutters are made from high-speed and carbon steel. These feeds will give satisfactory results under proper conditions. The feeds for roughing, of course, could in some cases be increased if conditions would permit, but as a rule the feeds given are sufficiently high.

TABLE IV. FEEDS FOR TURNING WITH SWING TOOLS—CUTTERS MADE FROM HIGH-SPEED AND CARBON STEEL

$\frac{1}{32}$-inch Chip				$\frac{1}{8}$-inch Chip			
Smallest Diameter of Stock	Brass Rod, Feed per Revolution	Machine Steel, Feed per Revolution	Tool Steel, Feed per Revolution	Smallest Diameter of Stock	Brass Rod, Feed per Revolution	Machine Steel, Feed per Revolution	Tool Steel, Feed per Revolution
$\frac{1}{16}$	0.0010	0.0008	0.0005	$\frac{3}{8}$	0.0020	0.0015	0.0010
$\frac{1}{8}$	0.0015	0.0010	0.0008	$\frac{7}{16}$	0.0025	0.0018	0.0015
$\frac{3}{16}$	0.0020	0.0015	0.0010	$\frac{1}{2}$	0.0030	0.0020	0.0018
$\frac{1}{4}$	0.0030	0.0020	0.0015	$\frac{9}{16}$	0.0035	0.0025	0.0020
$\frac{5}{16}$	0.0035	0.0025	0.0018	$\frac{5}{8}$	0.0038	0.0028	0.0022
$\frac{3}{8}$	0.0040	0.0030	0.0020	$\frac{11}{16}$	0.0042	0.0030	0.0025
$\frac{1}{16}$-inch Chip				$\frac{3}{16}$-inch Chip			
$\frac{1}{4}$	0.0025	0.0020	0.0010	$\frac{1}{2}$	0.0020	0.0010	0.0008
$\frac{5}{16}$	0.0030	0.0022	0.0018	$\frac{9}{16}$	0.0025	0.0018	0.0010
$\frac{3}{8}$	0.0035	0.0025	0.0015	$\frac{5}{8}$	0.0028	0.0015	0.0012
$\frac{7}{16}$	0.0040	0.0028	0.0018	$\frac{11}{16}$	0.0030	0.0018	0.0015
$\frac{1}{2}$	0.0045	0.0030	0.0020	$\frac{3}{4}$	0.0035	0.0020	0.0018
$\frac{9}{16}$	0.0050	0.0032	0.0025	$\frac{13}{16}$	0.0038	0.0022	0.0020
$\frac{5}{8}$	0.0060	0.0035	0.0028	$\frac{7}{8}$	0.0040	0.0025	0.0020

TABLE V. FEEDS FOR HOLLOW MILLS MADE FROM HIGH-SPEED AND CARBON STEEL

$\frac{1}{16}$-inch Chip				$\frac{3}{16}$-inch Chip			
Smallest Diameter of Stock	Brass Rod, Feed per Revolution	Machine Steel, Feed per Revolution	Tool Steel, Feed per Revolution	Smallest Diameter of Stock	Brass Rod, Feed per Revolution	Machine Steel, Feed per Revolution	Tool Steel, Feed per Revolution
$\frac{3}{16}$	0.0045	0.0030	0.0015	$\frac{1}{2}$	0.0060	0.0045	0.0020
$\frac{1}{4}$	0.0050	0.0040	0.0018	$\frac{9}{16}$	0.0065	0.0050	0.0023
$\frac{5}{16}$	0.0055	0.0045	0.0020	$\frac{5}{8}$	0.0070	0.0055	0.0025
$\frac{3}{8}$	0.0060	0.0050	0.0025	$\frac{11}{16}$	0.0080	0.0060	0.0030
$\frac{7}{16}$	0.0070	0.0050	0.0028	$\frac{3}{4}$	0.0090	0.0065	0.0035
$\frac{1}{2}$	0.0080	0.0060	0.0030	$\frac{13}{16}$	0.0100	0.0070	0.0040
$\frac{1}{8}$-inch Chip				$\frac{1}{4}$-inch Chip			
$\frac{3}{8}$	0.0070	0.0050	0.0030	$\frac{5}{8}$	0.0050	0.0035	0.0015
$\frac{7}{16}$	0.0075	0.0055	0.0035	$\frac{11}{16}$	0.0055	0.0040	0.0018
$\frac{1}{2}$	0.0080	0.0060	0.0040	$\frac{3}{4}$	0.0060	0.0050	0.0020
$\frac{9}{16}$	0.0090	0.0065	0.0050	$\frac{13}{16}$	0.0070	0.0055	0.0025
$\frac{5}{8}$	0.0110	0.0075	0.0060	$\frac{7}{8}$	0.0080	0.0060	0.0030
$\frac{11}{16}$	0.0130	0.0090	0.0070	..	......	......	......
$\frac{3}{4}$	0.0150	0.0110	0.0080	..	......	......	......

Feeds for Turning with Swing Tools

Owing to the fact that swing tools are not so rigidly constructed as the ordinary box-tools, it has been found advisable to decrease the feeds slightly below those used for box-tools. Feeds which have been found satisfactory for straight turning with swing tools are given in Table IV. These feeds are about 30 per cent less than those used for box-tools.

Feeds for Taper Turning

For taper or irregular turning with swing tools, the greatest depth of the chip should be considered, and the same feed used as that given in Table IV. For taper turning with the Brown & Sharpe standard taper turning tools, the greatest depth should be considered, and the same feed used as given in Tables II and III for roughing and finishing cuts, respectively. Where the taper is greater than ¼ inch per foot, it is advisable to use two taper turning tools, one for roughing, and one for finishing.

Feeds for Hollow Mills

In Table V are given feeds for hollow mills which are made from ordinary carbon or high-speed steel. These feeds apply both to hollow mills of the solid and inserted-blade types and are for taking a chip of from 1/16 to 1/4 inch deep. The feeds given are not excessively high, and in some cases could be increased, especially when the work is not exceedingly long, and when the tool would not be on the work for a considerable time.

CHAPTER IV

ANGULAR CUTTING TOOLS

When it is necessary to form the end of the work cone-shaped and produce a sharp point, a tool which is fed in similarly to an ordinary cut-off tool does not give satisfactory results. An example of this class of work and the attachment used for forming it are shown in Fig. 23. The work, which is shown at *A*, is a blank for a combination drill and countersink. The angular cutting-off attachment consists mainly of a bracket *B*, which is fastened to the machine by two cap-screws *C*. These screws are located in the holes which are used for fastening the slotting, cross-drilling and burring attachments to the machine. The sliding member *D*, fitting in dovetailed grooves cut in the bracket *B*, is used for holding an ordinary circular forming tool *E*, which is held to this sliding member by cap-screw *F*. The usual means for adjusting the circular tool is provided; this consists of an eccentric cap-screw *G* and a plate *H*. The eccentric screw *G* is locked by screw *I*.

Attached to the sliding member *D* is a rack *J* held by a screw *K* in a groove cut in the slide. This rack meshes with gear *L* which, in turn, meshes with gear *M* in contact with rack *N*. Rack *N* is attached to the cross-slide by means of a block *O* held in the *T*-slot cut in the cross-slide, by a block *Q* and two screws *P*. The gears *L* and *M* are held on studs *R* and *S* fitted with bronze sleeves on which the gears rotate. These bronze sleeves are provided with oil grooves, and oil holes are drilled through the studs, so that a copious supply of oil is given to the bearings.

The operation of this attachment is as follows: As the cross-slide advances, rack *N* attached to it rotates gear *M* which, in turn, through gear *L* and rack *J*, forces slide *D* in as indicated. Slide *D* is returned to its former position in a similar manner when the cross-slide drops back. The circular tool *E* follows a diagonal line of travel so that the point on the work is turned to the correct angle. Thus a very fine point can be made on the work, as no pressure is brought to bear on the part being severed, the weight of the work alone breaking it off.

An angular turning tool which is constructed on a different principle from that shown in Fig. 23 is shown in Fig. 24. This tool is held in the turret, and is operated by a rising block held on the cross-slide. The construction of this tool is as follows: Attached to the body *A* by a shouldered screw *B* is a plate *C*. Tapped into plate *C* is a screw *D*, checked by a nut *E*. The sliding member *F*, fitting over dovetailed ways formed on the angular face of holder *A*, is attached to block *C* by means of a screw *G*. The tool-holder *H* is made integral with the sliding member *F*, and holds the turning tool *I*, which is held in a slot cut in the holder, by two headless screws *J*, and rests on a pin *K*.

In operation, as the rising block presses on screw *D*, it swivels block *C* on screw *B*, and as block *C* is attached to slide *F* by screw *G*, it carries the slide along the face of the tool-holder, thus turning the recess in the work as shown at *L*. When the rising block drops back, the tool-slide *F* is returned by a coiled spring *M* held in body *A*,

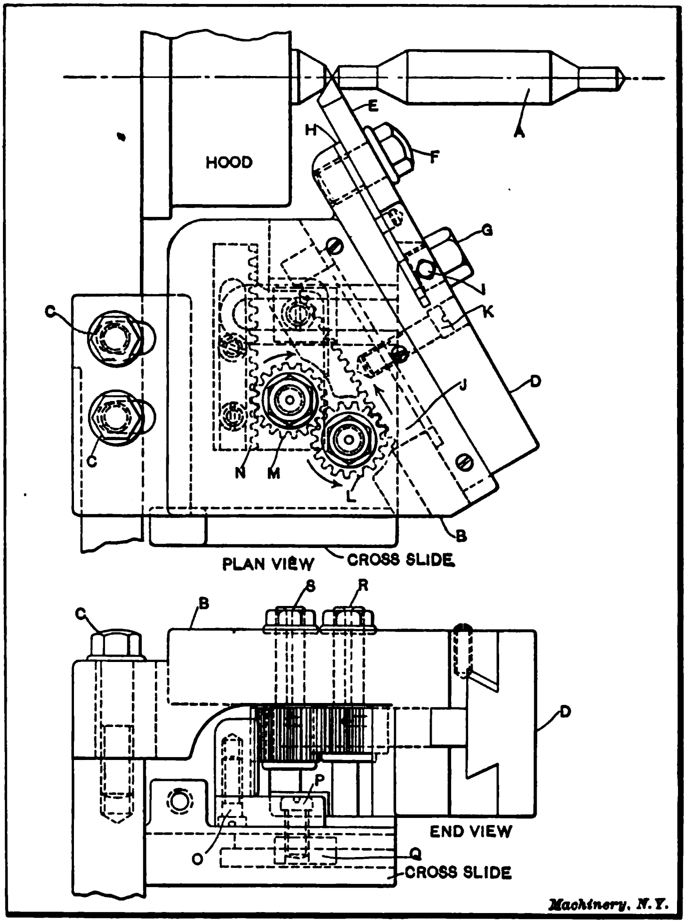


Fig. 28. Cross-slide Angular Cutting-off Tool

through a spring plunger *N* pressing against a pin *O* held in the sliding member *F*. A gib and adjusting screws are also provided to make allowance for wear. A bushing *P* held in the body of the holder by a screw *Q* supports the forward end of the work, while the recess is being turned.

An angular cutting-off tool which is held in the turret and operated by a rising block is shown in Figs. 25 and 26. The rising-block for operating this tool, which is held on the front cross-slide, is shown in Fig. 25. The construction of the holder, however, is more clearly shown in Fig. 26. All the parts in these two illustrations bear the same reference letters. The cutting-off blade *B* is held in a slot in the tool-slide *C* by adjusting-screws *D* and *F* and rests on pin *E*. Slide

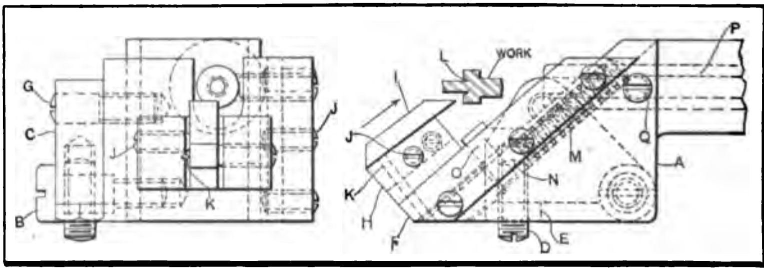


Fig. 24. Back Recessing Tool for Small Work

C is gibbed to a dovetailed guide on slide carrier *G*. This latter member is pivoted to the body *H* of the tool, the center of the pivot being the axis of bolt *J*, and is clamped by screw *K* in the proper location to guide slide *G* in forming the desired angle on the point of the work.

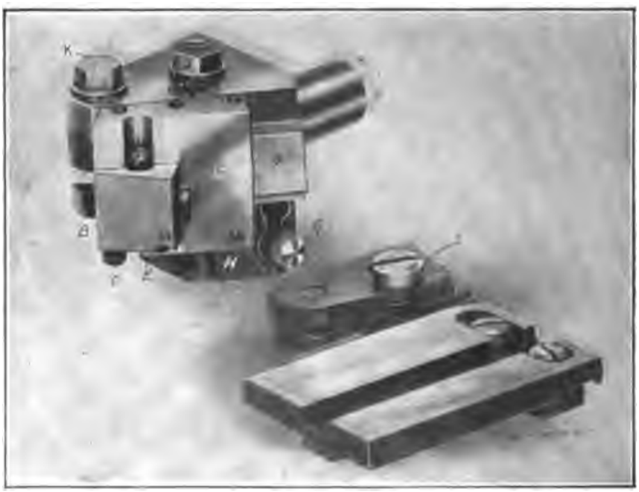


Fig. 25. Angular Cutting-off Tool held in Turret and operated by a Ris ng Block

The tool-slide *C* has attached to it a rack which meshes with the 32-pitch pinion *L*, pivoted to the under side of *G*. Pinion *L* meshes with a similar pinion *M* pivoted in a hole in the body of the tool about the center of bolt *J*, so that the correct relations between them are preserved, whatever the angular adjustment of *G* on *H*. Pinion *M* meshes with rack-teeth cut in plunger *N*. This is best seen in Fig. 26.

This plunger *N*, as can be seen in the side elevation, has at its front end a projection extending upward and bearing against a plunger *O* in the hole above it, which is pressed outward by a spring. By this means *N* is normally kept at the outer end of its movement, being limited in this direction by the seating of screw *P* in the recess provided for it in the body *H* of the tool. In this position the tool slide is withdrawn so that the blade clears the work.

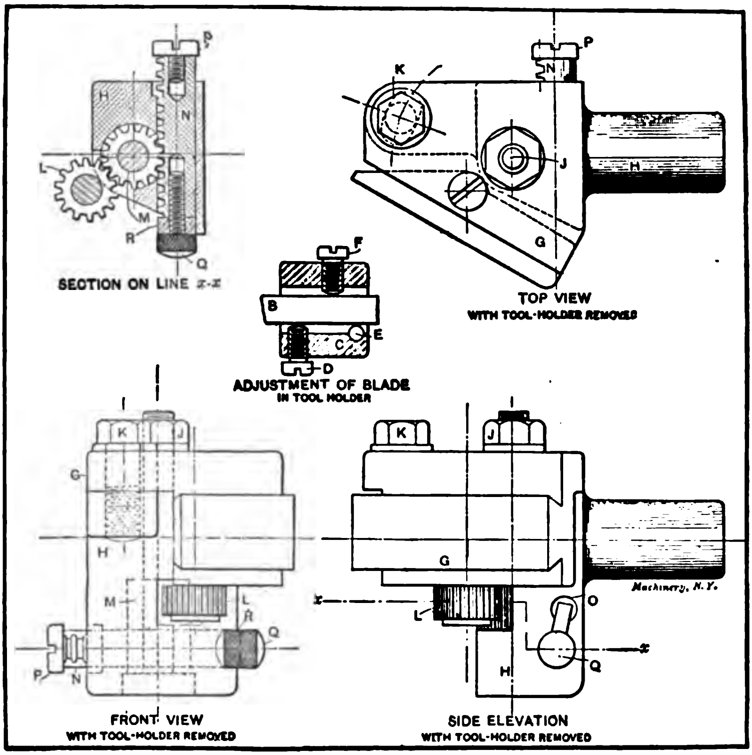


Fig. 26. Details of Tool shown in Fig. 25

The front end of *N* is provided with a knurled screw *Q* and lock-nut *R*. These are so located as to be in line with the pusher *S*, Fig. 25, which is attached to the front cross-slide of the machine. The cutting-off is effected by the movement of the cross-slide and pusher *S*. This bears on screw *Q*, presses plunger *N* inward, revolving pinions *M* and *L*, which, in turn, acting on the rack attached to the tool-slide, move cutter *B* inward, severing the work from the bar and forming the bevel point. The length of the inward travel of the tool is adjusted by screw *Q* and lock-nut *R*. For this operation the swiveled member *S* on the rising block need not be set at an angle, as the turret tool does not travel along its face, the pusher being used for forcing in the cutting-off slide only in a radial direction.

CHAPTER V

SHAVING TOOLS

When forming work of irregular contour, in the automatic screw machine, it is common practice to use a shaving tool, which is operated tangentially to the work and passes either under it or over it as conditions may require. It is customary to place the shaving tool on the rear cross-slide, so that the shaving operation can be accomplished at the same time as the turret operations, when the spindle is running forward.

Shaving tools are made from high-carbon tool steel. On the top face of the tool the irregular contour to be reproduced on the work is

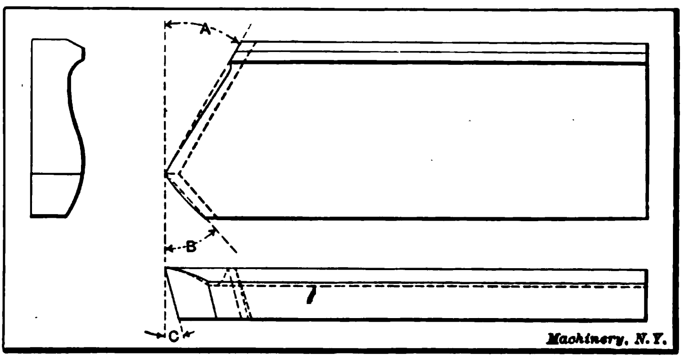


Fig. 27. Shaving Tool for Forming Long Work

formed. High-speed steel, as a rule, does not give very satisfactory results, owing to the fact that to get the best results from this steel, high peripheral velocities must be used; but when high peripheral velocities are used, the extreme cutting edge of a high-speed steel tool becoms ragged and will not produce a smooth finish.

It is not necessary, when applying a shaving tool to the work, to incline it at an angle to the horizontal plane to any great extent. The best results are obtained by holding the tool practically horizontal, so that when passing under the work, the forward end of the tool is at approximately the same height as the rear part. This produces a smooth finish on the work, as the shaving tool burnishes it after removing the material.

Shaving tools are used to follow a circular forming tool to produce a smooth finish, as well as to completely form the work, finishing it without having rough formed it with any other tool. Where the work has not been roughed down previous to shaving, a larger cutting angle is necessary, and if the work is long in proportion to its diameter, the tool should be ground with two cutting angles *A* and *B*, as shown in Fig. 27, so that the extreme point of the tool will be where the greatest amount of material is to be removed. This produces a shearing cut and removes the material more easily. The angles on the type of shaving tool shown in Fig. 27 for cutting the materials specified below are as follows:

Material	Cutting-angles in Degrees
Brass rod	$A=20$, $B=30$, $C=10$;
Machine steel	$A=30$, $B=40$, $C=15$;
Tool steel	$A=40$, $B=50$, $C=15$;

While the shaving tool shown in Fig. 27 is used extensively on the automatic screw machine, it is difficult to harden because of its length. If sufficient care is not exercised it will be distorted, and when the contour is of such a shape that it is impossible to grind the form after

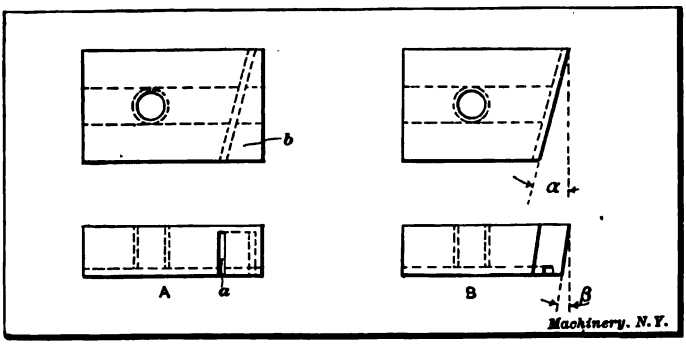


Fig. 28. Type of Shaving Tool used in the Shaving-tool Holder shown in Fig. 29

hardening, this becomes an objectionable feature. A shaving tool which does not present the same difficulty in hardening is shown in Fig. 28. This shaving tool is a short block which is held in the holder shown in Fig. 29. A support is also provided so that the work need not be supported from the turret except when the length being shaved is long in proportion to the diameter. Owing to the rigidity of the support, the cutting-angle can be less than the angle *A* shown in Fig. 27. The cutting-angles on the shaving tool shown in Fig. 28 for cutting various materials are as follows:

Material	Cutting-angles
Brass rod	$\alpha=10$ deg. $\beta=10$ deg.
Machine steel	$\alpha=15$ deg. $\beta=15$ deg.
Tool steel	$\alpha=20$ deg. $\beta=15$ deg.

The chief use of this tool is for finishing work after it has been rough formed with a circular form or other external cutting tool. As the support passes over the work after shaving, a burnished appearance is the result; of course, it is absolutely necessary to have the faces of the shaving tool and support polished if good results are to be expected. The first step in making the shaving tool shown in Fig. 28 is to form it into a block as shown at *A*. A saw slot *a* is cut at the desired angle, so that part *b* can be broken off after the shape required is milled on the top face and the tool hardened and polished. The polishing can be accomplished in a milling machine by holding a piece of brass or copper in a chuck, the outer end of the brass being formed to the contour of the tool. Emery is applied to this lap, and by running the carriage back and forth with the shaving tool held in the vise, a very smooth finish can be obtained. After the tool is polished, part *b* is broken off and the tool ground as shown at *B*. By leaving part *b* on until the tool is polished, the cutting edge will not be rounded and the tool can be more easily polished.

For cutting machine or tool steel it is preferable to make the shaving tool thinner at the rear end to provide for clearance. Making the tool

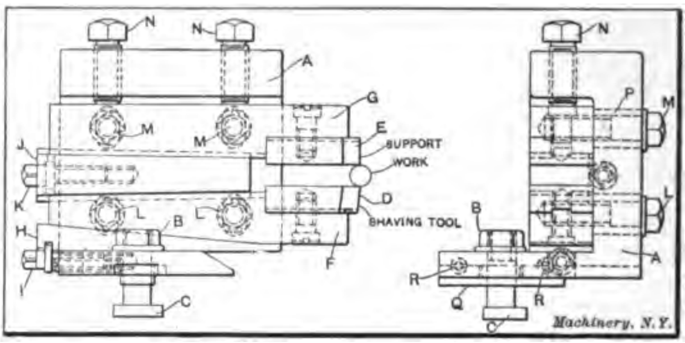


Fig. 29. Shaving-tool Holder which can be used for a Wide Range of Work

from 0.001 to 0.0025 inch thinner at the rear than at the front end, gives the desired result. This can be accomplished by packing up the rear end when milling the form on the tool. This type of shaving tool when used on steel should not be used for rough forming, but for finishing only.

When the work is rough formed before shaving, the amounts to be removed from the diameters are as follows:

Diameter	Amount to Remove in Inches
Up to ⅛	0.0050
⅛ — ⅜	0.0075
⅜ — ⅝	0.0100
⅝ — ⅞	0.0150

Shaving Tool Holders

It is necessary to hold a shaving tool rigidly if good results are to be expected, and if the work is small in diameter in proportion to the length being shaved, it is also necessary to use a support. A shaving-tool holder which will be found satisfactory for this class of work is shown in Fig. 29. This holder is held on the rear cross-slide and consists of a machine-steel body *A*, which is held to the cross-slide by means of the nut and bolt *B* and *C*, the latter fitting in the groove in the cross-slide. The shaving tool *D* and support *E* are held to the two members *F* and *G* by screws as shown. A tongue is formed on members *F* and *G* which fits in grooves cut in the shaving tool and support.

Gib *H* is provided for raising shaving tool *D* to the correct height. It is operated by collar-screw *I*, fitting into a slot in the gib and screwed into the base of holder *A*. The gib *J* is provided for increasing and diminishing the distance between shaving tool *D* and support *E*, thus governing the diameter of the work. A collar-screw *K*, fitting in a slot cut in gib *J* and tapped into the holder, is used for adjusting the gib. When members *F* and *G* are set correctly, they are held in the body *A* by means of screws *L*, *M* and *N*. Elongated slots *P* are

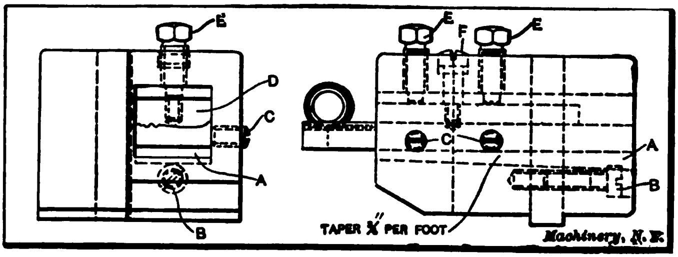


Fig. 30. Shaving-tool Holder of the Box Type

provided in holder *A*, so as to allow screws *L* and *M* to be moved up and down, which provides for adjustment for different diameters.

The ordinary adjustable block provided in the toolposts for holding circular tools is also provided in this holder. This block *Q* is adjusted by screws *R*, and is used for setting the side of the shaving tool parallel with the face of the chuck. The front edge of the support *E* should have the same face angle as the shaving tool *D*, but should be set a distance equal to 1/40 of the diameter of the work back from the face of the shaving tool.

In Fig. 30 is shown a shaving-tool holder for holding a shaving tool of the type shown in Fig. 27, which is operated from the rear cross-slide. This holder is of the box type, and a tapered gib *A* is provided for adjusting the tool for various heights. This gib is actuated by screw *B*, fitting in a slot cut in the gib and screwed into the holder. Set-screws *C* prevent lateral movement of the shaving tool, and a pad *D*, operated by two set-screws *E*, holds the shaving tool down on the adjustable gib. This pad *D* is made with the same contour on its lower face as the shaving tool so that it will hold the latter rigidly. Where the contour of the tool is of a shape difficult to make, it is, however, customary to have the pad bear only on two or three points. A screw *F* is provided for holding the pad when the shaving tool is removed. The shaving-tool holder is held to the cross-slide in the same manner as the circular-tool holder.

A shaving-tool and cut-off-tool holder combined is shown in Fig. 31. This type of holder is used when one of the cross-slides is occupied by a forming tool. The construction is similar to that shown in Fig. 30, except for the additional provision for holding the cut-off tool blade *A*. This is held in a groove cut in the holder, by a block *B* which, in turn,

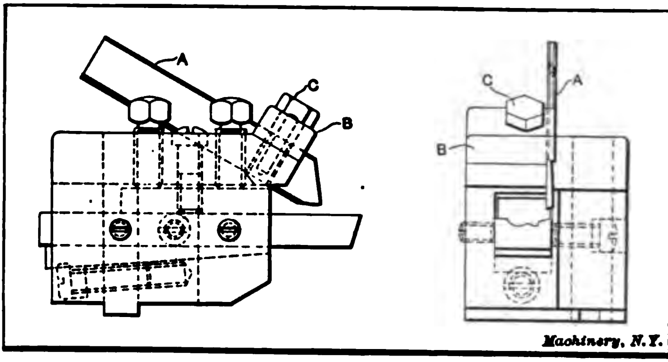


Fig. 31. Combination Cut-off and Shaving-tool Holder

is held by the cap-screw *C*. When using a combination shaving and cut-off tool of this kind, provision must be made so that the work when cut off will not stay on the shaving tool. A simple device for overcoming this difficulty is shown in Fig. 32. This consists simply of a split ring *A* which is held on the hood over the chuck by cap-screw *B*.

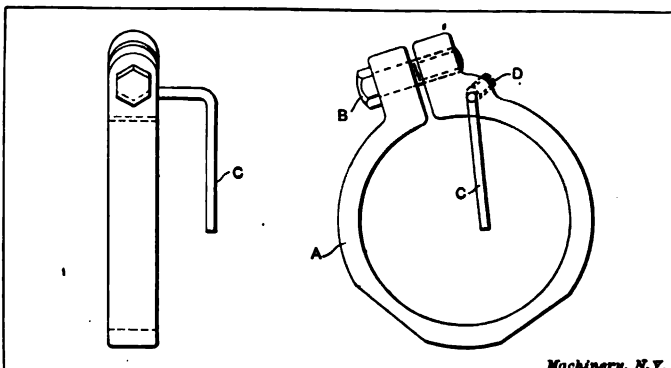


Fig. 32. Ejector used in Connection with the Shaving-tool Holder shown in Fig. 31

A wire rod *C*, which is so located that it will remove the work from the shaving tool when the cross-slide drops back, is held in ring *A* by a headless screw *D*.

In Fig. 33 is shown the holder which was used for holding the shaving tool shown in Fig. 27. This holder differs somewhat from those previously described in that provision is made for raising the front end of the shaving tool. The shaving tool rests on a pin *A* and is

TABLE VI. FEED PER REVOLUTION FOR SHAVING TOOLS

Width of Shaving Tool, in Inches	Smallest Diameter to be Shaved, in Inches										
	1/8	5/32	3/16	7/32	1/4	5/16	3/8	1/2	5/8	3/4	7/8
1/4	0.0025	0.0030	0.0035	0.0040	0.0045	0.0050	0.0060	0.0080	0.0100	0.0120	0.0150
5/16	0.0020	0.0025	0.0030	0.0035	0.0040	0.0045	0.0055	0.0075	0.0095	0.0115	0.0145
3/8	0.0015	0.0020	0.0025	0.0030	0.0035	0.0040	0.0050	0.0070	0.0090	0.0110	0.0140
7/16	0.0010	0.0015	0.0020	0.0025	0.0030	0.0035	0.0045	0.0065	0.0085	0.0105	0.0135
1/2	0.0025	0.0010	0.0015	0.0020	0.0025	0.0030	0.0040	0.0060	0.0080	0.0100	0.0130
5/8	0.0020	0.0008	0.0010	0.0015	0.0020	0.0025	0.0035	0.0055	0.0075	0.0095	0.0125
3/4	0.0015	0.0030	0.0035	0.0010	0.0015	0.0020	0.0030	0.0050	0.0070	0.0090	0.0120
7/8	0.0010	0.0025	0.0030	0.0040	0.0010	0.0015	0.0025	0.0045	0.0065	0.0085	0.0115
1	0.0008	0.0020	0.0025	0.0035	0.0045	0.0010	0.0020	0.0040	0.0060	0.0080	0.0110
1 1/8		0.0015	0.0020	0.0030	0.0040	0.0008	0.0015	0.0035	0.0055	0.0075	0.0105
1 1/4		0.0010	0.0015	0.0025	0.0035	0.0050	0.0010	0.0030	0.0050	0.0070	0.0100
1 3/8		0.0008	0.0010	0.0020	0.0030	0.0045	0.0060	0.0025	0.0045	0.0065	0.0095
1 1/2			0.0008	0.0015	0.0025	0.0040	0.0055	0.0020	0.0040	0.0060	0.0090
1 5/8				0.0010	0.0020	0.0035	0.0050	0.0015	0.0035	0.0055	0.0085
1 3/4				0.0008	0.0015	0.0030	0.0045	0.0010	0.0030	0.0050	0.0080
1 7/8					0.0010	0.0025	0.0040	0.0080	0.0025	0.0045	0.0075
2					0.0008	0.0020	0.0035	0.0075	0.0020	0.0040	0.0070
2 1/8						0.0015	0.0030	0.0070	0.0015	0.0035	0.0065
2 1/4						0.0010	0.0025	0.0065	0.0010	0.0030	0.0060
2 3/8						0.0008	0.0020	0.0060	0.0100	0.0025	0.0055
2 1/2							0.0015	0.0055	0.0095	0.0020	0.0050

adjusted by two set-screws *B*. The object in making this adjustment is to provide for clearance, which is necessary on account of the wide bearing surface.

Speeds and Feeds for Shaving

As a rule, shaving tools can be operated at the same speed as circular form tools, the speeds for which were given in Part III of this treatise, MACHINERY'S Reference Book No. 101, "Circular Form and Cut-off Tools for the Brown & Sharpe Automatic Screw Machine."

The feed at which a shaving tool can be operated satisfactorily is governed largely by the following conditions:

1. Amount of material to be removed.
2. Character of the material.
3. Angle of the cutting edge.
4. Length of the work in proportion to the diameter.

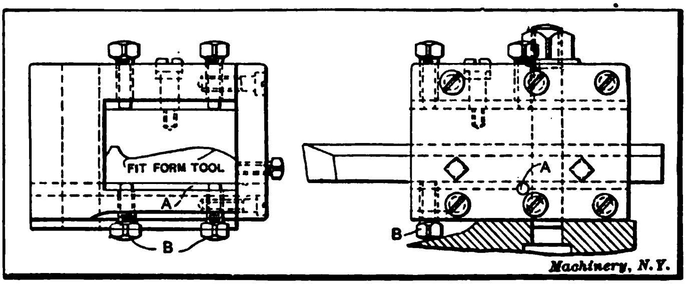


Fig. 28. Shaving-tool Holder for Long Work

The amount of material to be removed should, to a large extent, govern the angle of the cutting edge, and is a more important factor than is the nature of the material. Owing also to the extra amount of cutting surface and insufficient clearance, a shaving tool cannot be fed at the same rate of feed as a circular form tool can. That is to say, to remove the same amount of material requires a greater number of revolutions with a shaving tool than with a circular form tool. Where the length of the work is more than three and one-half times its diameter, a support should be used. This has been taken into account when arranging Table VI, and it should be understood that the feeds given under the heavy lines should be used only when the work is supported.

It is evident from the foregoing that the feed should be decreased when the cutting angle is decreased, and, on the other hand, the feed should be increased when the cutting angle is increased. The feeds given above the heavy lines in Table VI are applicable to shaving tools having the angles given in reference to Fig. 27, while the feeds below the heavy lines are for shaving tools having the angles given in reference to Fig. 28, and also for the angles given in reference to Fig. 27 when a support is used. When a shaving tool and support of the type shown in Fig. 29 are used, the feeds above the heavy lines in Table VI can be increased 50 per cent with satisfactory results.

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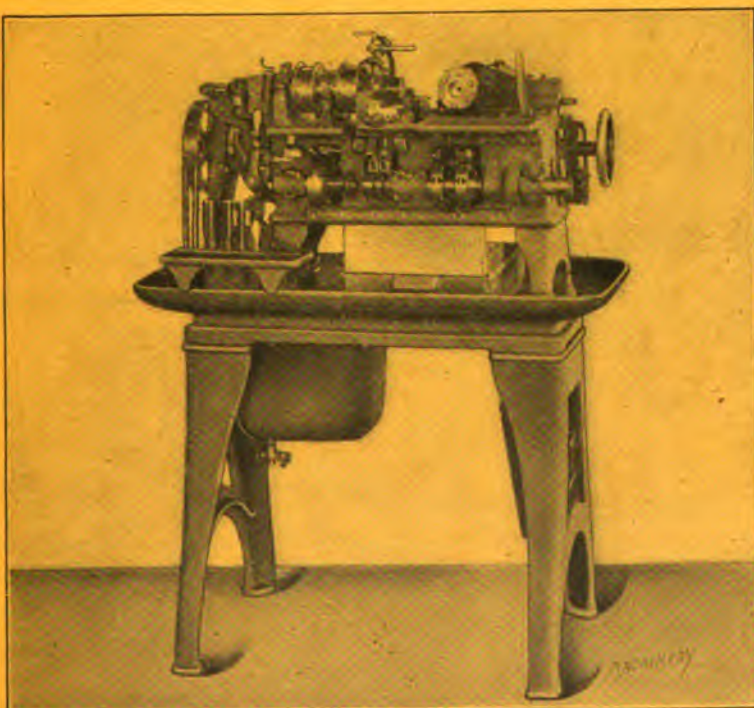
PRICE 25 CENTS

AUTOMATIC SCREW MACHINE PRACTICE

INTERNAL CUTTING TOOLS FOR BROWN & SHARPE AUTOMATIC SCREW MACHINES

BY DOUGLAS T. HAMILTON



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NUMBER 103

AUTOMATIC SCREW MACHINE PRACTICE

PART V

INTERNAL CUTTING TOOLS FOR BROWN & SHARPE AUTOMATIC SCREW MACHINES

By DOUGLAS T. HAMILTON

CONTENTS

49-55 Lafayette Street, New York City

Automatic Screw Machine Practice for the Brown & Sharpe automatic screw machines is covered in eight Reference Books. Nos. 99 to 106, inclusive. Reference Book No. 99, "Operation of the Brown & Sharpe Automatic Screw Machines," deals with the construction of these machines and the setting-up of the tools. No. 100, "Designing and Cutting Cams for Automatic Screw Machines," gives detailed instruction on cam design, and describes a simplified method for milling cams. No. 101, "Circular Form and Cut-off Tools for the Automatic Screw Machine," deals with the general arrangement and the calculations of these tools, and describes the different methods employed in their making. No. 102, "External Cutting Tools for the Automatic Screw Machine," deals with the design and construction of box-tools, taper turning tools, hollow mills, and shaving tools. No. 103, "Internal Cutting Tools for the Automatic Screw Machine," deals with centering tools, cross-slide drilling attachments, counterbores, reamers, and recessing tools. No. 104, "Threading Operations on the Automatic Screw Machine," treats on cam design for threading operations, threading dies, taps and tap drills, die and tap holders, and thread rolling. No. 105, "Knurling Operations on the Automatic Screw Machine," describes the construction of knurling holders, and gives directions for the making of knurls and the design of tools and cams used in connection with knurling operations. No. 106, "Milling, Cross-drilling and Burring Operations on the Automatic Screw Machine," describes screw-slotting attachments, index drilling attachments, and burring attachments, giving directions for their use and for the design of cams for them.

CHAPTER I

CENTERING AND DRILLING OPERATIONS

The conditions met with on the Brown & Sharpe automatic screw machines are such that, for general work, the simpler the design of the tool used, the more efficient the results obtained. Of course, in some cases it is necessary, where difficult shapes are to be formed, to make the tools somewhat complicated, but even then the simplest design possible should be adopted. It is obvious that in internal cutting there is more chance of the tool sticking and breaking, due to the clogging of chips and improper lubrication, than on external work. It is therefore necessary to make all cutting tools for internal work with as much chip space as possble, and also to provide means for proper lubrication. The periphery clearance given to the tools also has an important bearing on their efficiency. Where there is too much cutting surface in contact with the work, the tendency is to produce rough work and also to break the tool, as heating is developed at the point of contact, thus causing the tool and work to seize.

In making complicated tools for internal work the excessive use of springs, especially when flat, is objectionable, for if the spring fails to work, the cutting tool is generally broken. If a spring is necessary, a coil spring should be used, and provision should be made to have it long enough so that it will retain, as much as possible, its initial tension. Springs for internal cutting tools, as well as for other tools of a similar character, should always be tempered in oil, as this increases their life. The design of an internal cutting tool is largely governed by the material which it is to cut and the amount of material it is required to remove.

Centering and Centering Tools

When drilling holes which are less than 3/16 inch in diameter it is always advisable, especially when the hole passes through the work, to use a starting or centering tool. At *A* in Fig. 1 is shown a centering tool which is used for brass work, and at *B* one which is used for steel and soft iron. This latter tool is similar to the ordinary twist drill, except that the flutes are shorter. A worn-out twist drill is sometimes used for this purpose, with the point ground thin, as shown at *a*, which reduces the pressure and allows the drill to start easier. This tool also makes a better center than would a drill with a thicker point. The included angle of the cutting edges on a centering tool should be less than the drill which is to follow. If this is not the case, the point of the drill will start to cut before the body of the drill is properly supported; consequently, an imperfect center will be formed. If an imperfect center has been formed, the drill will run out, as is clearly shown at *C* in Fig. 1. It can be seen that it is practically impossible for a drill to start concentric with the center of the work when a small teat, as shown, has been left by the centering tool. Using a centering tool with a more acute angle obviates this trouble, as the body of the drill is well supported before the point of the drill starts to cut. This is clearly shown at *D* in Fig. 1. The included angle of the point which has been found most suitable for centering tools varies from 90 to 100 degrees; 90 degrees should be used, preferably, for brass, and 100 degrees for steel. The included angle of the point of the drill varies from 118 to 120 degrees, 118 degrees being generally used for the drill, as it has been found to give the best results. In Table I is given the length of the point for centering tools and twist drills, having included angles of 90 and 118 degrees, respectively. The

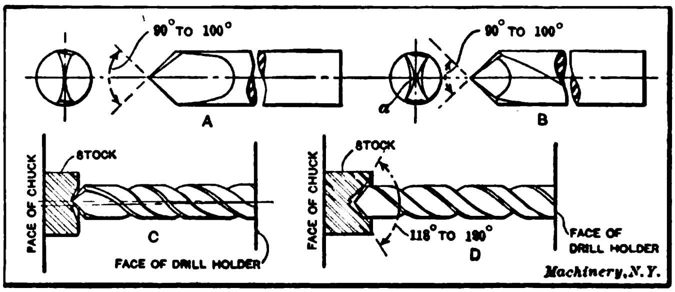


Fig. 1. Centering Tools—Starting the Drill Concentric

formulas for finding the length of point for the various angles are as follows (see Fig. 2):

For 90 degrees $b = 0.5d$.
For 100 degrees $b = 0.42d$.
For 118 degrees $e = 0.3c$.
For 120 degrees $e = 0.29c$.

where b = depth of centered hole,
c = diameter of drill,
d = diameter of centered hole.
e = length of drill point.

Cam Rise for Centering

When the length of the point of the centering tool is known, it is an easy matter to find the rise on the cam required for centering. There are four different conditions governing the amount of rise required for centering, which are as follows:

First: When the drill does not pass through the work and a stop for gaging the stock to length is used.

Second: When the drill passes through the work and a stop for gaging the stock to length is used.

Third: When the drill does not pass through the work and a stop for gaging the stock to length is not used.

Fourth: When the drill passes through the work and a stop for gaging the stock to length is not used.

The rises on the cam for centering as governed by the previous conditions are as follows (see Fig. 2):

First: $R = b + 0.010$ inch;

TABLE I. LENGTH OF POINT ON TWIST DRILLS AND CENTERING TOOLS

Size of Drill or Diameter of Center	Decimal Equivalent	Length of Point when Included Angle = 90°	Length of Point when Included Angle = 118°	Size of Drill or Diameter of Center	Decimal Equivalent	Length of Point when Included Angle = 90°	Length of Point when Included Angle = 118°	Size of Drill or Diameter of Center	Decimal Equivalent	Length of Point when Included Angle = 90°	Length of Point when Included Angle = 118°	Size of Drill or Diameter of Center	Decimal Equivalent	Length of Point when Included Angle = 90°	Length of Point when Included Angle = 118°	Size of Drill or Diameter of Center	Decimal Equivalent	Length of Point when Included Angle = 90°	Length of Point when Included Angle = 118°
60	0.0400	0.020	0.012	41	0.0960	0.048	0.029	22	0.1570	0.079	0.047	3	0.2130	0.107	0.064	31/64	0.4844	0.242	0.145
59	0.0410	0.021	0.012	40	0.0980	0.049	0.029	21	0.1590	0.080	0.048	2	0.2210	0.111	0.067	1/2	0.5000	0.250	0.150
58	0.0420	0.021	0.013	39	0.0995	0.050	0.030	20	0.1610	0.081	0.048	1	0.2280	0.114	0.068	33/64	0.5156	0.258	0.155
57	0.0430	0.022	0.013	38	0.1015	0.051	0.030	19	0.1660	0.083	0.050	15/64	0.2344	0.117	0.070	17/32	0.5313	0.266	0.159
56	0.0465	0.023	0.014	37	0.1040	0.052	0.031	18	0.1695	0.085	0.051	1/4	0.2500	0.125	0.075	35/64	0.5469	0.273	0.164
55	0.0520	0.026	0.016	36	0.1065	0.054	0.032	17	0.1730	0.087	0.052	17/64	0.2656	0.133	0.080	9/16	0.5625	0.281	0.169
54	0.0550	0.028	0.017	35	0.1100	0.055	0.033	16	0.1770	0.089	0.053	9/32	0.2813	0.141	0.084	37/64	0.5781	0.289	0.173
53	0.0595	0.030	0.018	34	0.1110	0.056	0.033	15	0.1800	0.090	0.054	19/64	0.2969	0.148	0.089	19/32	0.5938	0.297	0.178
52	0.0635	0.032	0.019	33	0.1130	0.057	0.034	14	0.1820	0.091	0.055	5/16	0.3125	0.156	0.094	39/64	0.6094	0.305	0.183
51	0.0670	0.034	0.020	32	0.1160	0.058	0.035	13	0.1850	0.093	0.056	21/64	0.3281	0.164	0.098	5/8	0.6250	0.313	0.188
50	0.0700	0.035	0.021	31	0.1200	0.060	0.036	12	0.1890	0.095	0.057	11/32	0.3438	0.171	0.103	41/64	0.6406	0.320	0.192
49	0.0730	0.037	0.022	30	0.1285	0.065	0.039	11	0.1910	0.096	0.057	23/64	0.3594	0.180	0.108	21/32	0.6563	0.328	0.197
48	0.0760	0.038	0.023	29	0.1360	0.068	0.041	10	0.1935	0.097	0.058	3/8	0.3750	0.188	0.113	43/64	0.6719	0.336	0.202
47	0.0785	0.040	0.024	28	0.1405	0.070	0.042	9	0.1960	0.098	0.059	25/64	0.3906	0.195	0.117	11/16	0.6875	0.344	0.206
46	0.0810	0.041	0.024	27	0.1440	0.072	0.043	8	0.1990	0.100	0.060	13/32	0.4063	0.203	0.122	23/32	0.7188	0.359	0.216
45	0.0820	0.041	0.025	26	0.1470	0.074	0.044	7	0.2010	0.101	0.060	27/64	0.4219	0.211	0.127	3/4	0.7500	0.375	0.225
44	0.0860	0.043	0.026	25	0.1495	0.075	0.045	6	0.2040	0.102	0.061	7/16	0.4375	0.219	0.131	25/32	0.7813	0.391	0.234
43	0.0890	0.045	0.027	24	0.1520	0.076	0.046	5	0.2055	0.103	0.062	29/64	0.4531	0.227	0.136	13/16	0.8125	0.406	0.244
42	0.0935	0.047	0.028	23	0.1540	0.077	0.046	4	0.2090	0.105	0.063	15/32	0.4688	0.234	0.141	27/32	0.8438	0.422	0.253

Second: $R = b - e + 0.010$ inch;

where R = rise on cam for centering,

b = depth of centered hole,

e = length of point on drill.

It will be noted that when using the second method, the rise on the cam would not be sufficient, on starting a new rod, to allow the centering tool to travel the full distance; or, in other words, would not be equal to the length of the point of the centering tool used. The correct way to start a new bar, however, is to throw over the operating lever, thus stopping the operation of the machine; then open the chuck by hand and feed the stock out just past the cutting-off tool, so as to allow it to face off from 1/16 to 1/8 inch from the end of the

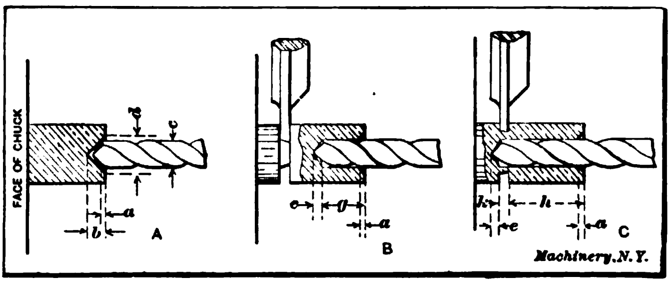


Fig. 2. Diagrams illustrating Method of Finding Cam Rise for Drilling and Centering

bar. Then the stock is fed out by hand, and the centering tool also operated by the hand lever, after which the machine can be started.

Third: The rise for the various machines is as follows:

For the No. 00, $R = b + 0.020$ inch.

For the No. 0, $R = b + 0.028$ inch.

For the No. 2, $R = b + 0.035$ inch.

The values which are added to b are for facing, and the feeds should be decreased for this. A dwell should also be allowed on the cam varying from 2 to 5 revolutions, the number of revolutions necessary being governed by the material to be cut. The dwell should be longer for steel than for brass stock. The feed for facing brass should be from 0.0015 to 0.002 inch per revolution, and for steel from 0.001 to 0.0012 inch per revolution.

Fourth: The rise for the various machines is as follows:

For the No. 00, $R = b - e + 0.020$ inch.

For the No. 0, $R = b - e + 0.028$ inch.

For the No. 2, $R = b - e + 0.035$ inch.

The feed should be decreased for facing, and a dwell of from 2 to 5 revolutions allowed. The suggestions previously given for starting a new bar should also be remembered. The time for starting a new bar in the manner given is practically negligible, as the machine anyway should always be stopped when a new bar is being inserted.

Special Centering Tool for Hard Material

The included angle of the point on the centering tools shown at *A* and *B* in Fig. 1 gives satisfactory results when used on soft material, such as brass or soft steel; but when the material is of a harder nature, trouble is sometimes encountered with the point of the centering tool breaking. This can be obviated by making a centering tool as shown in Fig. 3. This tool has a double angle, the extreme point being made to an included angle of 118 degrees, while the remaining

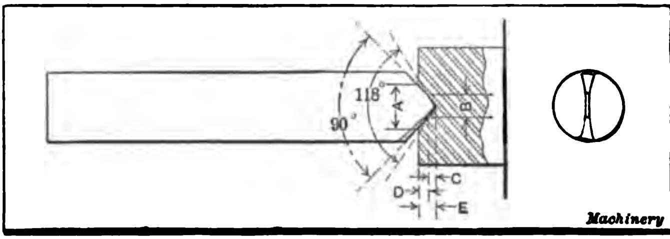


Fig. 3. Double-angle Centering Tool

part of the cutting edge is made to an included angle of 90 degrees. This strengthens the point of the tool, while at the same time it permits the drill to be supported by the center before the point starts to cut.

The following formulas are used for finding the dimensions (see Fig. 3):

$$B = \frac{A}{2}; \quad C = B \times 0.3; \quad D = A \times 0.25;$$

$$E = A \times 0.4; \quad R = E + 0.010.$$

TABLE II. FEEDS FOR CENTERING TOOLS

Diameter in Inches	Feed in Inches per Revolution		
	Brass Rod	Machine Steel	Tool Steel
1/4	0.004	0.003	0.002
5/16	0.004	0.004	0.003
3/8	0.005	0.0045	0 004
1/2	0.0055	0.005	0.0045
3/4	0.006	0.005	0.005
1	0.0065	0 005	0 0055

in which *A* = diameter of center in the work,
B = diameter of point where the 118-degree angle terminates,
C = length of point with 118-degree included angle.
D = length of part with 90-degree included angle.
E = total depth of centered hole.
R = rise on cam for centering (first condition).

Speeds and Feeds for Centering

The surface speeds for centering tools should be the same as for drills, a table for which will be given later. The feed for centering tools (as they are generally large enough to stand a heavy feed) is also the same in most cases. Table II gives the feeds for centering tools having diameters as specified. These feeds have been found satisfactory for general work.

Centering Tool Holders

The manner in which a centering tool is held when applied to the work governs to a considerable extent the results obtained. The tool should be held rigidly and concentric with the center of the work if

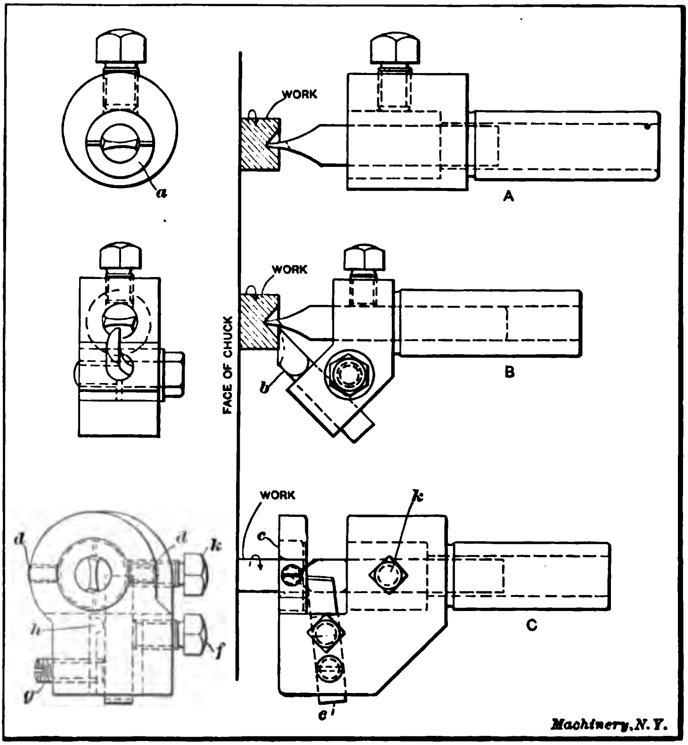


Fig. 4. Various Types of Centering Tool Holders

an imperfect center, as shown at *C* in Fig. 1, is to be avoided. At *A* in Fig. 4 is shown a common form of centering tool holder. This holder has been found very successful for general conditions when the work has been gaged to length by a stop, thus obviating the necessity of using a facing tool. It is provided with a split bushing *a*, as shown in the end view, or is made without the bushing, the hole for the centering tool simply passing through the body and the shank, and being of the same diameter as the centering tool. In most cases the holder with the split bushing is preferable, as the tool is more easily set concentric with the center of the work. At *B* in Fig. 4 is shown a combination centering and facing tool holder. This holder is used when the stop for gaging the work to length has been dispensed with, the tool *b* being used for facing the work to the required length. This is found to be a very suitable holder when the work does not project more than 2½ times its diameter from the face of the chuck. At *C* in Fig. 4 is shown a combination centering and facing tool holder with a supporting bushing *c*, which is held in the body of the tool by two headless screws *d*, shown in the end view. The centering tool is held in a split bushing by set-screw *k*. The turning or facing tool *e* is adjusted to cut the required diameter by set-screw *f* and headless screws *g*, the block *h* acting as a fulcrum. This holder is used when the work has been turned before centering, and it is also found convenient for centering long and slender work. A Brown & Sharpe floating holder is used for holding the centering tool when the turret and spindle are not concentric, or when extreme accuracy is desired.

Drills and Drilling

For general work commercial drills of the two-fluted type are used exclusively on the Brown & Sharpe automatic screw machines for drilling cylindrical holes. The spiral fluted drill is used for drilling machine steel, Norway iron, etc., and also for shallow holes in brass; but when deep holes are to be drilled in brass, a straight-fluted drill should be used in preference to a spiral drill, as it breaks up the chips, allowing them to be removed with greater ease. The grinding of the lips on the cutting edge of the drill has a considerable bearing on the shape of the chips produced and also on the amount of power required to force the drill into the work. If the angle as previously given is used, and if the point of the twist drill is ground thin, it will produce a long, curling chip, and will not require much power for drilling. When drilling, if the edges of the drill burn, it is an indication that the surface speed is too high; if the drill chips, the feed is too great; and if the drill splits at the point, that the proper clearance has not been given at the cutting edges. If the centering tool and drill have been ground to the correct included point-angle there is no reason why the drill should not produce a straight and cylindrical hole, provided the feed is not too heavy.

Cam Rise for Drilling

There are three general conditions which govern the amount of rise required for drilling. They are as follows:

First: When the drill does not pass through the work and a centering tool is not used.

Second: When the drill does not pass through the work and a centering tool is used.

Third: When the drill passes through the work and a centering tool is used.

There is also another condition, *viz.*, when the drill passes through the work and a centering tool is not used; but as this is not a commendable method, it is not here considered.

The rise on the cam for drilling as governed by the previous conditions is as follows:

First: $R = g + e + 0.010$ inch (see *B* in Fig. 2).

Second: $R = g - a + 0.010$ inch (see *B* in Fig. 2).

Third: $R = h + k - a + 0.010$ inch (see *C* in Fig. 2).

where R = rise on cam for drilling,
g = depth of hole to be drilled,
e = length of point on the drill (see Table I),
h = overall length of the work,
k = thickness of the cut-off tool,
a = distance that the straight part of the drill projects from the face of the work into the centered hole before starting to cut (see *A* in Fig. 2).

The values of a for centering tools having 90- and 100-degree point-angles are as follows:

For 90 degrees, $a = (d - c) \times 0.5$ inch.
For 100 degrees, $a = (d - c) \times 0.43$ inch.

where d = diameter of centered hole,
c = diameter of drill.

Deep-hole Drilling

The automatic screw machine lends itself to the production of *straight* holes, but when producing *deep* holes there are a number of difficulties to overcome: In the first place, the drill is not at the will of the operator, and cannot be withdrawn from the work when it begins to seize or plug up with chips; in the second place, keeping the point of the drill cool and removing the chips is a difficult proposition; and, in the third place, the feed of the drill is governed automatically. It is, therefore, necessary to have the drill well lubricated and the feed moderate.

For shallow holes the best results are obtained by giving a rotary motion to the work and a feeding motion to the drill, but when drilling deep holes, the drill and the work should both be given a rotary motion. This helps to clear the chips from the hole and also allows oil to penetrate to the cutting point of the drill.

When drilling deep holes the drill should not penetrate into the work more than two and one-half times the diameter of the drill before being withdrawn from the work. For drilling deep holes in tool and machine steel, the spiral fluted drill is generally used with good results, but for drilling deep holes in brass, the straight-fluted drill gives better satisfaction, as it does not produce a long, curling chip, which is generally objectionable. Further information on the subject of deep hole drilling can be obtained from MACHINERY'S Reference Book No. 25, "Deep Hole Drilling."

Designing Cams for Deep-hole Drilling

As was previously mentioned, the drill should be dropped back clear of the drilled hole, so that the chips can be removed from the flutes and the drill cooled and lubricated. To accomplish this the lead cam is laid out as shown in Fig. 5; to explain the method used for laying out the cam, we will take a practical example: Assume that a hole ⅛ inch in diameter and ⅞ inch long is to be drilled in a piece of brass rod. Now, it can be seen that this will require three distinct lobes on the cam, as it will be necessary to drop the drill back twice in producing the hole. The rises for the various lobes can be found with the aid of the following formulas:

Rise on first lobe $= 2\frac{3}{4} \times D + 0.005$ inch.
Rise on second lobe $= 2\frac{3}{8} \times D + 0.003$ inch.
Rise on third lobe $= 2 \times D + 0.003$ inch.
where $D =$ diameter of drill in inches.

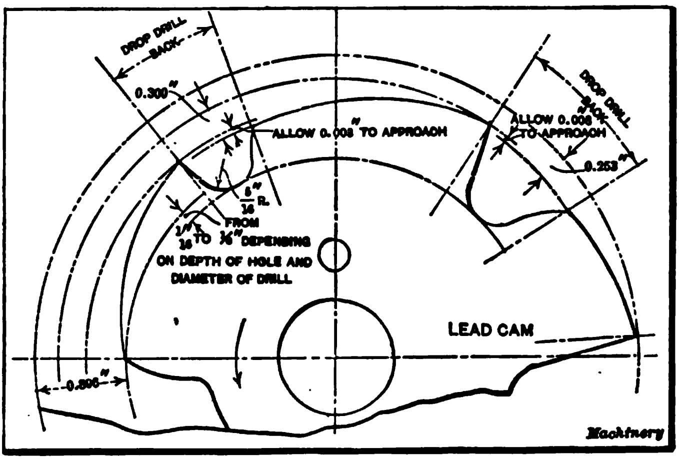


Fig. 5. Method of Laying out Cams for Deep-hole Drilling

The amount for each successive rise should be decreased in about the same proportion, and the feed on the drill should also be decreased slightly for each additional lobe when cutting machine and tool steel; but when cutting brass the feed can generally be uniform for each lobe. The rise on the various lobes would then be as follows:

Rise on first lobe $= 2\frac{3}{4} \times \frac{1}{8} + 0.005 = 0.349$ inch.
Rise on second lobe $= 2\frac{3}{8} \times \frac{1}{8} + 0.003 = 0.300$ inch.
Rise on third lobe $= 2 \times \frac{1}{8} + 0.003 = 0.253$ inch.

The depth to which the drill can be fed into the work before withdrawing can sometimes be increased, especially when a turret drilling attachment is used and the drill is greater than ⅛ inch in diameter.

The space on the cam surface necessary for dropping the drill back is generally equal to the space necessary for revolving the turret. It is, therefore, advisable to use more than one drill when there is a sufficient number of empty holes in the turret, as it will not be necessary to resharpen the drills so frequently, and they will also be kept cooler.

Oil-pump Attachment for Turret Tools

When a good supply of oil to the cutting edge of the tool is necessary for drilling deep holes, the attachment *A* shown in Fig. 6 is used. To the right of the engraving the attachment is shown inserted in the turret, and to the left it is shown removed. In explaining how this attachment works we will refer to the line engraving, Fig. 8. The oil is brought through the pipe *a*, as shown, up into the tube *c*,

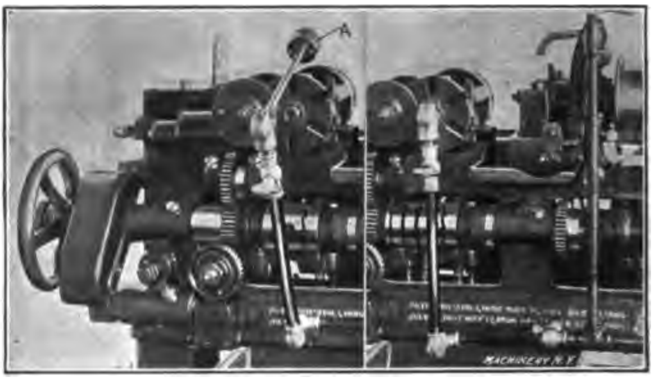


Fig. 6. No. 00 Brown & Sharpe Automatic Screw Machine equipped with Oil-pumping Attachment for Turret Tools

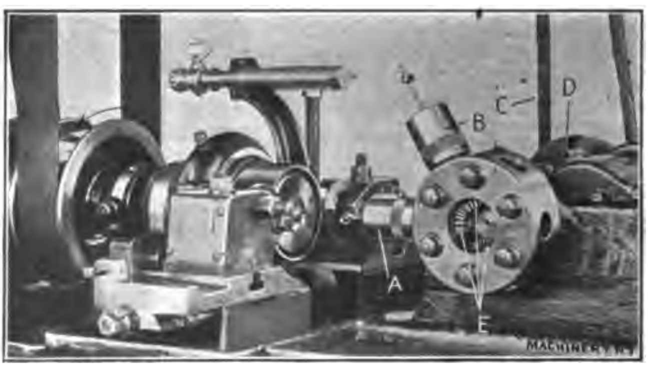


Fig. 7. No. 2 Brown & Sharpe Automatic Screw Machine equipped with Drilling Attachment

which is held in the split elbow *b*. The pipe *c* passes through the bronze bearing in the turret spindle to the oiling attachment *e*. This pipe has a slot *f*, 3/4 inch long by 3/32 inch wide, cut in the end facing the chuck. It is, therefore, obvious that oil can flow from this pipe only through the tools which are facing the chuck and in operation on the work. If any of the holes in the turret are not in use, a plug is inserted as shown at *g*. A clearer view of this plug is shown at *A*. The oiling attachment *e* is fastened to the turret by two small screws *i*. Thus the attachment rotates with the turret, bringing each hole successively into line with slot *f*, where the oil can flow through. The outer shell of this oiling attachment is shown at *B*. Slots 1/2 inch long by 3/32 inch wide are cut in the hexagonal surfaces as shown, allowing the oil to pass through. The idea of having these slots elongated is to provide oil to the tools where it is impossible to have the oil pass through the hole in the center of the tool. A hole can be drilled close to the outside of the shank, and passing through the body, thus allowing the oil to penetrate to the cutting point of the tool.

Turret Drilling Attachment

In Fig. 7 is shown a No. 2 Brown & Sharpe automatic screw machine equipped with a turret-drilling attachment, two drill holders *A* and *B* being shown in position in the turret. This attachment is

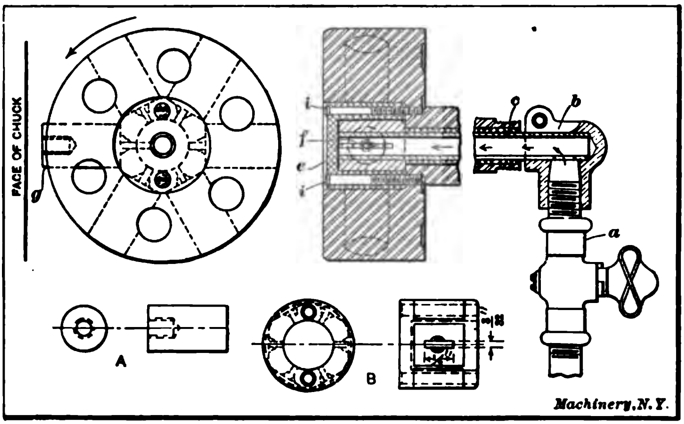


Fig. 8. Sectional View showing Construction of Oil-pumping Attachment for Turret Tools

driven from the overhead works by the ½-inch twisted belt *C*, the shaft passing through the turret connecting the pulley *D* with the bevel gears *E*. The manner in which this attachment is located and held in the turret is clearly shown in the sectional view Fig. 9. The pulley *D* is keyed to the shaft *F* and is also held in position with the nut *a*. Shaft *F* and bevel gear E_1 are made in one piece. The spindle of the drill holder is made of steel, hardened and ground, and runs in phosphor-bronze bearings.

