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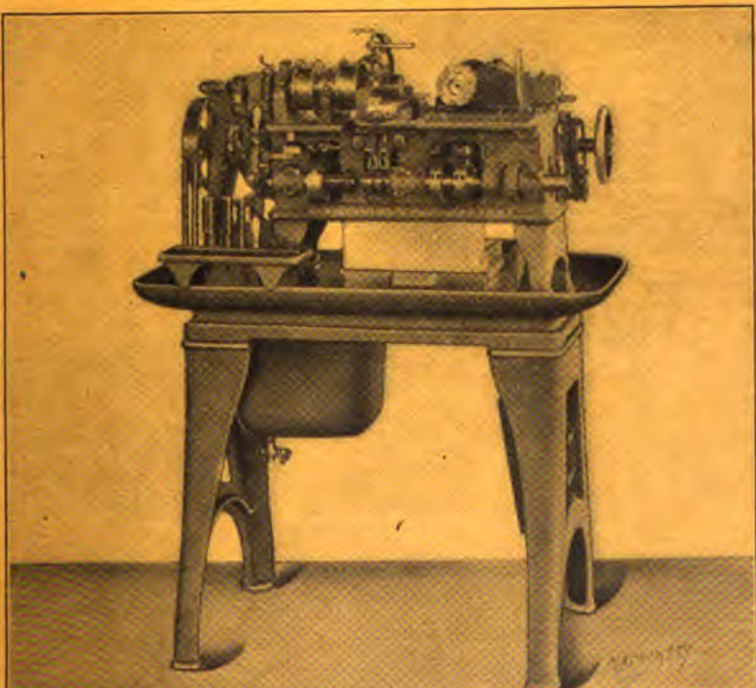
AUTOMATIC SCREW MACHINE PRACTICE

FORM AND CUT-OFF TOOLS FOR THE BROWN & SHARPE AUTOMATIC SCREW MACHINES

BY DOUGLAS T. HAMILTON



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NUMBER 101

AUTOMATIC SCREW MACHINE PRACTICE

PART III

CIRCULAR FORM AND CUT-OFF TOOLS FOR THE BROWN & SHARPE AUTOMATIC SCREW MACHINE

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

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_3; 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

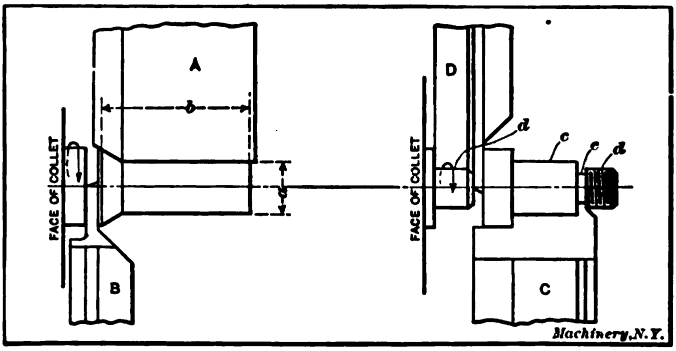


Fig. 1. Illustration showing Relation between Smallest Diameter of Work and Length of Forming Tool

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

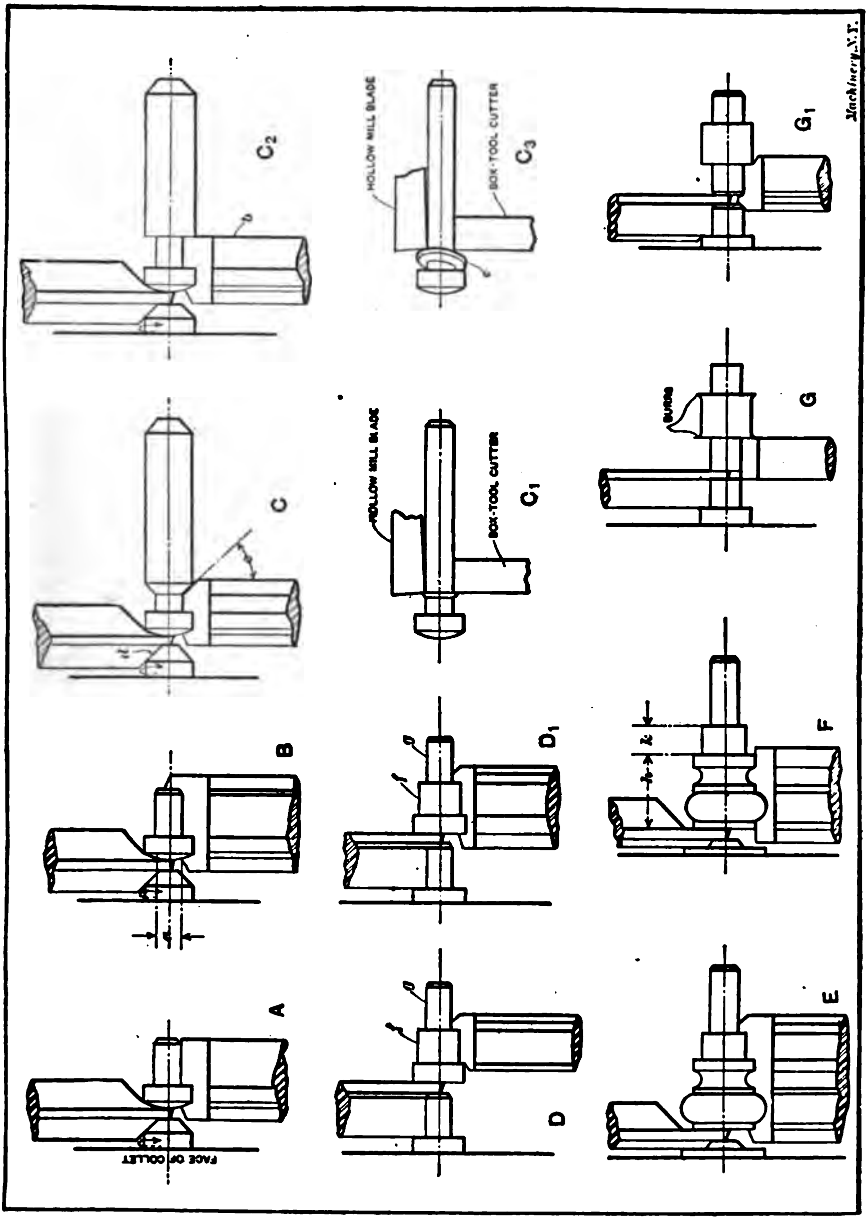


Fig. 3. Examples of Applications of Circular Form and Cut-off Tools

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

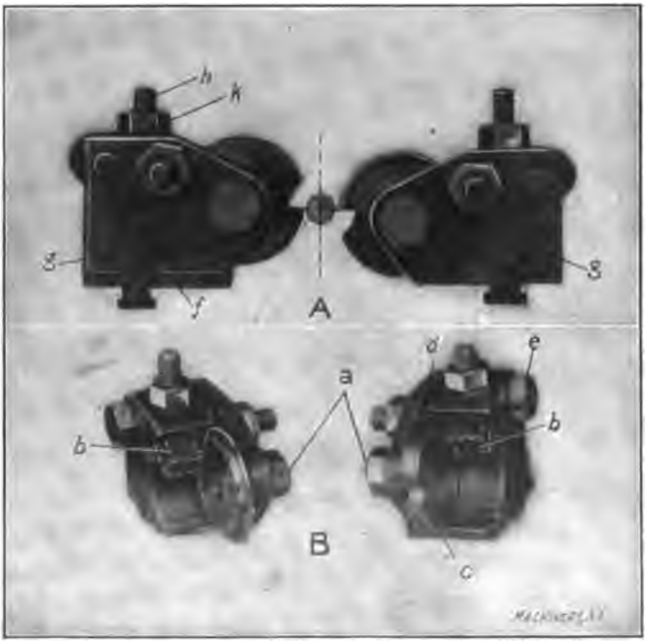


Fig. 4. Holders for Circular Form and Cut-off Tools

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

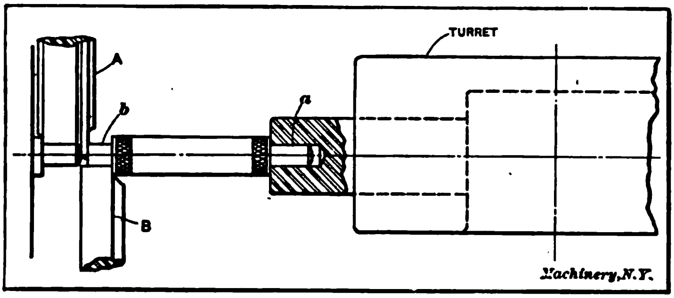


Fig. 5. Method of Supporting Long Work

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

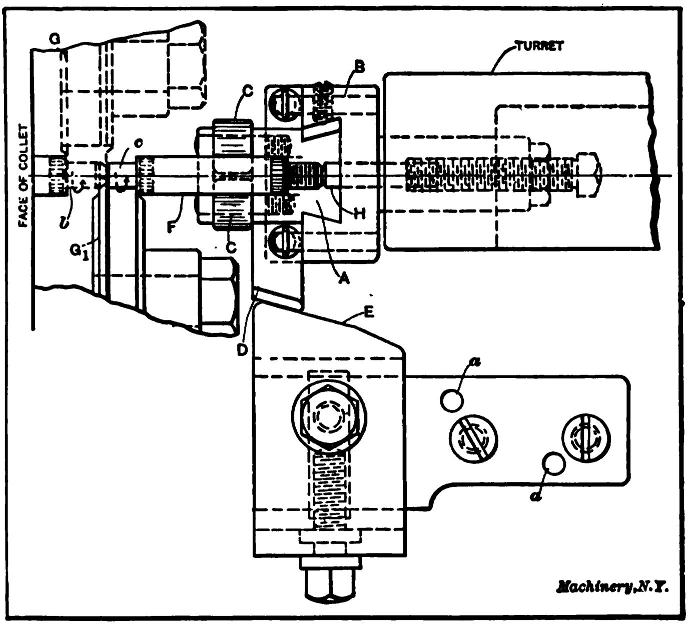


Fig. 6. Improved Method of Supporting Long Work

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

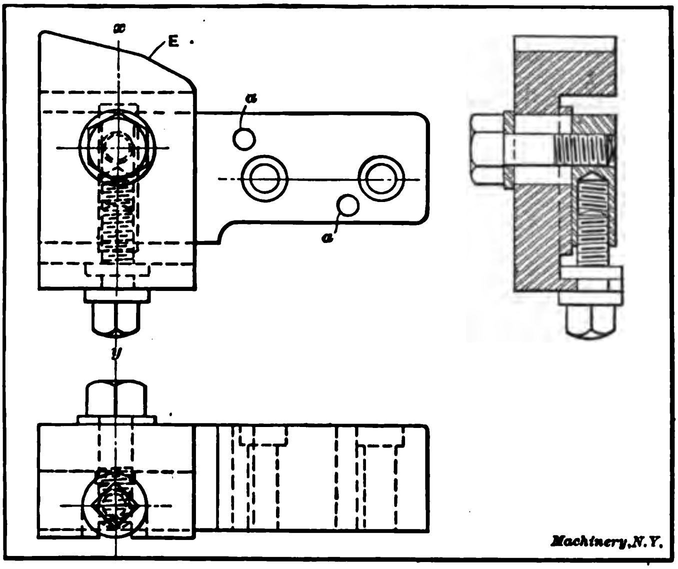


Fig. 7. Cam Attachment used in Connection with the Arrangement for Supporting Long Work shown in Fig. 6

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

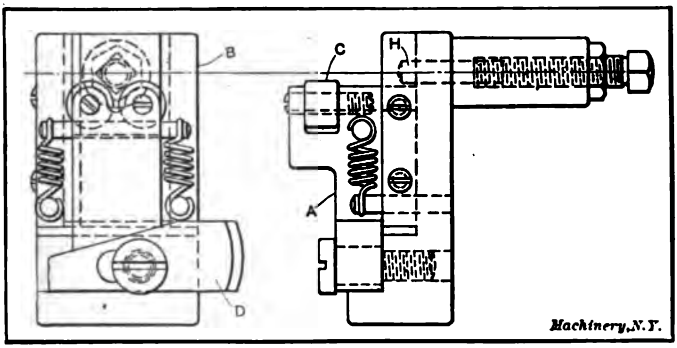


Fig. 8. Combination Stop and Support used in Arrangement for Supporting Long Work shown in Fig. 6

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

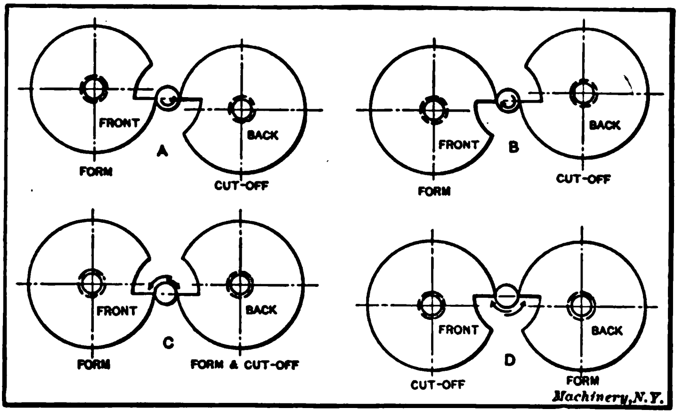


Fig. 9. Different Arrangements of Circular Tools

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 $r =$ 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

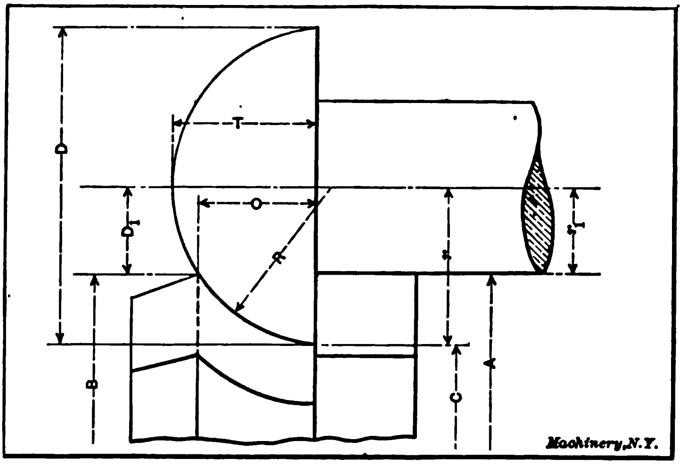


Fig. 10. Diagram for Calculating Dimensions of Circular Tools forming Spherical Screw Heads

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 $a = r \times \cos\phi$; $H = a \times \tan\beta$; $B = D - H$;

$Y = B \times \cot\theta$; $X = Y + a - d$; $C = D - h$;

$h = r - \sqrt{r^2 - d^2}$.

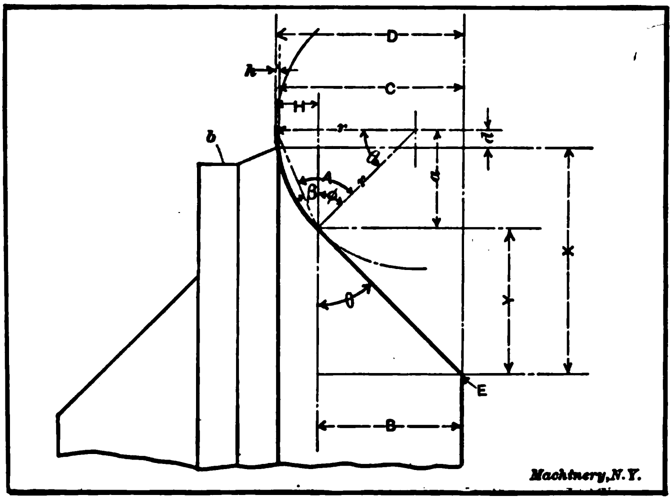


Fig. 11. Diagram for Determining Dimensions of Circular Cut-off Tool which forms Part of a Spherical Screw Head

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

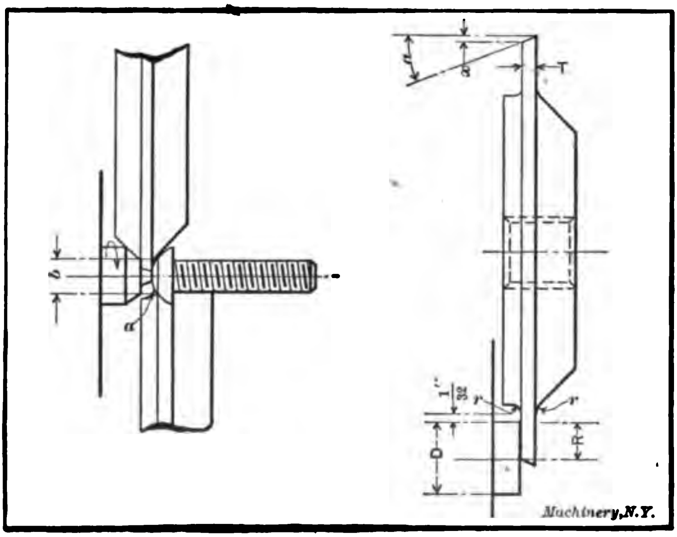


Fig. 12. Spherical Screw Head formed by Combination of Forming and Cut-off Tools

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 1. DIMENSIONS FOR CIRCULAR CUT-OFF TOOLS (For Notation See Fig. 13)

Diameter of Stock	Soft Brass and Copper			Hard Brass			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.

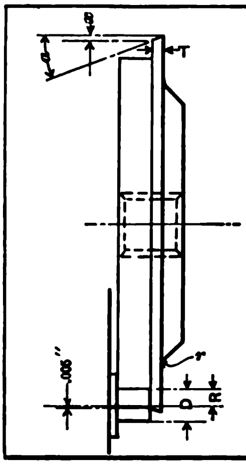


Fig. 14. Diagram showing Dimensions of Circular Cut-off Tool when it is used both for cutting-off and forming part of the Work

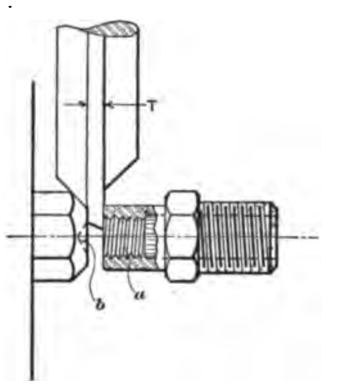


Fig. 15. Illustration showing a Case where a Cut-off Tool with Increased Thickness of Blade is required

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.

$$\text{Then } T = \sqrt{\frac{D \times \cot a}{8}} \times 0.14 = \sqrt{\frac{0.875 \times 2.747}{8}} \times 0.14 = 0.082 \text{ inch.}$$

$L = R + x + r + 1/32$, 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.

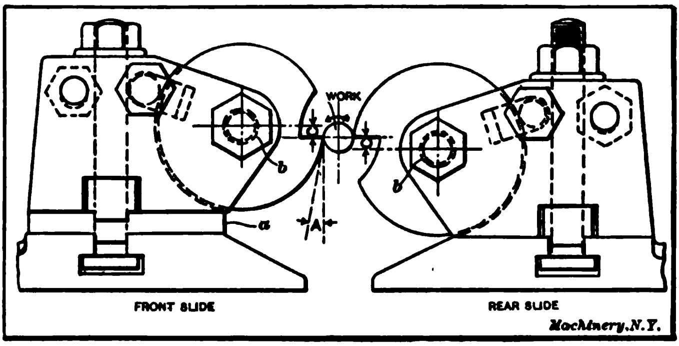


Fig. 16. Circular Form Tools and Holders showing Location of Center of Tool in Relation to Center of Piece being formed

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	$2\frac{1}{2}$ 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-

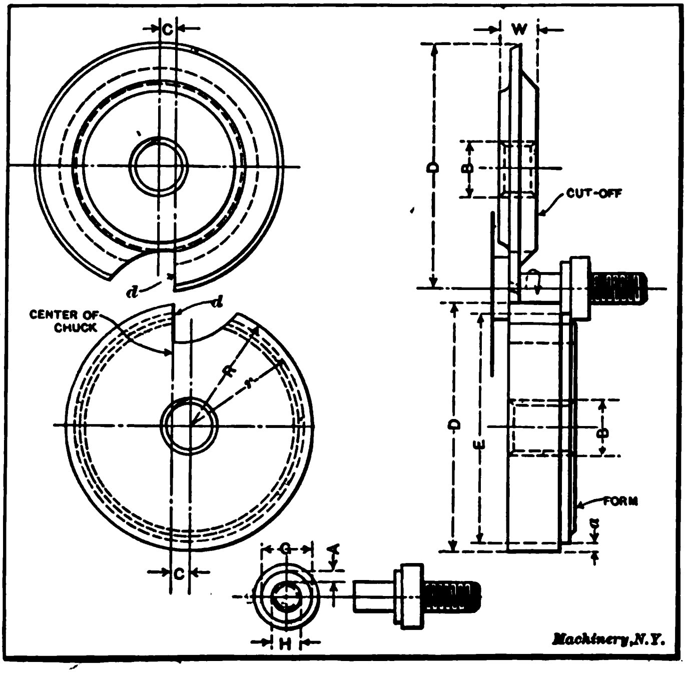


Fig. 17. Diagram showing Principal Dimensions of Circular Form Tools

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 varicus 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	1 3/4	1/8	3/8-16	1/4
0	2 1/4	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:

$$r = \sqrt{(\sqrt{R^2 - C^2} - A)^2 + C^2} \quad (1)$$

If the smaller radius r is given and the larger radius R is required, the formula would be:

$$R = \sqrt{(\sqrt{r^2 - C^2} + A)^2 + C^2} \quad (2)$$

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:

$$h = A \times \tan 15 \text{ deg.} = \tfrac{1}{8} \times 0.26794 = 0.03349.$$

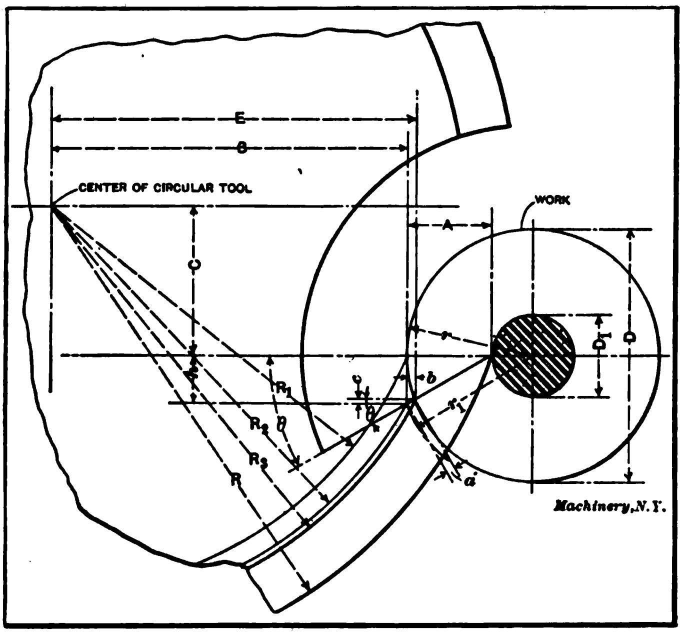


Fig. 18. Diagram for Calculating Form Tools having Top Rake

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:

$$R_3 = \sqrt{(C + h - c)^2 + E^2}.$$

Inserting the actual values in the formulas just given, we have:

$$a = 0.2832 - \frac{9}{32} = 0.00195,$$

$$b = 0.00195 \times \cos 15^\circ = 0.00188,$$

$$c = 0.00195 \times \sin 15^\circ = 0.00051,$$

$$E = 0.989 + 0.00188 = 0.99088,$$

$$R_3 = \sqrt{0.18923^2 + 0.99088^2} = 1.0088 \text{ inch.}$$

The found value of R_3 is the required radius of the tool. This radius is about 0.0075 inch greater than the radius R_1. The procedure may appear difficult at first sight, but a few examples in practice will make the user familiar with it.

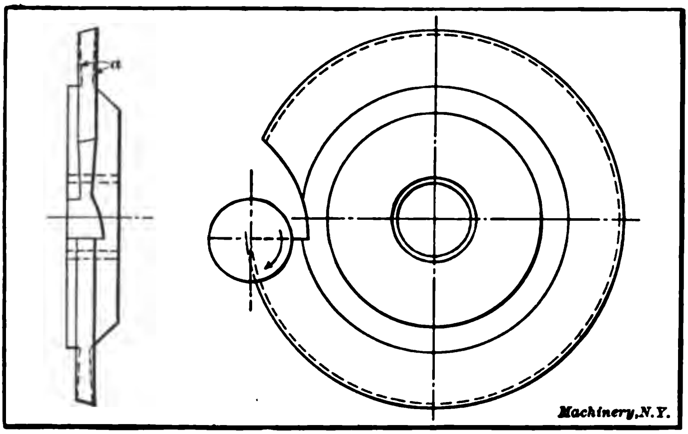


Fig. 19. Side Clearance on Circular Tools

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.

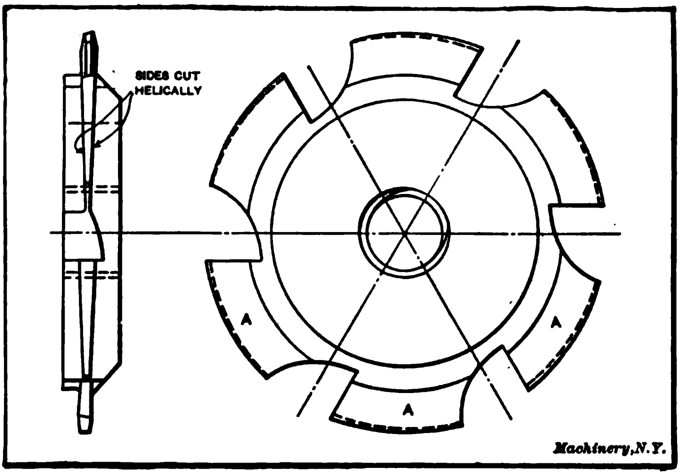


Fig. 20. Cut-off Tool with Side Clearance

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

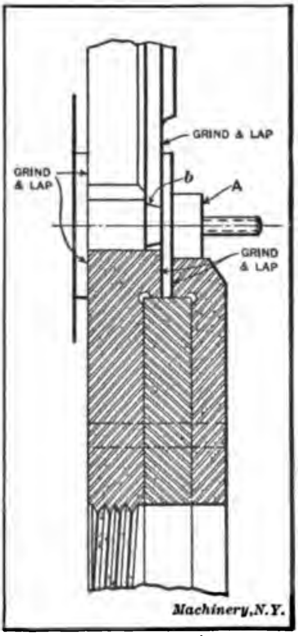


Fig. 21. Circular Form Tool without Side Clearance

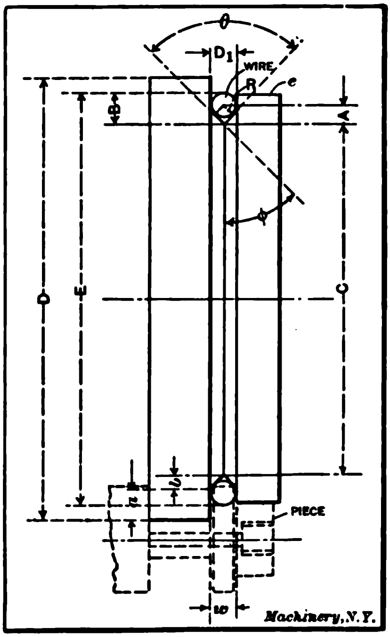


Fig. 22. Wire Method employed for Measuring Circular Form Tools

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

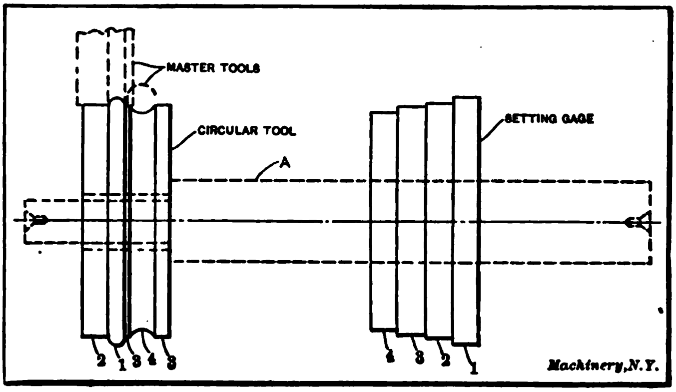


Fig. 28. Transfer Method for Making Circular Form Tools

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

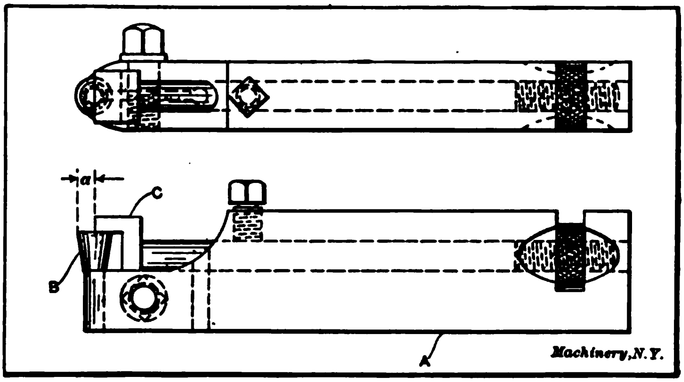


Fig. 24. Holder for Special Turning Tools

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

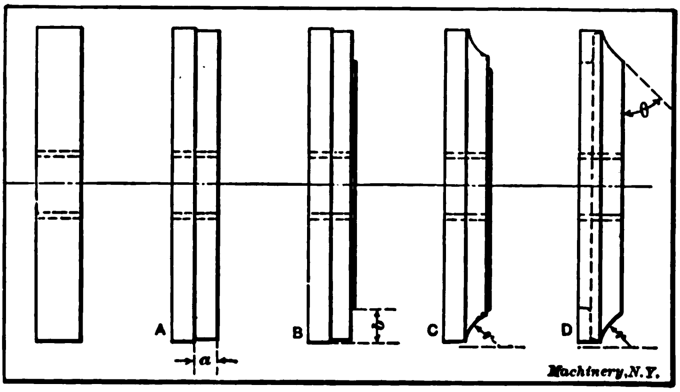


Fig. 25. Making Cut-off Tools for Spherical Work

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-

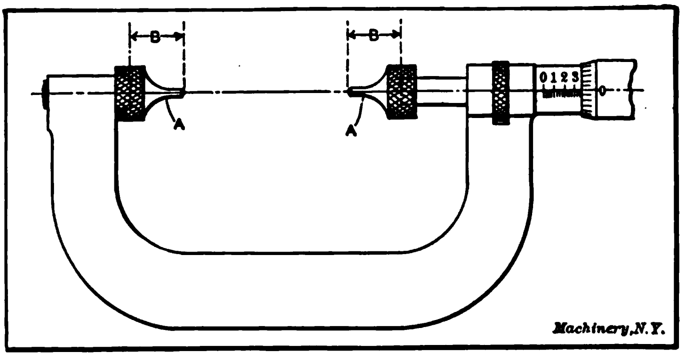


Fig. 26. Micrometer Arranged for Measuring Form Tools of Difficult Shapes

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.

$$\text{Then } b = \frac{w}{2} \times \cot \phi; \; C = D - 2\,(a + b)$$

$$A = \frac{R}{\sin \phi}; \; B = A + R; \; E = C + 2\,B.$$

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.

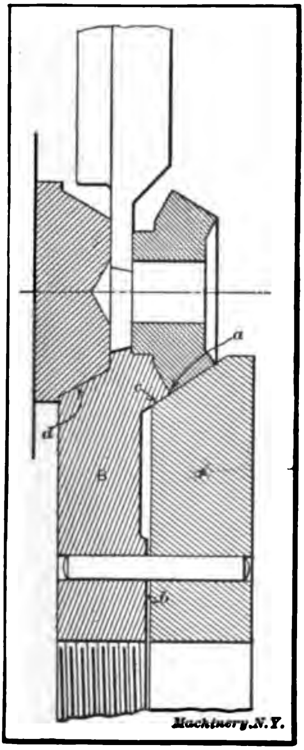


Fig. 27. Forming Tool for Bevel Gear Blanks

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):

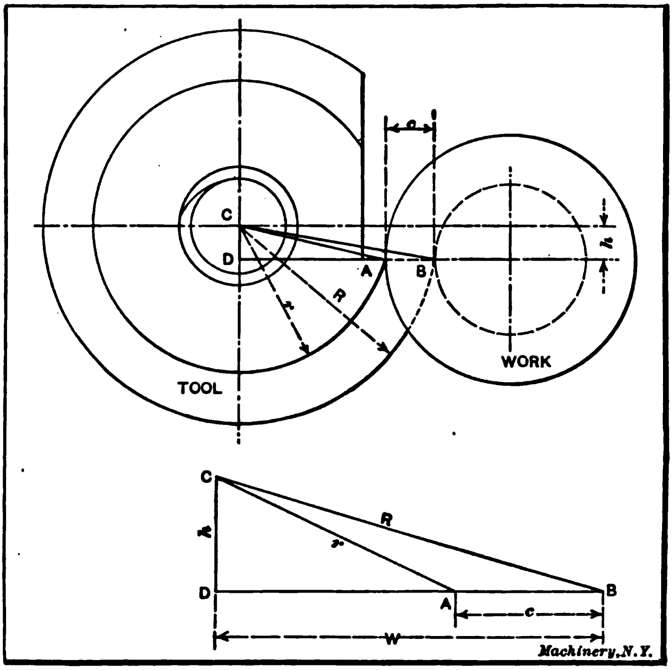


Fig. 28. Notation used in Formulas for Forming Tool Calculations

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

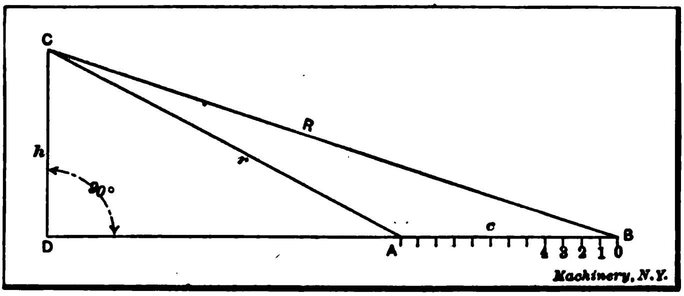


Fig. 29. Notation used in Formulas for Calculating Table IV

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			3.000000	
		0.049277	0.0009855		0.001971
50	1.450723			2.901446	
		0.049225	0.0009845		0.001969
100	1.401498			2.802996	
		0.049169	0.0009834		0.001967
150	1.352329			2.704658	
		0.049105	0.0009821		0.001964
200	1.303224			2.606448	
		0.049085	0.0009807		0.001961
250	1.254139			2.508278	
		0.048955	0.0009791		0.001958
300	1.205234			2.400468	
		0.048866	0.0009773		0.001955
350	1.156368			2.312736	
		0.048765	0.0009753		0.001951
400	1.107603			2.215206	
		0.048650	0.0009730		0.001946
450	1.058953			2.117906	
		0.048517	0.0009703		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	2.2222	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	1.4893	1.9889	2.7401	0.182	1.3907	1.8902	2.6418
0.133	1.4873	1.9869	2.7381	0.183	1.3888	1.8882	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	1.3799	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	1.9632	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

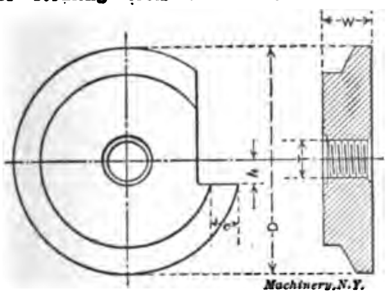
Length c on Tool	No. of B. & S. Machine		Length c on Tool	No. of B. & S. Machine		Length c on Tool	No. 2 B. & S. Machine	Length c on Tool	No. 2 B. & S. Machine
	No. 0	No. 2		No. 0	No. 2				
0.201	1.8527	2.6045	0.251	1.7543	2.5064	0.301	2.4085	0.351	2.3108
0.202	1.8508	2.6025	0.252	1.7523	2.5045	0.302	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	2.0209
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	⅛	⅜–16	¼
0	2¼	5/32	½–14	5/16
2	3	¼	⅝–12	⅜

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 — ¼ = 0.300; 0.300 ÷ 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:

$$\sin CBD = \frac{1}{6}$$

$$\cos CBD = \sqrt{1 - \sin^2 CBD} = \sqrt{\frac{35}{36}} = 0.9860133$$

From the "law of cosines" in trigonometry, we obtain:

$$r = \sqrt{R^2 + c^2 - 2 R c \times \cos CBD}$$

Substituting the known values, we have:

$$r = \sqrt{2.25 + 0.000001 n^2 - 0.0029580399 n}.$$

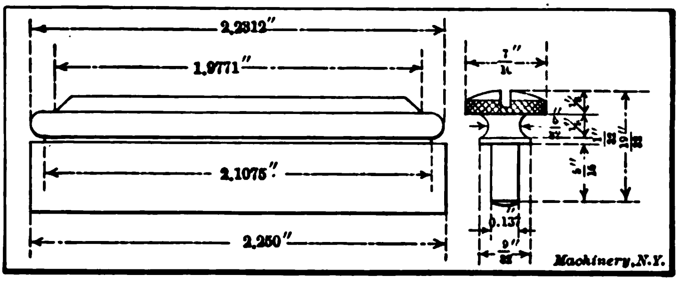


Fig. 30. Dimensions of Work and Tool in the Practical Example Given

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. Hence, 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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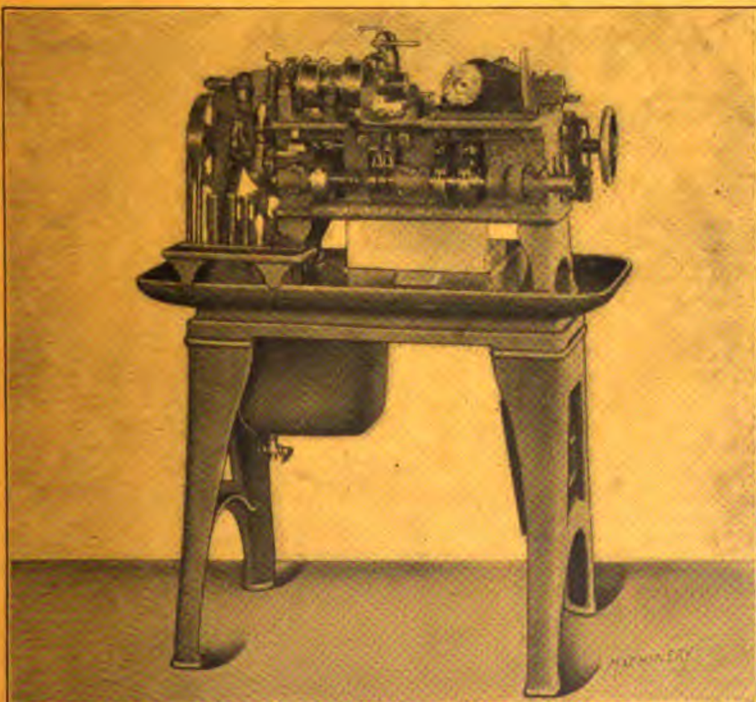
AUTOMATIC SCREW MACHINE PRACTICE

EXTERNAL CUTTING TOOLS FOR BROWN & SHARPE AUTOMATIC SCREW MACHINES

BY DOUGLAS T. HAMILTON



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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.

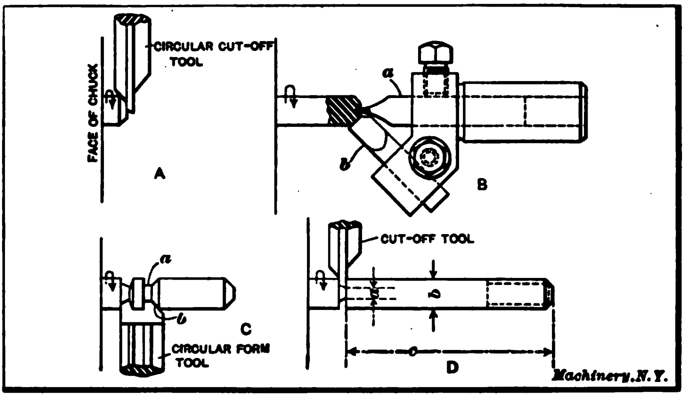


Fig. 1. Methods of Preparing Work for Turning

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

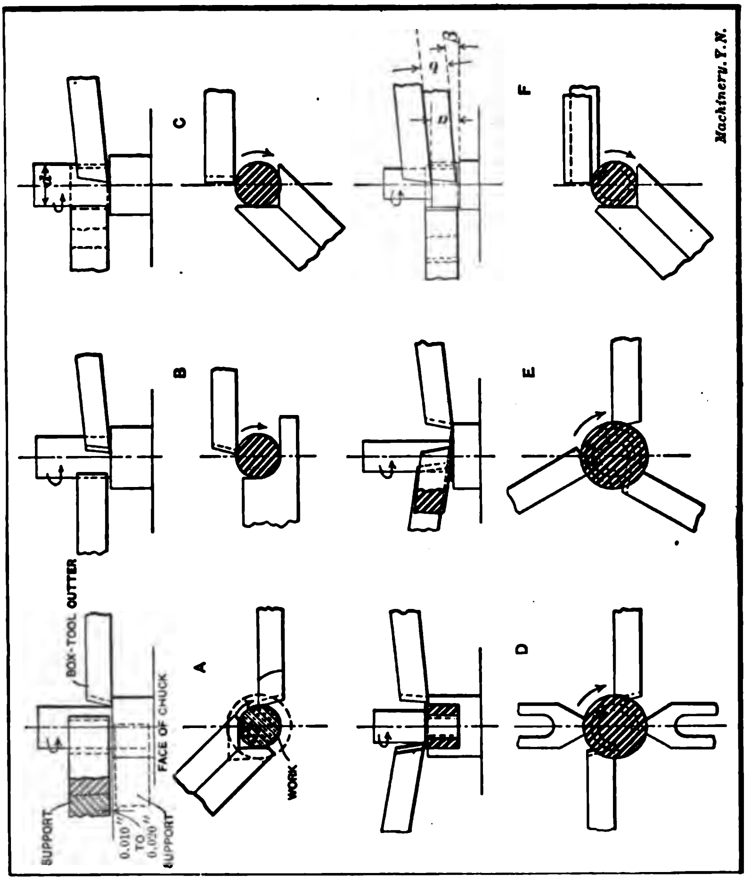


Fig. 2. Various Methods of Applying Box-tool Cutters to the Work

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

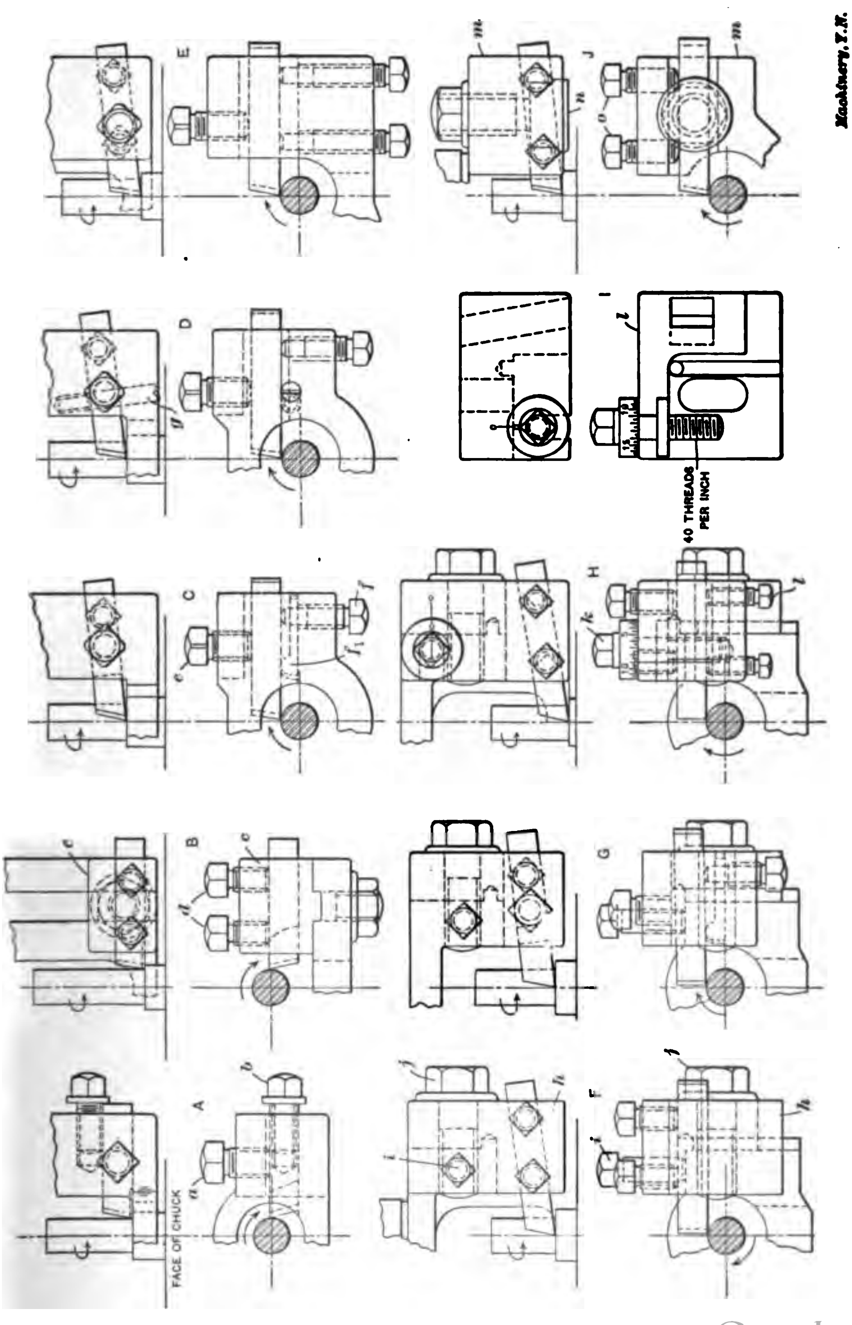


Fig. 3. Holding and Adjusting Box-tool Cutters for Various Conditions

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 *b*, 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

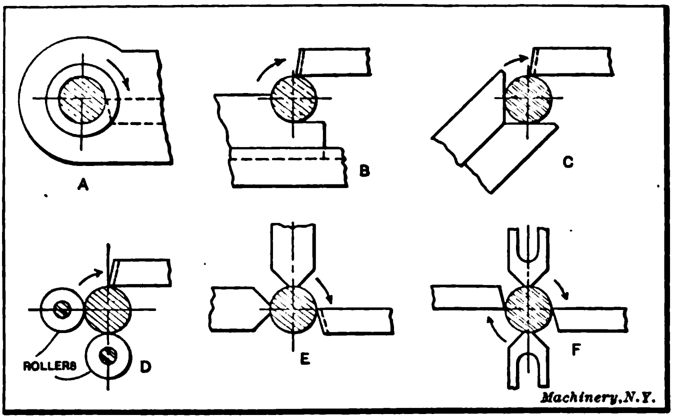


Fig. 4. Method of Applying Box-tool Supports to the Work

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

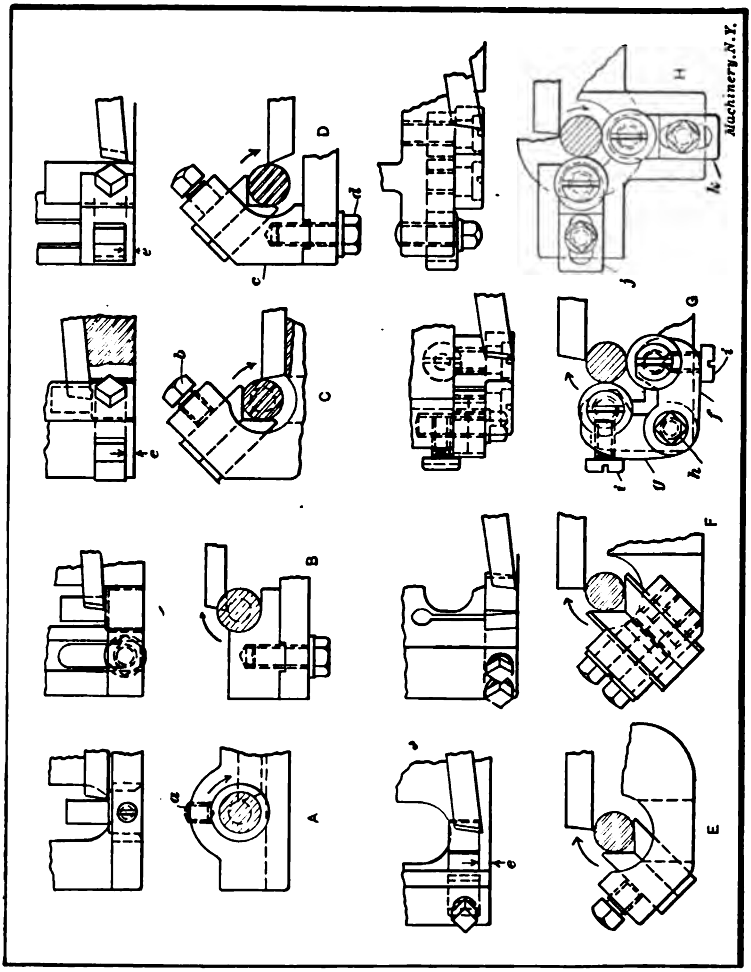


Fig. 5. Methods of Holding and Adjusting Box-tool Supports

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 ¼ to ⅜ 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.