The grooved pulley on the countershaft can be changed to increase or decrease the speed of the drill, as may be desired. The drill is revolved in the opposite direction to that in which the spindle and work are rotating, thus increasing the speed of the drill relative to the speed of the other tools. It is, therefore, obvious that the lobe on the cam for the drilling operation cannot be calculated from the speed of the spindle alone, but must also take into consideration the speed of the drilling attachment. To illustrate clearly the method of finding the number of revolutions required for drilling we will take a practical example. Before proceeding with the calculation we will assume the following values for speeds, depth of hole, time, etc.:

Let speed of spindle = 1200 R.P.M.,
speed of drilling attachment = 900 R.P.M.,
number of seconds to make one piece = 20,
total number of revolutions to complete one piece = 400,
depth of hole plus amount to approach = 3/8 inch,
diameter of drill = 1/8 inch,
feed on drill = 0.0032 inch per revolution.

The total number of revolutions required for drilling, if the drilling attachment were not used, would be $= \dfrac{0.375}{0.0032} = 117$ revolutions.

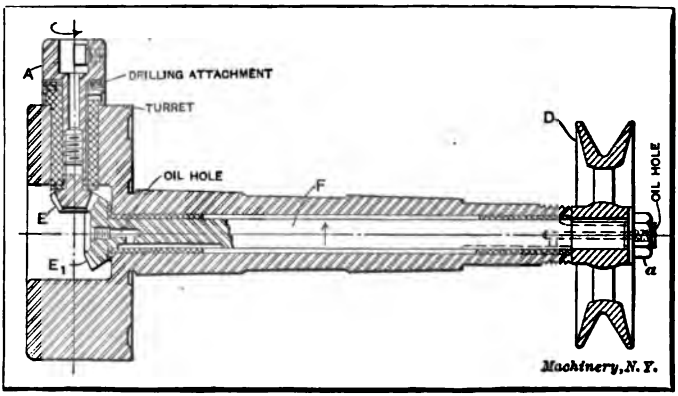


Fig. 9. Sectional View showing Construction of Drilling Attachment

The actual number of revolutions required for drilling when using the drilling attachment $= \dfrac{1200}{1200 + 900} \times 117 = 66.85$, or approximately, 67 revolutions.

Advantages of Turret Drilling Attachment

The following are three of the many advantages gained by using this attachment: First, the drill and the work are both given a rotary motion, which tends to produce a hole more straight than if the work alone were rotated; second, rotating the drill facilitates the removal of the chips from the hole and also allows the lubricant to penetrate to the cutting point; third, a suitable surface speed for the drill is obtained without increasing the cutting speed of the other tools in the turret.

It may also be mentioned that a spiral-fluted drill gives satisfactory results for drilling machine steel and brass when using this attachment; but for drilling brass where a long, curling chip is objectionable, the lips of the twist drill can be ground in, making the drill similar to a flat drill.

Cross-slide Drilling Attachment

It is sometimes found necessary to drill holes in a piece of work at right angles to the center line, or, in other words, across the piece. For this kind of work the cross-slide drilling attachment shown at *A* in Fig. 10 is found very serviceable. To apply this attachment to the cross-slide, the toolpost which carries the circular tool is removed and the attachment located in its place. The attachment is then held to the cross-slide by means of screw and nut *a*. The drill is held in a bushing in the spindle *b* by means of the headless screw shown. The two screws *c* are provided for taking up the wear in the bronze bearing. The small grooved pulley *d* is keyed to the spindle *b* and held by the nut and washer shown. The large grooved pulley *B* is located on the countershaft and drives the cross-slide drilling attachment through the medium of a $\frac{3}{8}$- or $\frac{1}{2}$-inch twisted belt, the size of the

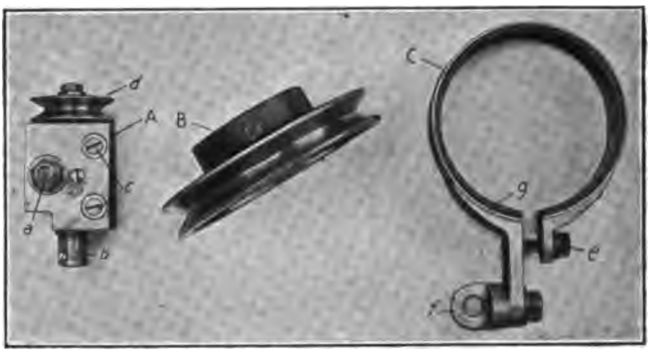


Fig. 10. Brown & Sharpe Cross-slide Drilling Attachment

belt depending on the machine to which the attachment is to be fitted. In cross-drilling it is necessary to stop the spindle and to hold it rigidly before the drill can operate. A brake shown at *C* for holding the spindle when drilling is used for this purpose. The brake proper is made from soft iron and has a strip of leather *g* attached to its inner surface, which grips the spindle firmly, preventing it from slipping. The cap-screw *e* is used for tightening the clamp on the pulley. The lug *f* is located on the pin which acts as a stop for the cross-slide tools.

It is obvious that when using a cross-slide drilling attachment, threading operations cannot be performed without the aid of a die and tap revolving attachment, as the spindle can rotate in one direction only. When using a revolving attachment in connection with the cross-drilling attachment, the threading attachment rotates the tap in the proper direction to release it from the work when the spindle is stopped. The tap is operated at one-half the spindle speed. Hence, for example, if a right-hand thread is being cut, the tap is rotated left-hand, advancing in the work when the spindle is running and retreating when the spindle is stopped. An opening die-holder is also sometimes used for cutting external threads when a cross-drilling attachment is used.

The method of fitting up this attachment is as follows: The belt is removed from the pulley nearest the collet, and the band *C* expanded over the pulley. It is then fastened to the pin which acts as a stop for the cross-slide, and clamped to the pulley by cap-screw *e*. The dogs on the drum are then set to throw the clutch onto the pulley, which is clamped just before the drilling attachment advances toward the work. After the drilling operation has been completed and the drill retreats from the work, the clutch is thrown out and onto the other pulley and the other operations continued. The spindle is started and stopped practically instantaneously, but it is advisable to allow a moment's time, equivalent to about five revolutions, before and

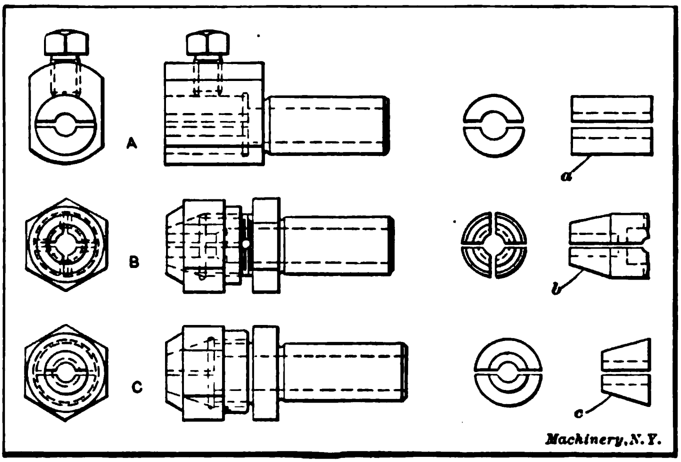


Fig. 11. Various Types of Drill Holders

after the drilling operation, for clearance. The drill should be ground with a more acute point-angle than for ordinary work, and should also be ground thin at the point to facilitate its starting into the work. The rise on the cam is similar to the rise for ordinary drilling, but the feed should be less. In most cases, for cross-drilling operations, it is an advantage to carry a guide bushing in the turret for locating the drill. Under this condition it is obvious that the work is drilled as if it were held in a jig, as the bushing is held in a floating holder that can be adjusted to produce the desired relation between the cross-hole and the outside diameter of the work.

Drill Holders

There are various types of drill holders used in the automatic screw machine, some of them being more complicated and expensive than is really necessary. The alignment of the turret holes with the spindle is nearly always perfect, and it is not necessary to have floating holders for holding a drill. At *A* in Fig. 11 is shown a common form of

TABLE III. FEEDS FOR HIGH-SPEED AND CARBON STEEL TWIST DRILLS

Diameter of Drill, Drill Gage or Inches	Brass Rod, Feed per Revolution	Machine Steel, Feed per Revolution	Tool Steel, Feed per Revolution	Diameter of Drill, Drill Gage or Inches	Brass Rod, Feed per Revolution	Machine Steel, Feed per Revolution	Tool Steel, Feed per Revolution
70	0.00070	0.00060	0.00050	$\frac{9}{32}$	0.0058	0.0052	0.0042
65	0.00075	0.00065	0.00055	$\frac{5}{16}$	0.0059	0.0055	0.0043
60	0.00080	0.00070	0.00060	$\frac{11}{32}$	0.0060	0.0058	0.0045
56	0.00120	0.00100	0.00080	$\frac{3}{8}$	0.0062	0.0060	0.0048
$\frac{1}{16}$	0.00180	0.00150	0.00100	$\frac{13}{32}$	0.0065	0.0062	0.0050
$\frac{5}{64}$	0.00250	0.00200	0.00120	$\frac{7}{16}$	0.0068	0.0065	0.0052
$\frac{3}{32}$	0.00250	0.00230	0.00150	$\frac{15}{32}$	0.0070	0.0068	0.0055
$\frac{7}{64}$	0.00300	0.00250	0.00180	$\frac{1}{2}$	0.0070	0.0070	0.0058
$\frac{1}{8}$	0.00320	0.00280	0.00200	$\frac{17}{32}$	0.0072	0.0072	0.0059
$\frac{9}{64}$	0.00350	0.00300	0.00230	$\frac{9}{16}$	0.0075	0.0075	0.0060
$\frac{5}{32}$	0.00380	0.00320	0.00250	$\frac{19}{32}$	0.0078	0.0078	0.0062
$\frac{11}{64}$	0.00400	0.00350	0.00280	$\frac{5}{8}$	0.0080	0.0079	0.0063
$\frac{3}{16}$	0.00420	0.00400	0.00300	$\frac{21}{32}$	0.0082	0.0080	0.0064
$\frac{13}{64}$	0.00450	0.00420	0.00320	$\frac{11}{16}$	0.0085	0.0082	0.0065
$\frac{7}{32}$	0.00480	0.00450	0.00350	$\frac{3}{4}$	0.0090	0.0083	0.0068
$\frac{15}{64}$	0.00500	0.00480	0.00380	$\frac{13}{16}$	0.0095	0.0085	0.0069
$\frac{1}{4}$	0.00550	0.00500	0.00400	$\frac{7}{8}$	0.0100	0.0088	0.0070

drill holder. This drill holder is serviceable and cheaply made. As can be seen, it is slabbed down on the sides to take up as little space as possible when working in conjunction with the cross-slide tools. The hole for the bushing is laid off eccentric to the main body of the holder, which allows enough stock on the upper portion to hold the set-screw. A plain bushing as shown at *a* is used. This bushing holds the drill very effectively. At *B* is shown a more expensive holder which is sometimes used for holding reamers and counterbores for operating on a piece which has previously been drilled concentric. This holder is made solid and then slotted as shown. The bushing part of the holder is shown at *b*. At *C* is shown a holder somewhat similar to that shown at *B*, but instead of the shank and drill holder being in one piece, a separate bushing is used. This holder is easier to set concentric with the work, but the extra cost prohibits its use to a great extent. The bushing as used in this holder is shown at *c*. For ordinary work the holder shown at *A* is recommended.

Drilling Speeds and Feeds

When drilling in the Brown & Sharpe automatic screw machines, the best results are generally obtained by giving the drills light feeds and high peripheral velocities. High-speed steel drills are commendable for drilling Norway iron, machine steel, tool steel, etc., but the ordinary carbon steel drills are suitable for brass and similar materials when the surface speed does not exceed that given in the following. The surface speeds here given for carbon and high-speed steel drills have been found satisfactory for the materials specified:

SPEEDS FOR ORDINARY CARBON STEEL DRILLS

Material	Surface Speed in Feet per Minute
Brass (ordinary quality)	160—180
Gun-screw iron	60— 70
Norway iron and machine steel	50— 60
Drill rod and tool steel	30— 40

SPEEDS FOR HIGH-SPEED STEEL DRILLS

Material	Surface Speed in Feet per Minute
Gun-screw iron	100—125
Norway iron and machine steel	80—100
Drill rod and tool steel	50— 60

Feeds for high-speed and ordinary carbon steel twist drills are given in Table III. The feeds given are for general work, but when the surface speed is not high the feed on the drill can be increased somewhat. It is found to be more satisfactory in general practice to keep the feed down, as a more straight hole can be produced than if the drill is forced.

Drills from 1/8 inch to 3/16 inch are capable of standing the heaviest feeds in proportion to their diameter, and when a hole does not pass through the work a ⅛-inch drill has been found to stand a feed of 0.016 inch per revolution when drilling brass. Feeds as heavy as this are not recommended, because concentric holes cannot be produced when the drill is forced to such an extent.

CHAPTER II

COUNTERBORING AND REAMING OPERATIONS

As a rule, more trouble is experienced in applying counterbores to the work on automatic machines than is experienced with any other cutting tool. This is probably due to the fact that counterbores are generally improperly made for the work on which they are to operate. Generally speaking, there are several reasons for the unsuccessful working of counterbores, some of which may be summed up as follows:

1. Too many cutting edges, not allowing enough chip space and also not providing for sufficient lubrication.
2. Too much cutting surface in contact with the work.
3. Insufficient clearance on the periphery of the teeth.
4. Improper location of the cutting edges relative to the center.
5. Improper method of holding the counterbore.
6. Improper grinding of the cutting edges.
7. Too weak a cross-section.
8. The use of a feed and speed in excess of what the tool will stand.

For general work, and especially for automatic work where the counterbore cannot be withdrawn when it plugs up with chips and seizes in the work, this tool should not have more than three cutting teeth. The periphery of the teeth should be backed off eccentrically, and the body of the counterbore should taper towards the back. The amount of taper generally varies from 0.020 to 0.040 inch per foot. The relation of the cutting edge to the center has an important bearing on the efficiency of the tool. For deep counterboring, where the difference between the diameter of the teat and the body of the counterbore is great, the cutting edge should never be located ahead of the center; in fact, if it is located a little below the center far better results are obtained. This rule is only general, of course, as the material to a considerable extent governs the location of the cutting edges.

Location of the Cutting Edges

At *A* in Fig. 12 is shown a three-tooth counterbore with its cutting edges located ahead of the center. Locating the cutting edge ahead of the center is advisable when the counterbore is to be used as a facing tool, or used for counterboring brass, and it is not required to extend into the work to a depth greater than its diameter, but it should preferably be used for facing operations only. If the counterbore is made in this manner and used on steel, the cutting teeth have a tendency to force the chips against the surface of the work. Consequently, when it is not properly lubricated, the work and counterbore become heated, and cause the chips to seize, thus producing poor work and, generally, a broken counterbore.

At *B* are shown the teeth cut radially to the center. For general work this is the best location for the cutting edges relative to the center. There is not the same tendency to force the chips against the surface of the work. Teeth cut radially to the center are suitable for either brass or steel work, but when used on steel, it is preferable to have the teeth cut spirally. A spiral which will give a rake of from 10 to 15 degrees generally gives the best results.

At *C* are shown the teeth cut below the center. This is the proper location for the cutting edges of the teeth where the difference between the diameter of the teat and the body of the counterbore is not very great, and where the counterbore is to extend into the work to a depth greater than its diameter. This, as can be seen, gives a lip to the counterbore which has a tendency to lift the chips from the cutting surface of the work, thus preventing them from seizing.

Various Types of Counterbores

When counterboring a hole where a large amount of material is to be removed, and where the counterbore is to extend into the work to

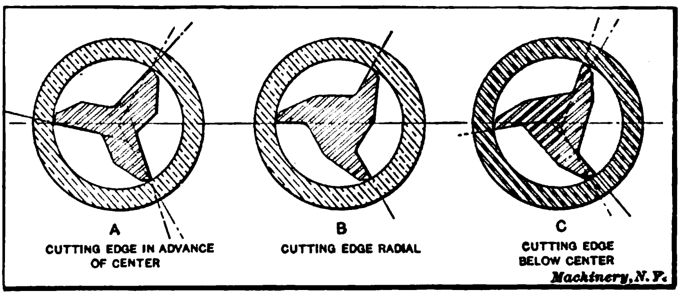


Fig. 12. Location of the Cutting Edges for Various Conditions

a depth greater than its diameter, it is generally advisable to rough out the hole to the diameter of the body of the counterbore with a three-fluted drill, such as shown at *A*, Fig. 13. Then the counterbore is used only for squaring up the shoulder at the bottom of the hole. This method is especially advisable when counterboring machine or tool steel.

At *B* is shown a counterbore which can sometimes be used to advantage on brass work, but which is not recommended for steel. It is made on the same principle as a flat drill with the exception that the teat has no cutting edges. At *C* is shown another counterbore for brass work, which has three cutting edges, and at *D* is shown a counterbore for steel work, having its teeth cut spirally. Teeth cut on a spiral which will produce a rake angle of 10 to 15 degrees are generally found suitable for machine or tool steel. Counterbores of the type shown at *C* and *D* should have inserted leaders or teats to facilitate their re-sharpening.

At *E* is shown a counterbore which is recommended for work having complicated shapes, or requiring to have two or more diameters finished with the same tool. This tool is backed off helically as shown, thus allowing it to be ground and still retain its initial shape and size. The backing off is accomplished on the lathe in the following manner: The lathe is geared up to cut six or eight threads per inch, depending on the diameter of the counterbore and the amount of clearance required. The counterbore, after being turned to the required dimensions, is milled as shown at *b*. It is then placed on the centers of the lathe, being driven by a dog, and a facing tool used for backing it off. The backing off is accomplished by pulling on the belt for each cut,

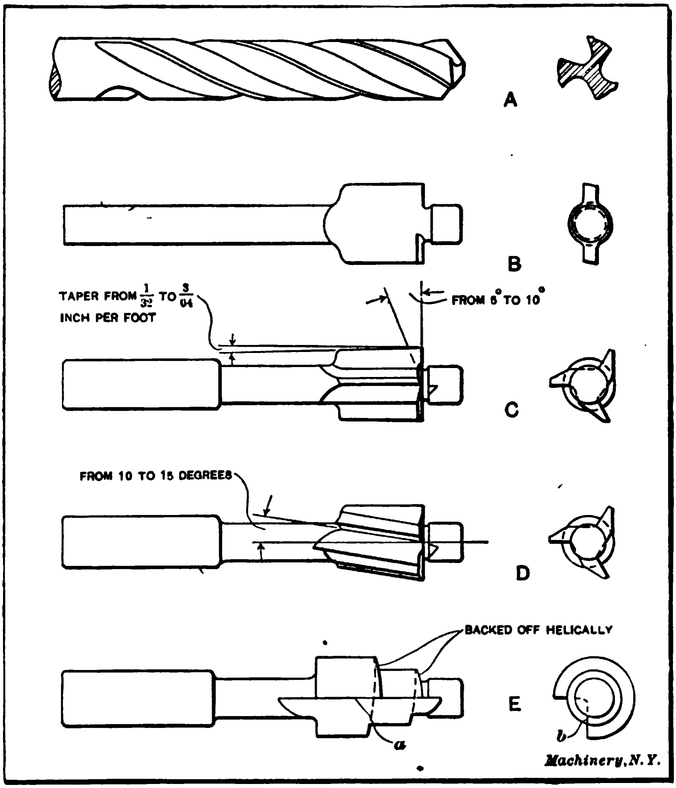


Fig. 13. Various Types of Counterbores

starting and finishing at the groove *b* until the backing off is completed. Where a backing-off attachment which is operated by a removable cam is available, this tedious operation can be done with greater ease and rapidity.

The counterbores described are for making pieces in which the hole extends through the work or to a depth which permits using a leader or teat; but for work in which the hole bottoms. that is, does not extend far enough into or through the work, these counterbores could not be used. The ordinary method used in producing holes which bottom is to use flat drills and combination counterbores and facing tools.

Flat Drills and Combination Counterbores

At *A* in Fig. 14 is shown a flat drill which is used for roughing out a hole having one diameter, and at *B* is shown the counterbore or facing tool which is used for squaring it up. The cutting edge *a* on the tool should be set about 0.1 times the diameter ahead of the center, and the thickness of the blade *b* should be about one-eighth of the diameter. At *C* is shown a flat drill or counterbore for producing

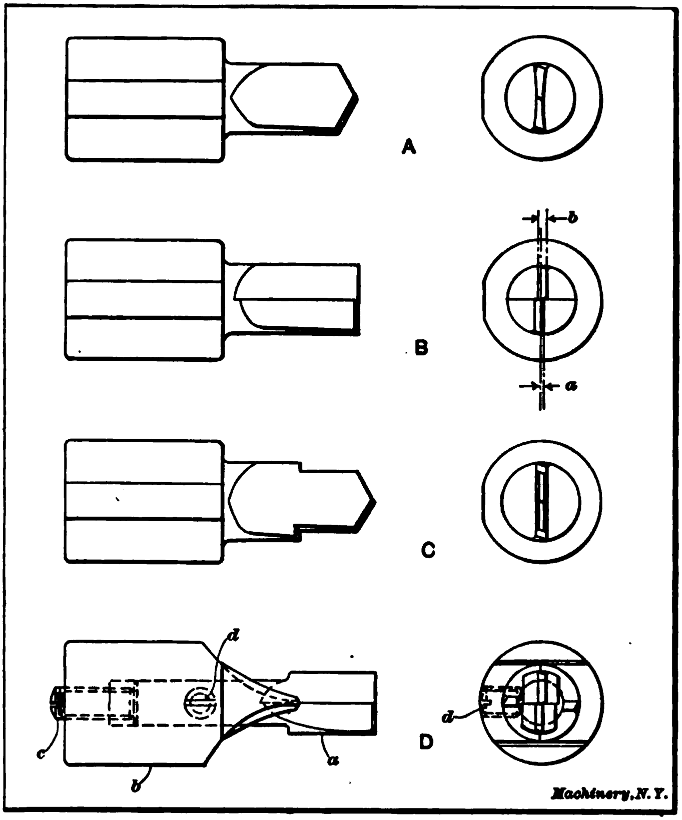


Fig. 14. Flat Drills and Combination Counterbores

a hole having two diameters, and at *D* is shown the combination counterbore and facing tool for squaring it up. This counterbore is adjustable, the part *a* being adjusted with relation to part *b* by means of the headless screw *c*, thus governing the distance between the shoulders, the headless screw *d* being used to prevent the part *a* from rotating. When the part *a* projects out from the part *b* a distance greater than one-half its diameter, care should be taken to have the shank a good fit in part *b*. These counterbores can be used for either brass or steel work, but for steel work it is preferable to use a spiral-fluted drill for roughing out the hole, instead of a flat drill, as the material can be removed with greater ease and rapidity.

Speeds for Counterbores

The surface speed at which a counterbore can be worked is slightly less than the surface speed used for drilling. The surface speeds given below are recommended for counterbores made from carbon and high-speed steel.

SPEEDS FOR COUNTERBORES MADE FROM CARBON STEEL

Material	Surface Speed in Feet per Minute
Brass (ordinary quality)	150-160
Gun-screw iron	50-60
Norway iron and machine steel	40-50
Drill rod and tool steel	30-35

SPEEDS FOR COUNTERBORES MADE FROM HIGH-SPEED STEEL

Material	Surface Speed in Feet per Minute
Brass (ordinary quality)	180-200
Gun-screw iron	80-90
Norway iron and machine steel	70-80
Drill rod and tool steel	45-50

Feeds for Counterbores

The method of holding a counterbore when applying it to the work, and the strength of the cross-section in proportion to the width of the chip being removed, governs to a considerable extent the amount of feed to be given. The material being cut and the depth to which the counterbore penetrates into the work, also have an important bearing on the rate of feed. These conditions should be taken into consideration when using the feeds given in Table IV. These feeds are for counterbores having three cutting edges, but for counterbores having one cutting edge the feed should be decreased from 40 to 50 per cent, and for two cutting edges, from 15 to 20 per cent. It is obvious that no definite rule can be laid down in regard to the exact feed to use, on account of the number of conditions which govern the rate of feed. The feeds given in Table IV should be used only when the counterbore penetrates from one-half to three-quarters of its diameter into the work. When the counterbore penetrates to a greater distance the feed should be decreased from 15 to 25 per cent. It is good practice to always drop the counterbore back after it has penetrated to a depth equal to half its diameter, to remove the chips, and to cool and lubricate it. The same method can be used for dropping back the counterbore as was described in connection with deep-hole drilling in the preceding chapter.

Holders for Counterbores

For counterbores having leaders, a rigid holder should not be used, as the leader will follow the hole previously drilled or reamed, and if the counterbore is not allowed to float, it will produce poor work, and a broken tool will sometimes be the result. At *A* in Fig. 15 is shown

TABLE IV. FEEDS FOR COUNTERBORES MADE FROM HIGH-SPEED AND CARBON STEEL

1/32-inch Chip				3/32-inch Chip				3/16-inch Chip			
Diameter of Counterbore in Inches	Brass Rod, Feed per Revolution	Mach. Steel, Feed per Revolution	Tool Steel, Feed per Revolution	Diameter of Counterbore in Inches	Brass Rod, Feed per Revolution	Mach. Steel, Feed per Revolution	Tool Steel, Feed per Revolution	Diameter of Counterbore in Inches	Brass Rod, Feed per Revolution	Mach. Steel, Feed per Revolution	Tool Steel, Feed per Revolution
1/8	0.0025	0.0018	0.0015	3/8	0.0040	0.0032	0.0020	9/16	0.0045	0.0035	0.0025
3/16	0.0030	0.0023	0.0020	7/16	0.0045	0.0035	0.0025	5/8	0.0048	0.0038	0.0028
1/4	0.0035	0.0030	0.0025	1/2	0.0050	0.0040	0.0030	11/16	0.0050	0.0040	0.0030
5/16	0.0045	0.0040	0.0030	9/16	0.0055	0.0045	0.0035	3/4	0.0055	0.0043	0.0032
3/8	0.0050	0.0045	0.0035	5/8	0.0060	0.0050	0.0040	13/16	0.0060	0.0045	0.0035
7/16	0.0060	0.0050	0.0038	11/16	0.0070	0.0055	0.0045	7/8	0.0065	0.0048	0.0038
1/2	0.0075	0.0052	0.0040	7/8	0.0075	0.0060	0.0050	15/16	0.0070	0.0050	0.0040
1/16-inch Chip				1/8-inch Chip				1/4-inch Chip			
1/4	0.0030	0.0028	0.0020	1/2	0.0050	0.0042	0.0025	11/16	0.0040	0.0030	0.0020
5/16	0.0035	0.0030	0.0025	9/16	0.0052	0.0045	0.0030	3/4	0.0042	0.0032	0.0022
3/8	0.0040	0.0035	0.0028	5/8	0.0055	0.0048	0.0032	13/16	0.0045	0.0035	0.0025
7/16	0.0045	0.0038	0.0030	11/16	0.0058	0.0050	0.0035	7/8	0.0048	0.0038	0.0030
1/2	0.0050	0.0040	0.0035	3/4	0.0060	0.0055	0.0040	15/16	0.0050	0.0040	0.0032
9/16	0.0055	0.0045	0.0038	13/16	0.0065	0.0058	0.0045	1	0.0050	0.0045	0.0035
5/8	0.0060	0.0050	0.0040	7/8	0.0070	0.0060	0.0050	......	......	......	......

a floating holder which will be found very serviceable for the conditions just mentioned. The sleeve or shank *a* is made to fit the turret and is bored out from 1/32 to 1/16 inch larger in diameter than the shank of the holder *b*. The holder *b* is kept from turning by the driving pin *c*, which is made a driving fit in the part *b* and a loose fit in the part *a*. The hole in the part *a* should be about 1/32 inch in diameter larger than the pin *c*. The two headless screws *d* are used for adjusting the counterbore so that it will enter easily into the drilled hole. They also help to keep the holder *b* from turning. It is good practice, when possible, to chamfer the hole so that the leader will enter easily. The counterbore is held by the split bushing *e* and set-screw *f*. If this holder is properly made and set it will be found to give good results for general work.

At *B* in Fig. 15 is shown a "floating" holder for holding the flat counterbore shown. This holder is not an actual floating holder, but would be better named an adjustable holder. It is made adjustable so that the tool can be set concentric with the center of the work. After adjusting, the part *a* is held tightly against the part *b* by the cap-screws *c*. The clearance holes in the part *a* for the cap-screws *c* are made about 1/16 inch in diameter larger than the body of the screw. The counterbore is held in the part *a* by set-screw *d*. This holder is

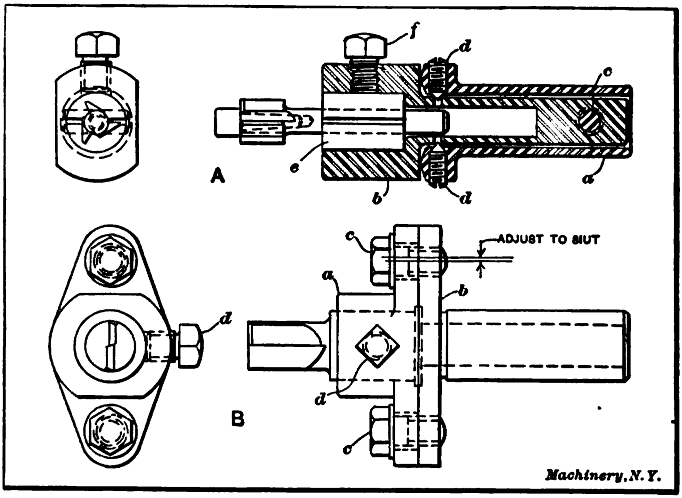


Fig. 15. Method of Holding Counterbores for Various Conditions

also found very serviceable for holding a counterbore when the hole to be counterbored penetrates into the work to a distance greater than its diameter and a chucking drill has been used to rough it out.

Reaming and Reamers

When it is necessary to make a perfectly round and accurate hole in the work, a reamer is used, the drilled hole being left slightly smaller to allow enough material for the reamer to true it up and bring it to the desired size. It is always advisable not to leave any more material to be removed by the reamer than is absolutely necessary. For general work the amounts given in the following list will give good results for reamers ranging in diameter from 1/8 to 3/8 inch. For reamers over 3/8 inch diameter, a drill 1/64 inch less in diameter is generally used, and this would leave from 0.012 to 0.015 inch to remove on the diameter, as it is obvious that a drill will cut slightly larger than its nominal size.

TABLE OF DIAMETERS OF HOLES DRILLED PREVIOUS TO REAMING

Diameter of Reamer in Inches	Diameter of Hole previous to Reaming, in Inches
1/8	0.120
3/16	0.182
1/4	0.242
5/16	0.302
3/8	0.368

There are various reasons for the inefficient working of a reamer, some of which are the following:

1. Chattering, which results when the teeth are evenly spaced.

2. Chips clinging to the teeth, which action results when high periphery velocities are used, with insufficient clearance.

TABLE V. FEEDS FOR REAMERS MADE FROM HIGH-SPEED AND CARBON STEEL

Diameter of Reamer in Inches	Brass Rod, Feed per Revolution	Machine Steel, Feed per Revolution	Tool Steel, Feed per Revolution
1/8	0.007	0.004	0.002
3/16	0.008	0.004	0.003
1/4	0.009	0.005	0.004
5/16	0.010	0.006	0.005
3/8	0.011	0.007	0.006
7/16	0.012	0.008	0.007
1/2	0.013	0.009	0.008
9/16	0.014	0.010	0.009
5/8	0.015	0.011	0.010
11/16	0.016	0.012	0.011
3/4	0.017	0.013	0.011
13/16	0.018	0.014	0.012
7/8	0.020	0.015	0.012

3. Expanding and contracting of the hole, which is caused by too heavy feed and insufficient clearance on the cutting edges.

4. Enlarged and tapered holes, due to holding the reamer rigid instead of floating.

There are various methods adopted to prevent reamers from chattering, but the unequal spacing of the teeth has been found the most satisfactory and inexpensive. For machine reamers varying from 1/8 to 1/4 inch, three cutting edges are sometimes used, but the difficulty encountered in measuring their diameter with micrometers limits their use to a certain extent. As a general rule, therefore, four and six cutting edges are used on reamers varying from 1/8 inch to 3/8 inch, and 8 to 12 cutting edges on reamers varying from 3/8 inch to 7/8 inch.

The clinging of chips to the teeth is generally due to high periphery velocities and improper lubrication. Insufficient clearance of the cutting edges also heats the work to a considerable extent, which causes the chips to cling. The clinging of the chips is more noticeable on steel containing a small percentage of carbon than it is on brass or steels which contain a high percentage of carbon.

Reamers are generally made slightly tapering towards the back; a taper varying from 0.002 to 0.005 inch per foot is generally used, and a less taper should be used for brass than steel, as brass work, especially thin tubing, contracts and expands more readily than steel, so that, if a perfect hole is desired, the reamer should be tapered but slightly. For reaming machine steel a rose reamer is generally used, as it has been found satisfactory for producing straight and perfect holes. This reamer tapers towards the back and is not relieved on the periphery of the cutting edges, the end of the reamer only being backed off.

The cutting edges of reamers are generally cut on the center (radial) for steel, but for brass work they are sometimes cut slightly ahead of the center, which produces a scraping action, and makes a smooth cut.

Reaming Feeds and Speeds

The surface speeds used for reaming should be slightly less than those used for counterboring, as the reamer generally penetrates to a greater depth and has more cutting surface in contact with the work, which tends to produce excessive heating of the work and reamer, resulting in chips clinging to the cutting edges, with rough and inaccurate work as a consequence. When a good supply of lard oil is used, the following surface speeds will be found satisfactory.

SPEEDS FOR REAMERS MADE FROM CARBON STEEL

Material	Surface Speed in Feet per Minute
Brass (ordinary quality)	120-125
Gun-screw iron	35-40
Norway iron and machine steel	30-35
Drill rod and tool steel	20-25

SPEEDS FOR REAMERS MADE FROM HIGH-SPEED STEEL

Material	Surface Speed in Feet per Minute
Brass (ordinary quality)	150-160
Gun-screw iron	65-75
Norway iron and machine steel	50-60
Drill rod and tool steel	30-40

The feeds for reamers given in Table V will be found suitable for general work, when no more material is removed on the diameter than previously stated. When reaming thin tubing, especially brass, the feed should be decreased somewhat.

The method used for holding a reamer when applying it to the work governs to a considerable extent the quality of the hole produced. When reaming a deep hole, if the reamer is held rigidly, it will nearly always produce a hole which will be tapered and large in diameter.

At *A* in Fig. 16 is shown a floating holder which is sometimes used. This holder is cheaply made, but is not a commendable holder for automatic screw machine work, although it can sometimes be used to advantage on the hand screw machine. One of the disadvantages of this reamer holder is that the reamer drops down as shown at *a* if much clearance is allowed between the diameter of the reamer shank and the diameter of the hole, thus preventing the reamer from entering easily into the work, which generally results in a broken reamer.

At *B* is shown a more efficient holder, especially for deep hole reaming. The reamer is guided at the rear by a cone-pointed screw *b*, and is kept from rotating and is guided at the same time by the two cone-pointed screws *c*. By means of these screws, the reamer can be set so

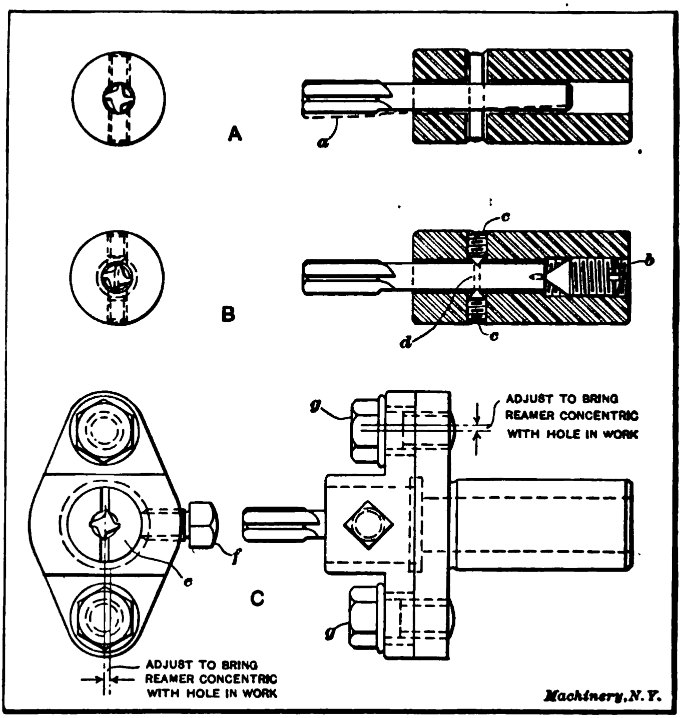


Fig. 16. Method of Holding Reamers for Various Conditions

that it will enter the drilled hole easily, and at the same time be allowed to adjust itself to correspond to the eccentricity of the hole in the work. The small hole *d* is drilled through the shank of the reamer, allowing the cone-pointed screws to enter. This holder will be found very satisfactory for holding reamers when it is not necessary to remove an excessive amount of material. At *C* is shown a floating holder which is used for reaming shallow holes. The reamer is held rigidly by a split bushing and set-screw *f*. The reamer is set concentric with the hole in the work by loosening the cap-screws *g* and then locating it in the hole by the bevel or rounded corners on the end of the reamer.

CHAPTER III

RECESSING TOOLS AND OPERATIONS

In this chapter, recessing tools and recessing operations will be described. The practice outlined is that generally accepted, and when used with discretion satisfactory results will be obtained. The speeds and feeds, of course, are liable to some variation on account of the conditions which govern them, but the feeds given are not exceedingly high and can be used to advantage in the majority of cases.

Three different types of recessing tool holders, commonly called swing tools, are described, but it will, of course, be seen that with slight modifications tool-holders of the description given can be used for various classes of work. Three types of recessing tools are also shown. These are suited for three different conditions, namely, for chamfering operations, for recessing operations, and for special conditions—that is, the third tool is used when the hole in the work is so small as not to permit the use of either of the other tools. Explicit instructions are also given for laying out cams for chamfering and recessing operations.

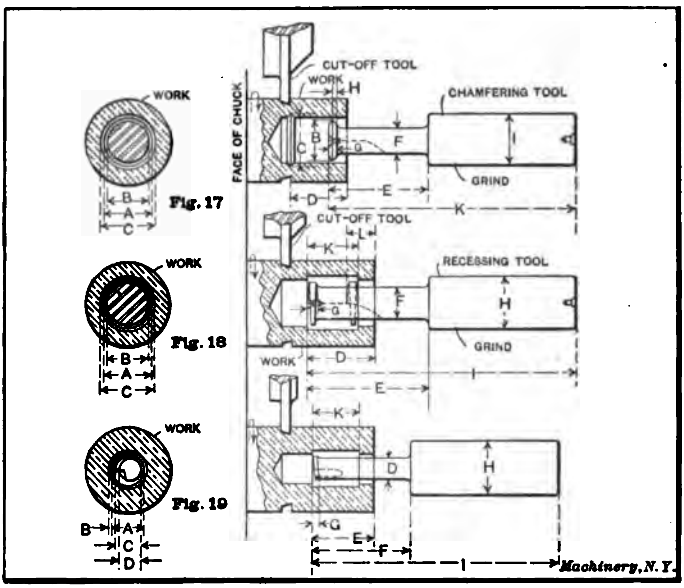
Recessing and Recessing Tools

When it is necessary to chamfer a hole in each end of a piece, a recessing or so-called "internal" chamfering tool is used, which eliminates a second operation. A recessing tool which works on the same principle as an ordinary boring-tool is used for chambering or relieving a hole in the center, that is, just leaving a bearing surface at each end. The recessing or chamfering operation should always precede the reaming operation, so that all burrs thrown into the hole by the recessing tool will be removed by the reamer. A recessing or chamfering tool should be operated from the front cross-slide whenever possible, for the following reasons: In the first place, it is generally more convenient to make the necessary adjustments; in the second place, turning the tool upside down allows the chips to drop to the bottom of the hole where they are easily removed, thus allowing the tool to work with less obstruction; and in the third place, the recessing tool can be more conveniently operated from the front cross-slide, by means of the rising block used in connection with the forming tool holder. The regular rising block, however, is removed and a special rising block substituted, which has a cam attached, used for operating the recessing tool holders.

If, on the other hand, the recessing tool holder is operated from the rear cross-slide, the recessing either must be done when the spindle is running backwards, or else it will be necessary to make a special circular tool holder, in which the distance from the hole through which the screw is inserted to hold the circular tool, to the top face of the cross-slide is of a less height than that ordinarily used on the rear cross-slide.

In cutting the finished piece from the bar after recessing, the feed should be decreased on the cut-off tool, so that the piece will be severed without leaving a burr where the two cuts meet. Decreasing the feed from 0.001 to 0.0005 inch per revolution is generally found sufficient.

At *A* in Fig. 20 is shown a recessing tool which is used for chamfering, and at *B* is shown a tool which is used for chambering. This latter tool removes the superfluous material in a similar manner to an ordinary boring-tool.



Figs. 17, 18 and 19. Diagrams illustrating the Method of Determining Proportions for Chamfering and Recessing Tools

The chamfering tool shown at *A* is not backed off, as it is smaller in diameter than the hole in the work, which gives it sufficient periphery clearance. For brass work, the cutting edge is cut radial as shown, or sometimes below the center when less clearance is necessary, as shown by the dotted line *a*, but for steel work it is cut above the center a distance equal to 0.1 of the diameter. The included angle β of the cutting edge is made as required, the angle usually being about 90 degrees.

The recessing or boring tool shown at *B* has its sides helically relieved, giving a clearance angle of from 5 to 8 degrees, which is found satisfactory for ordinary work. For brass work this tool is cut on the center or below, as shown by the dotted line *b*, and for steel work the same as already stated for chamfering tool *A*.

Where the hole in the work is of such a diameter that a tool made similar to those shown at *A* and *B* would be too slender to do efficient work, one similar to that shown at *C* and *D* can be used. The diameter of the cutting end of this tool need only be about 0.008 to 0.012 inch smaller than the hole. The distance *a* should be about 0.015 inch greater than the depth of the recess, and *b*, of course, will equal ½ *a*. The amount *c* that the cutting edge is cut below the center, should be enough to give the tool sufficient negative rake for brass, but for steel it should be cut 0.1 of the diameter above the center.

A good method of making this tool is as follows: Take a piece of drill rod of a diameter equal to the diameter of the shank required

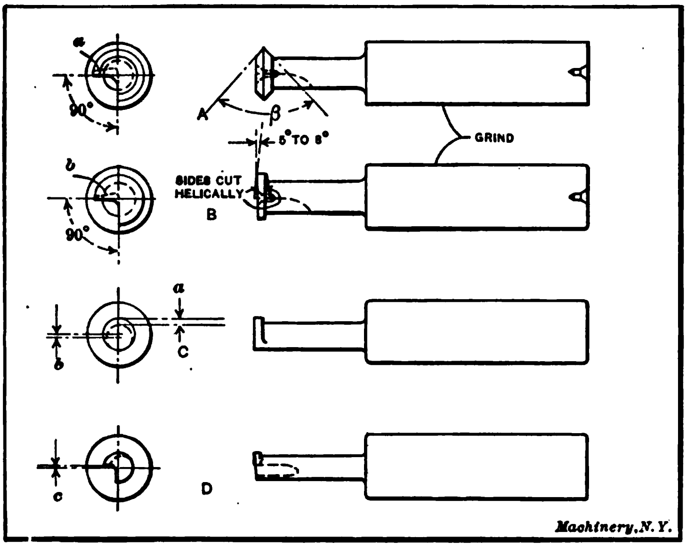


Fig. 20. Various Types of Recessing Tools

and insert it in a draw-in chuck held in a bench or other suitable lathe. Turn down the body of the tool to the diameter required, then remove the tool from the chuck, and put it back with a narrow strip of sheet steel or brass placed alongside of it, the thickness of which will equal the dimension *b*, Fig. 20. When the tool has been tightened in the chuck, light cuts can be taken until the desired amount of material has been removed. When the tool has been turned eccentric, as shown at *C*, a small groove is milled in it as shown at *D*, and the tool backed off for clearance. It is then hardened and drawn very carefully in oil. If the amount of eccentricity required on the tool is such that the tool could not be held firmly in a chuck with a piece of sheet steel inserted alongside of it, a bushing should be made with an eccentric hole, the eccentricity of the hole in the bushing being equal to the eccentricity required on the tool.

Chamfering and recessing tools should be made slightly smaller than the diameter of the drilled hole and the body should never be longer than is necessary to clear the work. allow the chips to pass out, and the oil to penetrate to the cutting edge. For general conditions the following proportions for chamfering and recessing tools will be found satisfactory:

Proportions for Chamfering Tools (for Notation see Fig. 17)

A = diameter of hole before reaming, or diameter of drill,
B = diameter of chamfering tool = A — 0.025 to 0.030 inch,
C = diameter of chamfered hole,
D = length of work, or distance that tool projects in from the face of the work,
E = length of body of tool = 1.25 D,
F = diameter of body of tool (when included angle = 90 degrees) = B — ($2H$ + 0.025 to 0.030 inch).
G = width of blade = 0.25 B = $2H$,
I = diameter of shank, as follows:

When A = from ⅛ to ¼ inch, I = ¼ inch.
A = from ¼ to ½ inch, I = ½ inch.
A = from ½ to ⅞ inch, I = 1 inch.

K = total length of tool, as follows:

When I = ¼ inch, K = E + ⅞ inch.
I = ½ inch, K = E + 1¼ inch.
I = 1 inch, K = E + 1½ inch.

Proportions for Recessing Tools (for Notation see Fig. 18)

A = diameter of hole before reaming, or diameter of drill,
B = diameter of recessing tool = A — 0.025 to 0.030 inch,
C = diameter of recessed hole,
D = distance from face of work to extreme depth of recessed hole,
E = length of body of tool = 1.25 D,
F = diameter of body of tool = B — (C — B + 0.020),
G = width of blade = 0.2 B,
H = diameter of shank, as follows:

When A is from ⅛ to ¼ inch, H = ¼ inch.
A is from ¼ to ½ inch, H = ½ inch.
A is from ½ to ⅞ inch, H = 1 inch.

I = total length of tool, as follows:

When H = ¼ inch, I = E + ⅞ inch.
H = ½ inch, I = E + 1¼ inch.
H = 1 inch, I = E + 1½ inch.

Proportions for Tools used in Recessing Holes of Small Diameter (for Notation see Fig. 19)

A = diameter of hole before recessing, or diameter of drill,
B = depth of recess,
C = diameter of cutting portion of recessing tool = A — from 0.010 to 0.020 inch,
D = diameter of eccentric body of tool = C — (B + from 0.010 to 0.020 inch),

E = distance from face of work to extreme depth of recessed hole,
F = length of body of tool = $1.20 E$,
G = width of blade = $0.20 C$,
H = diameter of shank of tool, which is the same as previously given for the tools shown in Figs. 18 and 19.
I = total length of tool, as follows:

When H is ¼ inch, $I = F + ⅞$ inch.
H is ½ inch, $I = F + 1¼$ inch.
H is 1 inch, $I = F + 1½$ inch.

It will be noted that the lengths of the bodies E and F on chamfering and recessing tools, respectively, will be governed to a considerable extent by the character of the holder used, and the relative positions of the cross-slide tools during the recessing operation, and also

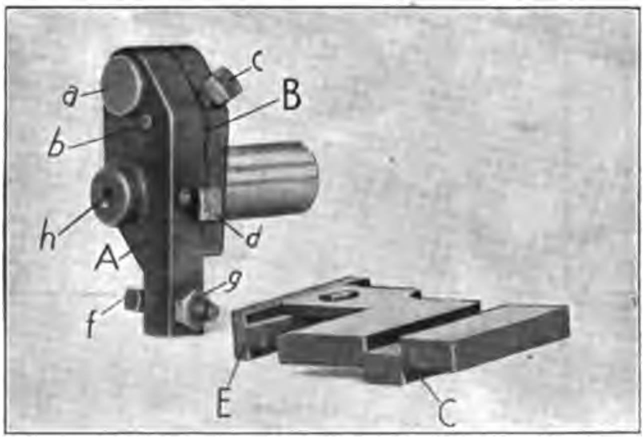


Fig. 21. B. & S. Swing Tool-holder and Rising Block for Operating it

by the depth of recessed hole required. Usually the proportions given will be found satisfactory for general work.

Recessing Tool Holders

In Fig. 21 is shown a recessing tool holder which is commonly called a swing tool. The swinging member A of this holder is held to the body B by a stud and screw a. The pin b held in the swinging member is kept tight up against the end of the set-screw c by means of a small coiled spring, not shown, which is held in the member B. The set-screw c is also used for bringing the tool concentric with the hole in in the work. The set-screw d holds the recessing tool in the swinging holder. To operate this tool, the ordinary rising block which is used under the circular tool holder is removed, as already mentioned, and the block shown to the right in the illustration is substituted in its place. This block is intended only for straight work, the cam E being adjusted longitudinally in a slot in plate C.

The rising block shown in Fig. 22 is adjustable for taper work.

Plate *C* has a longitudinal groove *c* cut in it, in which the adjusting arm *D* can be adjusted in or out, as desired. When the desired position is obtained, it is clamped by means of the screws *d*. On this adjustable plate *D* is fastened a swinging plate which rotates on the small pin *e* and is adjusted by the set-screw *f*. When this plate is set in the desired position it is locked by means of the screw *g*. This rising block can be used for a variety of work, as the setting and shape of the plate *E* will determine the shape produced on the work.

When it is essential to have a hole in the work concentric with the external circumference of the work, a block as shown in Fig. 22 can be used in conjunction with the recessing or swinging tool holder shown in Fig. 21, the operation of truing the hole being similar to

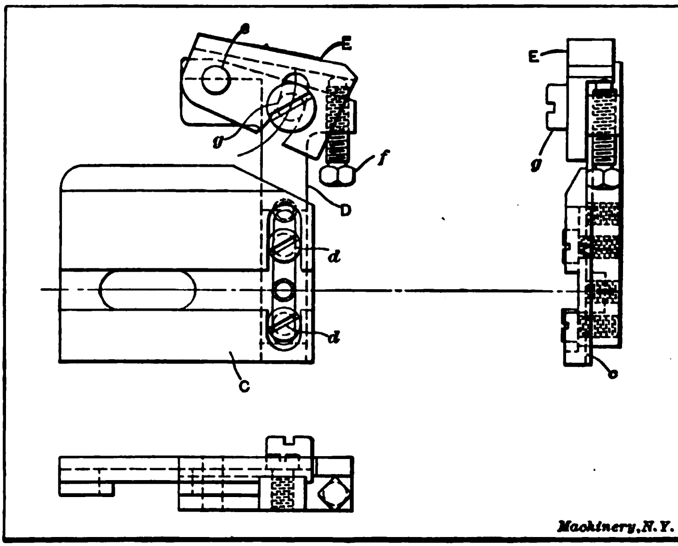


Fig. 22. Standard Rising Block used for Operating Swing Tools

boring a hole in an ordinary lathe. For this class of work, of course, it is usually necessary to take only one cut, so that complicated cams are avoided, but in special cases the work in hand will decide whether it would be advisable to take one or more cuts.

Returning to the swinging tool holder shown in Fig. 21, the set-screw *f* is used for bringing the recessing tool concentric with the hole in the work. A small clamping nut *g* is provided for locking it, when in the desired position. The sizes of the hole *h* in the holders for the various machines do not fit the sizes of shanks for recessing tools recommended above, but are smaller, as follows:

For the No. 00 machine, $h = 3/16$ inch,
No. 0 machine, $h = 1/4$ inch,
No. 2 machine, $h = 1/2$ inch.

For large recessing tools the shank sizes required to fit these holders are rather too small.

In Fig. 23 is shown another design of recessing tool holder which will sometimes be found very convenient. In the tool-holder shown the swinging member *A* is held to the body of the tool-holder *B* by means of the screw *C*. The body of this screw, which passes into the holder *B*, is turned eccentric to that part of the screw which works in the swinging member *A*. A detail view of this screw, used in a holder for a No. 00 machine, is shown to the right in the illustration. It can be seen that a slight adjustment of this screw will locate the recessing tool concentric with the hole in the work. This is found to be a very practicable addition in some cases, especially when the hole in the work is extremely small, not allowing the difference between the external diameter of the recessing tool and that of the hole to be very great. This screw also provides for any inaccuracy in the making of the holder, as it is usually found a difficult proposition to get these tool-holders to line up exactly.

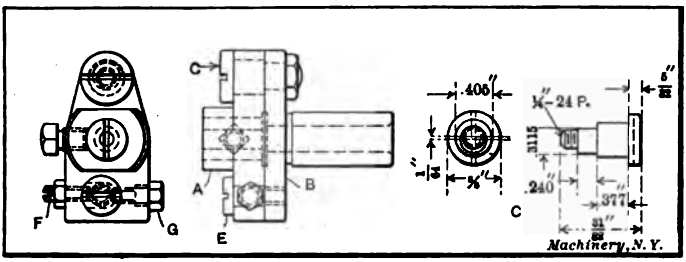


Fig. 23. Another Type of Swing or Recessing Tool Holder

The construction of this holder is somewhat different to that shown in Fig. 21, especially in the method of holding *A* to the member *B*. A shoulder-screw *E* is tapped into part *B* and is made a loose fit in the swinging part *A*, the latter having an elongated hole to allow the holder to swing. The head of the screw *E* allows the swinging part of the holder to slide easily underneath it. This holder has an adjustable stop *F*, so that once the holder is set, it will always come back into the exact position. The set-screw or stop *F* which bears against the body of the screw *E* is locked by means of a nut. *G* is the screw against which the operating cam attached to the rising block bears. This screw has a shoulder against which a small coiled spring acts, thus keeping the screw *F* held in the swinging member *A* up against the screw *E*. Split bushings are used for holding the recessing tools in this holder. This tool can be made very accurately and is used for fine and delicate work.

Performing Facing Operations with Swing Tools

Swing tools are not only used for recessing and chamfering operations, but can also be used for straight, taper and irregular turning operations, and when necessary may be used for facing. It is sometimes found necessary to cup out a piece of work, leaving a very thin wall. Now, if the ordinary facing tool were used in the turret, the cutting pressure would force this thin wall back, and as soon as relieved of the pressure, it would spring back again to its normal position, or nearly so, thus making it difficult to produce a perfectly square face in the work. For this class of work a swing tool as shown in Fig. 24 is found advisable. When in operation, the facing tool *C* shown in the holder is brought up until the cutting edge is in line with the face of the work. When it is in this position it is fed a slight amount into the work, equal to the depth of the cut to be taken. Then the cross-slide advances, forcing the tool forward, thus turning the face in a manner similar to that of an ordinary facing operation in the lathe. If one cut is not sufficient to true up the face, of course a second cut can be easily taken. This method of turning will be found satisfactory when all others fail. This swing tool is constructed some-

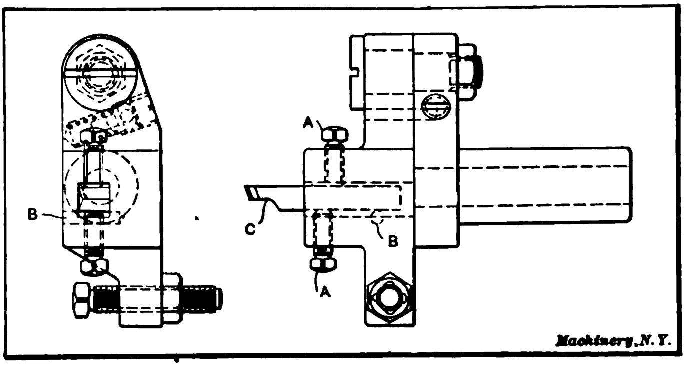


Fig. 24. Swing Tool used for Facing Operations

what similarly to those previously described, with a slight modification to suit the requirements. The turning tool *C* is made from a square section of either carbon or high-speed steel and is adjusted by means of the two set-screws *A*. The turning tool rests on the small pin *B* which acts as a fulcrum. By means of this pin and the two set-screws the tool can be set to the correct height.

When making a cup-shaped piece of work similar to that shown in Fig. 25, usually the best procedure to follow is to first drill, rough counterbore and form all at the same time. A rough counterbore can be used similar to that shown at *B*, Fig. 14. Following the counterboring operation, a swing tool similar to that shown in Fig. 24 is used to square up the inside face which has become slightly concave, due to the fact that the heat generated between the side of the form tool and the work causes the work to spring away from the tool.

If it is necessary to have the back face of the piece square as well as the inside face, a revolving support can be used in the turret, following the rough counterboring operation or the first facing operation, as the case may be; preferably it should follow the facing operation. This support is used in conjunction with a shaving tool carried on either cross-slide, as may be necessary, and is brought up against the inside face of the work. The shaving tool is then fed across the back face of the work, taking a light shaving cut. If necessary it can also take a light cut off the shank, if it is desired to get the diameter closer than within limits of 0.0015 inch. Care should be taken to have the spindle adjusted so that there is no end play, and to have the dwell on the cam uniform, because if the lobe for the revolving support is not uniform but has slight rises on it, it will produce an uneven finish on the back face of the work, thus defeating the object of the shaving operation.

When the wall is very thin, that is when the distance B equals about ten times the dimension A, two facing cuts should be taken. It is preferable, when performing facing operations of this character, to operate the swing tool from the front cross-slide and start the cut from the center of the work out to the full diameter. Operating the swing tool from the front cross-slide permits the tool to be turned upside down (when the spindle is running forward), thus allowing the chips to be removed easily. However, when high periphery velocities are used on steel, it is generally practicable to have the swing tool operated from the rear cross-slide, or else run the spindle backward, so that a good supply of oil can reach the cutting edge of the tool.

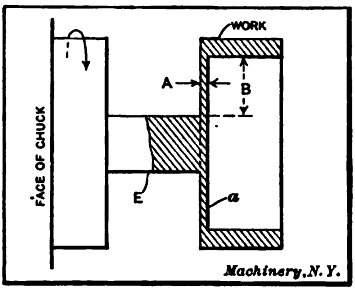


Fig. 25. Diagram giving Notation used in the Derivation of Feeds for Facing Operations

Feeds for Facing Operations

The feeds and depths of chip for facing operations are given in Table VI. The values of C in the first column equal B divided by A (see Fig. 25). For example, assume that $B = 0.25$ inch. Then when

$$A = 0.025 \text{ inch, } C = \frac{0.250}{0.0250} = 10, \text{ or, in other words, } B = 10 \text{ times } A.$$

It will be noted that the feeds given are approximately the same for brass rod and machine steel; this has been found satisfactory. When the distance B is greater than 12 times A, the form tool, or other means of supporting the thin wall against the pressure of the cut should be provided. Where the form tool is used for this purpose it should be made perfectly straight, that is, without side clearance, and it should be ground and lapped. In this operation the form tool is dropped back from the shank E of the work to a distance about 0.010 inch and allowed to dwell in this position until the facing operation is completed. A copious supply of good lard oil should be supplied to the tools. The feeds under these conditions can sometimes exceed those given in Table VI.

Rise on Cross-slide Cam for Recessing and Chamfering

When using the recessing holders previously described it is obvious that the rise on the cam will be greater than the distance which the tool is fed into the work. To illustrate the method of finding the rise on the cam, refer to Fig. 26, where

A = distance from center of fulcrum to center of the recessing tool,
B = distance from center of fulcrum to point of application of cam or center of screw f (see Fig. 21),
C = diameter of recessing tool,
D = diameter of drilled hole in the work,
E = diameter of recessed hole,

TABLE VI. FEEDS FOR FACING TOOLS MADE FROM HIGH-SPEED AND CARBON STEEL

Value of C	Brass Rod, Feed per Revolution	Machine Steel, Feed per Revolution	Tool Steel, Feed per Revolution
0.002-inch Chip			
12.0	0.0008	0.0007	0.0005
11.0	0.0010	0.0009	0.0007
10.0	0.0020	0.0015	0.0010
9.0	0.0030	0.0025	0.0015
8.0	0.0040	0.0030	0.0020
0.005-inch Chip			
7.0	0.0040	0.0030	0.0020
6.5	0.0050	0.0033	0.0023
6.0	0.0055	0.0040	0.0025
5.5	0.0060	0.0045	0.0028
5.0	0.0070	0.0050	0.0030
0.010-inch Chip			
4.5	0.0048	0.0030	0.0030
4.0	0.0050	0.0034	0.0034
3.5	0.0055	0.0037	0.0037
3.0	0.0060	0.0040	0.0040

r = travel of recessing tool $= \dfrac{E - C}{2}$,

R = rise on the cam.

Then $R : r :: B : A$. To illustrate this more clearly we will take a practical example. Let r equal 0.040 inch; B, $2\frac{1}{4}$ inches; A, $1\frac{1}{8}$ inch; then

$$R = \frac{0.040 \times 2\frac{1}{4}}{1\frac{1}{8}} = 0.080 \text{ inch.}$$

Care should be taken to set the recessing tool exactly in the center of the hole, so that it will not strike the side when being forced into or backed out of the work. If care is not taken in this respect, the appearance of the work turned out will not be creditable, and the tool may be broken.

Cam Lever Templets for Laying out Cams

In Fig. 27 are shown the cam lever templets for the Nos. 00, 0, 1 and 2 Brown & Sharpe automatic screw machines. These templets are used for laying out cams when it is necessary to have the starting or finishing points of the lobes on the cross-slide and lead cams in a certain definite relation to each other.

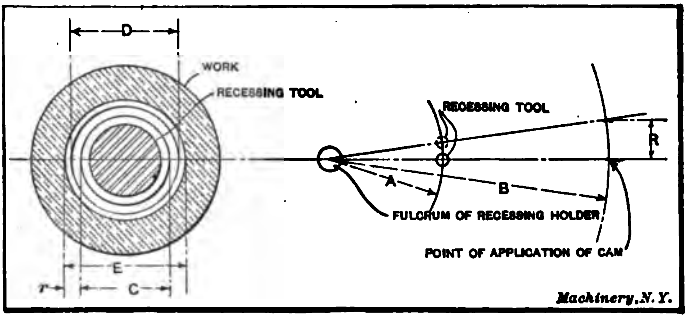


Fig. 26. Diagram for finding Rise on Cross-slide Cam for Recessing and Chamfering Operations

These templets are used as follows: The center *A* is pivoted at the center of the cam drawing by a pin or other pointed instrument which is inserted in the center hole provided in the lever. The main body of the templet *B* can then be rotated in any desired position so that

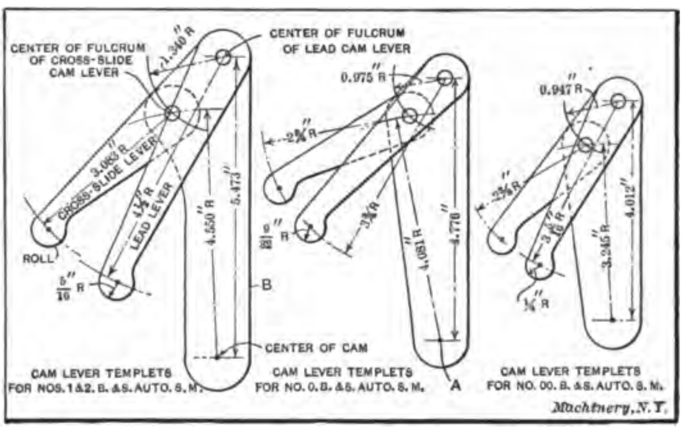


Fig. 27. Nos. 00, 0, 1 and 2, B. & S. Automatic Screw Machine Cam Lever Templets for finding the Starting and Finishing Points of the Lobes for the Cross-slide and Lead Cams

the rolls of the cam levers can be set in their respective relations to each other. In this way the starting or finishing points of the lead and cross-slide cam lobes can very easily be obtained, as will be further explained in the following.

These cam lever templets are made from sheet celluloid, thus making them transparent so that any marks placed on the drawing can easily be detected, such as the location of the roll, whether on the top of the lobe, on the rise of the lobe, or on the drop of it. The templets are manufactured by the Brown & Sharpe Mfg. Co., Providence, R. I.

Methods of Laying out Cams for Chamfering

In Fig. 28 is shown a method for finding the starting and finishing points on the lobes of the cross-slide and lead cams for chamfering. These points can very easily be obtained by means of the cam lever templets shown in Fig. 27. As was previously explained in regard to these templets the center *A* (see Fig. 27) is pivoted at the center of the cam.

There are two methods used in laying out a set of cams when it is necessary to obtain clearances or definite starting points for the lead and cross-slide lobes. The first one is to obtain a rough estimate of the total number of revolutions required to complete one piece, after which the revolutions are transferred into hundredths of cam circumference, and the location of the lobes laid out on the cam circles. Then the rises and drops are constructed and the amount of clearance obtained by the cam lever templets. This method usually requires considerable experience in this line of work.

Another method, and one which the writer considers superior to that given, is to first find the rise on the cross-slide cam for chamfering (see Fig. 26). Then draw a diagram as shown in Fig. 28. First draw circles *L* and *S*, representing the largest diameter of the lead cam and the largest diameter of the cross-slide cam, respectively. Then draw another circle *H* a distance *R* inside of the circle *S*, as shown, the dimension *R* being the rise on the cross-slide cam. It is obvoius that in chamfering operations the tool should have been moved longitudinally the proper distance into the work before the cross-slide cam starts to operate upon it. Therefore, the lead-cam roll should be on the highest point of the lobe before the cam on the cross-slide, used for feeding in the tool, touches the tool holder. In order to accomplish this result, proceed as follows. Draw a circle *G*, as shown in Fig. 28, which has a radius an amount $R + D + \frac{1}{16}$ smaller than that of circle *S*. The value of *D* is shown in Fig. 17; the 1/16 inch added to *D* allows for clearance. After these circles have been drawn, we can find the starting and finishing points of the lobes.

The cam lever templet is now brought into position, and the lead cam roll placed so that its circumference touches the lobe on the lead cam and its center coincides with the line *A* indicating the completion of the lead-cam rise. Then the cross-slide lever is swung down so that the circumference of the roll touches the circle *G* as shown, and with a sharp pencil a line is scribed around the circumference of the roll, which will determine the quick rise of the cam. The compasses are then set to the desired radius for the quick rise of the cam which is described so that it will cut the circle *H*, representing the start of the rise on the cross-slide cam, and also be tangent to the line which has been previously marked by scribing around the cross-slide lever roll.

Where the quick rise of the cam and the circle *H* meet, will be the starting point of the rise on the cross-slide cam, indicated by the line *B* as shown.

When we have found the starting points, the next thing is to obtain the ending or "finish" points of the lobe. It is obvious that the lead cam should hold the tool in position until the cross-slide cam has dropped back an amount equal to the distance which it has forced the tool into the work. A line *F* is taken at any convenient position for the "finish" of the lead cam, and the cam lever templet is then brought into position so that the roll of the lead lever touches the circle and the center coincides with the line *F* as shown. The cross-slide roll is then swung down until its circumference touches the circle *H* and a line is scribed around the circumference of the roll. Where this line

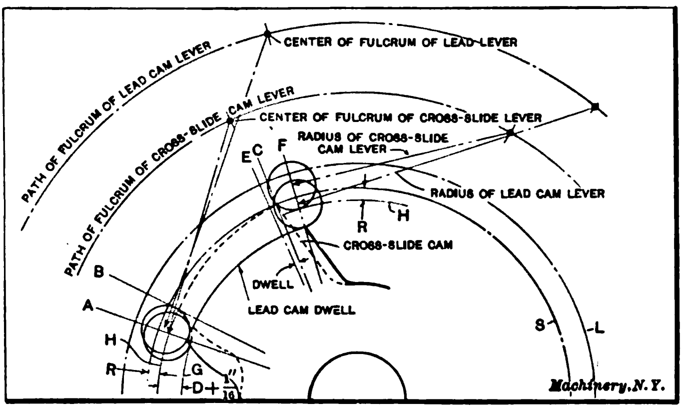


Fig. 28. Diagram for finding the Starting and Finishing Points of the Lobes of the Cross-slide and Lead Cams for Chamfering Operations

intersects the circle representing the largest diameter of the cam, will be the finishing point of the lobe, provided the distance *R* is not greater than the radius of the roll. If distance *R* is greater than this, the line representing the drop should be constructed tangent to the roll circumference, and where the line representing the drop intersects the outside circle will be the finishing point of the lobe, as indicated by line *C*. The space from *E* to *C* represents from one to two revolutions for dwell on the cross-slide cam.

Now it can be clearly seen that the advantage of this method is that the amount of clearance between the starting and finishing points of the lead and cross-slide cams is known in hundredths of the cam circle circumference before the cams themselves are laid out, thus facilitating the operation of laying out the cams.

Methods of Laying out Cams for Recessing

In Fig. 29 a method is shown for finding the starting and finishing points on the lobes of the cross-slide and lead cams for recessing. To determine these points the cam lever templets are again brought into operation. The starting point, determined by line *A*, and the circle representing the dwell on the lead cam are first laid out. A circle is then drawn, the radius of which is a distance *K* (see Figs. 18 and 19) greater than the circle representing the dwell on the lead cam. Before this is done, of course, a maximum diameter of cam should be decided upon, which will suit the length of the tool-holder used in the turret. A circle passing through the starting point of the rise of the cross-slide cam, as well as a circle representing the dwell on the cross-slide cam should also be drawn, the difference in radii between these two circles being the rise *R*. Now the cam lever templets are placed in position on the drawing, and the lead roll brought down so that it touches the lead cam, its center coinciding with line *A*. A circle *M* is next drawn, having a radius $L + \frac{1}{16}$ inch less than that of the circle

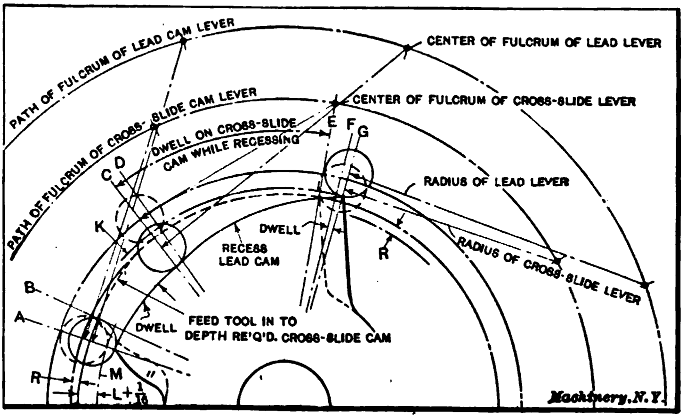


Fig. 29. Diagram for finding the Starting and Finishing Points on the Lobes of the Cross-slide and Lead Cams for Recessing Operations

passing through the starting point of the rise of the cross-slide cam. (See Fig. 18 for dimension *L*). The cross-slide roll is then swung down until its circumference touches the circle *M*, as shown, and a line is drawn around the circumference of the roll. The quick rise line of the cam is then constructed tangent to the roll, and where this line intersects the circle previously drawn and which determines the beginning of the slow feeding-in rise of the cross-slide cam, is the starting point of the slower rise of the cross-slide cam, as shown at *B*. The line *C*, which represents the finishing point of the rise on the cross-slide cam for feeding the tool in to take the desired chip, is then laid off and the cross-slide roll swung into position. The lead roll is then swung down until it touches the circle representing the dwell on the lead cam. The starting point of the rise on the lead cam, located on line *D*, is slightly in advance of the finishing point on the cross-slide cam.

The finishing points of the lobes are the next things that require attention. Any line, as *G*, is taken at a convenient location, and the cam lever templets are then brought into operation. The lead roll is first brought into position as shown, and then the cross-slide roll is swung down from the outside diameter of the cam a distance equal to *R*, and the drop laid off as before mentioned in regard to chamfering operations. The finishing point of the cross-slide lobe would then be on the line *E*. The space from *C* to *E* on the cross-slide cam would be for dwell, while the space from *D* to *G* on the lead cam would be the rise. The space from *F* to *G* is for dwell on the lead cam, which represents about one or two revolutions.

Speeds for Chamfering and Recessing Tools

The surface speeds used for recessing tools can be slightly greater than those used for counterbores on account of the light feeds and

TABLE VII. FEEDS FOR CHAMFERING TOOLS MADE FROM HIGH-SPEED AND CARBON STEELS

Diameter of Chamfering Tool in Inches	Brass Rod, Feed per Revolution	Machine Steel, Feed, per Revolution	Tool Steel, Feed per Revolution
1/8	0.0010	0.0008	0.0005
3/16	0.0015	0.0010	0.0008
1/4	0.0018	0.0015	0.0010
5/16	0.0020	0.0020	0.0012
3/8	0.0030	0.0022	0.0015
7/16	0.0040	0.0025	0.0018
1/2	0.0048	0.0030	0.0020
9/16	0.0055	0.0035	0.0021
5/8	0.0060	0.0038	0.0022
11/16	0.0065	0.0040	0.0024
3/4	0.0070	0.0045	0.0026
13/16	0.0075	0.0048	0.0028
7/8	0.0080	0.0050	0.0030

small amount of cutting surface in contact with the work. As a rule; the following surface speeds can be used on the materials specified with satisfactory results:

SPEEDS FOR RECESSING TOOLS MADE FROM CARBON STEEL

Material	Surface Speed in Feet per Minute
Brass (ordinary quality)	170-180
Gun-screw iron	60-70
Norway iron and machine steel	45-55
Drill rod and tool steel	35-40

SPEEDS FOR RECESSING TOOLS MADE FROM HIGH-SPEED STEEL

Material	Surface Speed in Feet per Minute
Brass (ordinary quality)	200-225
Gun-screw iron	90-100
Norway iron or machine steel	75-85
Drill rod and tool steel	50-60

TABLE VIII. FEEDS FOR RECESSING TOOLS MADE FROM HIGH-SPEED AND CARBON STEEL

0.010-inch Chip			
Diameter of Recessing Tool in Inches	Brass Rod, Feed per Revolution	Machine Steel, Feed per Revolution	Tool Steel, Feed per Revolution
1/8	0.0020	0.0012	0.0010
3/16	0.0030	0.0018	0.0015
1/4	0.0040	0.0025	0.0020
5/16	0.0080	0.0040	0.0040
3/8	0.0120	0.0060	0.0050
7/16	0.0160	0.0090	0.0060
1/2	0.0200	0.0100	0.0070

1/32-inch Chip			
Diameter of Recessing Tool in Inches	Brass Rod, Feed per Revolution	Machine Steel, Feed per Revolution	Tool Steel, Feed per Revolution
3/8	0.0040	0.0025	0.0015
7/16	0.0045	0.0030	0 0020
1/2	0.0055	0.0040	0.0025
9/16	0.0075	0.0050	0.0030
5/8	0.0085	0.0060	0.0035
11/16	0.0100	0.0065	0.0038
3/4	0.0120	0.0070	0.0040

0.020-inch Chip			
Diameter of Recessing Tool in Inches	Brass Rod, Feed per Revolution	Machine Steel, Feed per Revolution	Tool Steel, Feed per Revolution
1/4	0.0025	0.0015	0.0010
5/16	0.0035	0.0020	0.0015
3/8	0.0050	0.0030	0.0020
7/16	0 0080	0.0050	0.0040
1/2	0.0120	0.0070	0.0050
9/16	0 0160	0.0090	0.0055
5/8	0 0190	0.0100	0.0060

1/16-inch Chip			
Diameter of Recessing Tool in Inches	Brass Rod, Feed per Revolution	Machine Steel, Feed per Revolution	Tool Steel, Feed per Revolution
1/2	0.0030	0.0020	0.0010
9/16	0.0040	0.0028	0.0015
5/8	0.0050	0.0030	0.0020
11/16	0.0060	0.0035	0 0023
3/4	0.0075	0.0040	0.0025
13/16	0.0080	0.0045	0.0028
7/8	0.0085	0.0050	0.0030

Feeds for Chamfering

In Table VII are given the feeds to be used for chamfering tools when cutting various materials, and when the tools are of the diameters specified. It is obvious that the greater the length of the body of the tool is in proportion to its diameter, the smaller will be the feed. This should be taken into consideration when applying the feeds given. These feeds are for chamfering tools having the proportions given in Figs. 17 to 19, inclusive. When the diameter of the body is smaller in proportion to its length than given in Figs. 17

to 19, it would be advisable in most cases to use a slightly decreased feed. No definite rule, however, can be given for this, as the conditions vary so much. Therefore, the feed to be used will practically be a matter of judgment and can be found in no other way than by experience.

Feeds for Recessing

In Table VIII are given the feeds to be used when a chip from 0.010 to 1/16 inch thick is being removed. The same feeds as given in Table VII are used for feeding the recessing tool into the depth of chip required, while the feeds given in Table VIII are used for feeding the tool longitudinally. The same conditions as previously mentioned in connection with chamfering tools should be taken into consideration here also. For general conditions and for recessing tools made to proportions given in Figs. 17 to 19 the feeds in Table VIII will be found satisfactory. In steel work, especially, it is usually found advisable to decrease the feed as the tool approaches the end of its cut, when a chip varying from 1/32 to 1/16 inch thick is taken. This rule is also followed when a finishing cut is taken with a box-tool up to a shoulder.

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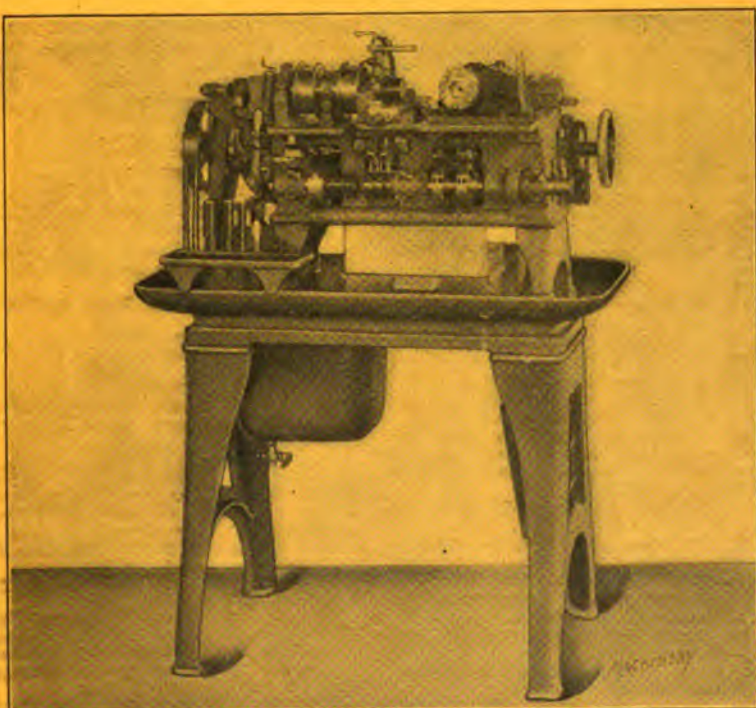
THREADING OPERATIONS ON THE BROWN & SHARPE AUTOMATIC SCREW MACHINES

BY DOUGLAS T. HAMILTON



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NUMBER 104

AUTOMATIC SCREW MACHINE PRACTICE

PART VI

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49-55 Lafayette Street, New York City

Automatic Screw Machine Practice for the Brown & Sharpe automatic screw machines is covered in eight Reference Books, Nos. 99 to 106, inclusive. Reference Book No. 99, "Operation of the Brown & Sharpe Automatic Screw Machines," deals with the construction of these machines and the setting-up of the tools. No. 100, "Designing and Cutting Cams for Automatic Screw Machines," gives detailed instruction on cam design, and describes a simplified method for milling cams. No. 101, "Circular Form and Cut-off Tools for the Automatic Screw Machine," deals with the general arrangement and the calculations of these tools, and describes the different methods employed in their making. No. 102, "External Cutting Tools for the Automatic Screw Machine," deals with the design and construction of box-tools, taper turning tools, hollow mills, and shaving tools. No. 103, "Internal Cutting Tools for the Automatic Screw Machine," deals with centering tools, cross-slide drilling attachments, counterbores, reamers, and recessing tools. No. 104, "Threading Operations on the Automatic Screw Machine," treats on cam design for threading operations, threading dies, taps and tap drills, die and tap holders, and thread rolling. No. 105, "Knurling Operations on the Automatic Screw Machine," describes the construction of knurling holders, and gives directions for the making of knurls and the design of tools and cams used in connection with knurling operations. No. 106, "Milling, Cross-drilling and Burring Operations on the Automatic Screw Machine," describes screw-slotting attachments, index drilling attachments, and burring attachments, giving directions for their use and for the design of cams for them.

CHAPTER I

ARRANGEMENT OF MACHINE FOR THREADING OPERATIONS

The subject of threading on the Brown & Sharpe automatic screw machine is a subject which confuses the beginner on account of the calculations necessary for determining the rise on the cam due to the relation between the speed of the spindle and the driving shaft. The various reversing devices, tripping devices and threading attachments are also of importance. Until the various devices and arrangements used are fully understood, good results cannot be expected.

Reversing the Spindle

On the No. 00 Brown & Sharpe automatic screw machine the spindle is reversed by means of a spring plunger shown at *A*, Fig. 1; this

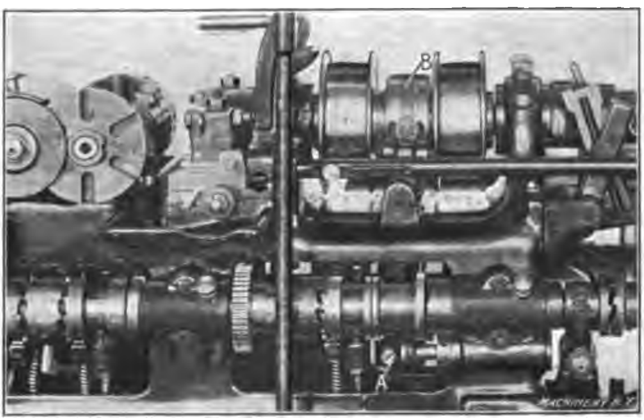

Fig. 1. Rear View of No. 00 Brown & Sharpe Automatic Screw Machine showing Reversing Mechanism

plunger, acting through the medium of the friction clutch *B*, reverses the spindle, from forward to backward, instantaneously. But, to reverse the spindle from backward to forward, onto a slow speed (as is sometimes necessary when cutting a thread), requires one revolution of the driving shaft. This shaft runs at 120 R. P. M. In a given case, the spindle speed equals, say, 2400 R. P. M.; then the revolutions required for reversing the spindle equal $\frac{2400}{120} = 20$ revolutions of the spindle. The 20 revolutions used for this purpose represents lost time, and to obviate this, the Brown & Sharpe Mfg. Co. has provided a speed ratio threading attachment which is used in the turret. This attachment will be described later.

On the No. 0 and No. 2 Brown & Sharpe automatic screw machines, the spindle is reversed instantly from forward to backward by means of cam *A* and lever *B*, Fig. 2. The spindle is reversed from backward to forward by means of the same cam *A* on the driving shaft. There are two lobes on this cam, and it, therefore, requires one-half revolution of the driving shaft to reverse the spindle. For example, let the spindle speed equal 1800 revolutions per minute; let the speed of the driving shaft equal 180 revolutions per minute. Then the number of revolutions required to reverse the spindle $= \frac{1800}{180 \times 2} = 5$ revolutions. To reverse the spindle from forward to backward and then forward again (as would be necessary where two threading operations come

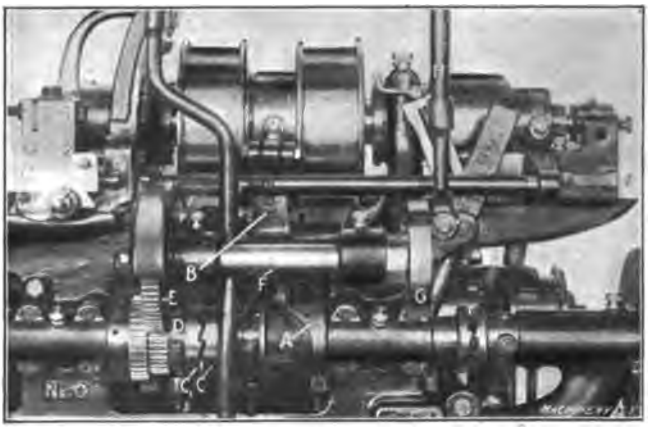

Fig. 2. Rear View of No. 0 Brown & Sharpe Automatic Screw Machine showing Reversing Mechanism and Belt Shifting Attachment

in succession) requires 4¾ hundredths of the cam surface on account of the tripping dogs on the drum, which cannot be placed any closer together. This will be referred to further under the heading "Setting the Tripping Dogs for Threading."

On the No. 2 Brown & Sharpe automatic screw machine, the spindle is reversed in the same manner as on the No. 0. For example, let the spindle speed equal 1200 revolutions per minute; let that of the driving shaft equal 120 revolutions per minute. Then the number of revolutions required to reverse the spindle from backward to forward $= \frac{1200}{120 \times 2} = 5$ revolutions; to reverse the spindle from forward to backward and forward again (as we explained regarding the No. 0 machine) requires 3¾ hundredths of the cam surface.

Setting the Tripping Dogs for Threading

The tripping dogs *a*, Fig. 3, which are used for reversing the spindle, feeding the stock, and revolving the turret are placed on the various drums on the front shaft as follows: The dog for reversing the spindle is placed on drum *A*, for feeding the stock, on drum *B*, and for revolving the turret, on drum *C*. These dogs operate the levers *D*, *E*, and *F*, respectively, which, in turn, disengage a clutch on the driv-

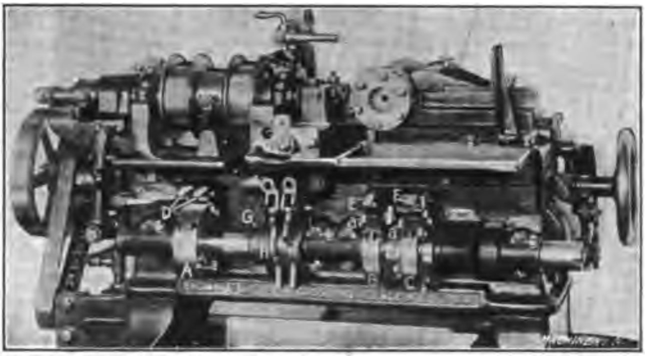

Fig. 3. Front View Showing Feeding, Reversing and Revolving Devices

ing shaft on the rear of the machine, thus operating the reversing, feeding and revolving devices. Where two threading operations follow in succession, the time required to revolve the turret is not always sufficient to bring the second tap or die into position. This is

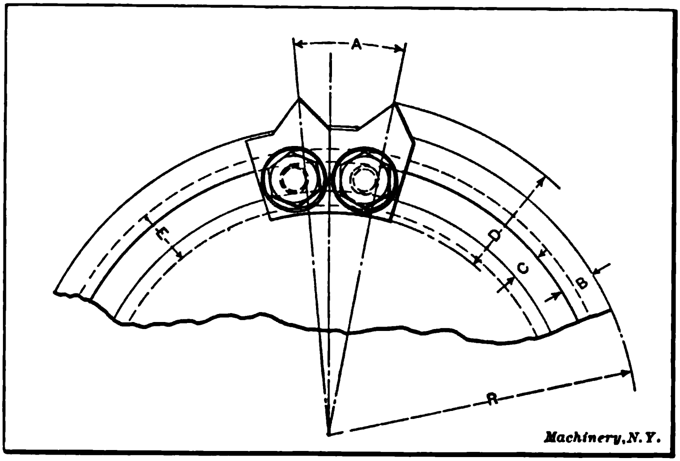

Fig. 4. Reversing Dogs in Position on Drum

illustrated in Fig. 4, where two tripping dogs are shown in position on the drum. To illustrate the method of determining whether extra time should be allowed for clearance, take a practical example. Assume that a set of cams is required to be used on the No. 2 Brown & Sharpe automatic screw machine. Let the spindle speed equal 1200 revolutions per minute; let the time required to complete one piece equal 20 seconds. Then the number of revolutions to complete one piece $= \dfrac{1200 \times 20}{60} = 400$ revolutions. Referring to the tables for laying out cams in MACHINERY'S Reference Book No. 100, we find

TABLE I. GENERAL DIMENSIONS OF DRUM AND REVERSING DOGS

No. of Machine	A	B	C	D	E	R
00	20°	15/64	1/4	15/16	1/8	2
0	17°	5/16	1/4	1 1/32	1/8	2 3/8
2	14°	13/32	5/16	1 1/4	3/16	3 1/4

that it requires five hundredths to feed stock, plus one hundredth for clearance. This gives 6 hundredths to revolve the turret. Referring to the accompanying Table I we find that the angle A is 14 degrees. Then if the number of hundredths of the cam surface utilized in revolving the turret is less than the equivalent of 14 degrees, we would have to add more for clearance. In this case it requires 6 hundredths to revolve the turret. Then, reducing 14 degrees to hundredths, we have, $\dfrac{100 \times 14}{360} = 3.88$ hundredths. Therefore, additional cam surface would not be necessary in this case.

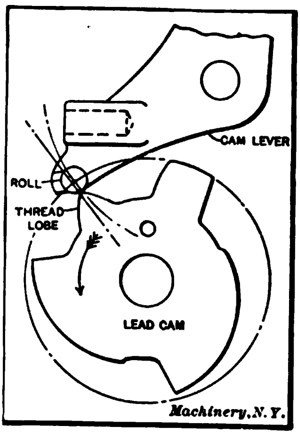

Fig. 5. Position of Roll on Thread Lobe when Spindle is reversed

Setting the Machine for the Use of Taps and Dies

Before the reversing mechanism can operate, the clutch G must engage with clutch H. (See Fig. 3.) After engaging these clutches, we set the reversing dog a so that the spindle will reverse just as the roll passes over the highest portion of the thread lobe on the rear cam, as shown exaggerated in Fig. 5. When the spindle is reversing at the exact point as mentioned, the die or tap holder containing the die or tap is placed in the turret, and brought into position as shown in Fig. 6. The cam roll is set on the thread lobe in the position shown. Here a button die holder A (draw-out type) is shown in position ready to start on the work. The face of the die should be set a distance a, which varies from 1/16 to 3/16 inch, depending on the pitch of the thread and the length of the threaded portion, away from the part to be threaded. If the die does not travel onto the work far enough at the first setting, the holder can be brought further out of the turret. The same procedure can be followed in setting the tap, except that it should be set more carefully, only going into the work a slight distance in starting, and then moving the holder out of the turret until the desired depth is reached. It is sometimes found necessary, after setting the tripping dog, to adjust it slightly, especially when using a draw-out die or tap holder. The turret should not be revolved until the die or tap is clear of the work.

When calculating the revolutions of the spindle required for threading, a greater number of revolutions should be allowed than the exact number of threads required on the piece, depending on the pitch of the thread, and in some cases on the length of the threaded portion, as when a short thread has to be produced, necessitating the threading of a longer portion and then facing it off. This is to allow the die to approach the end of the piece on the rise of the thread lobe. The

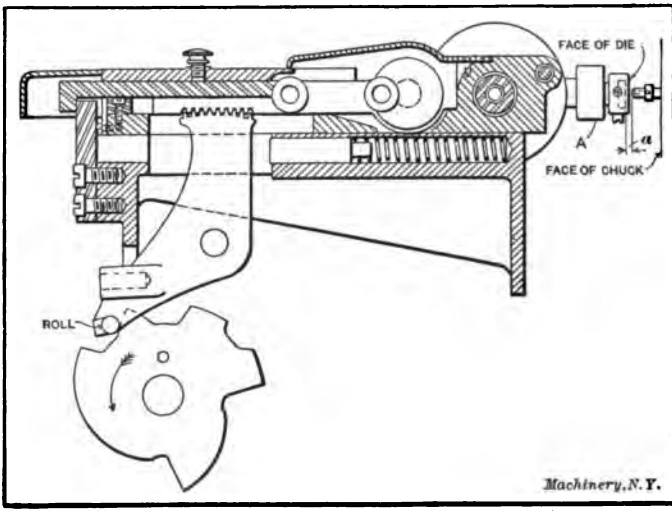

Fig. 6. Position of Roll on Thread Lobe when setting Die or Tap

actual number of revolutions required for threading can be found by the aid of the following formulas:

From 14 to 24 threads per inch, $R = Lp + 1.5$
From 28 to 48 threads per inch, $R = Lp + 3$ (1)
From 56 to 80 threads per inch, $R = Lp + 4.5$

where $L =$ length of the threaded portion, $p =$ the number of threads per inch, and $R =$ the revolutions of the spindle required for threading.

Owing to the inconvenience of dividing the cam surface into the same number of equal parts as the revolutions required to complete one piece, the Brown & Sharpe Mfg. Co. has adopted the system of dividing the cam surface into one hundred equal parts. The numoer of hundredths of cam circumference required for any operation is obtained by dividing the number of revolutions for each operation by the total number of revolutions required to complete one piece, taking the nearest decimal with two places. For example, if the number of revolutions required for the die to advance on to the work is 10, and the total number of revolutions required to complete one piece is 200, then $\frac{10}{200} = 0.05$, or 5 hundredths of the cam surface.

Constructing the Thread Lobe

The method of laying out the cam lobe for threading is shown at Fig. 7. The outer circle *A* indicates the relation between the center of the fulcrum of the lead lever and the cam. This circle represents the path which would be described by the center of the lead lever if

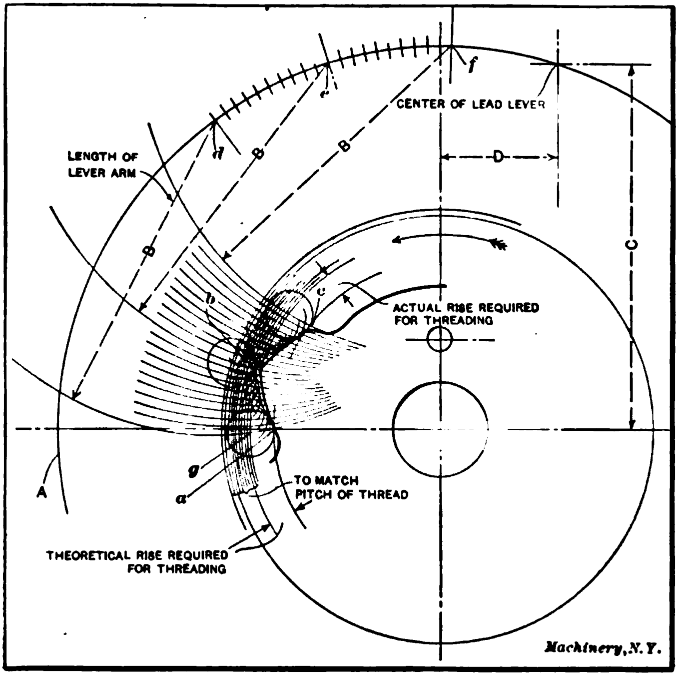

Fig. 7. Graphical Method of Constructing Thread Lobe

it were revolved around the cam. The radius *B* equals the distance from the center of the roll to the center of the fulcrum on the lead lever. *C* equals the vertical distance from the center of the cam to the center of the fulcrum on the lead lever, and *D* equals the horizontal distance. Before constructing the thread lobe, the number of hundredths of cam surface, the rise on the cam for threading, and the amount that the thread lobe is cut below the outer circle of the cam have to be determined. Then, after having drawn the various circles and lines necessary for the construction, we can proceed as follows: First, with the starting point *a*, the highest point *b* and the finishing point *c* of the cam lobe as centers, and with a radius equal to *B*, describe arcs intersecting the outer circle *A* at the points

d, e, and f. Then divide the spaces between the points d, e, and f into the same number of equal spaces as the number of revolutions required for threading. With a radius equal to B and with centers at the division points on circle A, describe arcs intersecting the thread lobe as shown. On the arc passing through point a locate center g of the roll circle so that this circle will pass through point a, and draw the roll circle. In a similar manner, draw the roll circle passing through point b, the highest point of the cam lobe. With the center of the cam as a center, draw a circle through point g and also a circle through the center of the roll circle which passes through point b. Divide the space between the two circles just drawn in the same number of equal spaces as the distances between d and e and e and f were divided. Then, with the center of the cam as a center, draw circles through these division points. The intersection between these circular arcs and the arcs drawn with the points on circle A as centers determine the center of the cam roll at the various steps of its progress, and cam roll circles drawn with these intersecting points as centers will determine the shape of the thread lobe. The form thus produced would, however, not give satisfactory results as crowding of the tap or die would occur, owing to the spindle speed and the speed of the driving shaft not being constantly in the same ratio. It is, therefore, avisable to cut down the cam lobe after the first couple of threads. This is shown in Fig. 7 where the actual and theoretical rise required for threading is shown.

Improved Method of Constructing Thread Lobe

In the method just described the rise on the thread lobe was determined graphically, this being a very complicated and tedious method. The advantage of the following method lies in its simplicity, as the lobe is determined mathematically. Before the thread lobe can be constructed, the length of the threaded portion, the number of threads per inch and the total number of revolutions of the spindle to complete one piece are required to be known. When the number of revolutions for threading and the number of threads per inch are known, the rise on the cam can be found by the following formulas:

From 14 to 24 threads per inch, $r = (R \div p) \times 0.85$
From 28 to 48 threads per inch, $r = (R \div p) \times 0.88$ (2)
From 56 to 80 threads per inch, $r = (R \div p) \times 0.90$

in which

R = revolutions required for threading,
p = number of threads per inch,
r = rise on cam.

In Tables II and III the results as obtained by formulas (1) and (2) for various numbers of threads per inch are tabulated. To show the advantages of these tables, take a practical example. Assume that a set of cams is required for the No. 00 Brown & Sharpe automatic screw machine. To make the piece as shown at A, Fig. 8, let the spindle speed equal 2400 revolutions per minute; the number of revo-

TABLE II. SPINDLE REVOLUTIONS AND CAM RISE FOR THREADING

Length of Threaded Portion	Number of Threads per Inch: 80	72	64	56	48	40	36	32	30	28	24	20	18	16	14
	First Line: Revolutions of Spindle for Threading Second Line: Rise on Cam for Threading														
1/32	7.00 0.079	7.00 0.088	6.50 0.091	6.50 0.104	4.50 0.082	4.50 0.099	4.00 0.098	4.00 0.110	4.00 0.117	4.00 0.126					
1/16	9.50 0.107	9.00 0.113	8.50 0.120	8.00 0.129	6.00 0.110	5.50 0.121	5.50 0.134	5.00 0.138	5.00 0.147	5.00 0.157	3.00 0.106				
3/32	12.00 0.135	11.50 0.144	10.50 0.148	10.00 0.161	7.50 0.137	7.00 0.154	6.50 0.159	6.00 0.165	6.00 0.176	5.50 0.178	4.00 0.142	3.50 0.149			
1/8	14.50 0.163	13.50 0.169	12.50 0.176	11.50 0.185	9.00 0.165	8.00 0.176	7.00 0.171	7.00 0.193	7.00 0.205	6.50 0.204	4.50 0.159	4.00 0.170	3.50 0.165	3.50 0.186	
5/32	17.00 0.191	16.00 0.200	14.50 0.204	13.50 0.217	10.50 0.192	9.50 0.209	8.50 0.208	8.00 0.220	7.50 0.220	7.50 0.236	5.50 0.195	4.50 0.191	4.00 0.189	4.00 0.212	3.5 0.21
3/16	19.50 0.219	18.00 0.225	16.50 0.232	15.00 0.241	12.00 0.220	10.50 0.231	10.00 0.244	9.00 0.248	8.50 0.249	8.50 0.267	6.00 0.213	5.50 0.234	5.00 0.236	4.50 0.239	4.0 0.24
7/32	22.00 0.248	20.50 0.256	18.50 0.260	17.00 0.278	13.50 0.247	12.00 0.264	11.00 0.269	10.00 0.275	9.50 0.279	9.00 0.283	7.00 0.248	6.00 0.255	5.50 0.260	5.00 0.266	4.5 0.27
1/4	24.50 0.276	23.50 0.294	20.50 0.288	18.50 0.297	15.00 0.275	13.00 0.286	12.00 0.293	11.00 0.303	10.50 0.308	10.00 0.314	7.50 0.266	6.50 0.276	6.00 0.283	5.50 0.292	5.0 0.30
9/32	27.00 0.304	25.00 0.313	22.50 0.316	20.50 0.329	16.50 0.302	14.50 0.319	13.00 0.318	12.00 0.330	11.50 0.337	11.00 0.346	8.50 0.301	7.00 0.298	6.50 0.307	6.00 0.319	5.5 0.33
5/16	29.50 0.332	27.00 0.338	24.50 0.345	22.00 0.354	18.00 0.340	15.50 0.341	14.50 0.354	13.00 0.358	12.50 0.367	12.00 0.377	9.00 0.319	8.00 0.340	7.00 0.330	6.50 0.345	6.0 0.36
11/32	32.00 0.360	29.50 0.369	26.50 0.373	24.00 0.386	19.50 0.357	17.00 0.374	15.50 0.379	14.00 0.385	13.50 0.396	12.50 0.398	10.00 0.354	8.50 0.361	7.50 0.354	7.00 0.372	6.5 0.39
3/8	34.50 0.388	31.50 0.394	28.50 0.401	25.50 0.410	21.00 0.385	18.00 0.396	16.50 0.403	15.00 0.413	14.50 0.425	13.50 0.424	10.50 0.372	9.00 0.383	8.50 0.401	7.50 0.396	7.0 0.42
13/32	37.00 0.416	34.00 0.425	30.50 0.429	27.50 0.442	22.50 0.412	19.50 0.429	17.50 0.428	16.00 0.440	15.00 0.440	14.50 0.456	11.50 0.407	9.50 0.404	9.00 0.425	8.00 0.425	7.0 0.42
7/16	39.50 0.444	36.00 0.450	32.50 0.457	29.00 0.466	24.00 0.440	20.50 0.451	19.00 0.464	17.00 0.468	16.00 0.469	15.50 0.487	12.00 0.425	10.50 0.446	9.50 0.448	8.50 0.451	7.5 0.45
15/32	42.00 0.473	38.50 0.481	34.50 0.484	31.00 0.498	25.50 0.477	22.00 0.484	20.00 0.489	18.00 0.495	17.00 0.499	16.00 0.503	13.00 0.460	11.00 0.468	10.50 0.496	9.00 0.478	8.0 0.48
1/2	44.50 0.501	40.50 0.506	36.50 0.513	32.50 0.522	27.00 0.495	23.00 0.506	21.00 0.513	19.00 0.523	18.00 0.528	17.00 0.534	13.50 0.478	11.50 0.489	10.50 0.496	9.50 0.504	8.5 0.51
17/32	47.00 0.529	43.00 0.538	38.50 0.541	34.50 0.554	28.50 0.522	24.50 0.539	22.00 0.538	20.00 0.550	19.00 0.557	18.00 0.566	14.50 0.514	12.00 0.510	11.00 0.519	10.00 0.531	9.0 0.54
9/16	49.50 0.559	45.00 0.563	40.50 0.570	36.00 0.579	30.00 0.550	25.50 0.561	23.50 0.574	21.00 0.578	20.00 0.587	19.00 0.597	15.00 0.531	13.00 0.553	11.50 0.543	10.50 0.558	9.5 0.57
19/32	52.00 0.585	47.50 0.594	42.50 0.598	38.00 0.611	31.50 0.577	27.00 0.594	24.50 0.599	22.00 0.605	21.00 0.616	19.50 0.613	16.00 0.567	13.50 0.574	12.00 0.566	11.00 0.584	10.0 0.60
5/8	54.50 0.613	49.50 0.619	44.50 0.626	39.50 0.635	33.00 0.605	28.00 0.616	25.50 0.628	23.00 0.633	22.00 0.645	20.50 0.644	16.50 0.584	14.00 0.595	13.00 0.614	11.50 0.611	10.5 0.63
21/32	57.00 0.641	52.00 0.650	46.50 0.654	41.50 0.667	34.50 0.622	29.50 0.649	26.50 0.648	24.00 0.660	23.00 0.675	21.50 0.676	17.50 0.620	14.50 0.616	13.50 0.637	12.00 0.637	10.5 0.63
11/16	59.50 0.679	54.00 0.675	48.50 0.682	43.00 0.691	36.00 0.660	30.50 0.671	28.00 0.684	25.00 0.688	23.50 0.689	22.50 0.707	18.00 0.638	15.50 0.659	14.00 0.661	12.50 0.664	11.0 0.66
23/32	62.00 0.698	56.50 0.706	50.50 0.710	45.00 0.723	37.50 0.677	32.00 0.704	29.00 0.709	26.00 0.715	24.50 0.719	23.00 0.723	19.00 0.673	16.00 0.680	14.50 0.684	13.00 0.690	11.5 0.69
3/4	64.50 0.726	58.50 0.731	52.50 0.738	46.50 0.747	39.00 0.715	33.00 0.726	30.00 0.733	27.00 0.743	25.50 0.748	24.00 0.754	19.50 0.691	16.50 0.701	15.00 0.708	13.50 0.717	12.0 0.72

TABLE III. SPINDLE REVOLUTIONS AND CAM RISE FOR THREADING

Length of Threaded Portion	Number of Threads per Inch: 80	72	64	56	48	40	36	32	30	28	24	20	18	16	14
	First Line: Revolutions of Spindle for Threading Second Line: Rise on Cam for Threading														
25/32	67.00 0.754	61.00 0.763	54.50 0.767	48.50 0.779	40.50 0.742	34.50 0.759	31.00 0.758	28.00 0.770	26.50 0.777	25.00 0.786	20.50 0.726	17.00 0.723	15.50 0.732	14.00 0.748	12.50 0.759
13/16	69.50 0.782	63.00 0.788	56.50 0.795	50.00 0.804	42.00 0.770	35.50 0.781	32.50 0.794	29.00 0.798	27.50 0.807	26.00 0.817	21.00 0.744	18.00 0.765	16.00 0.755	14.50 0.770	13.00 0.789
27/32	72.00 0.810	65.50 0.819	58.50 0.823	52.00 0.836	43.50 0.797	37.00 0.814	33.50 0.819	30.00 0.825	28.50 0.836	26.50 0.833	22.00 0.779	18.50 0.786	16.50 0.779	15.00 0.797	13.50 0.819
7/8	74.50 0.838	67.50 0.844	60.50 0.851	53.50 0.860	45.00 0.825	38.00 0.836	34.50 0.843	31.00 0.853	29.50 0.865	27.50 0.864	22.50 0.797	19.00 0.808	17.50 0.826	15.50 0.823	14.00 0.850
29/32	77.00 0.866	70.00 0.875	62.50 0.879	55.50 0.892	46.50 0.842	39.50 0.869	35.50 0.868	32.00 0.880	30.00 0.880	28.50 0.895	23.50 0.832	19.50 0.829	18.00 0.850	16.00 0.850	14.00 0.850
15/16	79.50 0.894	72.00 0.900	64.50 0.907	57.00 0.916	48.00 0.880	40.50 0.891	37.00 0.904	33.00 0.908	31.00 0.909	29.50 0.927	24.00 0.850	20.50 0.871	18.50 0.873	16.50 0.876	14.50 0.880
31/32	82.00 0.923	74.50 0.931	66.50 0.935	59.00 0.948	49.50 0.907	42.00 0.924	38.00 0.929	34.00 0.935	32.00 0.939	30.00 0.943	25.00 0.885	21.00 0.893	19.00 0.897	17.00 0.903	15.00 0.911
1	84.50 0.951	76.50 0.956	68.50 0.963	60.50 0.972	51.00 0.918	43.00 0.946	39.00 0.953	35.00 0.963	33.00 0.968	31.00 0.974	25.50 0.903	21.50 0.914	19.50 0.920	17.50 0.929	15.50 0.941
1 1/16	89.50 1.007	81.00 1.013	72.50 1.019	64.00 1.028	54.00 0.990	45.50 1.001	41.50 1.013	37.00 1.018	35.00 1.026	32.00 1.005	27.00 0.956	23.00 0.978	20.50 0.968	18.50 0.982	16.50 1.002
1 1/8	94.50 1.063	85.50 1.069	76.50 1.076	67.50 1.084	57.00 1.045	48.00 1.056	43.50 1.061	39.00 1.073	37.00 1.084	34.50 1.083	28.50 1.009	24.00 1.020	22.00 1.038	19.50 1.035	17.50 1.062
1 3/16	99.50 1.119	90.00 1.125	80.50 1.126	71.00 1.141	60.00 1.100	50.50 1.111	46.00 1.122	41.00 1.128	38.50 1.128	36.50 1.146	30.00 1.062	25.50 1.084	23.00 1.086	20.50 1.089	18.00 1.093
1 1/4	104.5 1.176	94.50 1.181	84.50 1.188	74.50 1.197	63.00 1.155	53.00 1.166	48.00 1.171	43.00 1.183	40.50 1.187	38.00 1.193	31.50 1.115	26.50 1.126	24.00 1.133	21.50 1.142	19.00 1.153
1 5/16		99.00 1.238	88.50 1.244	78.00 1.253	66.00 1.210	55.50 1.221	50.50 1.232	45.00 1.238	42.50 1.245	40.00 1.256	33.00 1.168	28.00 1.190	25.00 1.180	22.50 1.195	20.00 1.214
1 3/8		103.5 1.294	92.50 1.301	81.50 1.310	69.00 1.265	58.00 1.276	52.50 1.281	47.00 1.293	44.50 1.304	41.50 1.303	34.50 1.211	29.00 1.233	26.50 1.251	23.50 1.248	21.00 1.275
1 7/16			96.50 1.357	85.00 1.366	72.00 1.320	60.50 1.331	55.00 1.342	49.00 1.348	46.00 1.348	43.50 1.366	36.00 1.274	30.50 1.296	27.50 1.298	24.50 1.301	21.50 1.305
1 1/2			100.5 1.413	88.50 1.422	75.00 1.375	63.00 1.386	57.00 1.391	51.00 1.403	48.00 1.406	45.00 1.413	37.50 1.328	31.50 1.339	28.50 1.345	25.50 1.354	22.50 1.366
1 9/16			104.5 1.469	92.00 1.478	78.00 1.430	65.50 1.441	59.50 1.452	53.00 1.458	50.00 1.465	47.00 1.476	39.00 1.381	33.00 1.403	29.50 1.392	26.50 1.407	23.50 1.426
1 5/8				95.50 1.535	81.00 1.485	68.00 1.496	61.50 1.501	55.00 1.513	52.00 1.524	48.50 1.523	40.50 1.434	34.00 1.445	31.00 1.463	27.50 1.460	24.50 1.487
1 11/16				99.00 1.591	84.00 1.540	70.50 1.551	64.00 1.562	57.00 1.568	53.50 1.568	50.50 1.586	42.00 1.487	35.50 1.509	32.00 1.510	28.50 1.513	25.00 1.518
1 3/4				102.5 1.647	87.00 1.595	73.00 1.606	66.00 1.610	59.00 1.623	55.50 1.626	52.00 1.633	43.50 1.540	36.50 1.551	33.00 1.558	29.50 1.566	26.00 1.578
1 13/16				106.0 1.703	90.00 1.650	75.50 1.661	68.50 1.671	61.00 1.678	57.50 1.685	54.00 1.696	45.00 1.593	38.00 1.615	34.00 1.605	30.50 1.620	27.00 1.639
1 7/8					93.00 1.705	78.00 1.716	70.50 1.720	63.00 1.733	59.50 1.746	55.50 1.743	46.50 1.646	39.00 1.658	35.50 1.676	31.50 1.678	28.00 1.700
1 15/16					96.00 1.760	80.50 1.771	73.00 1.781	65.00 1.788	61.00 1.787	57.50 1.806	48.00 1.700	40.50 1.721	36.50 1.723	32.50 1.726	28.50 1.730
2					99.00 1.815	83.00 1.826	75.00 1.830	67.00 1.843	63.00 1.846	59.00 1.853	49.50 1.752	41.50 1.764	37.50 1.770	33.50 1.779	29.50 1.791

TABLE IV. HUNDREDTHS OF CIRCUMFERENCE EXPRESSED IN MINUTES

Hundredths of Circumference	Minutes	Hundredths of Circumference	Minutes	Hundredths of Circumference	Minutes	Hundredths of Circumference	Minutes	Hundredths of Circumference	Minutes	Hundredths of Circumference	Minutes
1.00	216	9.25	1998	17.50	3780	25.75	5562	34.00	7344	42.25	9126
1.25	270	9.50	2052	17.75	3834	26.00	5616	34.25	7398	42.50	9180
1.50	324	9.75	2106	18.00	3888	26.25	5670	34.50	7452	42.75	9234
1.75	378	10.00	2160	18.25	3942	26.50	5724	34.75	7506	43.00	9288
2.00	432	10.25	2214	18.50	3996	26.75	5778	35.00	7560	43.25	9342
2.25	486	10.50	2268	18.75	4050	27.00	5832	35.25	7614	43.50	9396
2.50	540	10.75	2322	19.00	4104	27.25	5886	35.50	7668	43.75	9450
2.75	594	11.00	2376	19.25	4158	27.50	5940	35.75	7722	44.00	9504
3.00	648	11.25	2430	19.50	4212	27.75	5994	36.00	7776	44.25	9558
3.25	702	11.50	2484	19.75	4266	28.00	6048	36.25	7830	44.50	9612
3.50	756	11.75	2538	20.00	4320	28.25	6102	36.50	7884	44.75	9666
3.75	810	12.00	2592	20.25	4374	28.50	6156	36.75	7938	45.00	9720
4.00	864	12.25	2646	20.50	4428	28.75	6210	37.00	7992	45.25	9774
4.25	918	12.50	2700	20.75	4482	29.00	6264	37.25	8046	45.50	9828
4.50	972	12.75	2754	21.00	4536	29.25	6318	37.50	8100	45.75	9882
4.75	1026	13.00	2808	21.25	4590	29.50	6372	37.75	8154	46.00	9936
5.00	1080	13.25	2862	21.50	4644	29.75	6426	38.00	8208	46.25	9990
5.25	1134	13.50	2916	21.75	4698	30.00	6480	38.25	8262	46.50	10044
5.50	1188	13.75	2970	22.00	4752	30.25	6534	38.50	8316	46.75	10098
5.75	1242	14.00	3024	22.25	4806	30.50	6588	38.75	8370	47.00	10152
6.00	1296	14.25	3078	22.50	4860	30.75	6642	39.00	8424	47.25	10206
6.25	1350	14.50	3132	22.75	4914	31.00	6696	39.25	8478	47.50	10260
6.50	1404	14.75	3186	23.00	4968	31.25	6750	39.50	8532	47.75	10314
6.75	1458	15.00	3240	23.25	5022	31.50	6804	39.75	8586	48.00	10368
7.00	1512	15.25	3294	23.50	5076	31.75	6858	40.00	8640	48.25	10422
7.25	1566	15.50	3348	23.75	5130	32.00	6912	40.25	8694	48.50	10476
7.50	1620	15.75	3402	24.00	5184	32.25	6966	40.50	8748	48.75	10530
7.75	1674	16.00	3456	24.25	5238	32.50	7020	40.75	8802	49.00	10584
8.00	1728	16.25	3510	24.50	5292	32.75	7074	41.00	8856	49.25	10638
8.25	1782	16.50	3564	24.75	5346	33.00	7128	41.25	8910	49.50	10692
8.50	1836	16.75	3618	25.00	5400	33.25	7182	41.50	8964	49.75	10746
8.75	1890	17.00	3672	25.25	5454	33.50	7236	41.75	9018	50.00	10800
9.00	1944	17.25	3726	25.50	5508	33.75	7290	42.00	9072	50.25	10854

TABLE V. HUNDREDTHS OF CIRCUMFERENCE EXPRESSED IN MINUTES

Hundredths of Circumference	Minutes	Hundredths of Circumference	Minutes	Hundredths of Circumference	Minutes	Hundredths of Circumference	Minutes	Hundredths of Circumference	Minutes	Hundredths of Circumference	Minutes
50.50	10908	59.00	12744	67.50	14580	76.00	16416	84.50	18252	93.00	20088
50.75	10962	59.25	12798	67.75	14634	76.25	16470	84.75	18306	93.25	20142
51.00	11016	59.50	12852	68.00	14688	76.50	16524	85.00	18360	93.50	20196
51.25	11070	59.75	12906	68.25	14742	76.75	16578	85.25	18414	93.75	20250
51.50	11124	60.00	12960	68.50	14796	77.00	16632	85.50	18468	94.00	20304
51.75	11178	60.25	13014	68.75	14850	77.25	16686	85.75	18522	94.25	20358
52.00	11232	60.50	13068	69.00	14904	77.50	16740	86.00	18576	94.50	20412
52.25	11286	60.75	13122	69.25	14958	77.75	16794	86.25	18630	94.75	20466
52.50	11340	61.00	13176	69.50	15012	78.00	16848	86.50	18684	95.00	20520
52.75	11394	61.25	13230	69.75	15066	78.25	16902	86.75	18738	95.25	20574
53.00	11448	61.50	13284	70.00	15120	78.50	16956	87.00	18792	95.50	20628
53.25	11502	61.75	13338	70.25	15174	78.75	17010	87.25	18846	95.75	20682
53.50	11556	62.00	13392	70.50	15228	79.00	17064	87.50	18900	96.00	20736
53.75	11610	62.25	13446	70.75	15282	79.25	17118	87.75	18954	96.25	20790
54.00	11664	62.50	13500	71.00	15336	79.50	17172	88.00	19008	96.50	20844
54.25	11718	62.75	13554	71.25	15390	79.75	17226	88.25	19062	96.75	20898
54.50	11772	63.00	13608	71.50	15444	80.00	17280	88.50	19116	97.00	20952
54.75	11826	63.25	13662	71.75	15498	80.25	17334	88.75	19170	97.25	21006
55.00	11880	63.50	13716	72.00	15552	80.50	17388	89.00	19224	97.50	21060
55.25	11934	63.75	13770	72.25	15606	80.75	17442	89.25	19278	97.75	21114
55.50	11988	64.00	13824	72.50	15660	81.00	17496	89.50	19332	98.00	21168
55.75	12042	64.25	13878	72.75	15714	81.25	17550	89.75	19386	98.25	21222
56.00	12096	64.50	13932	73.00	15768	81.50	17604	90.00	19440	98.50	21276
56.25	12150	64.75	13986	73.25	15822	81.75	17658	90.25	19494	98.75	21330
56.50	12204	65.00	14040	73.50	15876	82.00	17712	90.50	19548	99.00	21384
56.75	12258	65.25	14094	73.75	15930	82.25	17766	90.75	19602	99.25	21438
57.00	12312	65.50	14148	74.00	15984	82.50	17820	91.00	19656	99.50	21492
57.25	12366	65.75	14202	74.25	16038	82.75	17874	91.25	19710	99.75	21546
57.50	12420	66.00	14256	74.50	16092	83.00	17928	91.50	19764	100.00	21600
57.75	12474	66.25	14310	74.75	16146	83.25	17982	91.75	19818	......	......
58.00	12528	66.50	14364	75.00	16200	83.50	18036	92.00	19872	......	......
58.25	12582	66.75	14418	75.25	16254	83.75	18090	92.25	19926	......	......
58.50	12636	67.00	14472	75.50	16308	84.00	18144	92.50	19980	......	......
58.75	12690	67.25	14526	75.75	16362	84.25	18198	92.75	20034	......	......

lutions to complete one piece, 400; time to make one piece, 10 seconds. Referring to *A*, Fig. 8, the length of the threaded portion is ⅜ inch and the pitch of the thread 1/32 inch, or thirty-two threads per inch. Referring to Table II, we find that the number of revolutions required is 15 and the rise on the cam 0.413. To construct the lobe, convert the revolutions into hundredths of cam surface, or $\frac{15}{400} = 0.0375$, or 3¾ hundredths. Then draw the cam circle *B*, as shown in Fig. 8, and lay off on this circle 3¾ hundredths to advance on the screw and 3¾ hundredths to withdraw. Cut down the amount *C* below the outer cam circle *B* as required. Bisect the rise at *E*, and with *OE* as a radius and *a*, *b*, and *c* as centers draw arcs intersecting each other at *d* and *e*. With *d* as a center and radius *OE* join points *b* and *a*; with *e* as a center and radius *OE* join points *c* and *a*. This gives the shape of the thread lobe. For convenience in cutting, when a Brown & Sharpe circular milling attachment is available, the cam surface used for threading is divided into minutes. Then to obtain the lead (or the number of minutes traversed for each 1/1000 inch rise) divide the number of minutes contained in the portion of the lobe used, by the rise. For example, $\frac{0.810}{0.413} = 1.96$, or approximately 2 minutes. The equivalents of hundredths and minutes are tabulated in Tables IV and V. The information as derived by the various formulas is recorded on the drawing as shown in Fig. 8, being used by the toolmaker when cutting the cam.

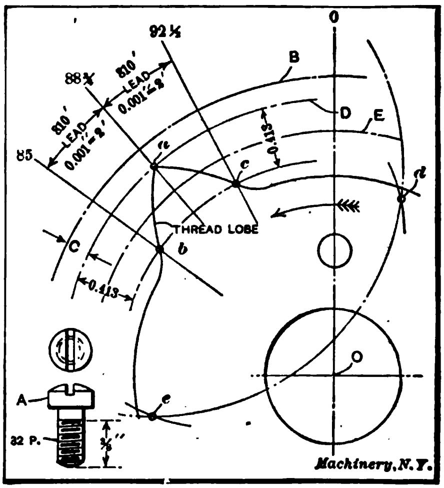

Fig. 8. Improved Method of Constructing Thread Lobe

Speed-changing Device

When threading brass, the spindle speed used for the other tools is generally also suitable for taps and dies, but when threading gun-screw iron, Norway iron, machine steel, tool steel, etc., the speed used is too high. As has been previously explained under the heading "Reversing the Spindle," time would be lost in threading if the machine were reversed from forward to backward and then forward again on the No. 00 Brown & Sharpe automatic screw machine. There are various methods of overcoming this difficulty. One method is to run the spindle backward with the large pulley and forward with the small pulley on the countershaft. There is an objection to this, however, *viz.*, as there are generally other tools in the turret besides the die or tap holder. They would either have to be made to cut left-hand or else run at the same speed as the tap or die. It can easily be seen that in the majority of cases, the tools used in the turret would not be working at their maximum capacity if made to cut right-hand.

Ratio Threading Attachment

The attachment *A*, shown in position in the turret in Fig. 9, serves to revolve the die or tap in the same direction as that in which the spindle is rotating, but at one-half the spindle speed. As before mentioned, it is used where no other slow movements are required except

Fig. 9. Ratio Threading Attachment

for threading, enabling the spindle to run at its maximum speed for all the other operations. The attachment is driven by a $\frac{3}{8}$-inch round belt from the overhead works, the shaft passing through the turret head connecting pulley *C* with bevel gears *D*, thus driving the attachment *A*. Spring *E* acts in the same manner as the spring in the ordinary draw-out die or tap holder. The method of determining the shape of the cam lobe when using this attachment is as follows: Let the spindle speed for the forming and cut-off operations equal 2400 revolutions per minute; then the forward speed of the spindle for threading is 1200, and the speed of this attachment 600 revolutions per minute. Assume the length of the threaded portion to be 3/16 inch and that 40 threads per inch are to be cut. Referring to Table II, we find that the thread cutting will require 10.5 revolutions. But considering that the speed of this attachment is one-half the spindle speed, we would require $10.5 \times 2 = 21$ revolutions of the spindle for cutting the thread. Again, as this attachment rotates in the same direction as the spindle, the speed of the attachment when backing off the work would be $2400 + 600$ or 3000 revolutions per minute. Then the number of revolutions of the spindle required for backing off the work would be $\frac{2400}{3000} \times 10.5$, or 8.5 revolutions, approximately. The same rise, 0.231, as given in Table II, is used for each side of the thread lobe, but the distance along the cam circumference in each part of the lobe is different, as it requires 21 revolutions to advance and only 8.5 revolutions to retreat.

Belt Shifting Attachment

The ratio threading attachment as shown in Fig. 9 is only suitable for cutting brass and fine threads on Norway iron, machine steel, etc.

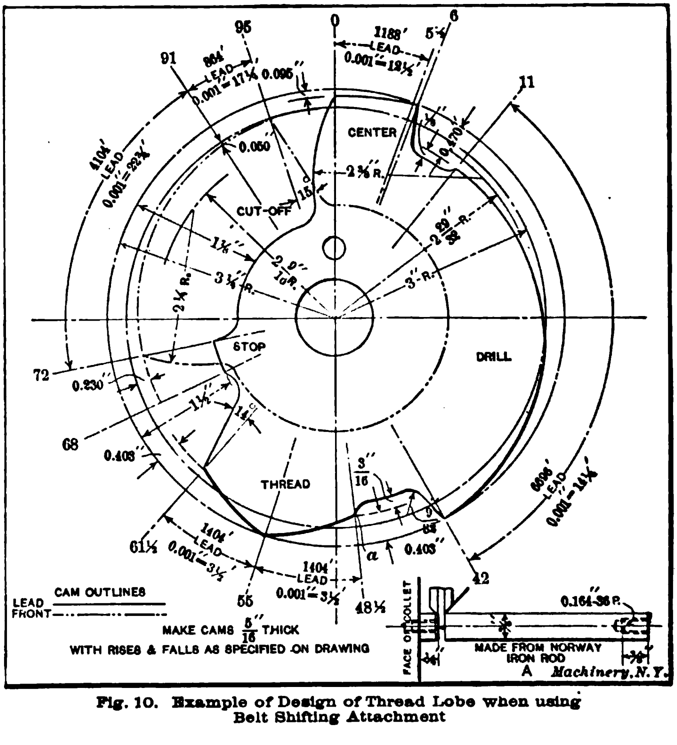

Fig. 10. Example of Design of Thread Lobe when using Belt Shifting Attachment

This attachment would not be entirely satisfactory for the No. 0 or No. 2 Brown & Sharpe automatic screw machine, as a more positive drive is generally required for these machines. In Fig. 2 is shown the No. 0 Brown & Sharpe automatic screw machine equipped with a speed-changing attachment. The countershaft is supplied with a large and a small pulley which will give the desired spindle speeds. This attachment is operated by the same dog and lever that reverse the spindle. When the dog on the cam shaft trips the lever, the clutches C and C_1 engage, thus driving gears D and E. Gear E, being attached to shaft *F*, revolves disk *G* on which the eccentric connecting-rod *H* is attached. When the rod *H* is drawn up or down it shifts the belt from the large to the small pulley or *vice versa*. The system of gearing provided shifts the belt twice for every revolution of the driving shaft. The number of revolutions of the spindle required to shift the belt with the spindle running at 1800 R. P. M. forward speed equals 7½ revolutions.

To explain the method of designing the thread lobe, we will take a practical example. Assume that it is required to make the piece as shown at *A*, Fig. 10, on the No. 0 machine, the spindle speeds being 1800 and 900 revolutions per minute, respectively, using the 900 revolutions per minute for tapping. The cams for making this piece are shown in Fig. 10. The time required to make one piece is 17 seconds, or 510 revolutions. The number of revolutions for threading found in Table II is 16.5; but as the tap will run at 900 revolutions per minute instead of 1800, we will require a time equivalent to 16.5×2 or 33 revolutions at the 1800 R. P. M. speed for threading. Then the hundredths required equals $\frac{33}{510} = 0.0647$, or approximately 6½ hundredths. The rise on the cam is given in Table II as 0.403. Referring to Table II, MACHINERY'S Reference Book No. 100, we find that it will require 4/100 to feed the stock, or 5/100 to revolve the turret; this equals 25.5 revolutions to revolve the turret. Then the actual number of hundredths of cam circumference between the last operation and the starting of the thread lobe, to revolve the turret and reverse the spindle is $25.5 + 7.5 = 33$ revolutions. Converting this into hundredths, we get 6.47 or approximately 6½ hundredths. It is always good practice to allow plenty of clearance for threading as the die or tap holder intended for the job may have to be replaced by one which would require more clearance.

CHAPTER II

TAPS AND DIES FOR SCREW MACHINE WORK

In Fig. 11 is shown the common form of spring screw threading die with its adjustable ring. Dies of this type are used to a large extent on the Brown & Sharpe automatics, but the results obtained are not always entirely satisfactory. There are a number of objections to this type of die. The common method of making these dies is to hob them out with a tap larger in diameter than the basic screw, and then to close them in by means of the adjusting ring shown. This produces an imperfect thread if a tap much larger in diameter than the basic size of the screw is used. The correct method of tapping out a die of this kind is to use a taper tap which gives clearance at

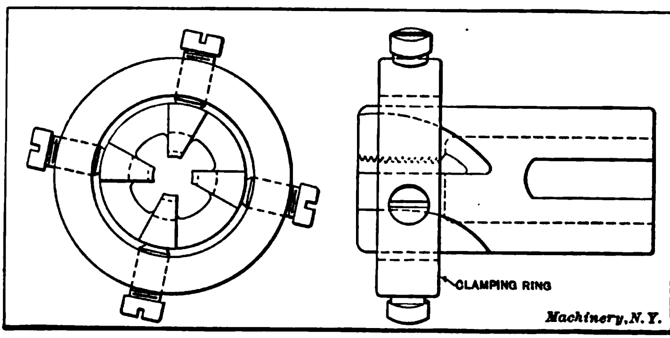

Fig. 11. Spring Screw Threading Die and Adjusting Ring

the back of the die. This necessitates the making of taper taps which adds to the expense of the die. This type of die is also difficult to harden without springing the prongs, thus causing chattering and producing a thread which is not correct in shape. Making a die with three prongs or cutting edges obviates chattering and produces a more nearly perfect thread. When cutting a small screw, the work sometimes breaks off in the die, making it practically useless, because in drilling out the broken pieces, the thread in the die is almost always injured. A type of die which overcomes this latter objection is shown in Fig. 12, the die here shown being split, allowing the broken screw to be easily removed. The location of the cutting edges on spring screw threading dies should be radial for brass, and about one-tenth of the diameter ahead of the center for Norway iron, machine steel, etc.