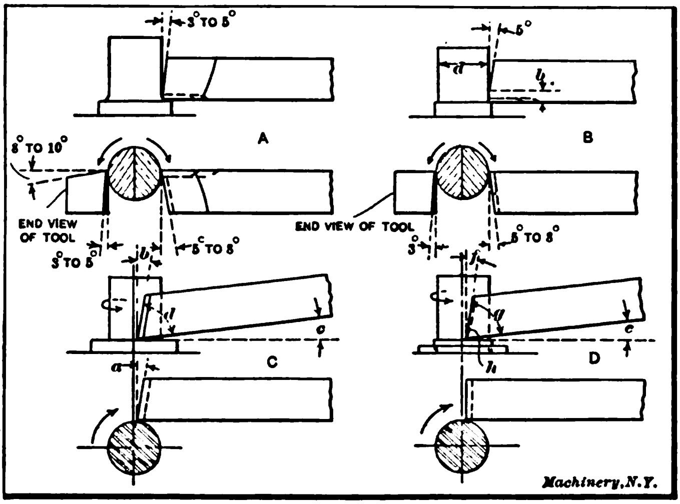


Fig. 6. Cutting-angles for Box-tool Cutters

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 $1/8D$ for tool steel, and $1/10D$ 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.

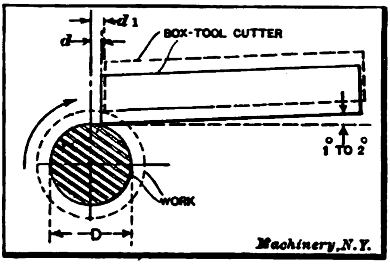


Fig. 7. Adjusting a Tangent Cutter for Turning Different Diameters

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
$\frac{1}{4}$	$\frac{3}{16}$	$\frac{3}{4}$	$\frac{3}{8}$
$\frac{3}{8}$	$\frac{1}{4}$	1	$\frac{7}{16}$
$\frac{1}{2}$	$\frac{5}{16}$	..	..

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.

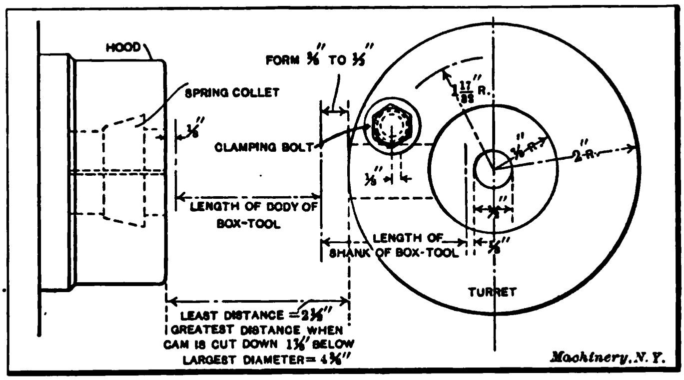


Fig. 8. Method of Determining Length of Body and Shank of Box-tool

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 ⅛ 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.

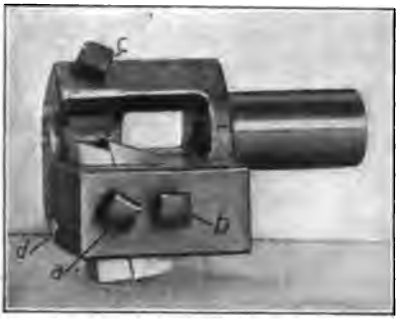


Fig. 9. Standard Box-tool made by the Brown & Sharpe Mfg. Co.

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 ⅝ 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 ⅛ inch of the ½-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

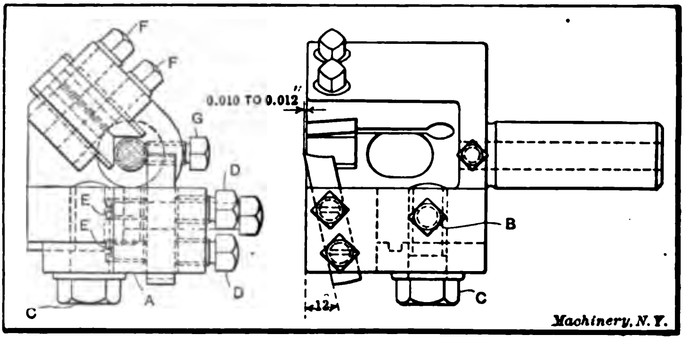


Fig. 10. Finishing Box-tool largely used for Steel Work

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.

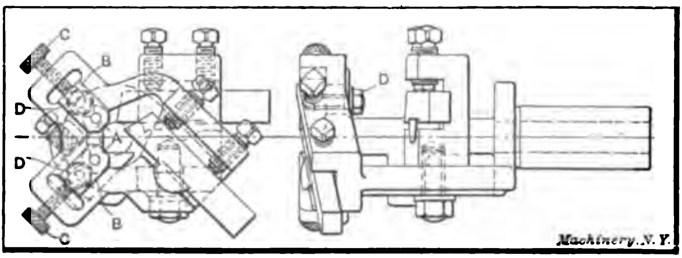


Fig. 11. Details of Box-tool shown in Fig. 12

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

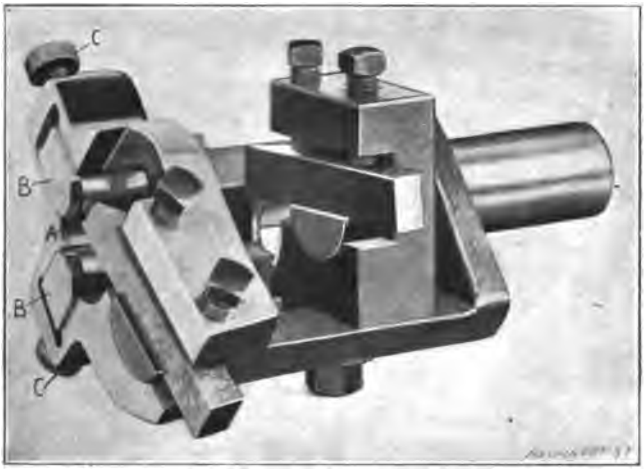


Fig. 12. Box-tool of the Roller Support Type

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.

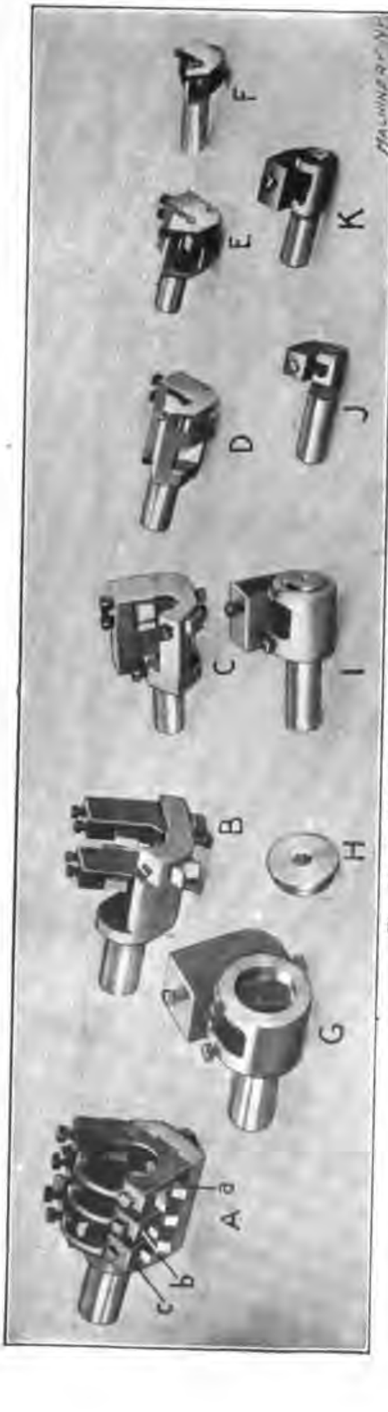
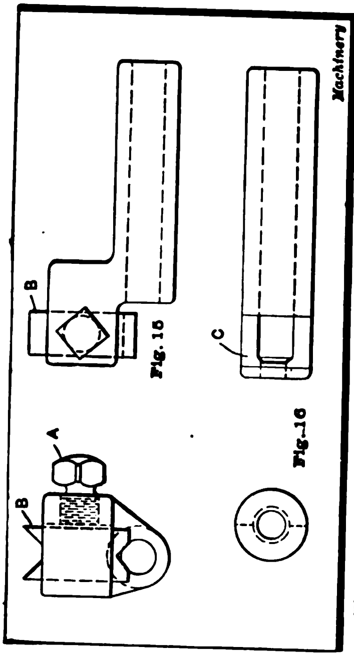


Fig. 13. A Collection of Interesting Designs of Box-tools



Figs. 15 and 16. Supports used in Connection with Swing Tools

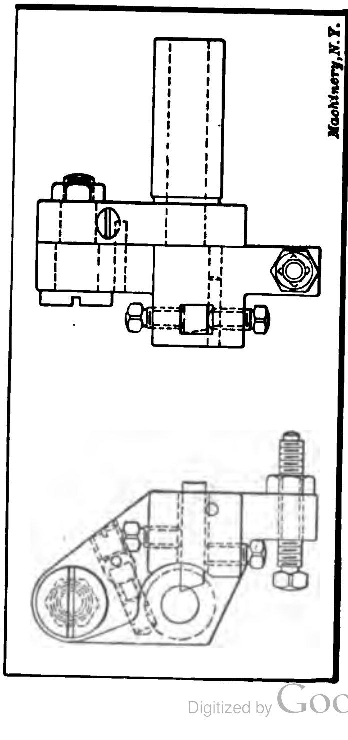


Fig. 14. Swing-tool used for External Cutting

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.

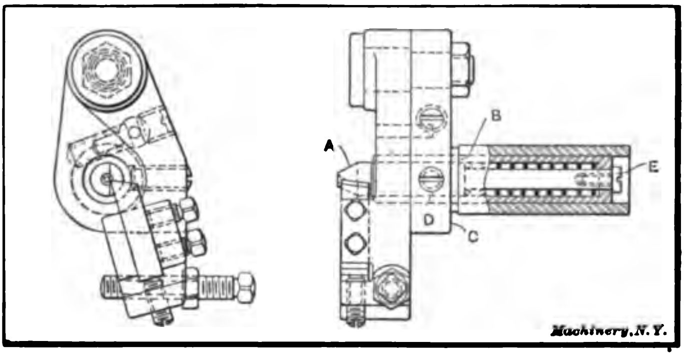


Fig. 17. Swing-tool used when the Work Turned must be Supported

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 set-screw 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.

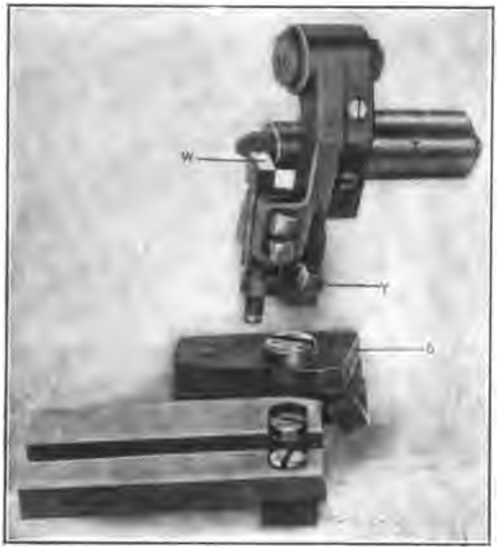


Fig. 18. Swing Tool for Delicate Turning

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.

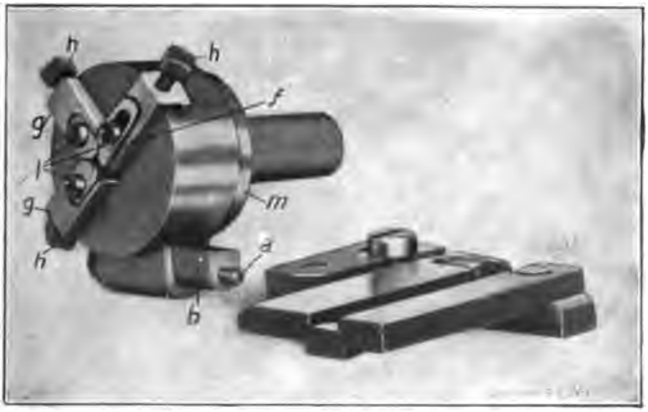


Fig. 19. Standard Taper Turning Tool

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

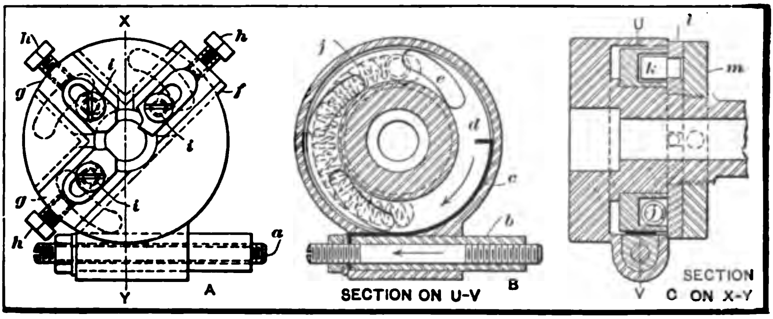


Fig. 20. Details of Taper Turning Tool shown in Fig. 19

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

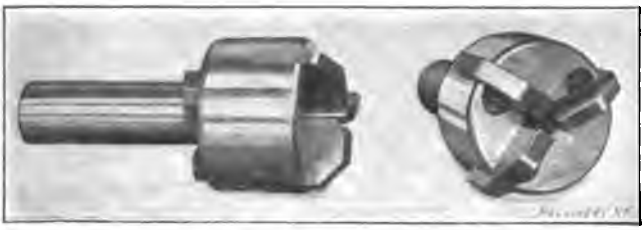
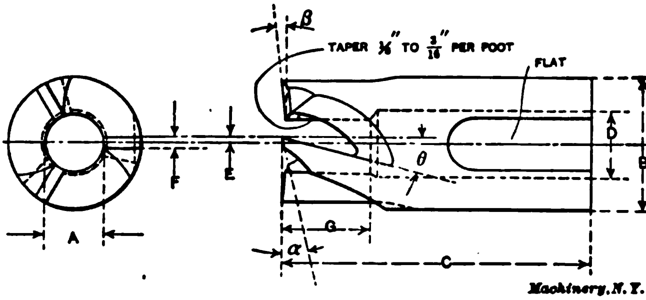


Fig. 22. Hollow Mill of the Inserted-blade Type

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



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	5/8	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
0.703	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 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.

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

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

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	0.0010	0.0008	0.0005	3/8	0.0020	0.0015	0.0010
1/8	0.0015	0.0010	0.0008	7/16	0.0025	0.0018	0.0015
3/16	0.0020	0.0015	0.0010	1/2	0.0030	0.0020	0.0018
1/4	0.0030	0.0020	0.0015	9/16	0.0035	0.0025	0.0020
5/16	0.0035	0.0025	0.0018	5/8	0.0038	0.0028	0.0022
3/8	0.0040	0.0030	0.0020	11/16	0.0042	0.0030	0.0025
1/16-inch Chip				3/16-inch Chip			
1/4	0.0025	0.0020	0.0010	1/2	0.0020	0.0010	0.0008
5/16	0.0030	0.0022	0.0018	9/16	0.0025	0.0018	0.0010
3/8	0.0035	0.0025	0.0015	5/8	0.0028	0.0015	0.0012
7/16	0.0040	0.0028	0.0018	11/16	0.0030	0.0018	0.0015
1/2	0.0045	0.0030	0.0020	3/4	0.0035	0.0020	0.0018
9/16	0.0050	0.0032	0.0025	13/16	0.0038	0.0022	0.0020
5/8	0.0060	0.0035	0.0028	7/8	0.0040	0.0025	0.0020

TABLE V. FEEDS FOR HOLLOW MILLS MADE FROM HIGH-SPEED AND CARBON STEEL

1/16-inch Chip				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
3/16	0.0045	0.0030	0.0015	1/2	0.0060	0.0045	0.0020
1/4	0.0050	0.0040	0.0018	9/16	0.0065	0.0050	0.0023
5/16	0.0055	0.0045	0.0020	5/8	0.0070	0.0055	0.0025
3/8	0.0060	0.0050	0.0025	11/16	0.0080	0.0060	0.0030
7/16	0.0070	0.0050	0.0028	3/4	0.0090	0.0065	0.0035
1/2	0.0080	0.0060	0.0030	13/16	0.0100	0.0070	0.0040
1/8-inch Chip				1/4-inch Chip			
3/8	0.0070	0.0050	0.0030	5/8	0.0050	0.0035	0.0015
7/16	0.0075	0.0055	0.0035	11/16	0.0055	0.0040	0.0018
1/2	0.0080	0.0060	0.0040	3/4	0.0060	0.0050	0.0020
9/16	0.0090	0.0065	0.0050	13/16	0.0070	0.0055	0.0025
5/8	0.0110	0.0075	0.0060	7/8	0.0080	0.0060	0.0030
11/16	0.0130	0.0090	0.0070	..	......	......	......
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*,

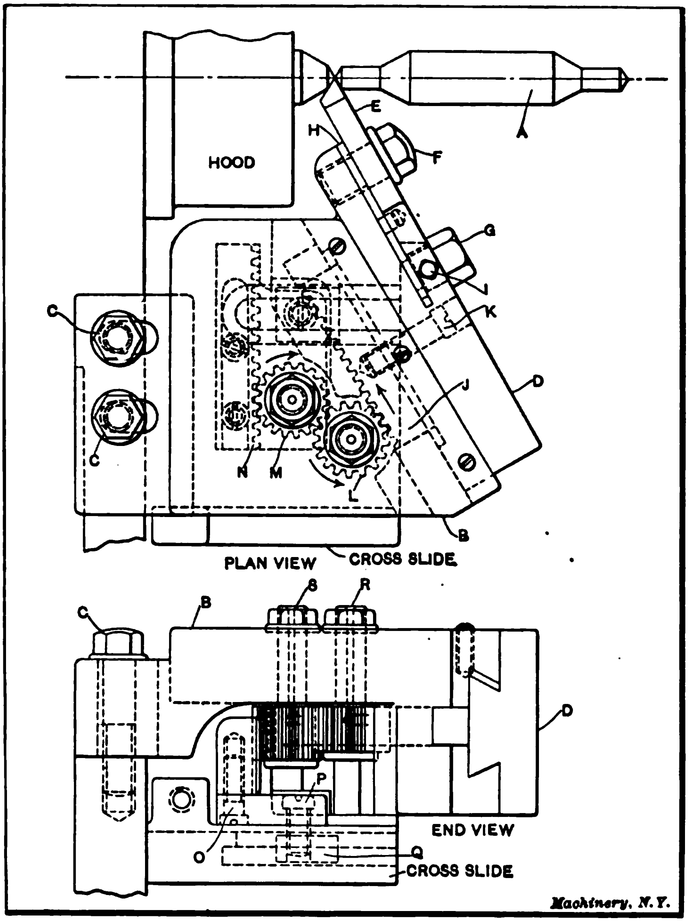


Fig. 23. Cross-slide Angular Cutting-off Tool

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

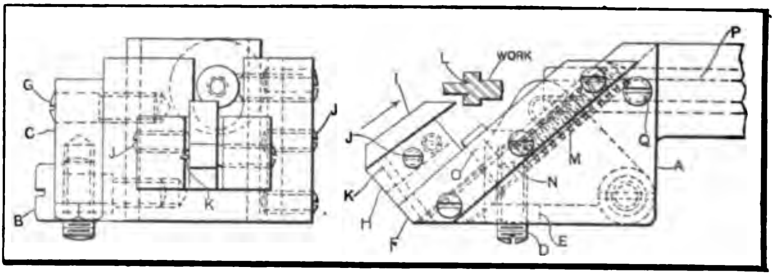


Fig. 24. Back Recessing Tool for Small Work

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 Rising 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.

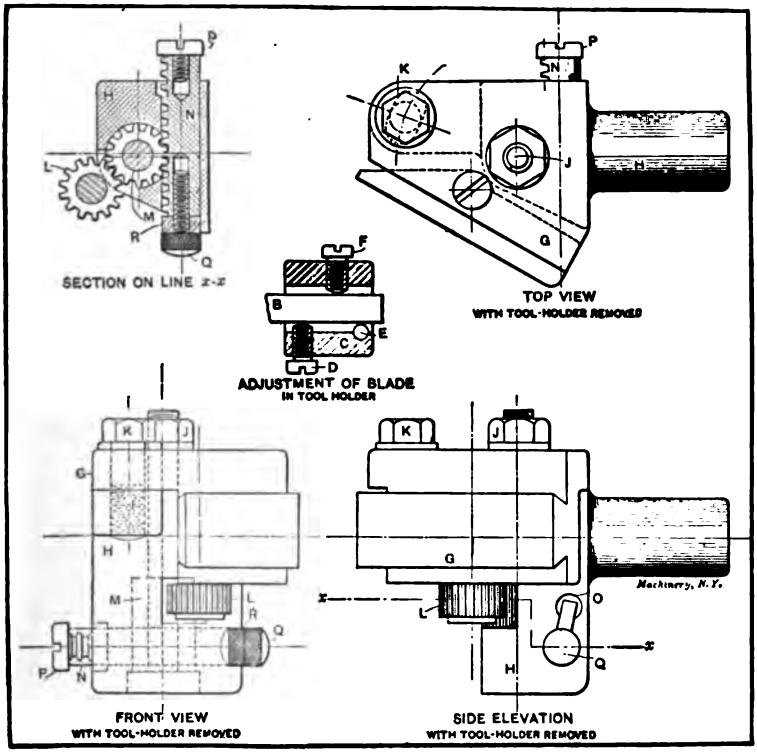


Fig. 26. Details of Tool shown in Fig. 25

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

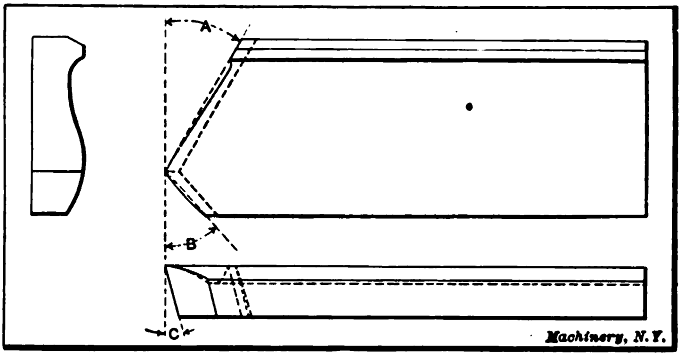


Fig. 27. Shaving Tool for Forming Long Work

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

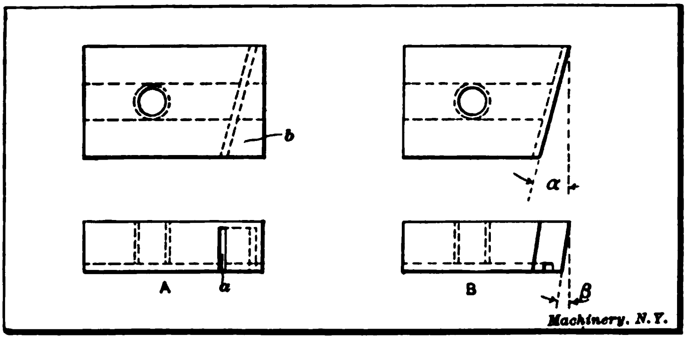


Fig. 28. Type of Shaving Tool used in the Shaving-tool Holder shown in Fig. 29

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

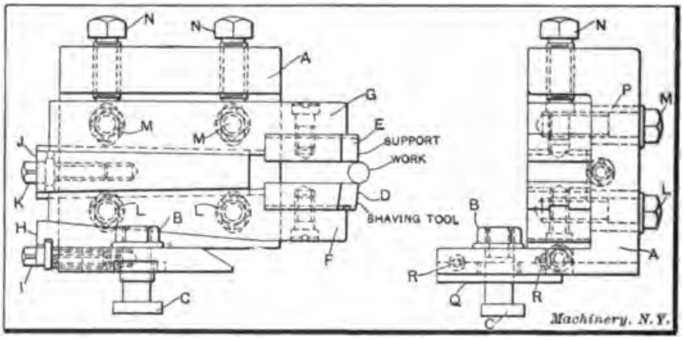


Fig. 29. Shaving-tool Holder which can be used for a Wide Range of Work

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 1/8	0.0050
1/8 — 3/8	0.0075
3/8 — 5/8	0.0100
5/8 — 7/8	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

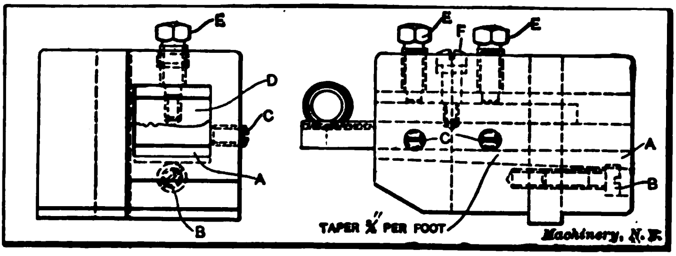


Fig. 30. Shaving-tool Holder of the Box Type

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,

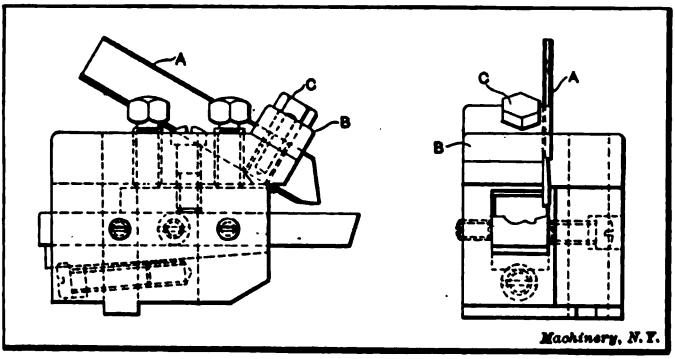


Fig. 31. Combination Cut-off and Shaving-tool Holder

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*.

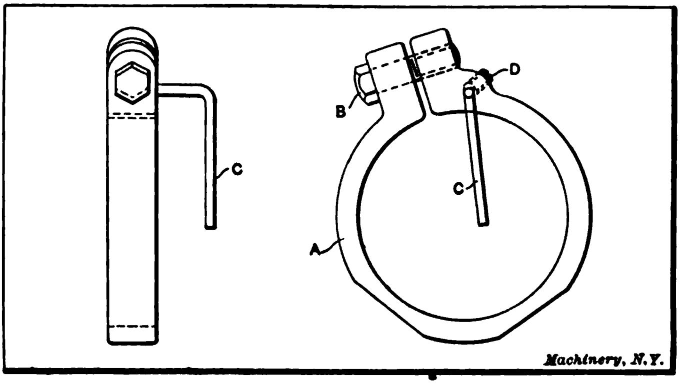


Fig. 32. Ejector used in Connection with the Shaving-tool Holder shown in Fig. 31

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.

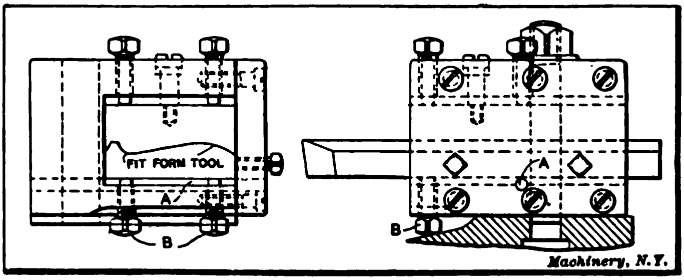


Fig. 33. Shaving-tool Holder for Long Work

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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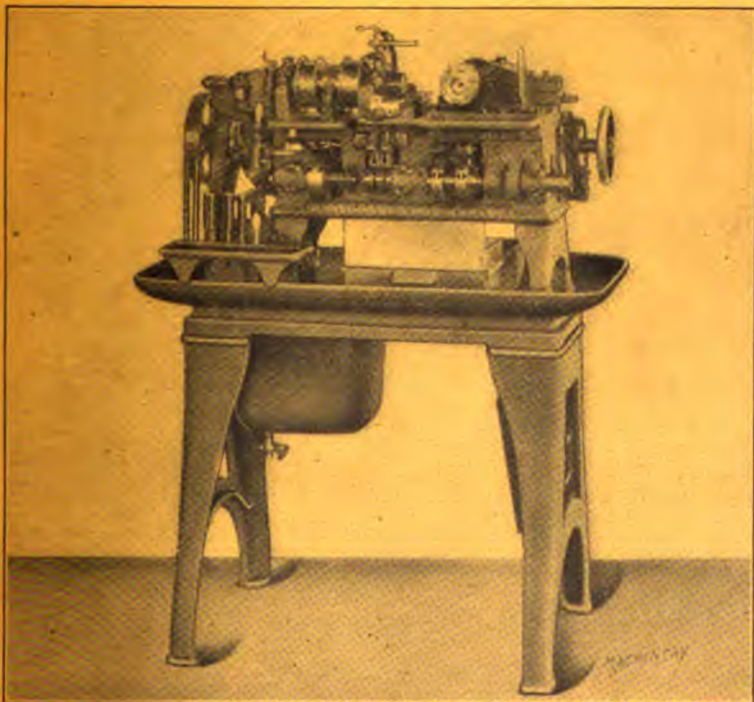
BY DOUGLAS T. HAMILTON



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NUMBER 103

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PART V

INTERNAL 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

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

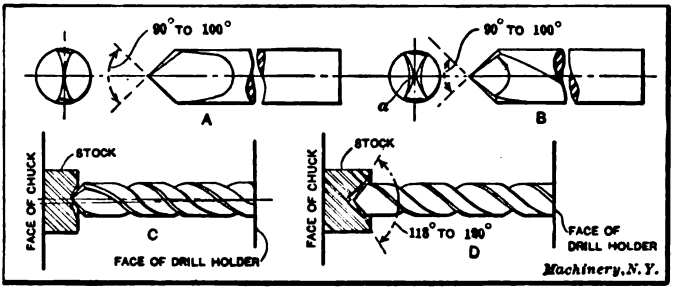


Fig. 1. Centering Tools—Starting the Drill Concentric

formulas for finding the length of point for the various angles are as follows (see Fig. 2):

For 90 degrees $b = 0.5d$.	where b = depth of centered hole,
For 100 degrees $b = 0.42d$.	c = diameter of drill,
For 118 degrees $e = 0.3c$.	d = diameter of centered hole.
For 120 degrees $e = 0.29c$.	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	0.2818	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

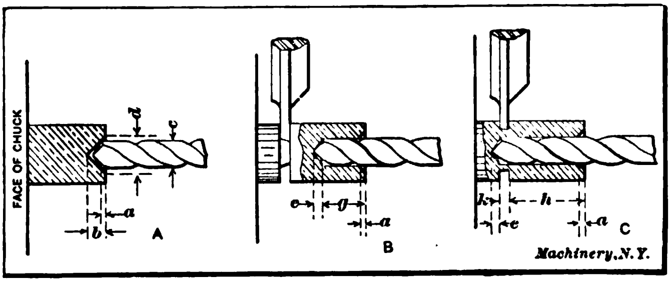


Fig. 2. Diagrams illustrating Method of Finding Cam Rise for Drilling and Centering

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

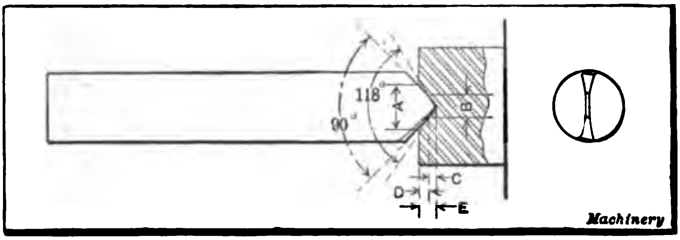


Fig. 3. Double-angle Centering Tool

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

	Feed in Inches per Revolution		
Diameter in Inches	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

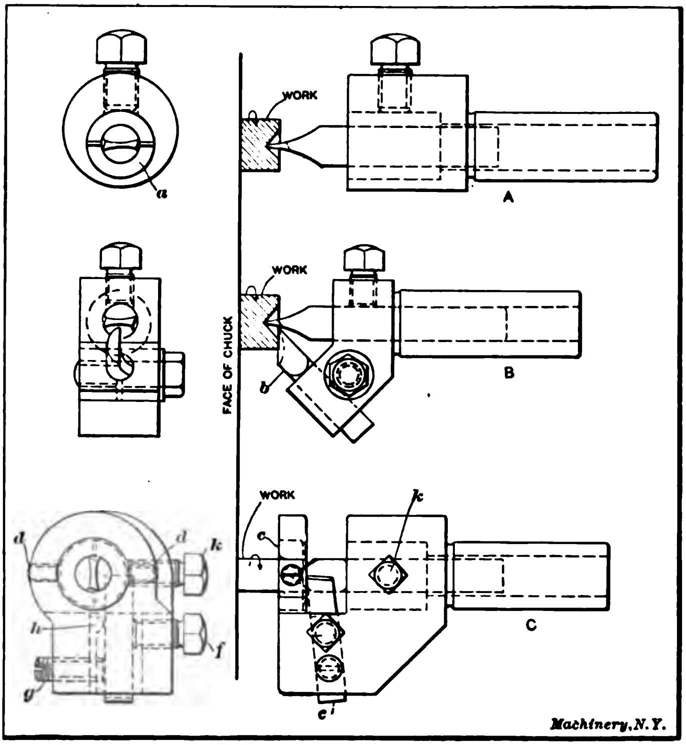


Fig. 4. Various Types of Centering Tool Holders

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.

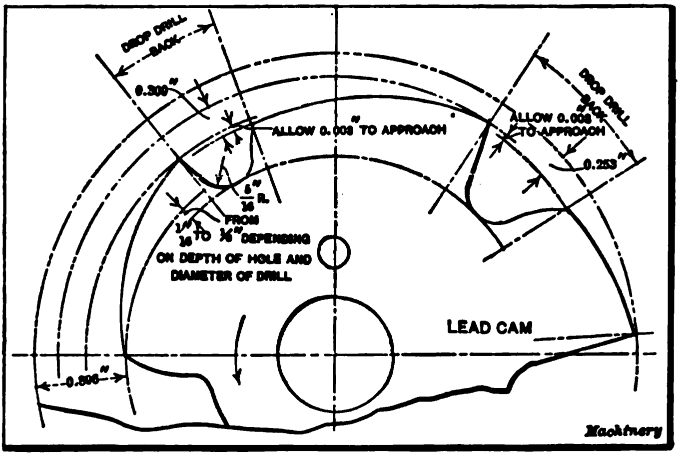


Fig. 5. Method of Laying out Cams for Deep-hole Drilling

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*,

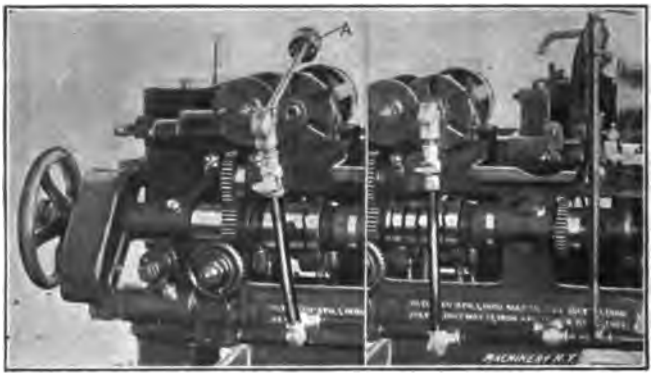


Fig. 6. No. 00 Brown & Sharpe Automatic Screw Machine equipped with Oil-pumping Attachment for Turret Tools

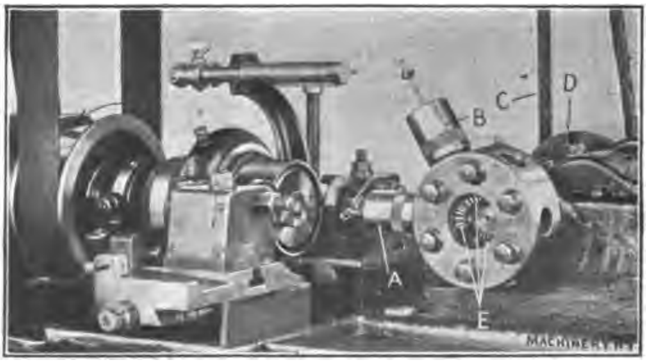


Fig. 7. No. 2 Brown & Sharpe Automatic Screw Machine equipped with Drilling Attachment

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

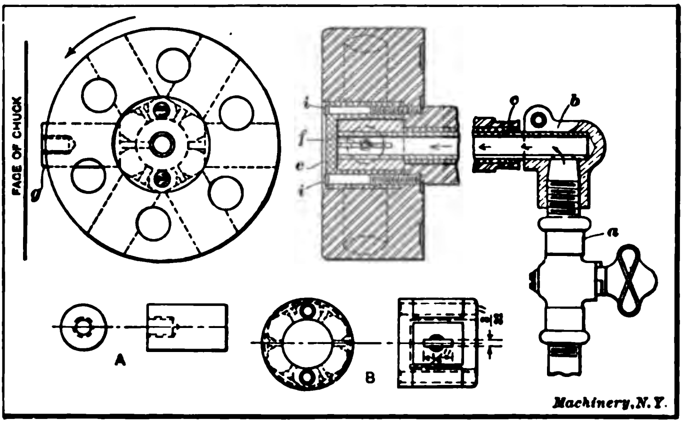


Fig. 8. Sectional View showing Construction of Oil-pumping Attachment for Turret Tools

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 = ⅜ inch,
diameter of drill = ⅛ 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 $= \frac{0.375}{0.0032} = 117$ revolutions.

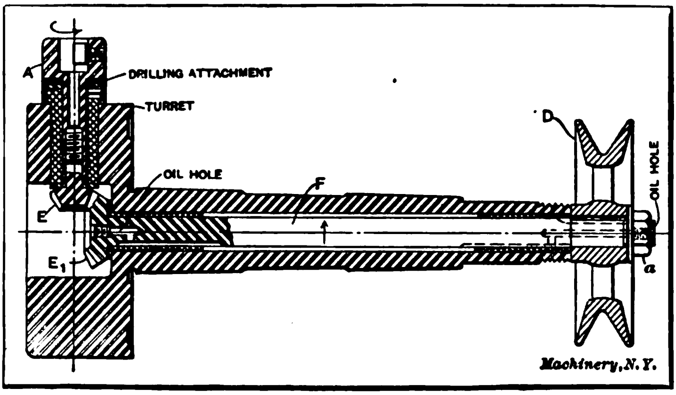


Fig. 9. Sectional View showing Construction of Drilling Attachment

The actual number of revolutions required for drilling when using the drilling attachment $= \frac{1200}{1200 + 900} \times 117 = 66.85$, 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 ⅜- or ½-inch twisted belt, the size of the

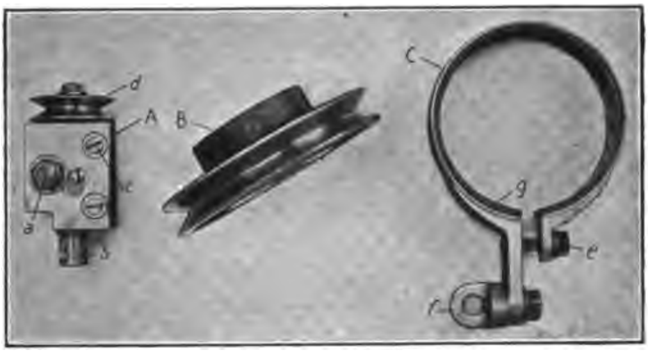


Fig. 10. Brown & Sharpe Cross-slide Drilling Attachment

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

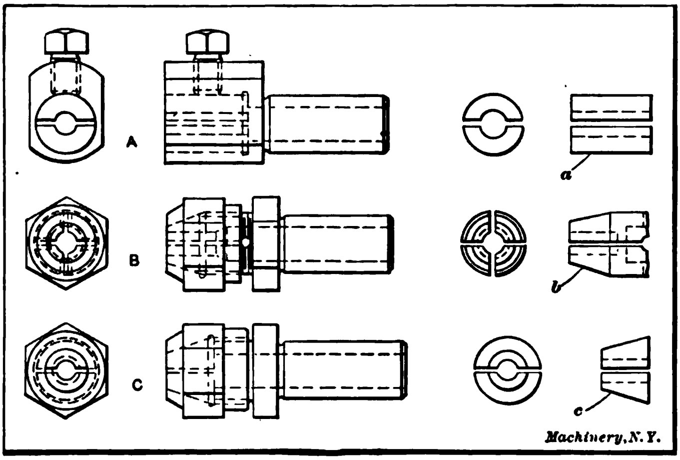


Fig. 11. Various Types of Drill Holders

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, Inches	Tool Steel, Feed per Revolution	Machine Steel, Feed per Revolution	Brass Steel, Feed per Revolution	Tool Steel, Feed per Revolution	Machine Steel, Feed per Revolution	Brass Steel, Feed per Revolution
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

...RATIONS

...g counterbores to ...d with any other ...at counterbores are ...they are to operate. ...or the unsuccessful ...be summed up as

...nough chip space and

... the work.
...of the teeth.
...relative to the center.
...erbore.
...es.

...s of what the tool will stand. ... automatic work where the ...n it plugs up with chips and ...t have more than three cutting ...ould be backed off eccentrically, ...and taper towards the back. The ...om 0.020 to 0.040 inch per foot. ... the center has an important bear... For deep counterboring, where the ...of the teat and the body of the coun... ...e should never be located ahead of ...ed a little below the center far better ...ule is only general, of course, as the ...ment governs the location of the cutting

...n of the Cutting Edges

...n a three-tooth counterbore with its cutting ...he center. Locating the cutting edge ahead ...ble when the counterbore is to be used as a ...counterboring brass, and it is not required to ...to a depth greater than its diameter, but it ...d for facing operations only. If the counter... ...anner and used on steel, the cutting teeth have ...chips against the surface of the work. Con... ...not properly lubricated, the work and counter... ...ood cause the chips to seize, thus producing poor ...a broken counterbore.

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 1/8-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

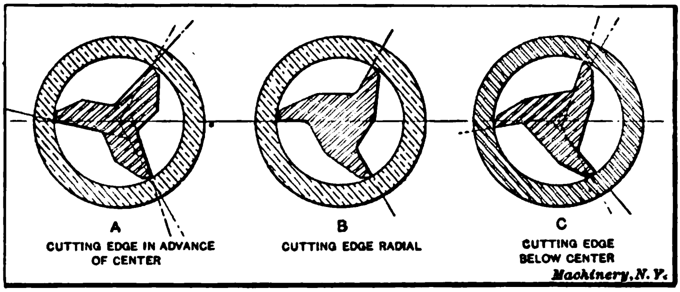


Fig. 12. Location of the Cutting Edges for Various Conditions

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,

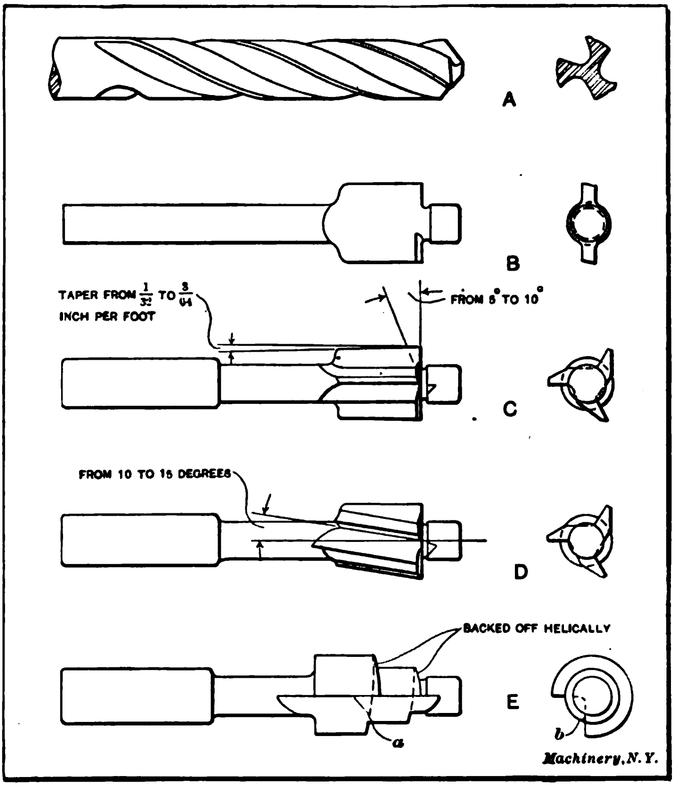


Fig. 13. Various Types of Counterbores

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

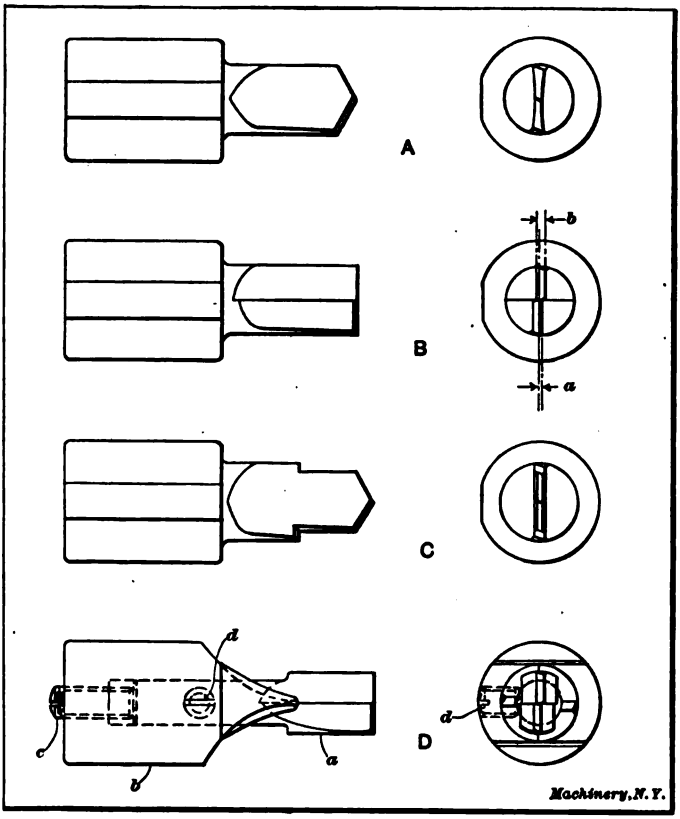


Fig. 14. Flat Drills and Combination Counterbores

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

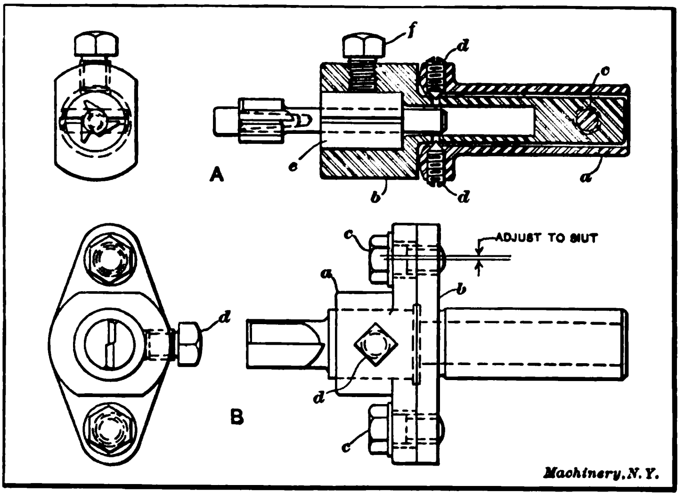


Fig. 15. Method of Holding Counterbores for Various Conditions

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

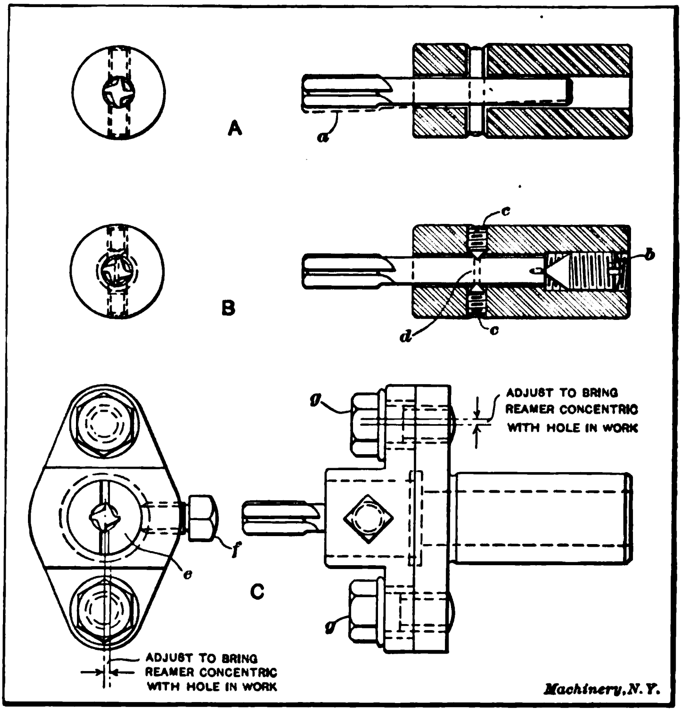


Fig. 16. Method of Holding Reamers for Various Conditions

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.