Adjustable Round Split Threading Dies

The adjustable round split die has an advantage over the spring screw threading die for the following reasons: It can be hardened without springing out of shape, and can be held more rigidly, which produces good results; and although it cannot be ground to advantage, its first cost is so much less than that of the spring screw threading die that it can be discarded when dull. On account of the rigid manner in which this die can be held, the cutting edges in all cases can be located ahead of the center about one-tenth of the diameter

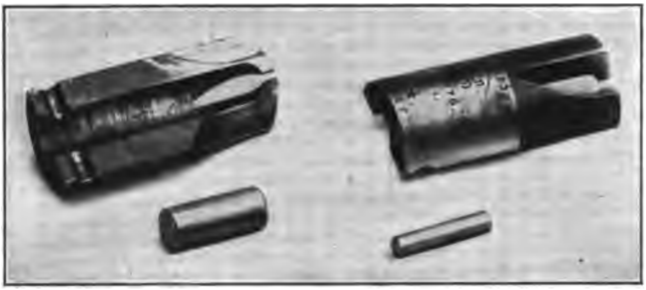

Fig. 12. Split Spring Screw Threading Die

which gives good results. In Fig. 13 is shown a type of adjustable round split button die as used by the Northern Electric & Mfg. Co., Ltd., of Montreal. This type of die has been found to give such favorable results that it is used by this firm in preference to all other types for screw machine work. In Tables VI and VII are given the sizes used by the above firm in making their dies for the

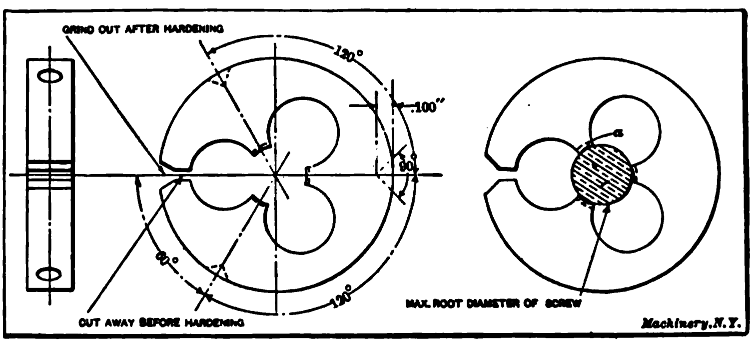

Fig. 13. General Dimensions and Design of Approved Type of Adjustable Round Split Button Die

Fig. 14. Illustration showing Clearance for Adjustable Round Split Button Die

A. S. M. E. standard and special screw sizes. The formulas used for the dies are as follows:

External diameter = basic external diameter of screw,

Pitch diameter = basic pitch diameter of screw,

$$\text{Root diameter} = \text{basic root diameter of screw} + \frac{0.10825}{\text{No. of threads per inch}}$$

This latter amount $\frac{0.10825}{\text{No. of threads per inch}}$ is added to the basic root diameter to provide for wear. While the sizes as given have been used by the firm mentioned, for a considerable time, theoretically it is not the correct way of making the die, because, to cut a clean thread, a die should have clearance as shown at *a*, Fig. 14, and as a screw is generally cut below the maximum diameter, the sizes as given would not provide any clearance at all; in fact it would be just the reverse, as the die would have to be closed, instead of opened up. When good results are desired the die should be tapped out smaller

TABLE VI. ADJUSTABLE ROUND SPLIT SCREW THREAD BUTTON DIE SIZES FOR A. S. M. E. STANDARD SCREWS

Size of Screw and Number of Threads Per Inch	External Diameter	Pitch Diameter	Root Diameter
0.060 — 80	0.060	0.0519	0.0424
0.073 — 72	0.073	0.0640	0.0535
0.086 — 64	0.086	0.0759	0.0640
0.099 — 56	0.099	0.0874	0.0739
0.112 — 48	0.112	0.0985	0.0827
0.125 — 44	0.125	0.1102	0.0930
0.138 — 40	0.138	0.1213	0.1028
0.151 — 36	0.151	0.1330	0.1119
0.164 — 36	0.164	0.1460	0.1249
0.177 — 32	0.177	0.1567	0.1330
0.190 — 30	0.190	0.1684	0.1431
0.216 — 28	0.216	0.1928	0.1658
0.242 — 24	0.242	0.2149	0.1834
0.268 — 22	0.268	0.2385	0.2040
0.294 — 20	0.294	0.2615	0.2236
0.320 — 20	0.320	0.2875	0.2496
0.346 — 18	0.346	0.3099	0.2678
0.372 — 16	0.372	0.3314	0.2841
0.398 — 16	0.398	0.3574	0.3101
0.424 — 14	0.424	0.3776	0.3235
0.450 — 14	0.450	0.4036	0.3495

than the basic screw, and then opened up, as this would give a good clearance as shown, enlarged, at *a*, Fig. 14. Making the root diameter of the die the same as the minimum screw would give the desired results. This has been experimented with and the results obtained were perfectly satisfactory. The following formulas should then be used for obtaining the sizes of adjustable round split button dies:

External diameter = basic external diameter of screw,

Pitch diameter = minimum pitch diameter of screw, or basic pitch diameter of screw $- \frac{0.168}{\text{No. of threads per inch} + 40}$

Root diameter = minimum root diameter of screw or basic root diameter $- \frac{0.10825}{\text{No. of th'ds per inch}} + \frac{0.168}{\text{No. of th'ds per inch} + 40}$

Making the external diameter equal to the basic external diameter allows for clearance, which is necessary, as the external diameter of the die should not be used for cutting the screw to size. This should be accomplished either by a finishing box-tool or by the cross-slide forming tools. It is obvious that making the dies to the sizes given in the formulas permits them to be used longer and still cut a clean thread. The work should be turned slightly smaller than the finished diameter required, depending on the material and the pitch of the thread.

TABLE VII. ADJUSTABLE ROUND SPLIT SCREW THREAD BUTTON DIE SIZES FOR A. S. M. E. SPECIAL SCREWS

Size of Screw and Number of Threads Per Inch	External Diameter	Pitch Diameter	Root Diameter
0.073 — 64	0.073	0.0629	0.0510
0.086 — 56	0.086	0.0744	0.0609
0.099 — 48	0.099	0.0855	0.0697
0.112 — 40	0.112	0.0958	0.0768
0.112 — 36	0.112	0.0940	0.0729
0.125 — 40	0.125	0.1088	0.0898
0.125 — 36	0.125	0.1070	0.0859
0.138 — 36	0.138	0.1200	0.0989
0.138 — 32	0.138	0.1177	0.0940
0.151 — 32	0.151	0.1307	0.1070
0.151 — 30	0.151	0.1294	0.1041
0.164 — 32	0.164	0.1437	0.1200
0.164 — 30	0.164	0.1424	0.1171
0.177 — 30	0.177	0.1554	0.1301
0.177 — 24	0.177	0.1499	0.1184
0.190 — 32	0.190	0.1697	0.1460
0.190 — 24	0.190	0.1629	0.1314
0.216 — 24	0.216	0.1889	0.1574
0.242 — 20	0.242	0.2095	0.1716
0.268 — 20	0.268	0.2355	0.1976
0.294 — 18	0.294	0.2579	0.2158
0.320 — 18	0.320	0.2839	0.2418
0.346 — 16	0.346	0.3054	0.2581
0.372 — 18	0.372	0.3359	0.2938
0.398 — 14	0.398	0.3516	0.2975
0.424 — 16	0.424	0.3834	0.3361
0.450 — 16	0.450	0.4094	0.3621

Tables for laying-out button dies are given in MACHINERY'S Data Sheet Book No. 3, "Taps and Dies," pages 30 and 31.

Machine Taps

Internal threading on the automatic screw machine presents certain difficulties. There is a tendency for the chips to clog and to break the tap at the moment of reversal, as the chips then lodge back of the cutting edges, tending to prevent the tap from reversing. The spindle revolving at a high rate of speed also has a tendency to break the tap. Taps for screw machine work should have liberal space for the chips, the lands being made just strong enough to resist the cutting pressure.

TABLE VIII. MACHINE TAPS FOR A. S. M. E. STANDARD SIZES

Size of Screw and Number of Threads Per Inch	Manufacturing Limits						Diameter of Shank, Stubbs' Wire Gage or Inches	Length of Threaded Portion	Length Overall
	External Diameter		Pitch Diameter		Root Diameter				
	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum			
0.060 — 80	0.0632	0.0623	0.0538	0.0533	0.0466	0.0447	51	3/8	1 1/4
0.073 — 72	0.0765	0.0755	0.0660	0.0655	0.0580	0.0560	47	1/2	1 3/8
0.086 — 64	0.0898	0.0888	0.0780	0.0775	0.0689	0.0668	42	9/16	1 3/8
0.099 — 56	0.1033	0.1021	0.0897	0.0892	0.0793	0.0770	36	9/16	1 1/2
0.112 — 48	0.1168	0.1155	0.1010	0.1004	0.0888	0.0862	31	5/8	1 1/2
0.125 — 44	0.1301	0.1288	0.1129	0.1122	0.0995	0.0968	29	5/8	1 1/2
0.138 — 40	0.1435	0.1421	0.1246	0.1239	0.1097	0.1069	26	5/8	1 1/2
0.151 — 36	0.1569	0.1555	0.1359	0.1352	0.1193	0.1164	21	11/16	1 1/2
0.164 — 36	0.1699	0.1685	0.1489	0.1482	0.1323	0.1294	17	11/16	1 1/2
0.177 — 32	0.1835	0.1819	0.1598	0.1590	0.1411	0.1380	12	3/4	1 5/8
0.190 — 30	0.1968	0.1952	0.1716	0.1708	0.1515	0.1483	8	3/4	1 5/8
0.216 — 28	0.2232	0.2215	0.1961	0.1953	0.1745	0.1712	1/4	1	2 1/2
0.242 — 24	0.2500	0.2483	0.2184	0.2176	0.1931	0.1896	9/32	1	2 1/2
0.268 — 22	0.2765	0.2747	0.2421	0.2412	0.2144	0.2108	9/32	1	2 1/2
0.294 — 20	0.3031	0.3013	0.2653	0.2643	0.2346	0.2309	5/16	1	2 1/2
0.320 — 20	0.3291	0.3273	0.2913	0.2903	0.2606	0.2569	11/32	1	2 3/4
0.346 — 18	0.3559	0.3539	0.3138	0.3128	0.2796	0.2758	3/8	1	2 3/4
0.372 — 16	0.3828	0.3808	0.3354	0.3344	0.2968	0.2928	13/32	1	2 3/4
0.398 — 16	0.4088	0.4068	0.3614	0.3604	0.3228	0.3188	7/16	1	2 3/4
0.424 — 14	0.4359	0.4338	0.3818	0.3807	0.3374	0.3333	15/32	1	2 3/4
0.450 — 14	0.4619	0.4598	0.4078	0.4067	0.3634	0.3593	1/2	1	2 3/4

TABLE IX. MACHINE TAPS FOR A. S. M. E. SPECIAL SIZES

Size of Screw and Number of Threads Per Inch	Manufacturing Limits						Diameter of Shank, Stubbs' Wire Gage or Inches	Length of Threaded Portion	Length Overall
	External Diameter		Pitch Diameter		Root Diameter				
	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum			
0.073 — 64	0.0768	0.0758	0.0650	0.0645	0.0559	0.0538	47	½	1⅜
0.086 — 56	0.0903	0.0891	0.0767	0.0762	0.0663	0.0640	42	9/16	1⅜
0.099 — 48	0.1038	0.1025	0.0880	0.0874	0.0758	0.0732	36	9/16	1½
0.112 — 40	0.1175	0.1161	0.0986	0.0979	0.0837	0.0809	31	⅝	1½
0.112 — 36	0.1179	0.1165	0.0969	0.0962	0.0803	0.0774	31	⅝	1½
0.125 — 40	0.1305	0.1291	0.1116	0.1109	0.0967	0.0939	29	⅝	1½
0.125 — 36	0.1309	0.1295	0.1099	0.1092	0.0933	0.0904	29	⅝	1½
0.138 — 36	0.1439	0.1425	0.1229	0.1222	0.1063	0.1034	26	⅝	1½
0.138 — 32	0.1445	0.1429	0.1208	0.1200	0.1021	0.0990	26	⅝	1½
0.151 — 32	0.1575	0.1559	0.1338	0.1330	0.1151	0.1120	20	11/16	1½
0.151 — 30	0.1578	0.1562	0.1326	0.1318	0.1125	0.1093	20	11/16	1½
0.164 — 32	0.1705	0.1689	0.1468	0.1460	0.1281	0.1250	17	11/16	1½
0.164 — 30	0.1708	0.1692	0.1456	0.1448	0.1255	0.1223	17	11/16	1½
0.177 — 30	0.1838	0.1822	0.1586	0.1578	0.1385	0.1353	12	¾	1⅝
0.177 — 24	0.1850	0.1833	0.1534	0.1526	0.1281	0.1246	12	¾	1⅝
0.190 — 32	0.1965	0.1949	0.1728	0.1720	0.1541	0.1510	8	¾	1⅝
0.190 — 24	0.1980	0.1963	0.1664	0.1656	0.1411	0.1376	7	¾	1⅝
0.216 — 24	0.2240	0.2223	0.1924	0.1916	0.1671	0.1636	¼	1	2½
0.242 — 20	0.2511	0.2493	0.2133	0.2123	0.1827	0.1789	9/32	1	2½
0.268 — 20	0.2771	0.2753	0.2393	0.2383	0.2087	0.2049	9/32	1	2½
0.294 — 18	0.3039	0.3019	0.2618	0.2608	0.2276	0.2238	5/16	1	2½
0.320 — 18	0.3299	0.3279	0.2878	0.2868	0.2536	0.2498	11/32	1	2¾
0.346 — 16	0.3568	0.3548	0.3094	0.3084	0.2708	0.2668	⅜	1	2¾
0.372 — 18	0.3819	0.3799	0.3398	0.3388	0.3056	0.3018	13/32	1	2¾
0.398 — 14	0.4099	0.4078	0.3558	0.3547	0.3114	0.3073	7/16	1	2¾
0.424 — 16	0.4348	0.4328	0.3874	0.3864	0.3488	0.3448	15/32	1	2¾
0.450 — 16	0.4608	0.4588	0.4134	0.4124	0.3748	0.3708	½	1	2¾

Of course, the flutes must not be made too deep, so as to reduce the cross-section of the tap too much. The cutting edges are, in general, radial.

In Tables VIII and IX are given the manufacturing limits, as adopted by the Northern Electric & Mfg. Co., Ltd., Montreal, for the A. S. M. E. standard and special sizes. The taps are made from Stubbs' imported drill rod. The diameters of shank used are given in the tables, and also the length of the threaded portion and the over-all length. All taps 0.100 inch in diameter and less, have three flutes, and all taps over 0.100 inch in diameter have four flutes. The formulas used by the above firm for the manufacturing limits are as follows (*T. P. I.* = threads per inch):

EXTERNAL DIAMETER

$$\text{Maximum} = \text{basic external diameter of screw} + \frac{0.10825}{T.P.I.} + \frac{0.224}{T.P.I. + 40}$$

$$\text{Minimum} = \text{basic external diameter of screw} + \frac{0.10825}{T.P.I.} + \frac{0.112}{T.P.I. + 40}$$

PITCH DIAMETER

$$\text{Maximum} = \text{basic pitch diameter of screw} + \frac{0.224}{T.P.I. + 40}$$

$$\text{Minimum} = \text{basic pitch diameter of screw} + \frac{0.168}{T.P.I. + 40}$$

ROOT DIAMETER

$$\text{Maximum} = \text{basic root diameter of screw} + \frac{0.336}{T.P.I. + 40}$$

$$\text{Minimum} = \text{basic root diameter of screw} + \frac{0.112}{T.P.I. + 40}$$

The only changes from the A. S. M. E. formulas for the taps are the minimum external diameter, and the minimum pitch diameters. The reason for increasing the minimum external diameters can easily be seen by comparing the results as obtained by the formulas used by the Northern Electric & Mfg. Co. and the A. S. M. E. respectively. For example: Take a tap 0.164—36 threads per inch. The minimum external diameter given by the A. S. M. E. is 0.1656 inch. Now the maximum or basic screw is 0.164 inch. This leaves 0.0016 inch for wear, when the tap has been made the minimum size. This amount has been found not to be sufficient. The minimum external diameter, as found by the formula used by the Northern Electric & Mfg. Co., is 0.1685 inch, which gives 0.0045 inch over the basic screw. As will also be noted, this decreases the limit between the maximum and minimum external diameters of the tap, allowing only 0.0014 inch. In all cases the limits as derived by these formulas have been found to be sufficient. It will also be noted that the minimum pitch diameter is also increased to extend the life of the tap. In Table X the results as obtained by the various formulas are given, which simplifies the calculations necessary in determining the limits, as the amounts given are added to the basic sizes of the screw. In the last two columns are given the single and double depth of the thread.

TABLE X. CALCULATED VALUES FOR FORMULAS FOR FINDING MANUFACTURING LIMITS FOR TAP AND DIE SIZES

No. of Threads Per Inch	Value of $\frac{0.10825''}{\text{T.P.I.}}$	Value of $\frac{0.112''}{\text{T.P.I.}+40}$	Value of $\frac{0.224''}{\text{T.P.I.}+40}$	Value of $\frac{0.336''}{\text{T.P.I.}+40}$	Value of $\frac{0.168''}{\text{T.P.I.}+40}$	Value of $\frac{0.64952''}{\text{T.P.I.}}$	Value of $\frac{1.29904''}{\text{T.P.I.}}$
80	0.0014	0.0009	0.0019	0.0028	0.0014	0.0081	0.0162
72	0.0015	0.0010	0.0020	0.0030	0.0015	0.0090	0.0180
64	0.0017	0.0011	0.0022	0.0032	0.0016	0.0101	0.0203
56	0.0019	0.0012	0.0023	0.0035	0.0018	0.0116	0.0232
48	0.0023	0.0013	0.0025	0.0038	0.0019	0.0135	0.0271
44	0.0025	0.0013	0.0027	0.0040	0.0020	0.0148	0.0295
40	0.0027	0.0014	0.0028	0.0042	0.0021	0.0162	0.0325
36	0.0030	0.0015	0.0029	0.0044	0.0022	0.0180	0.0361
32	0.0034	0.0016	0.0031	0.0047	0.0023	0.0203	0.0406
30	0.0036	0.0016	0.0032	0.0048	0.0024	0.0217	0.0433
28	0.0039	0.0016	0.0033	0.0049	0.0025	0.0232	0.0464
24	0.0045	0.0018	0.0035	0.0053	0.0026	0.0271	0.0541
22	0.0049	0.0018	0.0036	0.0054	0.0027	0.0295	0.0590
20	0.0054	0.0019	0.0037	0.0056	0.0028	0.0325	0.0650
18	0.0060	0.0019	0.0039	0.0058	0.0029	0.0361	0.0722
16	0.0068	0.0020	0.0040	0.0060	0.0030	0.0406	0.0812
14	0.0077	0.0021	0.0041	0.0062	0.0031	0.0464	0.0928

An ordinary machine tap is suitable for cutting brass, but it does not give satisfactory results when tapping Norway iron, machine steel, etc. In Fig. 15 is shown a tap which gives good results in threading Norway iron or machine steel. This tap should be slightly tapered towards the back for clearance. The end is ground at an angle of about 55 degrees, and slightly cupped at the center, and backed off as

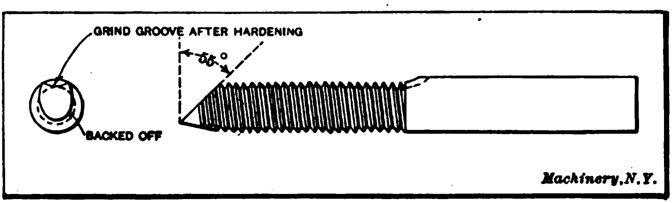

Fig. 15. A Tap Suitable for Norway Iron and Machine Steel

shown. A groove is ground the entire length of the threaded portion, after the tap has been hardened. This allows the oil to penetrate to the point in threading, and also provides clearance for the chips to back out. When made from Stubbs' imported drill rod and carefully hardened, this tap can be worked at a cutting speed of from 35 to 40 feet per minute, which would be impossible with an ordinary tap. Taps for threading copper have their flutes cut spirally and should also have an odd number of flutes. A right-hand spiral of about one turn in 12 inches should be used.

Tap Drills

The tapping size drills as recommended by the A. S. M. E. are not suitable for general work. The question of tap drills cannot be settled by giving a table and saying that the sizes therein contained are the best. Of course, to a certain extent, the sizes used in various shops do not vary greatly, but nevertheless there is really no standard size. Considering this, the writer submits a list of tapping size drills which have been adopted by the Northern Electric & Mfg. Co. for general work. These sizes have given good results in practice. The sizes as given in Table XI are used for all classes of work and material. The amount of thread obtained by these sizes is from 5/8 to 3/4 of a full thread.

Fig. 16. Button Die Holder of the Draw-out Type

Speeds for Dies and Taps

As a general rule, a die can be operated at a higher rate of speed than a tap, for the following reasons: A die can be left harder than a tap; and the die can be supplied with oil much easier than can the tap. The following surface speeds have been found suitable for taps and dies made from ordinary carbon steel and used on the materials specified below:

SURFACE SPEEDS FOR DIES

Material	Feet per Minute
Brass (ordinary quality)	190-200
Norway iron and machine steel	30-40
Drill rod and tool steel	20-30

SURFACE SPEEDS FOR TAPS

Material	Feet per Minute
Brass (ordinary quality)	150-160
Norway iron and machine steel	25-30
Drill rod and tool steel	15-20

Die and Tap Holders

The manner in which a die or tap is held when being applied to the work has a considerable bearing on the results obtained. The die or tap holders supplied by the Brown & Sharpe Mfg. Co. give satisfactory results in most cases, and, therefore, these holders should be used for general automatic screw machine work. In Fig. 16 is shown a button die holder of the draw-out type, as made by the above firm. This holder gives good results when the work is not required to be threaded up to a shoulder. In Fig. 17 is shown an improved design of releasing button die holder also made by this firm, a section through the holder

TABLE XI. TAP DRILLS FOR A. S. M. E. STANDARD AND SPECIAL MACHINE SCREWS

Special sizes are marked *

Size of Screw and Number of Threads Per Inch	Size of Tap Drill	Decimal Equivalent of Tap Drill	Size of Screw and Number of Threads Per Inch	Size of Tap Drill	Decimal Equivalent of Tap Drill
0.060 — 80	56	0.0465	*0.177 — 24	27	0.1440
0.073 — 72	53	0.0595	*0.190 — 32	19	0.1660
*0.073 — 64	53	0.0595	0.190 — 30	20	0.1610
0.086 — 64	49	0.0730	*0.190 — 24	21	0.1590
*0.086 — 56	50	0.0700	0.216 — 28	13	0.1850
0.099 — 56	45	0.0820	*0.216 — 24	14	0.1820
*0.099 — 48	46	0.0810	0.242 — 24	5	0.2055
0.112 — 48	42	0.0935	*0.242 — 20	7	0.2010
*0.112 — 40	43	0.0890	0.268 — 22	1	0.2280
*0.112 — 36	43	0.0890	*0.268 — 20	1	0.2280
0.125 — 44	37	0.1040	0.294 — 20	$\frac{1}{4}$	0.2500
*0.125 — 40	37	0.1040	*0.294 — 18	$\frac{1}{4}$	0.2500
*0.125 — 36	38	0.1015	0.320 — 20	J	0.2770
0.138 — 40	32	0.1160	*0.320 — 18	J	0.2770
*0.138 — 36	33	0.1130	0.346 — 18	$\frac{19}{64}$	0.2968
*0.138 — 32	32	0.1160	*0.346 — 16	$\frac{19}{64}$	0.2968
0.151 — 36	30	0.1285	*0.372 — 18	$\frac{21}{64}$	0.3281
*0.151 — 32	$\frac{1}{8}$	0.1250	0.372 — 16	P	0.3230
*0.151 — 30	$\frac{1}{8}$	0.1250	0.398 — 16	$\frac{11}{32}$	0.3437
0.164 — 36	28	0.1405	*0.398 — 14	$\frac{11}{32}$	0.3437
*0.164 — 32	28	0.1405	*0.424 — 16	$\frac{3}{8}$	0.3750
*0.164 — 30	28	0.1405	0.424 — 14	U	0.3680
0.177 — 32	24	0.1520	*0.450 — 16	$\frac{13}{32}$	0.4062
*0.177 — 30	24	0.1520	0.450 — 14	$\frac{25}{64}$	0.3906

being shown at *A*. The main feature of this die holder is that it can be reversed without shock; therefore, when threading small screws, it has less tendency to break off the screw in the die. At *B* and *C* are shown two views at the cross-section *X Y*. At *B* and *C* are also

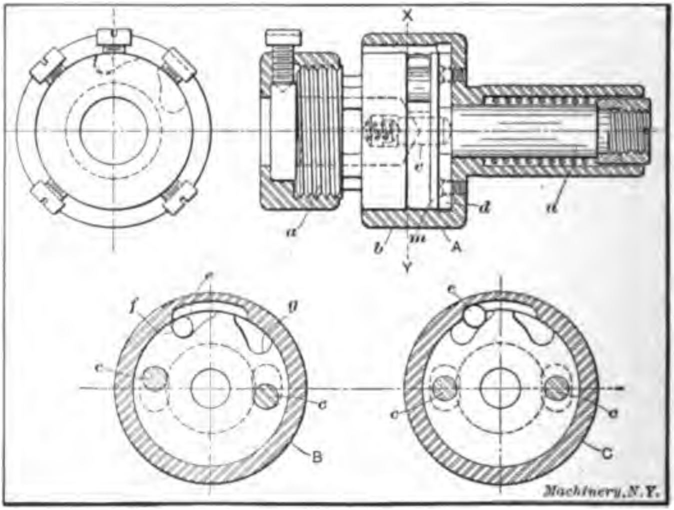

Fig. 17. Illustration showing Operating Parts of Releasing Button Die Holder

shown two small balls *e* which are used, allowing this die holder to reverse without shock. The operation of the holder is as follows: When the die holder or spindle *a* draws out from the body *b*, the driving pins *c* are also withdrawn, so that the ends of these pins are drawn out flush with the plate *m*. When the machine spindle is reversed, spindle

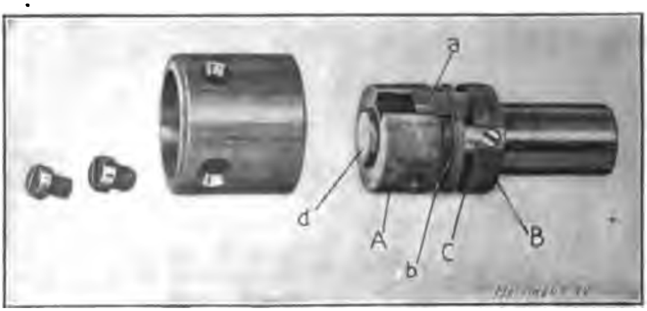

Fig. 18. Releasing Tap Holder

a revolves with the work, the centrifugal force throwing the ball *e* out of the deep part of the pocket as shown at *B* into the position as shown at *C*. This locks the holder, allowing it to be backed off the work. This holder can be used either for right- or left-hand threading simply by inserting the balls *e* in the different pockets, *e. g.*, when ball *e* is placed in pocket *f* it will cut a right-hand thread, and when placed in pocket *g* it will cut a left-hand thread. This holder is used to advantage, especially when cutting up to a shoulder.

In Fig. 18 is shown a releasing tap holder. The spindle *A* carries a pawl *a*, which is held back against the shoulder *C* by the spring *b*. When the spindle *A* is drawn out, the beveled portion on the pawl *a* allows it to slide past block *B*, thus allowing the spindle *A* to make one revolution, when the opposite face of pawl *b* comes in contact with block *B*, thus allowing the tap to back out of the work. A blank bushing *d* is shown in the holder.

Fig. 19. Cutting Thread Lobe on a Circular Milling Attachment

Using Two Taps

When a full thread is desired and the size of the tap will not stand the cutting pressure, it is sometimes found convenient to use two taps. The first tap should be ground tapered somewhat similar to a starting tap used for hand tapping. The taper should extend back a distance equal to that which the tap is to go into the work, so that the first thread in the work will be to the full diameter. The second tap is left with a full thread. To set the taps, the dogs on the drum should be set so that the spindle will be reversing at about the same point on both the thread lobes. Then the first tap is set and made to travel into the work the desired distance. The second tap is then set in the turret, the distance from the face of the turret being the same as for the first tap. If this procedure is followed, little difficulty will be encountered. A releasing tap holder as shown in Fig. 18 is preferable to the draw-out type for this purpose, as the taps are not required to be set as accurately.

Cutting the Thread Lobe

In Fig. 19 is shown a circular milling attachment in position on the Brown & Sharpe universal milling machine, equipped with a vertical milling attachment. Before cutting the cam the various lobes are laid out in their respective positions as designated on the drawing, and the metal is removed either by shearing in a punch press or by drilling a series of 3/16-inch holes about 1/16 inch from the outline of the various lobes. The cam is then placed on block *A*, as shown, which has a projecting stud, nut *B* being used to hold down the cam tightly against the face of this block. The block is held to the circular milling attachment by two screws not shown in the illustration. To cut the cam, raise the knee until the end mill passes the lower face of the cam *C* as shown, and bring the end mill into position at the bottom of the lobe, in other words, at the point where the die would start on the work. Then feed in the end mill the desired distance. The micrometer collars on the shafts carrying handles *D* and *E* are then set at zero. Referring to Fig. 10, we find that the lead on the lobe is one thousandth inch for each 3½ minutes of its circumference, but the smallest division on this attachment is five minutes. We will, therefore, revolve the attachment five minutes for each 0.0015 inch that we feed in the cam, continuing in this manner until that side of the lobe is finished. The attachment is then swung around and the other side of the lobe completed in the same manner. Milling the cam in this manner leaves a series of slight flats on the lobe which can be removed by filing, giving the cam lobe an approximately true curve.

CHAPTER III

THREAD ROLLING

The rolling of threads has for a considerable time been practiced in the manufacture of machine and wood screws, the threads being formed by dies which have V-grooves in their opposing faces, cut at an angle equal to the helix of the thread. The operation of rolling a screw in a thread rolling machine consists in passing the screw between two flat dies, one of which is stationary and the other reciprocating. This is the principle on which some of the thread rolling machines on the market work, while others have one stationary hollow cylindrical die and one revolving circular die. However, the principle on which they act is the same; that is, part of the material is raised to form the thread by forming a corresponding depression in the blank. This action makes the diameter of the finished screw larger than the blank.

The adaptation of thread rolling to the automatic screw machine is, however, of comparatively recent application—hence the scarcity of definite information on the subject. After considerable experimenting with this class of work, the Brown & Sharpe Mfg. Co. has found that the rolling of threads on steel parts is a very unsatisfactory practice, and thus confines the rolling of threads to brass and similar materials. The information given in this chapter, therefore, applies exclusively to the rolling of threads on these materials.

Obtaining the Diameter of the Blank

The rolling of a thread differs from cutting a thread with a V-tool, in that by the former method no material is cut away, the thread being formed by displacing the material, as stated. Theoretically, in a sharp V-thread, the volume of one convolution of thread above the pitch diameter should be greater than that of the space between the threads below the pitch diameter, on account of the greater circumference. Therefore, the diameter of the blank before rolling should presumably be greater than the pitch diameter. This, however, is not the case for all materials, brass in particular being an exception. As a rule, the diameter of the blank for brass should be approximately equal to the pitch diameter.

When rolling a U. S. standard thread, the pitch diameter is found to be slightly greater than the required diameter of the blank, because of the impracticability of making the thread roll with a flat top. If a thread roll is not made with a sharp V at the top, it will require a considerably greater pressure to force it into the work, and the roll does not produce as smooth and perfect a thread. Therefore, it has been found advisable to make all thead rolls, whether for forming a sharp V or a U. S. standard thread, with a sharp V top and bottom.

It is not necessary to make the bottom of the thread on the roll sharp, but there would be no advantage in having it flat, as the outside diameter of the screw is governed by the diameter of the blank.

The shape of the thread produced by a thread roll when the U. S. standard form is required is shown at *B* in Fig. 20. The pitch diameter d_2 is the same as the pitch diameter of the U. S. standard form shown at *A*. The root diameter d_3, however, is less than the root diameter d_1 of the U. S. standard thread shown at *A*. The pitch diameter d_2 is slightly greater than the required diameter of the blank, which can be found approximately by the following formula:

$$D = d_2 - \frac{d_5}{8} \qquad (1)$$

in which

D = diameter of the blank,
d_2 = pitch diameter of the screw,
d_5 = depth of U. S. standard thread. (See *A* Fig. 20.)

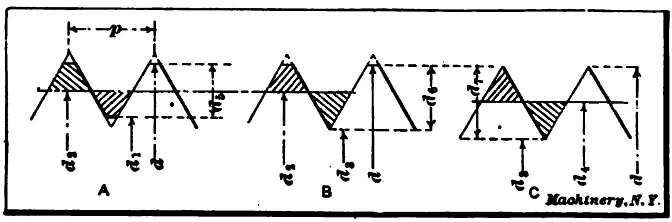

Fig. 20. Notation used in Calculating Diameters of Thread Rolls

The depth of the thread d_5 can be found by the following formula:

$$d_5 = \tfrac{3}{4} \times p \times \cos 30 \text{ deg.} = 0.6495\,p \qquad (2)$$

where p = the pitch of the thread or $\dfrac{1}{\text{number of threads per inch}}$

The pitch diameter is found by the formula:

$$d_2 = d - d_5 \qquad (3)$$

where d = the nominal external diameter of the screw.

When rolling a thread having a sharp V-form, the pitch diameter d_4, as shown at *C* in Fig. 20, can be used as the approximate diameter of the blank. The correct diameter of the blank in any case cannot be found by any formula, but by experiments only. It might be possible, however, to derive an empirical formula by making a series of experiments, and in each case determining the hardness of the metal. Then the results could be tabulated and used under similar conditions —when the metal is of the same hardness and the thread of the same shape. It is a simple matter, however, in the automatic screw machine, to reduce or increase the diameter of the blank, so as to give the correct finished diameter; thus it seems that any elaborate method of accurately obtaining the diameter of the blank by calculation is unnecessary.

Preparing Work for Thread Rolling

In most cases that part of the work on which a thread is to be rolled can be formed by the circular form tool. The thread to be rolled is generally at the rear of a shoulder, so that the thread roll has to be of a certain width, thus making it necessary to bevel the edges of the roll to prevent the threads at the ends from chipping. It is, therefore, desirable, when the work is to be threaded up to a shoulder, to make the form tool of such a shape that it will neck the work, as shown at *A* in Fig. 21, and also to reduce the diameter at *B* where the work is to be cut off.

The angle *a* should be 45 degrees, and the distance *C* should be equal to at least half the single depth of the thread, so that the part *B* will be slightly smaller than the root diameter of the finished piece. The distance *E* should be made equal to *C*, and the distance *F* equal to

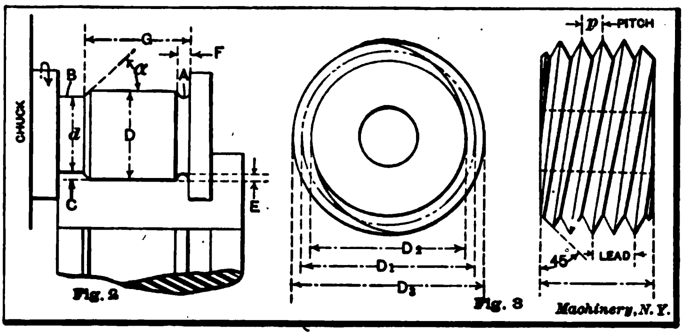

Fig. 21. Preparing a Piece with a Circular Form Tool

Fig. 22. Thread Roll with a Double Thread —Note Beveled Edges

at least the pitch of the thread. When it is not necessary to roll the thread up to a shoulder, the work need not be necked. However, better results are obtained, in most cases, by necking the work, whenever it would not be seriously weakened thereby.

Making the Thread Roll

The best results are obtained by using a thread roll with a single thread, but when the piece to be rolled is less than 5/8 inch in diameter, it is necessary to make the roll with a multiple thread in order to have it of the proper size. The roll should be made the opposite hand to that which it is required to produce; that is to say, for a right-hand thread, the thread roll is cut left-hand.

Owing to the displacement of the metal in forming a thread by rolling, there is no point in the formation of the thread where the contact is perfect. If the pitch diameter of the roll was made an exact multiple of the pitch diameter of the piece to be rolled, the contact would be perfect when the thread was completed, but not at any other point during the formation of the thread, and, therefore, would not allow the metal to flow. The Brown & Sharpe Mfg. Co. has found that the pitch diameter of the roll should not be an exact multiple of the pitch diameter of the finished piece, but should be slightly less. The pitch diameter of the roll for a U. S. standard thread can be found by the following formula:

$$D_1 = N \times \left(D - \frac{d_6}{3}\right) \qquad (4)$$

in which,

D_1 = pitch diameter of roll (see Fig. 22),

N = approximate ratio between pitch diameter of roll and pitch diameter of piece to be threaded,

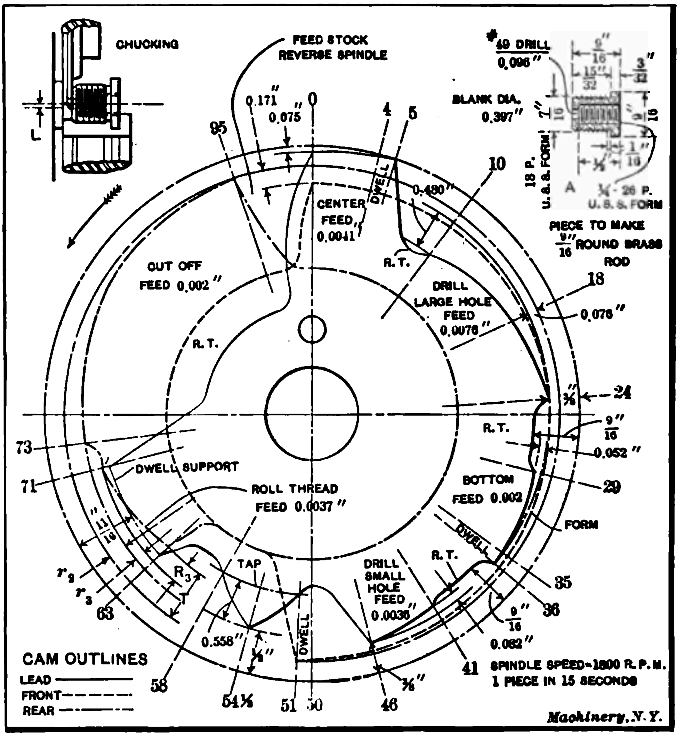

Fig. 23. Lay-out of a Set of Cams for Performing a Thread-rolling Operation

D = diameter of blank (see Fig. 21),

d_6 = depth of thread (see *B*, Fig. 20).

The depth of a U. S. standard thread as produced by thread rolling can be found by the following formula (for notation see *B*, Fig. 20):

$$d_6 = \tfrac{7}{8} \times p \times \cos 30 \text{ deg.} = 0.7578\, p \qquad (5)$$

where p = the pitch of the thread.

To illustrate clearly the method used in designing a thread roll for producing a U. S. standard thread, as shown at *B* in Fig. 20, take a practical example: Assume that it is necessary to design a thread roll for producing the thread on the piece shown at *A* in Fig. 23. As this is a U. S. standard thread, and it is impracticable to use a roll with a flat top, we use the blank diameter for calculating the pitch diameter of the roll, instead of the pitch diameter of the thread, as would be the case with a sharp V-thread. The blank diameter can be found by Formula (1). Before finding the blank diameter, however, it is necessary to find the depth of the thread, which can be found by substituting the known values in Formula (2), as follows:

$$d_5 = 0.6495\,p = 0.6495 \times 0.0555 = 0.0360 \text{ inch.}$$

Then

$$d_2 = d - d_5 = 0.4375 - 0.0360 = 0.4015 \text{ inch}$$

and

$$D = d_2 - \frac{d_5}{8} = 0.4015 - \frac{0.036}{8} = 0.4015 - 0.0045 = 0.397 \text{ inch.}$$

The pitch diameter of the thread roll can then be found by Formula (4), but before finding the pitch diameter it is necessary to find the depth of the thread d_6 (see *B*, Fig. 20) by inserting the values in Formula (5):

$$d_6 = p \times 0.7578 = 0.0555 \times 0.7578 = 0.042 \text{ inch.}$$

Then

$$D_1 = N \times \left(D - \frac{d_6}{3}\right)$$

$$= 2 \times \left(0.397 - \frac{0.042}{3}\right) = 0.766 \text{ inch.}$$

The root diameter D_2 and the outside diameter D_3 of the thread roll (see Fig. 22) can be found by the following formulas:

$$D_2 = D_1 - d_7 \quad \text{(See } C\text{, Fig. 20)} \qquad (6)$$

$$D_3 = D_1 + d_7 \qquad (7)$$

inserting the values, we have:

$$D_2 = 0.766 - 0.048 = 0.718 \text{ inch,}$$

and

$$D_3 = 0.766 + 0.048 = 0.814 \text{ inch.}$$

The same method as that given for the U. S. standard form of thread is used for the A. S. M. E. standard screws when designing a thread roll. A thread roll for a sharp V-thread, however, is calculated from the pitch diameter, which is also used as the approximate diameter of the blank. For a sharp V-thread the root, pitch and outside diameters of the roll are found by the following formulas:

$$D_1 = N \times \left(d_4 - \frac{d_7}{3}\right) \qquad (8)$$

$$D_2 = D_1 - d_7 \qquad (9)$$

$$D_3 = D_1 + d_7 \qquad (10)$$

in which

D_1 = pitch diameter of thread roll,
D_2 = root diameter of thread roll,

D_3 = outside diameter of thread roll,
N = approximate ratio between pitch diameter of roll and pitch diameter of piece to be threaded,
d_4 = pitch diameter of thread or diameter of blank,
$d_7 = 0.866\ p$ (see C Fig. 20).

In making a thread roll the outside diameter is turned to the size required, and the ends are beveled at an angle of 45 degrees, as shown in Fig. 22, to prevent the threads on the ends of the roll from chipping. If the roll is to be made with a multiple thread, the lathe must, of course, be geared to correspond. Before cutting the thread it is preferable to bevel the edges at an angle of 30 degrees, or equal to the angle of one side of the thread. This facilitates the starting of the thread tool. After the threads have been cut, the roll should again be beveled, but at an angle of 45 degrees.

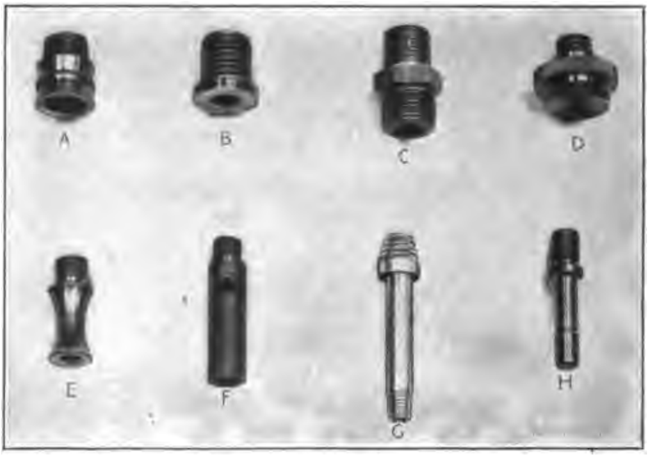

Fig. 24. Samples of Pieces having Rolled Threads

Thread rolls should be made from steel containing a high percentage of carbon. Precautions should be taken in hardening, because if the sharp edges become burnt the roll will be useless. Thread rolls, as a rule, are lapped after hardening. This is done by holding them on an arbor in the lathe, and using emery and oil on a piece of hard wood. A thread roll, to give good results, should not be made to fit loosely in the slot in the holder, but should be made a good running fit. If the roll is made to fit loosely in the holder, it will "chew up" the threads. The hole in the roll should also be made a good running fit on the pin in the holder, and in most cases should not be larger than 5/16 inch, ¼ inch being usually adopted for rolls 1 inch in diameter or less.

Applying a Thread Roll to the Work

The shape of the work and the character of the operations necessary to produce it, govern, to a large extent, the method employed in applying the thread roll. There are, however, other considerations to be observed, some of which are as follows:

1. Diameter of the part to be threaded.
2. Location of the part to be threaded.
3. Length of the part to be threaded.
4. Relation that the thread rolling operation bears to the other operations.
5. Shape of the part to be threaded, whether straight, tapered or otherwise.
6. Method adopted in applying the support.

When the diameter to be rolled is much smaller than the diameter of the shoulder preceding it, a cross-slide knurl-holder should be used.

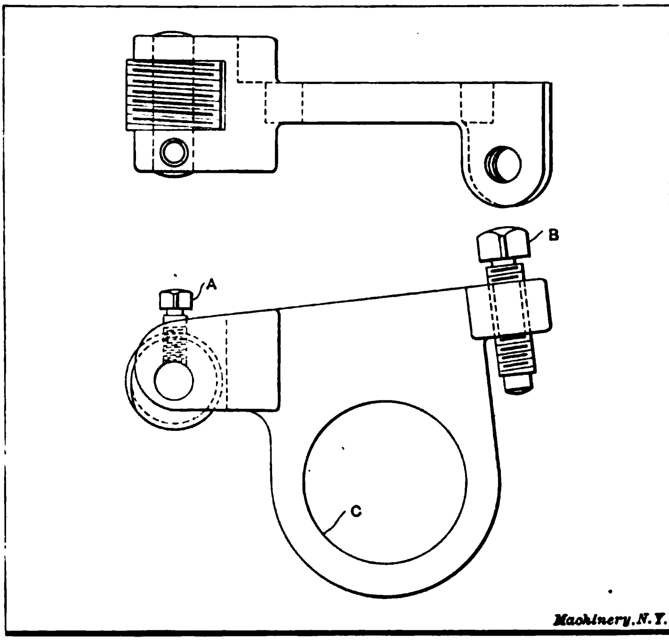

Fig. 25. Top Cross-slide Roll-holder

If the part to be threaded is not behind a shoulder, a holder on the swing principle should be used. When the work is long—greater in length than two-and-one-half times its diameter—a swing roll-holder should be employed, carrying a support. When the work can be cut off directly after the thread is rolled, a cross-slide roll-holder should be used. The method of applying the support to the work also governs to some extent the method of applying the thread roll, but as this depends entirely on the shape of the work, it would be impossible to say what method should be employed, unless the shape of the work were known.

When no other tool is working at the same time as the thread roll, and when there is freedom from chips, the roll can be held more rigidly by passing it under instead of over the work. When passing the roll over the work, it has a tendency to raise the cross-slide, while, on the other hand, if the roll is passed under the work, the pressure is downward, and hence the holder is more rigidly supported. Where the part to be threaded is tapered as shown on the aluminum piece *G* in Fig. 24, the roll can be best presented to the work by holding it in a cross-slide roll-holder.

Holders for Thread Rolls

As previously mentioned, certain considerations govern the method of applying the thread roll; the holder for the roll, therefore, has to be designed to suit these requirements. There are various types of special holders in use for holding thread rolls; a few of the more common or standard types will be described.

In Fig. 25 is shown what is called a "top" roll-holder. This holder

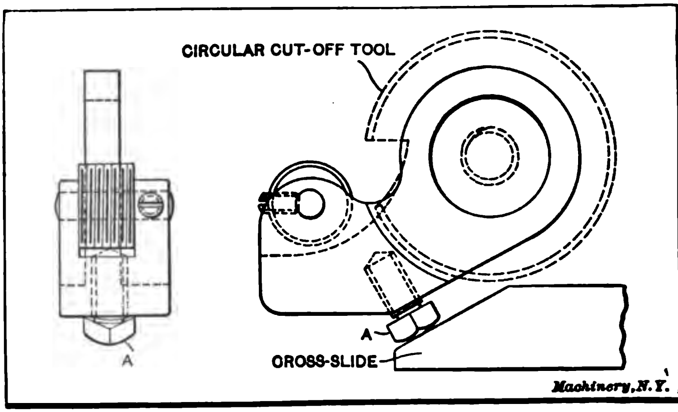

Fig. 26. Holder used when the Roll is passed under the Work

is held on a boss turned on the circular cut-off tool, and is clamped by the circular cut-off tool and the screw which holds the latter to the toolpost. The thread roll is held in a slot cut in the forward end of the holder on a pin, the latter being driven into the holder, as shown. As considerable pressure is required to force the roll into the work, there is a tendency to turn the pin in the holder; to obviate this, a flat is filed on the pin and a setscrew *A* is provided. The set-screw *B* is used for setting the roll to the proper depth, and rests on the toolpost. By making hole *C* in the holder to fit the screw in the toolpost, this holder could be held on the outside of the toolpost, instead of fitting on the circular cut-off tool. This thread-roll holder can be used for holding rolls for threading pieces such as shown at *A*, *B* and *C* in Fig. 24.

A thread-roll holder which is held on the cross-slide but passes under the work is shown in Fig. 26. This holder is held on a projection on the cut-off tool in a manner similar to that shown in Fig. 25. The support, the set-screw *A*, rests on the cross-slide, and is used for adjusting the roll to the proper depth, as well as for supporting the holder. This holder can be held more rigidly than the top roll-holder shown in Fig. 25; it is used when no other tool is operating on the work at the same time, and also where there is an absence of objectionable chips. Thread-roll holders which are held on the cross-slide

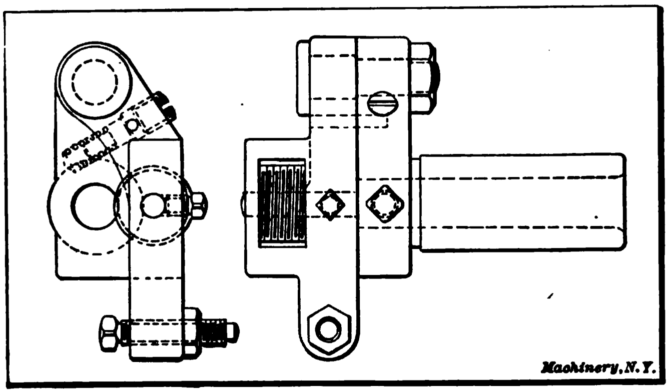

Fig. 27. Swing Holder for Holding a Thread Roll

can only be used when the work is cut off directly after the thread is rolled, and for this reason they should be held on the same slide as the cut-off tool. If the roll is brought back over the work, it produces a poor thread.

When it is necessary to bring in the cut-off or form tool more than once for the same piece, a cross-slide holder should not be used. Of

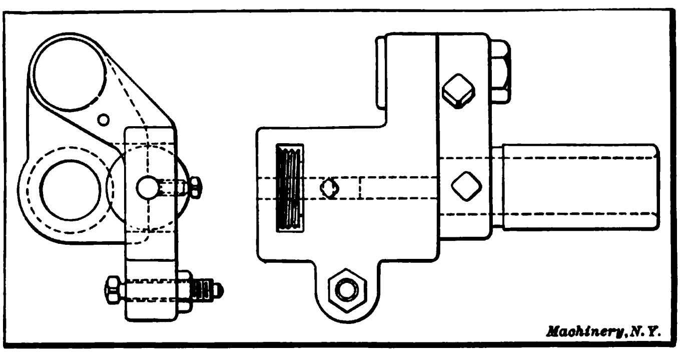

Fig. 28. Another Swing Roll-holder

course it would be possible to design a holder in which the roll would be held in a member free to oscillate, and held in position by a spring. This type of holder would be objectionable, however, owing to the fact that chips would get in between the movable member and the body, and prevent the part holding the roll from coming back into the same place each time, thus causing an endless amount of trouble.

When the work is of such a shape as to necessitate bringing in the form and cut-off tools more than once for the same piece, a swing holder should be used. Two holders of this type are shown in Figs. 27 and 28. These holders are made on the same principle as the ordinary swing tool, with the exception of the change in the swinging member to hold the roll. A hole is drilled in the shank of the holder and a set-screw provided for holding a support.

A thread-roll holder which is held on the cross-slide and holds a roll for threading the beveled piece shown at *G* in Fig. 24, is shown in Fig. 29. This holder is held to the toolpost in a manner similar to

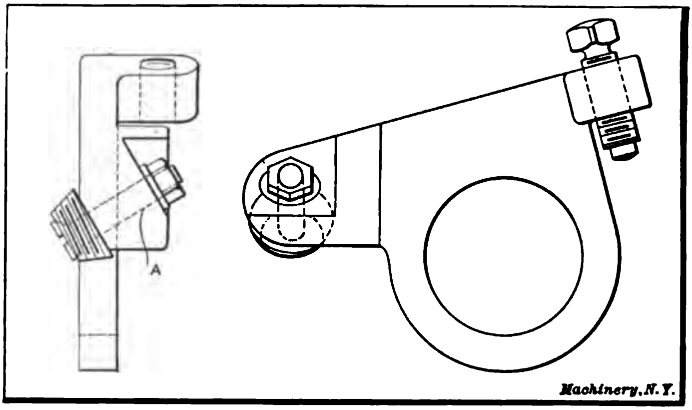

Fig. 29. Cross-slide Holder for applying a Thread Roll to a Beveled Piece

that of the holders previously described, but the roll in this case is held at an angle on the stud *A*.

Rise on Cam when using Cross-slide Roll-holder

In thread rolling, the roll is first brought against the work, then fed at a certain feed per revolution until the center of the roll is in line with the center of the work, and finally removed from the work on the quick rise of the cam. As the roll is removed from the work, the cut-off tool is brought into position. The rise on the cross-slide cam for thread rolling, when using a holder held to the toolpost, can be found by the aid of the following formulas derived from the diagram Fig. 30. This shows the outside circumference of the thread roll touching the circumference of the blank, and a horizontal line is drawn tangent to the root diameter of the finished screw.

Let D = diameter of blank,

d_3 = theoretical root diameter of screw,

R = blank radius,

R_1 = largest or outside radius of thread roll,

d = difference between radius of blank and radius of root of thread.

Then,

$$A = R + R_1 \qquad (11)$$

$$B = R + R_1 - d \qquad (12)$$

$$C = \sqrt{A^2 - B^2} \qquad (13)$$

For example, let it be required to find the rise on the cross-slide cam for threading the piece shown at *A* in Fig. 23. Substituting the known values of the diameter of the roll and the diameter of the blank in the above formulas, we have:

$A = 0.1985 + 0.407 = 0.6055$ inch.

$B = 0.1985 + 0.407 - 0.0218 = 0.5837$ inch.

$C = \sqrt{(0.6055)^2 - (0.5837)^2} = \sqrt{0.02634} = 0.162$ inch.

Then the rise R_3 on the cam (see Fig. 23) equals *C* (Fig. 30) plus from 0.010 to 0.015 inch, depending on the diameter of the roll and work.

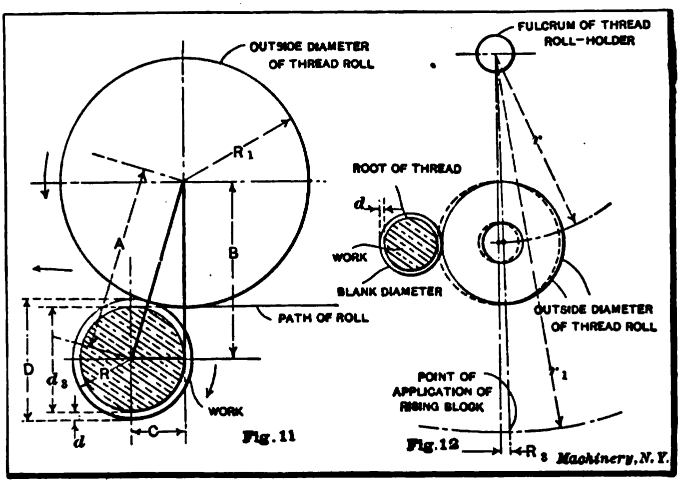

Fig. 30. Diagram used in Calculating the Rise on the Cam for Thread Rolling when a Cross-slide Holder is used

Fig. 31. Diagram used in Finding Rise on Cross-slide Cam when using Roll-holder of the Swing Type

This calculation is for rolling a U. S. standard thread, but the same method can be used for rolling any other shape, substituting, of course, the correct values.

Total Rise on Cross-slide Cam

As the work is cut off with the same cam, it is necessary to find the total rise on the cam for thread rolling and cutting off the piece; this can be found by the following formulas, which are derived from the diagram Fig. 32. Here the thread roll is shown touching the circumference of the blank, and the circular cut-off tool and thread-roll holder are shown in their relative positions.

Let T = total rise on cam (see Fig. 23),

C = distance from center of roll to center of work,

R_3 = actual rise required to roll thread, which equals C + from 0.010 to 0.015 inch,

R = radius of theoretical root of thread on piece,

r_1 = radius of work turned down with circular form tool, or $\frac{d}{2}$ (see Fig. 21),

L = distance of bevel on cut-off tool (see Fig. 23),

r_2 = actual rise on cam to cut off piece, which equals $r_1 + L +$ 0.010 inch (to approach) + 0.005 inch (to pass center),

R_1 = outside radius of thread roll,

R_4 = largest radius of circular cut-off tool,

R_5 = radius of thread-roll holder,

c = distance that cut-off tool is cut below center,

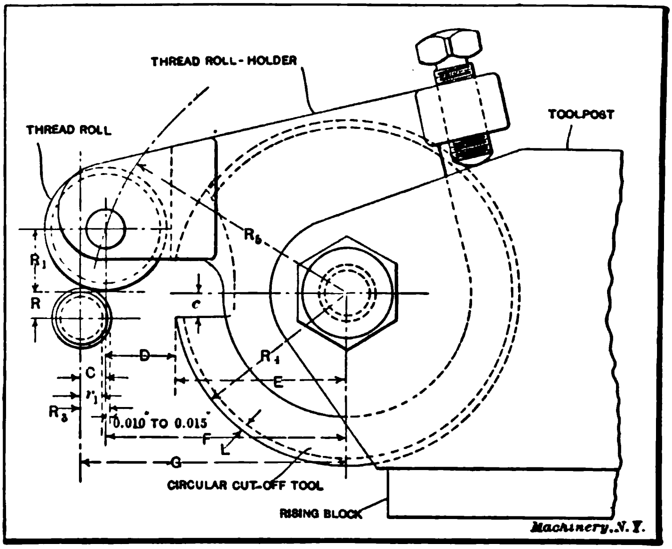

Fig. 32. Diagram used in Finding the Total Rise on the Cam for Thread Rolling and Cutting-off

E = distance from center of circular tool to edge, when tool is cut down below center,

F = distance from center of cut-off to center of roll, when it is touching piece as shown,

Then if

$$X = R + R_1 - c$$
$$F = \sqrt{R_5^2 - X^2}$$

Now the difference between the dimensions E and F, or the distance D, always remains constant, so that it is only necessary now to find the actual distances or rises required on the cam for thread rolling, approaching the work with the cut-off tool, and cutting the piece from the bar.

The rise r_3 required to bring the cut-off tool up into position, after thread rolling, to cut off the piece $= D - r_1 + 0.010$.

The total rise T on the cam equals $R_3 + r_2 + r_3$.

TABLE XII. FEEDS FOR THREAD ROLLING WITH CROSS SLIDE HOLDERS

Root Diameter of Blank	Number of Threads per Inch																
	80	72	64	56	48	44	40	36	32	30	28	24	22	20	18	16	14
	Feed per Revolution in Inches																
$\frac{1}{8}$	0.0050	0.0045	0.0040	0.0035	0.0030	0.0025	0.0020	0.0015	0.0010	0.0005	......	......	......	......	......	......	......
$\frac{3}{16}$	0.0055	0.0050	0.0045	0.0040	0.0035	0.0030	0.0025	0.0020	0.0015	0.0010	0.0005	......	......	......	......	......	......
$\frac{1}{4}$	0.0060	0.0055	0.0050	0.0045	0.0040	0.0035	0.0030	0.0025	0.0020	0.0015	0.0010	0.0005	0.0005	......	......	......	......
$\frac{5}{16}$	0.0065	0.0060	0.0055	0.0050	0.0045	0.0040	0.0035	0.0030	0.0025	0.0020	0.0015	0.0010	0.0010	0.0005	0.0005	......	......
$\frac{3}{8}$	0.0070	0.0065	0.0060	0.0055	0.0050	0.0045	0.0010	0.0035	0.0030	0.0025	0.0020	0.0015	0.0015	0.0010	0.0010	0.0005	0.0005
$\frac{7}{16}$	0.0075	0.0070	0.0065	0.0060	0.0055	0.0050	0.0045	0.0040	0.0035	0.0030	0.0025	0.0020	0.0020	0.0015	0.0015	0.0010	0.0010
$\frac{1}{2}$	0.0080	0.0075	0.0070	0.0065	0.0060	0.0055	0.0050	0.0045	0.0040	0.0035	0.0030	0.0025	0.0025	0.0020	0.0020	0.0015	0.0015
$\frac{5}{8}$	0.0085	0.0080	0.0075	0.0070	0.0065	0.0060	0.0055	0.0050	0.0045	0.0040	0.0035	0.0030	0.0030	0.0025	0.0025	0.0020	0.0020
$\frac{3}{4}$	0.0090	0.0085	0.0080	0.0075	0.0070	0.0065	0.0060	0.0055	0.0050	0.0045	0.0040	0.0035	0.0035	0.0030	0.0030	0.0025	0.0025
$\frac{7}{8}$	0.0090	0.0090	0.0085	0.0080	0.0075	0.0070	0.0065	0.0060	0.0055	0.0050	0.0045	0.0040	0.0040	0.0035	0.0035	0.0030	0.0030
1	0.0100	0.0095	0.0090	0.0085	0.0080	0.0075	0.0070	0.0065	0.0060	0.0055	0.0050	0.0045	0.0045	0.0040	0.0040	0.0035	0.0035

TABLE XIII. FEEDS FOR THREAD ROLLING WITH SWING HOLDERS

Root Diameter of Blank	Number of Threads per Inch																
	80	72	64	56	48	44	40	36	32	30	28	24	22	20	18	16	14
	Feed per Revolution in Inches																
$\frac{1}{8}$	0.0030	0.0025	0.0020	0.0015	0.0010	0.0005	......	......	......	......	......	......	......	......	......	......	......
$\frac{3}{16}$	0.0033	0.0028	0.0025	0.0020	0.0015	0.0008	0.0005	......	......	......	......	......	......	......	......	......	......
$\frac{1}{4}$	0.0036	0.0030	0.0030	0.0025	0.0020	0.0010	0.0010	0.0005	0.0005	0.0005	0.0005	......	......	......	......	......	......
$\frac{5}{16}$	0.0040	0.0035	0.0035	0.0030	0.0025	0.0015	0.0015	0.0010	0.0010	0.0010	0.0010	0.0005	......	......	......	......	......
$\frac{3}{8}$	0.0043	0.0040	0.0040	0.0035	0.0030	0.0020	0.0020	0.0015	0.0015	0.0015	0.0015	0.0010	0.0005	0.0005	0.0005	......	......
$\frac{7}{16}$	0.0046	0.0045	0.0045	0.0040	0.0035	0.0030	0.0025	0.0020	0.0020	0.0020	0.0020	0.0015	0.0010	0.0010	0.0010	......	......
$\frac{1}{2}$	0.0050	0.0048	0.0048	0.0045	0.0040	0.0035	0.0030	0.0025	0.0025	0.0025	0.0025	0.0020	0.0015	0.0015	0.0015	0.0005	0.0005
$\frac{5}{8}$	0.0053	0.0050	0.0050	0.0048	0.0043	0.0040	0.0035	0.0030	0.0030	0.0030	0.0028	0.0025	0.0020	0.0020	0.0018	0.0010	0.0010
$\frac{3}{4}$	0.0056	0.0055	0.0052	0.0050	0.0045	0.0043	0.0040	0.0035	0.0035	0.0032	0.0030	0.0028	0.0025	0.0022	0.0020	0.0015	0.0013
$\frac{7}{8}$	0.0060	0.0058	0.0055	0.0052	0.0048	0.0045	0.0043	0.0040	0.0038	0.0035	0.0032	0.0030	0.0028	0.0025	0.0022	0.0018	0.0015
1	0.0062	0.0060	0.0058	0.0054	0.0050	0.0048	0.0047	0.0043	0.0040	0.0038	0.0035	0.0032	0.0030	0.0028	0.0025	0.0022	0.0018

Rise on Cross-slide Cam when using Swing Roll-holder

When using a roll-holder of the type shown in Figs. 27 and 28, the rise on the cam can be found by the following formula derived from the diagram Fig. 31, where the thread roll is shown in two positions—before and after rolling the thread. The distance d, which in this case is taken to be 0.020 inch, represents the distance between the radius of the blank and the theoretical root diameter of the thread of the piece to be rolled. To this dimension, from 0.010 to 0.015 inch is added for the roll to approach the work. Let $d_1 = d +$ from 0.010 to 0.015 inch.

Then,

$$R_2 = \frac{d_1 \times r_1}{r} \qquad (16)$$

For example, let $d_1 = 0.030$ inch, $r = 1\frac{1}{8}$ inch, and $r_1 = 2\frac{1}{4}$ inches.

Then,

$$R_2 = \frac{0.030 \times 2\frac{1}{4}}{1\frac{1}{8}} = 0.060 \text{ inch.}$$

There is another method of holding the thread roll when applying it to the work which has not been mentioned. This consists in holding the roll in a holder fastened to the cross-slide, but instead of passing the roll over or under the work, it is presented radially to the work. The rise on the cross-slide would then be $d +$ from 0.010 to 0.015 inch (see Fig. 31).