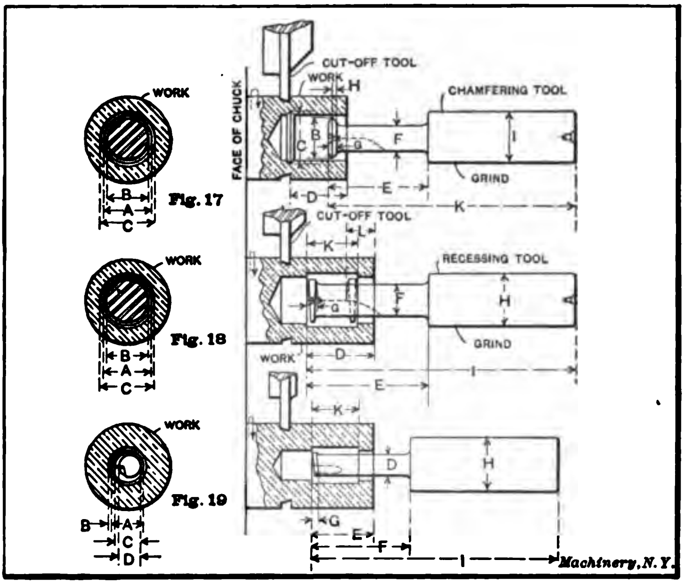
Recessing and Recessing Tools

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

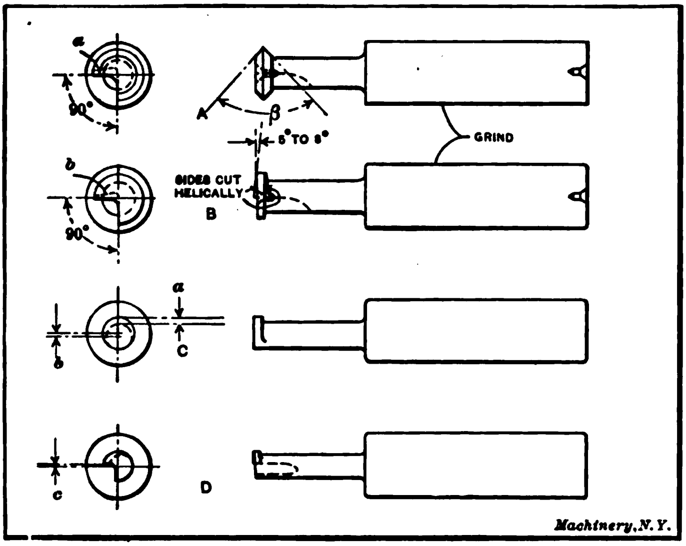


Fig. 20. Various Types of Recessing Tools

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 1/8 to 1/4 inch, I = 1/4 inch.
A = from 1/4 to 1/2 inch, I = 1/2 inch.
A = from 1/2 to 7/8 inch, I = 1 inch.

K = total length of tool, as follows:

When I = 1/4 inch, K = E + 7/8 inch.
I = 1/2 inch, K = E + 1 1/4 inch.
I = 1 inch, K = E + 1 1/2 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 1/8 to 1/4 inch, H = 1/4 inch.
A is from 1/4 to 1/2 inch, H = 1/2 inch.
A is from 1/2 to 7/8 inch, H = 1 inch.

I = total length of tool, as follows:

When H = 1/4 inch, I = E + 7/8 inch.
H = 1/2 inch, I = E + 1 1/4 inch.
H = 1 inch, I = E + 1 1/2 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

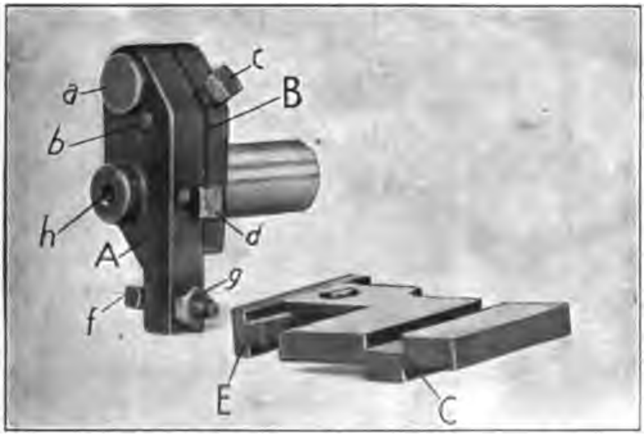


Fig. 21. B. & S. Swing Tool-holder and Rising Block for Operating it

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

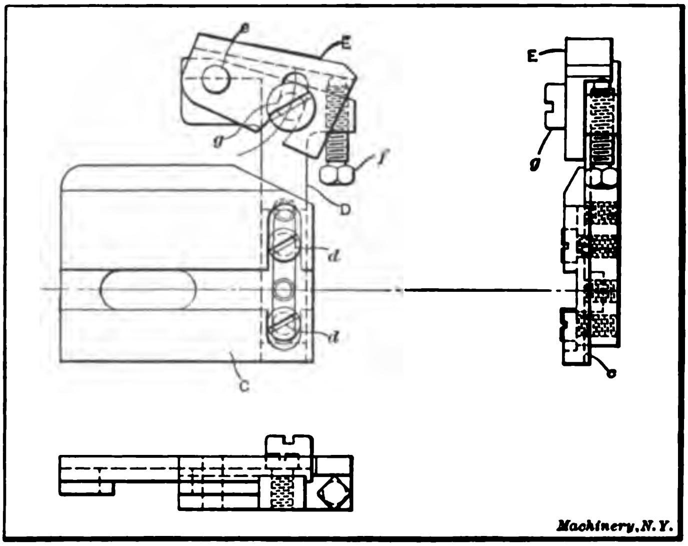


Fig. 22. Standard Rising Block used for Operating Swing Tools

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.

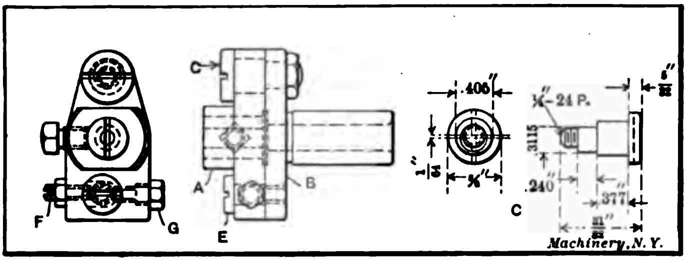


Fig. 23. Another Type of Swing or Recessing Tool Holder

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-

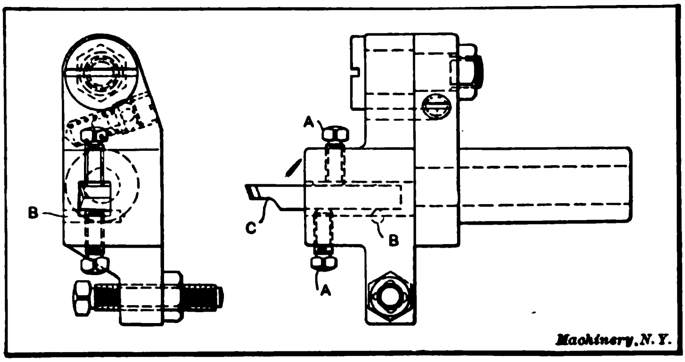


Fig. 24. Swing Tool used for Facing Operations

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.

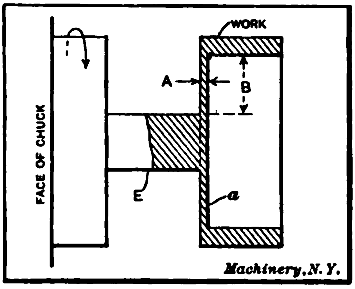


Fig. 25. Diagram giving Notation used in the Derivation of Feeds for Facing Operations

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 $A = 0.025$ inch, $C = \frac{0.250}{0.0250} = 10$, or, in other words, $B = 10$ 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

0.002-inch Chip			
Value of C	Brass Rod, Feed per Revolution	Machine Steel, Feed per Revolution	Tool Steel, Feed per Revolution
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	0.0022
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 $= \frac{E-C}{2}$,

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, 2¼ inches; A, 1⅛ inch;

then $R = \frac{0.040 \times 2\frac{1}{4}}{1\frac{1}{8}} = 0.080$ 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.

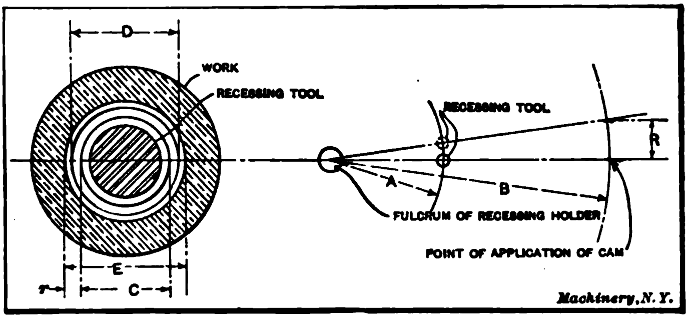


Fig. 26. Diagram for finding Rise on Cross-slide Cam for Recessing and Chamfering Operations

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

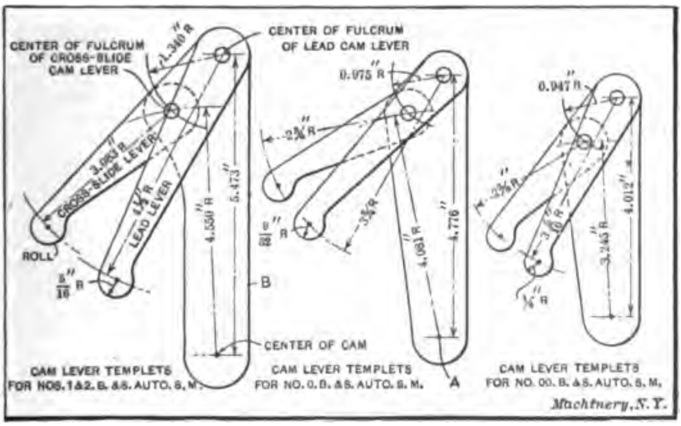


Fig. 27. Nos. 00, 0, 1 and 2, B. & S. Automatic Screw Machine Cam Lever Templets for finding the Starting and Finishing Points of the Lobes for the Cross-slide and Lead Cams

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

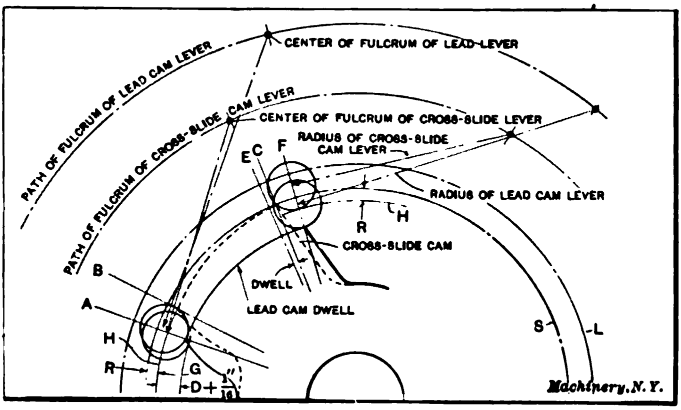


Fig. 28. Diagram for finding the Starting and Finishing Points of the Lobes of the Cross-slide and Lead Cams for Chamfering Operations

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

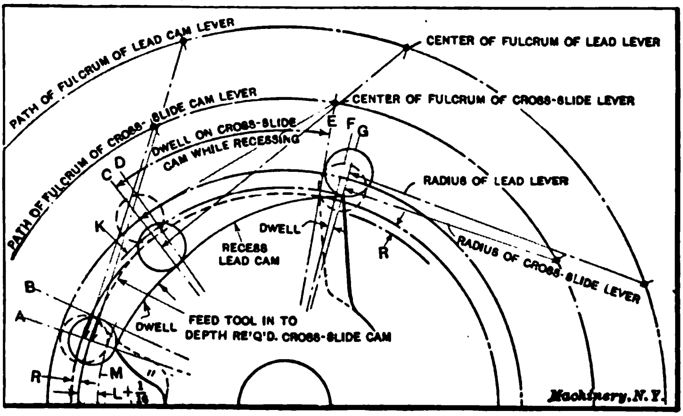


Fig. 29. Diagram for finding the Starting and Finishing Points on the Lobes of the Cross-slide and Lead Cams for Recessing Operations

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				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	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	3/8	0.0040	0.0025	0.0015
3/16	0.0030	0.0018	0.0015	7/16	0.0045	0.0030	0 0020
1/4	0.0040	0.0025	0.0020	1/2	0.0055	0.0040	0.0025
5/16	0.0080	0.0040	0.0040	9/16	0.0075	0.0050	0.0030
3/8	0.0120	0.0060	0.0050	5/8	0.0085	0.0060	0.0035
7/16	0.0160	0.0090	0.0060	11/16	0.0100	0.0065	0.0038
1/2	0.0200	0.0100	0.0070	3/4	0.0120	0.0070	0.0040
0.020-inch Chip				1/16-inch Chip			
1/4	0.0025	0.0015	0.0010	1/2	0.0030	0.0020	0.0010
5/16	0.0035	0.0020	0.0015	9/16	0.0040	0.0028	0.0015
3/8	0.0050	0.0030	0.0020	5/8	0.0050	0.0030	0.0020
7/16	0 0080	0.0050	0.0040	11/16	0.0060	0.0035	0 0023
1/2	0.0120	0.0070	0.0050	3/4	0.0075	0.0040	0.0025
9/16	0 0160	0.0090	0.0055	13/16	0.0080	0.0045	0.0028
5/8	0 0190	0.0100	0.0060	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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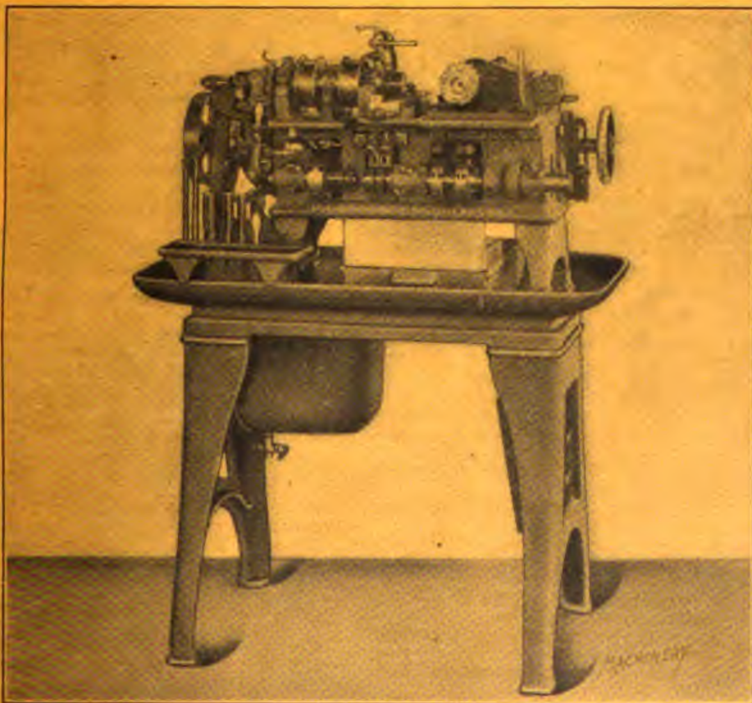
AUTOMATIC SCREW MACHINE PRACTICE

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

THREADING 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

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

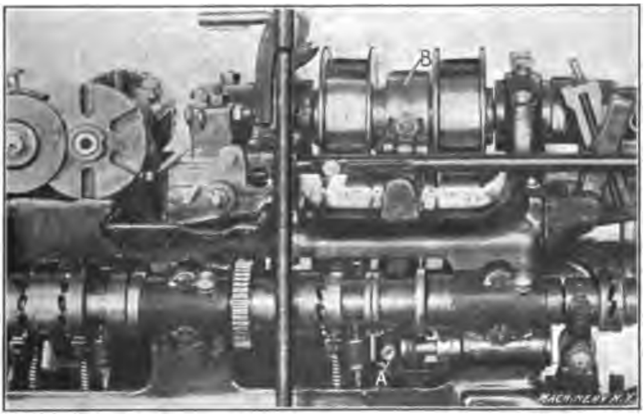

Fig. 1. Rear View of No. 00 Brown & Sharpe Automatic Screw Machine showing Reversing Mechanism

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

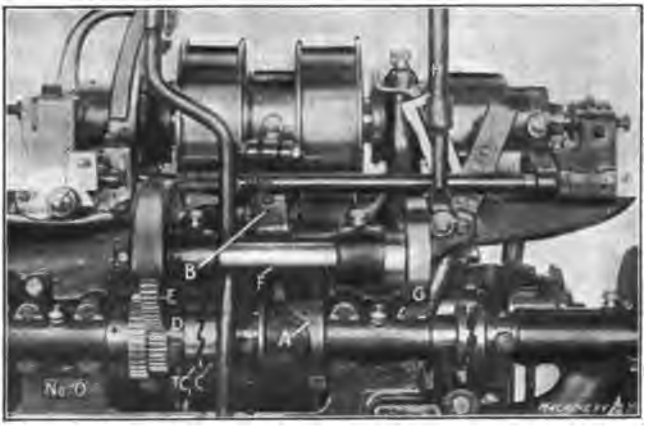

Fig. 2. Rear View of No. 0 Brown & Sharpe Automatic Screw Machine showing Reversing Mechanism and Belt Shifting Attachment

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-

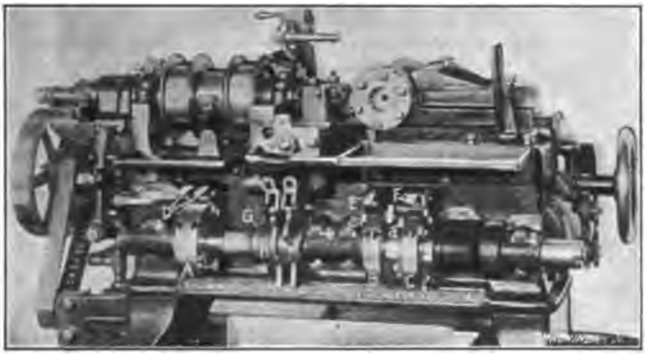

Fig. 3. Front View Showing Feeding, Reversing and Revolving Devices

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

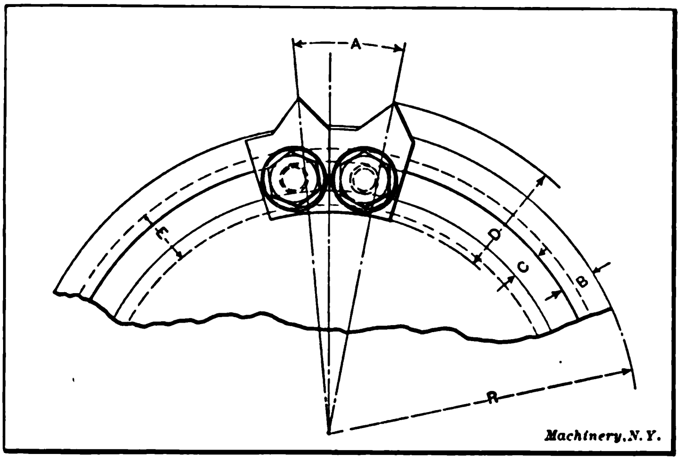

Fig. 4. Reversing Dogs in Position on Drum

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 $= \frac{1200 \times 20}{60} = 400$ 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°	$\frac{15}{64}$	$\frac{1}{4}$	$\frac{15}{16}$	$\frac{1}{2}$	2
0	17°	$\frac{5}{16}$	$\frac{1}{4}$	$1\frac{1}{32}$	$\frac{1}{2}$	$2\frac{3}{4}$
2	14°	$\frac{13}{32}$	$\frac{5}{16}$	$1\frac{1}{4}$	$\frac{3}{16}$	$3\frac{1}{4}$

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, $\frac{100 \times 14}{360} = 3.88$ hundredths. Therefore, additional cam surface would not be necessary in this case.

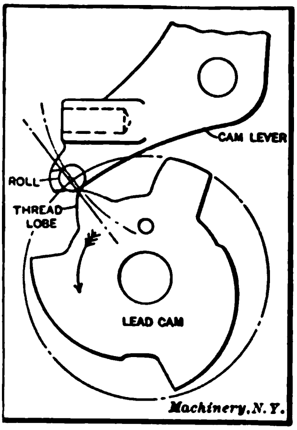

Fig. 5. Position of Roll on Thread Lobe when Spindle is reversed

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

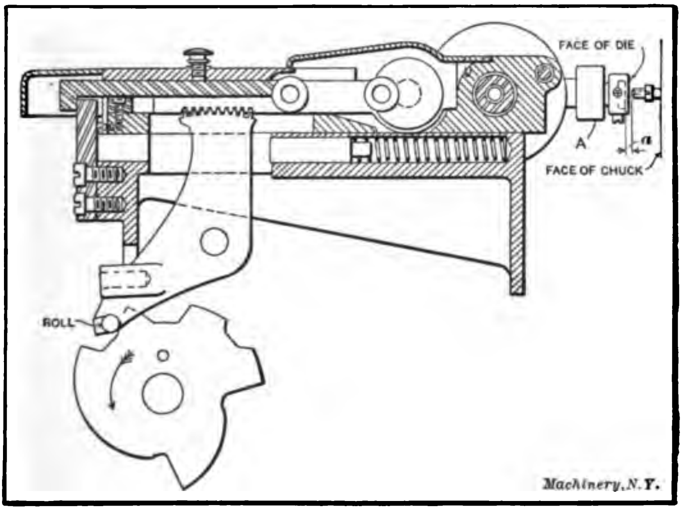

Fig. 6. Position of Roll on Thread Lobe when setting Die or Tap

actual number of revolutions required for threading can be found by the aid of the following formulas:

$$\begin{aligned} &\text{From 14 to 24 threads per inch, } R = Lp + 1.5 \\ &\text{From 28 to 48 threads per inch, } R = Lp + 3 \qquad (1) \\ &\text{From 56 to 80 threads per inch, } R = Lp + 4.5 \end{aligned}$$

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 number 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

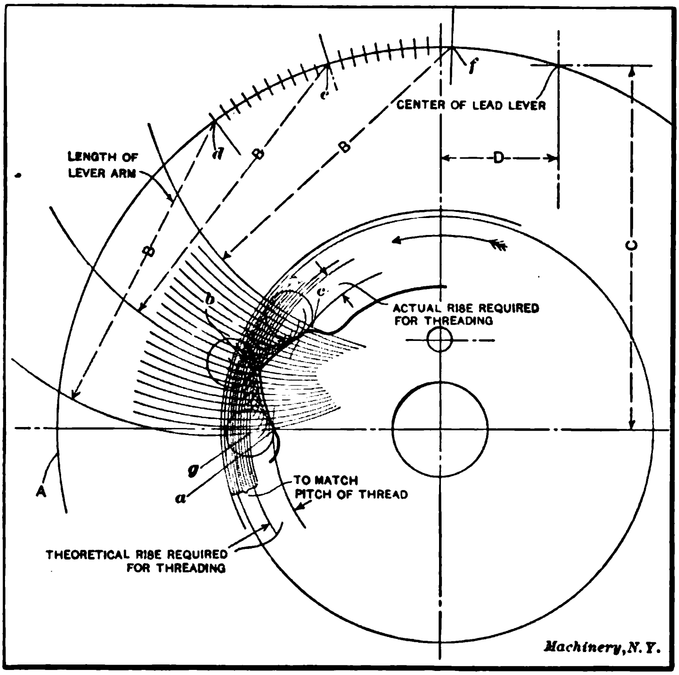

Fig. 7. Graphical Method of Constructing Thread Lobe

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	7.00	6.50	6.50	4.50	4.50	4.00	4.00	4.00	4.00					
	0.079	0.088	0.091	0.104	0.082	0.099	0.098	0.110	0.117	0.126					
1/16	9.50	9.00	8.50	8.00	6.00	5.50	5.50	5.00	5.00	5.00	3.00				
	0.107	0.113	0.120	0.129	0.110	0.121	0.134	0.138	0.147	0.157	0.106				
3/32	12.00	11.50	10.50	10.00	7.50	7.00	6.50	6.00	6.00	5.50	4.00	3.50			
	0.135	0.144	0.148	0.161	0.137	0.154	0.159	0.165	0.176	0.173	0.142	0.149			
1/8	14.50	13.50	12.50	11.50	9.00	8.00	7.00	7.00	7.00	6.50	4.50	4.00	3.50	3.50	
	0.163	0.169	0.176	0.185	0.165	0.176	0.171	0.193	0.205	0.204	0.159	0.170	0.165	0.186	
5/32	17.00	16.00	14.50	13.50	10.50	9.50	8.50	8.00	7.50	7.50	5.50	4.50	4.00	4.00	3.50
	0.191	0.200	0.204	0.217	0.192	0.209	0.208	0.220	0.220	0.236	0.195	0.191	0.189	0.212	0.212
3/16	19.50	18.00	16.50	15.00	12.00	10.50	10.00	9.00	8.50	8.50	6.00	5.50	5.00	4.50	4.00
	0.219	0.225	0.232	0.241	0.220	0.231	0.244	0.248	0.249	0.267	0.213	0.234	0.236	0.239	0.243
7/32	22.00	20.50	18.50	17.00	13.50	12.00	11.00	10.00	9.50	9.00	7.00	6.00	5.50	5.00	4.50
	0.248	0.256	0.260	0.273	0.247	0.264	0.269	0.275	0.279	0.283	0.248	0.255	0.260	0.266	0.273
1/4	24.50	23.50	20.50	18.50	15.00	13.00	12.00	11.00	10.50	10.00	7.50	6.50	6.00	5.50	5.00
	0.276	0.294	0.288	0.297	0.275	0.286	0.293	0.303	0.308	0.314	0.266	0.276	0.283	0.292	0.304
9/32	27.00	25.00	22.50	20.50	16.50	14.50	13.00	12.00	11.50	11.00	8.50	7.00	6.50	6.00	5.50
	0.304	0.313	0.316	0.329	0.302	0.319	0.318	0.330	0.337	0.346	0.301	0.298	0.307	0.319	0.334
5/16	29.50	27.00	24.50	22.00	18.00	15.50	14.50	13.00	12.50	12.00	9.00	8.00	7.00	6.50	6.00
	0.332	0.338	0.345	0.354	0.340	0.341	0.354	0.358	0.367	0.377	0.319	0.340	0.330	0.345	0.364
11/32	32.00	29.50	26.50	24.00	19.50	17.00	15.50	14.00	13.50	12.50	10.00	8.50	7.50	7.00	6.50
	0.360	0.369	0.373	0.386	0.357	0.374	0.379	0.385	0.396	0.393	0.354	0.361	0.354	0.372	0.395
3/8	34.50	31.50	28.50	25.50	21.00	18.00	16.50	15.00	14.50	13.50	10.50	9.00	8.50	7.50	7.00
	0.388	0.394	0.401	0.410	0.385	0.396	0.403	0.413	0.425	0.424	0.372	0.383	0.401	0.398	0.425
13/32	37.00	34.00	30.50	27.50	22.50	19.50	17.50	16.00	15.00	14.50	11.50	9.50	9.00	8.00	7.00
	0.416	0.425	0.429	0.442	0.412	0.429	0.428	0.440	0.440	0.456	0.407	0.404	0.425	0.425	0.425
7/16	39.50	36.00	32.50	29.00	24.00	20.50	19.00	17.00	16.00	15.50	12.00	10.50	9.50	8.50	7.50
	0.444	0.450	0.457	0.466	0.440	0.451	0.464	0.468	0.469	0.487	0.425	0.446	0.448	0.451	0.455
15/32	42.00	38.50	34.50	31.00	25.50	22.00	20.00	18.00	17.00	16.00	13.00	11.00	10.50	9.00	8.00
	0.473	0.481	0.484	0.498	0.477	0.484	0.489	0.495	0.499	0.503	0.460	0.468	0.496	0.478	0.486
1/2	44.50	40.50	36.50	32.50	27.00	23.00	21.00	19.00	18.00	17.00	13.50	11.50	10.50	9.50	8.50
	0.501	0.506	0.513	0.522	0.495	0.506	0.513	0.523	0.528	0.534	0.478	0.489	0.496	0.504	0.516
17/32	47.00	43.00	38.50	34.50	28.50	24.50	22.00	20.00	19.00	18.00	14.50	12.00	11.00	10.00	9.00
	0.529	0.538	0.541	0.554	0.522	0.539	0.538	0.550	0.557	0.566	0.514	0.510	0.519	0.531	0.546
9/16	49.50	45.00	40.50	36.00	30.00	25.50	23.50	21.00	20.00	19.00	15.00	13.00	11.50	10.50	9.50
	0.559	0.563	0.570	0.579	0.550	0.561	0.574	0.578	0.587	0.597	0.531	0.553	0.543	0.558	0.577
19/32	52.00	47.50	42.50	38.00	31.50	27.00	24.50	22.00	21.00	19.50	16.00	13.50	12.00	11.00	10.00
	0.585	0.594	0.598	0.611	0.577	0.594	0.599	0.605	0.616	0.613	0.567	0.574	0.566	0.584	0.607
5/8	54.50	49.50	44.50	39.50	33.00	28.00	25.50	23.00	22.00	20.50	16.50	14.00	13.00	11.50	10.50
	0.613	0.619	0.626	0.635	0.605	0.616	0.623	0.633	0.645	0.644	0.584	0.595	0.614	0.611	0.637
21/32	57.00	52.00	46.50	41.50	34.50	29.50	26.50	24.00	23.00	21.50	17.50	14.50	13.50	12.00	10.50
	0.641	0.650	0.654	0.667	0.622	0.649	0.648	0.660	0.675	0.676	0.620	0.616	0.637	0.637	0.637
11/16	59.50	54.00	48.50	43.00	36.00	30.50	28.00	25.00	23.50	22.50	18.00	15.50	14.00	12.50	11.00
	0.679	0.675	0.682	0.691	0.660	0.671	0.684	0.688	0.689	0.707	0.638	0.659	0.661	0.664	0.668
23/32	62.00	56.50	50.50	45.00	37.50	32.00	29.00	26.00	24.50	23.00	19.00	16.00	14.50	13.00	11.50
	0.698	0.706	0.710	0.723	0.677	0.704	0.709	0.715	0.719	0.723	0.673	0.680	0.684	0.690	0.698
3/4	64.50	58.50	52.50	46.50	39.00	33.00	30.00	27.00	25.50	24.00	19.50	16.50	15.00	13.50	12.00
	0.726	0.731	0.738	0.747	0.715	0.726	0.733	0.743	0.748	0.754	0.691	0.701	0.708	0.717	0.728

TABLE III. SPINDLE REVOLUTIONS AND CAM RISE FOR THREADING

Number of Threads per Inch

First Line: Revolutions of Spindle for Threading
Second Line: Rise on Cam for Threading

Length of Threaded Portion	80	72	64	56	48	40	36	32	30	28	24	20	18	16	14
25/32	67.00	61.00	54.50	48.50	40.50	34.50	31.00	28.00	26.50	25.00	20.50	17.00	15.50	14.00	12.50
	0.754	0.763	0.767	0.779	0.742	0.759	0.758	0.770	0.777	0.786	0.726	0.728	0.732	0.748	0.759
13/16	69.50	63.00	56.50	50.00	42.00	35.50	32.50	29.00	27.50	26.00	21.00	18.00	16.00	14.50	13.00
	0.782	0.788	0.795	0.804	0.770	0.781	0.794	0.798	0.807	0.817	0.744	0.765	0.755	0.770	0.789
27/32	72.00	65.50	58.50	52.00	43.50	37.00	33.50	30.00	28.50	26.50	22.00	18.50	16.50	15.00	13.50
	0.810	0.819	0.823	0.836	0.797	0.814	0.819	0.825	0.836	0.838	0.779	0.786	0.779	0.797	0.819
7/8	74.50	67.50	60.50	53.50	45.00	38.00	34.50	31.00	29.50	27.50	22.50	19.00	17.50	15.50	14.00
	0.838	0.844	0.851	0.860	0.825	0.836	0.843	0.853	0.865	0.864	0.797	0.808	0.826	0.823	0.850
29/32	77.00	70.00	62.50	55.50	46.50	39.50	35.50	32.00	30.00	28.50	23.50	19.50	18.00	16.00	14.00
	0.866	0.875	0.879	0.892	0.842	0.869	0.868	0.880	0.880	0.895	0.832	0.829	0.850	0.850	0.850
15/16	79.50	72.00	64.50	57.00	48.00	40.50	37.00	33.00	31.00	29.50	24.00	20.50	18.50	16.50	14.50
	0.894	0.900	0.907	0.916	0.880	0.891	0.904	0.908	0.909	0.927	0.850	0.871	0.873	0.876	0.880
31/32	82.00	74.50	66.50	59.00	49.50	42.00	38.00	34.00	32.00	30.00	25.00	21.00	19.00	17.00	15.00
	0.923	0.931	0.935	0.948	0.907	0.924	0.929	0.935	0.939	0.948	0.885	0.893	0.897	0.903	0.911
1	84.50	76.50	68.50	60.50	51.00	43.00	39.00	35.00	33.00	31.00	25.50	21.50	19.50	17.50	15.50
	0.951	0.956	0.963	0.972	0.918	0.946	0.953	0.963	0.968	0.974	0.903	0.914	0.920	0.929	0.941
1 1/16	89.50	81.00	72.50	64.00	54.00	45.50	41.50	37.00	35.00	32.00	27.00	23.00	20.50	18.50	16.50
	1.007	1.013	1.019	1.028	0.990	1.001	1.013	1.018	1.026	1.005	0.956	0.978	0.968	0.982	1.002
1 1/8	94.50	85.50	76.50	67.50	57.00	48.00	43.50	39.00	37.00	34.50	28.50	24.00	22.00	19.50	17.50
	1.063	1.069	1.076	1.084	1.045	1.056	1.061	1.073	1.084	1.088	1.009	1.020	1.038	1.035	1.062
1 3/16	99.50	90.00	80.50	71.00	60.00	50.50	46.00	41.00	38.50	36.50	30.00	25.50	23.00	20.50	18.00
	1.119	1.125	1.126	1.141	1.100	1.111	1.122	1.128	1.128	1.146	1.062	1.084	1.086	1.089	1.098
1 1/4	104.5	94.50	84.50	74.50	63.00	53.00	48.00	43.00	40.50	38.00	31.50	26.50	24.00	21.50	19.00
	1.176	1.181	1.188	1.197	1.155	1.166	1.171	1.183	1.187	1.198	1.115	1.126	1.133	1.142	1.153
1 5/16		99.00	88.50	78.00	66.00	55.50	50.50	45.00	42.50	40.00	33.00	28.00	25.00	22.50	20.00
		1.238	1.244	1.253	1.210	1.221	1.232	1.238	1.245	1.256	1.168	1.190	1.180	1.195	1.214
1 3/8		103.5	92.50	81.50	69.00	58.00	52.50	47.00	44.50	41.50	34.50	29.00	26.50	23.50	21.00
		1.294	1.301	1.310	1.265	1.276	1.281	1.293	1.304	1.308	1.211	1.233	1.251	1.248	1.275
1 7/16			96.50	85.00	72.00	60.50	55.00	49.00	46.00	43.50	36.00	30.50	27.50	24.50	21.50
			1.357	1.366	1.320	1.331	1.342	1.348	1.348	1.366	1.274	1.296	1.298	1.301	1.305
1 1/2			100.5	88.50	75.00	63.00	57.00	51.00	48.00	45.00	37.50	31.50	28.50	25.50	22.50
			1.413	1.422	1.375	1.386	1.391	1.403	1.406	1.413	1.328	1.339	1.345	1.354	1.366
1 9/16			104.5	92.00	78.00	65.50	59.50	53.00	50.00	47.00	39.00	33.00	29.50	26.50	23.50
			1.469	1.478	1.430	1.441	1.452	1.458	1.465	1.476	1.381	1.403	1.392	1.407	1.426
1 5/8				95.50	81.00	68.00	61.50	55.00	52.00	48.50	40.50	34.00	31.00	27.50	24.50
				1.535	1.485	1.496	1.501	1.513	1.524	1.523	1.434	1.445	1.463	1.460	1.487
1 11/16				99.00	84.00	70.50	64.00	57.00	53.50	50.50	42.00	35.50	32.00	28.50	25.00
				1.591	1.540	1.551	1.562	1.568	1.568	1.586	1.487	1.509	1.510	1.513	1.518
1 3/4				102.5	87.00	73.00	66.00	59.00	55.50	52.00	43.50	36.50	33.00	29.50	26.00
				1.647	1.595	1.606	1.610	1.623	1.626	1.638	1.540	1.551	1.558	1.566	1.578
1 13/16				106.0	90.00	75.50	68.50	61.00	57.50	54.00	45.00	38.00	34.00	30.50	27.00
				1.703	1.650	1.661	1.671	1.678	1.685	1.696	1.593	1.615	1.605	1.620	1.629
1 7/8					93.00	78.00	70.50	63.00	59.50	55.50	46.50	39.00	35.50	31.50	28.00
					1.705	1.716	1.720	1.733	1.743	1.743	1.646	1.658	1.676	1.678	1.700
1 15/16					96.00	80.50	73.00	65.00	61.00	57.50	48.00	40.50	36.50	32.50	28.50
					1.760	1.771	1.781	1.788	1.787	1.806	1.700	1.721	1.728	1.726	1.730
2					99.00	83.00	75.00	67.00	63.00	59.00	49.50	41.50	37.50	33.50	29.50
					1.815	1.826	1.830	1.843	1.846	1.853	1.752	1.764	1.770	1.779	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 3/8 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.

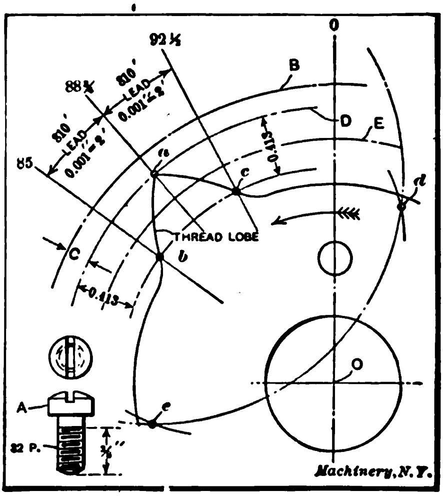

Fig. 8. Improved Method of Constructing Thread Lobe

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 ⅜-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.

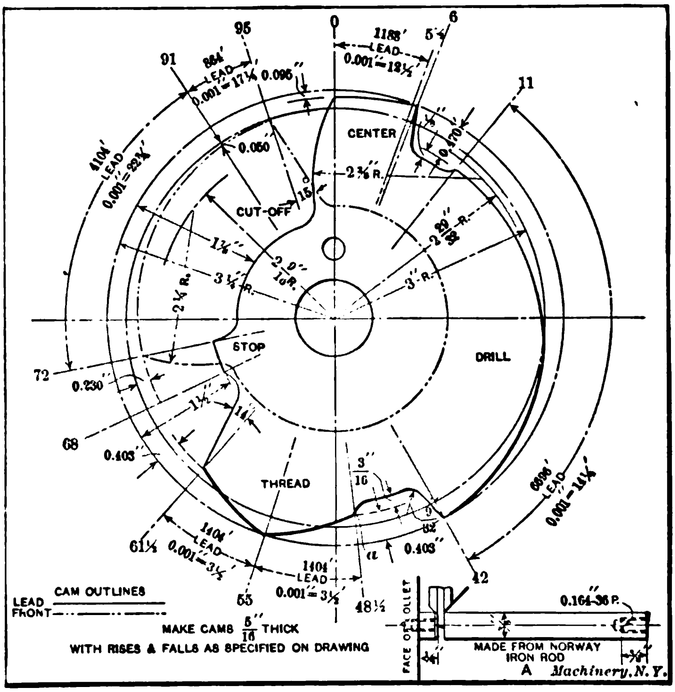

Fig. 10. Example of Design of Thread Lobe when using Belt Shifting Attachment

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

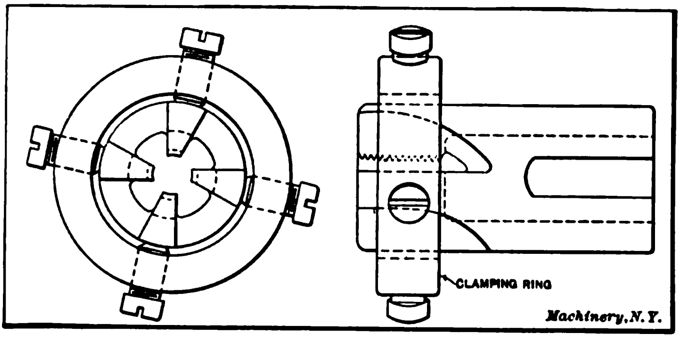

Fig. 11. Spring Screw Threading Die and Adjusting Ring

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

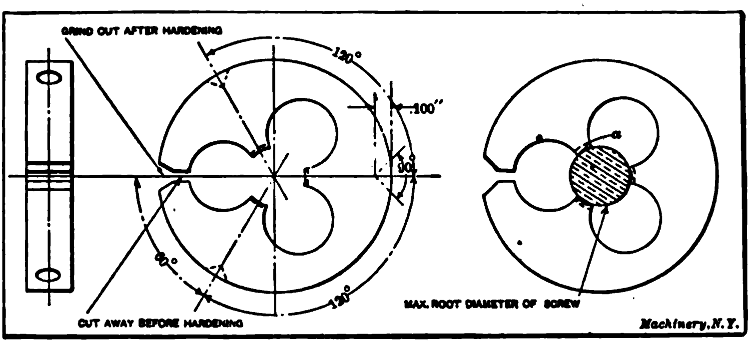

Fig. 13. General Dimensions and Design of Approved Type of Adjustable Round Split Button Die

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	0.1218	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	1¼
0.073 — 72	0.0765	0.0755	0.0660	0.0655	0.0580	0.0560	47	½	1⅜
0.086 — 64	0.0898	0.0888	0.0780	0.0775	0.0689	0.0668	42	9/16	1⅜
0.099 — 56	0.1033	0.1021	0.0897	0.0892	0.0793	0.0770	36	9/16	1½
0.112 — 48	0.1168	0.1155	0.1010	0.1004	0.0888	0.0862	31	⅝	1½
0.125 — 44	0.1301	0.1288	0.1129	0.1122	0.0995	0.0968	29	⅝	1½
0.138 — 40	0.1435	0.1421	0.1246	0.1239	0.1097	0.1069	26	⅝	1½
0.151 — 36	0.1569	0.1555	0.1359	0.1352	0.1193	0.1164	21	11/16	1½
0.164 — 36	0.1699	0.1685	0.1489	0.1482	0.1323	0.1294	17	11/16	1½
0.177 — 32	0.1835	0.1819	0.1598	0.1590	0.1411	0.1380	12	¾	1⅝
0.190 — 30	0.1968	0.1952	0.1716	0.1708	0.1515	0.1483	8	¾	1⅝
0.216 — 28	0.2232	0.2215	0.1961	0.1953	0.1745	0.1712	¼	1	2½
0.242 — 24	0.2500	0.2483	0.2184	0.2176	0.1931	0.1896	9/32	1	2½
0.268 — 22	0.2765	0.2747	0.2421	0.2412	0.2144	0.2108	9/32	1	2½
0.294 — 20	0.3031	0.3013	0.2653	0.2643	0.2346	0.2309	5/16	1	2½
0.320 — 20	0.3291	0.3273	0.2913	0.2903	0.2606	0.2569	11/32	1	2¾
0.346 — 18	0.3559	0.3539	0.3138	0.3128	0.2796	0.2758	⅜	1	2¾
0.372 — 16	0.3828	0.3808	0.3354	0.3344	0.2968	0.2928	13/32	1	2¾
0.398 — 16	0.4088	0.4068	0.3614	0.3604	0.3228	0.3188	7/16	1	2¾
0.424 — 14	0.4359	0.4338	0.3818	0.3807	0.3374	0.3333	15/32	1	2¾
0.450 — 14	0.4619	0.4598	0.4078	0.4067	0.3634	0.3593	½	1	2¾

TABLE IX. MACHINE TAPS FOR A. S. M. E. SPECIAL SIZES

Size of Screw and Number of Threads Per Inch	Manufacturing Limits: External Diameter, Maximum	External Diameter, Minimum	Pitch Diameter, Maximum	Pitch Diameter, Minimum	Root Diameter, Maximum	Root Diameter, Minimum	Diameter of Shank, Stubbs' Wire Gage or Inches	Length of Threaded Portion	Length Overall
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

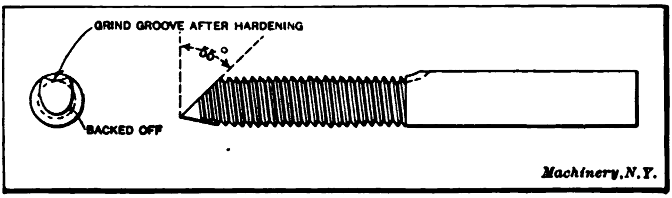

Fig. 15. A Tap Suitable for Norway Iron and Machine Steel

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

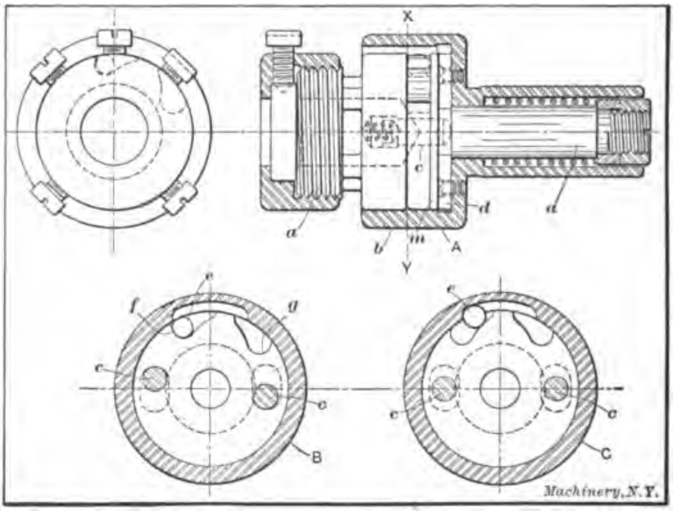

Fig. 17. Illustration showing Operating Parts of Releasing Button Die Holder

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

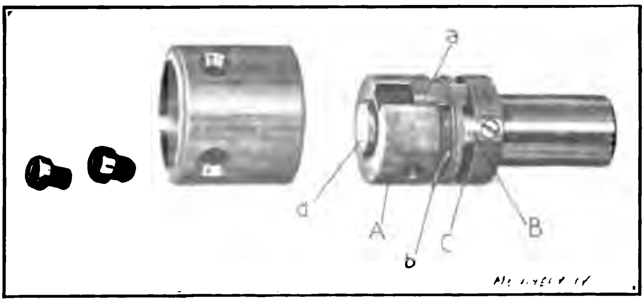

Fig. 18. Releasing Tap Holder

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:

$$D = d_2 - \frac{d_6}{8} \qquad (1)$$

in which

D = diameter of the blank,
d_2 = pitch diameter of the screw,
d_6 = depth of U. S. standard thread. (See *A* Fig. 20.)

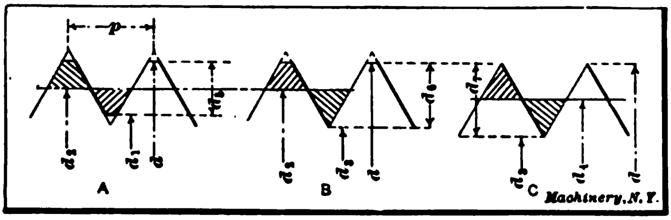

Fig. 20. Notation used in Calculating Diameters of Thread Rolls

The depth of the thread d_6 can be found by the following formula:

$$d_6 = \tfrac{3}{4} \times p \times \cos 30 \text{ deg.} = 0.6495\,p \qquad (2)$$

where p = the pitch of the thread or $\dfrac{1}{\text{number of threads per inch}}$

The pitch diameter is found by the formula:

$$d_2 = d - d_6 \qquad (3)$$

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

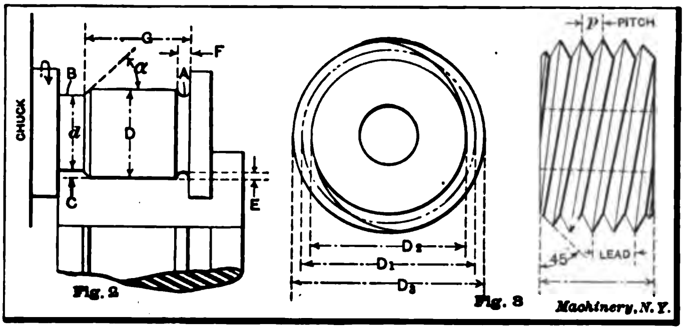

Fig. 21. Preparing a Piece with a Circular Form Tool **Fig. 22. Thread Roll with a Double Thread —Note Beveled Edges**

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,

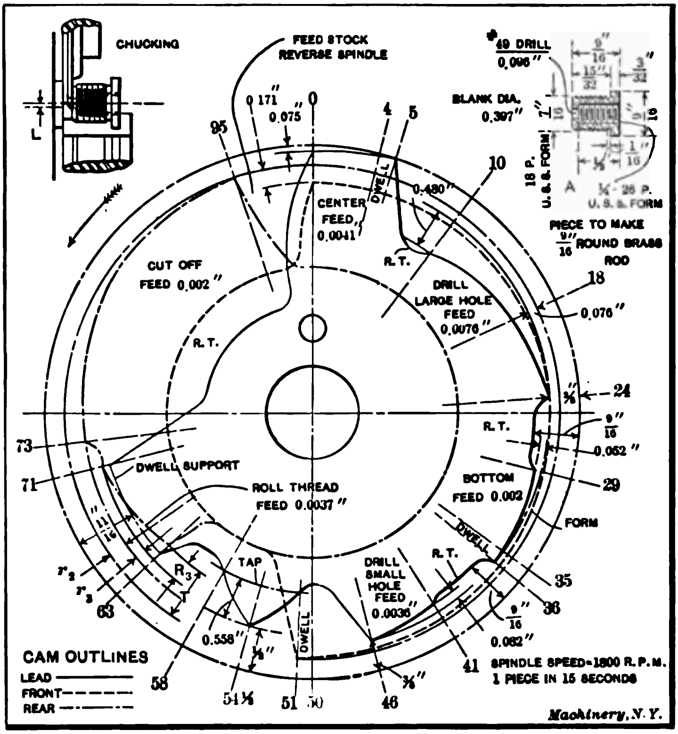

Fig. 23. Lay-out of a Set of Cams for Performing a Thread-rolling Operation

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.