Speeds and Feeds for Thread Rolling

When the thread roll is made from high-carbon steel and used on brass, a surface speed as high as 200 feet per minute can be used. Better results, however, are obtained by using a lower speed than this. When the roll is held in a holder attached to the cross-slide, and is presented either tangentially or radially to the work, it can be fed at a considerably higher speed than if it is held in a swing tool. This is due to the lack of rigidity in a holder of the swing type. Table XII gives the feeds to be used when a cross-slide roll-holder is used; and Table XIII gives the feeds to be used for thread rolling with swing tools.

The feeds given in Tables XII and XIII are applicable for rolling threads without a support when the root diameter of the blank is not less than five times the double depth of the thread. When the root diameter is less than this amount, a support should be used. A support should also be used when the width of the roll is more than two-and-one-half times the smallest diameter of the piece to be rolled, irrespective of the pitch of the thread. When the smallest diameter of the piece to be rolled is much less than the root diameter, the smallest diameter should be taken as the deciding factor for the feed to be used.

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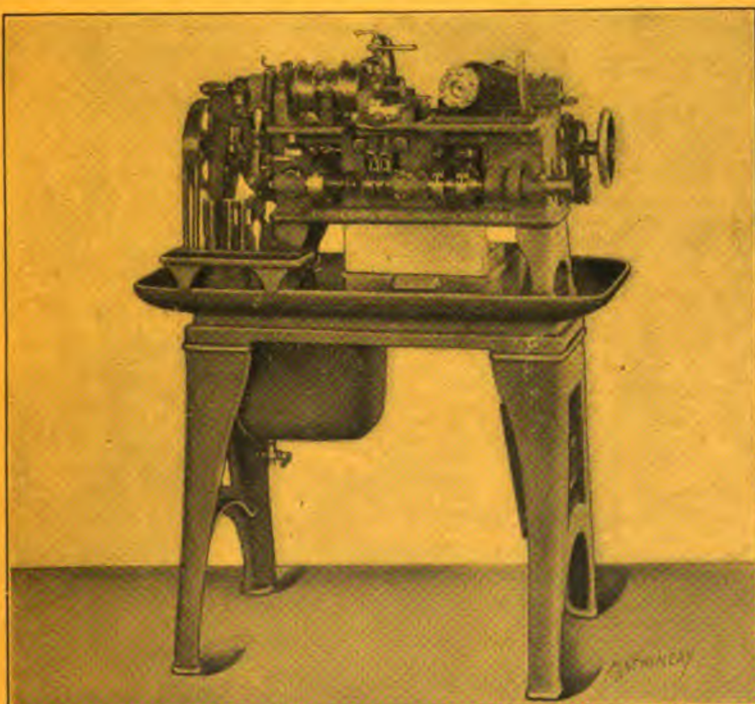
AUTOMATIC SCREW MACHINE PRACTICE

KNURLING OPERATIONS ON THE BROWN & SHARPE AUTOMATIC SCREW MACHINES

BY DOUGLAS T. HAMILTON



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NUMBER 105

AUTOMATIC SCREW MACHINE PRACTICE

PART VII

KNURLING OPERATIONS ON THE BROWN & SHARPE AUTOMATIC SCREW MACHINES

By DOUGLAS T. HAMILTON

CONTENTS

Automatic Screw Machine Practice for the Brown & Sharpe automatic screw machines is covered in eight Reference Books, Nos. 99 to 106, inclusive. Reference Book No. 99, "Operation of the Brown & Sharpe Automatic Screw Machines," deals with the construction of these machines and the setting-up of the tools. No. 100, "Designing and Cutting Cams for Automatic Screw Machines," gives detailed instruction on cam design, and describes a simplified method for milling cams. No. 101, "Circular Form and Cut-off Tools for the Automatic Screw Machine," deals with the general arrangement and the calculations of these tools, and describes the different methods employed in their making. No. 102, "External Cutting Tools for the Automatic Screw Machine," deals with the design and construction of box-tools, taper turning tools, hollow mills, and shaving tools. No. 103, "Internal Cutting Tools for the Automatic Screw Machine," deals with centering tools, cross-slide drilling attachments, counterbores, reamers, and recessing tools. No. 104, "Threading Operations on the Automatic Screw Machine," treats on cam design for threading operations, threading dies, taps and tap drills, die and tap holders, and thread rolling. No. 105, "Knurling Operations on the Automatic Screw Machine," describes the construction of knurling holders, and gives directions for the making of knurls and the design of tools and cams used in connection with knurling operations. No. 106, "Milling, Cross-drilling and Burring Operations on the Automatic Screw Machine," describes screw-slotting attachments, index drilling attachments, and burring attachments, giving directions for their use and for the design of cams for them.

CHAPTER I

CROSS-SLIDE KNURLING OPERATIONS

In designing a set of cams for knurling operations on the Brown & Sharpe automatic screw machines, it is desirable that as little experimental work as possible be required. The following formulas and data will prove of value in this connection. Before presenting these data and formulas, however, the different tools and appliances necessary for knurling will be briefly reviewed.

A very solid and rigid rear cross-slide knurl-holder is shown in Fig. 1. It is held by means of the cap-screw *B* on the outside face *A* of the cross-slide tool-holder. This screw also holds the circular cut-off tool in position. The holder allows the knurl to pass over the work, and re-

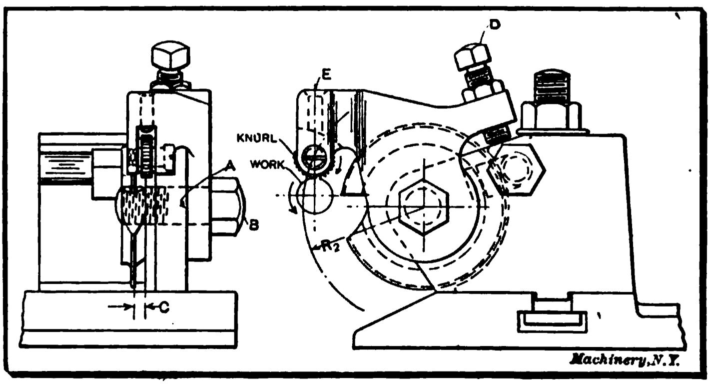
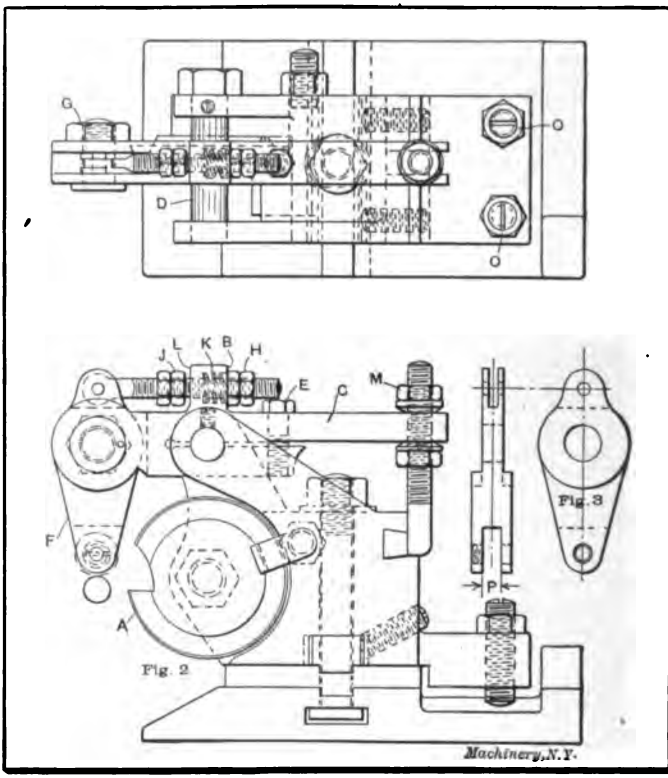


Fig. 1. Rear Cross-slide Knurl-holder

turns it after the piece has been cut off. It is simple and cheap, and covers a wide range of work, as the distance *C* to the circular cut-off tool can be changed so that the work will be cut off closer or further away from the knurl, as desired. The set-screw *D* rigidly supports the knurl-holder, and also provides means for adjusting. The oil hole *E* permits a good supply of oil to reach the knurl for removing all chips. This holder, however, can be used only on the tool-holder which carries the cut-off tool, because the finished piece must be severed from the bar before the knurl can return.

Universal Cross-slide Knurl-holder

The knurl-holder shown in Fig. 1 is limited in its range, but the one shown in Fig. 2, while more expensive and complicated, is also more efficient and universal. This holder eliminates the cross-slide tool-post, and carries the circular cut-off tool *A* in the same way as it would be held in the ordinary tool-post. It can also be used in conjunction with either circular form or cut-off tools on the front cross-slide. The knurl can operate at any desired position on the work by moving the arm *C* along the bar *D* and then clamping it by means of the cap screw *E*. The holder *F* which carries the knurl can be moved in or out to any position to suit the different diameters of stock being knurled, and is adjusted by means of adjusting nuts *H* and *J*. The nut *G* is adjusted to insure a good working fit of the holder, and also prevents side movements. When the knurl passes over the stock the nut *H* is brought up against the face *B* of the arm *C*, and also puts a tension on spring *K*,



Figs. 2 and 3. Universal Cross-slide Knurl-holder

so that when the knurl has passed over the work and the pressure on the spring is released, the spring forces the nut *J* up against the face *L* and permits the knurl to clear the work when passing back over the stock. The nuts *M* permit the arm *C* to be raised or lowered for different diameters of stock. The washers are convex, as shown, so that the arm is held firmly even when at an angle to the face of the nuts *M*. Screws *O* tend to steady the holder.

In Fig. 3 the knurl-holder proper is shown in detail. It will be seen that knurls of different widths may be used by making the distance *P* to suit.

Straight Knurls

Straight knurls, as shown in Fig. 4, are generally cut in the milling machine with a cutter of the desired angle. The greatest difficulty is met with in selecting a suitable angle for the teeth for knurling different materials. A blunt knurl will work better on soft materials than one with a more acute angle. The following angles are satisfactory for the materials specified below:

Brass and hard copper	90 degrees.
Gun screw iron	80 degrees.
Norway iron and machine steel	70 degrees.
Drill rod and tool steel	60 degrees.

When laying out a set of cams for knurling operations, it is necessary to know the depth of the tooth in the knurl.

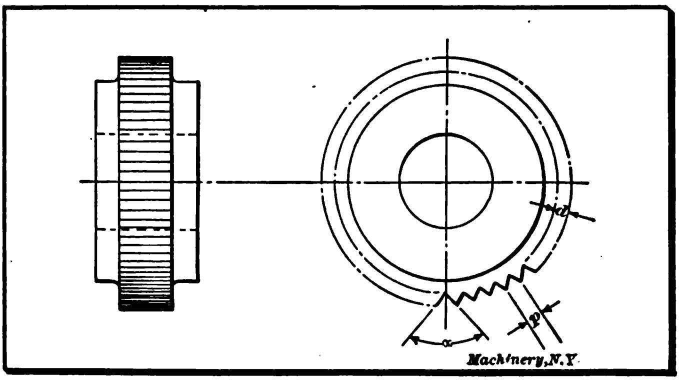


Fig. 4. Straight Knurl

If d = depth of tooth in knurl,
p = circular pitch of knurl,
P = "pitch of knurl" = number of teeth in one inch of the circumference $= \frac{1}{p}$,
a = included tooth angle of knurl,

then, for all practical purposes, the depth may be calculated as follows: When

$$a = 90 \text{ degrees}, \quad d = \frac{p}{2},$$

$$a = 80 \text{ degrees}, \quad d = \frac{p}{2} \times \tan 50 \text{ degrees},$$

$$a = 70 \text{ degrees}, \quad d = \frac{p}{2} \times \tan 55 \text{ degrees},$$

$$a = 60 \text{ degrees}, \quad d = \frac{p}{2} \times \tan 60 \text{ degrees}.$$

The values of *d* for different pitches ranging from 16 to 62 teeth per inch of circumference have been calculated from these formulas and are given in Table I.

Concave Knurls

The designing of a concave knurl which will work satisfactorily is, in most cases, a difficult problem, as the radius of the knurl cannot have the same radius as the piece to be knurled. It will be seen in Fig. 5 that if the knurl and the work are of the same radius, the material compressed by the knurl will be forced down on the shoulder *A*

TABLE I. DEPTH OF TEETH IN KNURLS

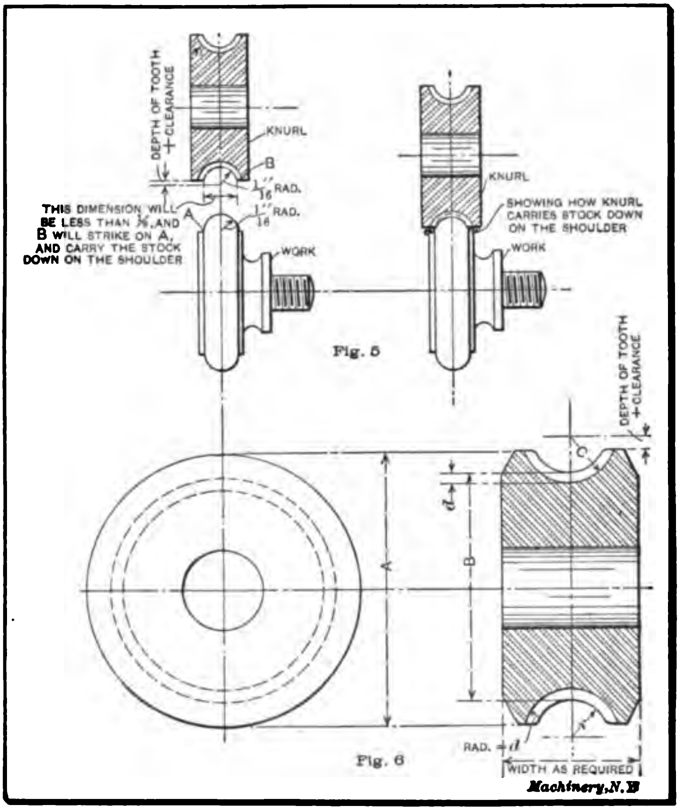
P = number of teeth in one inch of circumference
p = circular pitch
a = included angle of tooth
d = depth of tooth

P	p	$a = 90°$	$a = 80°$	$a = 70°$	$a = 60°$
		d	d	d	d
16	0.0625	0.0312	0.0371	0.0445	0.0540
18	0.0555	0.0277	0.0330	0.0395	0.0480
20	0.0500	0.0250	0.0297	0.0357	0.0433
22	0.0454	0.0227	0.0260	0.0324	0.0393
24	0.0416	0.0208	0.0247	0.0297	0.0360
26	0.0384	0.0192	0.0228	0.0274	0.0332
28	0.0357	0.0178	0.0212	0.0254	0.0308
30	0.0333	0.0166	0.0199	0.0237	0.0287
32	0.0312	0.0156	0.0185	0.0223	0.0270
34	0.0294	0.0147	0.0175	0.0209	0.0254
36	0.0277	0.0138	0.0164	0.0197	0.0239
38	0.0263	0.0131	0.0156	0.0187	0.0226
40	0.0250	0.0125	0.0148	0.0178	0.0216
42	0.0238	0.0119	0.0142	0.0169	0.0206
44	0.0227	0.0113	0.0134	0.0161	0.0195
46	0.0217	0.0108	0.0128	0.0154	0.0187
48	0.0208	0.0104	0.0124	0.0148	0.0180
50	0.0200	0.0100	0.0119	0.0142	0.0173
52	0.0192	0.0096	0.0114	0.0137	0.0166
54	0.0185	0.0092	0.0109	0.0131	0.0159
56	0.0178	0.0089	0.0106	0.0127	0.0154
58	0.0172	0.0086	0.0102	0.0122	0.0148
60	0.0166	0.0083	0.0090	0.0118	0.0143
62	0.0161	0.0080	0.0096	0.0114	0.0138

and will consequently make a poor looking job. The writer, having met with this difficulty, devised an empirical formula which gives satisfactory results.

A design of a concave knurl is shown in Fig. 6, and all the important dimensions are designated by letters. To find these dimensions, the pitch of the knurl required must be known, and also, approximately, the throat diameter *B*. This diameter, of course, must suit the knurl holder used, and be such that the circumference contains an even number of teeth with the required pitch. When these dimensions have been decided upon all the other unknown factors can be found from the formulas given in the following.

Let R = radius of piece to be knurled,
r = radius of concave part of knurl,
C = radius of cutter or hob for cutting the teeth in the knurl,
B = diameter over concave part of knurl (throat diameter),
A = outside diameter of knurl,
d = depth of tooth in knurl,
P = pitch of knurl (number of teeth per inch circumference),
p = circular pitch of knurl.



Figs. 5 and 6. Concave Knurls

Then, $r = R + \frac{1}{2} d$,
$C = r + d$,
$A = B + 2r - 3d + 0.010$ inch.

As the depth of the tooth is very slight, the outside circumference will be accurate enough for all practical purposes for calculating the pitch, and it is not necessary to take into consideration the pitch circle as is done when calculating gears.

Example:—Assume that the pitch of a knurl is 32, that the throat diameter B is 0.5561 inch, that the radius R of the piece to be knurled is 1/16 inch, and that the angle of the teeth is 90 degrees; find the dimensions required for making the knurl.

Using the same notation as above, we have:

$$p = \frac{1}{P} = \frac{1}{32} = 0.03125 \text{ inch},$$

$$d = 0.0156 \text{ inch (see Table I)},$$

$$r = \frac{1}{16} + \frac{0.0156}{2} = 0.0703 \text{ inch},$$

$$C = 0.0703 + 0.0156 = 0.0859 \text{ inch},$$

$$A = 0.5561 + 0.1406 - 0.0468 - 0.010 = 0.6399 \text{ inch}.$$

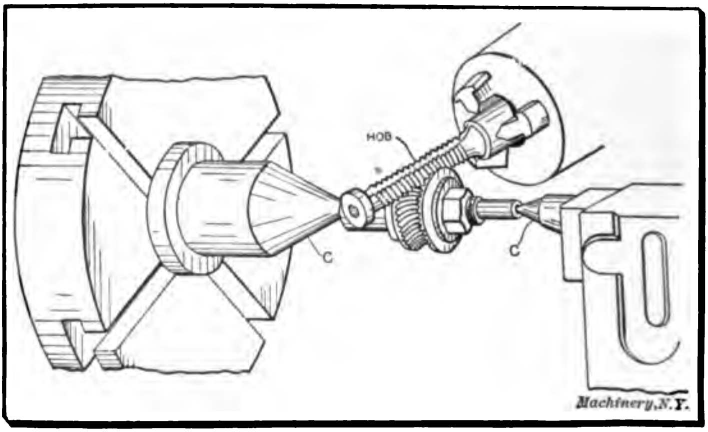


Fig. 7. Cutting a Concave Knurl by a Hob in the Milling Machine

Straight concave knurls, when very small, are generally made with a master convex knurl. When the knurls are large enough, a milling cutter with the proper radius is used for cutting the teeth. As it is very difficult to make a concave knurl when the radius is very small, and as the knurl in most cases is not required to be absolutely straight, the method described in the following for spiral knurls can be used for making straight concave knurls on the milling machine with teeth in planes practically parallel with the axis of the knurl.

Spiral Concave Knurls

It is, in general, very difficult to cut spiral concave knurls, especially when the radius of the knurl is very small. In Fig. 7 is shown a method which has worked very satisfactorily, and which is also easily accomplished. A hob as shown in Fig. 8 is used, the included angle of the threads of which is made to suit the material to be knurled. The hob is fluted similarly to a master tap, except that the flutes are not as deep and a greater number of flutes is used. The lead of the hob governs the angle of the spiral on the knurl, and the angle formed by cutting hobs with different leads can be derived, approximately, by means of the following formula:

Let a = angle required,
B = one-half the lead of the thread of the hob,
D = diameter of the hob.

$$\text{Then } \frac{B}{1.5\,D} = \tan a.$$

Example:—If a hob has a double thread, the lead of which is ⅛ inch, and the diameter of the hob is ¼ inch, find the angle a.

B = ½ of the lead = 1/16, and, therefore, $\tan a = 1/16 \div 3/8 = 0.1667$; $a = 9\frac{1}{2}$ degrees.

Cutting a Spiral Concave Knurl in the Milling Machine

It will be seen from Fig. 7 that when cutting a concave knurl in the milling machine, the knurl is held on an arbor shown in detail in Fig.

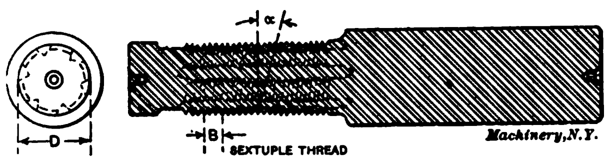


Fig. 8

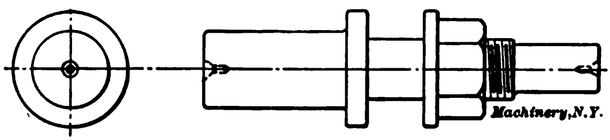


Fig. 9

Fig. 8. Hob used for Cutting Concave Knurls in the Milling Machine
Fig. 9. Arbor for Cutting Concave Knurls in the Milling Machine

9. This arbor rotates freely on the centers C, the knurl being held tightly against the shoulder on the arbor by the nut shown. When the knurl has been tightened, the arbor is put between the centers and the table of the milling machine is raised so that the hob comes in contact with the knurl. The machine runs slowly at the start so that the hob will not be forced, but will space the teeth equally. The speed can be increased after the hob has started to cut properly. The hob is held in a chuck provided with a shank fitting the socket in the milling machine spindle. The work should be fed slowly at first, and care should be taken that the arbor rotates freely on the centers, as otherwise the knurl will not follow the lead of the hob properly, and a well-shaped tooth will not be produced. Care should also be taken to have the diameter of the concave knurl the correct size so that it will contain an even number of teeth, as required by the circular pitch. When the knurl has been cut, the corners should be removed as shown in Fig. 6; then no ragged edges are left on the work, as is the case if the corners are not removed. The table of the milling machine should not be set over when cutting knurls in this manner, but should be left straight.

Designing and Cutting Diamond Knurls

The general methods of using diamond knurls are as follows:

1. When a knurl-holder, as shown in Fig. 10, can be used, a pair of spiral knurls are used, one right- and one left-hand.

2. When a cross-slide knurl-holder, as shown in Fig. 1, is used, only one knurl can be used, being cut both right- and left-hand. A knurl cut in this manner would produce a female knurl on the work; so if a male knurl is required on the work, the first knurl is used as a master knurl in cutting the second knurl which will produce a male knurl on the work.

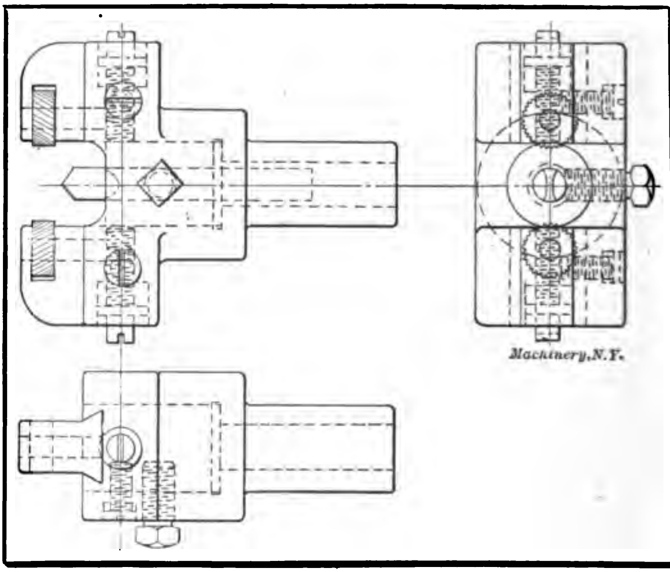


Fig. 10. Turret Knurl-holder for Brown & Sharpe Automatic Screw Machines

When only the pitch of the knurl required and the angle at which the teeth are cut, as indicated in Fig. 11, are known, then the number of teeth in the knurl must be found and also the spiral lead, as this governs the selection of the change gears used when cutting the knurl.

To Find the Number of Teeth on the Circumference of the Knurl

When the knurl is to form diamond shapes, as shown in Fig. 11, and the included angle is 60 degrees, the number of teeth can be found in the following manner. Let 22 be the normal pitch of the knurl. Then the circular pitch will be 0.0455 inch $\div$ cos 30 degrees $=$ 0.0525 inch, and the outside circumference divided by 0.0525 inch will be the number of teeth of the knurl.

To Find the Lead of the Spiral

To find the lead of a spiral of the knurl mentioned multiply the circumference of the knurl by the cotangent of 30 degrees. Assume that the knurl is 0.752 inch in diameter. Then the circumference equals 0.752 × 3.1416 = 2.3625 inches. The knurl has a circular pitch of 0.0525 inch, and the number of teeth therefore equals 2.3625 ÷ 0.0525 = 45 teeth. The lead equals 2.3625 × cot 30 degrees = 4.09 inches.

Speeds and Feeds for Knurling

When the knurl has been designed, the next thing to consider, before laying out the cams, is the speed and feed for knurling. This is a subject upon which very little has ever been published. As a general rule, a knurl can be worked at the same speed as the circular form and cut-off tools. It is good practice to feed the knurl gradually to the center of the work, starting to feed where the knurl touches the

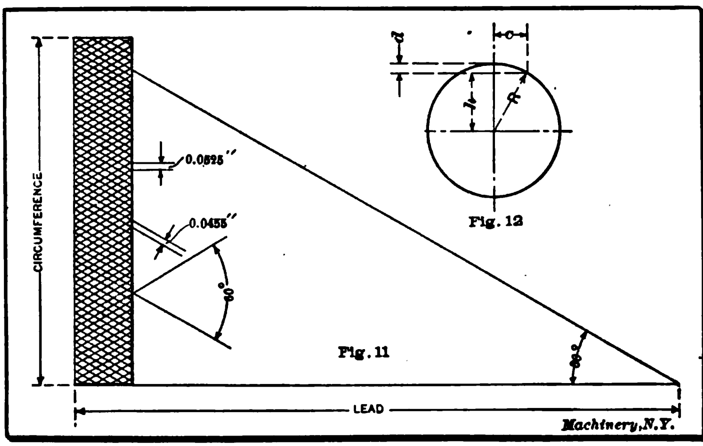


Fig. 11. Diagram for Finding Circular Pitch and Lead of Spiral Knurls
Fig. 12. Diagram for Calculations Relating to the Feeds of Knurls

work as is shown by the distance c in Fig. 12, and then to pass off the center of the work with a quick rise on the cam. The knurl should also dwell for a certain number of revolutions, depending on its pitch, and the nature of the material being worked upon. Some advocate the knurl being brought into position on the center of the work on the quick rise of the cam, and then being allowed to dwell for a certain number of revolutions; but the writer has found that this does not work satisfactorily, and cannot be depended upon. It might work when using a knurl which has a very fine pitch, on large stock, but under general conditions it will be found that gradually feeding the knurl to the center of the work will work better.

The feed required for a knurl is governed by the nature of the material being knurled, the diameter of the material, and the width and pitch of the knurl.

The surest and most practical way to find the feed required for a knurl on a certain kind of material is by experimenting. The writer has collected the results of different experiments and compiled them in Table II. This table covers practically all the different materials specified in this article, as the angle of the teeth in the knurls varies in accordance with the hardness of the material on which the knurl is used. In that case the feeds given in the table will be practically the same for all the materials previously specified. These feeds are only applicable when knurling from the cross-slide.

TABLE II. FEEDS FOR KNURLING

Diam. of Stock, Inches	Width of Knurl, Inches							
	1/16	1/8	3/16	1/4	5/16	3/8	7/16	1/2
	Feed per Revolution, Inches							
1/16	0.0010	0.0005	....	......	......	.....	......	......
1/8	0.0014	0.0009	0.0005	......	......	......	.....	......
3/16	0.0018	0.0012	0.0010	0.0005	......	......	.....	......
1/4	0.0022	0.0016	0.0014	0.0010	0.0005	.....	......	......
5/16	0.0026	0.0020	0.0018	0.0013	0.0010	0.0005	.....	......
3/8	0.0030	0.0025	0.0022	0.0017	0.0015	0.0010	0.0005	......
7/16	0.0034	0.0029	0.0026	0.0021	0.0018	0.0015	0.0010	0.0005
1/2	0.0039	0.0032	0.0030	0.0025	0.0022	0.0020	0.0014	0.0008
9/16	0.0042	0.0036	0.0034	0.0029	0.0028	0.0024	0.0017	0.0012
5/8	0.0046	0.0040	0.0038	0.0033	0.0031	0.0028	0.0020	0.0016
11/16	0.0050	0.0045	0.0042	0.0037	0.0034	0.0031	0.0023	0.0020
3/4	0.0054	0.0049	0.0048	0.0041	0.0038	0.0034	0.0026	0.0023
13/16	0.0059	0.0052	0.0052	0.0045	0.0042	0.0037	0.0029	0.0026
7/8	0.0062	0.0058	0.0055	0.0049	0.0045	0.0040	0.0033	0.0029
15/16	0.0068	0.0062	0.0058	0.0052	0.0048	0.0042	0.0037	0.0032
1	0.0070	0.0065	0.0060	0.0055	0.0050	0.0045	0.0040	0.0035

Under these conditions the depth of the tooth and the feed per revolution will govern the number of revolutions required to knurl. If in Fig. 12, R is the radius of the stock, d is the depth of the tooth, c is the distance the knurl travels at a given feed per revolution, and h equals $R - d$, then $c = \sqrt{R^2 - (R - d)^2}$.

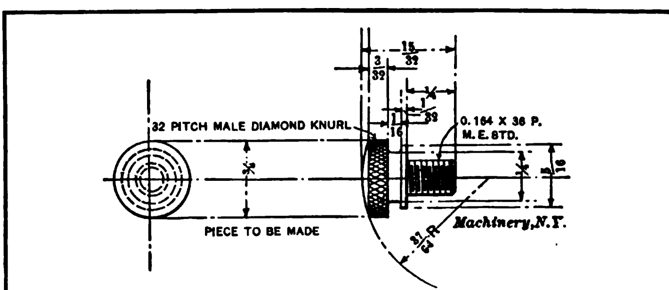


Fig. 13. Thumb-screw to be Knurled

Let $R = 0.125$ inch and $d = 0.0164$ inch; then $h = 0.1086$ inch. Therefore $c = \sqrt{0.125^2 - 0.1086^2} = 0.062$ inch = rise required.

Revolutions Required to Knurl

Assume that it is required to find the number of revolutions to knurl a piece of gun screw iron, ¼ inch in diameter, with a knurl ⅛ inch

TABLE III. DIMENSION A, FIG. 15, FOR DIFFERENT ANGLES OF CUT-OFF TOOLS

Thickness of Tool	β = 10 deg.		β = 15 deg.		β = 18 deg.		β = 20 deg.		β = 23 deg.	
	A	2 A	A	2 A	A	2 A	A	2 A	A	2 A
0.030	0.0052	0.0105	0.0080	0.0160	0.0097	0.0195	0.0109	0.0218	0.0127	0.0254
0.035	0.0061	0.0123	0.0093	0.0187	0.0118	0.0227	0.0127	0.0255	0.0148	0.0296
0.040	0.0070	0.0140	0.0107	0.0214	0.0130	0.0260	0.0145	0.0291	0.0169	0.0339
0.045	0.0079	0.0158	0.0120	0.0241	0.0146	0.0292	0.0163	0.0327	0.0190	0.0381
0.050	0.0088	0.0176	0.0134	0.0268	0.0162	0.0325	0.0182	0.0364	0.0212	0.0424
0.055	0.0096	0.0193	0.0147	0.0294	0.0178	0.0357	0.0200	0.0400	0.0233	0.0466
0.060	0.0105	0.0211	0.0160	0.0321	0.0195	0.0390	0.0218	0.0436	0.0254	0.0508
0.065	0.0114	0.0228	0.0174	0.0348	0.0211	0.0422	0.0236	0.0473	0.0275	0.0551
0.070	0.0123	0.0246	0.0187	0.0374	0.0227	0.0455	0.0254	0.0509	0.0296	0.0593
0.080	0.0140	0.0281	0.0214	0.0428	0.0260	0.0520	0.0291	0.0582	0.0339	0.0678
0.090	0.0158	0.0316	0.0241	0.0482	0.0292	0.0585	0.0327	0.0655	0.0381	0.0763
0.100	0.0176	0.0352	0.0268	0.0536	0.0325	0.0650	0.0364	0.0728	0.0424	0.0848
0.110	0.0193	0.0387	0.0294	0.0589	0.0357	0.0715	0.0400	0.0800	0.0466	0.0932
0.115	0.0202	0.0404	0.0308	0.0616	0.0373	0.0747	0.0418	0.0837	0.0487	0.0975
0.120	0.0211	0.0422	0.0321	0.0643	0.0390	0.0780	0.0436	0.0873	0.0508	0.1017
0.125	0.0220	0.0440	0.0335	0.0670	0.0406	0.0812	0.0455	0.0910	0.0530	0.1060

wide of 36 pitch. The included angle of the tooth for gun-screw iron is 80 degrees. The circular pitch is 0.0277, and, referring to Table I, the depth of the tooth is 0.0164; the distance *c*, as worked out in the previous example, is 0.062 inch. Then, referring to Table II, the feed per revolution for a knurl ⅛ inch wide, knurling on ¼-inch stock, is 0.0016 inch per revolution. Therefore, total revolutions required = 0.062 ÷ 0.0016 = 38.7 or, approximately, 39 revolutions. In some cases the feeds given in Table II can be increased 50 per cent and still give good results.

Let us now assume an example of a knurling operation on the No. 0 Brown & Sharpe automatic screw machine, and find the principal dimensions of the cam for performing same. A thumb-screw, as is shown at Fig. 13, is to be knurled with a 32-pitch knurl, ⅛ inch wide, using a cross-slide knurl-holder as shown in Fig. 1.

Total Rise on Cam

It is required to find the total rise on the cam to complete the knurling, and also to cut the finished piece from the bar. The total rise can be found by means of the following formulas, derived by the aid of the diagram in Fig. 15. This shows the knurl in position on the center of the work, and the circular cut-off tool is also shown in its relative position to the work and the knurl.

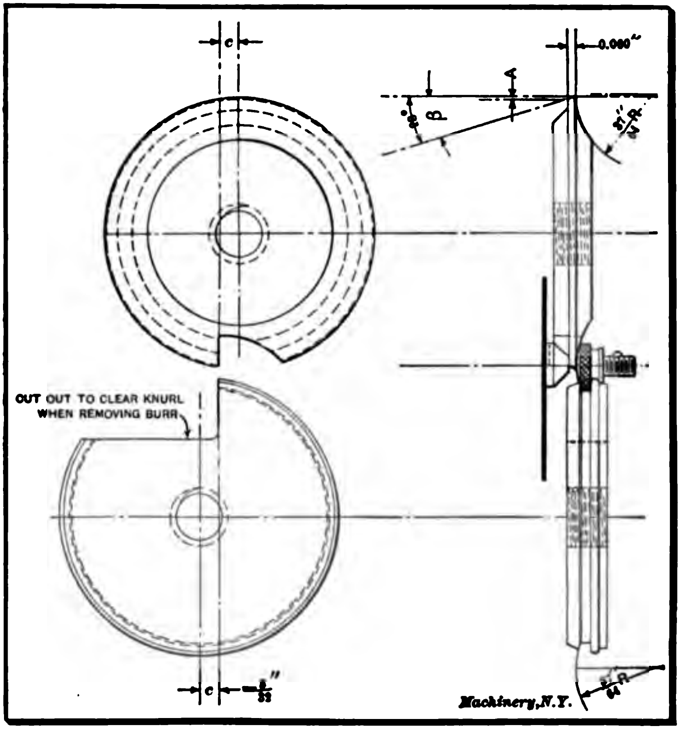


Fig. 14. Circular Forming and Cut-off Tools for Making Thumb-screw shown in Fig. 13

Let T = total rise on the cam,

N = rise required to knurl,

S = radius of stock to be cut off,

A = distance of bevel on cut-off tool as given in Table III,

C = total rise required to cut-off = S + 0.010 inch (to approach) + 0.005 inch (to pass center of stock) + A,

E = distance from center of circular tool to edge as shown, when tool is cut down below the center,

a = radius of knurl to outside diameter,

b = radius of stock minus depth of tooth in knurl,

c = distance from cutting face to center of circular tool,

$h = a + b + c$,

X = distance from center of cut-off tool to center of knurl, when it is in position on the center of the stock,

R = radius of stock,
r = radius of knurl,
R_1 = radius of cut-off tool,
R_2 = radius of knurl holder shown in Fig. 1,
F = distance between the knurling and cut-off operations. Then
$E = \sqrt{R_1^2 - c^2}$; $X = \sqrt{R_2^2 - h^2}$;
$N = \sqrt{R^2 - (R-d)^2}$ (See Fig. 12).

$$F = X - (S + E);\quad T = N + F + C,$$

For example, let it be required to design a set of cams to make the thumb-screw shown in Fig. 13, the material being 3/8-inch round brass rod, and on which is cut a 32-pitch knurl. For the knurling operation we will use a cross-slide knurl-holder, as shown in Fig. 1. R is 0.1875

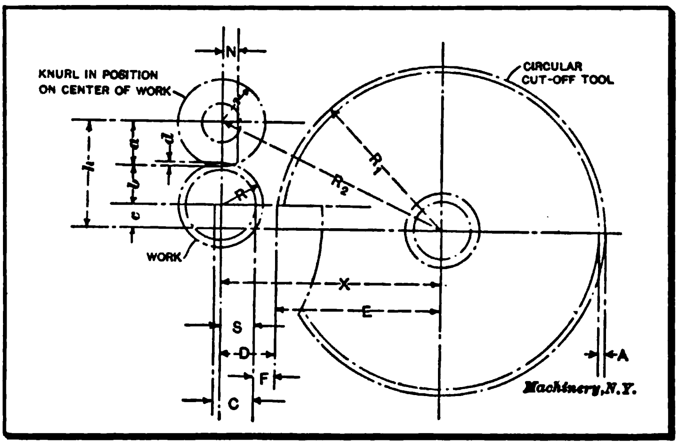


Fig. 15. Diagram for Finding Total Rise of Cam for Knurling Operation

inch, r is 0.375 inch, R_1 is 1.125 inch, R_2 is 1.625 inch; d is 0.0156 inch, angle on cut-off tool is 23 degrees, and the width of the cut-off tool is 0.060 inch; then, referring to Table III, A is 0.0254 inch. The cut down below the center on the circular tool c is 5/32 inch. Then, $a = 0.375$; $b = 0.1875 - 0.0156 = 0.1719$; $c = 0.1562$; $h = 0.7031$.

$E = \sqrt{(1.125^2 - 0.1562^2)} = 1.114$,
$X = \sqrt{(1.625^2 - 0.7031^2)} = 1.465$,
$N = \sqrt{0.1875^2 - (0.1875 - 0.0156)^2} = 0.075$,
$S = 0.1562$ inch, which is the radius of the shoulder left by the circular form-tool,
$C = 0.1562 + 0.010 + 0.005 + 0.0254 = 0.1966$,
$F = 1.465 - (0.1562 + 1.114) = 0.1948$,
$T = 0.075 + 0.1948 + 0.1966 = 0.4664$ inch, which is the total rise required on the cam, for the knurling and the cut-off operations.

Having determined the total rise required on the cam, we will consider briefly the other operations. The order of the various operations is given in the layout chart on page 20, and the position and type of tools used in the turret are shown in Fig. 16. As all the various operations are shown plainly on the chart very little explanation will be required.

Before starting to design the cams, the drawings of the tools suitable for performing the various operations are collected, using standard tools as much as possible. Then, after selecting the various tools, a lay-out of the circular form and cut-off tools, as shown at Fig. 14, is made. After having drawn the circular tools, and also laid out the turret operations as shown in Fig. 16, the order of the various operations is considered. Referring to the plan of operations shown in the chart, the work proceeds in the following order: Feed stock to stop and chuck, revolve turret, and rough turn with the hollow mill shown in Fig. 16; while the hollow mill is turning down the work, the circular form tool is brought in and forms the head; the form tool retreats so that it will clear the face of the hollow mill; then the turret is revolved and the finishing box-tool turns down the portion which is to be threaded. Now the turret is revolved and the die-holder is brought into position, and the work is threaded. By referring to Fig. 20, it will be seen that the highest portion of the lobe for the die is cut down equal to two threads, or 0.0554; this allows the die holder to draw out, and the spindle reverses on the tension of the spring (when a draw die-holder is used), which makes the die work easier, and does not

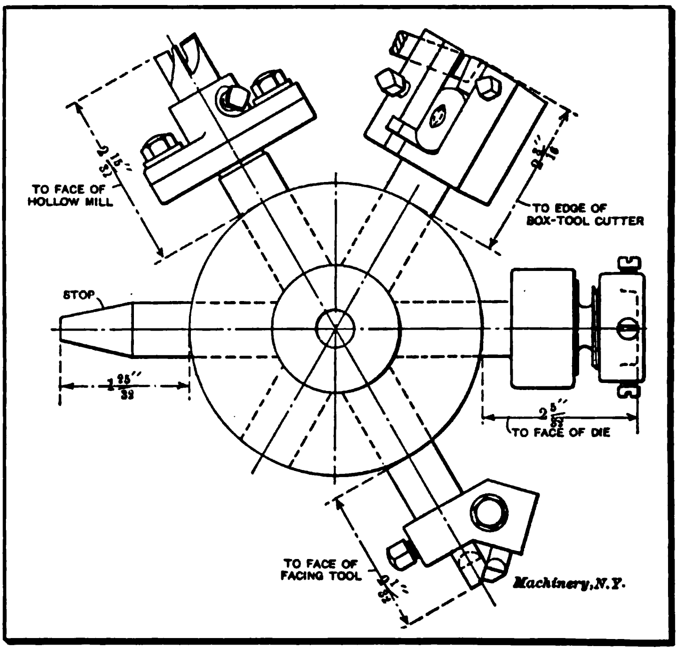


Fig. 16. Arrangement of Tools in the Turret

crowd it on the work. After the die comes off the work, clearance is allowed between the knurling tool and the die holder, which should be ample so that the tools will not come in contact with each other. Then the knurl travels onto the work, and dwells for 0.01 of the circumference (which in this case is equal to 4.2 revolutions of the spindle), when on the center of the work. It is then forced off the work by the rise shown in Fig. 20, on the back cam. The circular form tool is now brought in again and removes the burr thrown up by the knurl; the form tool is cut away to clear the knurl. Finally, the back cross-slide travels in, and the circular cut-off tool shown in Fig. 14 starts to cut off the piece, but while the piece is being cut off, the pointing tool shown in Fig. 16 is brought in and removes the burr that has been

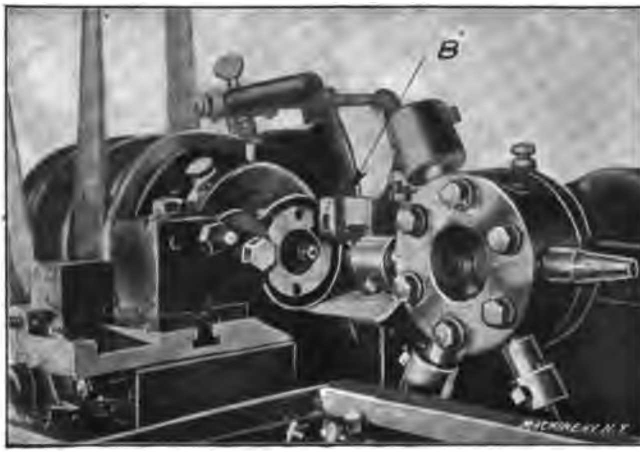


Fig. 17. Machine set up and ready for Making Thumb-nuts

thrown up by the die on the end of the screw; the piece is then severed from the bar, and clearance is allowed to let the cut-off tool return before the stock is fed out again.

Cutting the Cams

After the cam blanks have been laid out, they are roughed out by drilling a series of holes about 1/8 inch or 3/16 inch away from the finishing line or by punching, which is performed on an ordinary punch-press. Then the cam is put onto a circular milling attachment. A vertical milling attachment is used in connection with the circular attachment, and a mill of the required diameter, which depends on the size of the roll on the automatic screw machine, is used for cutting the cam. The circular attachment is graduated in degrees and minutes, and it is, therefore, necessary to find the number of minutes in the number of hundredths on the lobe of the cam to be milled.

The surface of the cam is divided into one hundred equal parts, and since there are 360 degrees in a circle, one-hundredth equals 3.6 degrees, or $3.6 \times 60 = 216$ minutes.

To find the number of minutes which is equal to 0.001 inch rise, divide the total number of minutes contained in the lobe by the total number of thousandths rise. When cutting the cam, the platen of the milling machine is moved till the cutter comes in contact with the edge or face of the cam; then the cutter is fed in 0.001 inch, and the circular attachment is turned the required number of minutes, which is equal to 0.001 inch rise. The milling operation is continued in this way until the lobe is completed. Milling the cam in this manner leaves

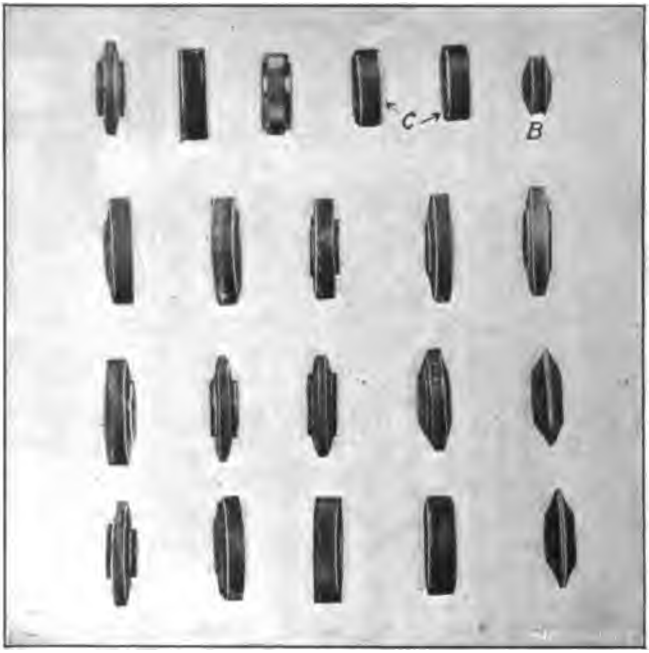


Fig. 18. A Collection of Knurls of Different Types

a series of little steps, or rises, which can be removed with a file, and in this way a true surface is obtained.

In the half tone, Fig. 17, are shown, in position, the tools used in making a knurled thumb nut. The cross-slide knurling tool illustrated in Fig. 1 is shown at *B* in position on the back cross-slide. In Fig 18 is shown a variety of knurls; at *B* is shown a concave knurl made by the method illustrated in Fig. 7, and at *C* is shown a pair of knurls which will produce a diamond knurl as shown in Fig. 11, when they are used in the knurl-holder shown in Fig. 10.

CHAPTER II

TURRET KNURLING OPERATIONS

The previous chapter deals particularly with cross-slide knurling operations, while the present takes up knurling from the turret, and special knurling operations. An adjustable knurl-holder for turret knurling is shown in Fig. 19. This holder can be used for either spiral or straight knurling, as the knurl-holders *A* can be swiveled to any angle. The illustration shows the holders set with the zero mark opposite 30 degrees, in which position the knurls would produce a diamond knurl, as shown on the piece *A* in Fig. 21. The

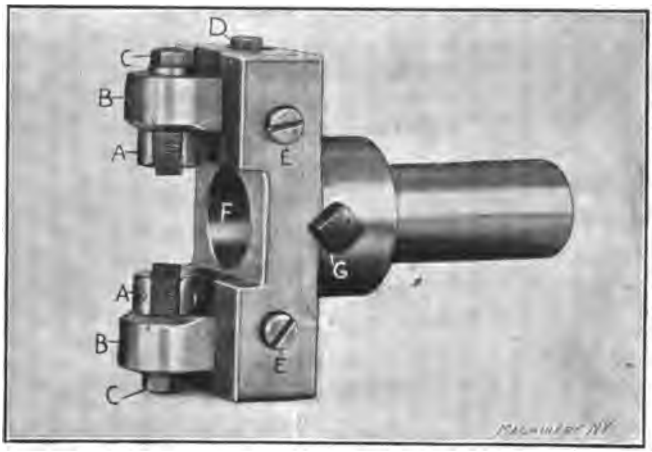


Fig. 19. Brown & Sharpe Adjustable Turret Knurl-holder

knurl-holders *A* are held in the lugs *B* by collar nuts *C* which are screwed onto the threaded shank of the holders. Lugs *B* are graduated at 5-degree intervals, so that the knurls can be easily set to the desired angle. These lugs project into the body of the holder and fit in beveled slots cut to receive them. The lugs are adjusted in and out by means of collar-head screws *D*, only one of which is shown in the illustration. These collar-head screws are locked by means of small brass shoes, operated on by the headless screws *E*.

This knurl-holder can also be provided with bushings which fit in the hole *F* for holding centering tools or other internal cutting tools, so that other operations can be performed at the same time as the knurling operation. The cutting tools are held in position in the bushing by means of the set-screw *G*. The chief advantage of this knurl-holder is that straight knurls can be used for spiral as well as for straight knurling. This is an important feature, as straight knurls

NAME *Knurled Thumb Screw*

MADE ON No. 0 B & S AUTO. SCREW MACHINE

MATERIAL USED *3/8" Round Brass Rod*

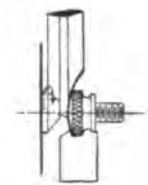
SPINDLE SPEEDS *1800* R.P.M. FORWARD, *1800* R.P.M. BACKWARD

1 PIECE *14* SECONDS, *2571* PIECES GROSS PRODUCT IN 10 HRS

No. *60* GEAR ON DRIVING SHAFT, ____ No. *28* GEAR ON WORM SHAFT.

No. ____ " " 1ST STUD. No. ____ " " 2ND STUD.

CHUCKING.



DESIGNER'S INITIALS *D.T.H.*

DATE, *May 11, 1909*

DWG No.	TOOL No.	REV.	TOTAL REVS. TO PRODUCE ONE PIECE.	HUND.	START	FINISH	RISE	FEED	OPERATIONS PERFORMED.
		21.	420	5	0	5			Feed stock to stop and chuck
		25.2		6	5	11			Revolve turret
		50.4		12	11	23	0.240"	0.00476"	Rough turn (with hollow mill)
		37.8		9	6	15	0.062"	0.00184"	Form (dwell 0.01)
		25.2		6	23	29			Revolve turret
		29.4		7	29	36	0.250"	0.0099"	Finish turn (with Box-Tool; dwell 0.01)
		25.2		6	36	42			Revolve turret
		11.55		2 3/4	42	44 3/4	0.320"	0.164"x36 P	Die on } Reverse Spindle
		11.55		2 3/4	44 3/4	47 1/2	0.320"	0.164"x36P	Die off } Reverse Spindle
		18.9		4 1/2	47 1/2	52			Clearance
		29.4		7	52	59	0.075"	0.00255"	Knurl on rise
		4.2		1	59	60			Dwell with knurl while removing burr and pass over Center; rise 0.080"
		16.8		4	60	64	0.020"	0.00158"	Remove burr (with form tool) dwell 0.01
		4.2		1	64	65	0.114"		Rise to cut-off
		21.		5	70	75	0.035"	0.00207"	Point Dwell 0.01 while cutting off
		88.2		21	65	86	0.156"	0.00175"	Start cut-off } Revolve Turret twice
		42.		10	86	96	0.040"	0.0009"	Finish cut-off } Revolve Turret twice
		16.8		4	96	100			Clearance
		CAMS. *Lead, Front, Back*							

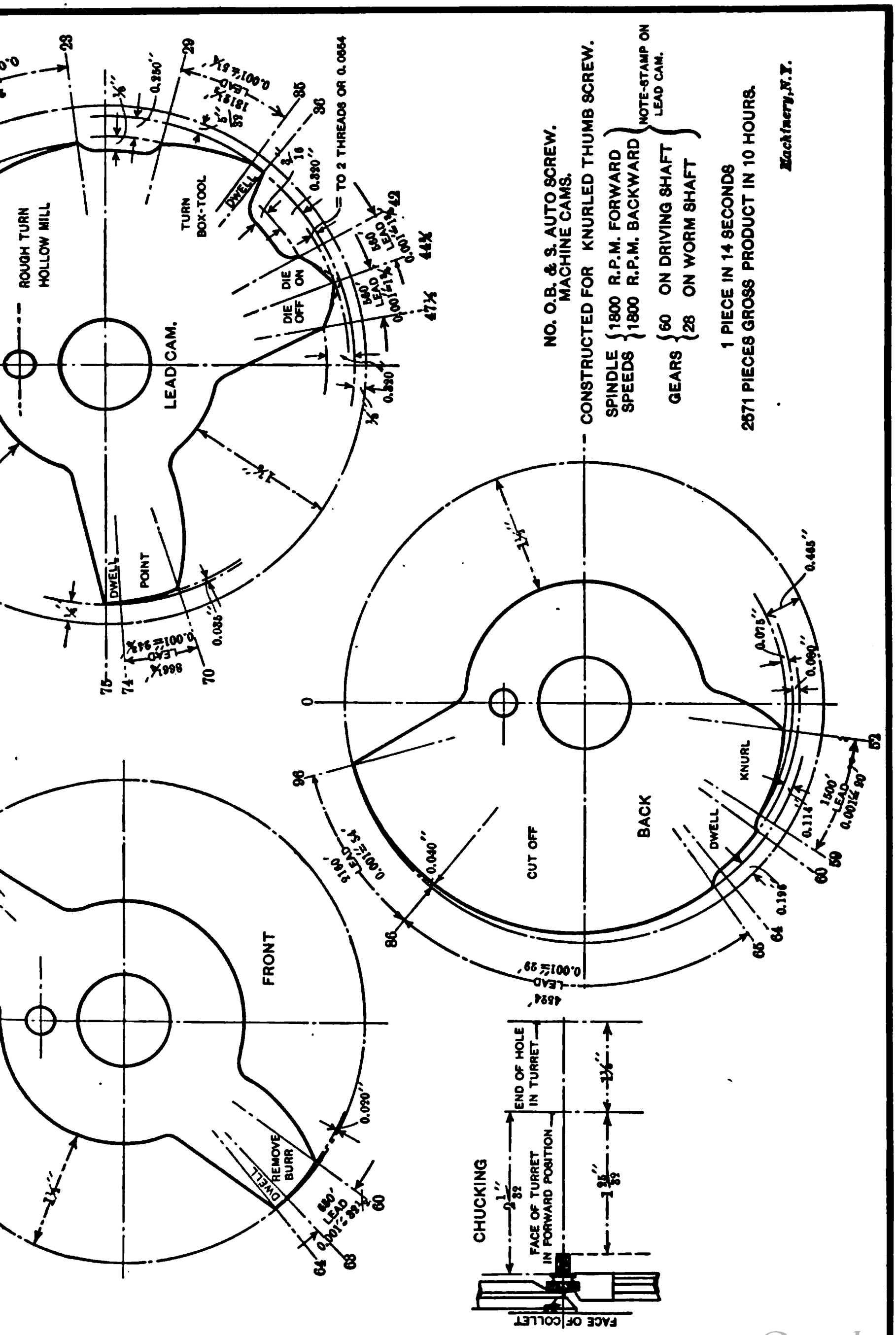


Fig. 20. Chart of Operations and Lay-out of Cams used for Making Thumb-screw shown in Fig. 18

are more easily and quickly cut than spiral knurls, and also produce better results.

Opening Knurl-holder

The range of the knurl-holder shown in Fig. 19 is somewhat limited, in that it is impossible to knurl work a distance away from the end, when the diameter to be knurled is smaller than or of the same size as the part preceding it. For this class of work it is necessary to bring the knurl-holder onto the work, and then force the knurls in to the depth required so that the work can be knurled in any desired position without passing over the whole surface. A knurl-holder which can be used for this class of work is shown in Fig. 22. This type is used especially for work similar to that shown at *B* and *C* in

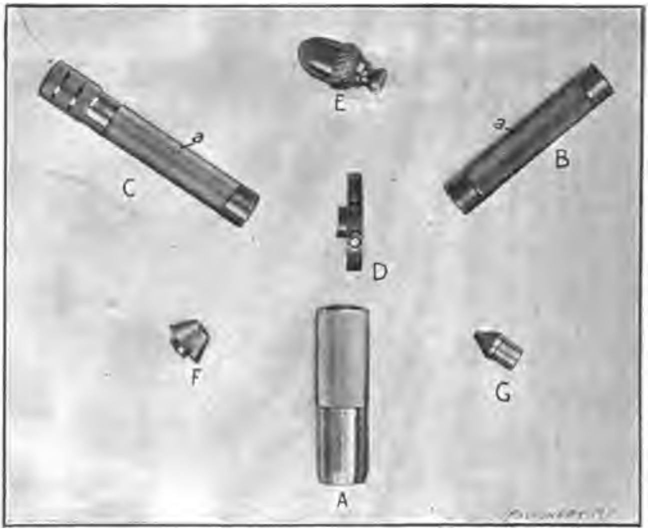


Fig. 21. Samples of Knurled Work

Fig. 21, where, as can be seen, the knurled portions *a* are practically in the center of the work.

The knurl-holder shown in Fig. 22 is made on the "swing" principle, and consists mainly of two swinging members *A*, in which the knurl-holders *B* are held by set-screws *C*. Rectangular holes are provided in the swinging members *A*, into which these knurl-holders *B* fit. As these two swinging members have to work together, it is necessary to connect them. This is accomplished, as shown in the illustration, by two connecting links *D*, attached to a stud *E* held in the main body of the holder *F* by the nut *G* which is screwed onto the shank of the stud.

In operation, the rising block, held on the cross-slide, presses against the point *a* of the screw *H*, and forces the right swinging member *A* in the direction of the arrow. This revolves the stud *E* in the direction of the arrow, which action, in turn, draws in the left swinging arm.

These members are held apart by coil spring *I* pressing against two spring plungers *J*, which, in turn, press against two pins *K* held in the swinging members. These pins *K* project into the main body of the holder, and are stopped by means of two headless screws *L*, which are tapped into the holder. The swinging members *A* are, as plainly shown, attached to the main body of the holder in the same manner as

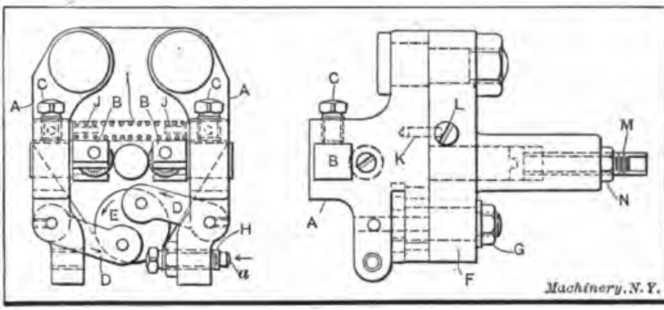


Fig. 22. Brown & Sharpe Opening Knurl-holder

an ordinary swing tool. The knurl-holders in this case, however, cannot be set to any desired angle, but are held rigidly, so to speak, in the swinging members. The forward ends of these holders are offset so that a straight knurl is held at an angle of 30 degrees with the axis of the holder for producing diamond knurling. However, the knurl-holder proper can be used for straight knurling or other knurling from

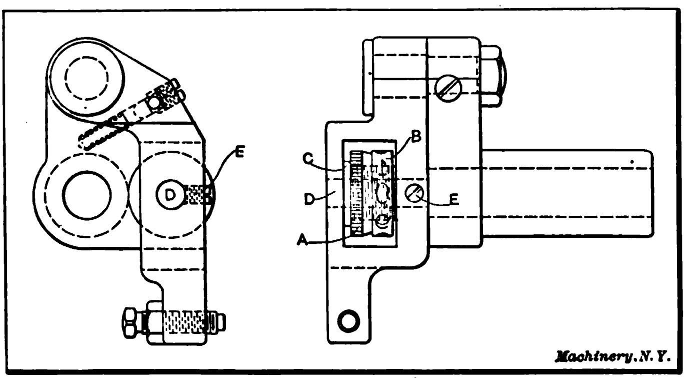


Fig. 23. Numbering Tool of the Swing Type

the turret, by supplying it with knurl-holders *B* of the desired shape to suit conditions.

This knurl-holder is provided with a stop *M*, similar in shape to an ordinary fillister-head screw, which is tapped into the shank of the holder. The screw is flattened on the end projecting from the holder, so that a wrench can be used for adjusting it, the nut *N*, of course, being used for locking when the stop is set in the desired position.

The advantage of this stop is that when all the holes in the turret are full and it is necessary to feed the stock out again, the holder will act as a stop when the stock is fed out into it. The rise on the lead cam is, of course, used to govern the position of the knurls on the work.

Numbering Tool

In Fig. 23 is shown a swinging knurl-holder which was used for rolling figures in a wheel for a cash register. The method of rolling

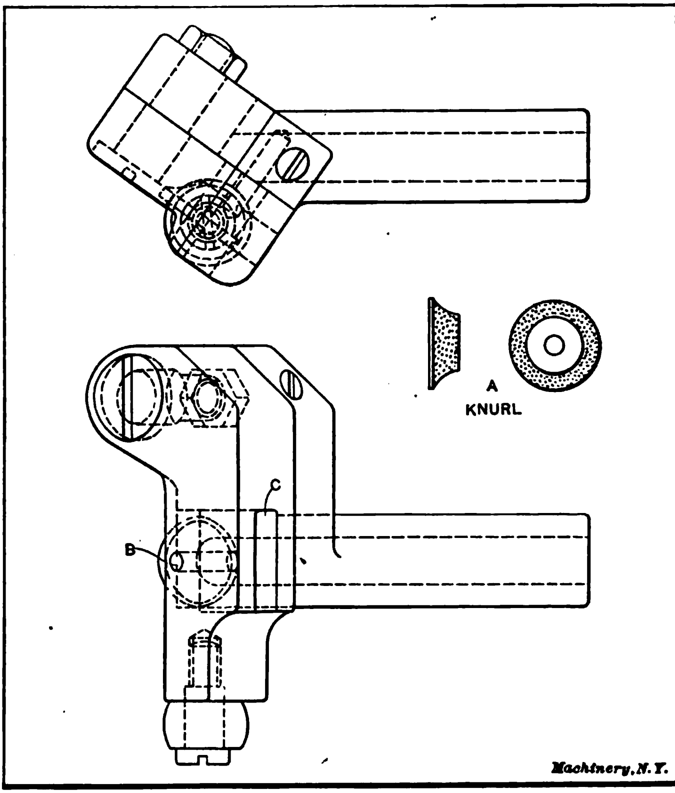


Fig. 24. Knurl-holder for Concave and Convex Knurling

the figures on the wheels is interesting. The knurl *A* and the numbering wheel *B* are made separately, and are screwed onto a sleeve *C* which, in turn, is held on a pin *D*. This pin is driven into the swinging member of the holder, and is held by a headless screw *E*.

The diameter of the knurl *A* is slightly larger than the diameter, over the figures, of the numbering wheel, so that the knurl comes in contact with the work first. The object of this is to provide a drive for the numbering wheel, so that it will not slip and "chew up" the figures which are being rolled in the work. The knurled portion is removed, after the letters have been rolled, by a circular form tool operated from the cross-slide, which operation leaves the work in the condition shown at *D* in Fig. 21. This idea of using a knurl to drive the numbering tool is worth noting, as the same principle could be used in a number of cases for performing work of similar character..

Knurl-holder for Concave and Convex Knurling

At *E* in Fig. 21 is shown an acorn nut, a portion of which is knurled as indicated. This operation would be difficult to perform with a cross-slide knurl-holder, owing to the fact that the knurl could not be brought in straight—that is, having its axis parallel to the axis of the spindle—as the knurl would have a tendency to glide off. This, however, was accomplished by knurling from the turret with a knurl-holder operated by a rising block held on the cross-slide.

The knurl-holder for performing this operation, and the knurl used, are shown in Fig. 24. This knurl-holder is of the swing type, and is

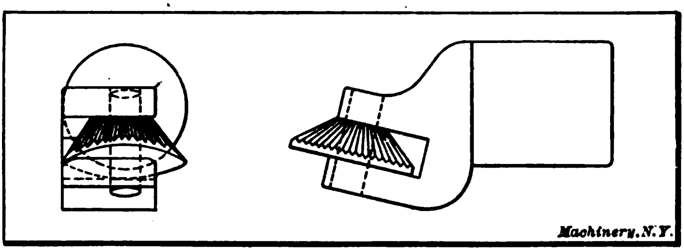


Fig. 25. Bevel Knurl-holder used in the Turret

offset as shown. The manner of holding the swinging member is that commonly used and needs no description. The angle to which the knurl-holder is offset is such that the knurl can be held with its axis parallel to the face of the work to be knurled. The face of the work in this case, however, is convex, so that the axis of the knurl is held parallel to an imaginary line, joining the smallest and largest diameters of the knurled portion. Forcing this knurl-holder in at an angle, makes it necessary to provide a roller on the swinging member, so that the pressure can be directed in a straight line and still deflect the swinging member to the required angle without cramping. The knurl *A* is held on a pin *B* driven into the swinging member of the holder, and a rectangular hole *C* is cut in the swinging member into which tho knurl fits.

Holders for Bevel Knurling

At *F* in Fig. 21 is shown a piece which is beveled and knurled, and in Fig. 25 is shown the knurl and holder which were used to perform the knurling operation. The holder is of simple design and will not need further explanation. The knurl is held, as shown, at the desired angle with the work, on a pin driven into the knurl-holder. This simple knurl-holder performed the operation successfully.