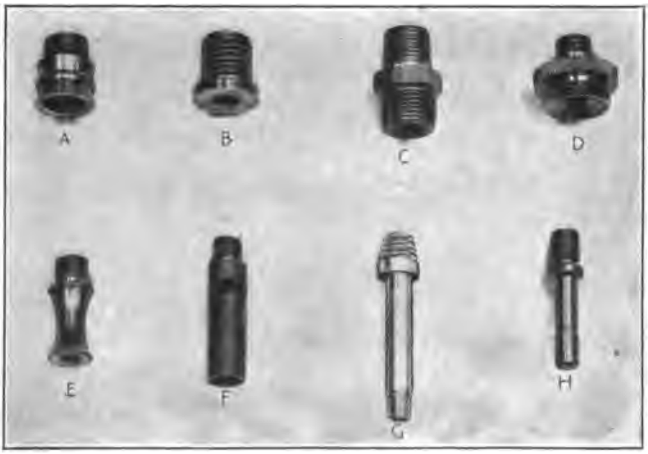

Fig. 24. Samples of Pieces having Rolled Threads

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.

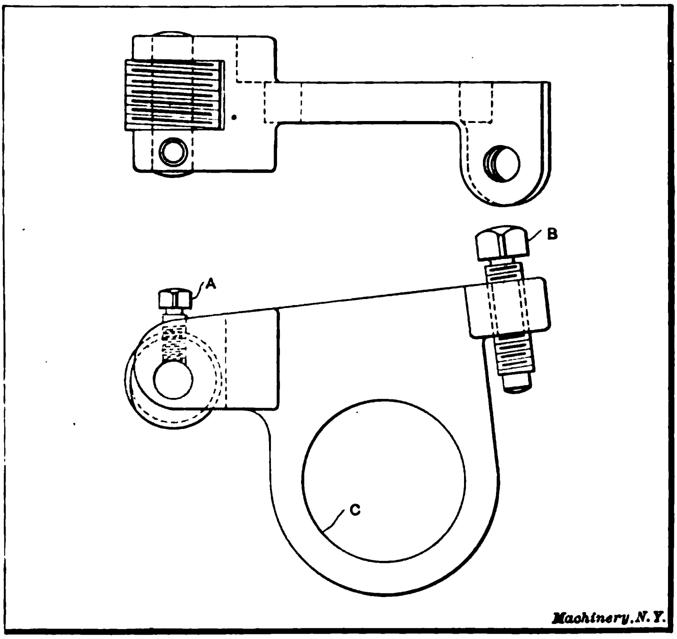

Fig. 25. Top Cross-slide Roll-holder

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

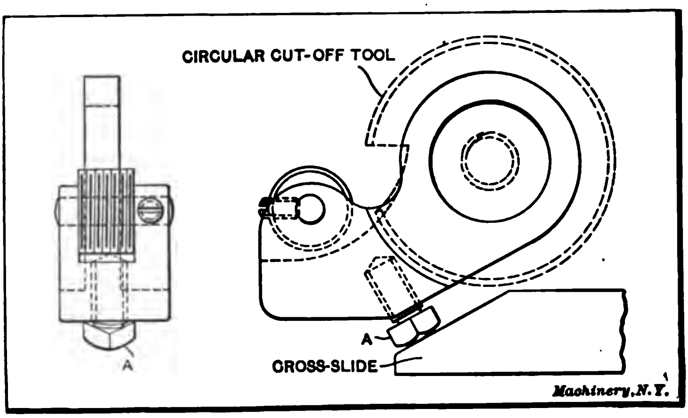

Fig. 26. Holder used when the Roll is passed under the Work

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

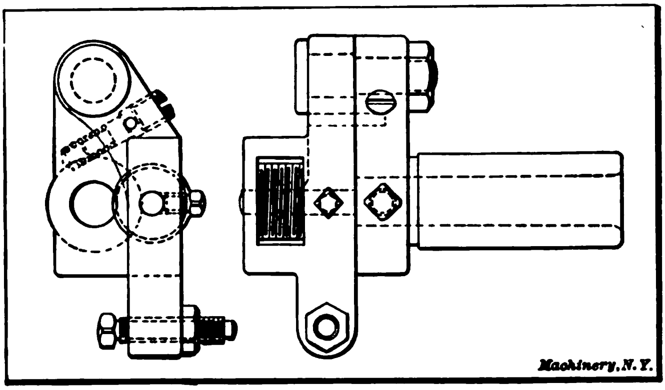

Fig. 27. Swing Holder for Holding a Thread Roll

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

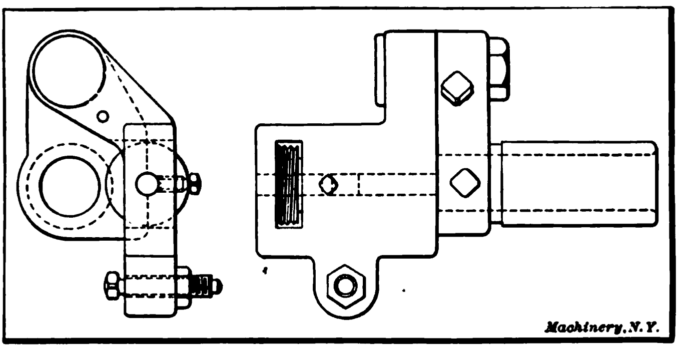

Fig. 28. Another Swing Roll-holder

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

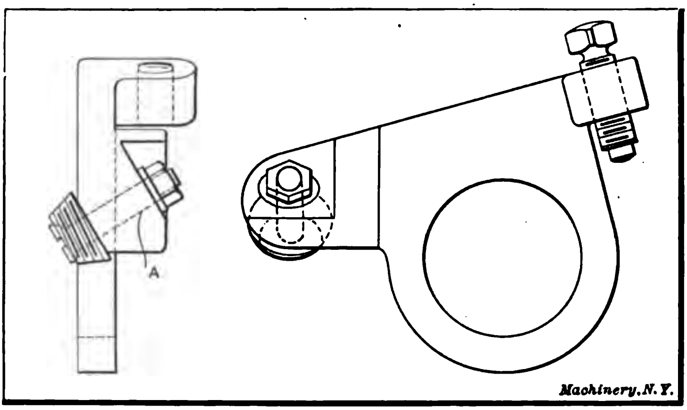

Fig. 29. Cross-slide Holder for applying a Thread Roll to a Beveled Piece

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_2 = 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,

$$A = R + R_1 \quad (11)$$

$$B = R + R_1 - d \quad (12)$$

$$C = \sqrt{A^2 - B^2} \quad (13)$$

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_2 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.

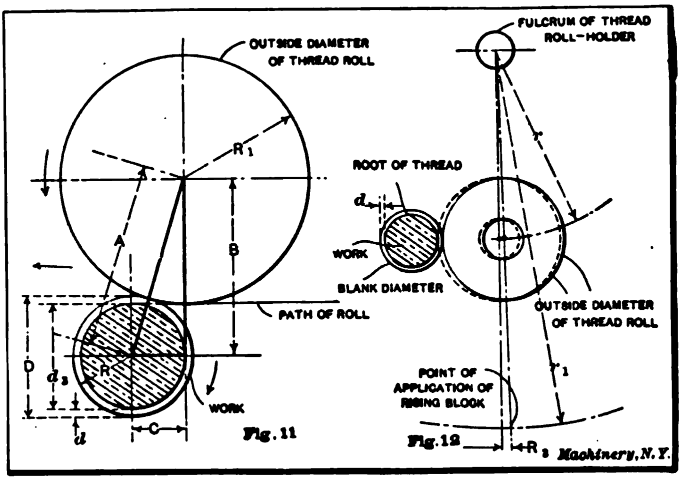

Fig. 30. Diagram used in Calculating the Rise on the Cam for Thread Rolling when a Cross-slide Holder is used

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_2 = 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_3 = 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,

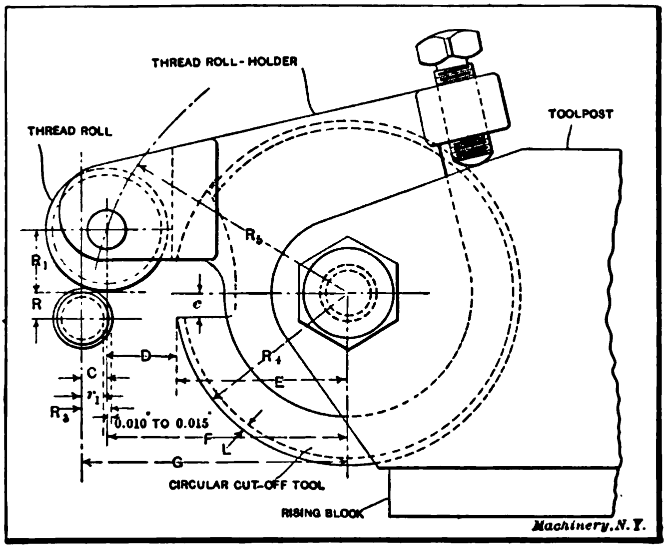

Fig. 32. Diagram used in Finding the Total Rise on the Cam for Thread Rolling and Cutting-off

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_2 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																
1/8	0.0050	0.0045	0.0040	0.0035	0.0030	0.0025	0.0020	0.0015	0.0010	0.0005	......	......	......	......	......	......	......
3/16	0.0055	0.0050	0.0045	0.0040	0.0035	0.0030	0.0025	0.0020	0.0015	0.0010	0.0005	......	......	......	......	......	......
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	......	......	......	......
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	......	......
3/8	0.0070	0.0065	0.0060	0.0055	0.0050	0.0045	0.0040	0.0035	0.0030	0.0025	0.0020	0.0015	0.0015	0.0010	0.0010	0.0005	0.0005
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
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
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
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
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																
1/8	0.0030	0.0025	0.0020	0.0015	0.0010	0.0005	......	......	......	......	......	......	......	......	......	......	......
3/16	0.0033	0.0028	0.0025	0.0020	0.0015	0.0008	0.0005	......	......	......	......	......	......	......	......	......	......
1/4	0.0036	0.0030	0.0030	0.0025	0.0020	0.0010	0.0010	0.0005	0.0005	0.0005	0.0005	......	......	......	......	......	......
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	......	......	......	......	......
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	......	......
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	......	......
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
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
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	0.0018
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,

$$R_3 = \frac{d_1 \times r_1}{r} \qquad (16)$$

For example, let $d_1 = 0.030$ inch, $r = 1\frac{1}{8}$ inch, and $r_1 = 2\frac{1}{4}$ inches.

Then,

$$R_3 = \frac{0.030 \times 2\frac{1}{4}}{1\frac{1}{8}} = 0.060 \text{ inch.}$$

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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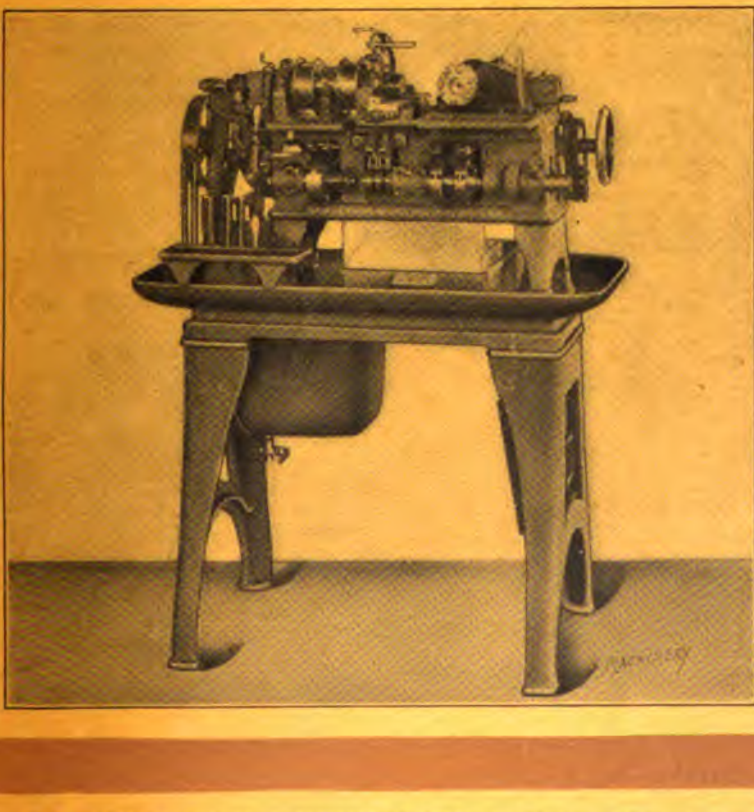
AUTOMATIC SCREW MACHINE PRACTICE

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-

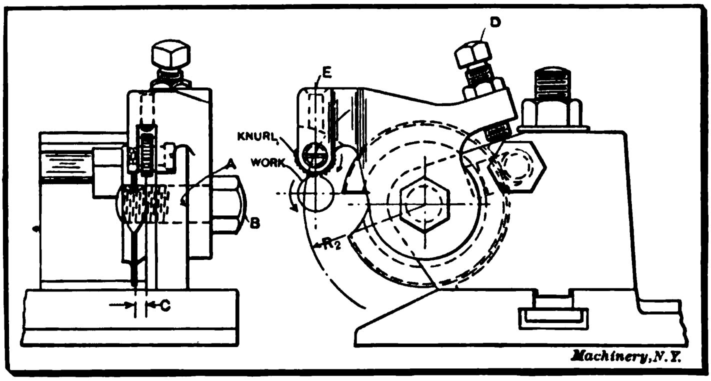
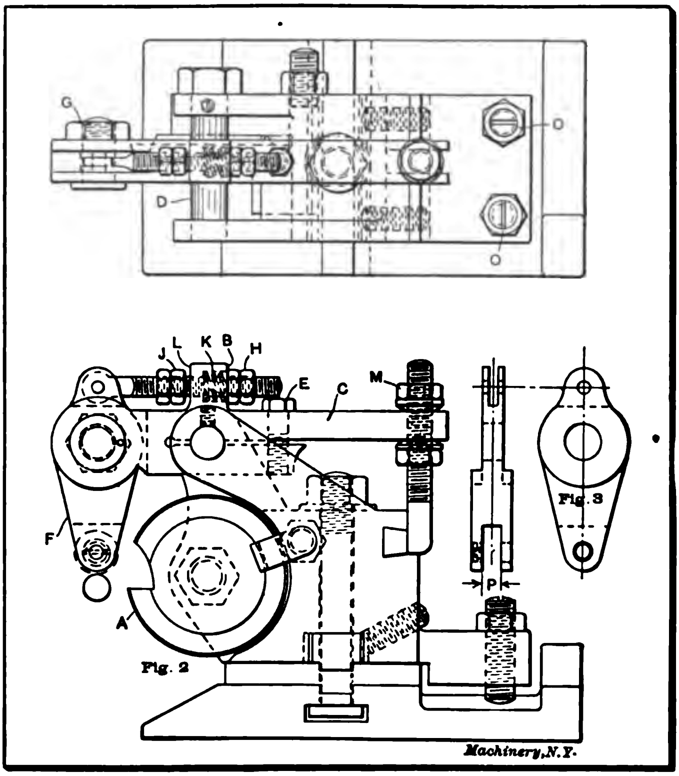


Fig. 1. Rear Cross-slide Knurl-holder

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.

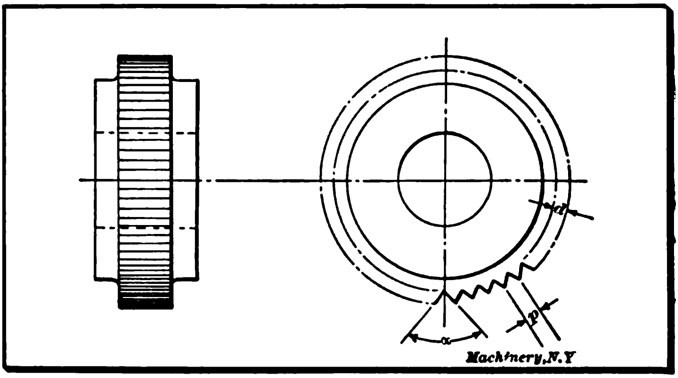


Fig. 4. Straight Knurl

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

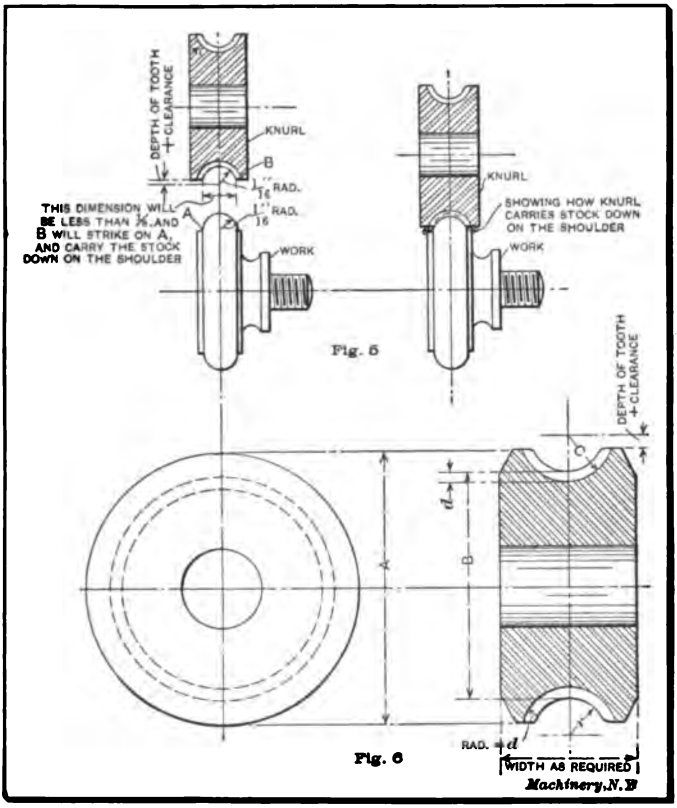
P = number of teeth in one inch of circumference
p = circular pitch
a = included angle of tooth
d = depth of tooth

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	0.0099	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, $r = R + \frac{1}{2} d$,
$C = \pm r + d$,
$A = B + 2r - 3d + 0.010$ 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:

$$p = \frac{1}{P} = \frac{1}{32} = 0.03125 \text{ inch,}$$

$$d = 0.0156 \text{ inch (see Table I),}$$

$$r = \frac{1}{16} + \frac{0.0156}{2} = 0.0703 \text{ inch,}$$

$$C = 0.0703 + 0.0156 = 0.0859 \text{ inch,}$$

$$A = 0.5561 + 0.1406 - 0.0468 - 0.010 = 0.6399 \text{ inch.}$$

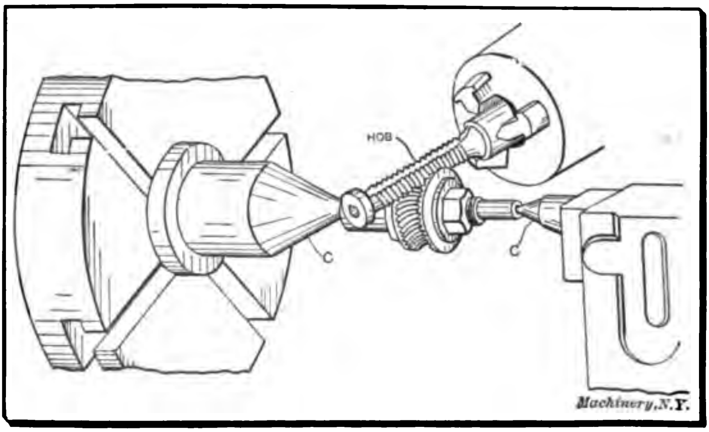


Fig. 7. Cutting a Concave Knurl by a Hob in the Milling Machine

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.

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.

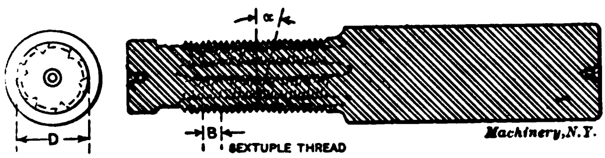


Fig. 8

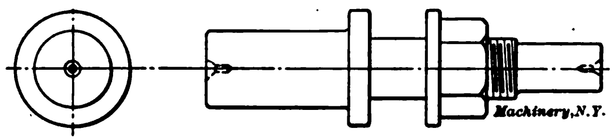


Fig. 9

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.

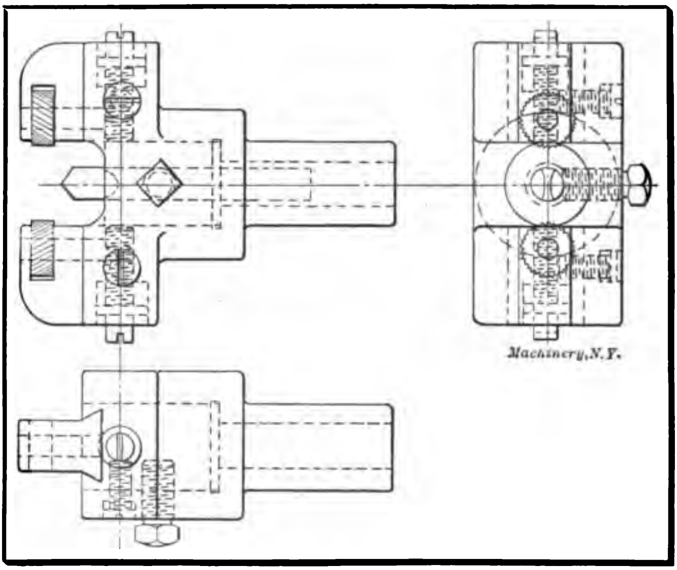


Fig. 10. Turret Knurl-holder for Brown & Sharpe Automatic Screw Machines

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

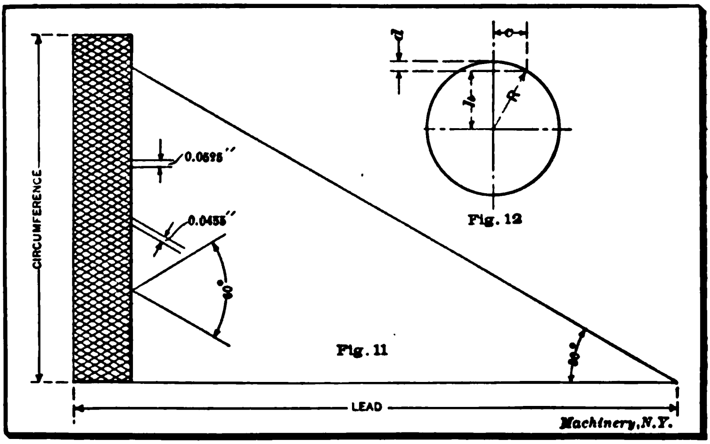


Fig. 11. Diagram for Finding Circular Pitch and Lead of Spiral Knurls
Fig. 12. Diagram for Calculations Relating to the Feeds of Knurls

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 $c = \sqrt{R^2 - (R - d)^2}$.

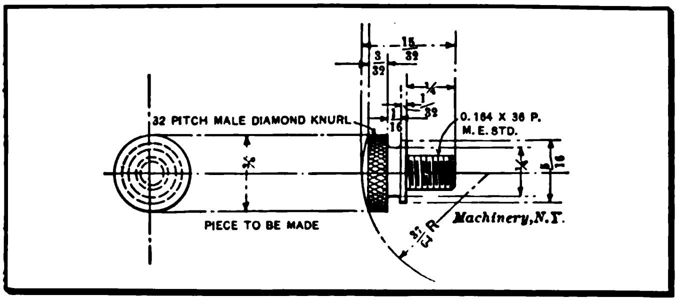


Fig. 13. Thumb-screw to be Knurled

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	0.0113	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.

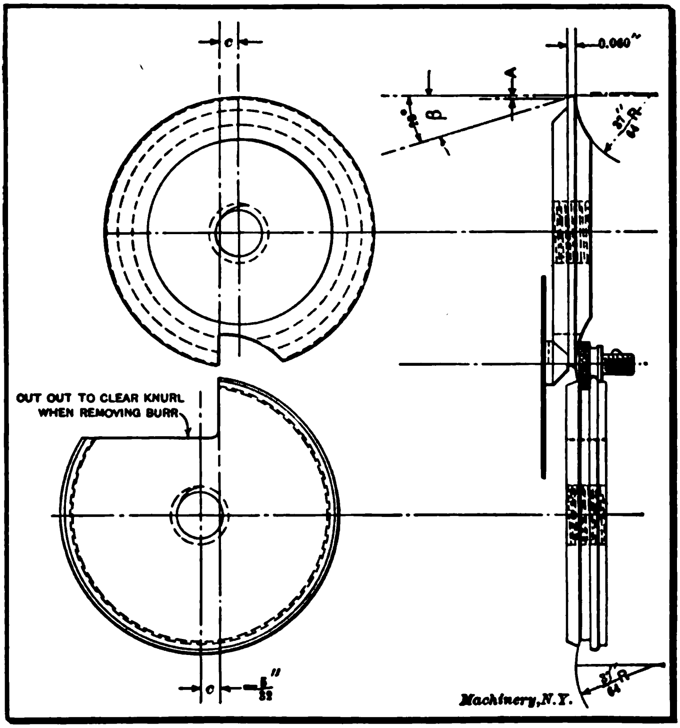


Fig. 14. Circular Forming and Cut-off Tools for Making Thumb-screw shown in Fig. 13

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).

$$F = X - (S + E);\ T = N + F + C,$$

For example, let it be required to design a set of cams to make the thumb-screw shown in Fig. 13, the material being ⅜-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

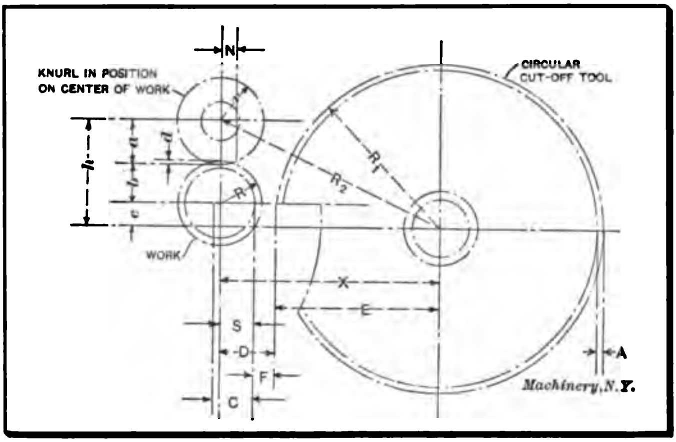


Fig. 15. Diagram for Finding Total Rise of Cam for Knurling Operation

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 opera-

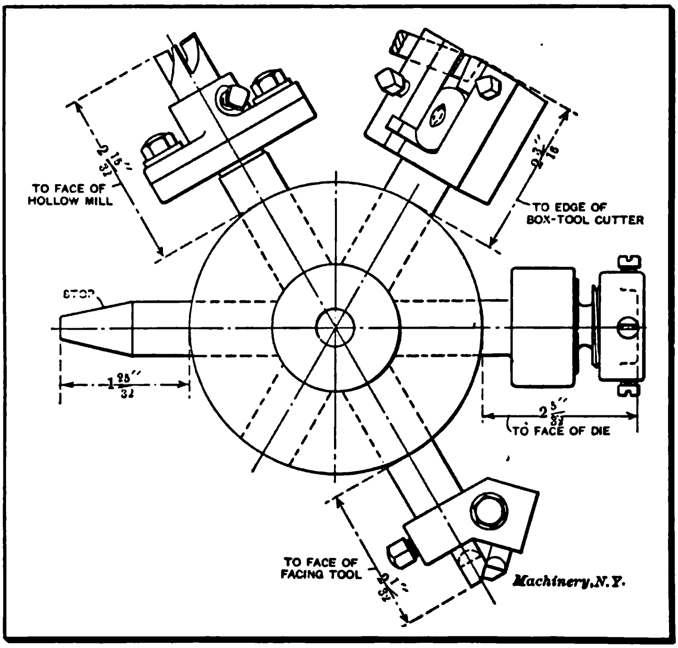


Fig. 16. Arrangement of Tools in the Turret

tions 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 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

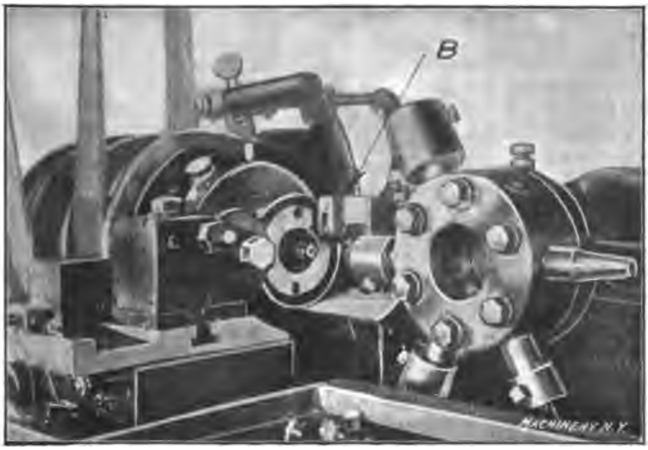


Fig. 17. Machine set up and ready for Making Thumb-nuts

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

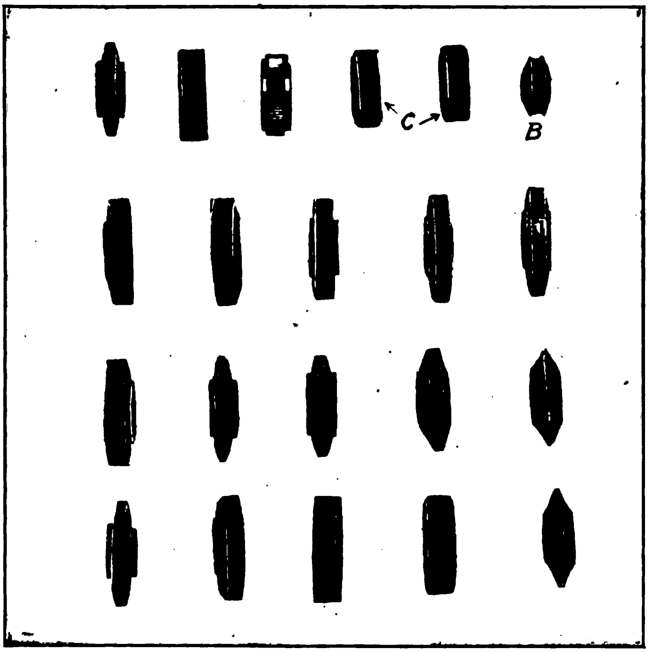


Fig. 18. A Collection of Knurls of Different Types

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

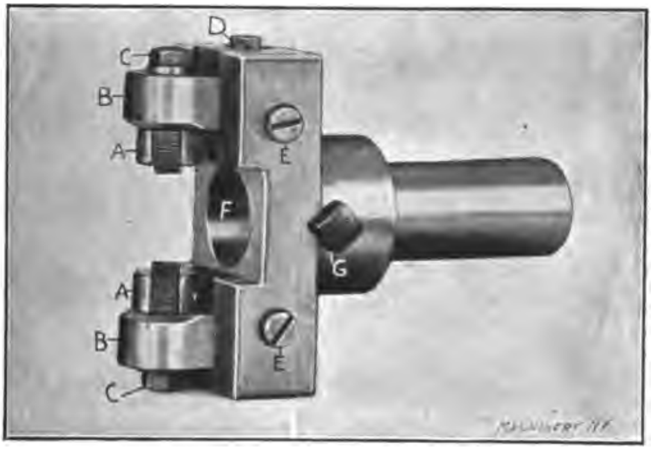


Fig. 19. Brown & Sharpe Adjustable Turret Knurl-holder

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*

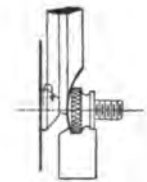
SPINDLE SPEEDS *1800* RPM FORWARD, *1800* RPM. BACKWARD

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		2¾	42	44¾	0.320"	0.164"x36P	Die on } Reverse Spindle
		11.55		2¾	44¾	47½	0.320"	0.164"x36P	Die off } Reverse Spindle
		18.9		4½	47½	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*

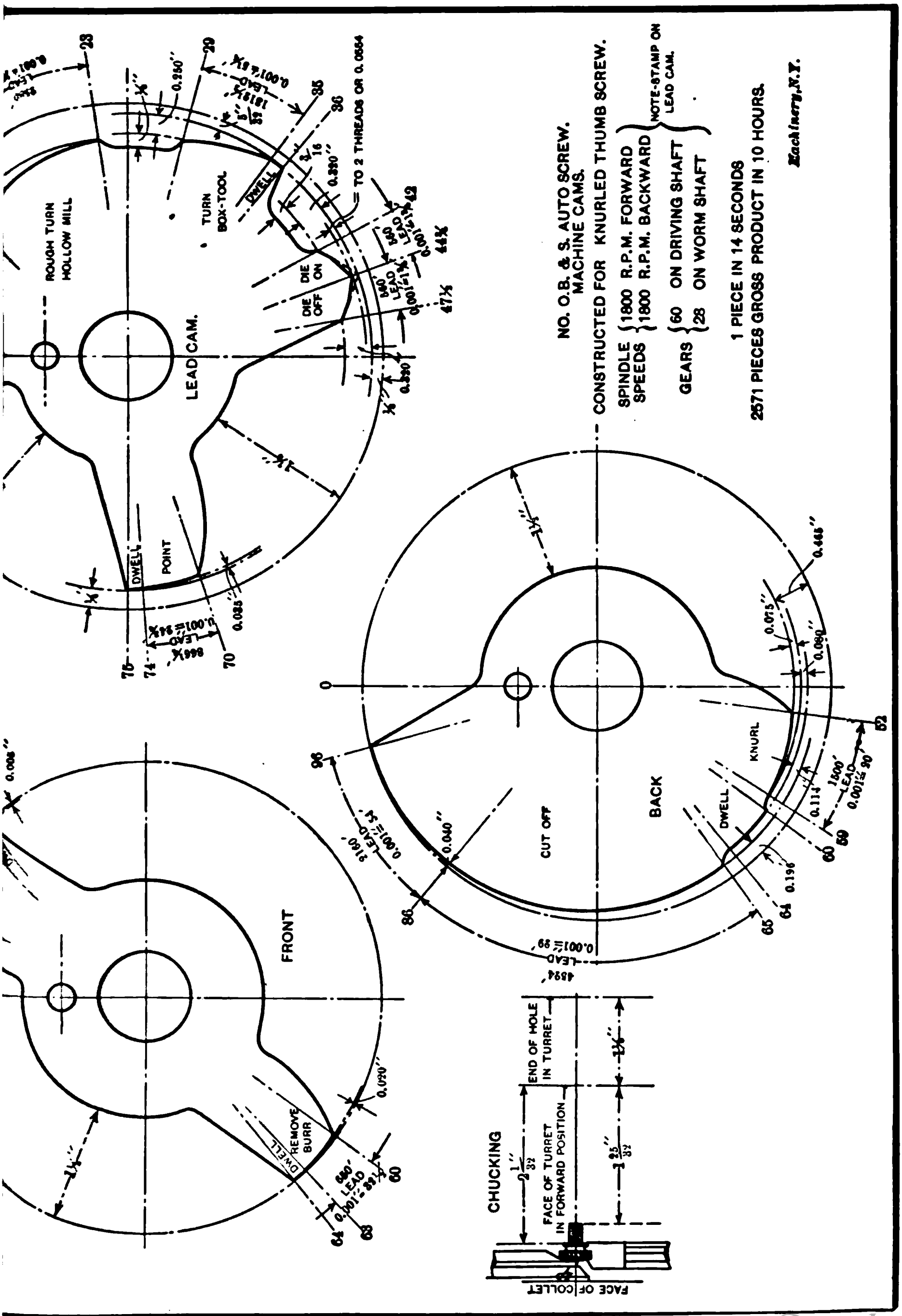


Fig. 20. Chart of Operations and Lay-out of Cams used for Making Thumb-screw shown in Fig. 18

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

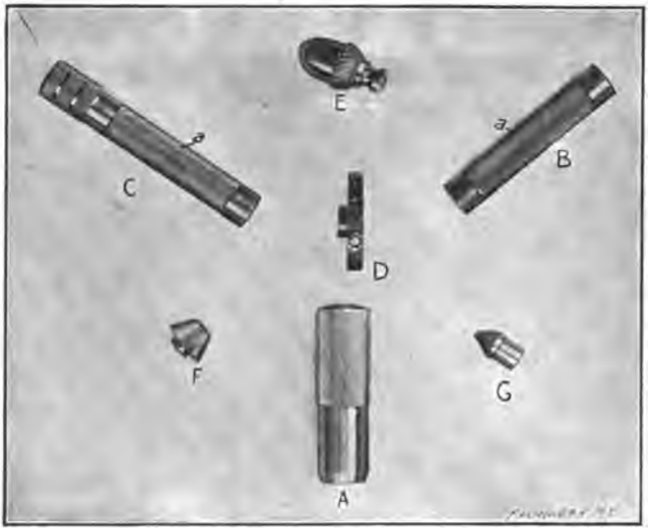


Fig. 21. Samples of Knurled Work

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

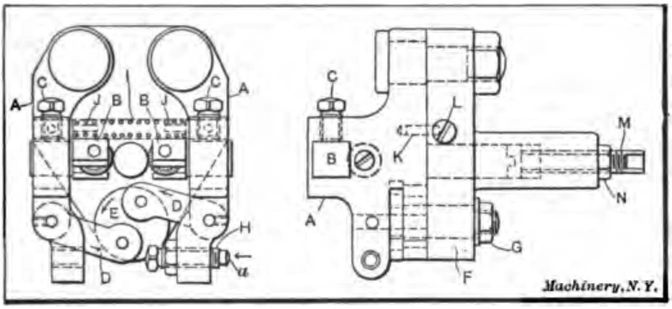


Fig. 22. Brown & Sharpe Opening Knurl-holder

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

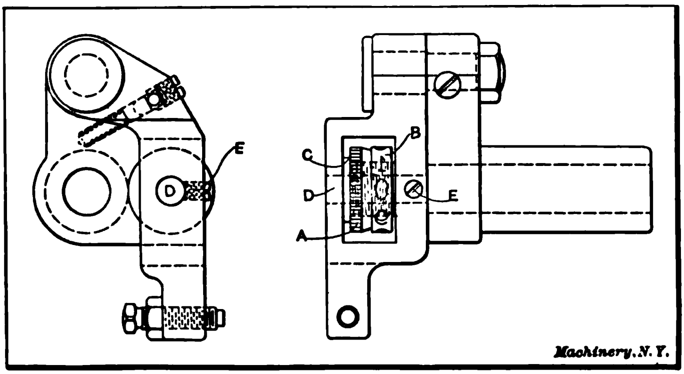


Fig. 23. Numbering Tool of the Swing Type

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

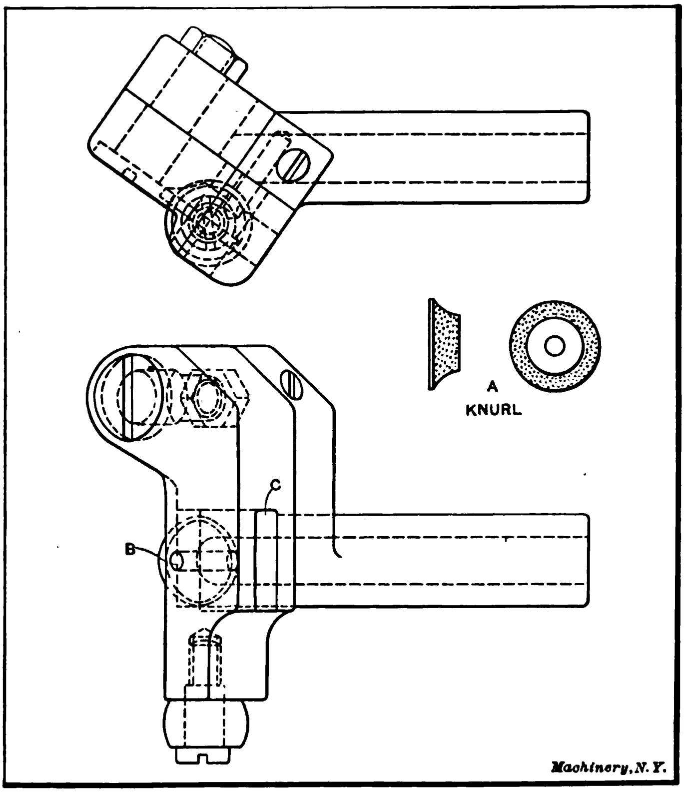


Fig. 24. Knurl-holder for Concave and Convex Knurling

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

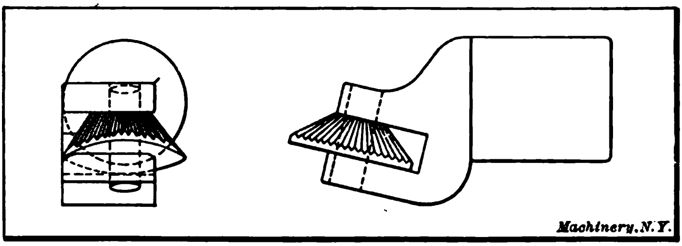


Fig. 25. Bevel Knurl-holder used in the Turret

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*.

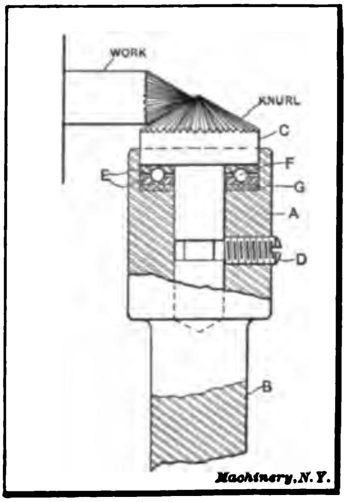


Fig. 26. Bevel Knurl-holder used on the Cross-slide

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,

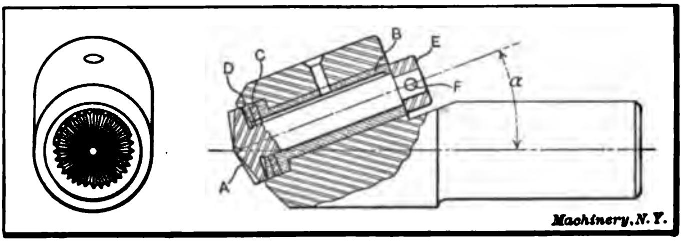


Fig. 27. Turret Knurl-holder for End Knurling

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

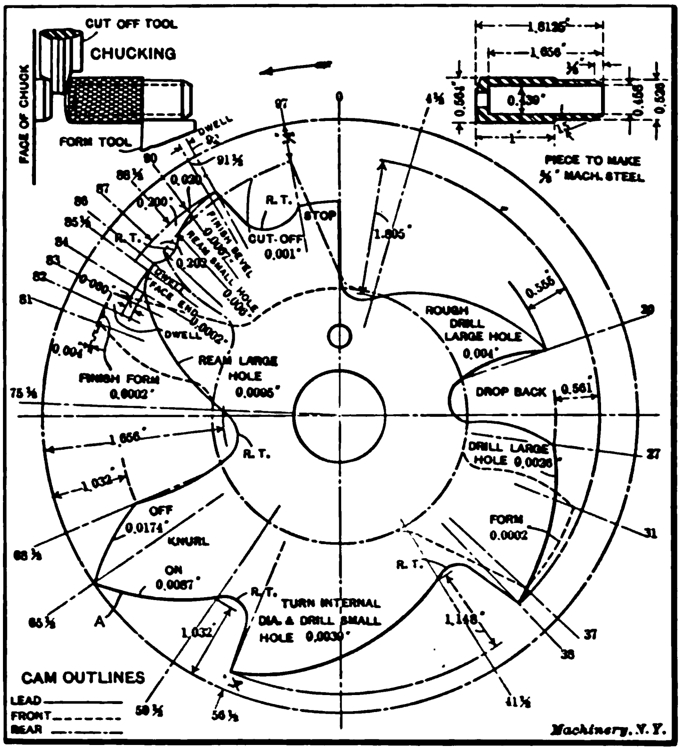


Fig. 28. Cams for Making Brown & Sharpe Micrometer Sleeve, showing Method of Laying out Lobe for Turret Knurling

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 θ = 20 degrees ,
Depth of tooth, d_1 = 0.027 inch,
Radius of knurl, R = 0.375 inch.

Then

$$R_1 = \frac{0.375}{\cos 20 \text{ deg.}} = \frac{0.375}{0.9397} = 0.399 \text{ inch.}$$

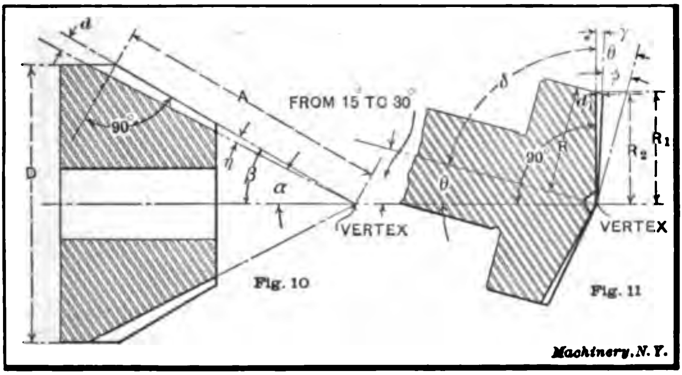


Fig. 29. Method of Finding the Cutting Angle of Bevel Knurls

Fig. 30. Method of Finding the Face Angle of End Knurls

$$R_2 = 0.399 - (0.027 \times \tan 20 \text{ deg.}) = 0.399 - 0.0098 = 0.389 \text{ in.}$$

$$\delta = 90 \text{ deg.} - 20 \text{ deg.} = 70 \text{ deg.}$$

$$\tan \gamma = \frac{0.027}{0.389} = 0.0694, \text{ the tangent of 3 deg. 58 min.}$$

$$\phi = 20 \text{ deg.} - 3 \text{ deg. 58 min.} = 16 \text{ deg. 2 min.}$$

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

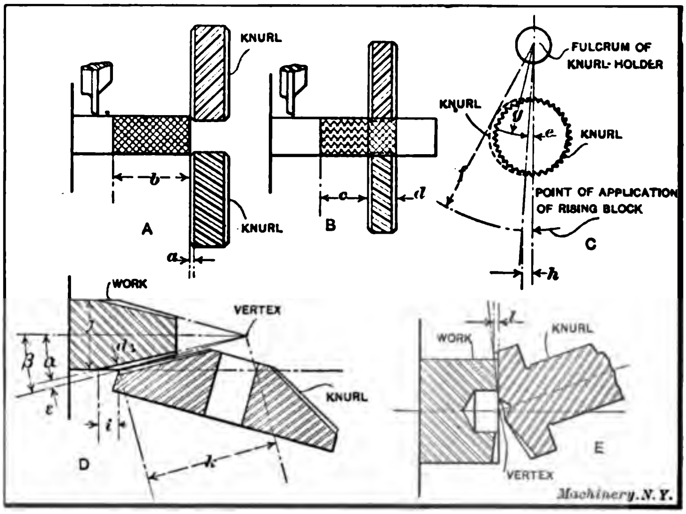


Fig. 31. Diagrams for Finding Rise on Lead and Cross-slide Cams for Turret Knurling

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 tooth. This value is slightly greater than the rise on the cam required for knurling, as the material is displaced. However, the depth of the tooth, e, is near enough for all practical purposes.

The method of obtaining the rise on the cam for bevel knurling when the knurl is operated on entirely by the lead cam, is shown at D, where i equals the rise required on the cam. The rise i is obtained by means of the following formulas, where

k = face cone radius of work,
j = diameter of work,

TABLE IV. FEEDS FOR TURRET KNURLING

Pitch of Knurl	Brass Rod, Feed per Revolution	Gun Screw Iron, Feed per Revolution	Machine Steel, Feed per Revolution	Tool Steel, Feed per Revolution
16	0.0100	0.0080	0.0060	0.0040
18	0.0105	0.0084	0.0063	0.0042
20	0.0110	0.0088	0.0065	0.0044
22	0.0115	0.0092	0.0068	0.0046
24	0.0118	0.0096	0.0070	0.0048
26	0.0123	0.0100	0.0072	0.0050
28	0.0128	0.0103	0.0074	0.0051
30	0.0135	0.0106	0.0076	0.0052
32	0.0140	0.0110	0.0078	0.0053
34	0.0145	0.0115	0.0080	0.0054
36	0.0150	0.0120	0.0082	0.0056
38	0.0153	0.0125	0.0084	0.0057
40	0.0158	0.0128	0.0086	0.0058
42	0.0164	0.0132	0.0088	0.0059
44	0.0168	0.0136	0.0090	0.0061
46	0.0173	0.0140	0.0092	0.0062
48	0.0178	0.0143	0.0094	0.0063
50	0.0182	0.0145	0.0098	0.0064
52	0.0185	0.0148	0.0103	0.0065
54	0.0189	0.0150	0.0108	0.0066
56	0.0193	0.0153	0.0111	0.0067
58	0.0195	0.0156	0.0115	0.0068
60	0.0198	0.0158	0.0118	0.0069
62	0.0200	0.0160	0.0120	0.0070

i = rise required on cam,
α = angle of bottom of tooth with axis of work,
β = angle of face with axis of work,
ϵ = tooth angle,
d_1 = depth of tooth.

$$k = \frac{j}{2 \sin \beta}; \sin \epsilon = \frac{d_1}{k}; \alpha = \beta - \epsilon$$

Then

$$i = \frac{d_1}{\sin \alpha} + 0.010 \text{ to } 0.015 \text{ inch.}$$

The method used for obtaining the rise on the cross-slide cam for bevel knurling when the knurl is operated on by both the lead and 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 OPERATIONS

The knurling operations dealt with in the previous chapters are what might be called "standard," and are met with frequently in automatic screw machine practice. The following examples are of a more special nature, and illustrate unusual applications of knurls. The data which follows should be of suggestive value to the designer of screw machine tools, inasmuch as it presents commendable methods of applying knurls to the work under varying conditions.

Bevel Knurling Tools operated from the Turret

The simple bevel knurling tool shown in Fig. 33 is provided with a tapered shank and is held in a standard floating holder in the tur-

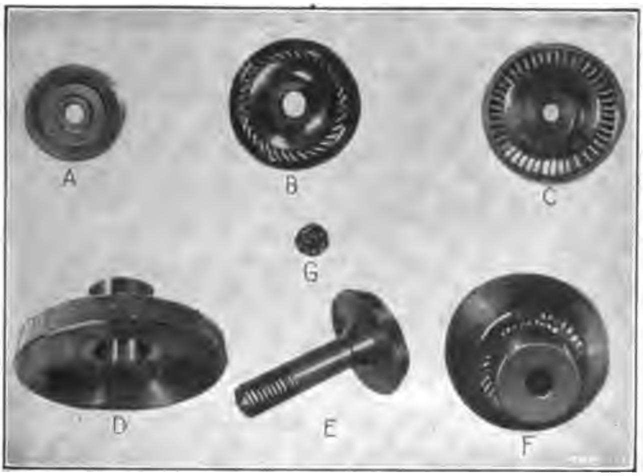


Fig. 32. Examples of Work Requiring Special Knurls and Knurl-holder Applications

ret. The piece to be knurled, *A*, is a small German silver button which has a convex face, but as the curvature is slight, a straightface diamond knurl can be used. In applying the knurl to the work, the center line *BC* of the knurl should be at right angles to that portion of the work it is required to knurl. This particular holder was used in a No. 00 Brown & Sharpe automatic screw machine, which was operated at a spindle speed of 1492 R. P. M., and with a feed to the knurl of 0.0023 inch per revolution of the work.

Another example of end-knurling from the turret is shown in Fig. 34. The piece to be knurled is shown at *A*, and also at *F* in Fig. 32. The knurl is presented from the turret under the body of the work,

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

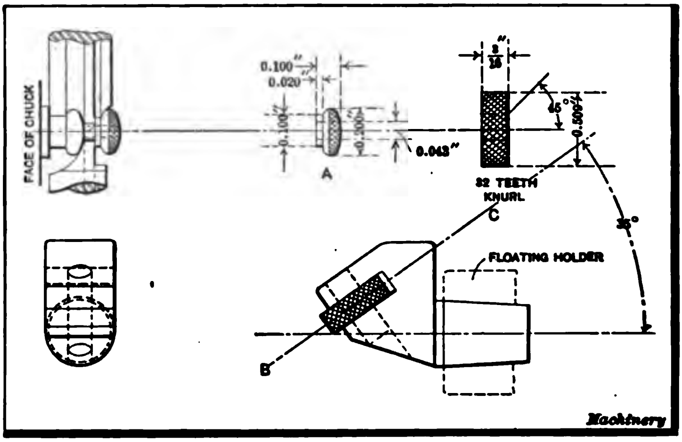


Fig. 33. End-knurling Tool held in Floating Holder

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

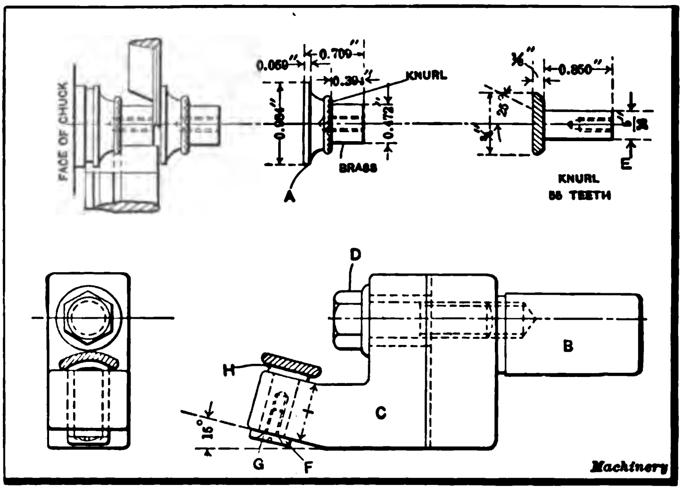


Fig. 34. End-knurling Tool held in Turret and Operated at an Angle

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 width of the holder, so as to allow the knurl and washer *G* to rotate freely.

The knurl *B* and the knurl holder *D* shown in Fig. 35 are used to produce a ratchet form of radial teeth in the shoulder of the piece

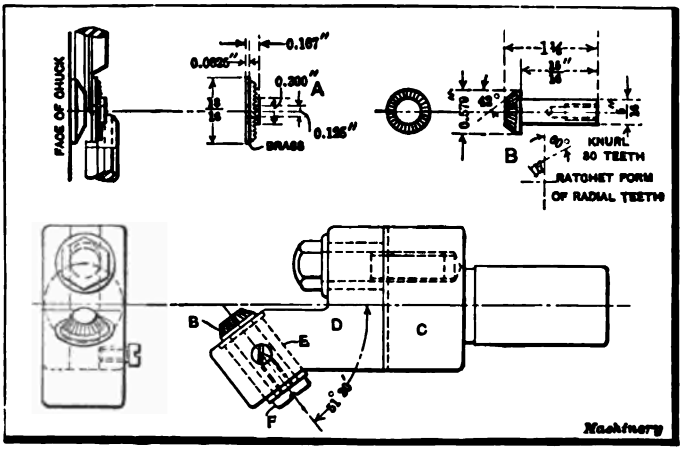


Fig. 35. Knurl and Knurling Tool-holder for producing Rachet Form of Radial Teeth

shown at *A*, and also at *C* in Fig. 32. The teeth in the knurl are cut at an angle of 60 degrees and are radial. The work is rotated at 1216 R. P. M., and a feed of 0.0008 inch is given to the knurl per revolution of the work.

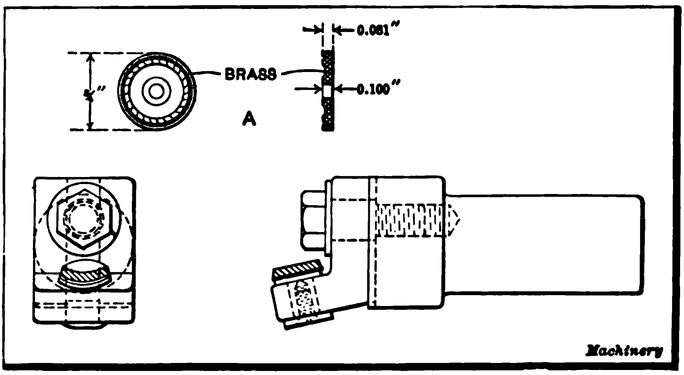


Fig. 36. Knurl and Holder for producing "Tangential" Form of Knurl

This holder is held in the turret of a No. 2 Brown & Sharpe automatic screw machine, and consists of a body and shank *C* to which the holder *D* is held by a screw. The knurl *B* rotates in a phosphor-bronze bushing which is prevented from turning by a screw. The knurl is retained in the bushing by a large-headed screw *F* provided with a shoulder. There is sufficient end play to allow the knurl to 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.

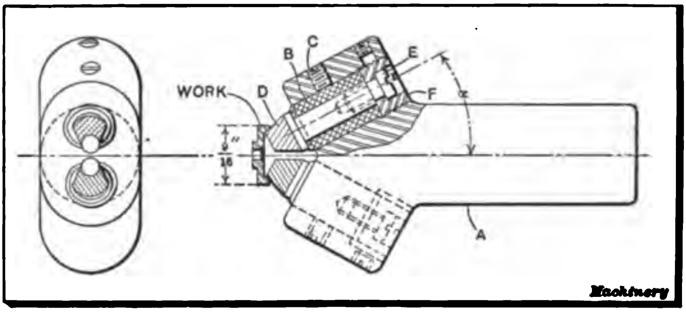


Fig. 37. Special Knurls and Holder for Internal Bevel Knurling

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,

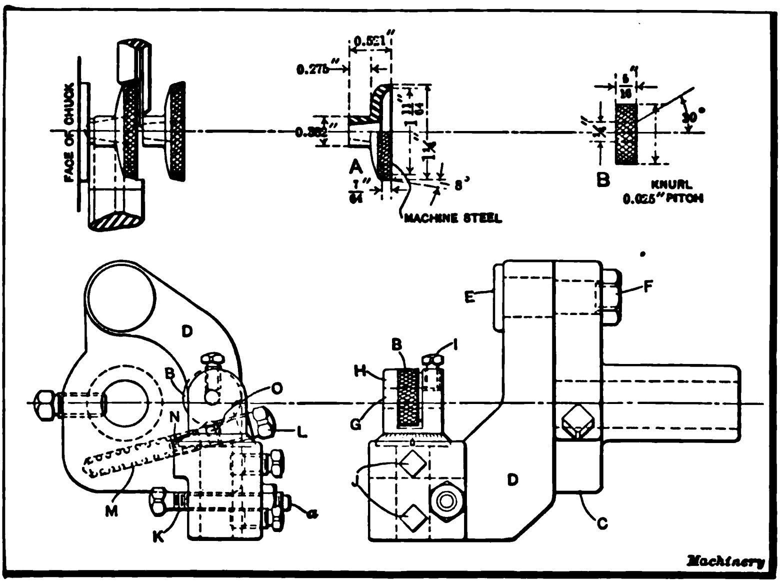


Fig. 38. Swing Type of Turret Knurl-holder for Knurling at Various Angles

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 90 degrees, and as shown at *A* in Fig. 32, a diamond-shaped knurl is to be produced. This operation can be more easily accomplished in this case with two spiral knurls than would be possible with one diamond knurl. Under these conditions it is advisable to have the angle *a* slightly less than half the angle on the work, so that it will be possible to use a bevel knurl, as a straight knurl would not work freely when operated from either the turret or cross-slide.

The holder *A*, Fig. 37, which is held in the turret, is made from a machine steel forging and is supplied with two lugs, bored to receive the phosphor-bronze bushings *B*, these being retained in the holder by

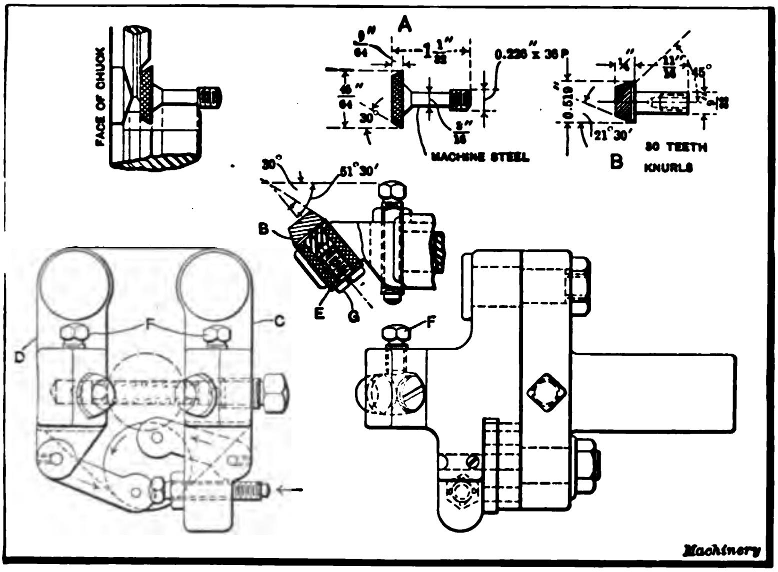


Fig. 39. Opening Type of Turret Knurl-holder for Bevel Knurling

screws *C*. The knurls *D* are provided with shanks and are retained in bushings *B* by screws *E*, which rotate with the knurls. The end thrust of the knurls in this holder is considerable, so that it is necessary to back up the bushings *B* with screws *F*.

Special Swing Knurl-holder

A special knurl holder which is held in the turret and operated from the cross-slide by a rising block under the front tool-post, is shown in Fig. 38. The work is shown at *A*, and also at *D* in Fig. 32. It will be noticed that the work is considerably greater in diameter than suitable for the ordinary capacity of the No. 2 Brown & Sharpe automatic screw machine, thus requiring the use of a special outside feeding attachment, the ordinary feed tube being removed. The work is revolved at 240 R. P. M., and the knurl holder advanced at the rate of 0.00077 inch per revolution of the work. This is the speed at which 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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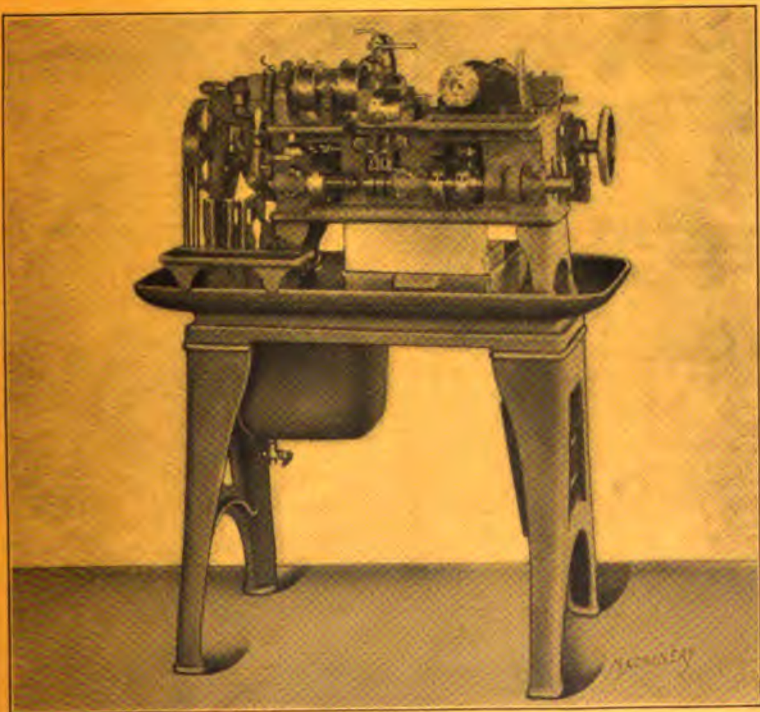
MILLING, CROSS-DRILLING AND BURRING OPERATIONS

BY DOUGLAS T. HAMILTON



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NUMBER 106

AUTOMATIC SCREW MACHINE PRACTICE

PART VIII

MILLING, CROSS-DRILLING AND BURRING OPERATIONS

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

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. 00 Brown & Sharpe Automatic Screw Machine equipped with a Screw-slotting Attachment

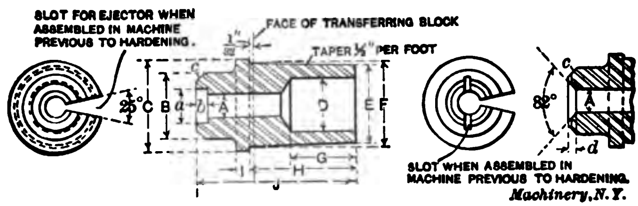
driven into it. This bushing grips the screw and holds it while the slotting saw *G*, held on an arbor and driven from pulley *I* through bevel gears, mills the slot in the head. The pulley *I* is driven by a round belt from the overhead works. The design and action of this device is described in detail 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	3/8	9/16	1/4	0.450	0.476	1/2	11/16	1/16	1
	3/16 to 1/4	1/2	9/16	5/16	0.450	0.476	1/2	11/16	1/16	1
0	1/8 to 1/4	1/2	11/16	5/16	0.600	0.631	9/16	3/4	1/16	1 1/8
	1/4 to 3/8	11/16	11/16	7/16	0.600	0.631	9/16	3/4	..	1 1/8
2	3/16 to 5/16	5/8	7/8	3/8	0.750	0.792	5/8	1	1/8	1 1/2
	5/16 to 1/2	7/8	7/8	9/16	0.750	0.792	5/8	1	..	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 from tool steel, and are not hardened until the cams have been tried out and the whole equipment is completed. The slot for the ejector is cut before the bushing is inserted in the transferring block, and the slot for the saw in the bushing for flat-head screws is cut when the bushing is held in position in the transferring block. When a bushing is to hold a fillister-head screw, the slotting saw does not, as a rule, touch the bushing at all, the depth of the counterbore *b* in the bushing being slightly less than the difference between the depth of the slot and the thickness of the head of the screw. The dimension *F* is not taken at the shoulder of the bushing, but is the largest diameter of the taper hole

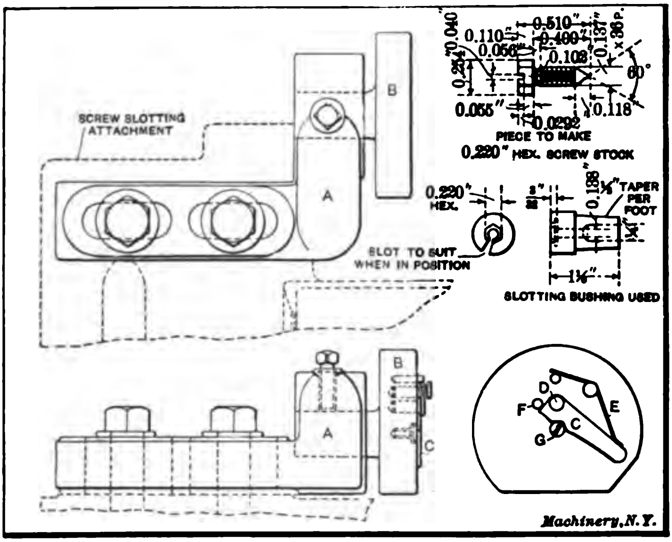


Fig. 2. Device for Locating Hexagon-head Screws in the Slotting-bushing

in the transferring block. This allows the bushing to be driven tightly into the block, 1/32 inch being allowed for driving. It is customary, however, to make the dimension *F* slightly larger than necessary and fit it into the block when trying out the job. The bevel in the bushing for holding flat-head screws is made to suit the included angle of the head, the angle shown being that adopted by the A. S. M. E.

Slotting Hexagon-head Screws

When the slot in the head of a hexagon screw has to bear some definite relation to the sides of the head, it is necessary that the screw be located in an exact position in the slotting-bushing. The bushing for holding the screw has usually an impression in it, which fits the hexagon head, but it is often difficult to get the screw to locate properly in the bushing. If the bushing is forced onto the work when it is attached to the bar, the screw will seldom be correctly located in the hexagon hole, but the corners of the head will be torn off, and 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

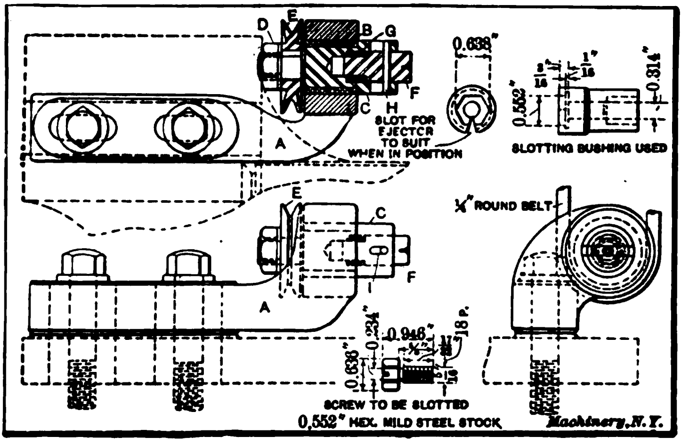


Fig. 3. Another Hexagon Screw Locating Device

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 ¼-inch round belt from the overhead works. Held in the spindle *C* is a spring plunger *F*, which is pressed forward by an open-wound spring *G*. This spring plunger is prevented from rotating by a pin *H*, which fits in an elongated slot *I*, cut in the spindle *C*.

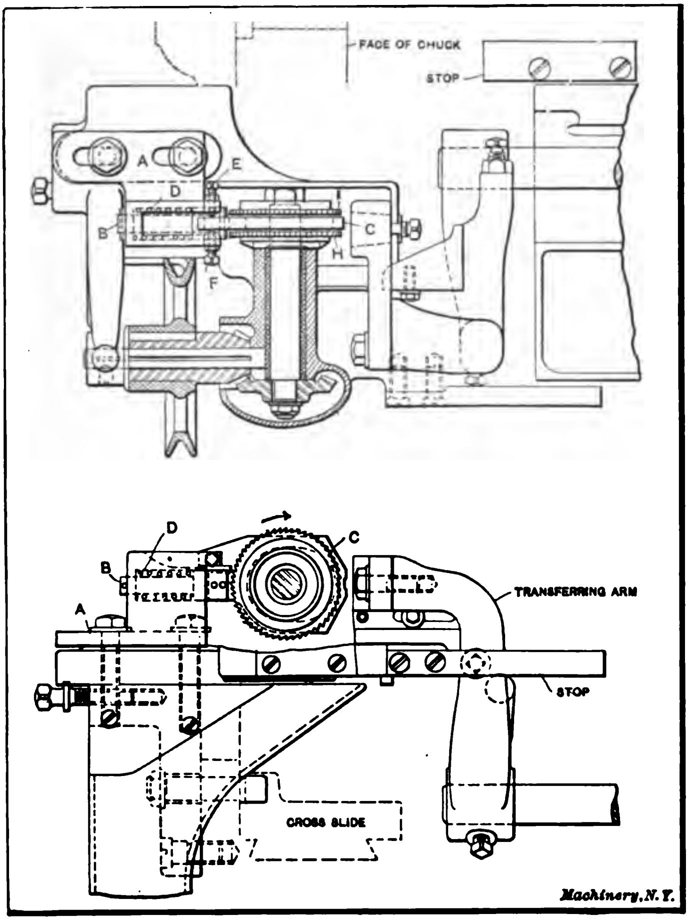


Fig. 4. Slabbing Attachment used on Screw-slotting Attachment

In operation, as the slotting-bushing lifts the screw from the chuck, the arm dwells in an intermediate position, travels forward and presses the screw against the rotating plunger *F*. As this plunger is driven slowly, and as the arm is advanced, the friction between the head of the screw and the plunger rotates the former. On the continued forward travel of the arm, the screw is located correctly in the bushing and forced in to the correct depth. The screw and the slotting bushing 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

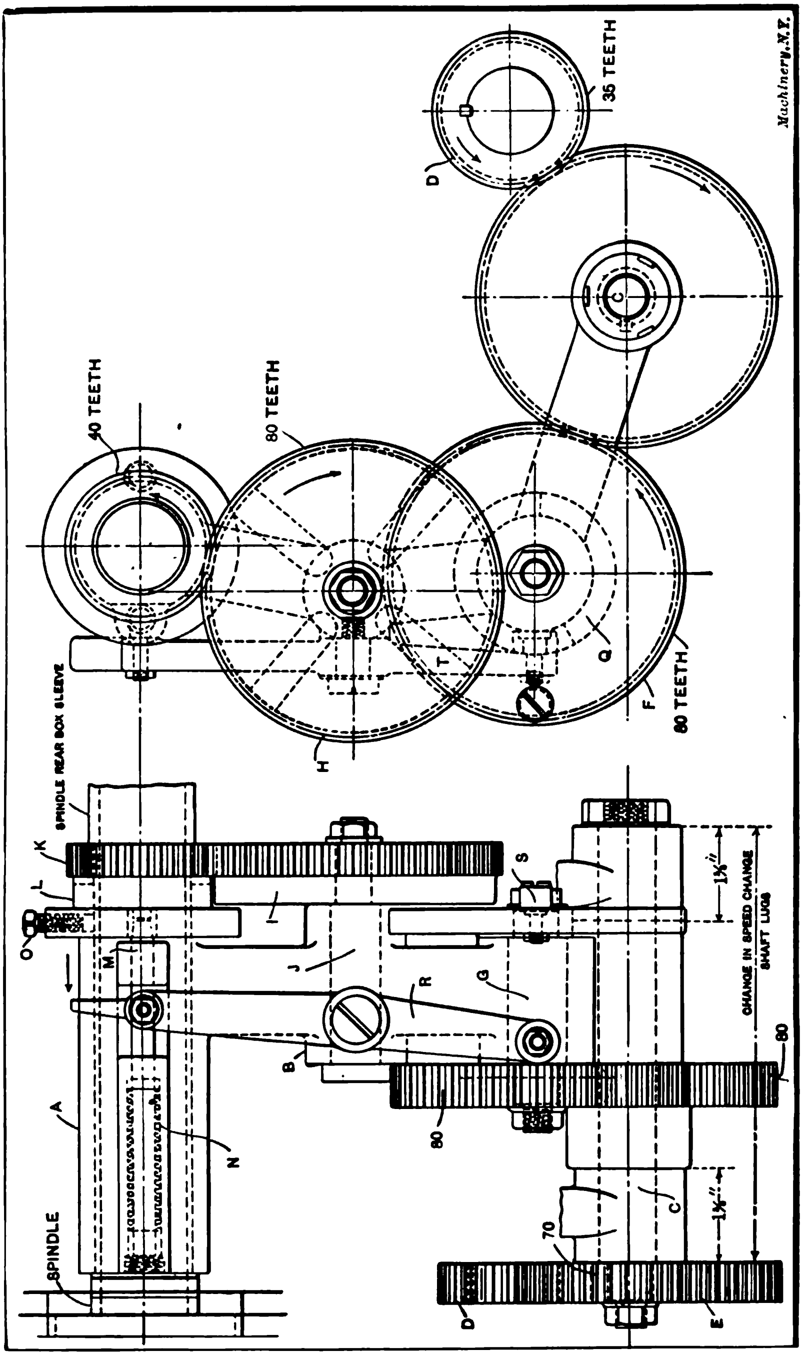


Fig. 5. Attachment for Indexing the Main Driving Spindle of a Brown & Sharpe Automatic Screw Machine

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

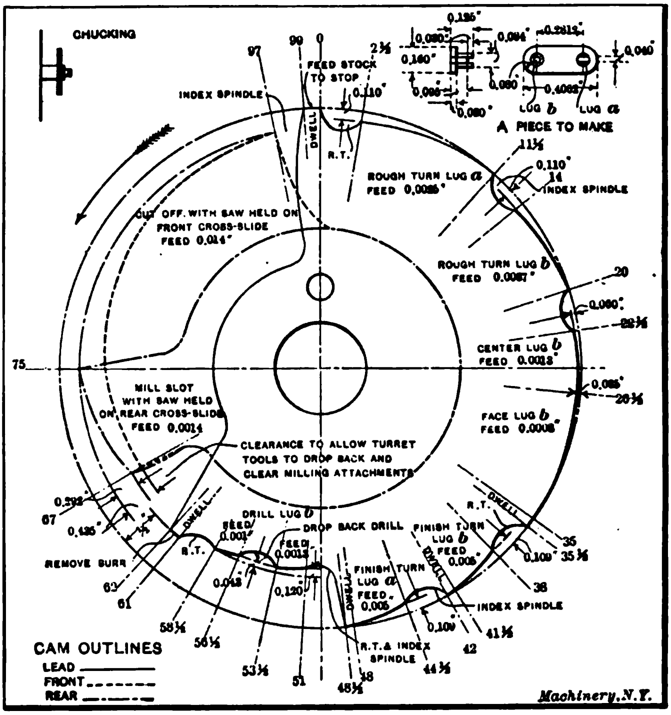


Fig. 6. Lay-out of a Set of Cams for Making a Piece requiring the Indexing of the Work-spindle

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 that the piece to be made has two lugs on it designated *a* and *b*. The stock from which this piece is made is of special shape, so that its outside circumference does not require to be finished; the lugs *a* and *b* are to be formed, drilled and slotted. The work is not revolved, but is only indexed to bring the stock into position for forming the two lugs. To turn these lugs, the turret is packed out an amount equal to one-half the distance between the center of the two lugs, and drilling attachments are used in the turret for holding hollow mills and drills. The order of operations is as follows:

Order of Operations	Revolutions	Hundredths
Feed stock to stop	4½	1
Revolve turret	12	2½
Rough turn lug *a* with hollow mill held in drilling attachment, speed 684 R. P. M. at 0.0025 inch feed	43	9
Index spindle and revolve turret	12	2½
Rough turn lug *b* with hollow mill held in drilling attachment, speed 684 R. P. M. at 0.0037 inch feed	28	6
Revolve turret	12	2½
Center and face lug *b* with centering tool held in drilling attachment, speed 684 R. P. M. at 0.0013 inch feed to center and 0.0008 inch feed to face	62	13
Revolve turret	12	2½
Finish turn lug *b* with hollow mill held in drilling attachment, speed 684 R. P. M., at 0.005 inch feed	19	4
Index spindle	12	2½
Finish turn lug *a* with hollow mill held in drilling attachment, speed 684 R. P. M., at 0.005 inch feed	19	4
Revolve turret and index spindle	12	2½
Drill hole in lug *b* with drill held in drilling attachment, speed 3555 R. P. M. at 0.0013 inch feed	12	2½
Pull out drill to remove chips	14	3
Finish drill hole in lug *b* with drill held in drilling attachment, speed 3555 R. P. M., at 0.0011 inch feed	9	2
Revolve turret	12	2½
Remove burr and broach with tool held in floating holder	4½	1
Clear	24	5
Mill slot in lug *a* with special milling attachment held on rear cross-slide, speed 400 R. P. M., at 0.014 inch feed	(26)	(8)
Cut-off with special milling attachment held on front cross-slide, speed 480 R. P. M., at 0.014 inch feed	143	30
Index spindle	10	2
	476	100

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

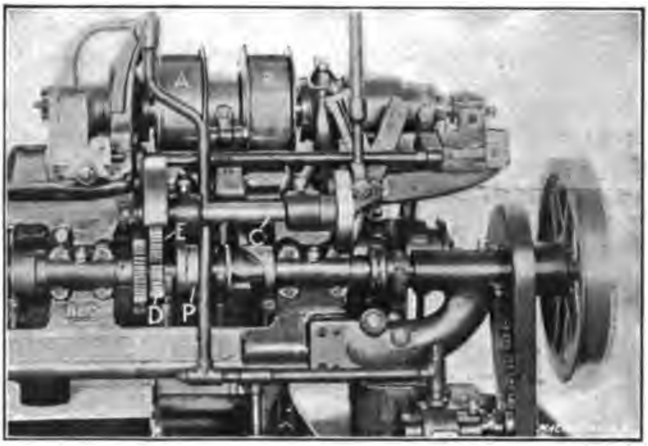


Fig. 7. Illustration showing the Location of the Indexing Attachment

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

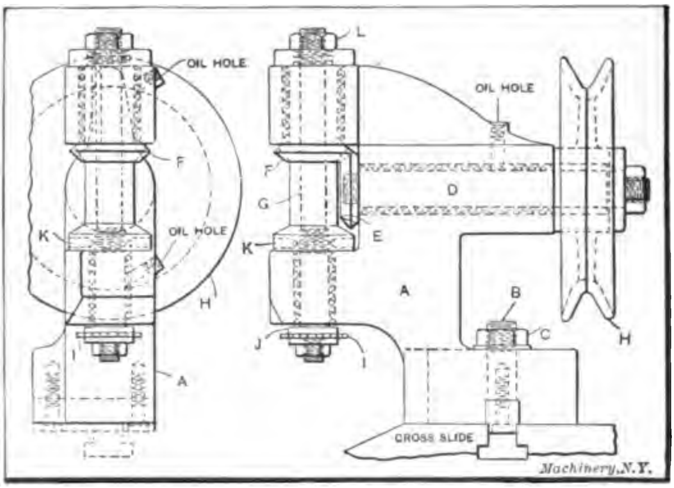


Fig. 8. Slotting Attachment held on the Rear Cross-slide

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

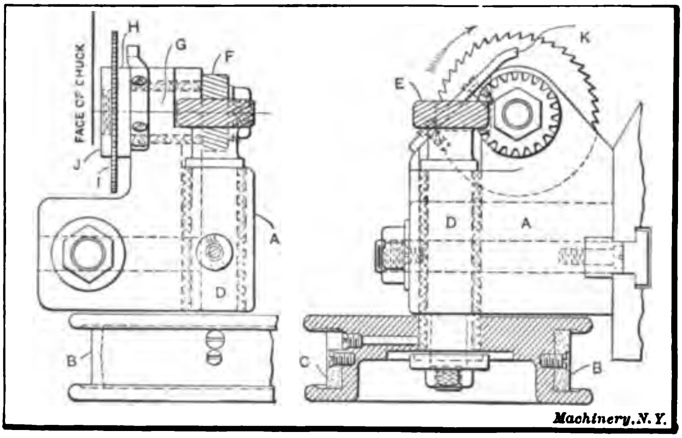


Fig. 9. Sawing Attachment held on the Front Cross-slide

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

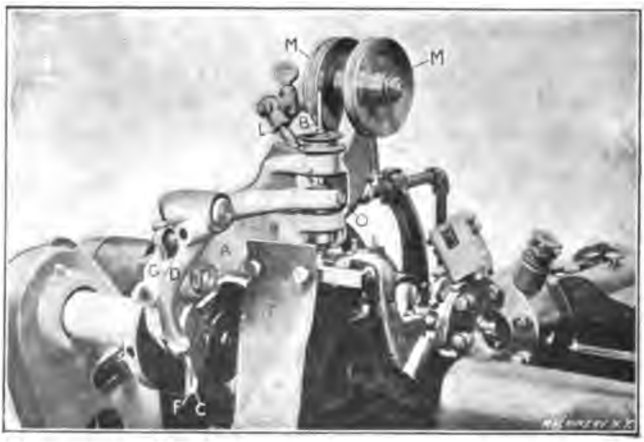


Fig. 10. Front View of the Index Drilling Attachment, placed on a No. 00 Brown & Sharpe Automatic Screw Machine

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 $\frac{3}{8}$-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 segment 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.

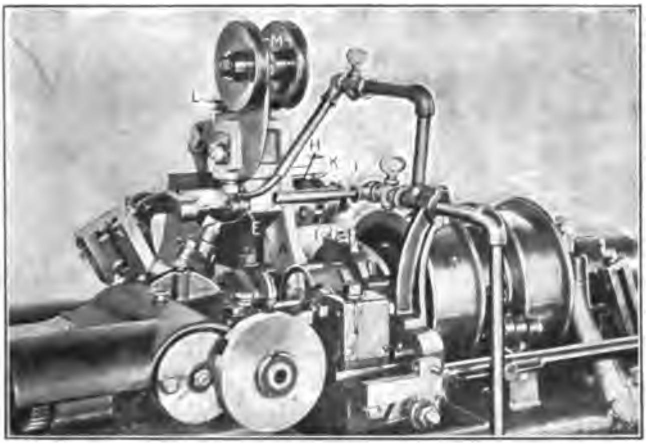


Fig. 11. Rear View of the Index Drilling Attachment in Place on a No. 00 Brown & Sharpe Automatic Screw Machine

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:

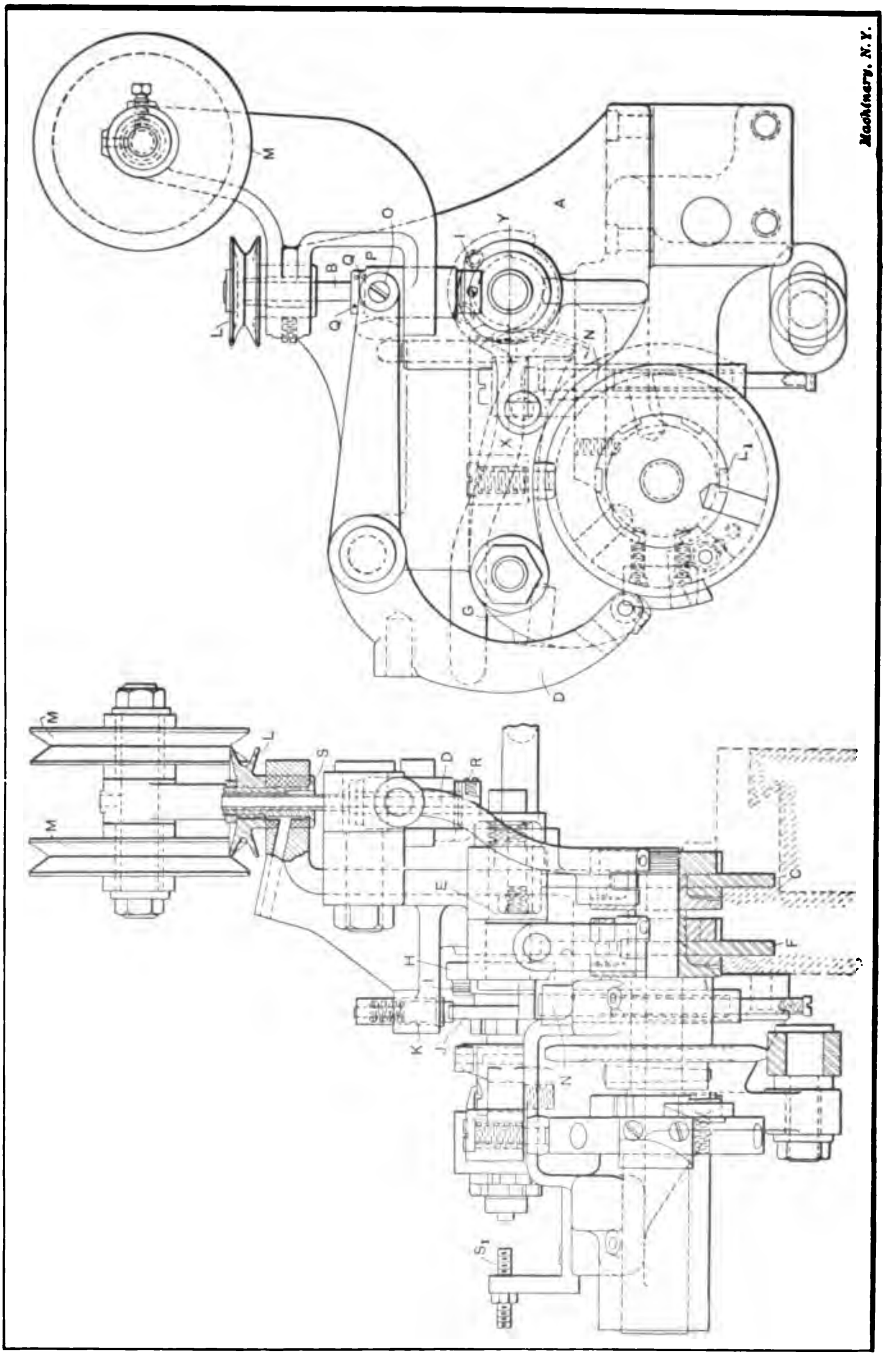


Fig. 12. Assembly View of the Index Drilling Attachment for the No. 00 Brown & Sharpe Automatic Screw Machine

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.

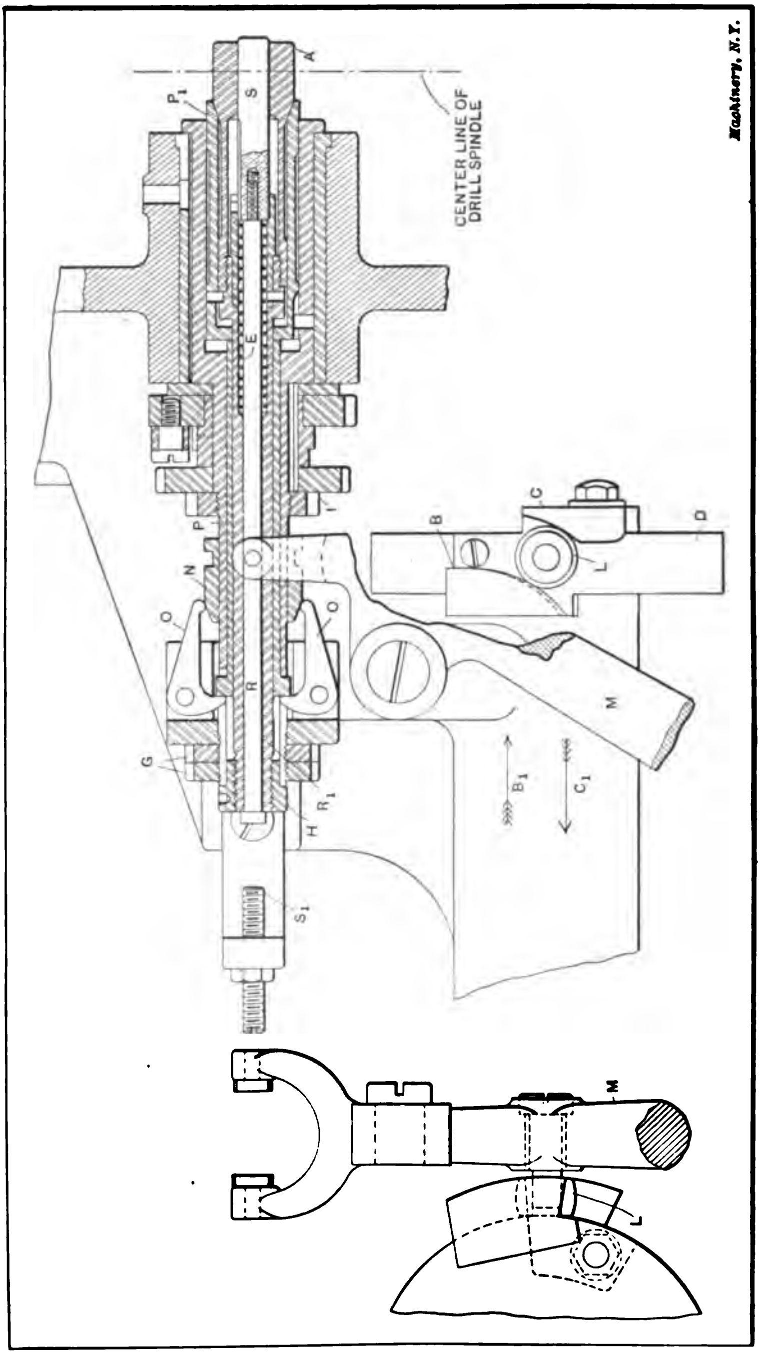


Fig. 18. Sectional View of the Index Drilling Work-spindle

Before laying out the lead and cross-slide cams, it is preferable to make a lay-out as shown in Fig. 15, drawing in the position of the circular form and cut-off tools and also the tools used in the turret. If this is done, the amount that the cams are to be cut down below the largest diameter of the cam circumference, and also the clearances necessary for the turret and circular form tools, can be found. After the necessary information has been obtained from this diagram, another diagram, such as in Fig. 11, Reference Book No. 100, "Designing and Cutting Cams for the Brown & Sharpe Automatic Screw Ma-

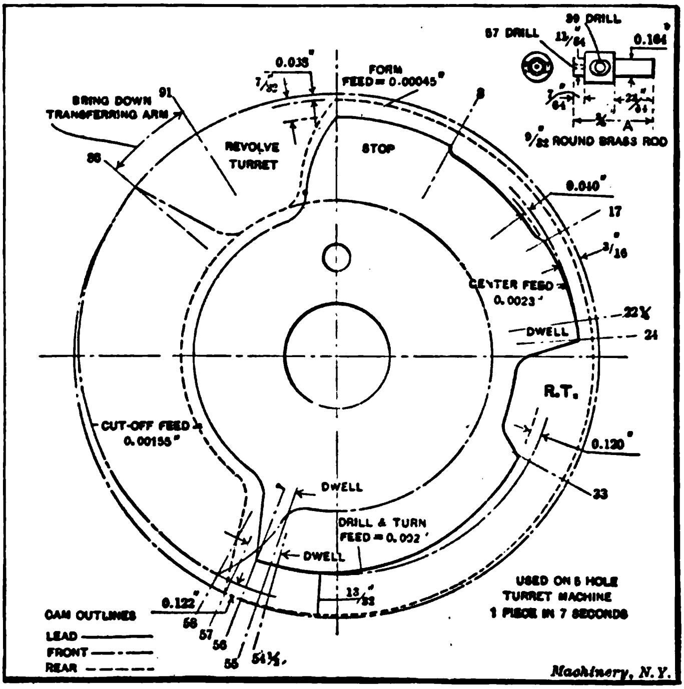


Fig. 14. Lay-out of a Set of Cams for a Cross-drilling Operation on the No. 00 Brown & Sharpe Automatic Screw Machine

chines," should be made so that the rises and the cut-downs on the transferring and advancing cams can be obtained. Of course, the example given in that illustration applies more particularly to a screw-slotting job; the method of procedure, however, for laying out the cams used on the index drilling attachment is similar.