At *G* in Fig. 21 is shown a piece somewhat similar to that at *F*, but it is smaller in diameter, and the included angle of the tapered portion is less. This piece was not knurled from the turret, however, but was operated on by a cross-slide knurl-holder of the type shown in Fig. 26. The body *A* of this holder is cylindrical in shape, while the shank *B* is of rectangular section, and is held in the cross-slide holder used for holding straight forming tools. This holder can be furnished for the Brown & Sharpe automatic screw machine when so desired. The knurl *C* is made with a shank, which passes into the body of the holder *A* and is held in the holder by a pointed set-screw *D* fitting in an annular groove cut in the shank of the knurl. As the thrust exerted on the knurl when in operation is considerable, it is necessary to provide this knurl-holder with roller bearings to reduce the friction. Two steel washers *E* act as retainers for the ball bearings *F*, and an additional bronze washer *G* is provided to separate the body of the holder from the tool-steel retainers. These retainers *E* are hardened, as is also the knurl *C*.

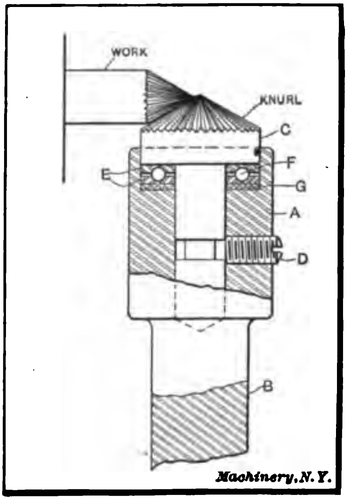


Fig. 26. Bevel Knurl-holder used on the Cross-slide

Turret Knurl-holder for End Knurling

It is sometimes necessary, when using special turret tools, especially those of the generating type, to knurl the end of the work so that the tool in the turret can be kept in step with the work. The knurl-holder, and knurl for performing this class of work are shown in Fig. 27.

The knurl *A* is held in the holder at an angle with the horizontal center line. The angle *a* at which the knurl is held should be from 15 to 30 degrees; about 20 degrees, however, is ordinarily used. The shank of the knurl *A* passes into the body of the holder and fits in a bronze sleeve *B*, the sleeve being driven into the holder. An oil groove is cut in this sleeve to supply oil to the shank of the knurl. A hardened steel washer *C* and a bronze washer *D* are also provided to reduce the friction. The knurl is held up against these washers *C* and *D* by a collar *E*, which is fastened to the shank of the knurl with a pin *F*.

This type of knurl-holder is also used for assembling operations. The piece to be assembled on the work in the chuck is put in place, and the knurl-holder is brought in, upsetting the end so that the part assembled cannot be taken off. A hole is usually drilled in the end of the knurl, as shown, to facilitate the cutting of the teeth.

Laying out Cams for Turret Knurling Operations

Knurling from the turret differs from knurling from the cross-slide, in that the turret knurl-holder cannot be taken off the work on the quick drop of the cam. If this were done, the knurls would "chew up" the knurling which has been made on the forward travel of the knurls. The method of laying out the rise on the lead cam for knurling from the turret is shown in Fig. 28. This is the lay-out of a set of cams for making a Brown & Sharpe micrometer sleeve, shown at *A* in Fig. 21. The other machining operations on this sleeve, however, are not within the scope of this article, so we will turn our attention to the lobe which performs the knurling operation. This lobe is shown at *A* on the lead cam. It will be noted that the part of the lobe for the forward travel of the knurls covers a greater number of hundredths of the cam surface than does the part of the lobe used for backing the knurls off the work. As a rule, the part of the lobe used in backing the knurl off the work should contain about half the number of hundredths used for feeding the knurl onto the work, or, in other words,

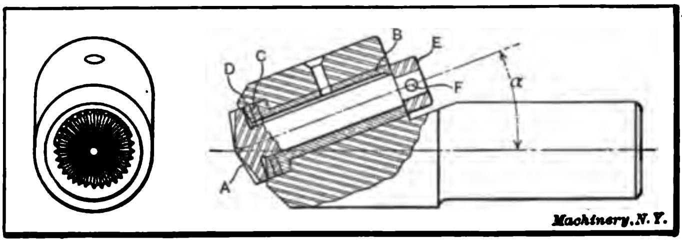


Fig. 27. Turret Knurl-holder for End Knurling

the feed used for backing-off should be about twice that used for feeding on.

Designing and Cutting Bevel and End Knurls

The making of bevel knurls differs from the making of bevel gears only in that the pitch circle of the knurl is not taken into consideration.

In Fig. 29 is shown the ordinary method of designing a bevel knurl. Angle a, of course, is made to conform to the face angle on the work. The face angle β on the knurl can be found by the following formula: First find tan η, which is equal to $\frac{d}{A}$ (d = depth of tooth, and A = length of face cone radius of knurl). The diameter of the knurl, D, is made to suit the requirements.

Then

$$\beta = a + \eta$$

The included angles of the teeth for the knurls used in knurling different materials were given in the previous chapter, together with a table giving the depth of teeth for various included angles.

In Fig. 30 is shown a method of designing an end knurl. The bottom of the tooth in the knurl should be at right angles to the center line of the spindle when the knurl is held in the position shown, so that the face of the teeth on the knurl projects past the perpendicular, thus forming the teeth in the work deeper at the outer circumference than at the center. In cutting the knurl, when the angle θ at which the knurl is held in the holder is known, the setting of the knurl in the milling machine is, of course a simple problem. The face angle of the

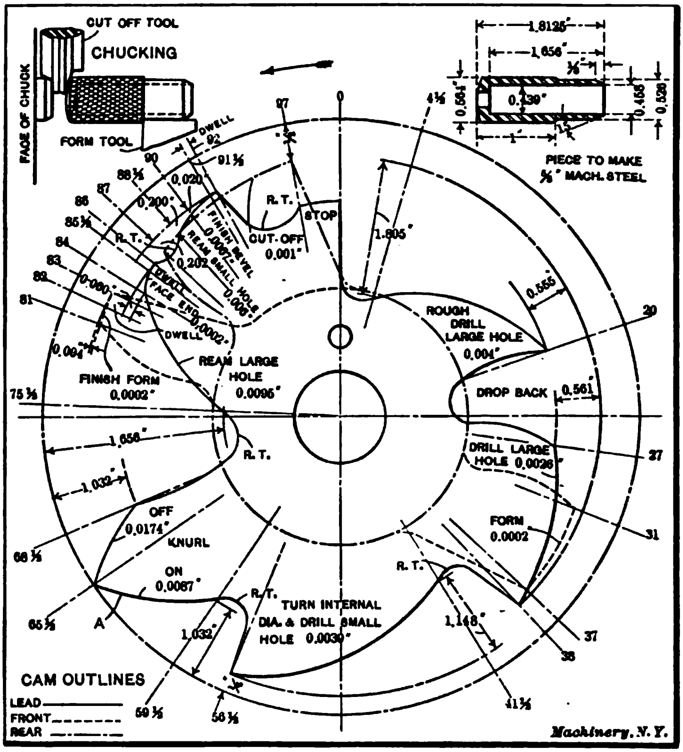


Fig. 28. Cams for Making Brown & Sharpe Micrometer Sleeve, showing Method of Laying out Lobe for Turret Knurling

knurl has to be found, however, before the knurl can be made. This angle can be found by the aid of the following formulas, in which

θ = angle of inclination of axis of knurl,
δ = angle of bottom of tooth with axis of knurl,
γ = tooth angle,
ϕ = face angle of knurl,
R = radius of knurl, made to suit requirements,
R_1 = distance from vertex to circumference at bottom of tooth,
R_2 = distance from vertex to circumference at face of tooth,
d_1 = depth of tooth.

$$\delta = 90 \text{ degrees} - \theta$$

$$R_1 = \frac{R}{\cos \theta}$$

$$R_2 = R_1 - (d_1 \times \tan \theta)$$

$$\tan \gamma = \frac{d_1}{R_2}$$

$$\phi = \theta - \gamma$$

For example, assume that it is required to design an end knurl with the following data:

Angle $\theta = 20$ degrees ,
Depth of tooth, $d_1 = 0.027$ inch,
Radius of knurl, $R = 0.375$ inch.

Then

$$R_1 = \frac{0.375}{\cos 20 \text{ deg.}} = \frac{0.375}{0.9397} = 0.399 \text{ inch.}$$

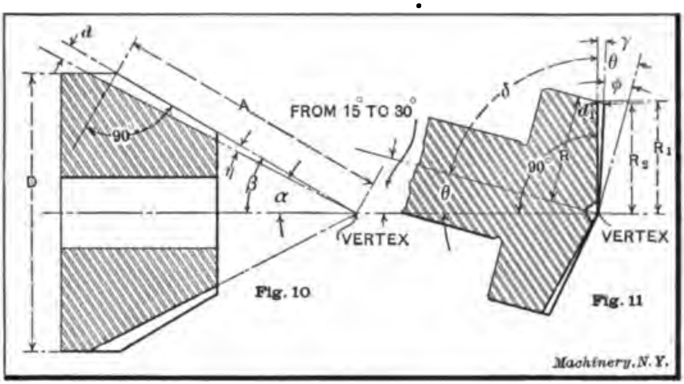


Fig. 29. Method of Finding the Cutting Angle of Bevel Knurls

Fig. 30. Method of Finding the Face Angle of End Knurls

$$R_2 = 0.399 - (0.027 \times \tan 20 \text{ deg.}) = 0.399 - 0.0098 = 0.389 \text{ in.}$$

$$\delta = 90 \text{ deg.} - 20 \text{ deg.} = 70 \text{ deg.}$$

$$\tan \gamma = \frac{0.027}{0.389} = 0.0694, \text{ the tangent of 3 deg. 58 min.}$$

$$\phi = 20 \text{ deg.} - 3 \text{ deg. } 58 \text{ min.} = 16 \text{ deg. } 2 \text{ min.}$$

For some classes of work it may be necessary to have the diameter of the knurl tapering, so that the circumference is at an angle of 90 degrees or less to the face of the knurl. This, however, decreases the strength of the teeth at the circumference, and promotes chipping of the teeth.

Rise on Lead and Cross-slide Cams for Turret Knurling

Knurling operations performed from the turret can be divided into five distinct groups as follows:

1. Spiral or diamond knurling, when the knurl-holder is operated on entirely by the lead cam.

2. Spiral or diamond knurling, when the knurl is operated on by both the lead and cross-slide cams.

3. Bevel knurling, when the knurl is operated entirely from the turret.

4. Bevel knurling, when the knurl is operated on by both the lead and cross-slide cams.

5. End knurling, when the knurl is operated on entirely from the turret.

The rise on the cam for knurling from the turret, subject to the conditions above stated, can be found by referring to Fig. 31. At *A* is shown the diagram for spiral or straight knurling when the knurl

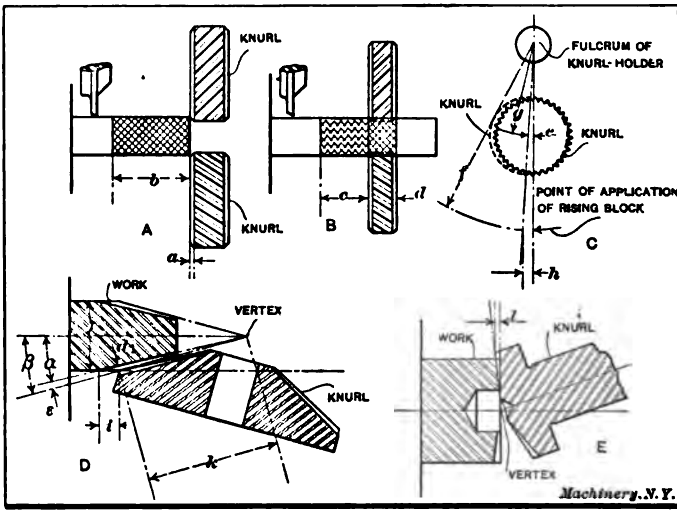


Fig. 31. Diagrams for Finding Rise on Lead and Cross-slide Cams for Turret Knurling

is operated on entirely from the turret. The rise on the lead cam for this operation would be $b + a$. The value a takes into consideration the bevel on the knurl, which is necessary to prevent the corners from chipping.

For spiral or straight knurling when the knurl is operated on by both the turret and cross-slide cams, the diagrams shown at *B* and *C* are used. Here the lead cam brings the knurls onto the work into the position shown, by the quick-rise of the cam. A dwell is then made on the lead cam, and the cross-slide cam forces the knurls in to the proper depth. The lead cam then advances, while a dwell is made on the cross-slide cam. The rise on the lead cam is equal to c, or the length of the knurled portion, minus the thickness d of the knurl. The rise h on the cross-slide cam is found by the following formula:

$$h = \frac{e \times f}{g}$$

The value e is equal to the depth of the too
greater than the rise on the cam required for
is displaced. However, the depth of the too
all practical purposes.

The method of obtaining the rise on the
when the knurl is operated on entirely by the
where i equals the rise required on the can
by means of the following formulas, where

k = face cone radius of work,
j = diameter of work,

TABLE IV. FEEDS FOR TURRET

Pitch of Knurl	Brass Rod, Feed per Revolution	Gun Screw Iron, Feed per Revolution	Machi Fee Revo
16	0.0100	0.0080	0.
18	0.0105	0.0084	0.
20	0.0110	0.0088	0.
22	0.0115	0.0092	0.
24	0.0118	0.0096	0.
26	0.0123	0.0100	0.
28	0.0128	0.0103	0.
30	0.0135	0.0106	0.
32	0.0140	0.0110	0.
34	0.0145	0.0115	0.
36	0.0150	0.0120	0.
38	0.0153	0.0125	0.
40	0.0158	0.0128	0.
42	0.0164	0.0132	0.
44	0.0168	0.0136	0.
46	0.0173	0.0140	0.
48	0.0178	0.0143	0.
50	0.0182	0.0145	0.
52	0.0185	0.0148	0.
54	0.0189	0.0150	0.
56	0.0193	0.0153	0.
58	0.0195	0.0156	0.
60	0.0198	0.0158	0.
62	0.0200	0.0160	0.

i = rise required on cam,
a = angle of bottom of tooth with axis
β = angle of face with axis of work,
ϵ = tooth angle,
d_1 = depth of tooth.

$$k = \frac{j}{2 \sin \beta}; \sin \epsilon = \frac{d_1}{k};$$

Then

$$i = \frac{d_1}{\sin a} + 0.010 \text{ to } 0.0$$

The method used for obtaining the rise
bevel knurling when the knurl is operated

cross-slide cams, is the same as that shown at *C* in Fig. 31. The holder in which the knurl is held is offset, so that the face of the knurl is held parallel with the face of the work when being fed in. The depth of the tooth, therefore, is used for obtaining the rise on the cross-slide cam, by the aid of the diagram shown at *C*. No rise is required on the lead cam, as the knurl is brought to the correct position on the work by the quick-rise of the cam, and then allowed to dwell until the knurling is completed.

The method of obtaining the rise on the lead cam for end knurling is shown at *E*, where it can be seen that the rise *l* equals the depth of the tooth. To dimension *l* should be added from 0.010 to 0.015 inch for the approach.

Speeds and Feeds for Knurling

Knurls, as a rule, can be operated at about the same speed as circular forming tools, if the proper feed is given and the knurl is provided with a copious supply of good lard oil. However, it may be advisable in some cases, especially when knurling tool steel or drill rod, to decrease the speed somewhat.

Definite information cannot be given for feeds for turret knurling, as it is impossible to take into consideration all the various conditions under which a knurl will be operated. When two knurls are employed for diamond or spiral knurling, the knurls can be operated at a higher rate of feed for producing a spiral than they can for producing a diamond knurl. The reason for this is that in the first case the two knurls would be working in the same groove, whereas in the latter case the two knurls are working independently of each other, so that each has to do its own share of the work. Another condition encountered is end knurling where the knurl only has to be fed in to the depth of the tooth. Here the feed varies, of course, from that used for spiral or diamond knurling; so it is obvious that no definite rule can be laid down which will cover all conditions. The diameter of the work is also a determining factor, making the problem still more difficult. Feeds for turret knurling are given in Table IV for knurling different materials. The feeds here given are applicable particularly to spiral and diamond knurling, but can also be used, with judgment, for bevel or end knurling. The diameter of the work is not taken into consideration, and allowance should be made for this when using the feeds given. The feeds to be used for backing the knurls off the work should be as follows: For brass, screw stock and machine steel, twice the feeds given in the table; and for tool steel, three times the feeds given in the table.

CHAPTER III

SPECIAL KNURLING OP

The knurling operations dealt with in what might be called "standard," and are m matic screw machine practice. The followi special nature, and illustrate unusual ap data which follows should be of suggestiv screw machine tools, inasmuch as it prese of applying knurls to the work under vary

Bevel Knurling Tools operated

The simple bevel knurling tool shown in a tapered shank and is held in a standard

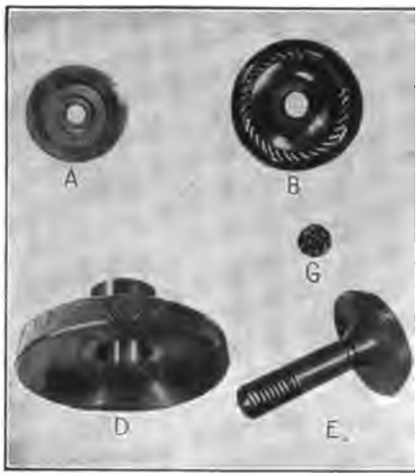


Fig. 32. Examples of Work Requiring Knurl-holder Applicatio

ret. The piece to be knurled, *A*, is a small has a convex face, but as the curvature is mond knurl can be used. In applying the ter line *BC* of the knurl should be at righ the work it is required to knurl. This pa a No. 00 Brown & Sharpe automatic screw ated at a spindle-speed of 1492 R. P. M., an of 0.0023 inch per revolution of the work.

Another example of end-knurling from t 34. The piece to be knurled is shown at *A* The knurl is presented from the turret un and produces a single spiral knurl, the teeth of which are at an angle of 25 degrees with the axis of the work. The holder is held in a No. 2 Brown & Sharpe automatic screw machine, and the work is rotated at

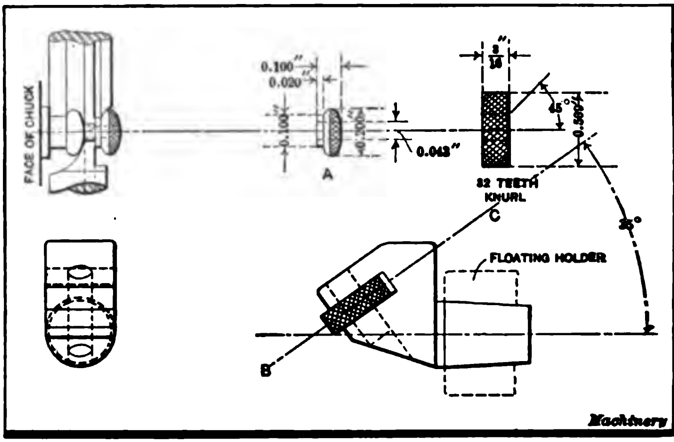


Fig. 33. End-knurling Tool held in Floating Holder

1200 R. P. M., with a feed to the knurl of 0.0024 inch per revolution.

The knurl holder consists of a shank *B* which fits the hole in the turret, and a holder *C* held to the body *B* by a screw, and located by a tongue and groove. The hole for screw *D* in holder *C* is larger than

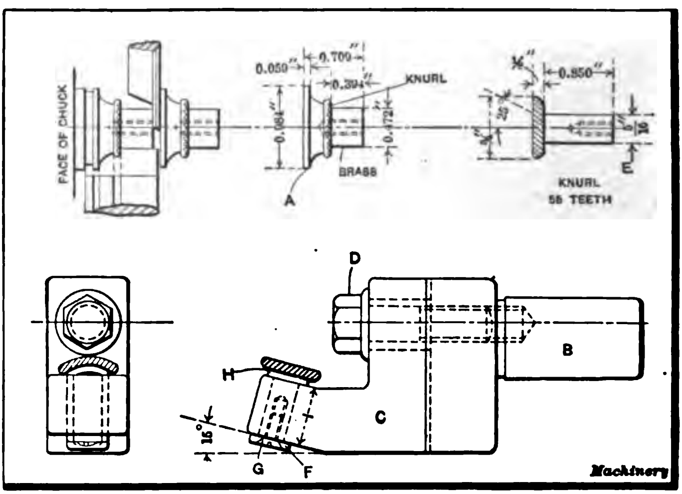


Fig. 34. End-knurling Tool held in Turret and Operated at an Angle

the body diameter of the screw, to provide for adjustment. The knurl which is shown detailed at *E* is provided with a shank which is a running fit in the hole in holder *C*. It is retained by a washer *F* and screw *G* and rotates on a hardened washer *H*. The distance *I* on the

knurl shank is slightly greater than the
to allow the knurl and washer *G* to rotate f

The knurl *B* and the knurl holder *D* shc
produce a ratchet form of radial teeth in

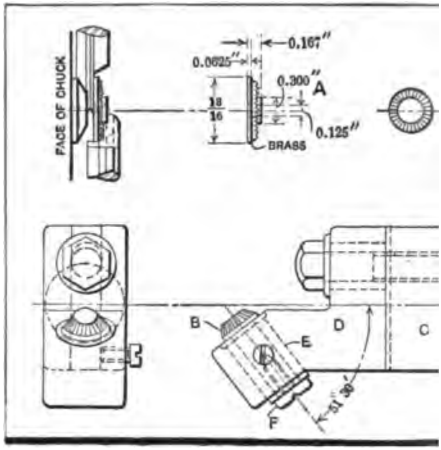


Fig. 35. Knurl and Knurling Tool-holder Form cf Radial Teeth

shown at *A*, and also at *C* in Fig. 32. The
at an angle of 60 degrees and are radial. T
R. P. M., and a feed of 0.0008 inch is given
of the work.

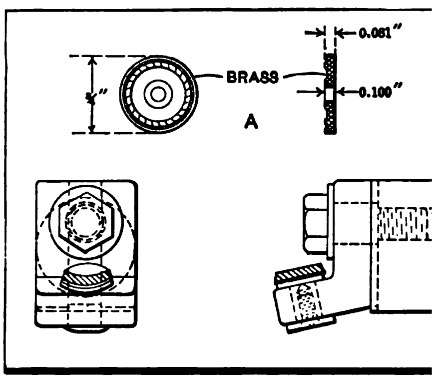


Fig. 36. Knurl and Holder for producing "T

This holder is held in the turret of a N
matic screw machine, and consists of a b
the holder *D* is held by a screw. The knu
bronze bushing which is prevented from
knurl is retained in the bushing by a larg
with a shoulder. There is sufficient end

rotate freely. It should be noted that in presenting the knurl to the work, the bottom of the teeth in the knurl should be at right angles to the center line of the holder or of the work.

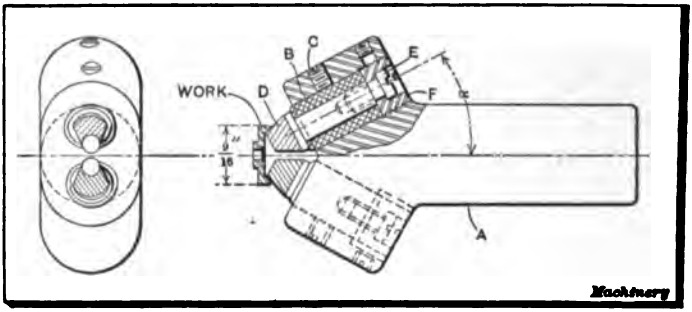


Fig. 37. Special Knurls and Holder for Internal Bevel Knurling

A knurl-holder bearing a marked similarity to that shown in Fig. 35 is illustrated in Fig. 36. In this case, however, the knurl is used for producing "tangential" teeth, as shown on the piece *B*, Fig. 32, and consequently it is provided with spiral teeth. It is not inclined at so small an angle with the center line of the holder, and approaches,

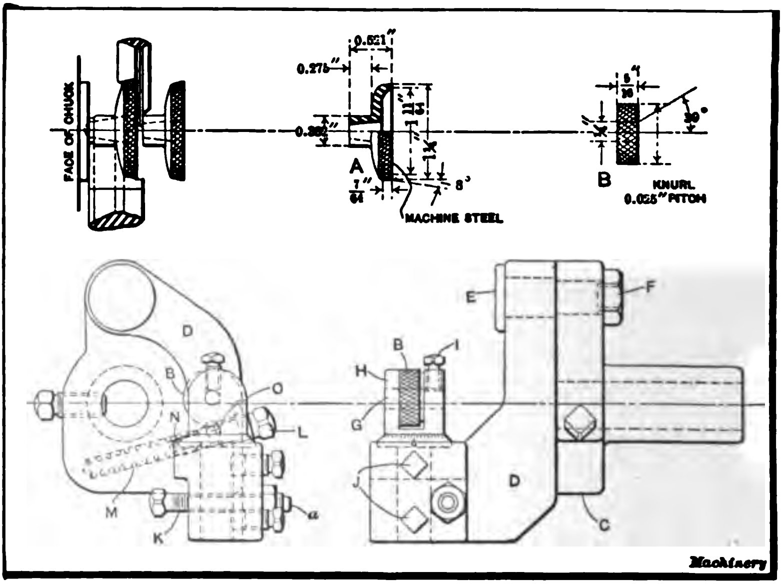


Fig. 38. Swing Type of Turret Knurl-holder for Knurling at Various Angles

when in operation on the work, as closely as conditions will permit, the action of a helical gear in mesh.

Internal Turret Knurl-holder

A special application of two bevel spiral knurls to the work is shown in Fig. 37. Here the portion of the work to be knurled is beveled at

an included angle of approximately 9
Fig. 32, a diamond-shaped knurl is
can be more easily accomplished in
than would be possible with one dia
tions it is advisable to have the ang
angle on the work, so that it will be
a straight knurl would not work freel
turret or cross-slide.

The holder *A*, Fig. 37, which is he
machine steel forging and is supplied
the phosphor-bronze bushings *B*, these

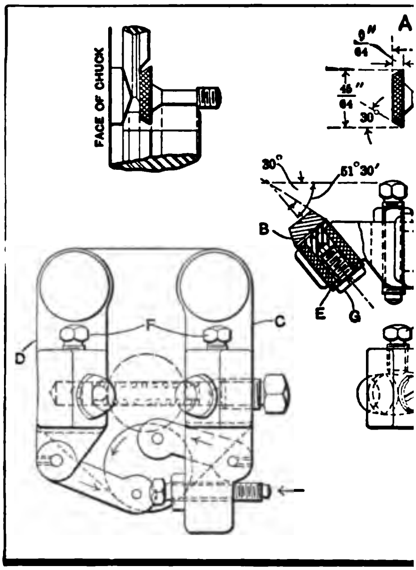


Fig. 39. Opening Type of Turret K

screws *C*. The knurls *D* are provid
in bushings *B* by screws *E*, which
thrust of the knurls in this holder is
sary to back up the bushings *B* with

Special Swing K

A special knurl holder which is
from the cross-slide by a rising bl
shown in Fig. 38. The work is show
It will be noticed that the work is
than suitable for the ordinary capaci
automatic screw machine, thus requi
feeding attachment, the ordinary fee
is revolved at 240 R. P. M., and the
of 0.00077 inch per revolution of the

the swinging arm *D* is moved, so that the actual feed to the knurl will be somewhat less than this amount.

The main body of holder *C* is provided with a shank held in the turret, and the swinging member *D* is held to its front face by a bolt *E* and nut *F*. The knurl *B* is held on pin *G* retained in the swivel holder *H* by screw *I*. The holder *H* is provided with angular graduations reading to degrees, so that the knurl can be set to the desired angle with the work. In the illustration the knurl is set straight, but in actual operation it is set around at an angle of 8 degrees. The shank of holder *H* is retained in the swinging member *D* by two set-screws *J*, which operate on bronze shoes to prevent marring the shank.

In operation, the rising block on the cross-slide comes in contact with the point *a* of the adjusting screw *K*, forcing the knurl into the work. The swinging member is returned to adjustable stop-screw *L* by a spring *M*, plunger *N* and pin *O*, the latter being driven into the swinging member and operating in an elongated hole in the holder *C*.

Special Opening Knurl-holder

An opening type of knurl-holder of a design almost identical with that shown in Fig. 22, is shown in Fig. 39. Two bevel knurls *B* are held in the swinging arms *C* and *D* in the manner shown in the sectional view. These arms are provided with offset lugs bored to receive the phosphor-bronze bushings *E*, which are prevented from turning by set-screws *F*. The knurls *B* are provided with shanks and are retained in the bronze bushings by screws *G*. The type of holder shown gives better results on the piece shown at *A*, and also at *E* in Fig. 32, than would a holder held on the cross-slide which would force the knurl straight into the work. The reason for this is that in operating a bevel knurl from the cross-slide on a tapered piece of work, the knurl has a tendency to glide off and produce an imperfect form of knurl. The opening type of holder obviates this difficulty to a considerable extent, as the power can be applied, so to speak, at right angles to the surface knurled. The knurls are brought into position by the turret and then fed into the work by the rising block on the cross-slide.

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Any intelligent man engaged in mechanical work can acquire a well-rounded mechanical education by using as a guide in his studies the outline of the course in mechanical subjects given below. The course is laid out so as to make it possible for a man of little or no education to go ahead, beginning wherever he finds that his needs begin. The course is made up of units so that it may be followed either from beginning to end; or the reader may choose any specific subject which may be of especial importance to him.

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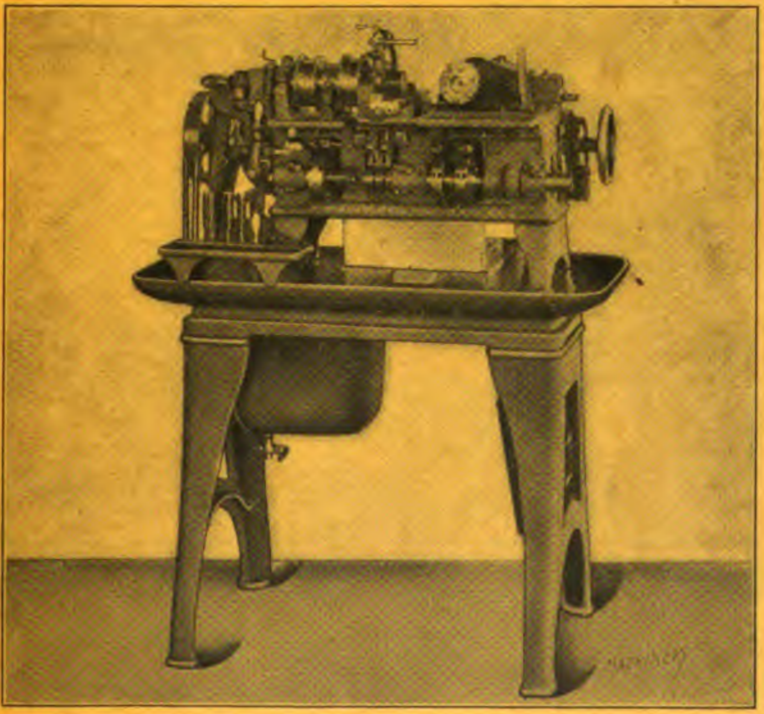
AUTOMATIC SCREW MACHINE PRACTICE

MILLING, CROSS-DRILLING AND BURRING OPERATIONS

BY DOUGLAS T. HAMILTON



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DESIGN AND SHOP F

NUMBER 1

AUTOMATIC MACHINE PI

PART VIII

MILLING, CROSS-DF BURRING OPEF

By DOUGLAS T. H.

CONTENT:

49-55 Lafayette Street, Ne

Automatic Screw Machine Practice for the Brown & Sharpe automatic screw machines is covered in eight Reference Books, Nos. 99 to 106, inclusive. Reference Book No. 99, "Operation of the Brown & Sharpe Automatic Screw Machines," deals with the construction of these machines and the setting-up of the tools. No. 100, "Designing and Cutting Cams for Automatic Screw Machines," gives detailed instruction on cam design, and describes a simplified method for milling cams. No. 101, "Circular Form and Cut-off Tools for the Automatic Screw Machine," deals with the general arrangement and the calculations of these tools, and describes the different methods employed in their making. No. 102, "External Cutting Tools for the Automatic Screw Machine," deals with the design and construction of box-tools, taper turning tools, hollow mills, and shaving tools. No. 103, "Internal Cutting Tools for the Automatic Screw Machine," deals with centering tools, cross-slide drilling attachments, counterbores, reamers, and recessing tools. No. 104, "Threading Operations on the Automatic Screw Machine," treats on cam design for threading operations, threading dies, taps and tap drills, die and tap holders, and thread rolling. No. 105, "Knurling Operations on the Automatic Screw Machine," describes the construction of knurling holders, and gives directions for the making of knurls and the design of tools and cams used in connection with knurling operations. No. 106, "Milling, Cross-drilling and Burring Operations on the Automatic Screw Machine," describes screw-slotting attachments, index drilling attachments, and burring attachments, giving directions for their use and for the design of cams for them.

CHAPTER I

MILLING ATTACHMENTS

One of the most commonly used milling attachments for the Brown & Sharpe automatic screw machines is the screw-slotting attachment. This attachment, shown at *A* in Fig. 1 is fastened to a boss provided for this purpose on the machine. The apron *B*, which is also an additional part, carries the arbor *C* to which the transferring arm *F* is attached. The transferring and advancing cam levers *D* and *E* are also fastened to bosses on this apron. These levers are operated by the advancing and transferring cams *J* and *K*. The block *H* is fastened to the arm *F*, and a slotting bushing to carry off the screw is

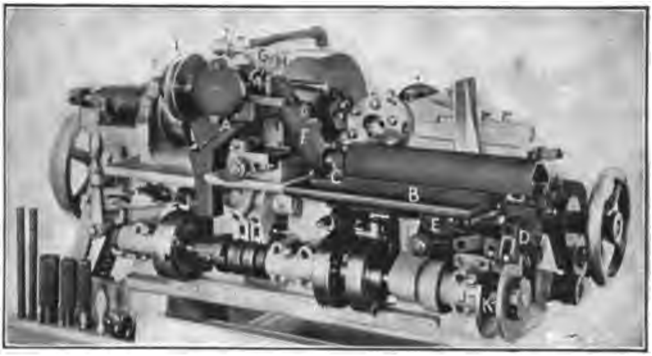


Fig. 1. No. OO Brown & Sharpe Automatic Screw Machine equipped with a Screw-slotting Attachment

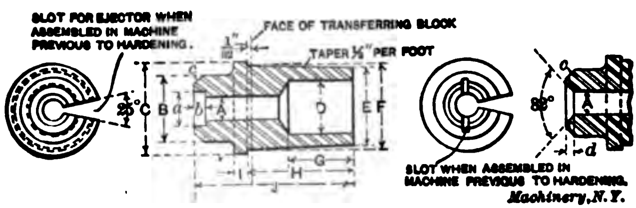
driven into it. This bushing grips the screw and holds it while the slotting saw *G*, held on an arbor and driven from pulley *I* through bevel gears, mills the slot in the head. The pulley *I* is driven by a round belt from the overhead works. The design and action of this device is described in detail in MACHINERY's Reference Book No. 100, "Automatic Screw Machine Practice—Designing and Cutting Cams for the Brown & Sharpe Automatic Screw Machine," where the laying out of cams for this device is also described.

Slotting-bushings

The method of holding the screw when presenting it to the saw in the screw slotting attachment is of special importance. In Table I is shown the standard form of slotting-bushings used for holding fillister- and flat-head screws. The type of slotting-bushing used for round- or button-head screws is similar to that shown for the fillister-head screw, except that in some cases the bushing is not counterbored for the head of the screw. The proportions for slotting-bushings for the various sizes of Brown & Sharpe automatic screw machines are also given in Table I. The diameter of the hole *A* governs the diameter *B* of the front end of the bushing, and also of the hole *D*. These sizes, of course, pertain only to bushings for standard screws, the slotting-bushing being made to suit the work as desired. The diameter *A* should be made from 0.001 to 0.0015 inch larger than the screw diameter, while the diameter *a* should be made from 0.002 to 0.003 inch larger than the diameter of the shoulder or head of the screw, as the case may be.

When a bushing is to hold a shouldered screw, and when the length of the shoulder is greater than or equal to the diameter of the shoulder,

TABLE I. PROPORTIONS FOR SLOTTING-BUSHINGS



Mch. No.	A	B	C	D	E	F	G	H	I	J
00	1/16 to 3/16 3/16 to 1/4	3/8 1/2	9/16 9/16	1/4 5/16	0.450 0.450	0.476 0.476	1/2 1/2	11/16 11/16	1/16 1/16	1 1
0	1/8 to 1/4 1/4 to 3/8	1/2 11/16	11/16 11/16	5/16 7/16	0.600 0.600	0.681 0.681	9/16 9/16	3/4 3/4	1/16 ..	1 1/8 1 1/8
2	3/16 to 5/16 5/16 to 1/2	5/8 7/8	7/8 7/8	5/8 9/16	0.750 0.750	0.792 0.792	5/8 5/8	1 1	1/8 ..	1 1/2 1 1/2

the diameter *A* is made to fit the body of the shoulder instead of the body of the threaded part of the screw. When the length of the shoulder is less than the diameter, the bushing is made to fit both the shoulder and the body of the screw. The screw head should also fit in the counterbored hole in the bushing. The distance between the shoulders on the screw should always be less than the distance between the shoulders in the bushing, so that the screw head alone will bear against the shoulder in the bushing. The distance *d* on the bushing for flat-head screws should be made equal to one-half the thickness of the head, when the body of the screw is greater than ¼ inch. When the body of the screw is less than this, the head, as a rule, is usually sunk the full depth in the slotting-bushing. The corner *c* should only be beveled when the diameter of the counterbored hole *A* will permit, otherwise the corner should not be beveled, but rounded slightly.

Slotting-bushings are usually made f
hardened until the cams have been tried
is completed. The slot for the ejector
inserted in the transferring block, and
bushing for flat-head screws is cut when
tion in the transferring block. When a
head screw, the slotting saw does not,
at all, the depth of the counterbore *b* i
less than the difference between the dep
ness of the head of the screw. The dim
shoulder of the bushing, but is the large

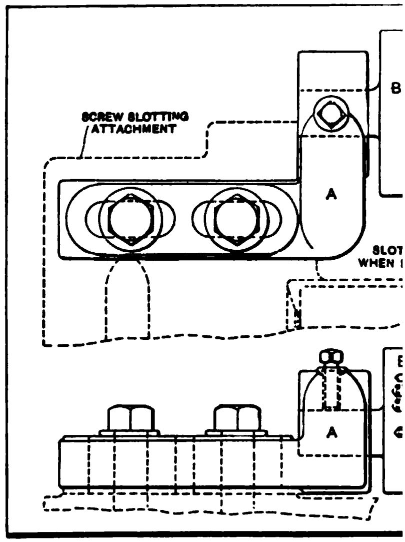


Fig. 2. Device for Locating Hexagon-head

in the transferring block. This allows th
into the block, 1/32 inch being allowed
however, to make the dimension *F* sligh
fit it into the block when trying out the
ing for holding flat-head screws is mad
of the head, the angle shown being that

Slotting Hexagon-he

When the slot in the head of a hexa
definite relation to the sides of the he
screw be located in an exact position in th
ing for holding the screw has usually a
the hexagon head, but it is often difficu
properly in the bushing. If the bushing
it is attached to the bar, the screw will
the hexagon hole, but the corners of the

screw broken off before it is severed from the bar. To obviate this difficulty, some device must be employed for locating the screw in the bushing, after it has been severed from the bar.

A device which is used for locating a hexagon-head screw in the slotting-bushing is shown in Fig. 2, where the screw and slotting-bushing are also shown. This device consists of a cast-iron bracket *A*, which is held on the slotting attachment, being retained in position with the same screws that hold the slotting attachment. Held in the boss of bracket *A* is a holder *B* to which is attached the locater *C*. This consists of a piece of sheet steel about 1/16 inch thick, held on a pin *D* and free to swivel. Pressing against this locater is a spring *E* which forces the locater against the stop pin *F*. A screw *G* acts as a stop, being adjusted in or out as desired to locate the head of the

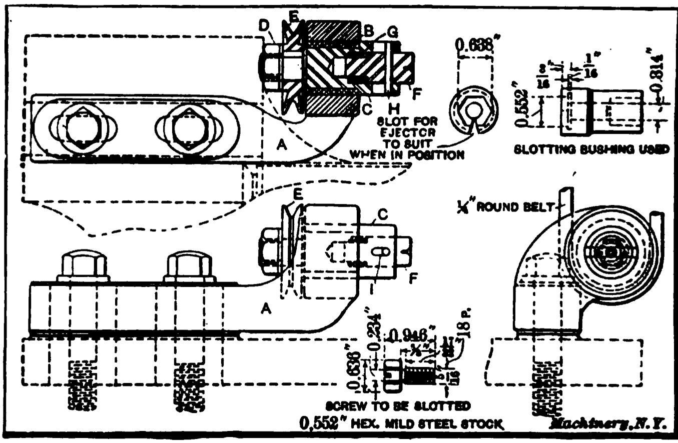


Fig. 3. Another Hexagon Screw Locating Device

screw against the shoulder in the bushing, and also acting as a stop for the locater *C*.

In operation, as the screw is removed from the chuck by the slotting bushing, the arm, in ascending, is brought to dwell in an intermediate position, and is then advanced towards the locater *C*. As this locater is beveled, the screw forces it up, and the action of the spring turns the screw around in the bushing, so that the hexagon head is located properly, the arm at the same time advancing and forcing the screw in to the desired depth. The method of designing the transferring cam to dwell in this intermediate position will be described in connection with the burring attachment, in another chapter.

In Fig. 3 is shown a device for locating hexagon-head screws in the slotting-bushing which differs somewhat in principle from that shown in Fig. 2. This device consists of a cast-iron bracket *A*, which is fastened to the slotting attachment as previously described. The bracket is provided with a phosphor-bronze sleeve *B*, in which a spindle *C* is free to rotate. Keyed to the spindle *C*, and held by a nut *D*, is a

grooved pulley *E*, which is driven by a
overhead works. Held in the spindle *C*
is pressed forward by an open-wound sp
is prevented from rotating by a pin *H*, v
I, cut in the spindle *C*.

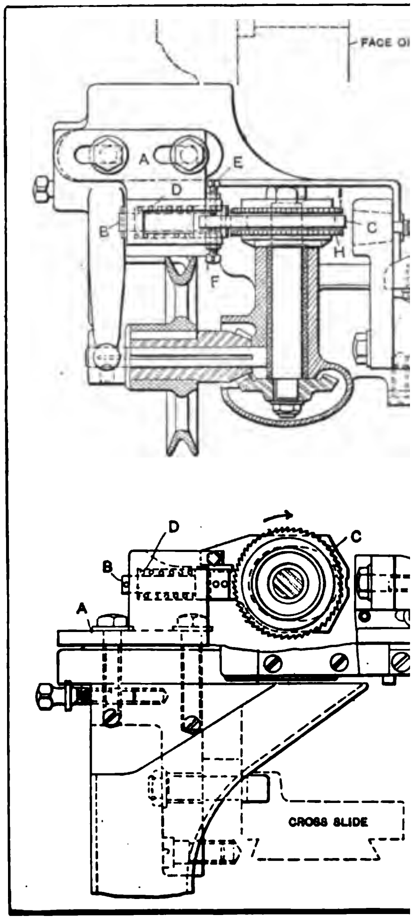


Fig. 4. Slabbing Attachment used on S

In operation, as the slotting-bushing li
the arm dwells in an intermediate positio
the screw against the rotating plunger
slowly, and as the arm is advanced, the
the screw and the plunger rotates the f
ward travel of the arm, the screw is lo
and forced in to the correct depth. The

used for holding it are shown in the illustration, where the principal dimensions on the slotting-bushing are also given.

Slabbing Attachment

A slabbing attachment which is fastened to the ordinary screw-slotting attachment is shown in Fig. 4. The screws which hold the slotting attachment to the frame of the machine are removed and the slabbing attachment *A* is seated on the top face of the base of the slotting attachment. The screws are again inserted, and the slabbing attachment fastened in position. The main body of the attachment is an iron casting, and a boss on it is bored out to receive a plunger *B* to which is attached a guide or ejector *C*. The plunger *B* is riveted to this guide member *C*, and a coil spring *D* is located behind the shoulder of the plunger to keep it out.

Two set-screws *E* and *F* with lock-nuts are provided for guiding the member *C*. This guiding or ejecting member *C* has an elongated hole bored in it, fitting over the saw arbor, so that the ejector can be forced back by the piece when it is being advanced to the slabbing saws by the transferring arm. The front face of the ejector *C* is knurled, so that the piece is prevented from rotating in the slotting-bushing when the saws *H* and *I* commence to cut. This attachment is driven in the same manner as the ordinary screw-slotting attachment, and the bushing in which the work is held while being slabbed is also of a similar type. Of course, the exact shape of the bushing would depend entirely on the shape of the work. In the lower view, the driving mechanism has been removed to show the slabbing attachment more clearly.

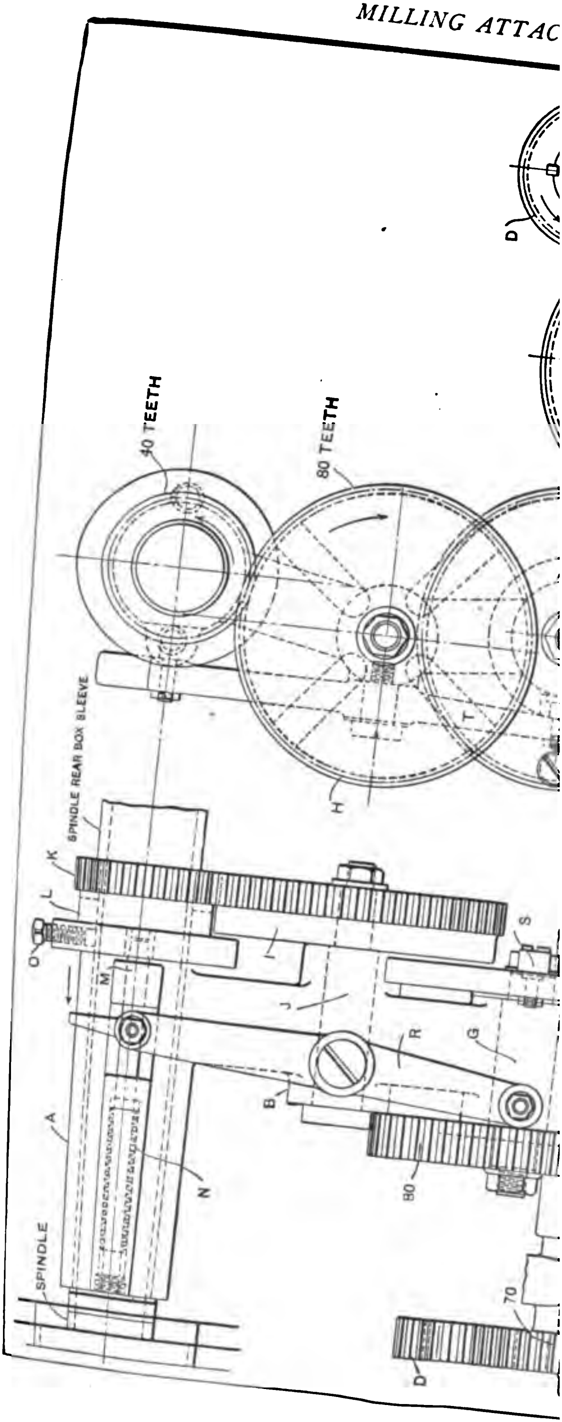
Spindle Indexing Device

A device which converts the Brown & Sharpe automatic screw machine into a milling machine is shown in Fig. 5. This device was designed for making a special piece, which is shown at *A* in Fig. 6, where the cams for making the piece are also shown.

To apply this device to the automatic screw machine, the pulleys *A* and *B* shown in Fig. 7 are removed, as is also the clutch mechanism. The outer sleeve *A* of the attachment shown in Fig. 5 is then slipped over the regular spindle. This sleeve is cast integral with a bracket *B*, the lower end of which is located on the shaft *C* shown in Fig. 7. This shaft is part of the belt-shifting arrangement which is used for obtaining two different speeds for the spindle when threading steel. The attachment is driven from the rear driving-shaft by the ordinary gears *D* and *E* which drive the belt-shifting arrangement as shown in Figs. 5 and 7. A 35-tooth gear *D* is placed on the driving shaft, which meshes with a 70-tooth gear *E* located on the shaft *C*. On the same shaft is an 80-tooth gear driving an 80-tooth gear *F* on the stud *G*.

A trip and indexing mechanism somewhat similar to that used on the turret, is used here for indexing and locking the spindle. The 80-tooth gear *H* meshes with a 40-tooth gear *K* keyed to the sleeve *L* held on the spindle. This sleeve has two holes drilled in it, in which the plunger *M* fits. A spring *N* behind this plunger keeps it in contact

MILLING ATTAC



with the sleeve *L*. This sleeve *L* is fastened to the main driving-spindle of the machine by a set-screw *O*. This attachment is operated as follows:

The dog on the drum held on the front cam-shaft, is set to trip the lever, which, when tripped, operates the tooth-clutch *P*, Fig. 7, thus rotating the rear driving-shaft. As the rear driving-shaft rotates at 180 R. P. M., the gear *D* will revolve at the same speed, while the gear *E* will revolve at 90 R. P. M., and will transmit a speed of 90 R. P. M. to the gear *F*. This gear *F* carries a cam *Q*, and a roller attached to

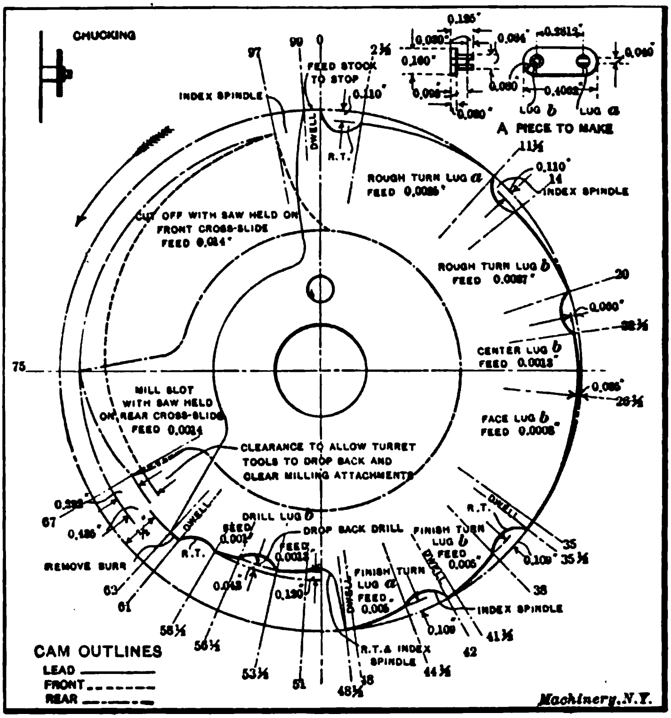


Fig. 6. Lay-out of a Set of Cams for Making a Piece requiring the Indexing of the Work-spindle

the lever *R* runs on this cam. Then when the dog trips the lever, the driving-shaft rotates, thus driving the gears, which in turn rotate the cam *Q*. As the cam *Q* is rotated, the arm *R* is moved in the direction indicated, which action withdraws the pin *M* from the bushing *L*. Now at the same time that the pin *M* is withdrawn, the roller *S* comes in contact with the slot *T* in disk *I* held on the stud *J*, thus rotating the disk on one quarter turn. This disk is provided with four slots *T*, and as this indexing device requires to be indexed 180 degrees to bring each part of the piece into position, the disk *I* is moved two spaces before another dog on the drum trips the lever that disengages the tooth-clutch *P*, Fig. 7.

Referring to Fig. 6, it will be seen two lugs on it designated *a* and *b*. Tl is made is of special shape, so that its require to be finished; the lugs *a* and slotted. The work is not revolved, bu stock into position for forming the twc turret is packed out an amount equal t the center of the two lugs, and drillin turret for holding hollow mills and d is as follows:

Order of Operations

Feed stock to stop....................

Revolve turret ....

Rough turn lug *a* with hollow mill h drilling attachment, speed 684 R. P. 0.0025 inch feed ....

Index spindle and revolve turret......

Rough turn lug *b* with hollow mill h drilling attachment, speed 684 R. P. 0.0037 inch feed ....

Revolve turret ....

Center and face lug *b* with centering to in drilling attachment, speed 684 R. at 0.0013 inch feed to center and 0.00(feed to face ....

Revolve turret.......................

Finish turn lug *b* with hollow mill h drilling attachment, speed 684 R. P. 0.005 inch feed ....

Index spindle ....

Finish turn lug *a* with hollow mill h drilling attachment, speed 684 R. P. 0.005 inch feed ....

Revolve turret and index spindle......

Drill hole in lug *b* with drill held in (attachment, speed 3555 R. P. M. at inch feed ....

Pull out drill to remove chips.........

Finish drill hole in lug *b* with drill l drilling attachment, speed 3555 R. P. 0.0011 inch feed ....

Revolve turret ....

Remove burr and broach with tool h floating holder ....

Clear ....

Mill slot in lug *a* with special milling ment held on rear cross-slide, spe R. P. M., at 0.014 inch feed.........

Cut-off with special milling attachmen on front cross-slide, speed 480 R. P. 0.014 inch feed ....

Index spindle ....

Cross-slide Slotting Attachment

The special slotting attachment designed for cutting the slot in lug *a* shown in Fig 6 is shown in Fig. 8. This attachment consists of a block *A*, the base of which is held to the rear cross-slide by a bolt and

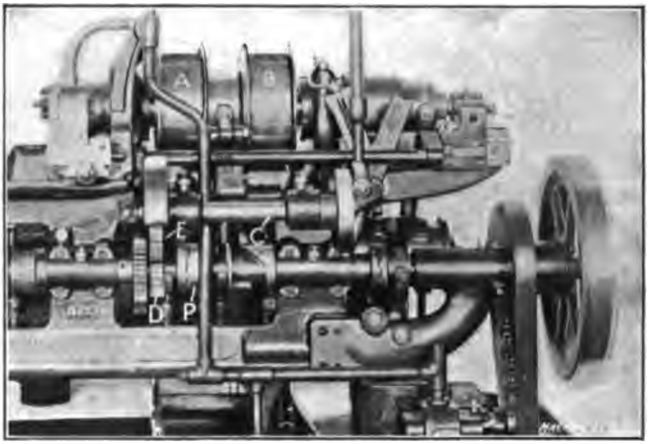


Fig. 7. Illustration showing the Location of the Indexing Attachment

nut *B* and *C* as shown, the former fitting in the T-slot in the cross-slide. The spindle *D* passing through the casting which is bushed with a bronze sleeve, has attached to it a bevel gear *E*, meshing with a

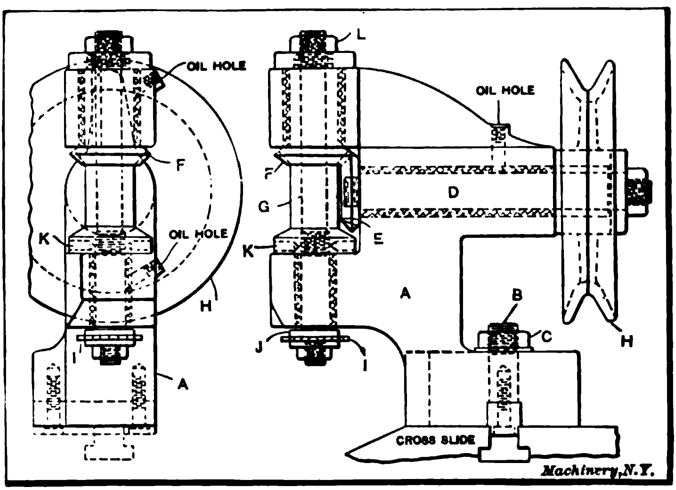


Fig. 8. Slotting Attachment held on the Rear Cross-slide

bevel gear *F* keyed to the vertical spindle *G*. This vertical spindle *G* also runs in bronze bushings. The pulley *H* is keyed to the rear end of shaft *D* and is held to it by a nut and washer as shown. A round belt which passes over a grooved pulley held on the countershaft, drives this pulley *H*, which, in turn, drives the slotting saw *I* held on the lower end of the vertical spindle. Adjustment is provided for the slotting saw *I* by varying the thickness of the washer *J* and also by means of the adjusting nuts *K* and *L*. Gear *F* has a shank which fits in the upper member, so that the spindle *G* can be adjusted without affecting the position of this gear.

Cross-slide Sawing Attachment

The attachment which is used for cutting off the piece shown at *A* in Fig. 6 is shown in Fig. 9. This attachment is held on the front

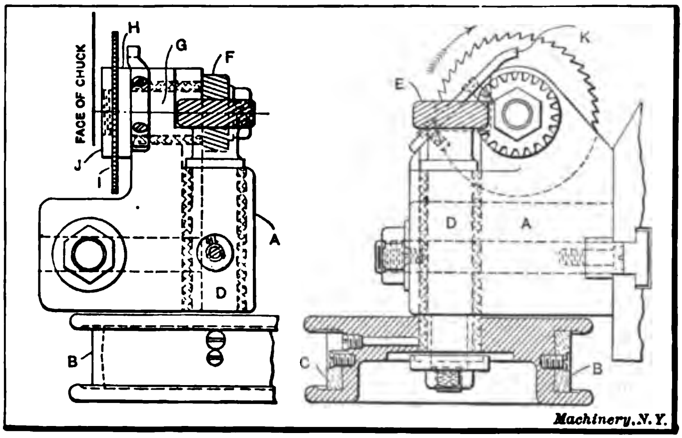


Fig. 9. Sawing Attachment held on the Front Cross-slide

cross-slide, and consists of a holder *A* somewhat similar to the ordinary holder used for the circular form tools, and is also held to the cross-slide in a similar manner. A three-quarter inch flat belt, which passes over a pulley fastened to the countershaft, drives this attachment through the pulley *B*. This pulley *B* has a leather strip *C* fastened to it which increases the friction and gives a more positive drive to the cutting-off saw. The pulley *B* is keyed to a shaft *D*, and also held to it by a nut and washer as shown. The shaft *D* which passes through a bronze bushing held in the holder *A* has a helical gear *E* cut on its forward end. This helical gear meshes with a mating gear *F* held on the cutter spindle *G*, which is located at right angles to the spindle *D*. The spindle *G* fits in a bronze sleeve held in the holder *A*, and is provided with a shoulder *H* against which the slotting saw *I* is held by the nut *J*. The guard *K* is used to prevent the work from springing away from the saw when almost cut off.

CHAPTER II

CROSS-DRILLING ATTACHMENTS

In order to avoid a separate operation in manufacturing parts requiring to be cross-drilled, the Brown & Sharpe Mfg. Co. has designed what is called an "index drilling attachment." This attachment, which is used for drilling cross-holes in studs and capstan-screws, is illustrated in Figs. 10, 11 and 12.

The Brown & Sharpe index drilling attachment, which is shown located on a No. 00 automatic screw machine in Figs. 10 and 11, consists mainly of a cast-iron bracket *A*, fastened by cap-screws to a boss

Fig. 10. Front View of the Index Drilling Attachment, placed on a No. 00 Brown & Sharpe Automatic Screw Machine

provided for that purpose on the machine. In this bracket are held the work- and drilling-spindles, the latter being held in a vertical position and in line with the work-spindle. The camshaft from which the attachment is operated, is driven by a chain and sprocket, which is shown encased in Fig. 10. A sprocket-wheel for driving the attachment is placed on the front camshaft of the machine, and an idler pulley, fastened to a bracket, gives the chain the desired tension on the sprocket. Figs. 10 and 11 give a general idea of the construction of this index drilling attachment, but for a more detailed description reference should be made to Fig 12. Similar parts in the three illustrations bear the same reference letters.

The drilling-spindle *B* is driven by a 3/8-inch round belt from the overhead works through pulleys *L* and *M*, the pulleys *M* acting as idlers, to change the direction of the belt from a vertical to a horizontal position. Spindle *B* is operated by a cam *C* acting through a lever *D*, while the indexing of the work-spindle *E* is accomplished by a cam *F* acting through a lever *G*. The forward end of the lever *G* has teeth cut in it (see Fig. 18) which mesh with the segment gear *H* on the work-spindle *E*, Fig. 12. A ratchet *I*, held to the segment gear by a shoulder screw and nut as shown, and acted upon by a spring, fits in a ratchet disk I_1 (see Fig. 18) which is keyed to the work-spindle *E*. The locking plate *J* has V-notches cut in it, the number of which (usually four) equals the indexings of the spindle required, this plate being used for locking purposes only. A spring plunger *K* fits in the notches in plate *J* and holds it in place until the spindle is again indexed.

In operation, when the indexing lever *G* is raised by the cam *F*, it depresses the spring plunger *N*, and at the same time rotates the seg-

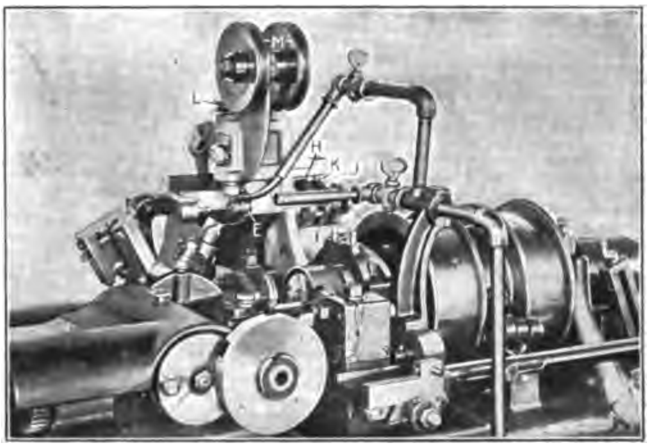


Fig. 11. Rear View of the Index Drilling Attachment in Place on a No. 00 Brown & Sharpe Automatic Screw Machine

ment gear *H* carrying the ratchet *I*. The spring plunger returns the lever to its normal position when the roll on the lever drops down to the smallest diameter of the cam, and in so doing returns the indexing disk *H* to its normal position ready for the next indexing. The work-spindle is indexed by the ratchet *I* meshing in one of the teeth in the ratchet disk I_1.

The drilling-spindle *B* is raised and lowered by means of the lever *D*, which is connected to it by two screws *O*, holding two shoes, the latter fitting in milled slots cut in the sleeve *P*. This sleeve is held on the spindle *B* by check-nuts *Q*. The drill-spindle runs in bronze bearings, and is provided at its lower end with three set-screws *R* for holding the drill. The upper end of the drill-spindle fits in a steel bushing *S*, to which it is keyed. The pulley *L* is also keyed to bushing *S*, and as the spindle *B* is provided with a groove, it is possible to rotate the spindle, and at the same time move it up and down by the lever *D*.

A general outline of the construction of the various details of the attachment is given in the following:

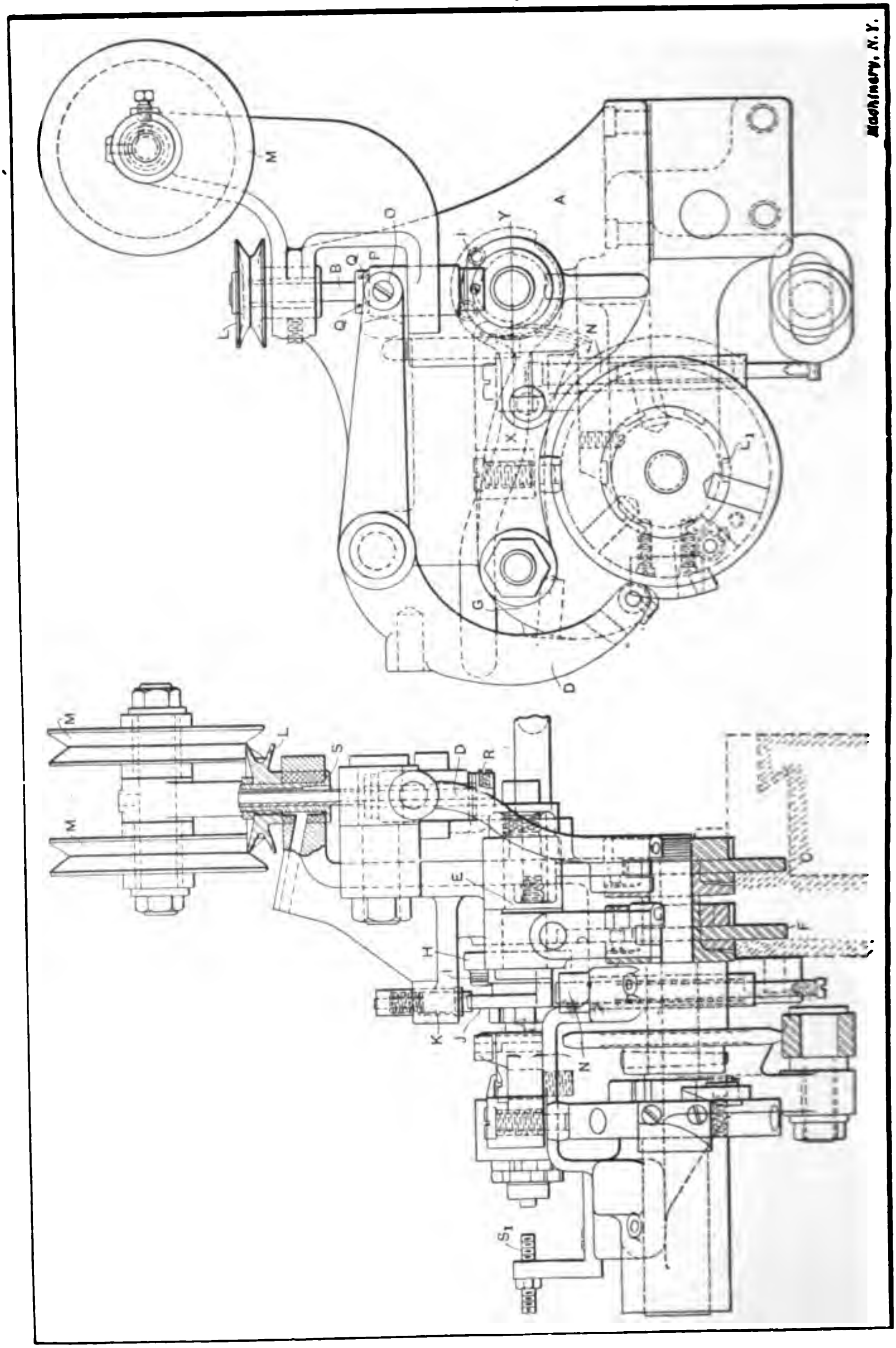


Fig. 12. Assembly View of the Index Drilling Attachment for the No. 00 Brown & Sharpe Automatic Screw Machine

Construction of the Index Work-spindle

Fig. 13 shows a sectional view of the index work-spindle, the section being taken on the line *X–Y*, Fig. 12. The spindle, as has been previously stated, is indexed, but otherwise remains stationary. The chuck *A* is closed by means of the cam *B*, which is fastened by screws to the drum *D*, while the cam *C* operates the lever *M* for opening the chuck. A roller *L*, attached to the lever *M*, and which is guided by the cam-blocks *B* and *C*, operates the lever *M* for closing and opening the chuck.