Laying out the Transferring and Advancing Cams

As the method of laying out the transferring and advancing cams is described in Part II of this treatise, MACHINERY'S Reference Book No. 100, it will not be necessary to describe it here. The drawing of the transferring and advancing cams used in connection with the piece shown at *A* in Fig. 14, is shown in Fig. 16. Here the lobes and their 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

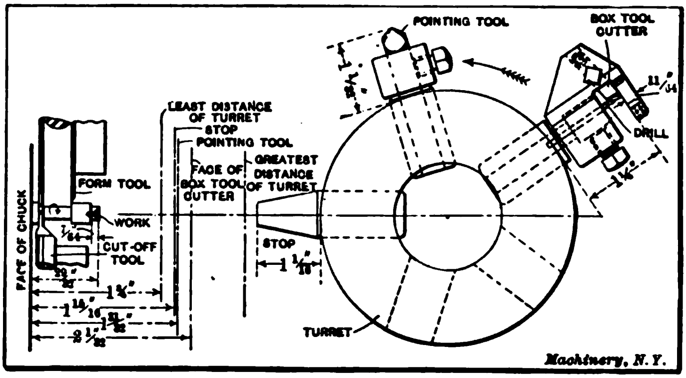


Fig. 15. Diagram for Obtaining the Cut-down on the Lead Cam, and Clearance for Tools

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

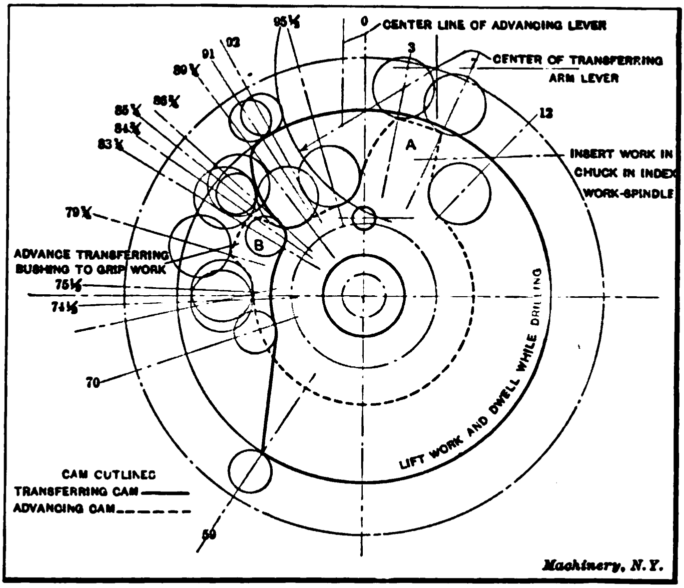


Fig. 16. Transferring and Advancing Cams for Lifting and Placing the Work in the Index Drilling Chuck

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

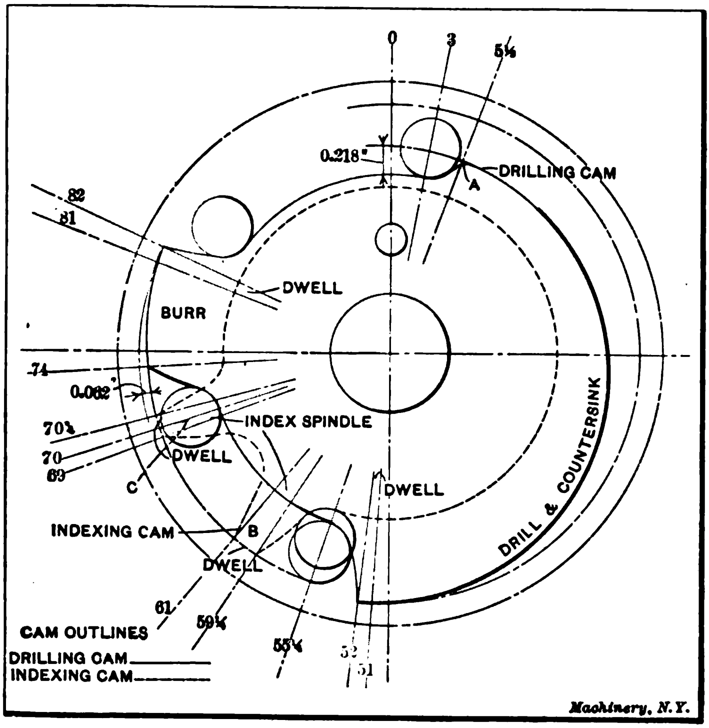


Fig. 17. Indexing and Drilling Cams for the Piece shown at A in Fig. 14

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

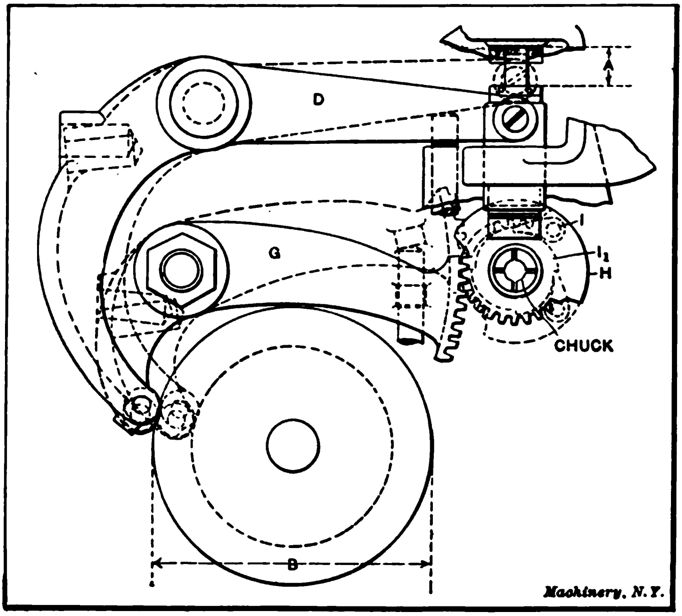


Fig. 18. Diagram illustrating the Movement of the Indexing and Drilling Levers

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

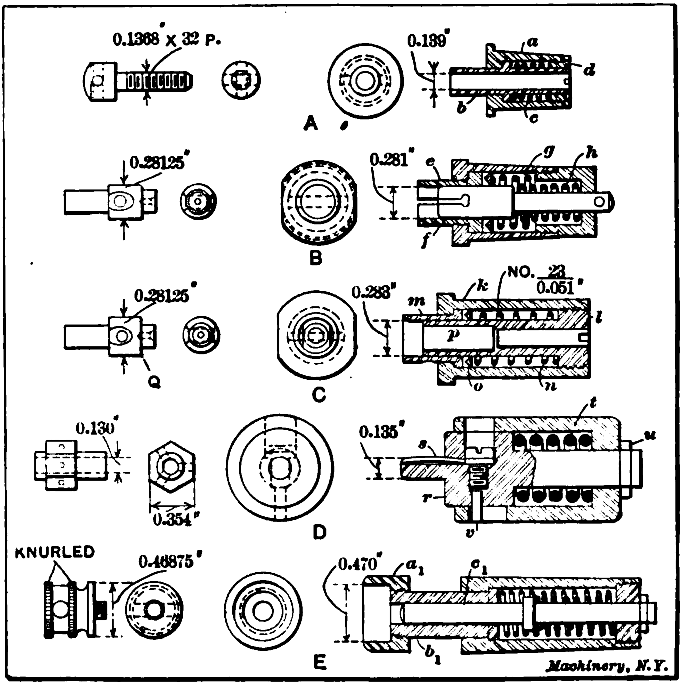


Fig. 19. Representative Types of Transferring Bushings and the Work they were designed to hold

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,

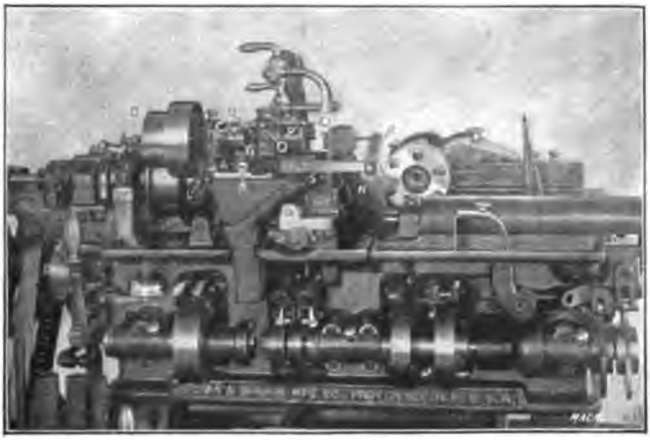


Fig. 20. Front View of No. 00 Brown & Sharpe Automatic Screw Machine equipped with a Burring Attachment

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

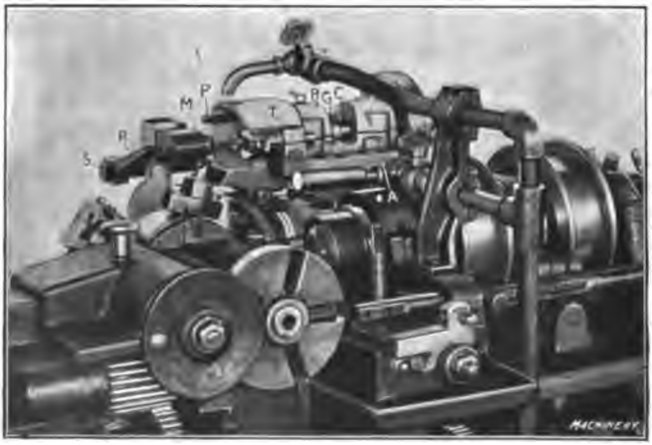


Fig. 21. Rear View of the Burring Attachment placed on a No. 00 Brown & Sharpe Automatic Screw Machine

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-

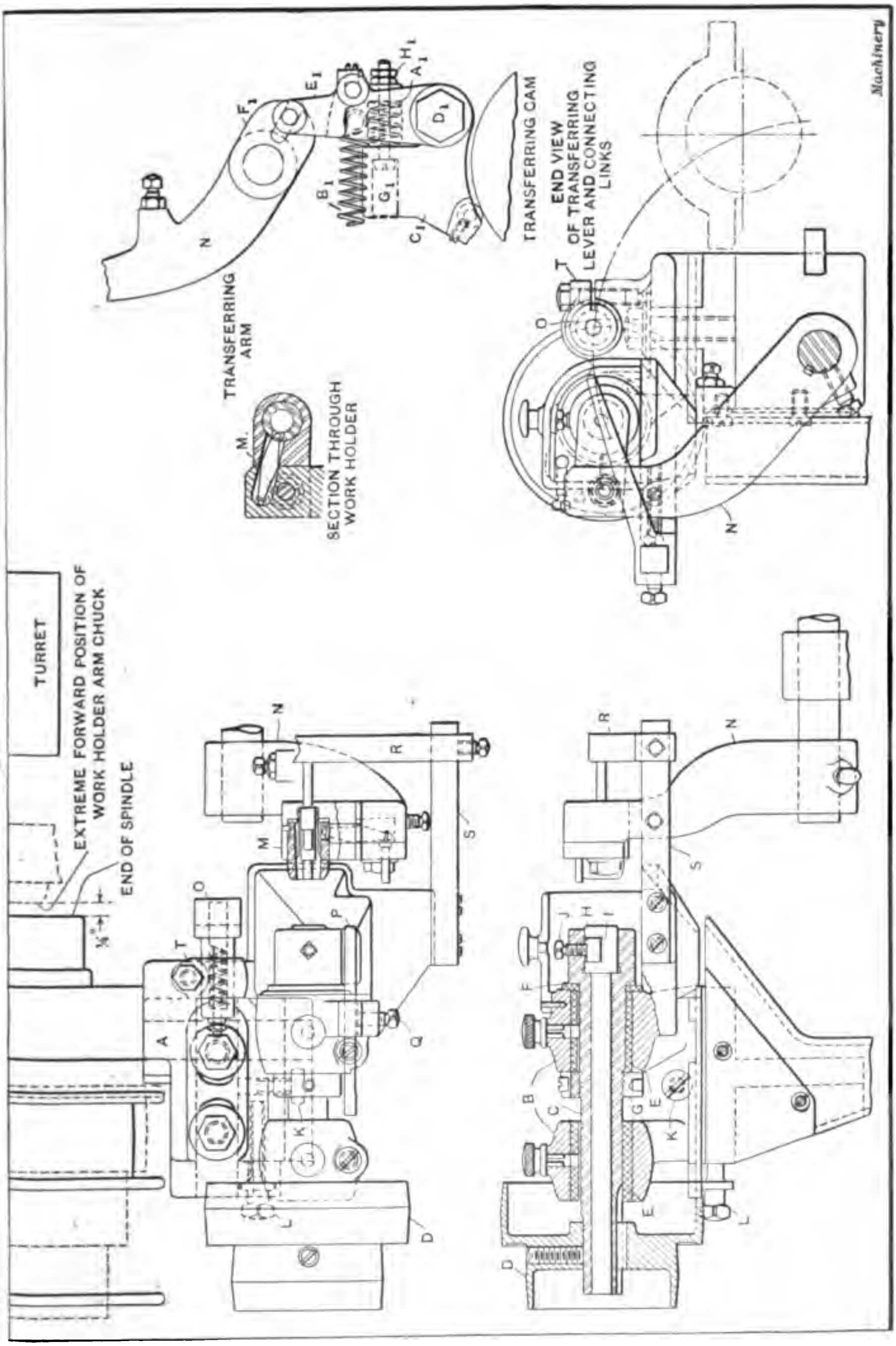


Fig. 22. Plan, Sectional and End Views of the Burring Attachment used on the No. 00 Brown & Sharpe Automatic Screw Machine

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

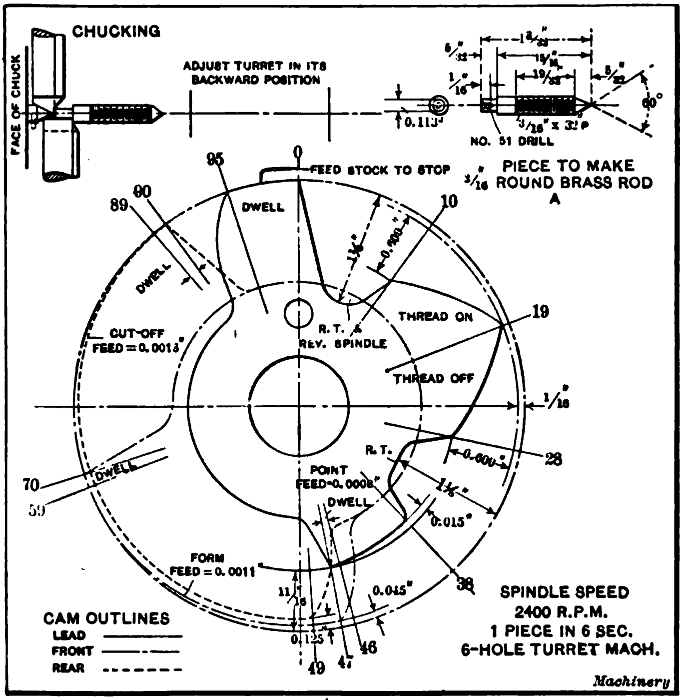


Fig. 23. Lead and Cross-slide Cams for Making a Cone-pointed Screw having a Hole drilled in the Rear End

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 making this screw are also shown in Fig. 23, where the functions of the various lobes are clearly indicated. It might be mentioned, however, that it was necessary to ad-

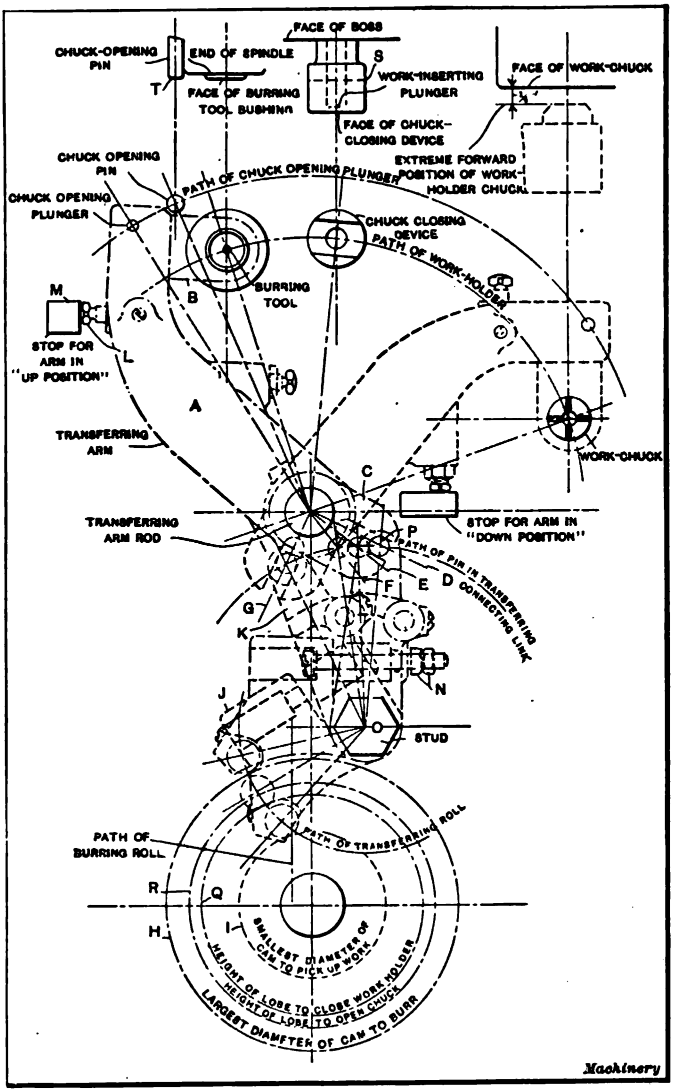


Fig. 24. Diagram used in Determining Rises on the Transferring and Burring Cams

just the turret slide back to the extreme limit to make this long screw in a No. 00 B. & S. automatic screw machine. The time allowed to feed stock is also less than that usually provided, being 5 hundredths instead of 10 hundredths of the cam circumference. The reason for 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.

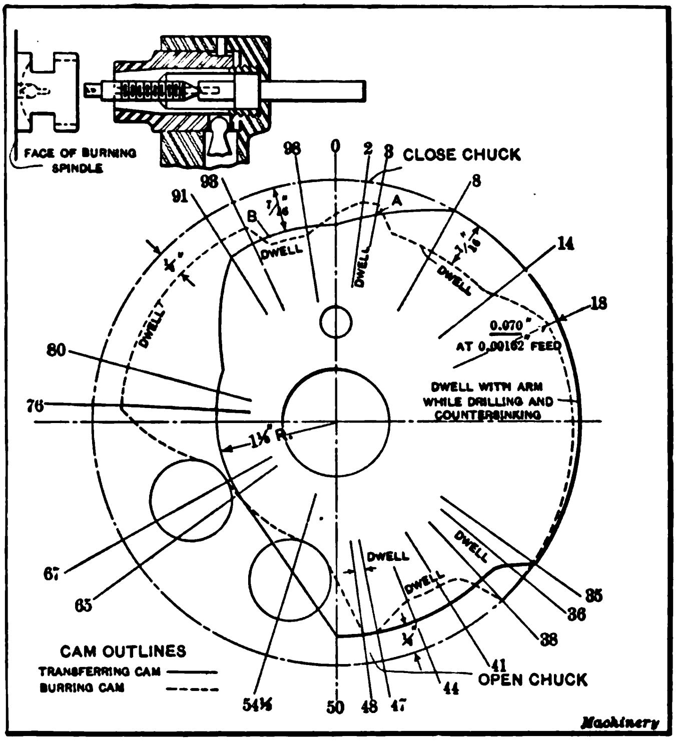


Fig. 25. Transferring and Burring Cams for the Piece shown at A in Fig. 23

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

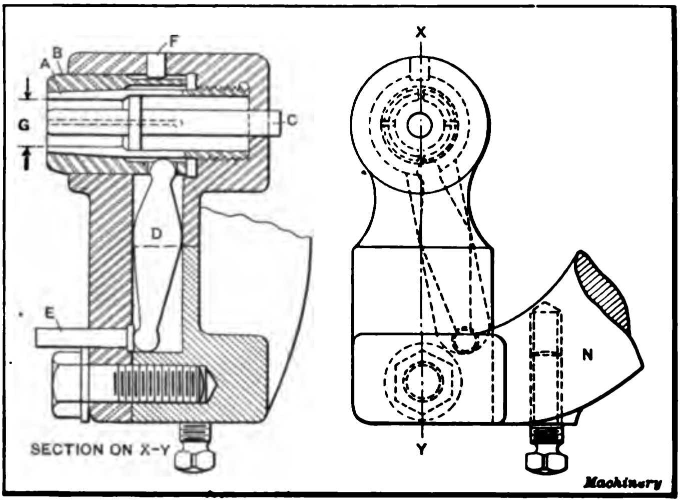


Fig. 26. Standard Work-holder used in Connection with the Burring Attachment

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 clearly seen. The operation of this work-holder has been described, but it may be advisable here to give a few more particulars regarding it. The diameter *G* of the chuck *A*, is made equal to the maximum diameter of the work. The chuck-closing sleeve *B* is made with a tapered hole to suit the chuck *A*, the taper being about ten degrees, and is provided with a slot in which a pin *F* fits, preventing the sleeve from turning around. The sleeve is also cut out to receive the ball end of the lever *D*, which is used for releasing it from the chuck, thus allowing the work to be pushed out by the plunger *C*. The lever *D*, as before mentioned, is operated by means of the headed pin *E*.

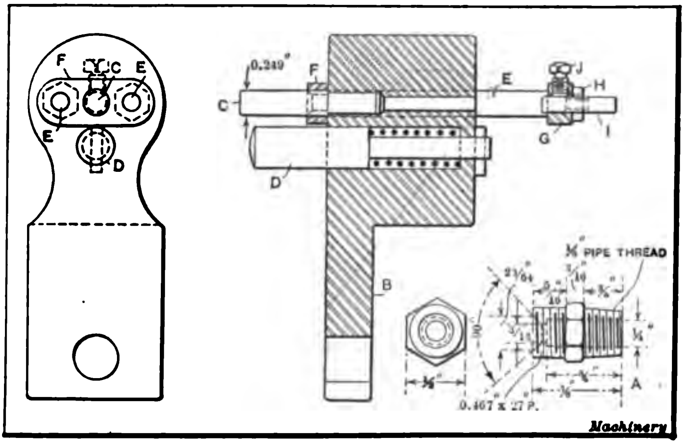


Fig. 27. A Work-holder of Special Design

Another type of work-holder, which was developed for a special piece, is shown in Fig. 27. This was for holding the threaded piece *A*, which, as can be seen, could not be gripped in a chuck of the type shown in Fig. 26 on account of the end which is placed in the chuck being tapered and threaded, thus preventing the chuck from gripping it securely. The work-holder consists essentially of a machine steel block *B* of the shape shown, which is fastened to the transferring arm by a cap-screw. This block is provided with a boss in which holes are drilled for the work-holder *C*, locating pin *D*, and ejecting pins *E*. The locating pin *D* comes in contact with the flats of the hexagon, and thus prevents the work from turning around on the work-holder *C*. The work-holder *C* is driven into the block *B*, and two studs or pins *E* pass through the block *B*, on the forward end of which is fastened an ejecting block *F*, forming a link connecting the two studs. The rear ends of these studs are also provided with a link *G* held to them by nuts *H*. An adjustable pin *I* located in the link *G* is retained by the set-screw *J*. This pin *I* comes in contact with the finger *R*, Fig. 22, and ejects the work after it has been burred.

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

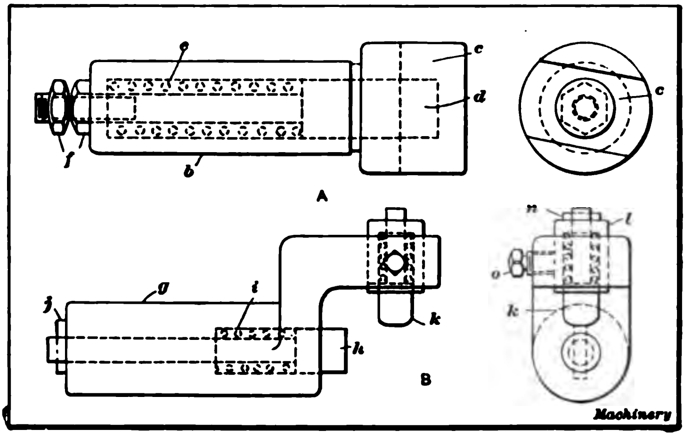


Fig. 28. Standard Chuck-closer, and Device for Locating Work on the Holder shown in Fig. 27

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 countersink *c* of the required shape and diameter is held in this holder by means of a set-screw bearing on the clamping block. The front end of the holder is counterbored to receive the work-holder chuck, and is also provided with two slots *d* which allow the chips to escape.

Another type of burring tool, and the work on which it is used is shown at *C*. In this case the burring tool is a combination holder and tool, being made to fit the hole in the burring spindle. It is also provided with a leader *e* to fit the work, which is turned down on the rear end to suit the holder and held in it by a set-screw as shown.

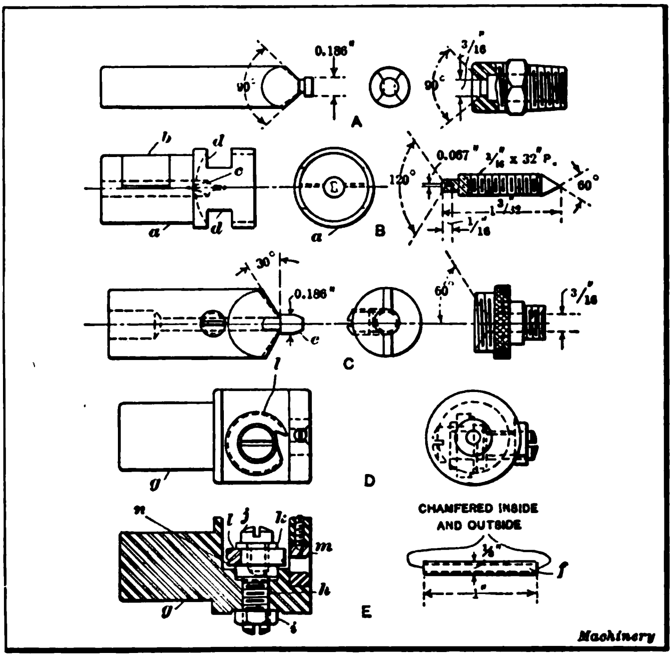


Fig. 29. Various Types of Burring Tools and Burring-tool Holders

Three views of still another type of burring tool and holder are shown at *D* and *E*. This holder and tool is used principally for chamfering the inside and outside of tubing as shown at *f*. The tool used is similar to a circular form tool except that it is of small size. It is held in the holder *g* on a stud *h*, which is threaded into the holder and is provided with a nut *i* for locking it in the desired position. The stud carrying the circular tool is slotted in the lower end, so that it can be adjusted, thus bringing the tool in the correct position to chamfer the inside and outside of the work.

The circular tool *l* is held on the stud by means of a screw *j* and washer *k*. The front end of the holder is provided with a bushing *m*, which fits the external diameter of the work and is held in place by a headless screw as shown. When designing this type of tool, it is 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.

Preliminary Course in Arithmetic

JIG SHEETS 1A TO 5A:—Whole Numbers: Addition, Subtraction; Multiplication, Division, and Factoring.

JIG SHEETS 6A TO 15A:—Common Fractions and Decimal Fractions.

Shop Calculations

Reference Series No. 18. SHOP ARITHMETIC FOR THE MACHINIST.

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.

Drafting-room Practice

Reference Series No. 2. DRAFTING-ROOM PRACTICE.

Reference Series No. 8. WORKING DRAWINGS AND DRAFTING-ROOM KINKS.

Reference Series No. 33. SYSTEMS AND PRACTICE OF THE DRAFTING-ROOM.

General Shop Practice

Reference Series No. 10. EXAMPLES OF MACHINE SHOP PRACTICE.

Reference Series No. 7. LATHE AND PLANER TOOLS.

Reference Series No. 25. DEEP HOLE DRILLING.

Reference Series No. 38. GRINDING AND GRINDING MACHINES.

Reference Series No. 48. FILES AND FILING.

Reference Series No. 32. SCREW THREAD CUTTING.

Data Sheet Series No. 1. SCREW THREADS. Tables relating to all the standard systems.

Data Sheet Series No. 2. SCREWS, BOLTS AND NUTS. Tables of standards.

Data Sheet Series Nos. 10 and 11. MACHINE TOOL OPERATION. Tables relating to the operation of lathes, screw machines, milling machines, etc.

Reference Series Nos. 50 and 51. PRINCIPLES AND PRACTICE OF ASSEMBLING MACHINE TOOLS.

Reference Series No. 57. METAL SPINNING.

Jigs and Fixtures

Reference Series Nos. 41, 42 and 43. JIGS AND FIXTURES.

Reference Series No. 3. DRILL JIGS.

Reference Series No. 4. MILLING FIXTURES.

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DROP-FORGING DIES AND DIE-SINKING

BY CHESTER L. LUCAS AND J. WILLIAM JOHNSON

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DROP-FORGING DIES
AND
DIE-SINKING

By CHESTER L. LUCAS and J. WILLIAM JOHNSON

CONTENTS

CHAPTER I

LAYING-OUT AND MACHINING OPERATIONS

The art of drop forging has worked a great change in the product of the blacksmith shop, both in regard to the quality and the quantity of the work produced. It has created a new branch of the business, and has enabled forgings to be employed in thousands of cases where this had formerly been impossible on account of the expense. Drop forgings are made to-day for nearly every branch of metal manufacturing, although the automobile industry has given rise to a much greater demand for them than has any one other industry. Drop-forgings are made that weigh but a fraction of an ounce, and others that weigh a hundred pounds or over. They are made from iron, steel, copper and bronze. It is needless to speak of the advantages of the operation of drop forging; economy of manufacture, strength, interchangeability, and the general appearance of the product, are all important factors.

The object of this treatise is not, however, to deal with the drop-forging operation itself, but to treat of the dies for this interesting work, and to consider some of the methods and tools used in the die-sinking. The good die-sinker must be somewhat of an all-round mechanic; he must have the knowledge of machine work of the machinist; the skill of the ornamental die-sinker, for sinking the irregular impressions; and a knowledge of steel working so as to know just how the hot steel will flow under the dies. The majority of the drop-forge die-sinkers of to-day have emanated from the ranks of the machinists and tool-makers, but the die-sinkers of to-morrow will be specialists whose thorough training has been acquired entirely in this one important class of work.

Classes of Drop-forging Dies

Drop-forging dies, like dies for the punch-press, are of several different types. Perhaps the most simple form of drop-forging die would be a pair of dies for producing a simple round forging, as, for instance, a gear blank. These dies would require a central impression turned in each of the dies of the pair. Before using the dies, a square plate of steel is worked under the hammer, drawing out a short shank at the side, and "knocking down" the corners. This roughly shaped block of steel is held by the shank and placed between the dies and thus brought to shape.

The most common form of drop-forging die, however, is the one in which there is a central impression to shape the forging, and a side impression, called the "edger," "break-down" or "side-cut," that helps to properly distribute the hot steel. To make clear the use of these two sets of impressions, a drop-forging die of this description may be likened to a drawing of the finished forging, in which the outline of the central impression would resemble the plan view of the forging, and the two halves of the edger would correspond to the side elevation of the forging. Of course this illustration is not literally correct, but it expresses the general idea. The edger is always on the right-hand side of the die, and the steel bar is struck first in the break-down, edgewise, and then turned and struck flat in the impression, alternating in this manner until the forging is "full."

There are also dies that in addition to the central impression and the edger are made with an anvil or "fuller," as it is sometimes termed. The anvil is formed in the dies at the left-hand side, and is used to draw out the stock previous to striking it in the edger or in the impression

Fig. 1. A Group of Untrimmed Forgings

itself. Dies with anvils are necessary in making forgings in which there is a considerable displacement of the stock. A double-ended wrench, which is thin in some places and very much thicker and wider in other places, may be mentioned as an example. The anvil consists of two flat-faced parts of the die, whose faces, called "fullers," come just near enough together to flatten the stock to such dimensions that when finished in the central impression very little stock will be left to be squeezed out as the fin. After the stock has been thus drawn out to roughly fit the impression, the forging is shaped in the usual way by means of the edger and the die impressions. A considerable number of large drop-forging dies require anvils. In making the dies for difficult forgings, there are often other special features incorporated in the dies, which will be more fully described later.

Fig. 2 shows the lower half of a set of dies with a break-down *A*, an anvil *B*, and the die impression *C*. The sprue is shown at *D*, the gate at *E*, the flash at *F*, and the shank at *G*. In Fig. 1 are shown several completed forgings before being trimmed. The center of the eyebolt is the only part that has been trimmed. The excess metal around the forging is called the "fin" and is removed in a separate operation, which may be done either hot or cold. If the forgings are to be cold-trimmed, as is the case with most small forgings, the dies are made with a cut-off to sever the forging from the bar when finished. If the forgings are to be hot-trimmed, they are severed in the trimming press,

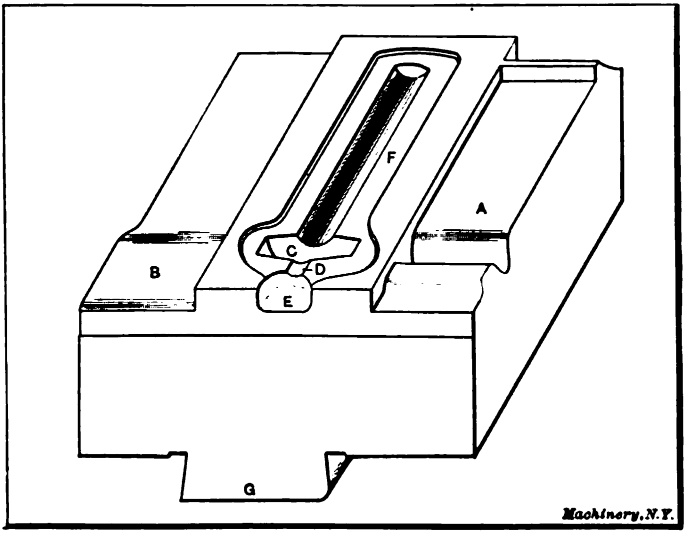

Fig. 2. The Lower Die of a Pair of Drop-forging Dies

and the forging dies will need no cut-off. Fig. 3 shows a group of small finished forgings.

Thus far we have considered only dies with one impression, but in dies for first-class forgings, especially when there is a large number to be made, two impressions are provided, the forming and the finishing. The forging is nearly completed by the edger and the forming impression (and anvil if needed), and finally struck several blows in the finishing impression to bring it up to size and finish it. Thus the finishing impression is saved the severe duty of completely forming the forging, and hence the dies last longer. On small and medium-sized forgings these two impressions are placed side by side in the same die, but if the forging is large, the finishing impression is made in a separate set of die-blocks and set up in a hammer set close to that which forms the forging. The forger uses both hammers to get out the work in such cases. It is seldom that more than two impressions are cut in the same set of dies, but if the piece is small and the number of pieces to be forged great, it is often advisable to make the sets of dies with two or more finishing impressions in addition to the forming impression. If this is done, the die has a longer life, for after one of the finishing [illegible] drawing of the finished forging in which the [illegible] impression would resemble the [illegible] halves of the edger would correspond to the [illegible]. Of course this illustration is [illegible] the general idea. The edger is always [illegible] and the stock that is struck first in the [illegible] and struck flat in the impression after [illegible] the forging is [illegible]

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impressions gives out by spreading or "checking," there is still a good finishing impression left.

In addition to these different styles of drop-forging dies, the dies for trimming the fin from the forging must be taken into consideration. As already indicated, trimming dies are of two classes: those for trimming the forging while it is hot, and those for trimming the forging after it is cold. The making of drop-forging dies for forgings of other metals than steel or iron involves the use of special methods. This phase of the subject will be treated later.

Information Required by the Die-sinker

Before the die-sinker begins making the die, he should be given certain information about the job he is to do, in order to make a set of dies that will give satisfactory results. As a general rule, he is furnished with either a drawing or a model of the finished part, or, what is most satisfactory of all, with a sample forging. He must know what finishing operations the forging is to pass through, so as to allow enough stock for machining, and he must know of what metal the piece is to be made, so as to cut the dies large enough to allow for the shrinkage of the metal.

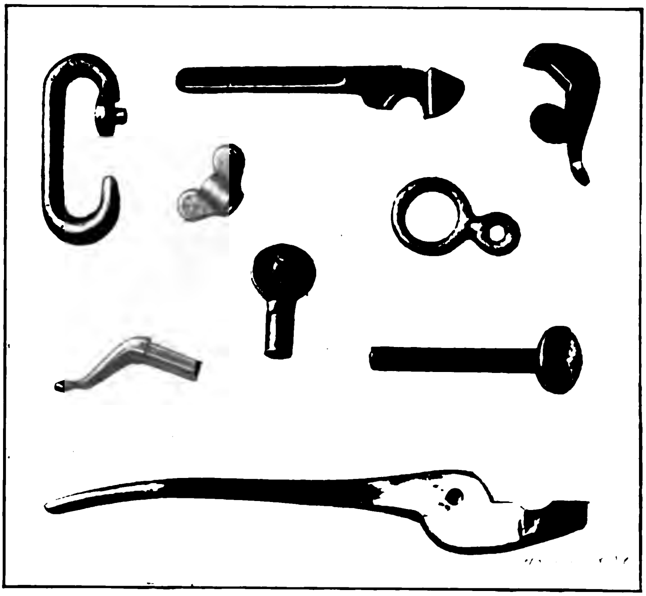

Fig. 3. A Number of Small Finished Drop Forgings

With this information supplied he must decide upon a number of other points that are largely a matter of judgment on his part—points that have to do with the successful working of the dies. He must decide, first, whether to make the set of dies with a forming impression in addition to the finishing impression; second, the way in which to "face" the impression on the die-block so as to be able to use the best form of edger; third, whether to include an anvil in the dies; and fourth, the type of hammer or hammers the dies will be used in, so that the dies are made in blocks of the proper size. In making the trimming dies he must also decide whether to trim the forging hot or cold. With these points decided, he is prepared to start the making of the dies.

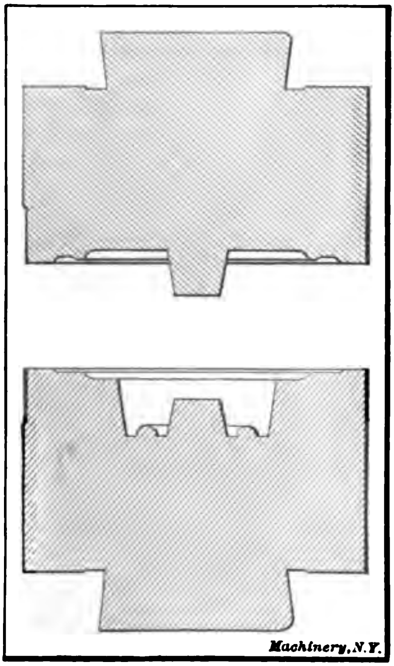

Fig. 4. Drop-forging Dies of a Type that should be made of High-carbon Steel and not hardened

Steel for Drop-forging Dies

Open-hearth crucible steel is the material from which nine-tenths of all drop-forging dies are made; a 60-point carbon steel is used for most of the dies. In some cases, however, steel as low as 40-point carbon and as high as 85-point carbon is used, but few shops use anything but 60-point carbon steel for the general run of work. If a low-carbon steel is used, a special hardening treatment is required, which outweighs any saving in the price of the steel. Of course, the high-carbon steels make good dies, but except in special cases, there is no necessity for using so high-priced a steel. The average 60-point carbon steel die, if properly hardened, should last for from 15,000 to 40,000 forgings and sometimes as many as 70,000 forgings are made from one set of dies.

In making dies for large forgings it is often considered advisable to use 80-point carbon steel for the dies, and not to harden them. This obviates the danger of "checking" or cracking in hardening, and the steel, unhardened, is hard enough to resist the tendency to stretch.

In Fig. 4 is shown, in section, a pair of drop-forging dies for forging automobile hubs. Dies of this design should be made of high-carbon steel and left soft on account of the projecting ring in the bottom of the impression which would be likely to break off if the die were hardened. A steel fairly high in carbon should always be employed for dies that are to be used for making forgings from tool steel or other hard steel. When making forgings for very thin parts that cool quickly while being forged, it is usually preferable to use tool steel for the dies, in order that they may be hardened to a depth sufficient to withstand the tendency of the dies to "dish." A drop-forging die or any die used in the drop hammer, is said to be "dished" when the force of the blows it receives causes the central part of the face to sink beneath the level of the remainder of the face. This condition results in forgings or stampings that are too thick in their central parts. Dishing is usually traceable to a low grade of steel or to improper hardening.

Preparation of the Stock

The best method of preparing the die-blocks is to plane the stock in lengths of from six to eight feet, after which it may be cut to any lengths required by the sizes and shapes of the forgings for which the dies are being made. Occasionally a pair of die-blocks must be planed for a special job, but it is quicker and cheaper to plane them in lengths when the work warrants it, although many shops do not take advantage of this. The steel may be obtained from the mills in ordinary sections suitable for dies six or eight inches in height, which are the sizes mostly used. At the time of planing, the dies are

Fig. 5. Laying out the Dies: Transferring a Line from One Die to the Other of a Pair

"shanked" with the proper bevel and height of shank, to agree with the system in vogue in the shop where the dies are to be used.

The die-blocks are planed on the front and left-hand sides for a distance of two inches, or a little less, from the face. These two cuts are merely "skin chips," and are perfectly square with each other and with the shank of the die; their purpose is to furnish faces from which the impressions may be laid out. The use of these "matching-sides" is plainly indicated in Fig. 5. The reason for using the left side is because the edger is always to the right, and in cutting away for this part of the die, the lay-out face would be destroyed. This would make it impossible to work from that side afterward, in case it should be necessary to make changes in the impression. On the left side the anvil is formed, but this interferes but little with the working face that has been planed, because the anvil occupies but little space, at least as regards depth. In planing these working faces, care must be exercised to have the faces perfectly parallel with the shanks of the dies; otherwise the two halves of the forging will appear to be twisted with relation to each other, and to correct the error it will be necessary to "shim" the dies—a practice that should be permitted only as a last resort.

There are various precautions taken to prevent blunders in the setting up of the dies. The forger usually lines up the dies by matching the sides of the die-blocks. On dies whose matching faces have been cut away, the die-sinker usually cuts a deep "nick" from one die to the other, while they are in alignment. The shank of the upper die-block is milled with a "half-hole" to fit the familiar "dutchman" in the hammer of the drop-press.

Laying out the Dies

We are now ready to take up the work of laying out and cutting the impressions in the dies. The laying-out of drop-forging dies is totally different from the laying-out of blanking dies, this being due principally to the different allowances that must be made for shrinkage, draft and finish. The allowance for shrinkage is an important one. In order to properly understand the considerations to be taken into account, it is necessary to understand the trimming methods employed for removing the fin. Small forgings are invariably completed, and the fin trimmed off after they are cold; such forgings are said to be cold-trimmed. Larger forgings are trimmed hot and then struck once or twice to finish and staighten them, as it is probable that the trimming has somewhat distorted them. At the time of the last blow, the forging has cooled to a low red heat. In making dies for small cold-trimmed steel forgings, the proper allowance for shrinkage is 3/16 inch to the foot or 0.015 inch to the inch. Such forgings are completed at a bright red heat, and the rate of shrinkage is great.

In making dies for hot-trimmed steel forgings, which are of medium and large size, the proper allowance for shrinkage is 1/8 inch to the foot or 0.010 inch to the inch. Hot-trimmed forgings, receiving the finishing blow while relatively cold, shrink a smaller amount than forgings that are cold-trimmed. These proportions hold true for all dimensions of the die impression, whether they be depth, width or length. In making dies for forging bronze or copper, the same principles apply, and the rate of shrinkage for cold-trimmed forgings is 3/16 inch to the foot, and for hot-trimmed forgings 1/8 inch to the foot, or practically the same as for steel.

The Draft Allowance

It would be very convenient if we could sink forging dies with sides perfectly straight, the same as a die-casting mold, but in die-sinking this is impossible, as the forging would stick in the die. To overcome this tendency, we employ "draft," just as the pattern-maker does. The amount of draft given a drop-forging die varies from 3 degrees to 10 degrees. If the die is for a thin regular forging, like an oval treadle plate, 3 degrees is ample, but if the forging die is deep, with narrow ribs which are apt to stick, at least 7 degrees is necessary. Should the die be for forging a piece that is ring-shaped or has a ring in its make-up the central plug that forms the interior of the ring will require a draft of 10 degrees, because, as the forging cools while being worked, it tends to shrink together around the plug, and if the draft is insufficient, it will stick in the die. With the above exceptions, however, the majority of drop-forging dies are cut with a 7-degree draft. For convenience in laying out, it is well to remember that a 7-degree taper equals practically a 1/8-inch taper to the inch, and a 10-degree taper, 3/16-inch to the inch.

The Allowance for Finish

By "the allowance for finish" is meant the additional metal that is "put on" the forging at those places that are to be machined. Very often it happens that there is no finish required on the forging, in which case, of course, there will be no allowance. Usually, however,

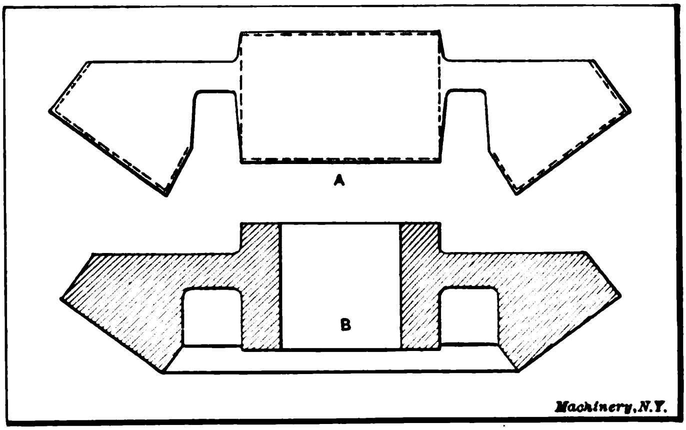

Fig. 6. Templet with Shrinkage, Draft and Finish Allowances added, used in turning out the Impression in a Die for a Bevel Gear Blank. B shows the Finished Gear Forging after being machined

there are bosses to be faced off or other places that require machining, and in such cases the forging is left 1/32 inch oversize at these points.

Scribing the Outline

In laying out the dies the first step is to copper the faces of both the upper and lower die, after which center lines should be scribed from the two matching sides of the die-blocks. If the forging is irregular in outline, it is advisable to make a templet. Not only will the templet be useful in laying out the two impressions, but if the forging is to be hot-trimmed, the templet can be used in laying out the trimming die and punch. The use of a templet insures that the two dies will match perfectly, for after laying out the lower die, the templet is simply reversed and used for the upper die. The templet should be made of thin sheet metal, and if brass or zinc is used, it may be sawed out with a band or scroll saw and then filed to the line in the usual way. Fig. 6 shows at *A* a templet for a bevel gear forging, with the various allowances made, ready to be used in laying out the impression; *B* is the finished gear blank. First the outline of the finished forging is laid out, then the draft allowance is added, and at those points that must be machined, allowance is made on the templet for this purpose. In laying out the set of lines for the shrinkage allowance, a shrink-rule is used, either a ⅛ inch to the foot or a 3/16 inch to the foot, as the case may require.

Frequently it happens that the outline of the forging at the parting line is simple and regular, as, for instance, in the case of an eye-bolt forging. In the case of such a simple shape, there is no necessity for a face templet, as the outline may be laid out from the two matching sides of the dies by means of a square and dividers. In order that the outlines of the impressions on the two blocks may come in perfect alignment, two and sometimes three combination squares are used in locating the templet on the blanks, in case a templet is used. The templet is placed in its proper position on the face of one of the die-blocks, and a combination square is set from each of the matching sides to the edge of the templet. With the templet against the ends of the square blades, the outline is scribed; then, without changing the blades of the squares, they are placed in corresponding positions on the other die-block, thus locating the templet (now reversed), and the outline is scribed on this die. The combination square also affords a good way for transferring lines from one die to the other. Fig. 5 shows the die-sinker transferring a measurement from one die to the other die upon which he has started work. After the outlines of the two impressions are scribed on the faces of the die-blocks, they should be either lightly prick-punched at intervals along the lines, or they should be traced with a small, sharp chisel, using the chisel after the manner of a punch, and moving it after each tap of the hammer so as to obtain a clear, deep, continuous line.

In planning the lay-out of a drop-forging die, there are several points that must not be overlooked. The heaviest end of the forging should always be at the front of the die-block, as illustrated in Fig. 2. This makes the forging easier to handle while being forged and still on the bar, and it also permits the use of a liberal-sized sprue. In selecting a die-block and laying out the impression, there should be at least 1½ inch left all around the impression from the outside edge of the block or from any part of the die, such as the edger, anvil or forming impression. If the forging has a hub or other projection that extends some distance from the body of the forging on one side, as in the illustration at the center of Fig. 3, the upper or top die should contain this deeper impression. This is an important point, for every die-sinker and drop-forger knows that it is easier to "shoot" the metal up than down; just why it is so, however, is difficult to understand.

Sinking the Impression—The Machine Work

The work of sinking the impressions in the dies may be roughly divided into two parts: the machine work, and the hand work. In the machine work, the lathe and the vertical milling or die-sinking machine are the two principal machine tools used. Generally speaking, if there are parts of the impression that can be cut out on the lathe, it is good policy to do this work first, although there are exceptions to this rule which will be mentioned later. The advantage of doing the lathe work first lies in the fact that a large amount of the stock is removed quickly and uniformly, so that the die-sinker has a better chance to start tne milling cutters.

The best method of holding the dies for the lathe work is by means of a special bolster, bolted to the faceplate. The bolster is planed to

Fig. 7. The Pratt & Whitney No. 2 Die-sinking Machine

take the shank of the die-block, which is held in place by a key. This method has certain advantages over the practice of holding the die-block with set-screws, in that the block may be more easily made to run true, and there is less danger of the die-block working loose. Much time may be saved in the turning if the lathe is equipped with a compound rest. for the draft may then be bored out by swinging the rest over the required number of degrees. If the lathe work is other than very plain, it is necessary to make use of templets. In turning out the impression for a bevel gear blank, for instance, the templet for the turning would appear as shown at *A* in Fig. 6. A study of this templet will give a good idea of the allowances for draft, shrinkage and finish. The lines of the finished gear show a straight hub, that is, there is no bevel on its sides. In cutting the impression, however, these lines must be given a draft of 7 degrees to prevent the forging from sticking in the dies. The top and bottom of this hub, as well as the face where the teeth are to be cut, will of course be machined; therefore 1/32 inch is added to the templet at these places. The shrinkage allowance is taken care of by laying out the dimensions of the templet with the 1/8 inch to the foot shrink-rule, as the forging will be trimmed hot.

The Die-sinking Machine

The die-sinking machine is by far the most important asset of the die-sinker's equipment. At the present time, most die-sinking shops are equipped with machines of the Pratt & Whitney make—the No. 2 machine for the small and medium work and the No. 3 for the heavy

Fig. 8. Special Cutter Chuck for the Die-sinking Machine

work. These two machines will take care of any dies to be made, and in small shops where but one die-sinking machine is installed, the No. 2 size will be found sufficient, if the work is not very large. The illustration, Fig. 7, shows the latest model of the No. 2 machine. The dies are held in the vise of the machine, the shank of the die-block furnishing a good gripping surface. The cutters are held in a spring chuck, that, by substituting different collets, will accommodate cutters made of stock from 1/4 inch to 1 inch diameter. This chuck, shown in Fig. 8, and its parts in Fig. 9, is made in three pieces—the shank *A*, which is recessed to take the split collet *B*, and the sleeve *C*, which has an internal taper bearing surface. As the sleeve is screwed onto the shank, the split collet is compressed, drawing together upon the cutter without throwing it out of center. The sleeve is tightened by the aid of a spanner wrench, and no trouble is experienced from the cutter slipping in this style of chuck.

Cutters for Die-sinking

The subject of cutters for die-sinking is a very important one, for neither good nor fast work can be done with poor cutters. The very best of roughing cutters can be made from "stub ends" of Novo drills, and nearly every die-sinker takes advantage of this fact. These short drills are ground ball-pointed on the cutting end, given clearance, and the center ground out as shown at *D* and *E* in the illustration, Fig. 9. This kind of cutter is so easily and quickly made, and stands up so well in "hogging out" the stock, that it does not pay to use any other kind.

For finishing, the cutters are made with three or more flutes, so as to get smooth surfaces. Finishing cutters must be provided in a large variety of shapes to take care of the various forms in the dies being cut. At *F*, *G*, *H* and *I* in Fig. 9 are shown good examples of finishing cutters, most of which are made for finishing dies with a draft of 7 degrees; at *J* and *K* are shown special cutters, the former for cutting very narrow grooves, and the latter for shallow dies with a draft of 2 degrees.

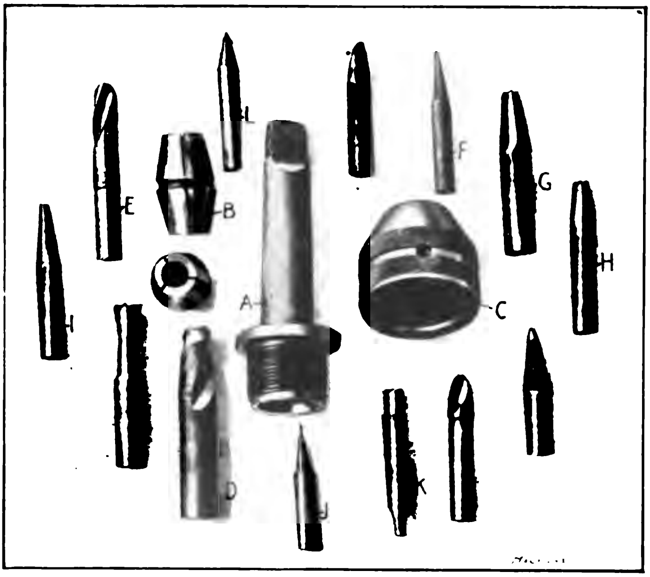

Fig. 9. Chuck Parts and Cutters for the Die-sinking Machine

The die-sinker is guided in the milling by the lines laid out on the face of the die-block and by the index on the pilot wheel of the die-sinking machine, the scribed lines giving the outline, and the index of the pilot wheel taking care of the depth of the various parts of the impression. Except when using special cutters like hub and forming cutters, no oil is used on the tools. The speeds at which the cutters should work vary with the size and style used. If the cutter is a small one, like that shown at *J*, Fig. 9, the speed may be much higher than would be used with a stout cutter like that shown at *G*. Of course, special forming cutters that are sometimes as large as 3 inches in diameter must run very much slower, and the use of lard oil is

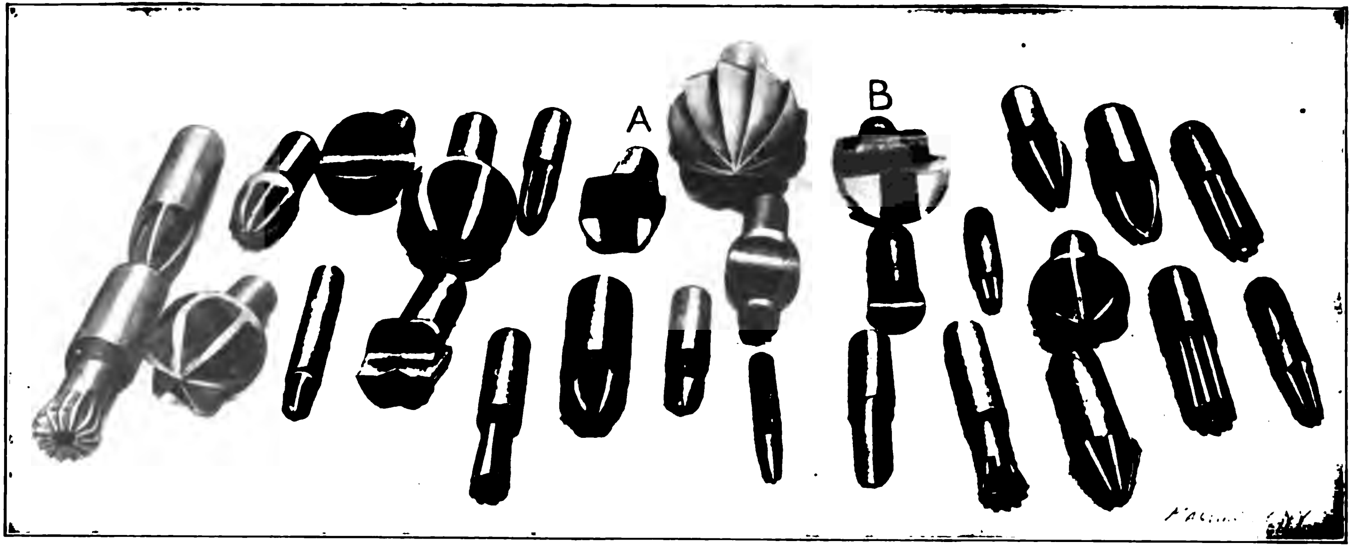

Fig. 10. Hub, Forming and Miscellaneous Cutters for the Die-sinking Machine

advisable. Fig. 10 illustrates some of these hub and forming cutters, and also shows a large variety of finishing cutters of various shapes and degrees of draft.

All circular parts of the impression are not bored out in the lathe, and indeed it is rarely advisable to bore out any parts under 3 inches in diameter, especially if they are deep. These small circular depressions are best taken care of by special forming cutters or by the circular attachment on the die-sinking machine.

A great many forgings for machine parts have bosses in which must afterward be drilled a central hole. It is not practical to forge the part with the hole, but it is a great help to "spot" the forging, and thus obviate the necessity of using a jig for the following operation of drilling the forgings. To produce the projection in the die for this "spot," a hub cutter is used. (See *A* and *B* in Fig. 10.) On account of being milled out at the center, and relieved, the cutter will leave a cone-shaped projection in the bottom of the impression that will produce a deep countersink in the boss of the forging.

It is very essential that a large cutter should be correctly located in relation to the outline of the impression before being fed into the die. In order to check its location, it is well to scribe, from the same center, a circle one or two inches larger than the one that is used for obtaining the outline. On this outer circle, four points, equidistantly spaced, should be prick-punched. After lightly entering the cutter, the outline should be tested with dividers from these four points.

The Circular Attachment

The circular attachment on the die-sinking machine is a valuable feature in milling the impressions. By its use much circular work may be done that would be awkward to bore out in the lathe, and short arcs

Fig. 11. Using the Circular Attachment

may be cut far quicker than in any other way. When this is used, a straight pointed rod is held in the chuck in place of a cutter. The machine table is adjusted with the two feed handles until the indicating marks, placed on the sides for this purpose, are in line. The table is lowered and the die-block located in the vise so that the center point of the arc to be milled is directly under the indicator in the chuck. Thus located, the table may be moved off center far enough to bring the cutter to the part of the impression that is to be milled, and the line followed by using the feed provided. In Fig. 11 the die-sinker is cutting the impressions for forming the eye of a chain hook, using the circular attachment in doing so. The old-style method of cutting these curves, used when the die-sinking machines were not equipped with circular attachments, was to loosen the check-nuts of the swivel vise, and after moving the die to the proper distance from the center, clamp a long steel bar to the vise, and rotate the vise by hand. This method is here mentioned for the benefit of those whose die-sinking equipment is not of modern design.

Throughout all the machine work on the impressions, it must be remember that as little stock should be left to be taken out by hand as is possible, for not only is hand work slower, but its quality can never equal machine work that is properly done. To this end, the finishing cutters should be run over the last cut two or three times, so as to get the smoothest possible surfaces. The heavy milling should

Fig. 12. Roughing out the Impression

be done with the roughing cutter, held in the chuck close to the cutting point, after the manner illustrated in Fig. 12. If, after the finish milling, the surfaces are smooth and the line is "split," there will be little left to be done by hand save the corners and possibly a few irregular shapes that cannot be milled. In the final milling cut for finishing to correct depth, exact dimensions may be obtained by setting the cutter so that it just touches the surface of the die. and then moving the index on the pilot wheel to zero and raising the table to the required dimension, as indicated by the reading of the index.

CHAPTER II

HAND OPERATIONS

The really difficult work of die sinking is the hand work that is necessary to finish the impression; at least this part of the work requires more patience and manual skill than the machine operations connected with die sinking. Some impressions are full of corners and irregular places that must be chipped out and smoothed by hand, nearly every job having a number of such places. These places must be chipped, scraped, riffled and polished, and to facilitate this finishing, the die is held in the ball vise shown in Fig. 13. This useful device, almost too well known to be described, rests on a pad of leather, which in shop practice is made by coiling up a short length of two-inch belting, and riveting it at intervals. By the use of the ball vise, the die

Fig. 13. Ball Vise used in Holding Dies for Hand Work

may be held at any desired angle or position, and will remain where put with sufficient stability to resist any ordinary chipping or filing.

Chisels and Chipping

Die-sinker's chisels are made preferably of Jessop's steel, but any good tool steel will do in the absence of Jessop's. The stock should be hexagon or octagon, and forged out to the shapes best suited to the work. Two or three dozen shapes and sizes of chisels are necessary for the different shaped places that must be chipped out in the general run of work. The most useful shapes are the round and flat varieties, some of which are shown in Fig. 14. The round variety embraces a great many different curves. The flat varieties should run from 1/32 to 1/2 inch in width. After hardening, the chisels should be drawn to a light blue, this temper being the same as that given the ordinary cape chisel, and which will be found a good ordinary temper. The die-sinker's chipping hammer, illustrated in Fig. 15, is flat-faced and double-ended, so that either end can be used. To aid the die-sinker in chipping out parts of the impression that are to be the same

Fig. 14. Chisels and Scrapers used in Die Sinking

depth, depth gages like those shown in Fig. 16 are used, and occasionally the micrometer depth gage will be found indispensable; but there are few jobs that require such accuracy. In Fig. 16 are also shown the two shrink rules that are used in laying out the die impressions.

In chipping out the stock from the corners and other places that cannot be milled, there are a few general rules that should be fol-

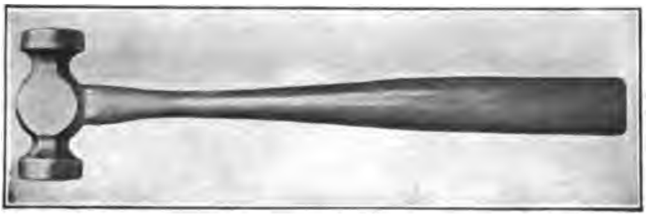

Fig. 15. Die-sinkers' Chipping Hammer

lowed. It is always advisable to chip down or away from the outline of the impression, for by so doing there will be no danger of breaking out "chunks" at the ends of the cuts. In using flat chisels care should be taken to leave as little work for the corners to do as possible, for the corners are the weakest parts of flat chisels. Oil should be used sparingly on the cutting edges of all chisels. For convenience in picking out the different chisels, it is a good plan to keep them, points up, in round cans or boxes. In all chipping, the die-sinker should "make haste slowly," taking light cuts and many of them, frequently trying the templets and depth gages so as to be sure he is not taking out too much stock.

Fig. 18 shows the die-sinker chipping out what appears to be a simple part of an impression, but in reality it is an awkward place, being the oval end of the impression for a chain shackle. The second impression is the forming impression; both of them have been milled

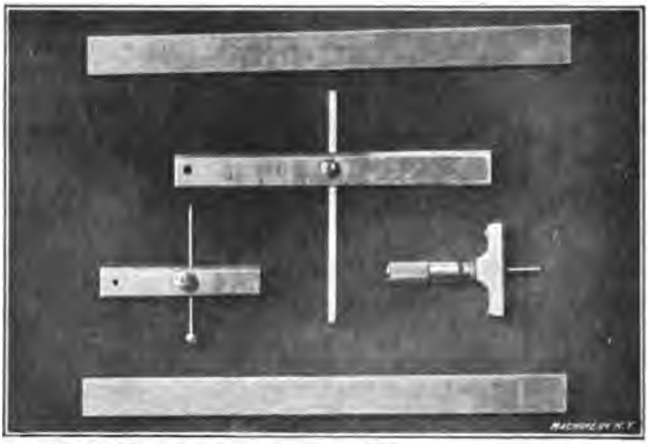

Fig. 16. Shrink Rules and Gages used in Laying out and Sinking the Impressions

out as much as possible and are now being cleaned up by chipping, after which scraping and riffling will follow before the rest of the im-

Fig. 17. Scraping Out the Impression

pressions are milled. In most cases, however, it is best to complete the milling while the die is on the die-sinking machine.

Scraping, Riffling and Polishing

The idea of the chipping is to remove as much stock as possible from parts of the impression that cannot be milled or otherwise machined. Of course, it is impossible to finish the die by chipping alone; therefore, after the bulk of the steel is taken out by milling and chipping, the impression must be smoothed by scraping and riffling.

Scrapers are of several different types. Nearly every mechanic is familiar with the three-cornered and half-round scrapers, and both of these tools are used at times in scraping out a die; but by far the most useful kinds of scrapers are those made of square and half-round straight sections. These scrapers are short, made to cut on the end only, and "pare" out the stock very quickly. As shown in Fig. 14, these tools are fitted into short, round handles that fit the hand snugly.

Fig. 18. Chipping Out the Die

After grinding and stoning the edge of the scraper, the corners are slightly stoned off so that there will be no tendency to "dig in." By the use of the scrapers, the high points left by the chipping operation are reduced, and the surface of the impression smoothed. Fig. 17 shows the method of holding the scraper; in this instance the die-sinker is scraping out the oval end of the shackle impression, the milling and chipping having been finished. Scraping is not intended to remove much of the stock, but is more of a finishing operation. By scraping alternately in different directions, the impression is kept free from grooves and ridges. Should there be any chatter marks left by the milling operation, they may be taken out by scraping.

As soon as the die impression has been finished as regards dimensions with the scrapers, the surface may be carefully smoothed by riffling. The rifflers, or small bent files, may be obtained in a large variety of shapes, sizes and cuts. As the illustration, Fig. 19, shows, the riffler is held lightly in the hand and is worked back and forth over the surface to be smoothed. In other words, it is filing on a small scale. A collection of the most useful of the different rifflers is shown in Fig. 21. The most common form is the "spoon" riffler, which comes in many different grades of curves, its name describing its shape perfectly. By turning the riffler while using, many different kinds of curves may be obtained, so that there are few spots in a die that cannot be reached with a spoon riffler.

Next in point of usefulness comes the flat riffler, which is made in different shapes and widths to take care of the flat surfaces and panels in the impressions. Other styles are the hook riffler, the knife riffler and the round taper riffler. As with scraping, the rifflers must be worked over the surface with ever-changing directions to prevent the formation of grooves and ridges.

As a final finish to the impression, emery cloth, wrapped around a file or a piece of wood, should be applied to every part of the impression, until the surface is perfectly smooth and free from imperfections, using first the coarse and then the fine emery cloth. Often the shape of the impression is such that it can best be polished with emery and oil used on the end of a stick of wood. The emery will imbed itself in the wood as it does in a lap. The reason for this finish is first to get a good surface on the forging and second, to assist the forging to come easily from the die while being worked.

Types and Typing

Frequently it happens that in a drop-forging die there are irregular bosses or ends that cannot be finished on the die-sinking machine, and that are particularly difficult to chip out, scrape and riffle to a finish.

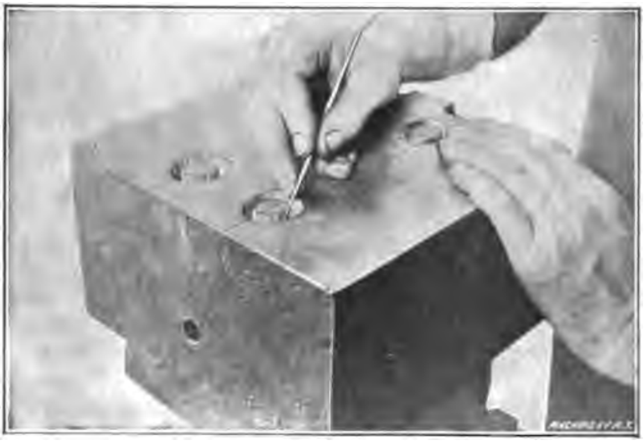

Fig. 19. Using the Riffler—Smoothing the Impression

Usually these places are deep and narrow, and generally it happens that there are two of these awkward places to cut out, one in each of the two dies. It is customary to take care of such places in dies by means of typing.

A "type" is a punch or small block of steel whose end is shaped exactly like that part of the forging that is difficult to cut in the die. Types are hardened and drawn to a purple temper. The part of the die that is to be typed is milled and chipped out to as near the outline and depth as is considered safe. The face of the type is then rubbed lightly with Prussian blue, placed in the impression, and with a piece of copper or brass on its top, the type is struck hard into the impression with a hammer. This operation leaves the high places with a blue facing.

These high places are next chipped away, care being taken not to go too deep, and the process is repeated. If properly done, the typed part of the impression will gradually assume the shape of the type and at last, by striking in the type a number of times, the impressions will take on the smooth finish of the type and be ready for riffling. If the part of the impression to be typed is cylindrical, the type may be

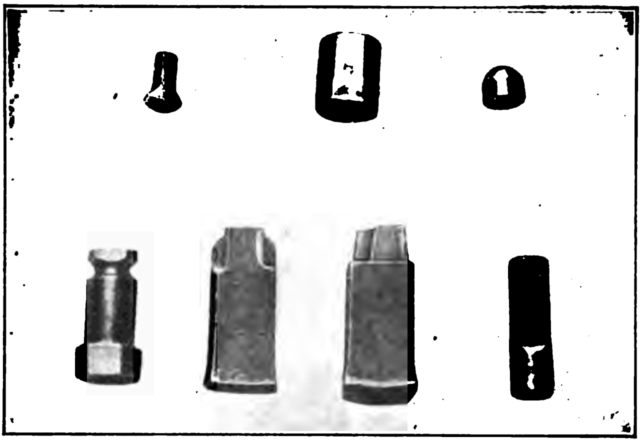

Fig. 20. A Collection of Turned and Milled Typing Tools

turned up in the lathe; but if not, it must be milled and filed to shape. Fig. 20 shows a few types for different die sections, some of which have been turned in the lathe.

In making types for shaping the impressions in dies for forgings whose ends or hubs are shaped like the forging shown in Fig. 22, there

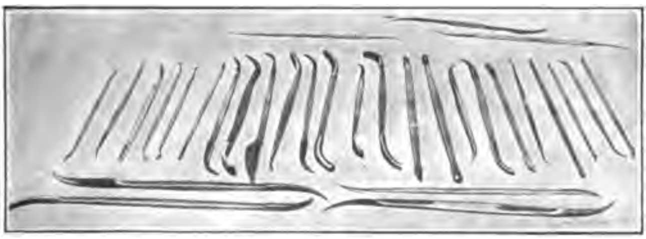

Fig. 21. Die-sinkers' Assortment of Rifflers

is a very convenient rule to bear in mind. The rule is this: Shape the sides of the type with a curve, the radius of which is equal to twice the diameter of the hub. This rule insures the proper amount of draft on the impressions, and as this form is very commonly used on bosses at ends of rocker arms, levers, etc., the application of the rule is very frequent.

While speaking of the machine work on the die impression, it was stated that there were exceptions to the rule of doing all machine work on the impressions first. In typing, we find one of these exceptions.

Let us assume that we have a die to sink for the forging shown in Fig. 23. The impression would consist essentially of a ring with four projecting bosses that must be typed. If the ring were turned first, trouble would be experienced in typing the four bosses, as the type would have a tendency to slide into the ring at every blow. With such a proposition, it is far better to mill out and type the bosses before doing the lathe work, in order to save time and trouble in the typing.

Lettering

When the forging must show lettering, the dies are usually stamped at the bottom of the impression with the desired letters. This produces raised lettering on the forgings. The stamps used are not the usual sharp-line stamps in common use in the machine shop, but are made deep and with a flat face, so as to give body to the letters on the forging.

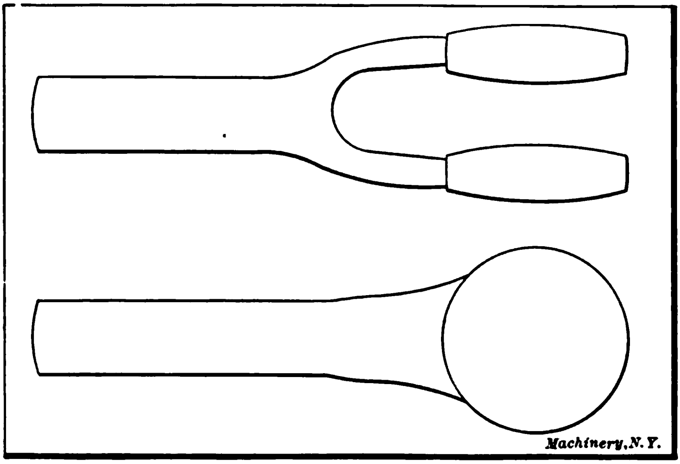

Fig. 22. A Forging to which the Rule for Making the Type Applies

In putting in the lettering, care must be used in the spacing, for if too closely spaced, there is danger of the stock between the letters breaking out. To space a word properly, the central letter of the word should be stamped lightly in the center of the space to be lettered, and from this central letter the rest of the word is added on either side. If the letters are extra large in size, it is advisable to mill or chip out the letters after they have been lightly stamped in the die, after which they may be put in to the full depth without a large displacement of the steel.

The Gate and Sprue

In ninety-nine cases out of one hundred, a drop forging is made complete while still a part of the bar from which it is started and afterwards severed. To hold the forging while being worked, a sprue must be provided. The sprue is the connecting-link between the bar of rough steel and the forging. To form the sprue a channel is cut from the front end of the impression to the edge of the die-block. The size of the sprue should be governed by the weight of the forging, and in all cases it should be no heavier than is necessary to support the forging while being worked and trimmed.

The gate is an opening in the front of the die to receive the bar stock, and is made large enough to admit the bar without forging or crushing it at all. Fig. 24 shows the operation of cutting the gate, and also illustrates the way in which the matching sides are planed. The second gate in the die is, of course, for the forming impression. The ⅝-inch hole shown in the front of the die-block is for the purpose of lifting the die; by placing therein a short bar of ⅝-inch rod, and another bar

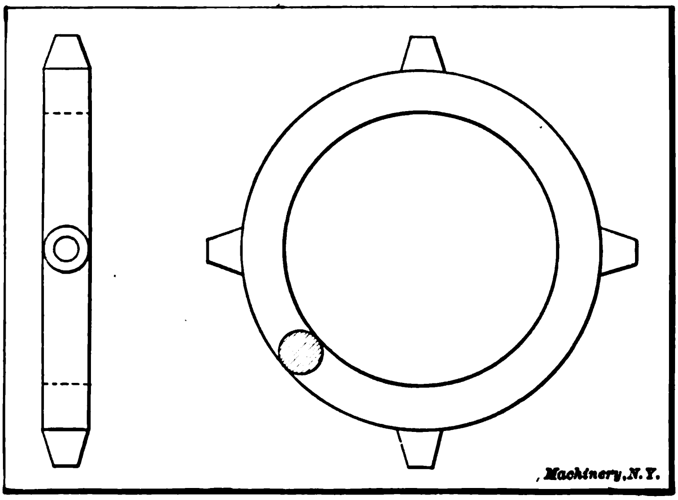

Fig. 23. A Forging for which the Die Impression should be milled and typed before Turning

in the hole on the opposite side, the block may be handled easily either by hand or with a chain fall.

Taking Leads or Impressions

For the purpose of seeing just how the forging will look when it comes from the dies, as well as to check up the shrinkage allowances and see if there are defective places in the impression, it is customary to take a lead proof from the finishing impressions of the upper and lower dies after they have been completed. Frequently the machinist would like to be able to use a "putting-on" tool in his work, especially after he has read his micrometers; with the die-sinker it is very easy to put on stock if the forging needs it, by simply making the dies a little larger at the desired point. A lead will show up any places on the forging that may need more stock; also, by weighing the lead, a good idea of the weight of the finished forging may be obtained.

Roughly speaking, the finished forging will weigh two-thirds as much as the lead proof. The shrinkage of lead is practically the same as that of steel, so that the finished forging will measure very nearly the same as the lead. In the case of dies for eye-bolts, etc., this rule

Fig. 24. Milling the Gate

Fig. 25. Milling the Flash

Fig. 26. Milling the Breakdown

must be disregarded, because the plugs in such dies that form the central openings will hold the lead from shrinking naturally, whereas the forging shrinks most after it has been taken from the dies. Fig. 27 shows a group of leads from dies for eye-bolts, hooks, etc.

In taking the lead, the impressions in both upper and lower dies are cleaned out, dusted with powdered chalk, and the dies stood on end, after which the dies are clamped together with a large C-clamp, care being taken to have the matching sides perfectly in line with each other. The lead is now heated, care being taken not to burn it, and is poured slowly and evenly into the dies until it fills the impression and gate. As soon as the lead has cooled, the dies are unclamped, and the lead removed and examined. After making any changes that the lead shows to be necessary, another lead should be taken to make sure that the impressions are correct. Fig. 28 illustrates the method of pouring a lead.

The Flash

In theory, the amount of the forging metal in the die impression when struck should *just* fill the impression—no more and no less. This is, of course, impossible in practice, although the dies are made to come as near to this ideal as possible. As a matter of fact, there

Fig. 27. A Group of Lead Proofs

is always some stock that must be disposed of, after the impression is full; but if the dies are well planned and the forging is well done, there will be but a small amount of extra metal, provided that the right size of stock is used. This excess stock that is squeezed out is called the "fin."

To take care of this metal that is crowded out of the impression, each die is relieved around the impression by milling a flat, shallow recess, about 1/64 inch deep and 5/8 inch in width all around the impression. These dimensions are for dies of average size; in larger dies, the recess or "flash" as it is called, would be a little deeper and wider. Both upper and lower dies are flashed in this manner. In addition, the upper die is back-flashed; that is to say, there is a deeper recess, sometimes called the "gutter," milled around the impression at a distance of 1/4 inch from the impression at every point. This back-flash is 3/64 inch deep, and acts as a relief for the excess metal after it has squeezed through the flash proper. Only the finishing impression is provided with flash and back-flash. The fin is trimmed from the forging by means of trimming dies, when the forging is either hot or cold, depending on the size and shape. Fig. 25 shows the operation of milling the flash.

The relative positions of the flash and back-flash in regard to the impression itself are clearly shown on the wrench forging in Fig. 29,

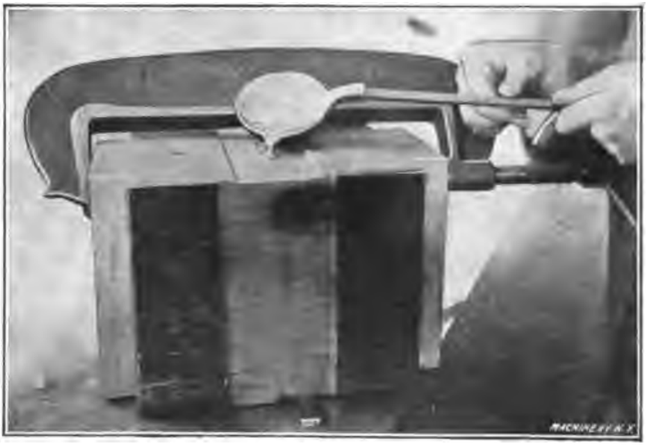

Fig. 28. Pouring a Lead Proof

and the sectional view of a pair of dies in Fig. 30. In Fig. 29, the fin has entirely filled the back-flash, as the two ridges at the sides of the wrench show. This indicates that the stock was a little too full, not being drawn small enough at this part of the forging. Fig. 30 illustrates the appearance of the flash in section, with the back-flash in the upper die. As before stated, the forming impression is not flashed.

Fig. 29. A Forging showing the Effect of Flash and Back-flash

This set of dies was for forging a plain ring, and although a simple set of drop-forging dies, they illustrate a few points of interest.

The finishing impression is placed as near the center of the blocks as is practical, to secure the best effect of the blow, as well as for strength. The plugs that form the center of the ring are given a 10-degree bevel inside, while the rest of the impression has but 7 degrees. These plugs come within 1/8 inch of meeting, and the forming impression has plugs that are well rounded over, to give them strength for the hard service that they receive, as well as to spread the stock. These plugs barely meet. The edges of this forming impression are also rounded to give strength, and to prevent the formation of cold-shuts. In the finishing impression these corners are made nearly sharp, so as to finish the forging. The opening on the right is the breakdown or edger.

The Breakdown

One of the most baffling points of drop-forge die sinking, to the novice, is the planning and making of the breakdown, edger or side-cut. These three terms are identical in meaning and all three are in common use in various shops. In laying out the breakdown, there are many points to be considered that are obtained only through experience, and appreciation comes only after learning, but we can at least give our atten-

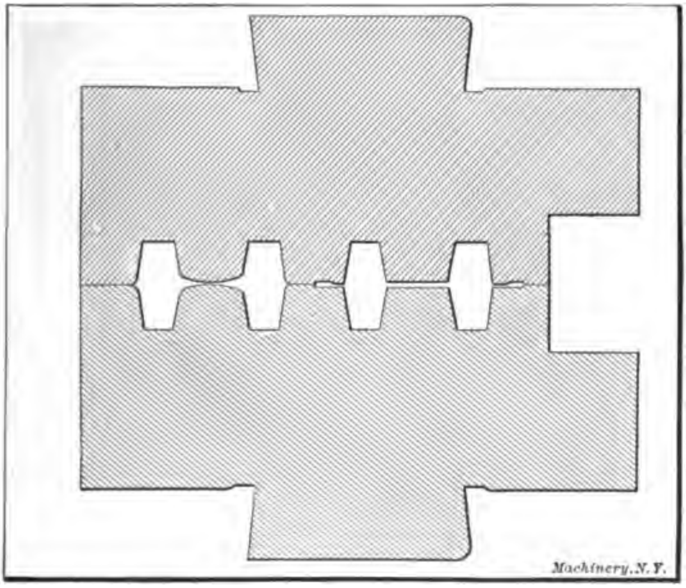

Fig. 30. Sectional View of a Pair of Drop-forging Dies, showing the Flash

tion to a few general principles that should be observed in this part of drop-forge die sinking.

After the face impressions are finished, and the flash, gate and sprue completed, the dies are clamped together just as they were for taking the lead. Next, the rough surfaces of the right-hand sides of the blocks are chalked. The reason for using the right-hand side of the dies for the breakdown, is to make the forging operation easier for the forger, as it is much easier to swing the bar on this side. A half-lead, or a templet of the forging, is then laid on the dies and the outline scribed. The location of this templet is important. If the piece is symmetrical, one-half of the outline should be on each die. If not, a parting line must be decided upon and the templet placed with this line even with the parting line of the two dies. A second line is next scribed 1/16 inch inside of this outline in all places except the following: First, in all vertical places of the breakdown, the outline is given a draft of 7 degrees, part of which is marked outside the outline, and from that point running to the same distance within the outline at the bottom of the breakdown outline. Second, all right angles or abrupt bends should be well rounded off, so as to prevent the formation of cold-shuts. Fig. 31 illustrates a few templets and the breakdowns for the forgings, showing the points of difference between the templet outline and the breakdown outline.

The width of the section used as the breakdown should be sufficiently wider than the forging to give plenty of room for the work or forging. For a forging 1 inch thick, the edger should be 1½ inch wide, and about the same proportions should be followed for forgings of other widths. At the rear end of the breakdown, a cut-off is pro-

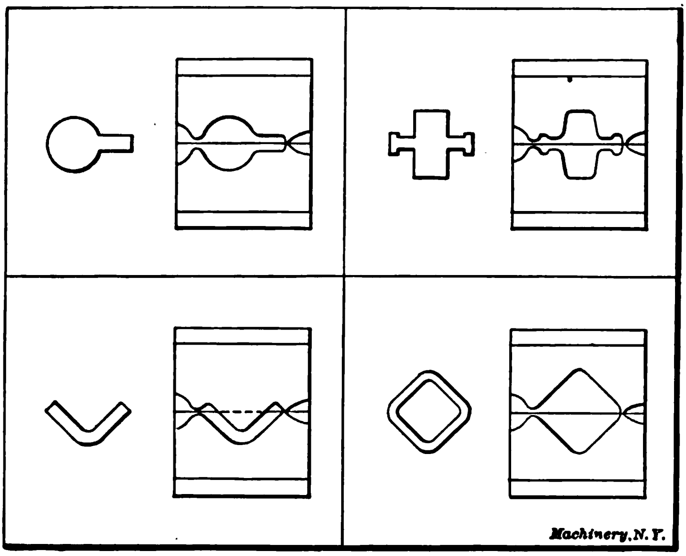

Fig. 31. Specimen Breakdown Lay-outs Compared with their Templets

vided to trim off any extra stock that has been drawn out on the anvil. Beyond this cut-off the die is cut away for clearance. The breakdown must be provided with a section that corresponds to the gate and sprue of the die impression, but it must be made slightly longer, so that the forging will not be stretched off when struck in the impression. This may be noticed on the die shown in Fig. 11 at the left-hand side. The breakdown will be at the right when the die is set up in the hammer, as this particular die is a top die.

The breakdown section should be a part of the die-block, and not bolted on the side as is sometimes done. There are cases where the breakdown must be a separate piece, but in nine out of ten dies, it is practicable to have the breakdown a part of the die-block. Sometimes it happens that the form of the edger or breakdown must extend above the face of the die-block itself. If the amount of projection is not over 1 inch, the best way to accomplish this result is to plane away the rest of the face of the die, so as to leave the edger projecting. If the distance is greater than 1 inch, a separate piece may be dovetailed in and held in place by a pin driven through the edger and into the die-block. The inserted piece should be a force fit in the dovetailed recess in the die-block. The breakdown should never be built up with a piece bolted on the side of the block, for the bolts will jar loose or shear off. Generally speaking, it is poor practice to use screws for dies or attachments for a drop hammer on account of the vibration.

Fig. 26 shows the method of setting up the die-block in the die-sinking machine for the purpose of milling the breakdown. After the correct outline for the edger has been determined, the line should be scored plainly with a small chisel. The die-block is then held in the vise of the machine on its side, and with a long straight cutter the breakdown is gradually cut in to the line.

The cut-off connected with the breakdown section of the die should not be confused with the cut-off for severing the forgings from the bar when they are to be cold-trimmed. The cut-off on the breakdown merely cuts the stock to length after being drawn out on the anvil.

The Anvil

There is little to be said in regard to the anvil. The two fullers have slightly crowned faces and the corners are well rounded. Beyond these fullers, the die is milled away to clear the stock after it has been reduced, and to clear any large parts that must be left. The anvil is placed on the left-hand side of such dies as require it, and as has before been stated, its purpose is to reduce the stock for the thin sections of the forging. If a double-ended wrench is to be forged, like the one shown in Fig. 29, an anvil will be necessary to thin out the stock between the thick ends of the wrench, before striking it into the impression or edger of the die. If the thin part of the wrench is ½ inch by 2 inches, the fullers would be left just 1 inch apart; that is, each face would be ½ inch under the face of the die itself. Thus it will be seen that the fullers are to square the stock to the dimensions that will "fill" the die when struck in the impression. The forger draws out the stock under the anvil just as the blacksmith would under a trip hammer. About one-half of the drop-forging dies made require anvils in their make-up.

The Cut-off

Dies that are made for cold-trimmed forgings require a cut-off to cut the forgings from the bar after completion. This part of the die is usually placed across one of the two rear corners—wherever there is the most room. The cut-off is made by milling away the stock, so as to leave on each die corresponding chisel-like projections. These edges are not brought up sharp, but are left with a face of ⅛ inch so as to hold up well in use. Only forgings that are to be cold-trimmed require this method of cutting off, but as most small forgings are cold-trimmed, the cut-off is very commonly found on drop-forging dies.

Some die-sinkers prefer to cut a vertical channel into the sides of the dies, and set in steel sections that reach to the die-shoe, flush with the bottom of the die-block. In such cases these blades project from the sides of the dies for three or four inches. This method has the advantage of permitting new chisels to be inserted, in case of breakage—an advantage that obviates annealing, re-milling and then hardening the dies in case the cut-off gives out.

Hardening Drop-forge Dies

The hardening of drop-forge dies is an important part of the die making, and in small shops, it often falls to the lot of the die-sinker himself to attend to the hardening, or at least to oversee it. Dies that contain less than 60-point carbon must be packed in boxes with granulated raw bone, sealed air-tight and carbonized before hardening. Those open-hearth steel dies containing 60-point carbon or over, or those of tool steel, will harden without such preliminary treatment.

The Hardening Equipment

A good furnace for the hardening of drop-forge dies is the No. 2 Brown & Sharpe hardening and annealing furnace. Other makes may be just as efficient, but so many shops use this particular furnace for the work, that there is no doubt in this case.

The hardening tank should be about 4 feet square and 3 feet deep. The water supply should come in at the bottom, and the supply pipe should discharge upwards, so as to send a strong current toward the top of the tank. The overflow should be a 6-inch pipe opening from a point near the top of the tank. If dies must be hardened in a tank without circulation, a large wooden paddle must be used to agitate the brine during the hardening. The best method of securing a good supply of cold brine, is to have a small reservoir out-of-doors that is covered over and yet exposed to the air. From this cooling tank, the brine may be pumped to the hardening room, returning by the overflow to be cooled. Across the tank, about 12 inches from the top, two bars should be suspended, forming a support upon which to rest the dies while being hardened. The brine should be a 40 per cent solution, and in the absence of a hydrometer, salt should be added to the water until the brine will float a raw potato.

Packing and Heating

For heating, the dies are placed in cast-iron boxes, in the bottom of which two inches of burnt granulated bone has been placed. Cast-iron boxes are used because cast iron stands the heat well, and the boxes are easily made. The walls should be at least ½ inch thick. Burnt granulated bone is merely the raw bone after it has been used for pack-hardening a number of times. Upon this 2-inch layer of burnt bone, the die is laid face down, and settled down so that the bone fills the impression and the entire top face. This layer of bone serves a double purpose, in that it prevents the formation of scale on the face of the die, and also does not allow the steel to decarbonize. Steel heated in the open for any length of time will lose its carbon or a good part of it.

With the face of the die thus protected, the box, with the die, is placed into the furnace and heated slowly and evenly. This heating takes from six to eight hours, according to the size of the die-block. The proper heat for quenching a 60-point carbon die lies between 1425 F. and 1450 F. As the die is but partly covered, the heat may be seen at all times.

Quenching the Die

When the die has reached the hardening heat, the cast-iron box, with the die therein, should be taken to the hardening tank. Here the die is held by the shank and placed upon the spider within the tank. The water is turned on full force, striking against the face of the die and driving away any steam that would "pocket" in the impression if it were not for the force of the stream. If the steam were allowed to pocket in the impression, soft spots would be found on the face that would be detrimental to the life of the die. The supply valve is left wide open until the brine reaches half way to the top of the die; at this time the valve should be closed enough to keep the level of the brine at this point. As soon as the die has cooled sufficiently to allow the water to cling or remain at the corners of the top of the die, the shank of which has at this time changed to a dull red color, the die should be placed in a tank of oil and remain there until cold.

A kink in hardening that is worth noting is the method of keeping the die flat when it tends to "hump" up at the shank. The hardener has a short straightedge that he keeps laying on the shank to see if a hump is forming, and such a condition is very apt to arise when hardening large dies. As soon as he notices a perceptible hump, he takes a small hose and plays a stream of water upon the bulging point until it goes back into shape. Care must be taken not to continue this small stream too long, or the hump will be driven to the face. A slight hump on the shank (not over 1/32-inch) will not be objectionable, as this will leave the face of the die comparatively flat. This slight bulging shank may be surfaced or ground flat after the die is cold.

Tempering the Die

The operation of tempering the die is accomplished by drawing the die in a tank of oil. The oil should be brought to a temperature of 450 degrees F. and kept there long enough to insure the heat penetrating through the die. After removing from the oil, the corners of the die and the cut-off must be drawn to a purple color with the aid of a blow torch. The quickest way to do this part of the tempering is to polish off these places as soon as the die is taken from the oil tempering tank, and then apply the blow torch, making use of the heat that is already in the die. After the die is cold, the oil should be cleaned off as much as possible, and the impression polished out with emery and oil on the end of a stick. This final polishing completes the work of making the drop-forging die.

CHAPTER III

SPECIAL OPERATIONS IN DROP FORGE DIE-SINKING

In the first two chapters, the principles of making drop-forge dies were treated upon, covering all of the main operations of sinking the impressions in the dies. There are, however, many special operations that must be employed at times to correctly shape the impressions, and these are fully as essential to good die-sinking as are the rudiments of the trade.

Cherrying

In making the impression in a drop-forging die for producing forgings for valve stems or other forms in which each die will have at

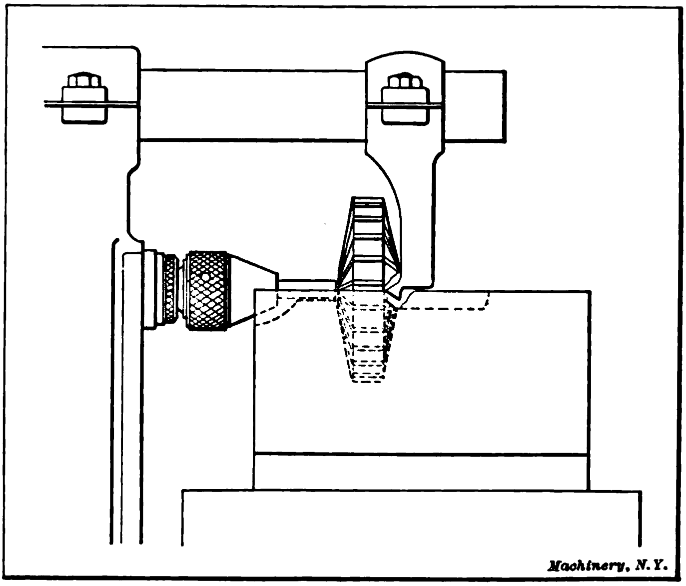

Fig. 32. Cherrying a Die on the Milling Machine

least one-half of its impression of the cylindrical shape, it is obvious that some means must be provided to sink a cutter into the die block to exactly one-half of its depth. There are several different methods of reaching this end, one of which is to use a special milling fixture in which the cutter is supported on a very short arbor and rotated by means of a raw hide pinion that meshes between the teeth of the cutter, this pinion being driven by the spindle of the milling machine. Of course, the bulk of the steel in the impression is roughed out in the ordinary way before the special attachment and the finishing cutter are put into use.

Another method of sinking the cutter to one-half its depth is by the use of the method called "cherrying." Cherrying and cherries are terms somewhat unfamiliar to the general machinist and toolmaker. A cherry is a milling cutter, usually made integral with an arbor whose length varies with the requirements of the job to be done. The cherry is held in the spindle of the milling machine. The die to be cherried is roughed out on the die-sinking machine as nearly to size as possible and the sprue and gate cut. On dies that are to be cherried the sprue is made circular in shape so as to accommodate the shank of the cherry; that is, the impression in each of the two halves is semi-circular. Next, the die is mounted on the milling machine and the table raised to bring the cherry into the impression that has previously been roughed out. After the cherry has been carefully centered, the table

Fig. 33. Collection of Cherries used in Die-sinking

is raised to bring the cherry to the proper depth into the die, cutting very slowly on account of the large amount of cutting surface involved when the cherry is well into the die. When the impression is deep and is located at quite a distance from the front of the die block, the shank of the cherry must be long, and if the front end of the impression is shallow, the shank of the cherry will necessarily be small in diameter. In such cases, and in fact in all cases where possible, the cutting end of the cherry should be supported. This support consists of an arm, swung from the supporting arm of the milling machine. The cutting end of the cherry is deeply centered and the support consists of a very short center that is cut away to clear the rest of the die, substantially as shown in Fig. 32.

Fig. 33 shows a group of cherries used in different dies, as accumulated in doing general drop-forge die-sinking, these being of the average type. The operation of cherrying has been described in preference to some of the special milling fixtures, because it is the most common method used in this connection. The special fixtures are not found in the majority of die-sinking departments, although the best-equipped shops employ them for special jobs that would be difficult to cherry.

Indicator Used in Making Deep Impressions

Fig. 34 shows a most interesting operation and the indicator used in connection therewith. This die is for making the sister hook illustrated in Fig. 40 and as may be seen, there is a very deep part of the impression used for forming the eye, that would be very difficult to mill out without the fixture shown in this illustration. The main rod of the fixture is screwed or clamped to the body of the die-sinking machine. This rod terminates in a ball and socket joint from which is supported a cross bar that holds the pointer of the indicator. The die in which the impression is to be milled is laid out as usual, and in addition, a line is scribed on the side of the die that indicates the

Fig. 34. Milling out a Deep Impression with the Aid of an Indicator

shape of the bottom of the impression, as projected from the impression that is to be cut. This line may be seen on the side of the die block that is shown on the machine in the illustration, Fig. 34. After the die has been set up on the die-sinking machine, a roughing cutter is held in the chuck and the table of the machine raised until the cutter just touches the top surface of the die. Next the indicator is adjusted so that the needle is on a line with the surface of the die and at the same part of the scribed outline on that side of the die that agrees with the position of the cutter within the outline of the die impression. With the cutter and indicator thus located, the impression may be roughed out, the die-sinker always keeping the needle of the indicator within the lines on the side of the die. After the die impression has been roughed out, a finishing cutter may be adjusted in the same manner as was the roughing cutter, and by carefully watching the indicator to see that the cutting is always within the scribed lines, the die may be finished much quicker than would be possible without an attachment of this kind.

Cutter Milling Fixtures

The die-sinker uses so many special cutters in addition to the regular cutters, that it is essential that he be equipped to make cutters as expeditiously as possible, especially as it often happens that he must stop in the midst of the work of cutting the impression to replace a broken cutter or to make a new type of cutter. The cutter milling fixture shown in Fig. 35 is a great help in fluting all kinds of die-sinking cutters. As the illustration shows, it is merely a special form of index head, fitted with spring chucks to take the standard sizes of cutter shanks. The fixture is used on the die-sinking machine, using an end-mill for cutting the flutes. Both the fixture and its operation are so simple that a description is hardly necessary. The cutter blanks are turned up to the proper clearance angle and fluted while being held

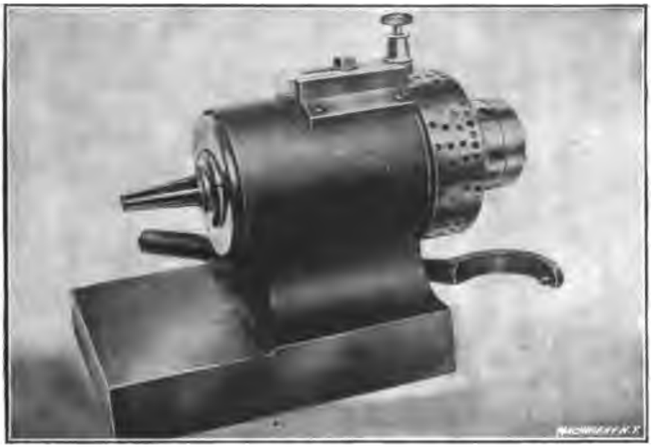

Fig. 35. Fixture for Fluting Cutters, used on the Die-sinking Machine

in the spring chuck of the fixture. The fixture is held in the vise of the die-sinking machine and the vise swung around enough to give the proper taper to the fluting out, which on a seven-degree cutter would be about five degrees. By means of the indexing arrangement at the back end of the fixture, the cutters may be given any number of flutes desired. It is only necessary to compare the time of setting up this fixture with the time of rigging up a horizontal miller for the job, to see where the advantage of this fluting method lies, especially when it is considered that this operation does not bring another machine into use.

Making Dies for Bronze and Copper Forgings

In making the dies for the production of drop forgings from bronze and copper, there are several points of the work that differ from the making of dies for steel or iron forgings. Foremost among these differences is the finish that must be given the dies. Copper, and bronze as well, are much softer metals than iron or steel; consequently the metal is driven into every detail of the dies during the forging operation. On account of this fact, the dies must be perfectly free from scratches of any kind in order to obtain a copper or bronze forging with a smooth finish. This only means that extra care must be used in polishing out the dies both before and after hardening.

Forgings of copper and bronze are used for machine parts that would be liable to rust from the action of water and also in places that require a non-magnetic metal part. On account of their density they are tougher and harder than a casting of similar metal could possibly be. However, the hammering that is necessary to form such forgings is very hard on the dies, even though the metal being worked is soft. To prevent the dies from dishing or spreading, tool steel is nearly always used for the dies, unless the forgings to be produced are extra large and heavy. The shrink, draft and finish allowances on this class

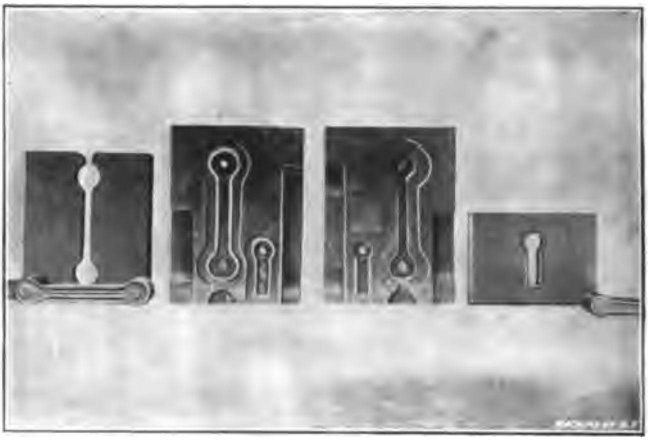

Fig. 36. Set of Dies for Drop-forging and Trimming Shackles and Pins

of drop-forge dies are practically the same as on dies for steel and iron. Bronze and copper forgings are trimmed the same as are forgings of iron and steel, but the dies must be kept sharp, in order to do good work; if allowed to become dull, the trimming will be ragged, leaving the forging with a rough surface on the edge.

Dies for Chain Shackles

In making the dies for drop-forging and trimming shackles for chains, we have a representative job of die-sinking, and in addition, there are several special points that are worth noting. Fig. 36 shows a set of dies for drop-forging and trimming a shackle and the pin used in connection therewith. The dies for the drop-forging are the pair in the center and the different parts of the die are well shown, the anvil, breakdown and the central impression. In addition, the impressions for the pin that is put through the shackle after it has been bent to shape, are included at the side of the central impression. The reason for this is that the shackle pin impressions are so small that there is plenty of room for them without crowding the main impressions. Another reason, fully as important, is the fact that with every lot of shackles the same number of pins must be made, and by placing the pin impressions by the side of the shackle impressions, the job is set up and ready for use whenever the shackle dies are set up.

Fig. 37 shows the die-sinker starting to mill out the impressions in one of a pair of shackle dies. The system of lighting the work, when artificial light is required, is indicated in the illustration where two adjustable incandescent lights are attached to the frame of the die-sinking machine. When these lights are swung down close to the cutter every detail of the cutting may be seen, for by the use of two lights, on opposite sides of the work, there is no shadow thrown on the die by the cutter.

Fig. 37. Starting to Mill out a Drop-forge Die

The trimming dies for this job are interesting in that they illustrate both styles of dies, hot trimmers and cold trimmers. The die for trimming the shackles shown at the left of Fig. 36 is a hot trimmer, made in one piece. At the front is the punch for this die, recessed out to fit the forgings. The trimming die on the right is a cold trimmer for the pin that goes through the shackle.