In operation, as the lever *M* is forced by the cam *C* in the direction indicated by the arrow C_1, it withdraws the clutch sleeve *N* from beneath the fingers *O*, allowing the latter to drop and release their pressure on the sleeve *P*. Now, as the mouth or front end of the sleeve P_1 is beveled to an angle which is greater than the angle of repose, and as the chuck *A* is split and spring-tempered, the withdrawal of the clutch sleeve *N* from beneath the fingers *O* allows the bevel on the chuck to force the sleeve *P* back, thus permitting the chuck to open and the work to be ejected by the plunger *S*. Inversely, as the lever *M* is forced by the cam-block *B* in the direction of the arrow B_1, the clutch sleeve *N* is forced under the fingers *O*, so that their circular bearings or ends rest on the straight cylindrical portion of the sleeve. This action on the fingers *O* causes the sleeve *P* to be pushed forward and butt against the sleeve P_1, forcing it over the tapered portion of the chuck *A*, and thus closing the latter on the work.

The work, when forced into the chuck *A*, butts against a brass ejector or stop *S* which is screwed onto the rod *R*. This rod passes entirely through the spindle R_1, and is held outward by a coil spring *E*. When the work forces the ejector *S* into the chuck, the head on the rod *R* comes against the stop-screw S_1, which is clamped by the lock-nut shown. The position of the stop-screw governs the distance to which the work can be inserted in the chuck, thus locating the position of the drilled holes. The desired grip of the chuck *A* on the work is obtained by adjusting the check-nuts *G*. The work-spindle can be taken out by removing the nuts *H* and *I* and the lever *M*.

Laying out Cross-slide Cams for Cross-drilling Operations

The method of laying out a set of cams for a cross-drilling operation is similar to that for any other job, except that there are a number of special points to be considered which relate chiefly to the clearance allowances for the transferring arm in its ascent and descent to and from the work-spindle. Possibly the best way to illustrate the method employed is to take a practical example and describe each step. Assume that it is required to make the piece shown at *A* in Fig. 14, which is a binding post, made from 9/32-inch brass rod. The turret and cross-slide cams, also shown in this illustration, are laid out in the usual manner, except that sufficient space is allowed, as shown from 86 to 91 (on the cam circumference) for bringing down the transferring arm to grip the work. One hole should be left vacant in the turret, so that the transferring arm can be brought down without coming in contact with any of the turret tools.

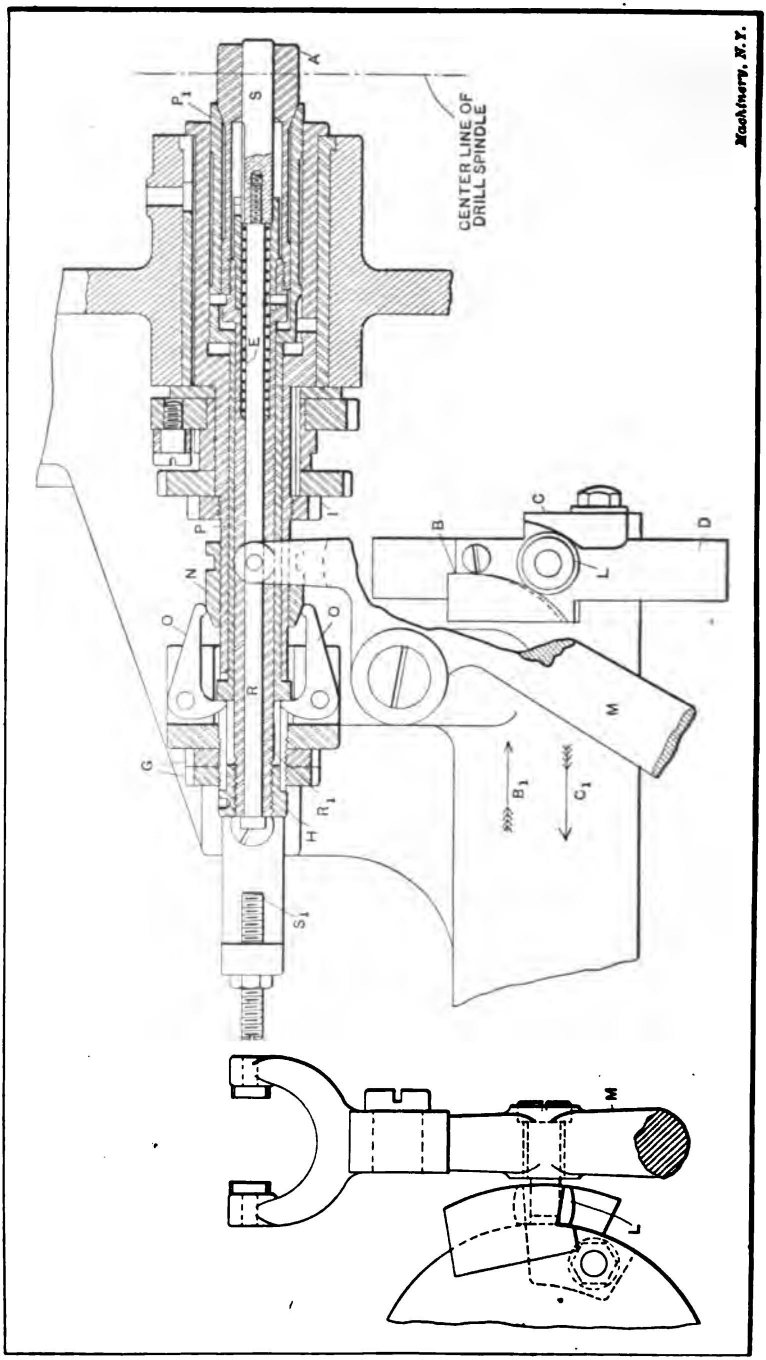


Fig. 15. Sectional View of the Index Drilling Work-spindle

Before laying out the lead and cro
make a lay-out as shown in Fig. 15,
circular form and cut-off tools and a
If this is done, the amount that the
the largest diameter of the cam circu
necessary for the turret and circular
the necessary information has been
other diagram, such as in Fig. 11, Re
and Cutting Cams for the Brown &

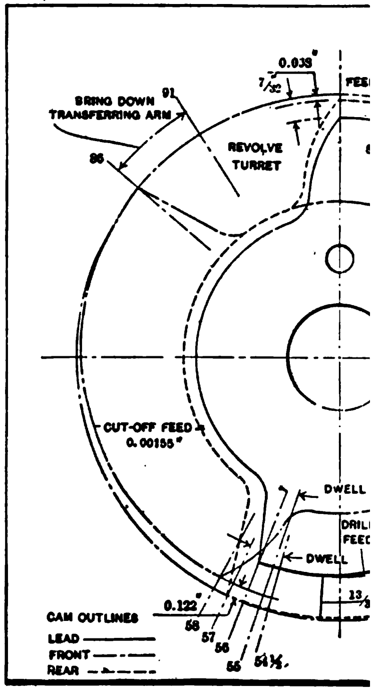


**Fig. 14. Lay-out of a Set of Cams fo
the No. 00 Brown & Sharpe Au**

chines," should be made so that the
transferring and advancing cams can
ample given in that illustration appli
slotting job; the method of procedu
cams used on the index drilling attach

Laying out the Transferring

As the method of laying out the t
is described in Part II of this treati
No. 100, it will not be necessary to d
the transferring and advancing cams u
shown at *A* in Fig. 14, is shown in F

uses are clearly indicated. The lay-out of these cams does not differ materially from that for a screw-slotting job except, of course, that the lobes on the advancing cam are made with a dwell, no feeding movement being necessary. To determine the relative heights of the lobes *A* and *B* on the advancing cam, a diagram similar to that in Fig. 11, Reference Book No. 100, should be drawn, the slotting saw being replaced by the chuck *A* and stop *S*, shown in Fig. 13. The lobe *A*, Fig. 16, should be of sufficient height to force the work into the chuck to the proper distance, and thus locate the stop *S*, Fig. 13, up against the stop-screw S_1.

Laying out the Indexing and Drilling Cams for the Cross-drilling Attachment

In laying out a set of indexing and drilling cams, it is always preferable to start from some predetermined point. The practice usually

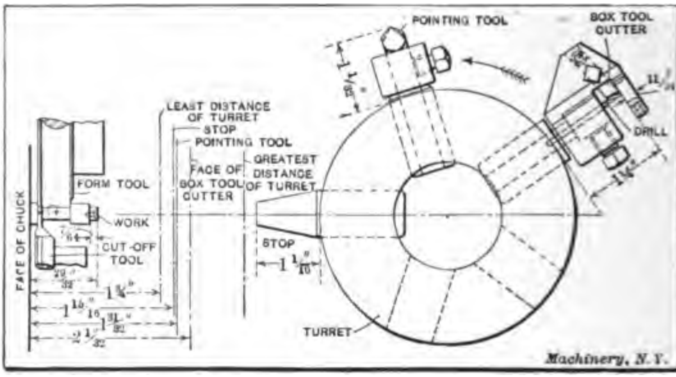


Fig. 15. Diagram for Obtaining the Cut-down on the Lead Cam, and Clearance for Tools

followed is to allow 1½ hundredth clearance between the finishing point on the inserting lobe *A* (see Fig. 16) and the starting point *A* on the drilling cam, Fig. 17, and then lay out the corresponding lobes on the drilling and indexing cams from this point. As soon as the advancing roller is on the top of the lobe *A*, Fig. 16, the index drilling chuck should be opened, and closed again before the roll drops off the lobe. About one hundredth of the cam surface should be allowed for clearance, so in this case the chuck should be opened at 4 on the cam circumference. The chuck is opened by the cam *C* on the drum *D*, Fig. 13, in the manner previously described.

The indexing and drilling cams used for drilling the binding post shown at *A* in Fig. 14 are shown in Fig. 17. Here it can be seen that the drill begins to operate at 5½ and finishes at 52, one one-hundredth being allowed for the drill to make a smooth finish. The order of operations for the lead, cross-slide, advancing, transferring, drilling and indexing cams is given in the tabulated arrangement on the following page.

Lead and Cross-slide Cams

Order of Operations	Revolutions	Hundredths
Feed stock to stop and chuck	22.40	8
Revolve turret	25.20	9
Center 0.040 inch rise at 0.0023 inch feed, dwell 0.125	19.60	7
Revolve turret	25.20	9
Drill and turn with box-tool 0.120 inch rise at 0.002 inch feed, dwell 0.15	64.40	23
Form with circular tool 0.058 inch rise at 0.00045 inch feed, dwell 0.25	(159.60)	(57)
Clearance	5.60	2
Cut-off 0.122 inch rise at 0.00155 inch feed, and revolve turret	78.40	28
Clearance for transferring arm	14.00	5
Revolve turret	25.20	9
Total	280.00	100

Transferring and Advancing Cams

Order of Operations	Revolutions	Hundredths
Place transferring bushing on work	11.2	4
Drop arm back from work	5.6	2
Lift up transferring arm	20.2	7¼
Clearance	2.8	1
Dwell with transferring arm while placing work in chuck and drilling	187.6	67
Place work in index drilling chuck	21.0	7½
Dwell with arm while closing chuck	11.2	4
Drop back arm	14.0	5
Dwell with arm while drilling	131.6	47
Drop down transferring arm to pick up piece	30.8	11
Clearance	2.8	1
Advance to put bushing on work	11.9	4¼

Drilling and Indexing Cams

Order of Operations	Revolutions	Hundredths
Drill and countersink 0.218 inch rise at 0.0017 inch feed, dwell 0.10	127.4	45½
Lift out drill	9.1	3¼
Push down lever to index	11.2	4
Dwell to allow spring to return lever	4.9	1¾
Index second time	22.4	8
Dwell to allow spring to return lever	4.9	1¾
Clearance	9.1	3¼
Countersink 0.062 inch rise at 0.0031 inch feed, dwell 0.10	22.4	8
Pull out drill, open chuck, and allow clearance, to drop and raise transferring arm and close chuck	65.8	23½

Referring to Fig. 17, it will be seen that the indexing cam is provided with two projecting lobes *B* and *C*, which are used to force the lever down and thus rotate the indexing disk. These two lobes are necessary because the piece to be drilled has only one cross-hole countersunk on both sides, which necessitates indexing the spindle four times for each piece. Since the indexing and drilling cams rotate at the same speed as the turret and cross-slide cams, the time required for indexing is approximately equal to the time required for feeding the stock, which can be verified by referring to the illustration, the space required being from 61 to 69. Three hundredths of the cam surface is the minimum space which should be allowed, on account of the rolls requiring that space to drop down. A milling cutter at least 1/16 inch larger in diameter than the roll should be used for cutting

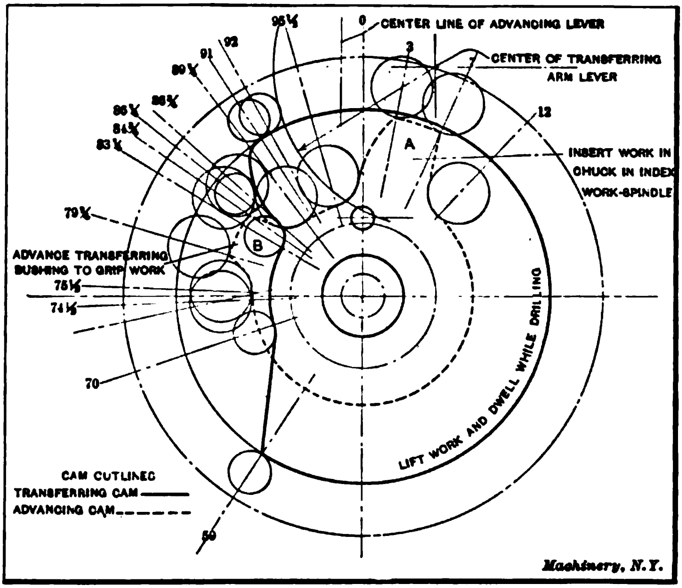


Fig. 16. Transferring and Advancing Cams for Lifting and Placing the Work in the Index Drilling Chuck

the cams. The motion transmitted by the cams to the indexing and drilling levers *G* and *D* is clearly shown by the full and dotted lines in Fig. 18. The maximum travel of the index drilling spindle is equal to the distance *A*, which on the attachments used is as follows:

No. of Machine	Distance A in Inches
00	9/16
0	3/4
2	13/16

The maximum diameters of the indexing and drilling cams for the attachments used on the various machines are as follows:

No. of Machine	Distance B in Inches
00	4
0	4 1/2
2	4 1/2

The cut-down required on the cam for indexing can be found by laying out a diagram similar to that shown in Fig. 18. When the indexing disk I_1 is provided with six teeth instead of four, the cut-down required will be, of course, proportionately less.

Speeds and Feeds for Cross-Drilling

The speeds and feeds used for cross-drilling do not vary from those used when drilling from the turret, and to obtain the required speed for the drill a grooved pulley of suitable size should be placed on the

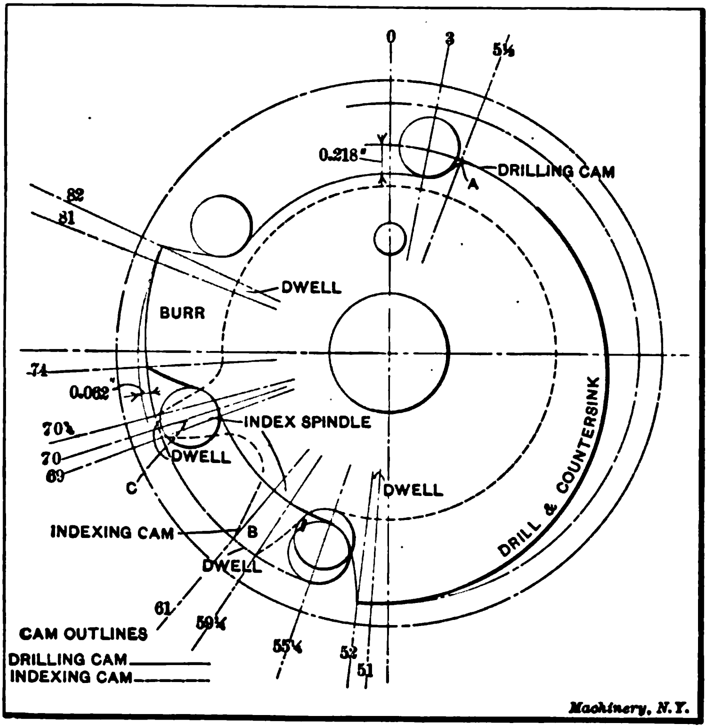


Fig. 17. Indexing and Drilling Cams for the Piece shown at A in Fig. 14

countershaft. The drilling speeds and feeds for ordinary carbon and high-speed twist drills for drilling different materials are given in Machinery's Reference Book No. 103, "Internal Cutting Tools for the Brown & Sharpe Automatic Screw Machines."

Transferring Bushings

When transferring a piece of work from the work-spindle to the index drilling spindle, it is necessary to have a transferring bushing which will insert the work in the index drilling chuck. The ordinary screw-slotting bushing cannot be used for this purpose, except when the work is sufficiently long and the hole in a suitable place, so that the work can be inserted in the chuck without the aid of a spring plunger. When he work is not of the character specified, it is necessary to use a transferring bushing in which is placed a spring plunger for inserting the work in the index drilling chuck.

At *A* in Fig. 19 is shown a capstan-screw and the transferring bushing used for inserting it in the index drilling chuck. This screw, as shown, has two holes drilled clear through the head at right angles to each other. The transferring bushing consists of a shell *a* which is held in the transferring block. Inserted in this shell is a spring plunger *b*, pressed outward by a coil spring *c*, this coil spring being retained in the bushing by means of the nut *d*. The hole in the spring

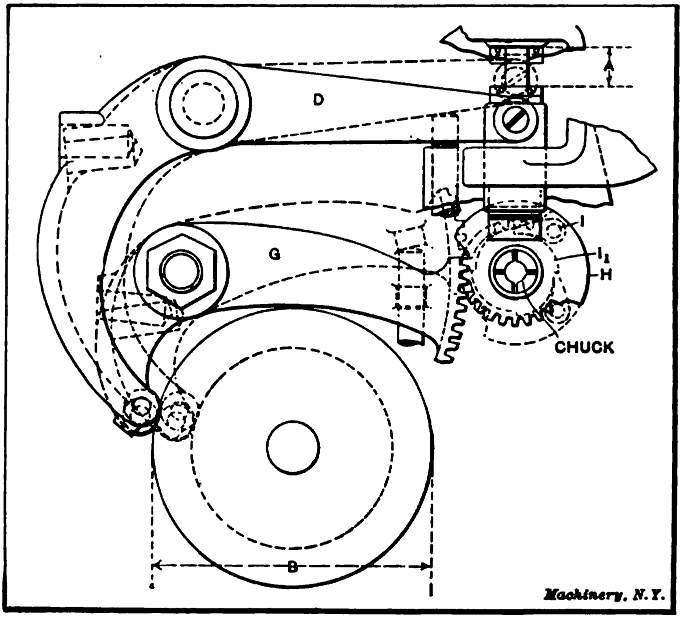


Fig. 18. Diagram illustrating the Movement of the Indexing and Drilling Levers

plunger should be larger in diameter than the body of the screw, so that the work can be inserted easily into the plunger. The type of transferring bushing shown at *A* is suitable for capstan-screws and similar work.

Another transferring bushing for holding a binding post is shown at *B*. This bushing differs from that shown at *A* in that it is provided with a spring chuck as well as with a plunger. The reason for this was that the piece had to be inserted in the chuck to such a distance that it was necessary for the chuck *e* to retreat so that the work could be inserted. This transferring bushing was not a success on account of this combination arrangement of spring chuck and plunger. Difficulty was encountered with the spring chuck *e*, because of the variations in the diameter of the stock. When the stock was much greater in diameter than the hole in the chuck, the chuck was forced back into the holder so that the work was not held, as the plunger *f* kept it out.

Owing to the short amount of grip on the work, it had to fit snugly in the bushing, or it would drop out while being transferred from the work chuck to the index drilling chuck. To overcome this difficulty several methods were adopted. First, the spring *g* was made stiffer, so that when work slightly larger than the hole in the chuck was encountered, it could be inserted without pushing back the plunger. This

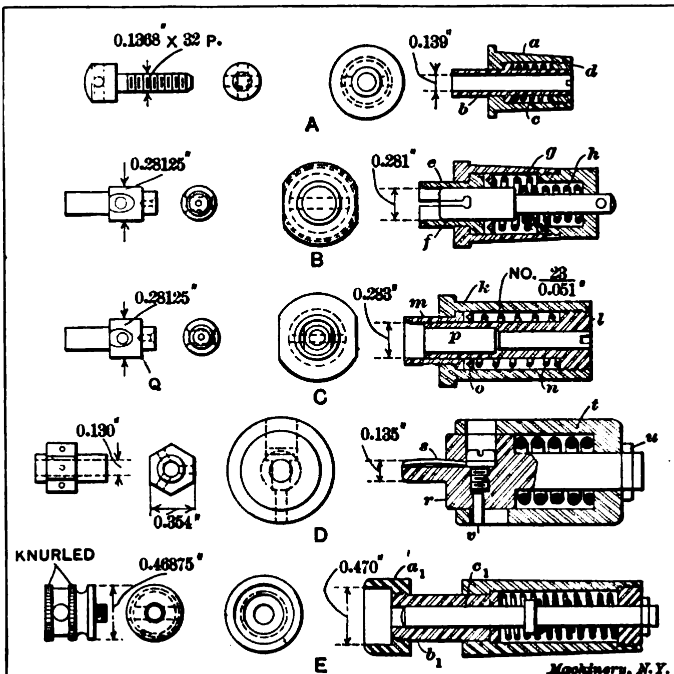


Fig. 19. Representative Types of Transferring Bushings and the Work they were designed to hold

overcame the difficulty of placing the work in the chuck *e*, but when the latter was transferred to the index drilling chuck, the work could not be ejected from the chuck. The spring *h* was made stiffer, but this brought about the same conditions as before, and prevented the work from being located properly in the chuck *e*.

This type of bushing was finally discarded and the one shown at *C* was adopted.. This bushing consists of an outer sleeve *k*, as before, in which is screwed a stationary holder *l*. A chuck *m* is made a sliding fit on holder *l*, and also in the sleeve *k*, and is pressed outward by a spring *n*. This spring acts against a washer *o*, which is beveled, as shown, to reduce the friction, thus preventing the spring from being twisted in the holder when work of larger diameter than the chuck is encountered, causing the chuck to rotate. The hole *p* in the holder is made slightly larger than the diameter *Q* on the work, while the hole in the bushing *m* is made slightly larger than the largest diameter of the work. The holder *l* is slabbed on both sides on the front end, as shown in the end view, and the index drilling chuck is cut out so that this holder can be inserted in it, thus carrying the work right into the chuck. This bushing proved very satisfactory, both as regards gripping the work and inserting it in the chuck, and was used on the piece shown at *A* in Fig. 14.

A transferring bushing of a different type is shown at *D*. This bushing, instead of passing over the work, has a plunger *r* which is inserted in a hole in the work. This plunger is slotted, as shown, and a flat spring *s* is held to it by a screw. Spring *s* is curved and rounded so that it fits snugly in the work. The plunger *r* is held out by a coil spring *t*, and is retained by a pin *u*. A small pin *v*, driven into the plunger and fitting in a slot cut in the bushing, prevents the plunger from rotating. As shown in the illustration, this bushing is not tapered on the shank, but is perfectly straight, so, obviously, a special transferring block had to be made to hold it.

Another type of transferring bushing is shown at *E*. This bushing has a marked resemblance to that shown at *B*, but gives satisfaction because of the character of the work. The hole in the chuck a_1 could be made larger than the diameter of the work, and still the latter would not drop out; thus the difficulty of inserting the work in the chuck is overcome. The hole in the plunger b_1 to which the chuck is attached is made larger than the teat or threaded part on the work. A spring plunger c_1 is used for inserting the work in the index drilling chuck. Obviously, there are a number of different types of transferring bushings used, but as those shown incorporate the principal features of bushings of this type, it would seem that any further descriptions are unnecessary.

CHAPTER III

BURRING ATTACHMENTS

Quite frequently it is found necessary to drill holes in both ends of a piece of work. This cannot be done while the piece is attached to the bar, but necessitates rehandling the work. The Brown & Sharpe Mfg. Co. has designed what is called a "burring" attachment, which is used in connection with its automatic screw machines for drilling and chamfering holes in both ends of the work.

A front view of the burring attachment fastened on a No. 00 Brown & Sharpe automatic screw machine is shown in Fig. 20. Fig. 21 shows a rear view, while Fig. 22 shows plan, end and sectional views,

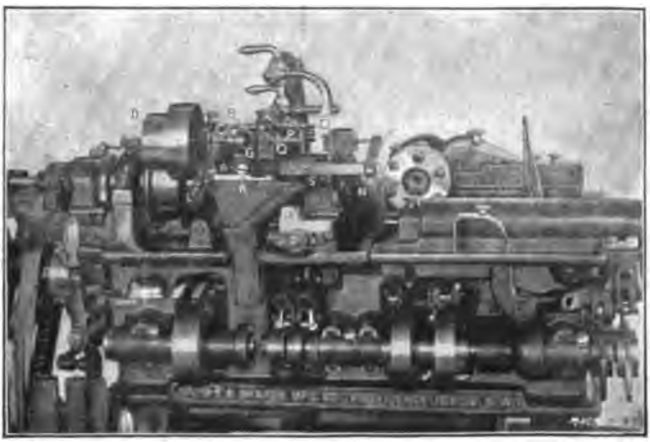


Fig. 20. Front View of No. 00 Brown & Sharpe Automatic Screw Machine equipped with a Burring Attachment

respectively. The attachment consists essentially of a cast-iron base *A*, provided with bearings *B*, in which a spindle *C* is free to rotate, being driven by the two-stepped cone pulley *D*. The bosses *B* are provided with phosphor-bronze sleeves *E* and a thrust washer *F*. The nut *G* is provided for taking care of the end play of the spindle. The burring tool is held in a bushing *H*, fitting in the nose of the spindle *C*, and is furnished with a clamping block *I* acted upon by a set-screw *J*.

This burring attachment can be adjusted to and from the machine by means of the collar-head screw *K*, and the top part of the attachment can be adjusted on its base in a plane with the axis of the spindle, by means of the collar-head screw *L*. The standard work-holder *M* is shown in section in Fig. 22, and more clearly in Fig. 26, to which reference should now be made. Here *A* is the chuck, slotted and spring tempered, B the chuck-closing sleeve and C the ejector. The chuck-closing sleeve is operated by means of a lever D, which is acted upon by pin E. To close the chuck, the arm N, Fig. 22, is made to dwell in an intermediate position between the work-spindle and the burring spindle, or, in other words, directly in front of the chuck-closing device O. The arm N is then advanced, when the device O forces the sleeve B onto the chuck A, thus closing the latter on the work.

The chuck A, Fig. 26, which is screwed into the transferring block, is opened by means of the pin E coming in contact with the end of the rod P held in the burring head by a set-screw Q, see Fig. 22. When pin E comes in contact with rod P, the former forces back lever D, which, in turn, releases the chuck-closing sleeve B and allows the chuck to expand, thus facilitating the removal of the work. The work

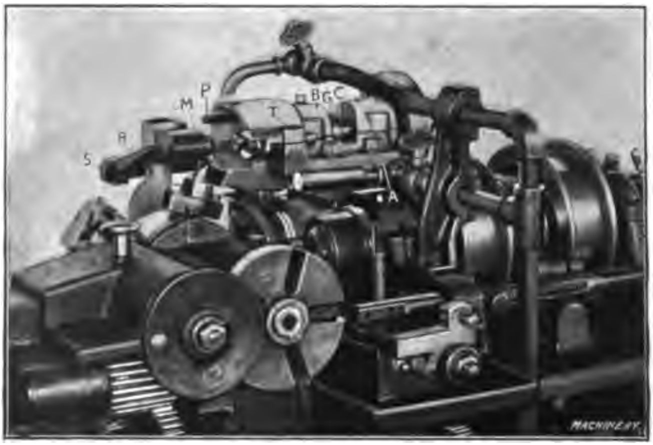
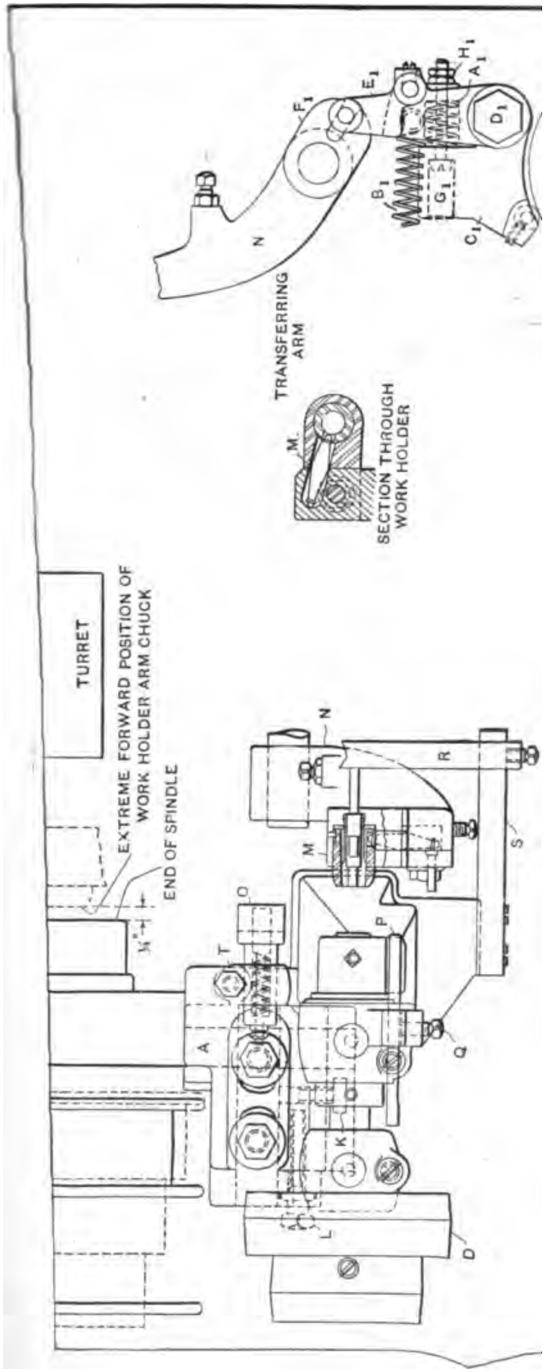


Fig. 21. Rear View of the Burring Attachment placed on a No. OO Brown & Sharpe Automatic Screw Machine

is removed by means of the plunger C, which comes in contact with the finger R, Fig. 22, when the arm N drops back. This finger is held by a set-screw on a square rod S, which, in turn, is fastened to the base of the burring attachment.

Referring now to the view to the right in Fig. 22, the transferring arm N is made to dwell in an intermediate position by the combined action of the two cams—transferring and burring—and the two springs A_1 and B_1. The transferring lever C_1 is fulcrumed on the stud D_1 and works in a slot in the connecting link E_1. The link E_1, in turn, is connected to a slotted block F_1, which is fastened to the transferring arm shaft by a cone-pointed set-screw, not shown. The spiral spring A_1 bears against the face of the transferring lever C_1, the transferring lever being held to the link E_1 by means of the fillister head screw G_1 and two check nuts H_1. The spring B_1 is used to keep the roll in the lever C_1 in contact with the transferring cam, while the spring A_1 is used to steady the transferring arm. When the set-screw in the arm N comes in contact with the square rod S, the lever C_1 continues com-


TURRET
EXTREME FORWARD POSITION OF WORK HOLDER ARM CHUCK
END OF SPINDLE
TRANSFERRING ARM
SECTION THROUGH WORK HOLDER
A
D
K
M
N
O
P
Q
R
S
T

pressing the spring A_1, thereby keeping a tension on the arm *N* while the burring operation is being performed. The spring B_1 is fastened to the link E_1 and to the tray or bracket-holder for the transferring arm rod. The height of the lobe on the transferring cam governs the angular position of the arm *N*.

Laying out Cross-slide and Lead Cams for Burring Operation

The same remarks which were made in the previous chapter in regard to laying out cross-slide cams for cross-drilling operations apply

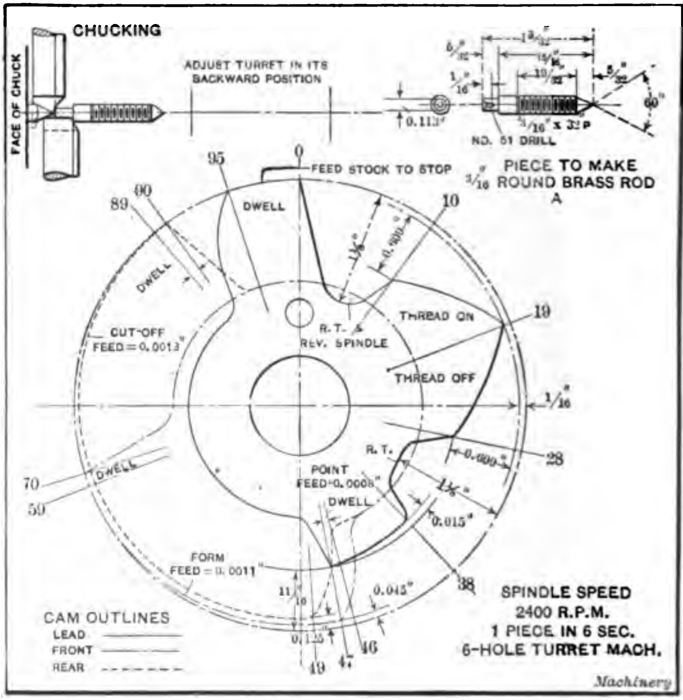


Fig. 23. Lead and Cross-slide Cams for Making a Cone-pointed Screw having a Hole drilled in the Rear End

to the laying out of cross-slide cams for burring operations, it being absolutely necessary to leave sufficient clearance for the arm to ascend and descend to and from the work-spindle. The character of the work and the shape and size of the work-holder also play an important part in regard to the amount of clearance necessary. This, of course, has to be worked out for each individual case. To illustrate clearly the method of designing a set of cams for an ordinary burring operation, we will lay out a complete set of cams for producing the cone-pointed screw shown at *A* in Fig. 23. As can be seen a No. 51 drill hole is to be produced in the rear end of this screw, which without the use of this attachment would necessitate rehandling the work and performing a second operation on it.

The cross-slide and lead cams for ma
in Fig. 23, where the functions of the
cated. It might be mentioned, howev

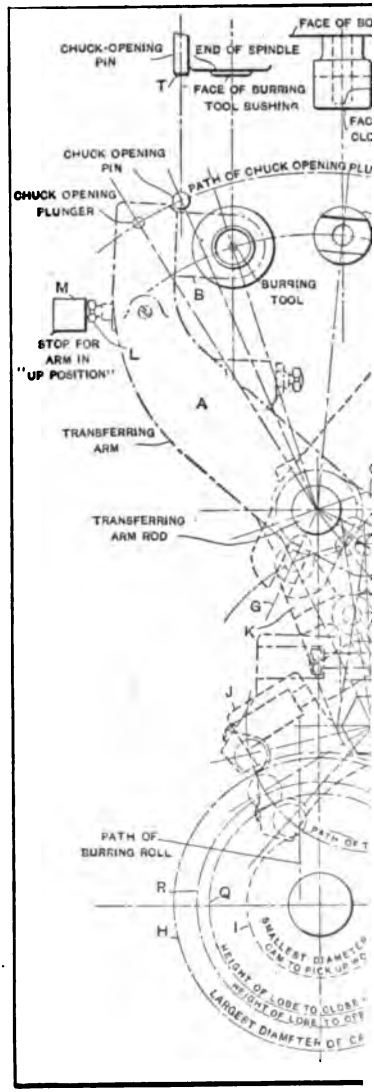


Fig. 24. Diagram used in Determi
and Burring

just the turret slide back to the extre
in a No. 00 B. & S. automatic scre
feed stock is also less than that usu
instead of 10 hundredths of the car

this is that the turret is not revolved, but is just advanced to gage the stock to length.

Laying out the Transferring and Burring Cams.

Before proceeding to lay out the transferring and burring cams, a diagram similar to that shown in Fig. 24 should be made. Here the work-chuck, chuck-closing device, burring tool and chuck-opening pin should be laid out in their respective positions, and the angular movement of the arm from one point to the other should be determined.

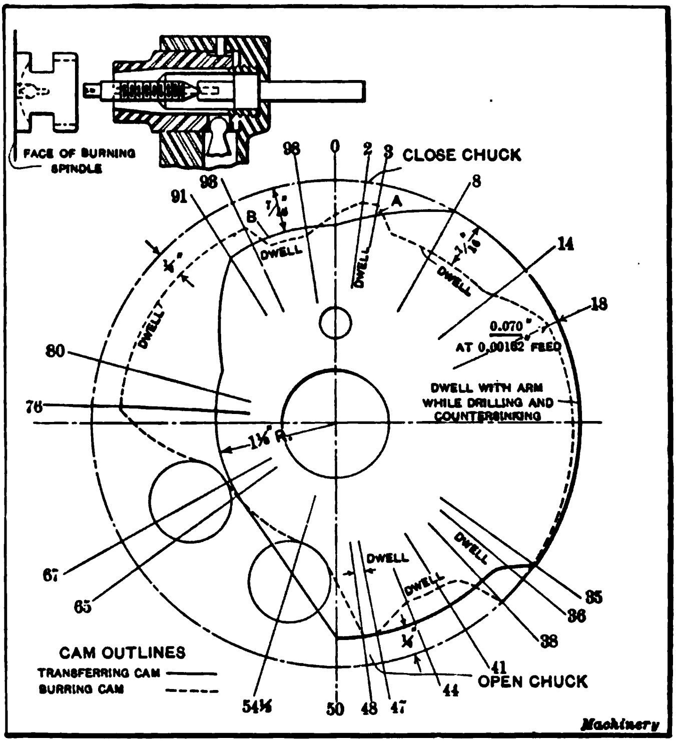


Fig. 25. Transferring and Burring Cams for the Piece shown at A in Fig. 23

A good method for obtaining the angular movement of the arm *A* is shown in Fig. 24. All those parts which are designated by full lines are drawn in; then make a templet of the arm *A*, work-holder *B* and slotted block *C*, on tracing cloth. Now by pivoting this templet on the center of the transferring arm rod, and swinging it around to he various positions, the lines *D*, *E*, *F* and *G* can be drawn which represent the center of the slot in the block *C*, when the arm is swung to the various positions. Next draw the circles *H* and *I*, representing the largest and smallest diameters of the transferring cam, after which a templet of the transferring lever *J* and connecting link *K* should be made on tracing cloth.

As was previously mentioned, the lever *J* should compress the spring A_1, see Fig. 22, when the set-screw *L* touches the square rod *M*, thus steadying the arm during the burring operation. To provide for this the nuts *N* are adjusted, so that the spring A_1 will bear the weight of the arm *A*. To proceed, pivot the templet of the transferring lever and connecting link on the center of the stud *O*, swing the templet so that the center of the pin *P* comes in line with the lines *E* and *F*, respectively, and draw circles *Q* and *R* representing the heights of the lobes for closing and opening the chuck. Care should be taken in laying out the lobes to lift the arm from the chuck-closing device to the chuck-opening pin, as the space between the two members is not adjustable. As the spring A_1, see Fig. 22, is compressed further when

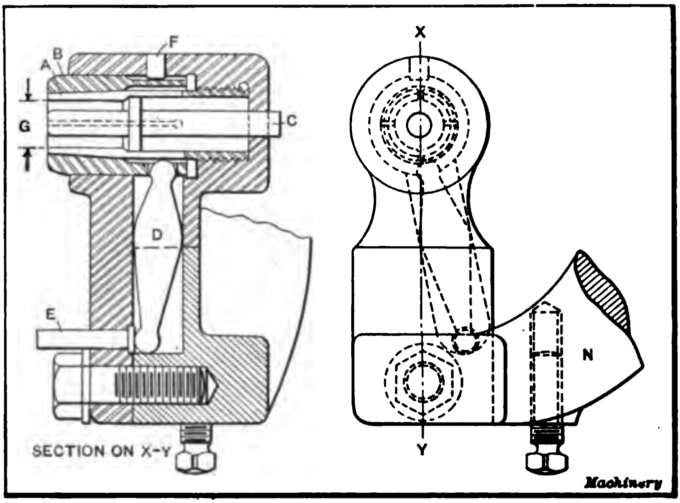


Fig. 26. Standard Work-holder used in Connection with the Burring Attachment

the arm *A* is in the "up position" than when it is in the "down position," it is necessary to start swinging the arm *A* from the work-chuck, and to proceed towards the burring tool. It will be found that the roll in the lever *J* will fall below the largest diameter of the cam, when the arm is in line with the burring tool; this allows the spring A_1 to be compressed and thus steady the arm.

To obtain the heights of the lobes on the burring cam, a diagram similar to that shown in the upper view of Fig. 24, should be made. The burring tool should be drawn in position, as well as the work in the work-chuck. The chuck-closing device *S*, and chuck-opening pin *T* are adjustable within a considerable range, but it is best to work from a setting which will be most convenient to the burring tool and work.

The method used in obtaining the heights of the lobes on the advancing cam was described in connection with Fig. 11, Reference Book No. 100 (Part II of this treatise), while the proper procedure to follow in laying out the lobes on the transferring cam in their correct relation to the lobes on the advancing cam was described in connection with Fig. 12 in the same book. The diagrammatical method used in laying out the transferring and advancing cams for the Nos. 0 and 2 B. & S. automatic screw machines was illustrated in Fig. 14 of Reference Book No. 100.

The transferring and burring cams used in connection with the piece shown at *A* in Fig. 23 are shown in Fig. 25, as is also a sectional view of the work-holder with the work in position. The order of operations for making the piece is as follows:

Lead and Cross-slide Cams

Operations	Revolutions	Hundredths
Feed stock to stop	12	5
Revolve turret and reverse spindle	24	10
Thread on	21.6	9
Thread off	21.6	9
Revolve turret	24	10
Point, 0.015 inch rise at 0.0008 inch feed, dwell 0.10	21.6	9
Form, 0.045 inch rise at 0.0011 inch feed, dwell 0.10	(55.2)	(23)
Cut off, 0.125 inch rise at 0.0013 inch feed, dwell 0.10, and revolve turret four times	98.4 + 4.8	41 + 2
Clearance to bring down arm	12	5
Total	240	100

Transferring and Burring Cams

Operations	Revolutions	Hundredths
Drill and countersink, 0.070 inch rise at 0.00162 inch feed, dwell 0.20	48	20
Drop back with piece	7.2	3
Rotate to open chuck	28.8	12
Dwell on burring cam to open chuck	2.4	1
Drop back to eject piece	10.7	4½
Drop down to grip work	36	15
Dwell with arm before advancing	4.8	2
Advance on work	21.6	9
Raise arm to close chuck	26.4	11
Advance arm to close chuck	9.6	4
Close chuck	2.4	1
Rotate to burring spindle	19.2	8

Referring to Fig. 25, the lobe *A* on the burring cam moves the arm forward to close the chuck, and during this period the transferring arm roll is on the "dwell" on the lobe *B* of the transferring cam. The springs previously referred to steady the arm when in this intermediate position, but on account of this undependable method of steadying the arm, it is not advisable to make a piece in less than three seconds on the No. 00 B. & S. automatic screw machine.

Work-holders and Chuck-closing Devices

The standard work-holder furnished in connection with the burring attachment is shown in detail, connected to the arm *N*, in Fig. 26,

where its construction can be clearl
work-holder has been described, but it
a few more particulars regarding it. '
is made equal to the maximum diam
closing sleeve *B* is made with a tap
the taper being about ten degrees, and
a pin *F* fits, preventing the sleeve fr
is also cut out to receive the ball en
for releasing it from the chuck, thus
out by the plunger *C*. The lever *D*, s
by means of the headed pin *E*.

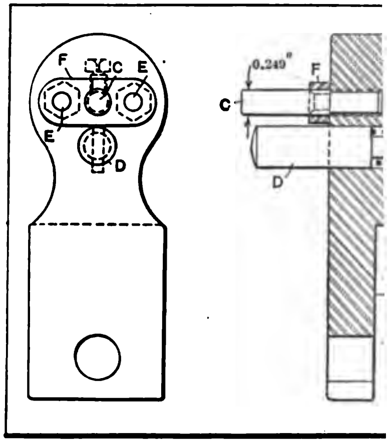


Fig. 27. A Work-holder c

Another type of work-holder, which
piece, is shown in Fig. 27. This was fo
which, as can be seen, could not be g
shown in Fig. 26 on account of the en
being tapered and threaded, thus preve
it securely. The work-holder consists
block *B* of the shape shown, which is f
by a cap-screw. This block is provid
are drilled for the work-holder *C*, locat
The locating pin *D* comes in contact wi
thus prevents the work from turning
The work-holder *C* is driven into the
E pass through the block *B*, on the fo
an ejecting block *F*, forming a link c
rear ends of these studs are also provi
by nuts *H*. An adjustable pin *I* locat
the set-screw *J*. This pin *I* comes in
22, and ejects the work after it has b

The standard chuck-closing device provided with the burring attachment shown at *O*, Fig. 22, is shown more clearly at *A* in Fig. 28. It consists of a body *b* provided with a slot *c* in its front end through which the chuck passes on its transit from the work-spindle to the burring tool. The body *b* is counterbored to receive the spring plunger *d*, which is acted upon by the spiral spring *e*. The plunger is adjusted by means of the check-nuts *f*, and forces the work into the chuck against the ejecting pin *C*, see Fig. 26.

A special locating device used in connection with the work-holder shown in Fig. 27 is shown at *B*, Fig. 28. This device consists of a body *g*, which fits in the clamping bracket *T* on the burring attachment (see Fig. 22). The device is provided with a spring plunger *h* acted

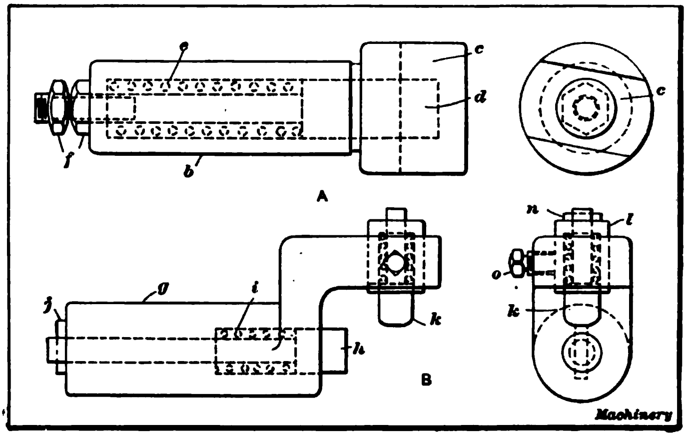


Fig. 28. Standard Chuck-closer, and Device for Locating Work on the Holder shown in Fig. 27

upon by the spring *i*, and is retained in the holder by means of pin *j*. This plunger *h* is used for forcing the work onto the pin *C*, Fig. 27. The plunger *k*, which rotates the work on the work-holder, and thus locates it correctly against pin *D*, is held in a bushing *l* counterbored to receive a spring, and is retained in the holder by means of the pin *n*. The bushing itself is held in the holder by means of the set-screw *o*.

Burring Tools and Holders

The type of burring tool and holder used in the burring attachment is governed entirely by the work it is to perform. In Fig. 29 are shown a few representative types of burring tools and their respective holders. *A* is the burring tool used for burring the piece shown at *A* in Fig. 27. This is made from round drill rod, as shown, and is provided with a leader fitting in the work, the cutting face being tapered to the required angle. The type of burring tool and holder used for drilling and countersinking the screw shown at *A* in Fig. 23, is shown at *B*. The holder *a* is made to fit in the burring spindle, and is slotted out to receive the clamping block *b*. A combination drill and counter-

sink *c* of the required shape and dia
means of a set-screw bearing on the
of the holder is counterbored to rece
is. also provided with two slots *d* whi

Another type of burring tool, and t
shown at *C*. In this case the burring
tool, being made to fit the hole in t
provided with a leader *e* to fit the wo
rear end to suit the holder and held

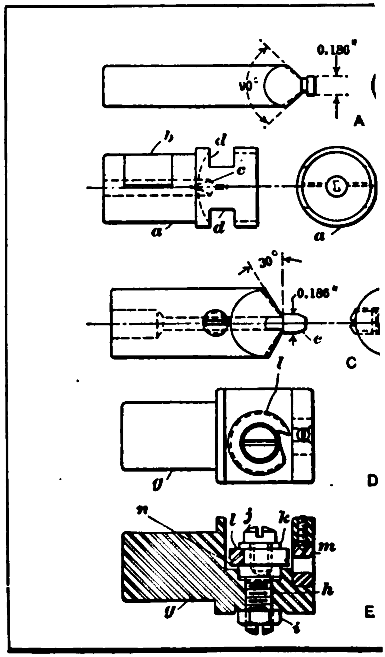


Fig. 29. Various Types of Burring To

Three views of still another type o
shown at *D* and *E*. This holder and to
fering the inside and outside of tubing
similar to a circular form tool except
held in the holder *g* on a stud *h*, wh
and is provided with a nut *i* for locking
stud carrying the circular tool is slott
can be adjusted, thus bringing the tool
fer the inside and outside of the work.

The circular tool *l* is held on the st
washer *k*. The front end of the holder
which fits the external diameter of th
a headless screw as shown. When d

preferable to lay out the work on a large scale, about 10 to 1, and from this obtain the diameter of the tool, and the distance it is to be cut down below the center, so that the tool will clear and not rub, which would tend to produce a poor finish on the work. The depth of the recess *n* should only be a few thousandths greater than the length of chamfer required on the work, because the greater the depth *n*, the smaller the diameter of the tool, and also the smaller the amount of tool circumference that can be utilized for cutting. From the diagram the location of the stud *h* can also be obtained.

Speeds and Feeds for Burring

The speeds used for burring when the tools are made from ordinary carbon steel should be similar to those used for drills, a table of which was given in MACHINERY's Reference Book No. 103, "Internal Cutting Tools for the Brown & Sharpe Automatic Screw Machines." The feeds used when the burring tool is smaller in diameter than ¼ inch should never be greater than 0.003 inch for brass, 0.002 inch for machine steel, and 0.001 inch for tool steel. The feeds should also be decreased near the end of the cut, and a dwell equal to at least three revolutions of the burring tool should be allowed on the burring cam. When the burring tool is ¼ inch or greater, the same feeds as those used for centering tools, given in the article previously referred to, can be used with satisfactory results.

OUTLINE OF A COURSE IN SHOP AND DRAFTING-ROOM MATHEMATICS, MECHANICS, MACHINE DESIGN AND SHOP PRACTICE

Any intelligent man engaged in mechanical work can acquire a well-rounded mechanical education by using as a guide in his studies the outline of the course in mechanical subjects given below. The course is laid out so as to make it possible for a man of little or no education to go ahead, beginning wherever he finds that his needs begin. The course is made up of units so that it may be followed either from beginning to end; or the reader may choose any specific subject which may be of especial importance to him.

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Jig Sheets 6A to 15A:—Common Fractions and Decimal Fractions.

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Reference Series No. 52. Advanced Shop Arithmetic for the Machinist.

Reference Series No. 53. Use of Logarithmic Tables.

Reference Series Nos. 54 and 55. Solution of Triangles.

Data Sheet Series No. 16. Mathematical Tables. A book for general reference.

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Reference Series No. 8. Working Drawings and Drafting-room Kinks.

Reference Series No. 33. Systems and Practice of the Drafting-room.

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Data Sheet Series No. 2. Screws, Bolts and Nuts. Tables of standards.

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Reference Series No. 4. Milling Fixtures.

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Reference Series No. 13. Blanking Dies.

Reference Series No. 26. Modern Punch and Die Construction.

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Reference Series No. 15. Spur Gearing.

Reference Series No. 37. Bevel Gearing.

Reference Series No. 1. Worm Gearing.

Reference Series No. 20. Spiral Gearing.

Data Sheet Series No. 5. Spur Gearing. General reference book containing tables and formulas.

Data Sheet Series No. 6. Bevel, Spiral and Worm Gearing. General reference book containing tables and formulas.

General Machine Design

Reference Series No. 9. Designing and Cutting Cams.

Reference Series No. 11. Bearings.

Reference Series No. 56. Ball Bearings.

Reference Series No. 58. Helical and Elliptic Springs.

Reference Series No. 17. Strength of Cylinders.

Reference Series No. 22. Calculations of Elements of Machine Design.

Reference Series No. 24. Examples of Calculating Designs.

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THE EXTRU
OF META

CONTENTS

Fig. 1. Two-thousand-ton Hydraulic Extrusion Press, built by Watson-Stillman Co., New York

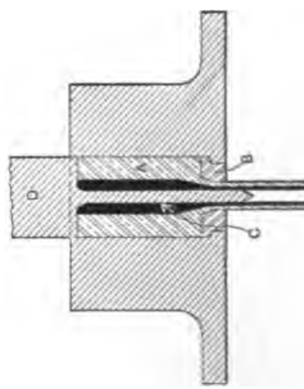


Fig. 2. Making Tin-lined Lead Pipe

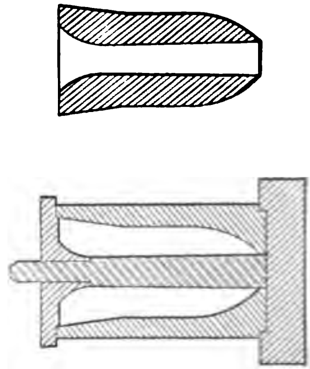


Fig. 3. Improved Ingot Mold and Lead Ingot

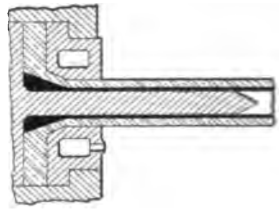


Fig. 4. Jacketed Die

Machinery

the methods employed in producing extruded shapes as secret processes. Like many other methods, however, they are secret in name only, and the details can always be obtained by those who make a study of this subject.

Historical Review

The first patents on record were taken out in England in 1797. Like the die-casting process, the extrusion process started by using lead for the metal to be extruded. Lead-tin alloys were used later, and these developed into the lead-tin-antimony compositions that are used for type and anti-friction metals, and led the way to the copper-zinc alloys that may contain small percentages of aluminum, lead, nickel, iron or other ingredients.

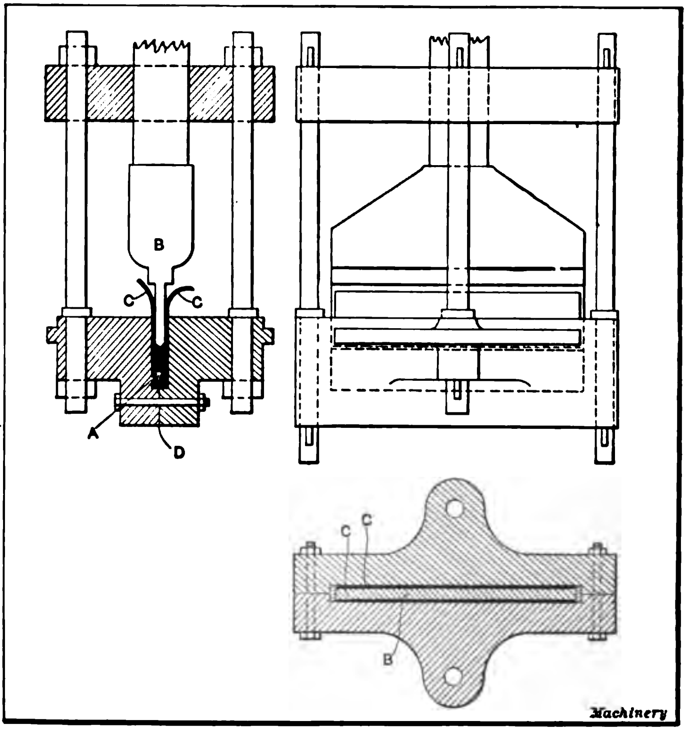


Fig. 7. Machine for Making Lead Sheets

One of the first forms of extrusion machines is shown in Fig. 5. In this the cylinder was packed full of lead and the whole heated so that the hand-screw would squirt the lead out at the end in the form of a lead rod of the shape or size desired. The lead-tin alloys used for soldering were made into rods in a similar manner. The next step was to put a rod in the center of the plunger as shown in Fig. 6. This rod partly filled the opening through which the metal passed, so that the latter was extruded in the shape of a tube. This simple tool was

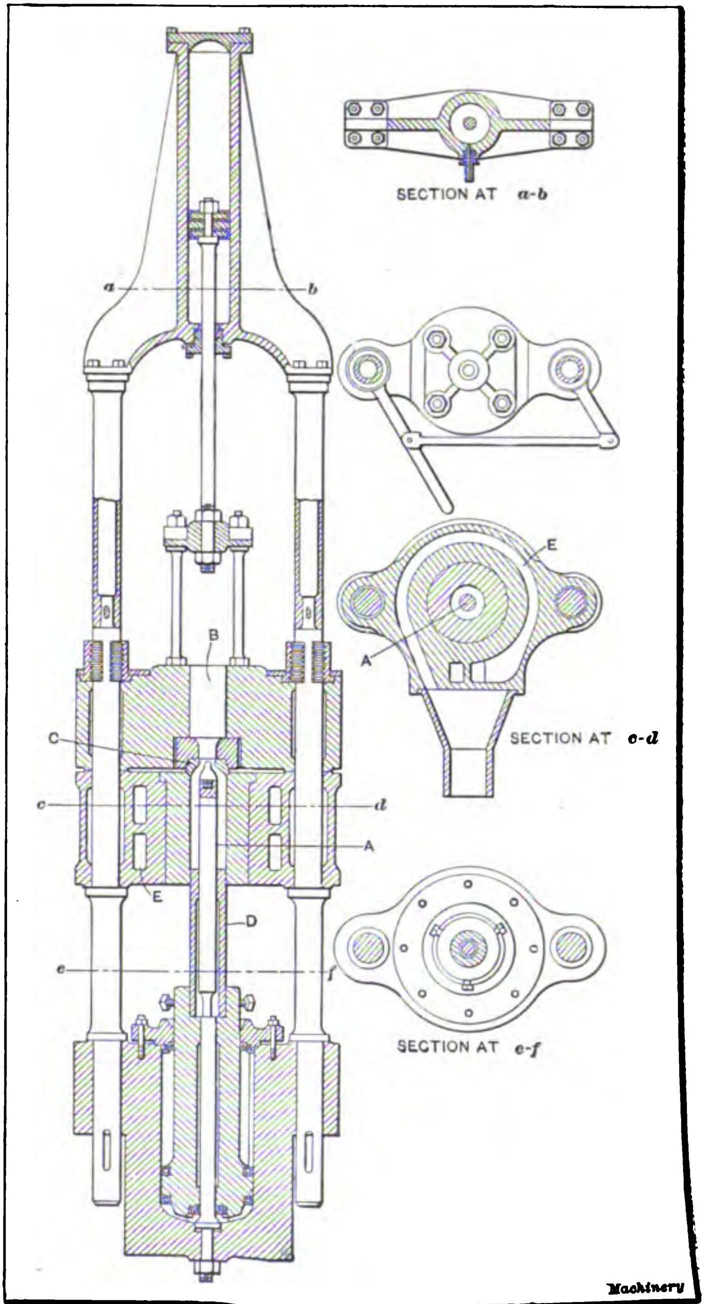


Fig. 8. Hydraulic Press for Making Tin-lined Lead Pipe

enlarged and developed into a power-driven machine, and used in the manufacture of lead pipe. The machine, still further enlarged, was used for making very large lead pipe, which, after it left the machine, was split longitudinally and straightened out into lead sheets.

Later, special machines were designed for making lead sheets in a different manner. In 1847, J. Robertson designed the machine shown in Fig. 7. In this, the opening at *A* was filled with lead and plunger *B* was forced down into it, causing the lead to rise on both sides in thin sheets as shown at *C*. This machine was improved by making plunger *B* entirely fill opening *A* and cutting a slot at *D* to allow the lead sheet

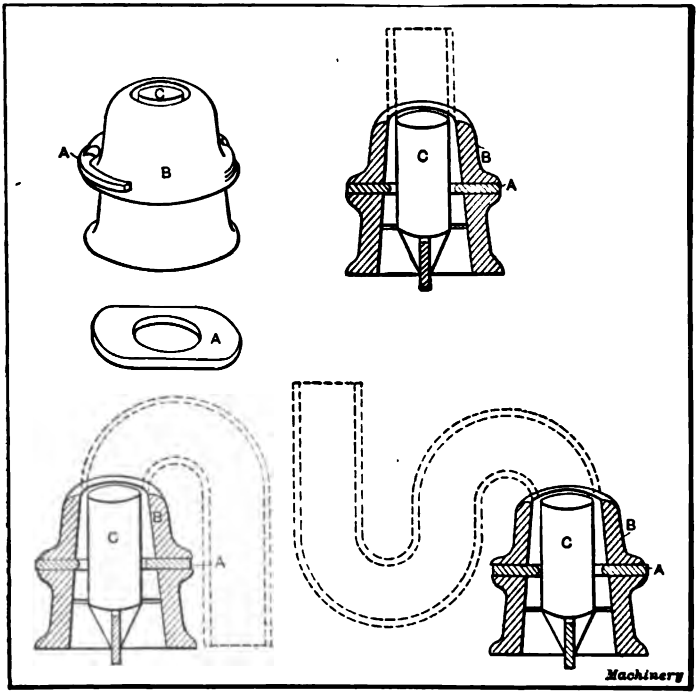
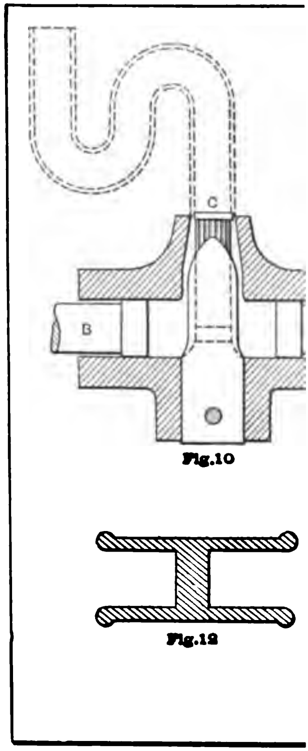


Fig. 9. Device for Making Lead Traps

to come out at the bottom. Still later, the machine was made horizontal and dies inserted at *D*, so that the sheets could be more easily handled and sheets of different thicknesses made by inserting different dies.

In 1863 tin-lined pipe was made by placing a hollow ingot of tin inside of a hollow lead ingot and forcing both through the die as shown in Fig. 2. In this, *A* is the hollow lead ingot; *C*, the hollow tin ingot; *B*, the die; and *D*, the ram that forces the metal through the die. Previous to this, lead pipe was lined with tin by melting it inside of the pipe, but it was very difficult to make the tin cover the whole interior of the pipe, and it would be likely to form lumps and be unequal in thickness. While the new method overcame this trouble, it

presented other difficulties due
Therefore, the lead ingots were
Fig. 3, and the tin ingots were
them fit the inside of the lead
was due to the uneven heating
shown in Fig. 4, so that steam
them. In this way the die co
perature before starting to mak
ture while running.



Figs. 10 and 11. Other Devices
truded Shape use

In 1869, A. H. Hamon of Par
shown in Fig. 8 for manufactur
ingot that surrounded the hollo
at *A*, and ram *D* was operated
and the opening at *B*, where it
air or steam was sent through
correct temperature for extru
melting point of the tin, but h
that it could easily be extrude
tically the same as that of th

Some details have been improved, however, and metals of a higher melting temperature can be extruded. Thus, some of the more plastic brasses are now made into commercial shapes.

In 1873, Robert Cunningham patented a device for making curved pipe for water traps, and a re-issue of this patent was granted in 1881. This device is shown in Fig. 9. It can be attached to any machine that contains hot lead and the required mechanism for squirting the lead through it. The diaphragm *A* moves back and forth through case *B*. Its center hole will thus, at times, be eccentric with the interior opening of the case, and, thereby, control the volume of metal that passes through this opening on different sides. When the hole in the diaphragm is central with the case, the volume of metal that passes through

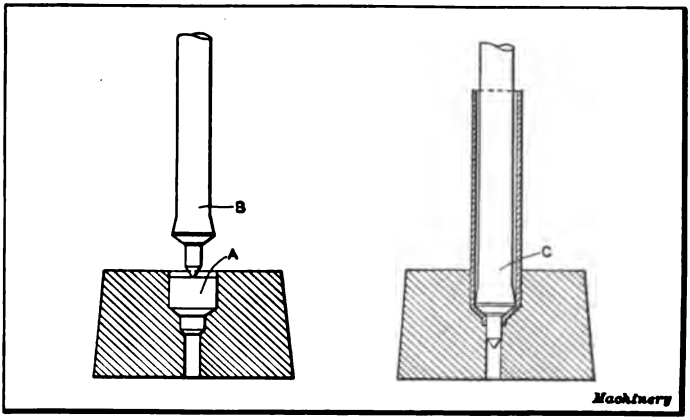


Fig. 13. Method of Tube Making

on all sides of core *C* will be equal, and the extruded pipe will be straight, as shown in the upper right-hand corner of the illustration. When the diaphragm is moved to the left, however, the largest volume of metal will pass on the left-hand side of core *C*, and the pipe will curve to the right, as shown in the lower left-hand view. When diaphragm *A* is pushed to the right, the volume of metal will be largest on the right-hand side, and the pipe will curve in the opposite direction. Thus, by pushing this diaphragm to the right and left the required distance, traps can be made as shown in the lower right-hand view, and these can be given any desired form.

Another method of accomplishing the same results is shown in Fig. 10. In this case the volume of metal on different sides of the core is controlled by two rams. When rams *A* and *B* are forced in at an equal speed, the metal coming out around core *C* will be equal in volume on all sides and the pipe will be straight. If ram *A* is made to travel faster than ram *B*, the volume of metal to the right of core *C* will be the greater, and the pipe will curve to the left. If ram *B* is made to travel faster than *A*, the volume of metal to the left of core *C* will be the greater, and the pipe will curve in the opposite direction.

In Fig. 11 is shown still another device that performs the same work.

In this case ram *A* is made in
at a different speed. Hence,
can be forced through the ope
This causes the lead pipe to
sired, or extrudes it in a strai

The softer metals were als
purposes, such as printers' le
glass windows (as shown in I
metal foil were also produced.
alloys, and many different c
tougher and better wearing n

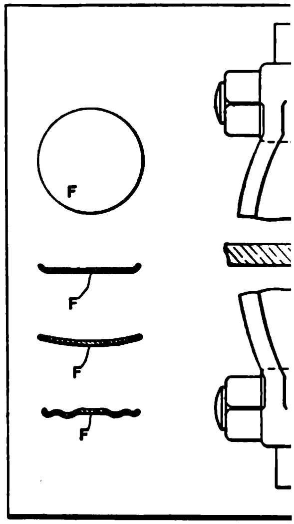


Fig. 14. Co

such as are used for artists'
made by a similar process. A
with plunger *B* in position to
is shown at the bottom of its s
The grids or plates for second
process as much as twenty-fi
strips of metal crossing each
as to form hollow squares. T
squares in them. They were
which was later cut up into t

When metals or alloys with
lead and tin first used were f
sion process, several problems
presented themselves. One of
of the temperature. It was v
and bronzes, as they were m
tin base. It was necessary t

point, as otherwise it would be difficult to cool the extruded shape to the solid state before it left the die. Also, if the metal was too soft when being extruded, it would not be subjected to the compression required to give it the additional strength that made the process really valuable. On the other hand, if the temperature was not high enough,

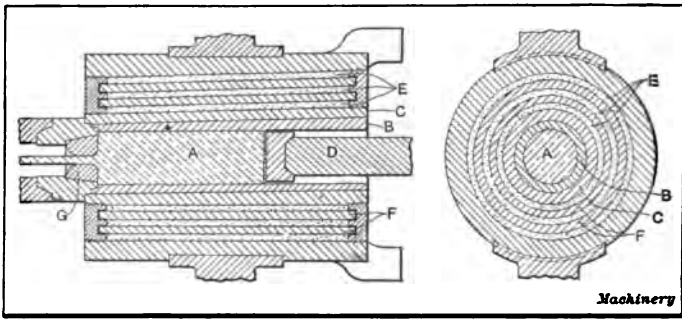


Fig. 15. Steel and Asbestos Container

the metal would not extrude through the die opening, and the billet would spread in the cylinder or container, grip the side walls, and thus become wedged in.

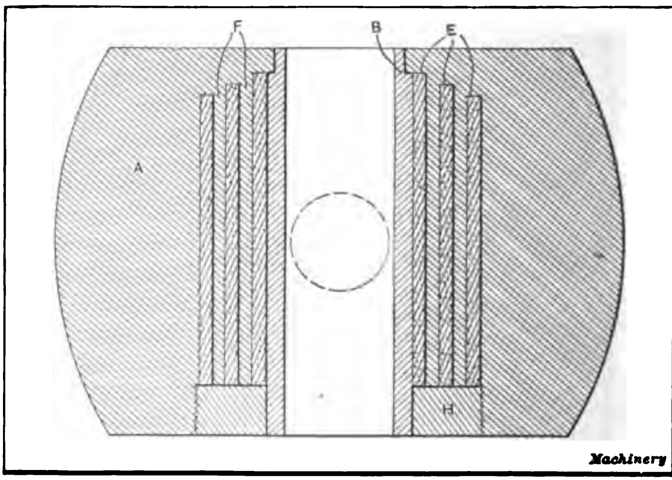


Fig. 16. Cast Container with Layers of Heat-insulating Materials

It was also difficult to find a metal for the dies that would withstand the strains produced by the hydraulic ram, or keep cool enough when the heated metal was being forced through. It was found, however, that tungsten steel would not soften enough to be pressed out of shape when brasses and bronze were extruded at a temperature just below the melting point. To maintain this temperature while the whole billet was being extruded was, however, difficult. This difficulty was finally

overcome by designing specia
part of all extruding machine

Bill

One of the first designs of t
in England in 1893. This de
the billet of metal that is b
container; *C*, a case built a
through which the flames fro
this apparatus, copper and zi

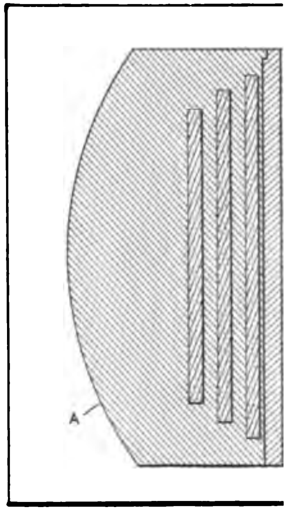


Fig. 17. Ano

from 800 to 900 degrees F., w
let was inserted in the conta
was placed over the end of t
wall of the container tightly,
squeezing back past the ram
from metal with a higher me
the metal being extruded.

While this device worked
was difficult to control the cok
ture. Another difficulty was
away from the head, owing to
used to withstand the pressu
siderable heat was given out
the thick cylinder wall was
than the interior. This cause
frequently resulted in cracks
billet container was designe
asbestos.

One of the first built-up containers is illustrated in Fig. 15. This also was designed by Mr. Dick in the same year as the coke-fired container. Most of those in use at the present time are built on this principle; *A* is the billet; *B*, the tapered container that fits into a tapered hole in the built-up cylinder; *D*, the ram; *E*, the openings between the steel rings *F*, which are packed full of asbestos; and *G*, the die through which the billet is extruded.

By surrounding the walls with several layers of refractory material, like asbestos, supported by steel rings, the heat was prevented from penetrating the cylinder walls. By thus keeping the cylinder at a lower temperature, it had greater power to resist the pressure from the ram; and by retaining the heat in the billet, its temperature was

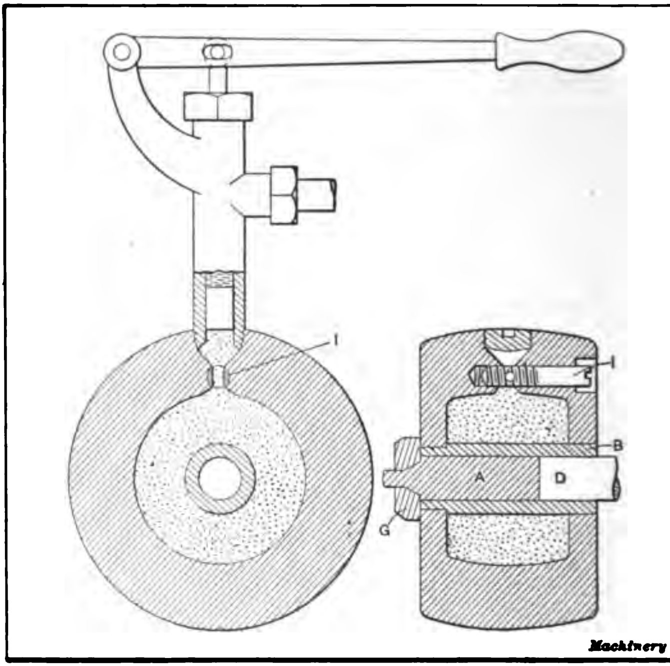


Fig. 16. Heat Insulation forced into Place by Pump

kept more uniform, and it could be more easily extruded. This design also greatly reduced the unequal expansion and contraction and the consequent cracking and breaking. These cylinders, or containers, enabled the extrusion process of manufacturing metal shapes to become much more of a commercial success, and to-day many parts are being manufactured more economically in this manner than they formerly were by casting in sand molds.

Following the Dick designs, many forms of billet containers have been designed. Fig. 16 shows one in which the outer case *A* and steel rings *F* were cast in one piece. After the billet container *B* had been

put into position, the opening
rials, and ring *H* was screw
made from broken granite, sc
insulating materials, and the
cast solidly around them. E
as a separate piece, because tl
the container proper may las
manufacture cylinders in thi
cast may shrink much more
This is almost sure to cause
fying. A style in which the c
After the billet container *B* h

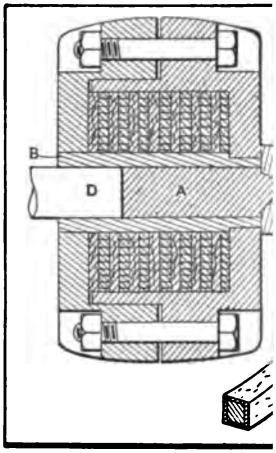


Fig. 19. Container wo

is filled with refractory mate
materials through valve *I*, w

In Fig. 19, lining *B* is w
the cylinder clamped togethe
shown at *J* is used, and the
This retains the heat and s
from bulging or cracking un
The rings of asbestos may
in solid, or it may be wound
same size, staggered. A se
pearance of a checker board.

Electric

One of the latest types of
be extruded can be electrical
die-block and the end of the
is shown in Fig. 20. Here
the billet container; *C*, the
the winding of metallic tape

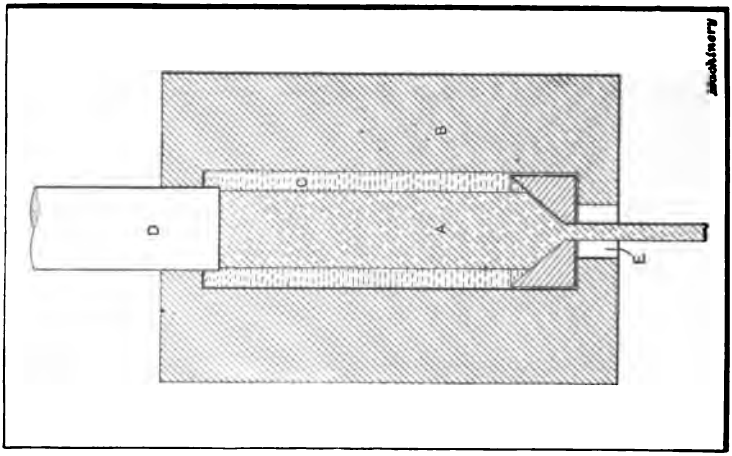


Fig. 21. Liquid-surrounded Ingot

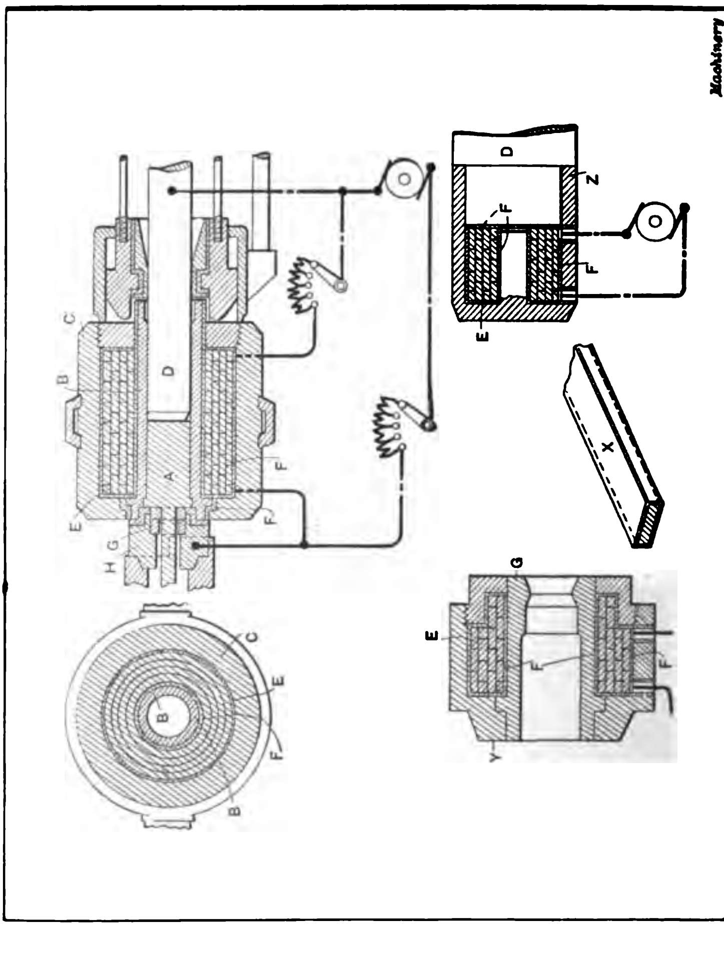


Fig. 20. Electrically-heated Container

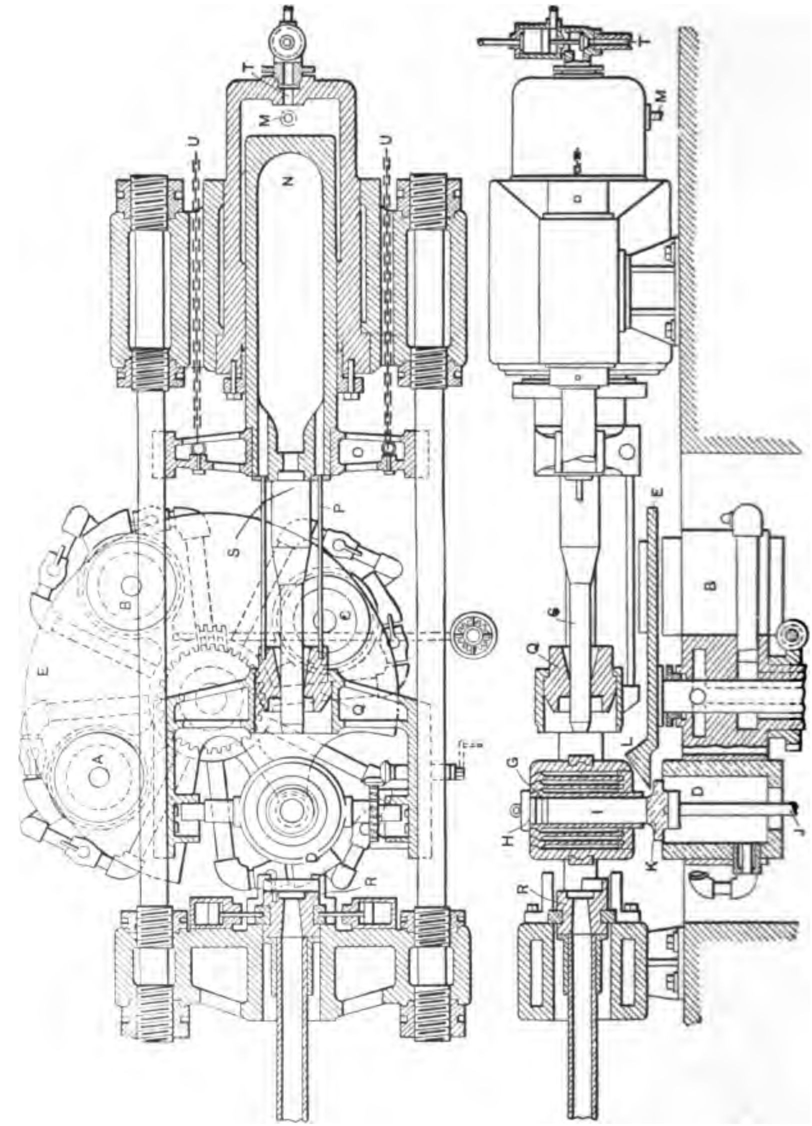


Fig. 22. Main Features of a Modern Extrusion Machine

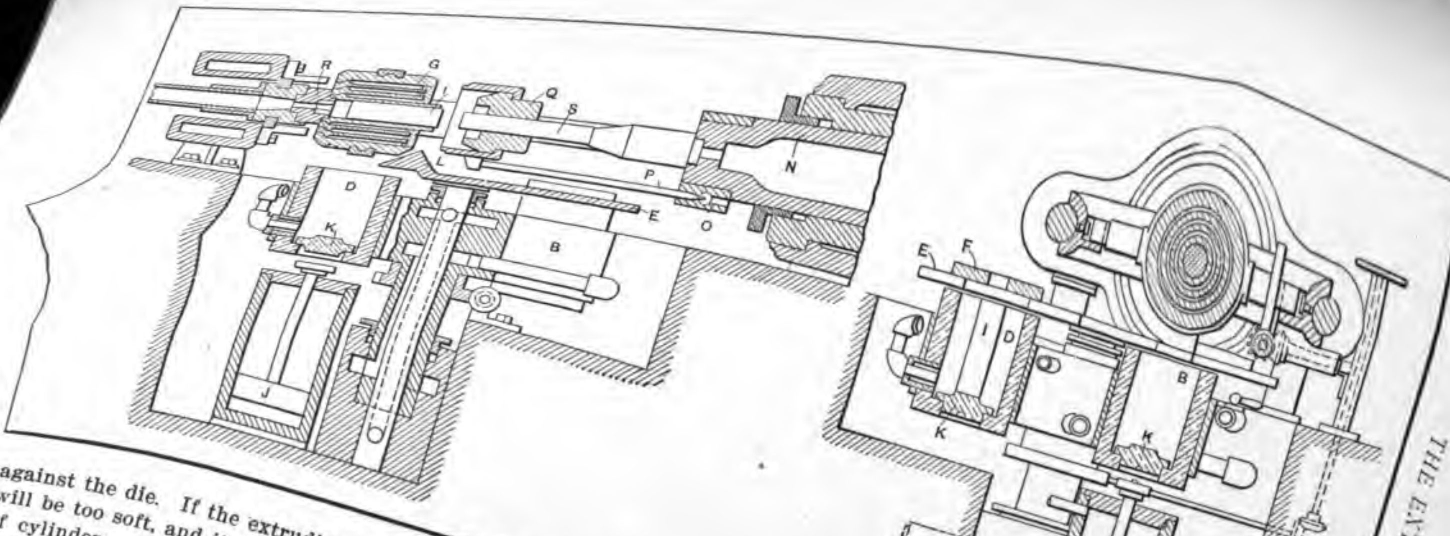


Fig. 28. Main Features of a Modern

against the die. If the extruding metal is heated too high it will be too soft, and its grain will be coarsened. The of cylinders requires that the ram or plung billet container so tight that no met force its way between the r the same time it m

When metals are extruded at atmospheric temperature, a higher pressure must be used. The metal is condensed more and the grain greatly refined. This adds strength, hardness, and toughness to the metals to a degree that it is impossible to attain in other ways. One illustration of the pressures required is shown by the fact that to extrude aluminum at 600 degrees F. only requires one-fifth of the pressure that is required at 70 degrees.

A Modern Extrusion Press

The principal parts of a complete modern extrusion machine are shown in detail in Figs. 22 and 23. Nearly all of the hand labor is done away with in this machine. It heats the billets to the proper temperature, inserts them in the container by hydraulic pressure, and extrudes them by the same pressure. Four gas-heated furnaces are located around a central shaft under the extruding press so that their tops come a little above the floor line. Three of the furnaces, when they are in the positions *A*, *B* and *C*, are covered with a disk screen *E*, that has an opening over each furnace. When starting the operations, the cold billet is inserted in the furnace located at *A;* cover *F*, containing a vent-hole, is placed over it, and the furnace revolved to the position at *B*. It is next revolved to the position at *C*, and while in the positions *B* and *C*, other billets are being extruded. After this, it is turned to the position at *D*.

The cylinder is then revolved on trunnions to the position shown at *G;* cover *H* is placed over it, and billet *I* is pushed up into it by hydraulic piston *J* raising loose block *K* from the bottom of the furnace where billet *I* rests on it. The gas for heating the furnaces enters the hollow shaft on which they revolve, and passes out through ports and piping to each of the four furnaces. The air passes through ports surrounding this hollow central shaft and then through pipes to the different furnaces. After the billet is in the cylinder, this is again revolved on its trunnions to the extruding position; projection *L*, on disk cover *E*, prevents the billet from falling out while the cylinder is being revolved.

With the extrusion cylinder in position, fluid is admitted under pressure to the hydraulic cylinder through port *M*. This moves the hollow piston *N* forward and first transmits power to the device *O* and rod *P* and causes part *Q* to butt against extrusion cylinder *G* and hold it firmly in its seat against the die and die-holder *R*. Container cover *H* has, of course, been removed. Now, ram *S* acts on billet *I* and extrudes it through die *R*. When the ram has reached the end of its stroke, the fluid is allowed to escape through port *T* and with the other mechanism attached, the ram is brought back to the starting position by weights attached to chains *U*.

In this machine, as well as in others, a small end of the billet cannot be extruded. This part often sticks in the cylinder, but it is easily removed by turning the cylinder over the furnace at *D* and turning on the gas, so as to melt it out. With this machine many alloys can be extruded that could not be used with the cruder and simpler machines formerly employed.

Several new extrusion presses have also been brought out abroad. Those best known in Germany are built by the firm of Friedr. Krupp A. G., Grusonwerk in Magdeburg-Buckau. The methods and processes used in connection with one of these machines will be described in the following. The complete installation consists of a foundry for producing the metal blocks, a heating furnace, and a hydraulic press and pumping arrangement.

The Casting of the Metal Blocks

The metal blocks are cast in long sections and are afterwards cut up into pieces of suitable size for the presses. The blocks are cast in permanent molds, and in order that as smooth a surface as possible may

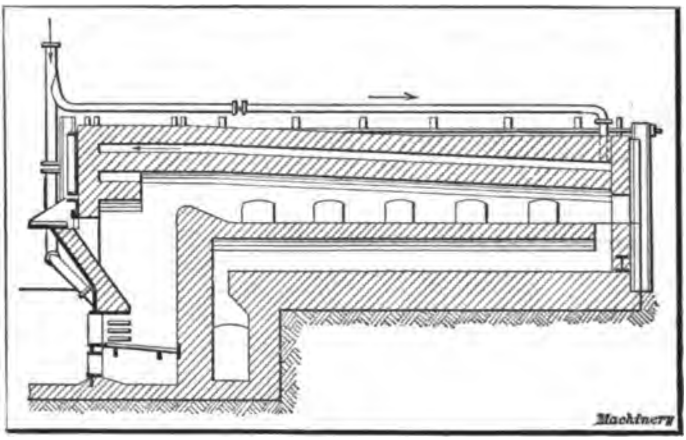


Fig. 24. Section through the Heating Furnace

be obtained, it is necessary that the inside of the mold be of a close-grained metal, free from flaws. In order to still further insure against blow-holes or porous parts in the cast blocks, the molds are covered on the inside with a preparation, the same as is done in the casting of copper and brass in general.

After the blocks are cast and cut into parts, they are inspected for defects, and any burrs or fins that may be present are removed by chisels or scraping. Special care must be used in producing hollow parts for pipe. In this case, it is especially important that the core be central with the outside, in order that homogeneous walls of uniform thickness may be obtained in the extruded pipe.

Heating the Metal Blocks

The metal blocks are heated in a special furnace which should be placed close to the extrusion press. The important feature about the heating is that the block must be heated clear through to the center, and not be brought to the press when merely the surface has been brought to the required temperature. A furnace used for heating the blocks is illustrated in Fig. 24. The blocks are inserted at the end opposite the grate, and roll by gravity down the somewhat inclined surface toward the fire-box. When the required temperature is obtained, they are pulled out through an opening at the side. In order that good results may be obtained in the extrusion process, it is important that the blocks do not come in contact with the brickwork of the furnace. The surface on which the blocks rest is, therefore, covered with a cast-iron plate. The length of the furnace is made to suit the

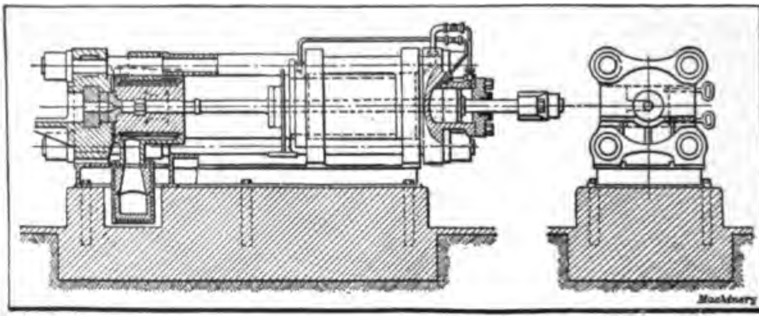


Fig. 25. General Arrangement of Krupp Extrusion Press

capacity and speed of the action of the press. The width is usually made about three feet. The heated blocks are most conveniently transferred from the furnace to the press by means of an overhead trolley.

The Hydraulic Extrusion Press

The hydraulic extrusion press shown in Fig. 25 is of the horizontal type. The press consists mainly of the hydraulic cylinder, the dies, the pressure chamber or extrusion cylinder, and a head which holds the dies. Four heavy connecting bars tie this head to the hydraulic cylinder. The pressure chamber is located between the head and the hydraulic cylinder and moves on four guide bars.

TABLE I. GENERAL DIMENSIONS OF EXTRUSION PRESSES

Dimensions	Smaller Size	Larger Size
Total pressure, pounds	1,430,000	2,200,000
Maximum pressure, pounds per sq. in.	3770	4125
Diam. of hydraulic cyl., inches	22	26
Stroke, inches	27½	31½
Diam. of extrusion cyl., inches	4⅜	5½
Max. diam. of extruded bars, inches	2	2¾
Required horsepower	100-150	175-225

These presses are built in two sizes, the main dimensions of which are given in Table I. The output of the presses varies according to the size and form of the cross-section of the different extruded shapes. With trained operators and simple cross-sectional shapes, it is possible to extrude about 20,000 pounds of metal in ten hours in the small-size press and 35,000 pounds in the larger press. This output cannot be obtained, however, when tubing of difficult sections is being extruded. The figures given above correspond to two hundred press operations in ten hours. In order to be able to maintain this efficiency the press chamber must be sufficiently heated at the beginning of the work and there must be no interruption in the operation. For the complete installation required for one press, four men are necessary, one of whom works at the furnace.

Details of the Hydraulic Press

The hydraulic cylinder is made of steel casting and lined on the inside with a copper bushing. The pressure chamber is made of so-called "Krupp special" steel which even when heated has a high tensional strength. This chamber or cylinder is forged and is provided with a jacket of steel casting. Between the pressure chamber and jacket an open space is provided through which the heated gases from the fire-place arranged beneath the pressure chamber can pass. By this means the chamber is heated to the required temperature, the gases from the combustion escaping through a pipe above the pressure chamber into the chimney. The required temperature to which the pressure chamber should be heated by external means is about 600 degrees F. This heat is required so that the metal blocks which are heated to some 1650 or 1800 degrees F. may not be suddenly cooled. Should sudden cooling take place, the surface of the metal block may lose its plasticity and the extrusion may either be unduly delayed or be made entirely impossible. The high temperature of the walls of the pressure chamber, while the extrusion takes place, requires an especially high quality of metal, and it has been proved in a number of instances that forged Krupp special steel answers the requirements better than any other known material.

In order to prevent too high a pressure in the hydraulic cylinder, a safety valve is provided on the pump which opens at a pressure of about 4500 pounds per square inch. In order to instantly relieve the pressure in the hydraulic cylinder, a releasing valve is inserted between the pump and the controlling valve on the machine.

The dies containing the shape for the extruded form are held in the head. This latter takes the pressure during the extrusion process. One of the greatest difficulties in the past with machines of this type has been to remove the remainder of the metal block in the pressure chamber when operations are suspended or when practically all the metal has been extruded. Part of the metal would usually be pressed in between the joints, solidify and make the removal of the various parts difficult. In the Krupp press this difficulty is taken care of as follows: As already mentioned the pressure chamber is placed between the head and the hydraulic cylinder, but is movable on four guide rods. A tapered hole is provided in the pressure chamber in the end towards the head, and the dies are formed with a corresponding taper. An auxiliary hydraulic cylinder is provided at the right-hand end of the press in Fig. 25, and the pressure chamber is connected with the piston of the auxiliary cylinder by means of a cross-head and two connecting-rods. By this means the pressure chamber can be operated. Before the beginning of the extrusion, the pressure chamber is forced against the die by means of this auxiliary cylinder, and due to the tapered hole and the tapered end of the die a very close-fitting joint is provided, so that the metal, during the extrusion process, cannot enter between the two surfaces. At the end of the extrusion, the auxiliary cylinder operates the pressure chamber in the opposite direction, thus opening up a space between the die and the pressure chamber and making it possible to easily remove the remaining metal from the top of the die.

The press can be operated with considerable rapidity. For simple shapes, it is possible to go through the complete cycle of operations

TABLE II. INFLUENCE OF THE EXTRUSION PROCESS ON THE PROPERTIES OF METALS

Metal	Cast		Extruded	
	Tensile Strength, Pounds per Square Inch	Elongation, Per Cent	Tensile Strength, Pounds per Square Inch	Elongation, Per Cent
Copper	28,500	35	34,000	38–40
Magnalium	43,000–64,000	5	53,000–71,000	10
Aluminum	14,000–17,000	3	33,000–38,000	4.3
Delta-metal	83,000	11	98,000	21.8
Durana-metal	58,000–74,000	35	60,000–81 000	38

for one metal block in three minutes, this time being divided as follows: Putting the metal block into the pressure chamber, 1 minute 25 seconds; extrusion, 50 seconds; opening up the space between the pressure chamber and die, 10 seconds; removing the remaining metal, 15 seconds; and returning to the original position, 20 seconds. The effect of the extrusion process on the tensile strength of various metals is indicated by Table II.

Examples of Work Produced by the Extrusion Process

The half-tone illustration Fig. 26 shows sections manufactured by the extrusion process by the Coe Brass Mfg. Co., Ansonia, Conn., the well-known makers of extruded shapes. Various special forms of angles are made in this way. Gears, ratchet wheels, gear racks, padlock hasps, and other special shapes are turned out in long bars which are afterwards sawed up to give the pieces their required thickness. Moldings have also been made for the Navy Department. An extruded angle that was made for the Navy had a tensile strength of 85,000 pounds per square inch, an elastic limit of 33,800 pounds per square inch, an elongation in 8 inches of 18.1 per cent, and a reduction of area of 20 per cent. Some quite intricate shapes have been made.

Where parts, such as flat lock keys, can be made in the punch press, they can be made cheaper this way than by the extrusion process. Such parts as the hasp on padlocks, however, are made more econom-

ically by the extrusion process, as they would be difficult to punch out owing to their thickness. There are also numerous other lock parts that are cheaply made from extruded metal. The extruded shapes can be made to within 0.0005 inch of the correct size. This makes the process very useful for parts that would otherwise have to be machined.

Metals and Metal Alloys used in the Extrusion Process

In the extrusion of metals it is natural that lead should have been the one first used, as this is the most plastic of metals. Lead in the form of filings can be compressed into solid metal with 13 tons pressure to the square inch. It will flow through all the cracks of the apparatus. like liquid, when a pressure of 32 tons per square inch is applied to it. Its plasticity as compared with that of other metals is shown by the fact that powdered tin can be made into solid metal with a pressure of 19 tons per square inch; copper, with 33 tons; zinc, antimony, aluminum and bismuth with 38 tons, while other metals require considerably greater pressure than this. Tin would flow through the cracks of the apparatus like liquid at a pressure of 47 tons per square inch. and the other metals at a considerably higher pressure. Lead and tin. or any alloys that might be made from them, however, have very little strength and thus their use has been limited.

While copper is very malleable, ductile and tough, and consequently would flow freely through a die under pressure, it has but limited strength, and, consequently, cannot be used for very many purposes. As lead, bismuth or antimony have an injurious action on copper and make it hard, brittle and cold short, these elements cannot be alloyed with it for extrusion purposes, except in very small quantities. When more than 0.5 per cent lead is added to copper it makes it both hot and cold short, and it cannot be worked hot; 0.2 per cent lead, however, may be present without impairing the tenacity of copper. Tin in small quantities does not appear to affect the working properties of copper, except to make it somewhat harder. Larger percentages of tin, however, would render copper too hard for extrusion purposes, and would give it a flaky grain that weakens the metal. When zinc is alloyed with copper, 1 per cent zinc will make the copper hard and red short, but 20 per cent zinc alloyed with 80 per cent copper will produce an exceedingly malleable alloy. Small percentages of zinc do not alter the character of copper in other ways. The zinc also produces a greater tensile strength.

An alloy composed of 55 per cent copper and 45 per cent zinc was the first comparatively strong metal that was used for extrusion purposes. This is also one of the most common alloys used at the present time. The brasses that contain from 50 to 60 per cent copper and 40 to 50 per cent zinc are the most plastic, and hence are the alloys most frequently used for extruded metals. The brasses containing from 75 to 85 per cent copper are malleable while hot, but are rather too hard to extrude easily, while the brasses containing from 62 to 70 per cent copper are not malleable at a red heat and hence are difficult to extrude.

Small quantities of iron add strength to the brasses and do not make

them difficult to extrude; hence Delt
similar alloys can be used in the extr
used in small percentages, makes co
per cent is used, and hence the alumi
per cent of aluminum are the most
taining 90 per cent copper and 10 per c
cent copper, 10 per cent zinc, and 5
but ordinarily the copper content is k
aluminum bronzes, however, a tensile
pounds per square inch is obtained, wi
to 60,000 pounds, an elongation in 8 in
reduction of area of about 20 per cent.
made for the Government have shown

Pure zinc can be greatly strengthen
ducted in the proper way. If the area
the area of the zinc billet to be extrud
temperature of the metal is kept betw
the extruded metal is submitted to a
pounds per square inch, the coarse cry
zinc is transformed into a fine grain,
ties of brass. A tensile strength of 29
be obtained in this way and an elong
For comparison, ordinary zinc only
pounds per square inch and almost no
in the extruded condition can also b
tools and it is quite malleable and flex

CHAPTER II

THE EXTRUSION OF SHELLS AND TUBES

Just because a diemaker miscalculated a little, leaving the face of a punch too long, there is a growing corporation doing business in a comparatively new field of metal goods manufacturing. This, in a nutshell, explains the existence of the Metallic Shell & Tube Co., of Pawtucket, R. I., although the whole story is somewhat longer.

In 1903, George W. Lee was located in Binghamton, N. Y., engaged in the manufacture of the familiar one-piece collar button shown at *A* Fig. 27. After a short time it became apparent that by means of such machines as the multiple plunger press others were turning out collar

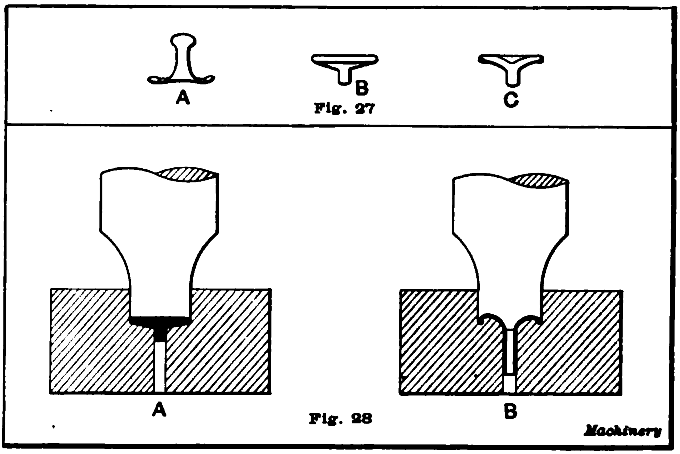


Fig. 27. A, Collar Button; B, Fastener; C, Improved Fastener. Fig. 28. A, Die for Fastener, with Work in Place; B, Die intended to produce a Fastener of Improved Design, showing Piece actually produced.

buttons by the ton so cheaply that he could not compete with them. Naturally, he began to look around for some other similar product that he could manufacture with his equipment of presses, shears and tools, and he hit upon the idea of a fastener, part of which is shown at *B*, Fig. 27. He immediately patented this "bachelor's button," and commenced to manufacture it on a small scale.

After getting fairly well started, it occurred to him that if he made a slight change in his dies, so as to give the face of the button the appearance indicated at *C*, Fig. 27, the product would have a more finished appearance, without increasing the cost of manufacture. The dies for the button appeared about as shown at *A*, Fig. 28, in which the aluminum blanks, ½ inch in diameter, were placed and formed in the usual manner. To obtain the improved shape of the face of the button, he assumed that it would only be necessary to leave a small projection on the punch. He then made a punch with the projection left a little longer than he had intended, but he concluded to try it out. To his amazement, he found that instead of the slightly changed button that he had expected, he had a tube about ¾ inch long, with the flanged face of the button intact, as shown at *B*, Fig. 28. He pondered over the matter, tried more blanks in this die, with the same results, and decided that the explanation was that the metal, being confined on all sides except for the annular opening formed by the opening in the die and the projection of the punch, *had* to go through this space when pressure was applied.

With this principle in mind, he tried several other experiments along the same lines, and finally applied for patents on the process of extruding tubular metal bodies by means of dies of the type shown in Fig. 29. When the patent examiner at Washington read the specifications and saw the drawings, he was incredulous, and before allowing

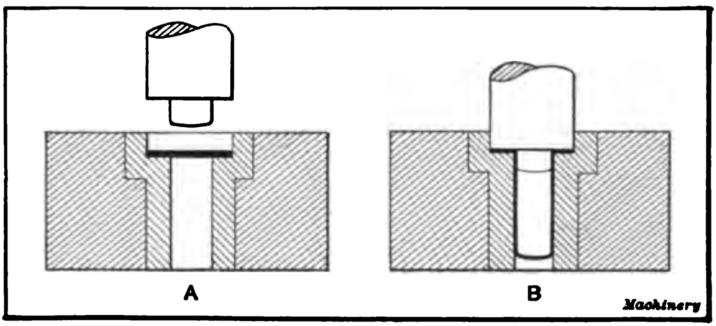


Fig. 29. Lee's Method of Making Tubular Articles, Patented in 1906. A, the Die with Blank in Position; B, the Extruded Shell

the patents, Lee was obliged to make several tubes for the examiner; after furnishing affidavits as to his work, the patents were allowed. During the next four years Lee worked incessantly on the process, but with little real success.

At this point Mr. Leslie E. Hooker and three other men bought the patent rights of Lee and organized a company to make a commercial success of the extrusion process. Mr. Hooker had been watching the experimental work for some time. He took out several patents on improvements, and started a factory in Pawtucket, R. I., where at present the extrusion process is being worked successfully. The company is making tubes and shells in large quantities, and as manufacturers and designers are becoming more and more aware of the value of extruded work, the prospects seem unusually bright for the future.

General Outline of the Process

Since George W. Lee stumbled over the extrusion process in 1903, many changes have been made in the details of the methods, but in general the principles are the same. Briefly stated, the extrusion of tubular bodies is accomplished by confining a metal blank within a strong cylindrical chamber whose only outlet is through an annular opening at the bottom, formed by the projection on the punch and the hole in the bottom of the die. The size of this opening may be made of any required dimension, so that tubes and shells of different measurements can be made.

Figs. 30 and 31 illustrate the features of dies for extruding tubular shapes. The containing ring is shown at *A*, the lower die at *B*, and the punch at *C*; part *D* is the former. In Figs. 29 to 32 inclusive, the die rings, dies and punches only are shown, for they are the vital parts of the apparatus. In Figs. 30 and 31 the blanks are shown at *F*, just after the extruding operation has started.

Fig. 30 shows a plain flat blank being extruded, but as the process was developed it was found better in every way to use a cup-shaped blank like that shown in Fig. 31. This shape of blank takes no longer

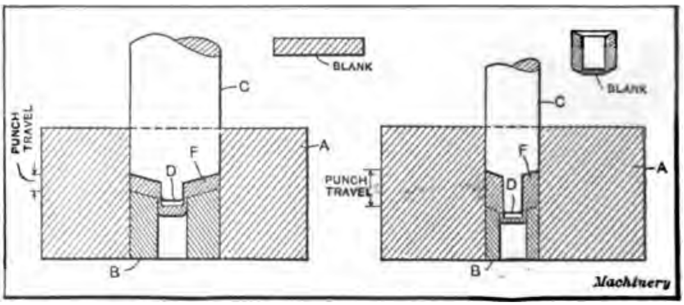


Fig. 30. Extruding from a Flat Blank **Fig. 31. Extruding from a Cup-shaped Blank**

to make than the flat blank, if cut and drawn in one operation. The chief advantage in using the cup-shaped blank lies in the fact that the metal extrudes more easily, for the work is distributed over a longer space. This fact is more readily apparent by noting the differences in the distances traveled by the punches in Figs. 30 and 31. There is, however, a limit to the proportions of this cup, for if made too deep and narrow, the punch will be too weak to stand the strain; if made too shallow, on the other hand, the object of cupping will be defeated. In general, the walls of the cup should be from 3/32 to 1/8 inch; from 3/8 to 1/2 inch is a proper depth for the cup. In some instances, as in cartridge case making, it is desirable to have the bottom of the tube as thick as possible, in which case the cup is made without reducing the thickness of the bottom. In nearly every tube. however, it is advantageous to have the bottom of the finished tube of the same thickness as the walls of the tube; therefore, after cupping, the bottom is thinned down by stamping, and the top edge of the cup is chamfered toward the inside at the same operation.

Suppose a shell is wanted with tapering walls, thickest near the bottom, as in the cartridge work illustrated at *P*, *Q*, *R*, and *S* in Fig. 34. To produce this effect, as indicated at *K*, the former is made with its sides sharply tapered towards the point, as shown in Fig. 32. Then, when the former enters the die opening, the space around the former is quite large, and the walls of the tube at this point will be correspondingly thick, as shown at *A*. At the end of the stroke, illustrated at *B*, the space around the former is very narrow, because the thick part of the former has entered the hole in the die through which the tube is being extruded. At this point, then, the walls of the tube will be very thin. To be a little more specific, let us assume that we wish to make a shell or tube, six inches in length, the walls of which are to be 1/16 inch thick at the base and 1/64 inch thick at the top. The former is 3/8 inch in diameter at its widest point. As there is a differ-

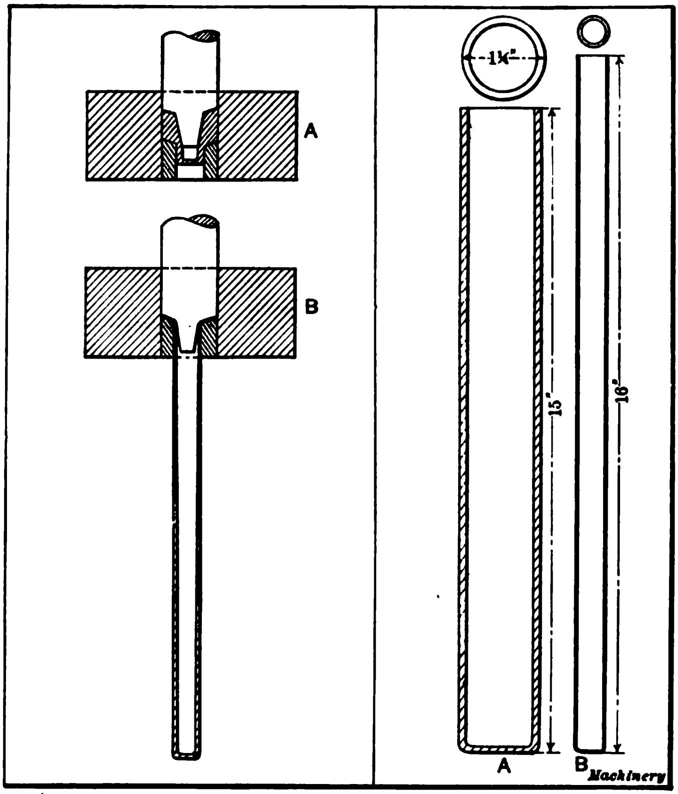


Fig. 32. Making Tubes with Taper Walls

Fig. 33. Comparison of Tube-making Methods

ence of 3/64 inch in the thickness of the walls of the tube, there must be twice this amount of difference in the diameters of the former at its end and base. Therefore, the former for this tube must measure 9/32 inch at the end, to produce the tube shown in Fig. 32.

Some idea of the speed at which the tubes are extruded from the dies may be obtained by observing the fact that in extruding an 18-inch tube, the punch moves but ½ inch. As most extruding is done without using geared presses, the tube metal moves the 18 inches in a very small fraction of a second, generating a good deal of heat while doing so. The operators of the presses are very careful to keep out of the way of the tubes that are being extruded.

Presses for Extruding

Nearly all types of presses or extrusion machines, as they are commonly called, have been tried—power presses, drop presses, screw presses and even steam hammers. Hydraulic presses have not yet been used to any extent on tubular work, because large sized work has not yet been attempted. Drop presses are not satisfactory on account of the shock of the blow and the consequent shortening of the lives of the dies. The wear and tear on the dies is great, even under the most favorable conditions, so that it is important that everything possible should be done to lighten their work. Screw presses are very powerful, and the shock of the blow is not excessive, but it is difficult to strike exactly the same blow each time, especially with the German type of press using the friction drive; therefore, their use has been given up. Steam hammers, of course, are out of the question for several very apparent reasons.

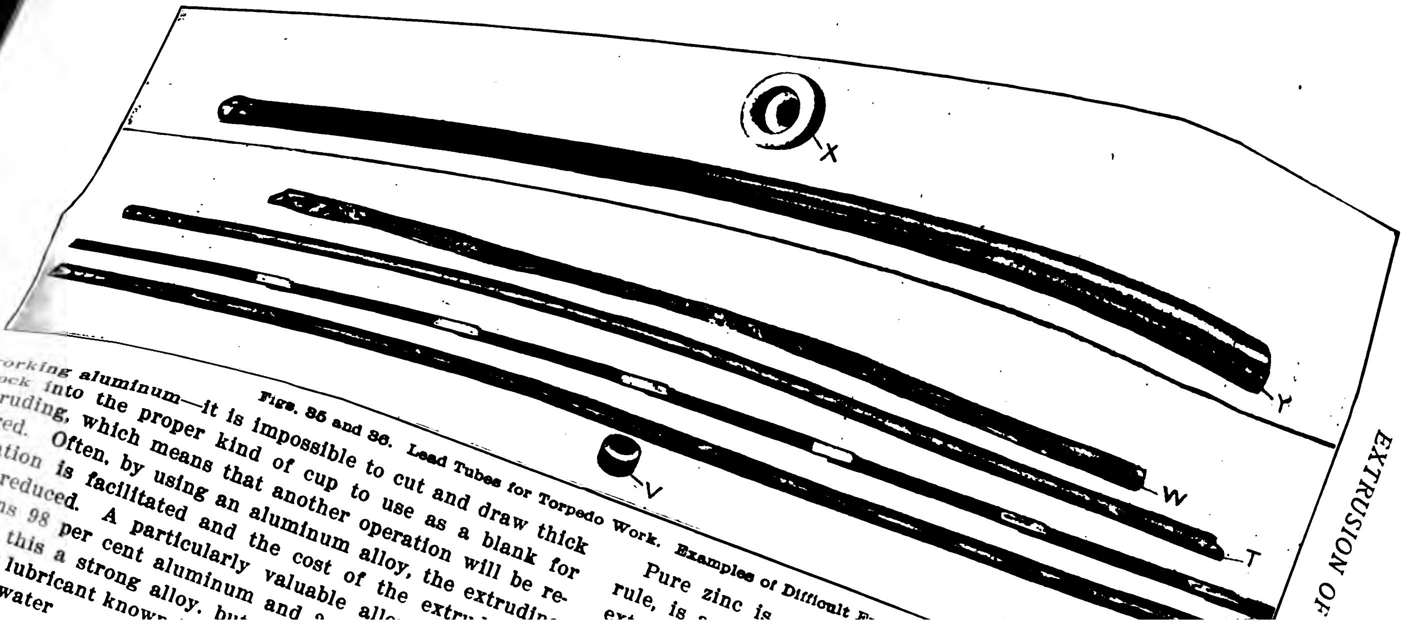
Fig. 34. Miscellaneous Examples of Extruded Work

So far, the most satisfactory style of press seems to be the crank press, of the geared or plain type. There is the danger of springing the shaft, but on the whole this type seems to be as good as any. Ferracute presses are used for extruding, and so are Bliss presses. Small tubes may be extruded on Bliss No. 52 presses, and for heavier work the No. 37 Bliss press of the geared type is very satisfactory. These presses have strokes of 1½ inch, which seems to meet all requirements.

Metals used in Tubular Extrusion

It is almost needless to say that the softer the metal is, the easier it may be extruded. Naturally, then, lead is the easiest metal to extrude, and it is used to a great extent in alloys that contain small percentages of other metals, for making collapsible tubes and similar goods. Pure tin is still more used for the better grade of collapsible tubes.

Aluminum comes next in order, and in fact, there is no better metal to extrude, if aluminum will meet the requirements of the work for which the shell is to be used. There is one slight disadvantage in



Figs. 35 and 36. Lead Tubes for Torpedo Work. Examples of Difficult E

working aluminum—it is impossible to cut and draw thick stock into the proper kind of cup to use as a blank for extruding, which means that another operation will be required. Often, by using an aluminum alloy, the extruding operation is facilitated and the cost of the extru... ticle reduced. A particularly valuable allo... contains 98 per cent aluminum and ... only is this a strong alloy, but ... The best lubricant known ... is soapy water

Pure zinc is ... rule, is ... ext...

copper. The better the grade of the metal, the better it will extrude, although ordinary commercial copper works very well. Lard oil is used as a lubricant. The better mixtures of brass can be extruded fairly well, although not as well as copper. For this reason a metal consisting of 70 per cent copper and 30 per cent zinc is a better metal for this purpose than the "two-and-one" mixture for brass. In short, the more copper in the brass, the better.

Gilding metal, containing mostly copper in its composition, is a good metal to extrude. This metal is used largely by the jewelry trade as a base upon which to gold-plate; hence its name. Pure gold will work well in the extrusion process, but 14-carat gold cannot be extruded at all; it is too tough. The reason for this is not very clear, as copper is used in the 14-carat gold alloy; but the fact remains that gold and

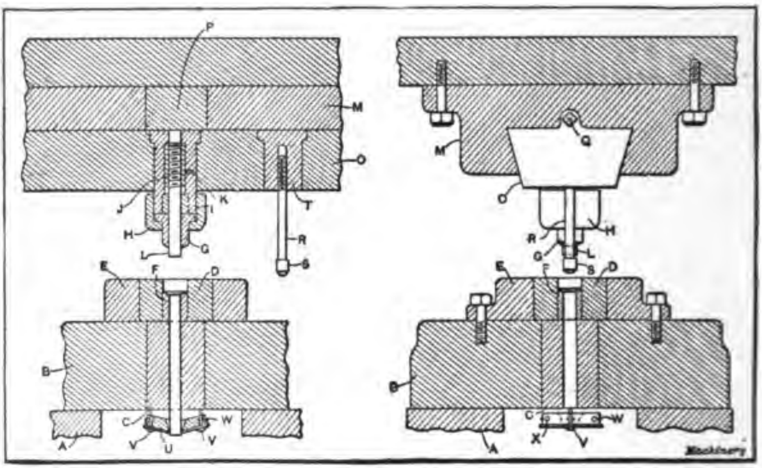


Fig. 37. A Modern Die for Extruding Tubular Shapes

copper, two soft metals in themselves, make a very tough alloy. So far, it has been found impossible to extrude iron or steel, as the dies give out under the extreme pressure required.

The effect of extrusion upon the structure of the metal being worked is beneficial, in that the grain of the metal is toughened and made much stronger. To start with, the metal is soft. After the blanking and cupping process, the cups are annealed. When the tubes come through the dies they are as tough and springy as could be desired, and still they are not brittle.

When extruding thin tubes, especially of the softer metals, holes are punched through the bottoms of the cups to let the air into the tubes while they are being extruded; otherwise the air pressure from without would cause a tube with thin walls to collapse, because the interior would be almost a perfect vacuum. Of course, if the bottom of the tube must be kept intact, this method cannot be adopted. The effect of the air pressure is well illustrated by the flattened tube shown at *W*, Fig. 36.

A Modern Extrusion Die

Fig. 37 represents a modern style of die for extruding tubular metal shapes. As will be noticed, the principles are the same as in the original Lee dies, although several details have been changed and a few features added. In this illustration, *A* represents the bed of the press; *B* is a bolster in which the hardened steel bushing *C* is a very hard driving fit. Bolted to the bolster is the die shoe *E* which is shrunk around the die ring *D*. By shrinking the die shoe around the die ring, a very tight fit is assured. Another important reason is that the temper of the high-speed steel die ring can, by being mounted in this way, be drawn just enough to leave the die tough, enabling it to stand the strains incident to its use. The die ring is ground out after hardening and a bushing *F* is fitted. This bushing is a very important part of the die, for in the old-style dies, when the interior of the die gave out, a new die ring was required. If a bushing now breaks, it merely means that a new one is to be slipped in, without even taking the die from the press. These bushings may be made several at a time and kept in readiness for an emergency. It is very essential that the inclined face of this bushing be polished very smooth, and that the edge of the hole be slightly rounded, so as to help the metal to form itself into the shape of the tube. The size of the hole in this bushing governs the size of the tube, and it must be ground to size and lapped to a smooth finish.

The Punch and Former

Second in importance only to the die, is the punch and former. It is the function of these parts to force the metal to flow through the hole in the die and to form the inside of the tube or shell being extruded. The punch *G* is really a removable tip to the punch body *I*, being held to it by the taper sleeve or nut *H*. The reason for having the punch in two parts is to make it easier to replace in case of breakage—there are plenty of breakages in extrusion tools. The end of the punch is turned off on a bevel to agree with the face of the die, and this surface must be just as highly polished as that of the die. The outside of the punch must be a close sliding fit in the die ring, for if it is loose there will be danger of its breaking.

The former *L* sizes the inside of the extruded tube, and as the metal is constantly slipping past its end, it is polished very highly, as is also the inclined face of the punch itself. An important feature of the former is its independent movement with relation to the punch. The internal end of the former is threaded into the bushing *J* which is free to slide within the punch body *I*, but is prevented from turning by the screw *K*, engaging a groove in the bushing. When the cup-shaped blank is struck by the punch, former *L* is pushed back to the position shown in Fig. 37. As the metal flows inward, a tremendous pressure is brought to bear on the former in a downward direction, and on the punch in an upward direction. This pressure often breaks the solidly combined punches and formers. In this die, the pressure carries the former and its sliding bushing down into the tube, and by the time the limit of the movement is reached, the extrusion process has had a fair chance to start, and the pressure is consequently diminished.

The Slide and the Stripping Punch

After each extruding operation there is a thin washer-like piece of scrap left in the dies and attached to the tube, for it is impossible to extrude every particle of the metal. The means taken to clear the die of this scrap are interesting. The body of the punch *I* is driven into a slide *O*, which works in the head-block *M*. This block is, in turn, bolted to the ram of the press. The travel of slide *O* is limited by two stops, one of which is shown at *Q*. Into the head-block is driven a block of hardened steel *P*, directly in line with the dies below. When slide *O* is at one end of its travel. the punch is backed up by this block. At the other extreme of the travel of the slide, stripping punch-base *T* comes in line with the die and consequently is also, in its turn, backed up by block *P*. A threaded hole in base *T* receives the stripping punch *R* which at its lower end has a bushing *S*. the diameter of which is midway between that of the hole in the die and that of the inside of the tube. After the tube has been extruded, the slide is moved to its other position. bringing the stripping punch *R* in line with the die. At the next stroke of the press, the stripping punch enters the die, the front end of the bushing severs the tube from the scrap, and on the return, the top edge of the bushing catches the scrap and pulls it out of the die The slide is then moved back to its original position, and at the next stroke of the press another tube is extruded. Thus it will be seen that every second stroke produces a tube or shell, while the intervening stroke removes the scrap from the die. After the stripping punch becomes filled with these scrap washers, it is unscrewed from the base and cleared of the scrap.

Another improvement on this extruding die is the device beneath the die for preventing the tubes from being pulled up into the die when the stripping punch ascends. This device consists essentially of two semicircular leaves *U*, held together by a spring *W*. These leaves, or gripping jaws, are supported by two pins *V* which allow the jaws to tip slightly downward when pushed from above. Therefore the tubes are permitted to pass downward through the jaws, but the jaws resist any upward pull by gripping the tube and effectually holding it.

After the tubes have been extruded, their forms may be changed by making them square or hexagonal, or they may be straight or spirally fluted. These operations are done by running them through dies, properly shaped, with punches of the same shapes to support the interiors. Round tubes that must be very straight and true are sometimes run through round dies to correct errors. At *M*, *N*, and *O*, Fig. 34, are illustrated tubes of hexagonal and square sections.

Some Examples of Extruded Work

Perhaps the most impressive pieces of tubular extrusion done at the Metallic Shell & Tube Co. factory, are the lead tubes shown at *T* and *U*, Fig. 36. This work really does not require as much skill to produce as the majority of the extruded shapes, but it shows up well. These tubes, which are 36 inches long, are used as containers for the explosive for torpedoes. They are cut to short lengths, and the ends folded over. The blank, after being cupped, appears in front of the tubes. Lead is so easy to extrude that care was not even taken to chamfer the top face of the blank.

For really difficult work in this line, the copper tube *Y* in Fig. 35 is a fine example. It is but ⅜ inch in diameter and is 16 inches long. The walls are less than 0.010 inch thick. Fig. 33 is shown for a comparison of the two methods of making sheet-metal shells with closed ends; *A* represents the shell for a bicycle pump and is about as deep and narrow a shell as can be successfully drawn. To make this

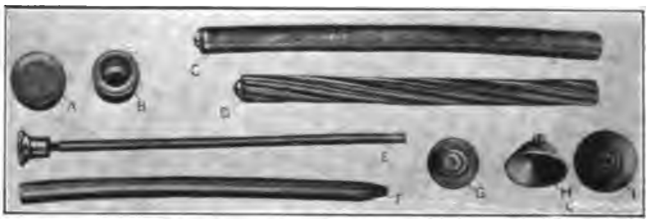


Fig. 38. A, B, C, and D, Steps in Making an Instrument Case by Extrusion; E and F, Extruded Parts for Automatic Pencils; G, Bullet Jacket; H and I, Hat-pin Guards

shell from copper or brass would require at least twelve operations. Contrasted with this piece of work is the copper tube at *B* which was made in three operations. In fact, it would be impracticable to use more than three operations for extruding this tube. It would be impossible to duplicate this tube by ordinary press drawing operations.

Instrument Cases

A very pretty illustration of an extruded product is shown in the aluminum instrument case illustrated at *D* in Fig. 38, together with the successive steps in its making. The first operation consists in blanking the disk *A*. The next operation is to cup this blank by punching the center in a die that also forms the ornamental bead on the end of the tube. Then the blank is extruded to make the tube *C* itself. Finally the tube is trimmed to length and run through the fluting die, which completes the tube, straightening it as well. The fluting die is merely a thin die having spiral grooves in it. The punch, or mandrel, is free to turn as it pushes the tube through the die.

The two parts of an automatic pencil, shown at *E* and *F*, Fig. 38, represent some neat specimens of the extrusion process. The core of the pencil shown at *E*, which has a small hole running through the tube section, was first extruded with the hole clear through the head. Afterward the piece was put in another die and the head flanged, closing in the end of the hole at the same time. The larger tube *F* was extruded in the usual manner, and the end closed in by another operation.

At *G*, Fig. 38, is shown a small aluminum bullet jacket which shows the flange of scrap that is left by the dies. In this case, however, the flange is a necessary part of the bullet jacket.

The hat-pin guard, shown at *H* and *I*, is a somewhat unusual piece of extrusion work. The former is made just the size of the hole; the punch is chamfered off to fit the inside of the bell and the die is of the same shape as the under part of the guard. In this case, as with the bullet jacket, there is no scrap and the pieces must be taken from the die either by hand or by an ejector.

At *J*, Fig. 34, is shown an electrician's wire coupling used in splicing breaks in a wire. This piece is extruded as a plain round copper tube, and then slightly flattened in the center by a simple press operation. The small bushing at *L* shows that thick walls may be extruded as well as thin ones. At *P*, *Q* and *R* are shown three stages in making a brass cartridge case, as already mentioned. At *S* the end of the shell has been reduced by closing-in in a press, and the groove has been turned at the base of the cartridge.

CHAPTER III

MAKING COLLAPSIBLE TUBES BY THE EXTRUSION PROCESS

The extrusion process is extensively used for making collapsible tubes of tin and lead, for containing dentifrice, artists' colors and other preparations. The New England Collapsible Tube Co., of New London, Conn., is employed in the work of making these collapsible tubes. The business of the company was originally established by the late Dr. Sheffield, in 1850, as a dentifrice manufacturing business. He made at that time only the tubes he required in putting out his preparations. Later, however, the demand for good collapsible tin tubes became so strong that the company commenced to make them for outside concerns, and now the tube department has grown to be far larger than the dentifrice department.

The best collapsible tubes are made from pure tin. Lead is often used for tubes for paste, glue, and ink; but for toilet preparations, like dentifrice, only the purest tin is employed. Tin ore is found in Germany, Spain, Russia, Malacca, Australia, Mexico and the United States. The amount of tin ore mined in the United States, however, is very small, and not nearly sufficient to meet the demands of this country. The very best tin is obtained from the Straits of Malacca, as this tin is particularly free from impurities. This is a very important requisite in tin for the extrusion of collapsible tubes for dentifrice, because foreign matter would not only cause the tubes to be poor, but the quality of the dentifrice would be affected, and moreover there would be constant trouble from injury to the dies.

Fig. 39 illustrates a few finished collapsible tubes and their caps. Those marked *A* have been decorated by lithographing; those marked *B* have been embossed; while those marked *C* are plain tubes onto which labels may be pasted. Collapsible tubes may be made as large as 2½ inches in diameter, and of any length up to 9 inches. The thickness of the walls of the tubes ranges from 0.005 inch to 0.010 inch, varying with the size of the tube. If desired, raised lettering may be produced upon the shoulder of the tube. The opening in the top of the tube may be of any size, either round or oblong in shape.

The cold extrusion of collapsible tin tubes is totally different from the hot extrusion process for solid shapes described in Chapter I, and it is just the reverse of the cold tubular process described in Chapter II. The extrusion of tin, however, is much more easily accomplished than the extrusion of copper and brass. Briefly stated, collapsible tin tubes are made by placing a round blank of tin in a die-cavity shaped like the head of the tube, and of the same internal diameter as the external diameter of the tube to be made. Then a punch, whose greatest diameter is the same as the inside diameter of the tube, comes down on the blank. It forces the metal into the bottom of the die, and squeezes the excess metal upward through the narrow annular opening between

Fig. 39. Collapsible Tin Tubes made by Extrusion

the outside of the punch and the inside of the die-cavity. The tin literally "crawls" up the punch as it is extruded. When the punch ascends, it automatically swings outward to allow the operator to remove the completed tube, otherwise there would not be room to withdraw the tube from the punch. The threading of the head is done in another operation in this factory, although some companies make the die in halves, with half of the threaded section in each, necessitating the opening of the die after each stroke of the press.