Connecting-rod Forging

In Fig. 38 is illustrated a forging for a connecting-rod that is shown as a further example of forgings for which the die impressions are best milled and typed for the irregular spots before the central hubs are cut. This illustration shows the finished connecting-rod. The parts that would require typing, are, of course, the projecting lugs through which the bolts pass. The forging for this connecting-rod would be solid at the two ends and into these open places in the impression the types would naturally slip, should the central opening of the impression be cut out before the projecting lugs were typed.

A Simple Set of Dies for Drop-forging a Thrust Collar

The thrust collar shown in Fig. 39 can be drop-forged in a pair of dies with but one impression. It would hardly seem possible to do this, at first thought. but as a matter of fact, it is a practical piece of drop-forging. The secret of the success of this forging operation lies in the preparation of the stock from which the forging is to be made. The stock should be cut into blanks somewhat smaller in diameter than the greatest diameter of the forging and of such a thickness as will just give stock enough to fill the die, after allowing for a sprue

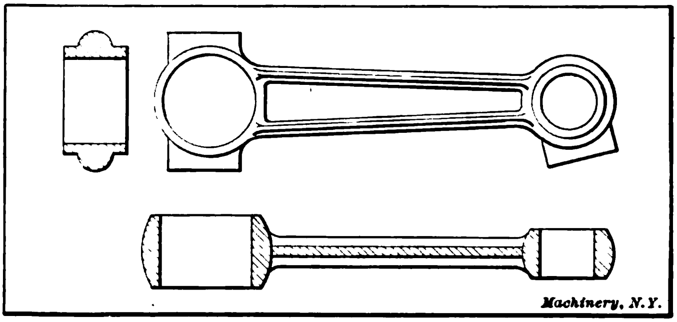

Fig. 38. Connecting-rod Forging, after Machining, to illustrate a Case where Parts of the Die Impression should be milled and typed before the Hub Impressions are milled

for handling the forging while being worked. The size of this blank can best be obtained by weight, the blank being two-thirds of the weight of the lead proof, after adding enough for the weight of the sprue and an allowance for the shrinkage of the steel in the fire from scaling,

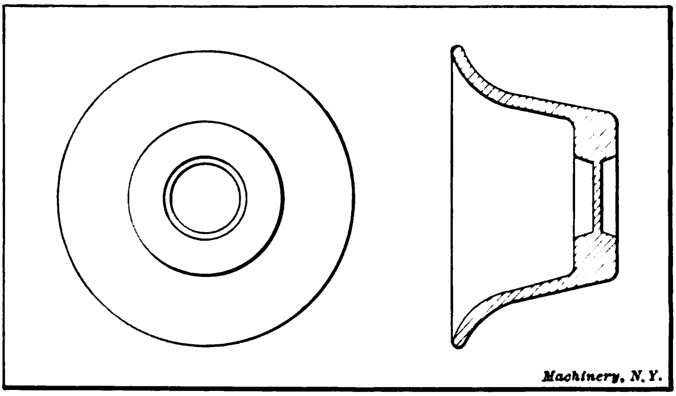

Fig. 39. Thrust Collar, made in a Pair of Dies with but One Set of Impressions; no Breakdown or Anvil required

etc. The corners of this blank are first hammered in and a short sprue drawn out under the hammer, after which the stock may be placed in the impression of the forging die and struck until full.

No breakdown or anvil are required with this set of dies and the central impression is designed so that the lower die will contain the cavity while the upper half will have the projecting plug. This arrangement is for the purpose of taking advantage of the "shooting up" tendencies of the hot steel. For trimming the central web from the forging, a loose punch is used; that is, a punch that is not fastened in any way to the ram of the trimming press. The cutting end of this punch is made to the size that is wanted for the opening in the forging; back of the cutting edge, the stock is relieved to clear the forging when going through. When used, the punch is pushed through the forging, the punch dropping through the forging to the bolster, from whence it is taken and used again on the next forging. The trimming of this piece should be done hot, although if the central hole is small, that part of the trimming may be done cold. If the hole is trimmed hot, however, the dies will meet much more quickly, saving quite a little time in the forging operation.

Dies for Drop-forging Sister Hooks

Another interesting set of dies shown in Fig. 40, is for drop-forging sister hooks used in the United States Navy. The set consists of the

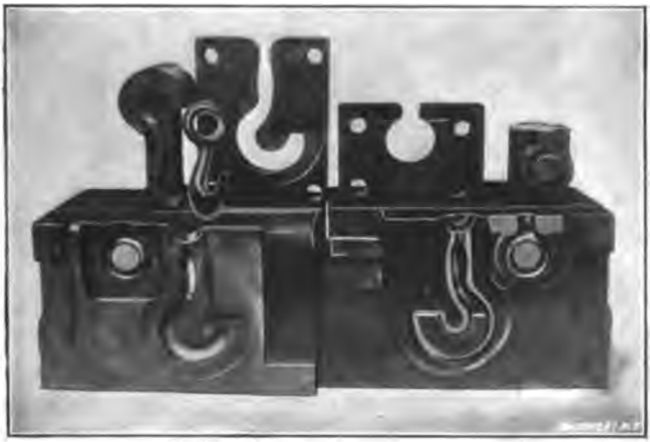

Fig. 40. Set of Dies for drop-forging and trimming Sister Hooks

two forging dies and the two pairs of trimming dies, one of which trims the hook end and the other takes care of the ring end of the sister hook. The center of the ring is trimmed by another die not shown. It is obvious that the entire forging could not be trimmed in one operation on account of the two different parting lines on the forging. It is also obvious that the shape of the forging makes it necessary to forge each end of the hook separately. To take care of this requirement, an additional set of impressions is cut in the dies to shape the ring at the end of the sister hook. This ring impression is gated the same as the main impression, but it is not used until after the front end of the hook has been completed and the forging with its unfinished ring end has been cut off from the bar. The forgings are made just as though the hook end were solid, being trimmed and cut from the bar, leaving the hook end in the shape of a flat disk. Then the ring ends of these semi-completed forgings are reheated and struck in the second set of impressions at the front of the die. It will be noticed that these impressions are gated in such a manner that the hooks will not be crushed while being struck. The stock that is within the center of the ring is more than enough to form the outside in good shape, so no extra allowance need be made.

In the illustration, Fig. 40, the two trimming dies are shown placed on the top of the forging dies. These trimming dies are each made in two halves, being dowelled and screwed to bolsters while in use, a matter that will be more fully treated under the head of trimming dies. In this illustration will also be noticed the way in which trimming punches are cut away to properly support the forging during the trimming operation.

Dies for Upsetting Cam-shaft Forgings

The forging shown at *B*, Fig. 41, is for a cam shaft that is shown, after machining, at *C* in the same illustration. To produce this piece,

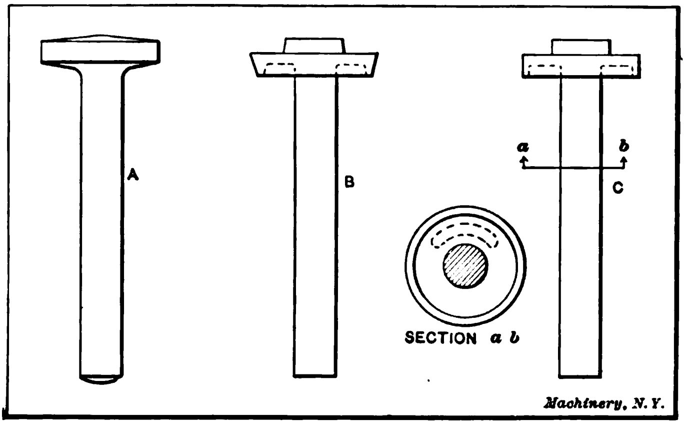

Fig. 41. The Operations of Making a Cam-shaft

a forging is made as shown at *A*, in the same illustration. This is done in a simple pair of dies, having half of the impression in each die. The forging is finished in the pair of dies shown in Fig. 42. A pair of dies of this design are known as "upsetting dies" and consist essentially of a recess to take care of the shank of the forging, confining it while a blow is struck to shape the head of the cam shaft in the impressions of the dies. Dies of this kind work after the manner of heading dies used in making rivets and screw blanks, except that they are not split for ejecting. The forging is forced from the die by means of a knock-out, as shown in the illustration. When the blow is struck, the knock-out pin is down, resting on the bottom of the die-shoe; after the striking is completed, the forger strikes the knock-out handle with a hand hammer, and the forging is ejected from the die. Ejection is made easier by the fact that the forging is losing heat all the time after the blows have been struck, consequently it is shrinking in diameter. Another precaution, taken to prevent the forging from sticking in the die, is the practice of giving the recess a draft of one-half degree.

The impressions in the faces of the dies, in which the top of the forging is shaped, involve one feature that has not been touched upon before. Around the part of the lower die that contains the impression, the stock is turned down for about one-half inch, leaving the shoulder on a 15-degree bevel. To match this part, the upper die is recessed for the same distance and on the same bevel, thus forming a "lock" that insures the dies properly meeting within close limits of alignment. This particular lock, owing to its form, is called a circular lock. Circular locks are formed on dies that must produce forgings that are to be accurate to size. or of such a shape that there would be diffi-

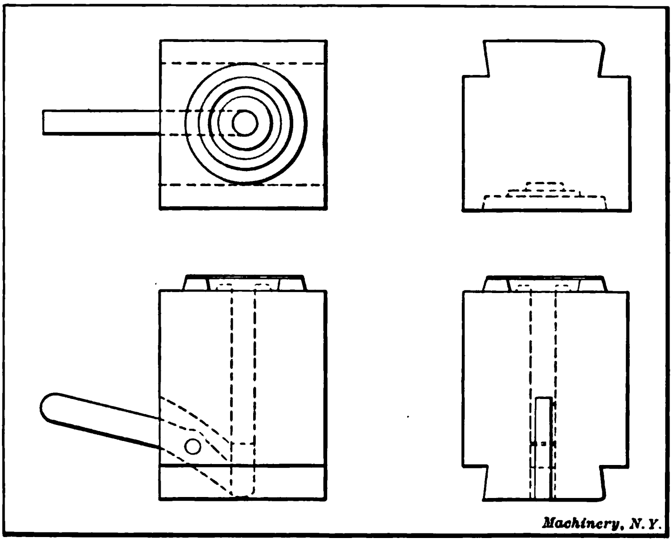

Fig. 42. Upsetting Die for the Second Operation in Forging the Cam-shaft

culty in setting the dies and holding them in proper alignment without such a help as the lock.

As to the impressions for shaping the top of this cam-shaft forging, there is nothing out of the ordinary about them. All parts are sunk with a seven-degree draft, including the sunken section for the outside of the cam. While being machined, these beveled sides are cut straight. The best method of cutting the arc impression for the cam is by the use of the circular attachment on the die-sinking machine.

A Lock Die for a Hinge

A difficult job of die-sinking is illustrated in the set of dies shown in Fig. 43. This set of dies is for drop-forging the heavy hinge shown on the top of the dies. At the right is the trimming die and punch. In these dies we have a good example of lock dies of another variety, and a more complicated one as well. The forming impression and breakdown for this piece were cut in another set of die blocks, as the forging was too large to admit of the various impressions being placed on the same block. The finishing die shown is the most important and it will be noticed that the draft, flash, gate and sprue are just as much in evidence as they were in the straight type of die. In one of the dies may be noticed the cone-like projections for spotting the centers of holes that are afterwards to be drilled in the forging. The leaves of the hinge are inclined from the base at an angle of 70 degrees. If they were at right angles with the base, the forging of the piece would be simplified a great deal. The hot trimming die shown has its face cut to agree with the parting line of the forging dies, so that the fin will lie against the cutting edge of the die at all

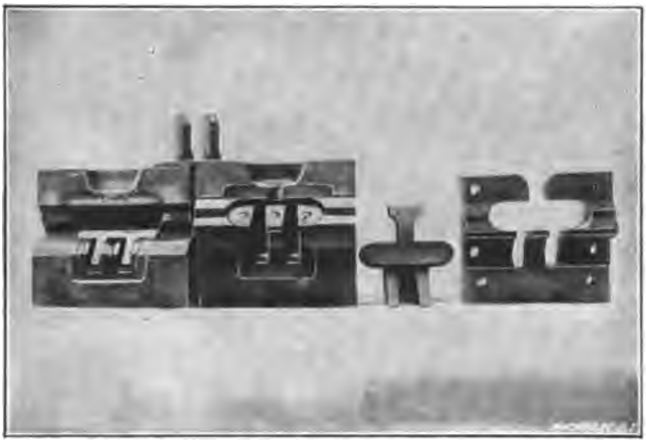

Fig. 43. Lock Dies for Forging and Trimming a Special Hinge

points. In cutting the deep parts of the impressions for the leaves of the hinge, the indicator previously described is a great help.

Dies for Making Extra Long Drop Forgings

An extra long forging cannot well be made in a die with one full length impression for several good reasons. First, the dies would be so large and heavy that the item of stock alone would be almost prohibitive, and second, such dies could only be used in an extra large hammer. The drawing in Fig. 44 shows the method of forging such awkward shaped pieces, taking for example a long heavy spanner wrench, three feet six inches in length. The impressions of each half of the wrench are cut side by side in the die blocks, keeping in from the edge of the die about one inch. At the halfway point where the two impressions leave off, square notches are cut nearly to the depth of the impressions; these notches are the key-note of the whole method of producing such forgings. They serve as locating points to start the forgings from and they will, in this particular die, prevent the metal from sliding forward when struck in the tapering impression for the handle. As the steel fills these notches, it forms lugs on the forgings; these lugs fit into the notches in the second impression, thus locating the blank in the proper position. Some forgings would require breakdowns for each end of the piece when made in this manner, but this spanner wrench only requires a breakdown for the hook end. The horn, or bender, is dovetailed into the upper breakdown after the manner previously described.

Method of Forging Spanner Wrench of Very Large Dimensions

The method of forging the spanner wrench is as follows. Steel is used that is large enough to make the heavy end of the wrench. One forging is made complete, care being taken to note the length of the bar required to make the forging. After the proper length of the blank has been ascertained, the stock is cut to this size and the entire lot of forgings are made and trimmed on one end. The trimming dies

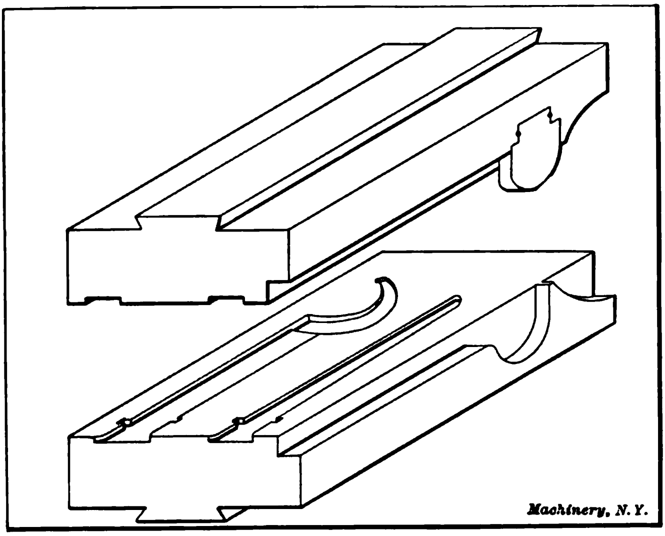

Fig. 44. Drop-forging Dies for Making a Long Forging by Halves, to Obviate the Necessity of Large Dies

for both ends are shown in Fig. 45. The stock for the handle end of the wrench is then drawn down and forged in the second set of impressions in the dies, using the lugs formed in the first operation as a guide to the proper location for the second operation. In turn, this small end is trimmed as was the forward end, and at last, when the forging is completed it is moved backward in the trimming die just enough to clip off the lugs on the sides and then struck once more in the dies to round the edges where the lugs were clipped off.

It often happens that the forging is of such a shape that no lugs are required to locate the forging in the second impression. A boss, hub or other projection, either vertical or lateral, does just as well as the lugs just described. With care in the forging, it is possible to make drop forgings of this character within 1/32-inch limits of variation in length.

Trimming Dies

All drop forgings require trimming after the forging proper is done. The ideal forging comes from the dies with a small amount of fin evenly distributed all around the forging, at the parting line. In many ways the fin is to be desired, provided it is uniform. Its presence denotes that the dies are "full" in every respect and after being trimmed, the forging is sure to present a clean edge with all traces of the parting line removed. At the time of the trimming operation, a good part of the draft that has been given the forging may be trimmed off in case it is detrimental to the finished product.

Trimming dies are of two general classes, called hot-trimming dies and cold-trimming dies, according to the condition the forgings are in when trimmed. These two classes differ materially in their design

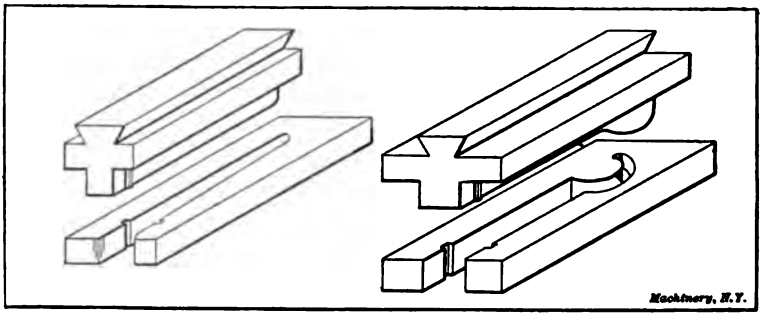

Fig. 45. Trimming Dies for Long Forgings made in Halves

and in the steel from which they are made, although the die-making operations are similar.

Hot trimmers, as they are called in the shop, trim the fin from the forging while the forging is being made. Fig. 46 illustrates a plain hot-trimming die and punch. Generally, the forging is practically completed, then trimmed and struck again to correct any twists or distortions due to the trimming as well as to bring the edges up sharp and size the forging. In the case of a piece having a large displacement of stock, there is apt to be more fin than in a uniform piece; consequently if this fin is trimmed out of the way just before the forging is finished, it is obvious that the dies will have a better effect upon the forging while striking the finishing blows. Most forgings of the medium and larger classes are hot trimmed.

Cold trimmers must do a great deal harder work than the hot trimmers, and for this reason they are made from high carbon steel and hardened the same as any blanking die. Forgings that are to be cold trimmed are severed from the bar when finished, with the fin untrimmed, and run through the trimming die when cold. Thus it will be seen that to trim other than small forgings in this manner, would be too great a strain upon both punch and die.

Hot-trimming Dies

There is a special grade of steel, commonly known as hot-trimming die-stock, that is used exclusively for making hot-trimming dies. The objection to using ordinary tool steel for hot-trimming dies is that the edges of the hardened die check very badly after the die has been in use for a short time. Checking is followed by breaking away of the steel around the edges, rendering the die unfit for use. This special grade of steel, used for hot trimmers, requires no hardening, and after the die has been put into use, the edges toughen up and give better service than the best hardened tool steel could possibly do.

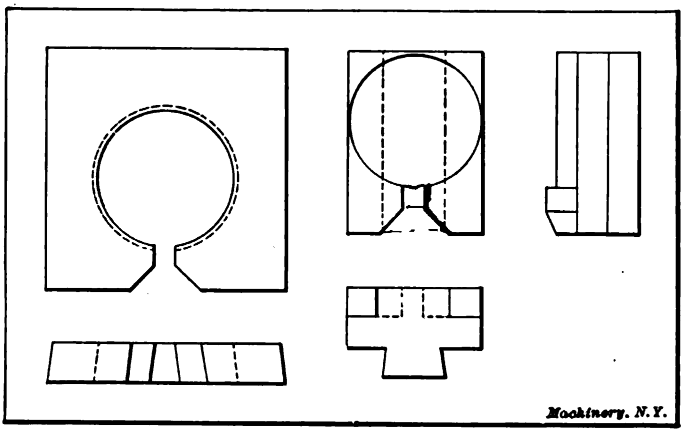

Fig. 46. Illustrating a Plain Hot-trimming Die and Punch

Hot-trimming dies, as well as cold-trimming dies, are made either solid or in sections, of which there may be two, three or even more. If the piece to be trimmed is a plain, regular shape, the die is best made in one piece, and at the other extreme, if the forging is a difficult one to trim, the die is built up of two or more pieces; the die construction is a matter to be decided by the die maker. Naturally a one-piece die is much easier to handle in setting up, etc., but a die of two or three sections has the advantage of being more easily sharpened and closed in whenever necessary. Fig. 47 shows the general idea of hot-trimming dies of one and two sections, and a cold trimmer in three sections. As shown, the different sections are properly located by means of dowels set between the sections. A die made in sections must have a special bolster on which the parts are mounted, while a one-piece trimmer can be mounted on a bolster that is used for other trimming dies.

The main difference in the appearance of hot- and cold-trimmers lies in the fact that the hot-trimmers are left open in the front, while cold-trimmers have no openings of this kind. The opening in a hot-trimming die is for the purpose of clearing the sprue that connects the forging to the bar, otherwise the forging would be severed from the bar at the first trimming operation. As hot-trimmed forgings are trimmed two or three times in the forging operation, it is of course, necessary that the forging should remain intact with the bar until it is finished. The trimming die is made to trim the sprue section as well as the forging itself. After the forging is completed, it is cut off at the sprue by means of the special cut-off on the side of the trimming press. The opening at the front is cut clear through the thickness of the die stock, and there must be a corresponding opening through the bolster, so that the forgings may be carried

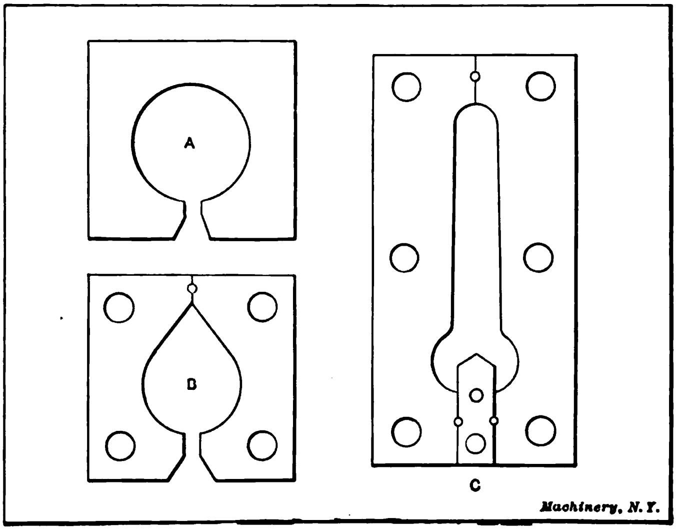

Fig. 47. Trimming Dies: A, One-piece Hot-trimmer; B, Two-piece Hot-trimmer; and C, Three-piece Cold-trimmer

through the die and bolster after trimming and taken out from beneath. The die shoe is made with an open space in the center beneath the die and bolster; therefore when the forging is trimmed, it drops through the die and bolster into this open space and is drawn out through the front of the shoe, still instact with the rest of the bar of steel. The positions of the die, bolster and shoe are graphically shown in Fig. 48.

Making a Hot-trimming Die

In making a hot-trimming die, the templet used in laying out the outline for the impression in the drop-forging dies comes into use again, for with it the trimming die may be laid out. The shrinkage allowances in this case are correct, being the same in the trimming dies as they were in the forging die. In connection with the templet, a half-lead should be taken from the forging dies, using the top die for the purpose. A half-lead is easily taken by standing the die on end and clamping a piece of steel or iron over its face, and pouring the molten lead in the ordinary manner. This half-lead must be replaced in the impression after pouring, and the edges peened out to fill the impression when it is cold, for the shrinkage spoils it for use as a templet without this peening. The reason for taking this lead from the top die is that the forging is usually laid in the trimming die with the same side up as in the forging die, so as to be convenient for the forger. Using the lead from the top die as a templet will give the trimming die the proper outline to agree with the forging die without reversing. Another reason for using the top half of the lead, is due to the fact that it is easier to fit the die to the top half-lead than the bottom half-lead. The die is tried by pushing the lead up through the back side of the die at intervals during the filing. It is obvious, therefore, that the impression side of the top lead will show up the places in the die that must be filed out, far more clearly than

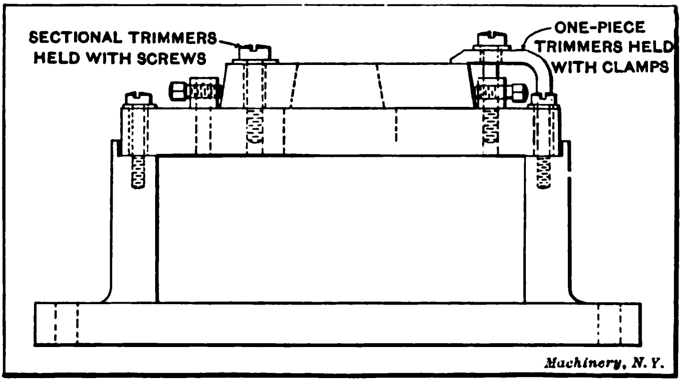

Fig. 48. Showing Method of Mounting a Trimming Die on the Bolster and Shoe

would the flat side of the bottom half-lead, in case it were used.

After the die has been laid out and the outline lightly prick-punched, a row of holes is laid out, the edges of which just clear each other and the outline of the die opening. The size of these holes is dependent upon the size of the die to be made; but for other than small dies, one-half inch is a good size for the holes. After these holes are drilled, the central core may be knocked out and the die is ready for milling.

Fig. 49 illustrates the operation of milling out a trimming die. The die is set up in the vise of the die-sinking machine and a stiff, straight cutter is held in the chuck. With this cutter the die is milled up to the scribed outline, cutting away the rough stock left by the drilling operation. The cutting section of this cutter should be long enough to extend through the entire thickness of the die. After the opening is roughed out, the straight cutter should be replaced by a three-degree cutter that is made with the larger diameter at the bottom. With this cutter the stock may be taken out just to the line. Next, the die should be turned bottom side up in the vise, and a four-degree cutter of the regular die-sinking type placed in the cutter chuck. This cutter should be entered into the opening in the die to within 7/16-inch of the face of the die (which is now at the bottom), and a clearance milled all around the opening, about as shown at Fig. 50. As this illustration shows, this method of putting in the clearance leaves a sort of shelf about one-third the distance from the face of the die to the bottom. Trimming dies are, on an average, 1½-inch thick; therefore, with the above clearance, there will be less than ½ inch to file at those points and corners that require filing.

Fig. 49. Milling out a Trimming Die

Should the die be composed of more than one piece, the sections must be fitted and dowelled for alignment before drilling or milling, after which they may be clamped together in the vise of the die-sinking machine just as though they were one piece and treated that way during the milling operations. After the milling has been completed, some filing will be necessary to smooth up the cutting edge and to clean out any corners or angles that could not be milled. For a one-piece die, no holes are required to hold the die to the bolster, as that feature is taken care of by the clamps and side screws with which the bolster is supplied; this feature is illustrated in Fig. 48. This style of bolster is used only with one-piece trimmers. If the trimmer is made up of more than one piece, the parts must be screwed and dowelled to the bolster.

Punches for Hot-trimming Dies

The general idea of a punch for a hot-trimming die is not to cut, but to support the forging while it is being pushed through the die. If the forging has a broad flat top face, the trimming punch need be little more than a flat punch that covers the top of the forging and acts as a "pusher" without regard to the size of the die itself. Such punches are commonly made of cast iron, and for wrench forgings and other flat work, especially of the larger class, they answer the purpose as well as a steel punch. A wood pattern is usually made, and the casting from it will require little machining before it is ready for use. If the forging is of a round section, the punch must be hollowed out to fit the top face of the piece. There is but one part of the forging where the punch should fit fairly well, and that is the sprue section, for unless this part is fitted close, it will bend up and make extra work for the forger. On the other parts of the die it is an advantage to have the punch fit the die very loosely, so that the fin will not stick to the punch during the trimming. Punches for hot trimming are not usually hardened. They are held in the ram of the trimming press by means of a taper shank and key.

Cold-trimming Dies

Cold-trimming dies are made from good tool steel, 100- to 125-point carbon, and after making are hardened and drawn to a dark straw color. The machine operations in the making are the same as with the hot-trimmers except that the opening at the front is omitted because the forgings are not trimmed until they have left the forging press, and are cut from the bar at the sprue. Although trimming

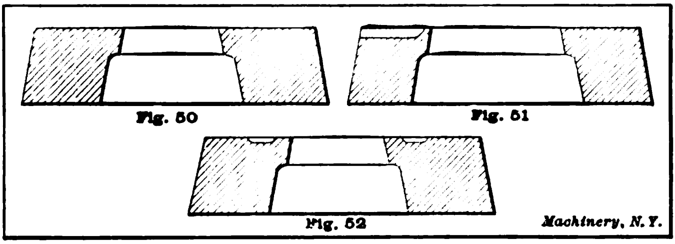

Fig. 50. Section of Trimming Die to show the Clearance given to the Cutting Edge. Fig. 51. Section of Cold-trimmer to show Method of Cutting away a Space at the Front to clear Rough Sprues. Fig. 52. Section of Trimming Die to show Channel Cut around the Die-opening to accomodate Forgings that must be trimmed wrong-side up

dies for cold work are not made with an opening in the front, there is usually a shallow space cut away just outside of the cutting edge at the front of the die to clear the ragged end of the sprue that is necessarily left after the forging is severed in the cut-off of a pair of drop-forging dies. This clearance appears about as shown in the illustration Fig. 51.

In laying out the cold trimmer for a drop forging, the shrinkage problem comes up again. One of the best methods of obtaining the outline, is to measure with a shrink-rule the templet that was used in laying out the drop-forging dies, and to make the outline of the trimming die to these dimensions as read from a standard rule. In making a cold-trimming die, it is a wise plan to first trim up one of the forgings by hand and then to keep away from the lines of the trimming die until it is sure that they are going to be correct for the actual forging. With this precaution it will be easier to fit the forging closer, for there is always a little uncertainty due to the difference in shrinkage arising from the use of the different steels from which the forgings are made.

The average thickness of trimming dies lies between one and two inches, probably being nearer the one-inch limit on small and medium work. In the case of lock dies, the thickness will depend upon the amount of irregularity caused by the parting line of the forging dies. The surfaces of some cold-trimming dies are cut away to within ¼ inch of the cutting edges of the dies. The reason for this is that on account of their shape, it is often advisable to trim some forgings in the opposite direction to that in which they were forged. This is not often necessary, but when it is, the trimmer must be cut away to clear the backflash that is left on the upper side of most fins. Such a trimming die is shown in Fig. 52. On account of the fact that in drop forging the steel is more easily forced up than down, into the dies, high projections would be in the upper dies, but it would be

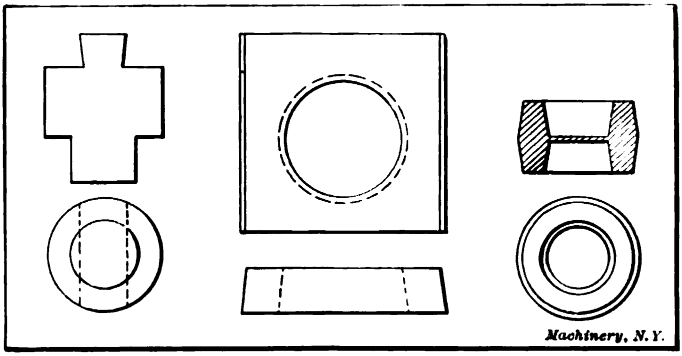

Fig. 53. Trimming Inside and Outside of a Ring Forging at the same Time

rather awkward to trim such forgings from this direction. For this reason the die is cut away as shown and the forging trimmed in the opposite way.

Punches for Cold-trimming Dies

The punches for cold-trimmers are made from tool steel, and are hardened and drawn to a very dark straw color. These punches are not hardened to make them cut better, but to prevent them from upsetting at the edges. As with hot-trimming punches, the punch should fit the die loosely, but it should support the forging at every point while it is being pushed through the die.

There are two cases in which trimming punches must fit the dies as closely as the average blanking die for sheet metal work. One case is in trimming forgings on which the fin comes at the corner of the forging and the other case is similar, being on forgings that are formed all in one die, having the other die flat. Unless the dies fit fairly well, burrs will result at the trimmed edges of such forgings.

Trimming a Ring Forging

Fig. 53 shows a trimming die that trims the inside and outside of a ring forging at one operation. The die is a hot-trimmer and made to fit the outside edge of the ring. The punch is made with a pilot punch that just fits the inside of the ring at the parting line, while the shoulder that pushes the fin off from the outside edge of the forging, is left far enough from the face of the pilot punch to allow the center web to be cut out before the shoulder strikes the top face of the ring. The forging is laid in the trimming die, and the punch comes down and cuts out the central web before the shoulder of the punch reaches the top face of the ring. As soon as enough pressure is brought upon the top of the ring, the outside fin and the sprue are trimmed off. With this style of a punch and die, it is best

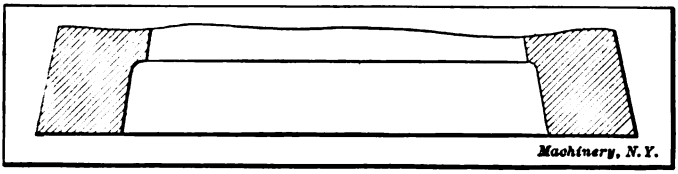

Fig. 54. The Way in which Long Trimming Dies are Sheared

to trim the outside very close, cutting off some of the draft so as to give more support to the punch while trimming the inside fin. The die will not require a stripper as might be supposed, for the inside punch will strip itself owing to the fact that it cannot draw the forging back through the trimming die. The inside punch should be

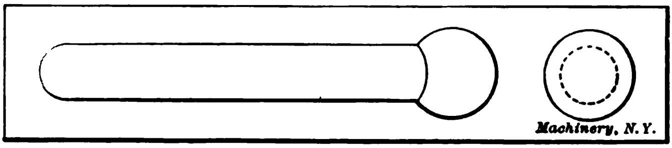

Fig. 55. A Difficult Forging to trim because of its Tendency to roll

no longer than necessary and should have a very slight taper toward the cutting edge.

General Notes on Trimming Dies

Trimming dies for forgings that are very irregular in shape, having been forged in lock dies, must have the surface of the trimming die, whether a hot- or cold-trimmer, shaped to agree with the face of the drop-forging die. The reason for this is very apparent, the object being to prevent the bending of the forging while being trimmed. A good example of this point is shown in the trimming and forging dies illustrated in Fig. 43.

Forgings that are to be cold trimmed should be pickled in a weak solution of sulphuric acid to remove the scale formed in the forging operation; by so doing, the dies will last much longer, saving the cutting edge from the hard scale that otherwise would have to be cut in trimming the forging.

A particularly difficult piece to trim is shown in the illustration Fig. 55. The difficulty lies in the tendency of the forging to roll in the dies while being trimmed. If the forging is matched this tendency will be reduced, but even then, if conditions are not of the best, the forging will not trim well. One way of helping to overcome this rolling tendency, is to roughen the surface of the punch where it comes in contact with the forging. This causes the punch to grip the surface of the forging, but it also tends to mar the forging.

If the outline of the forging to be trimmed is long, or of a large perimeter, it will be a good plan to shear the die. Fig. 54 shows the method of shearing a trimming die by grinding hollows in its surface at intervals. This, of course, lessens the force required for the trimming or rather it divides the work of trimming, whereas in the case of a straight die, the trimming must be all concentrated into one stage of the blow.

By making the trimming die slightly smaller than the outline of the die impression, it is possible to trim off some of the draft that was given the forging in the dies. The appearance of this bevelled edge of the forging is often considered objectionable and by making the trimming die small, most of the draft may be shaved off.

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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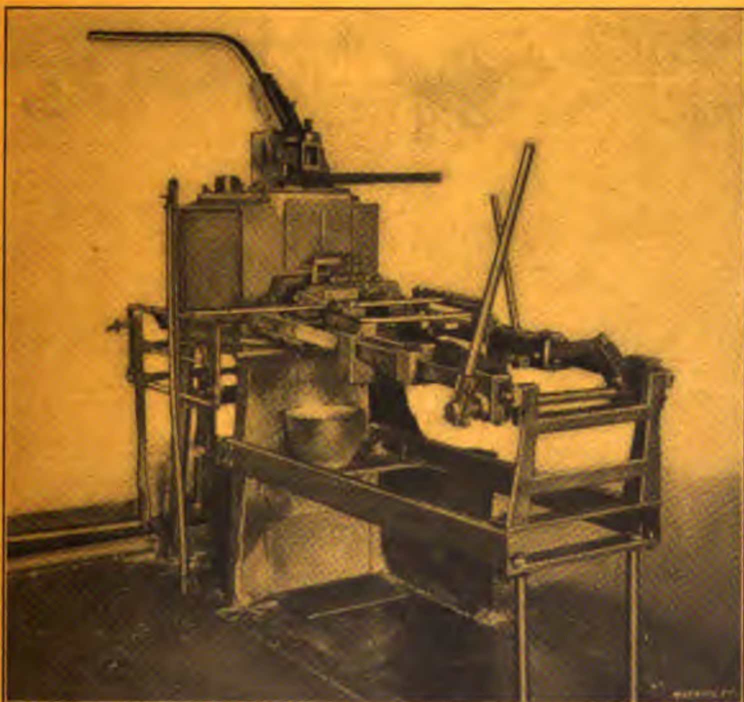

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NUMBER 108

DIE-CASTING MACHINES

CONTENTS

CHAPTER I

THE DESIGN OF DIE-CASTING MACHINES

Die-castings have become fairly well known in the past few years, but the machines, metals and methods employed in their manufacture are as yet very little known. This is due no doubt to the fact that the apparatus and methods employed have been zealously guarded as secrets by those engaged in this manufacture. It may be surprising to many to learn that the commercially successful manufacture of castings from alloys in metal die-molds has not been accomplished through any recent invention, nor been the result of any one individual's efforts. Like most other industries, it has been of a gradual growth, through a

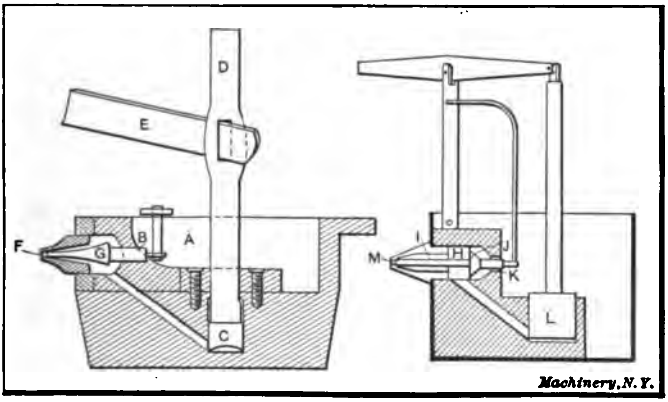


Fig. 1. Type-casting Machine built in 1849. Fig. 2. Improvement in the Type-casting Machine, made in 1856

period covering more than sixty years. The machines have been slowly perfected, and the alloys for the castings have been continually improved. Thus it is now possible to make dense, sound die-castings from alloys nearly as strong as brass, and a process by which a very strong bronze can be cast in die-molds is being developed.

Historical Development of Die-casting Machines

The first machines or methods along this line were used to manufacture bullets and type. Many inventions for casting bullets were made and several patents taken out in the years preceding and following the American rebellion and the Mexican war.

Of the type-casting machines, the first one of which we can obtain an illustration was patented on March 27, 1849, by J. J. Sturgiss. A sectional view of this machine is shown in Fig. 1. This illustrates the basic principle on which most of the die-casting machines in use to-day are built. In this machine the molten metal flows from the pot *A* which is surrounded with heat, through the opening *B* into the cylinder *C*. Plunger *D* is then forced down by the lever *E*, which is operated by a cam and connecting-rods, and forces the metal out of nipple *F* into the type-mold. Piston valve *G* is then forced forward to squeeze the metal into the mold and also cut off the liquid stream, so it will flow back into the pot.

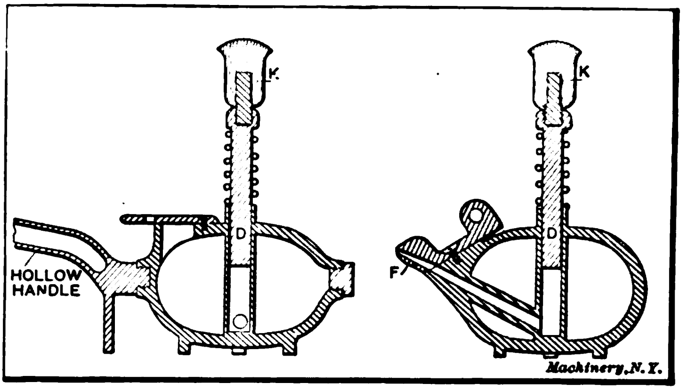


Fig. 3. Small Hand-operated Machine built in 1872

This was followed in 1852 by another patent by W. P. Barr covering other points on a machine which worked in practically the same manner as that shown in Fig. 1. As shown in Fig. 2, E. Peluze patented an apparatus on similar lines in 1856. His improvement over the two former machines was in the piston valve *H*. In this, valve *I* was

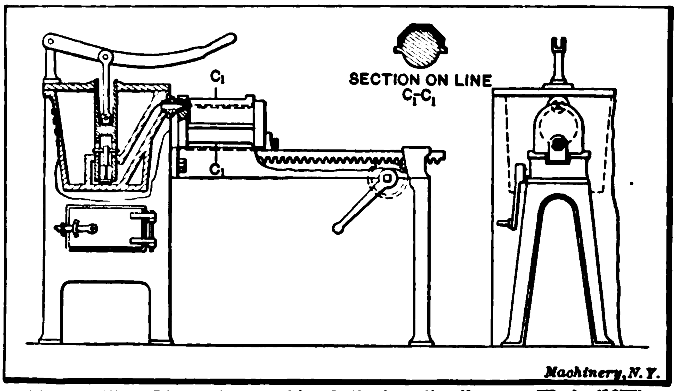


Fig. 4. First Die-casting Machine built for Miscellaneous Work (1877) set up for Casting Bearings

moved back until beveled surface *J* closed opening *K*, through which the molten metal flowed. Plunger *L* was then forced down, and this made the metal flow through nipple *M* into the type-mold. After this, piston valve *I* was forced forward, the same as in Fig. 1, and for the same reasons.

In 1872 a small hand machine was patented, as shown in Fig. 3. This was filled with molten metal from a melting pot, and when set on the bench, the palm of the hand was brought down forcibly on the wooden knob *K*. This forced down piston *D* and squeezed the metal out through nipple *F*. Other machines were invented in the following years for making medals, sewing machine bobbins and various other small articles. The type-metal apparatus was also improved by such inventions as that shown in Fig. 6, in which a much better design and arrangement were made of heating chamber, melting pot, cylinder, plunger, etc.

The first attempt to apply these principles to a more universal manufacture of castings was made by C. and B. H. Dusenbury in the

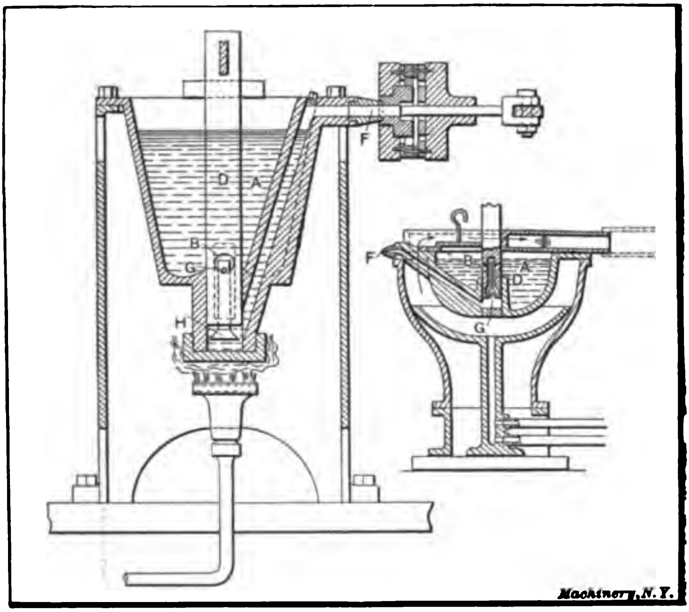


Fig. 5. Die-casting Machine patented in 1892. Fig. 6. Improvement made in 1888 on Machine shown in Figs. 1 and 2

machine shown in Fig. 4, which they patented in 1877. In this, the same principles as used on former machines were adopted for the melting pot, cylinder, plunger, outlet passage and nipple. In addition thereto, arrangements were made by which the die-molds, that contained impressions for journal bearings, were located on the machine, and exchanged for others when desired. Thus a wide range was given to the machine. The method of moving the mold away from the nipple so it could be opened and closed was accomplished by the gear and rack.

Little was done with this method of casting until after C. W. Weiss was allowed some claims, on March 8, 1892, on practically the same machine that was patented by the Dusenburys in 1877. This is shown in Fig. 5. From this time on the die-casting business has steadily grown until it is now quite an important factor in the manufacture of many products. The many improvements have given us automatic machines that insert wires, bushings, clock wheels, etc., of steel, bronze or other strong metals, into the molds; and close them, cast the alloy and eject the finished casting out of the mold. Between this and the simple hand-operated machine there are belt-driven, motor-driven and semi-automatic machines used in the manufacture of die castings.

Hand-operated Machines

The strictly hand-operated machines have been perfected to an extent that enables one man to turn out a large number of castings with an alloy that is not very high-priced. Thus a machine may be placed in a room or in any part of a shop where there is no power. The only thing required to operate it is a supply of gas to heat the melting pot

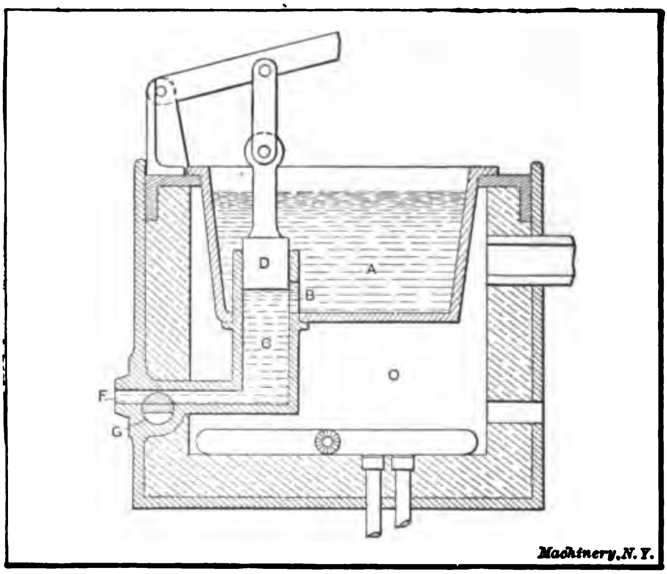


Fig. 7. Melting Pot with Side Outlet

and melt the metal, and a man. The output of these hand-operated machines is so large that it is only under very special conditions that the automatic machines can be economically operated. These conditions would require a very large number of castings from the same mold, and the castings could not be very intricate. With the hand-operated machines, however, very intricate castings can be made from the white-metal alloys generally used.

The modern hand-operated machine with its melting pot and method of forcing the metal into the molds has undergone many changes and has been the subject of a great deal of designing. In connection with it, valves and sprue-cutters have been made in several different ways.

The ways and means of holding the molds for the cast and then opening, or parting them to eject the casting have also been improved in various ways. From the melting pot the metal has been forced through the sides, top and bottom, and then into the molds. A cylinder and plunger has been the favorite method used, and this has been designed in various styles and sizes. Some have used air for forcing the metal into the mold, but with no success.

Melting Pots and Plungers

In Fig. 7 is shown one of the latest styles of machines with the outlet from the melting pot in the side. In this the burning gas in chamber *O* keeps the metal molten in pot *A* and it flows through passage *B* into pressure chamber *C*. From here it is forced by plunger *D*

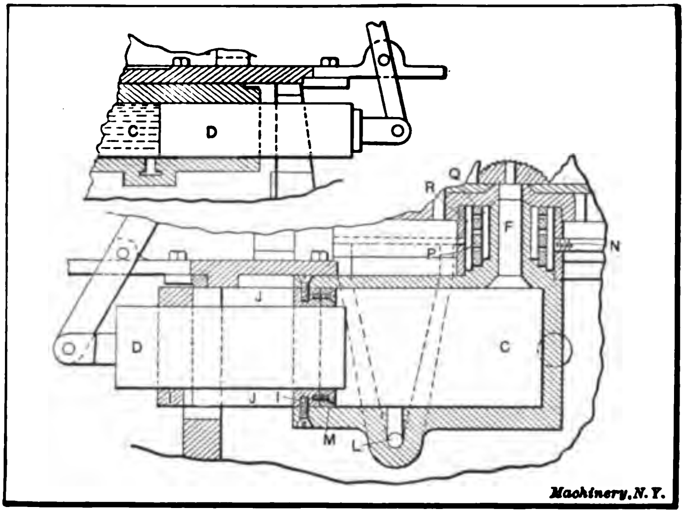


Fig. 8. Long Type of Plunger. Fig. 9. Plunger smaller than Cylinder—Auxiliary Heating Chamber for Outlet Passage

through nozzle *F* into the mold. Valve *G* is then turned over to stop up the passage and thus cut off the flow of metal. This style of machine brings the pressure chamber *C* down into the gas chamber, where it is easily heated to the right temperature for casting. The metal that lies between valve *G* and the end of nozzle *F*, however, has to be removed before it freezes and before the mold is opened. It is therefore necessary each time a casting is made to move the entire mold away from nozzle *F*, while the sprue-cutter is in position for keeping the metal away from the casting. This extra metal then falls to the floor. This has been overcome in some machines, and hence one cause of trouble is removed. Another fault is that while plunger *D* is traveling past port *B* it forces the metal out into melting pot *A* and thus keeps it continually churned. This causes the dross and slag that should rise to the top to mix with the molten metal and enter the castings.

The plungers used with this type of machine differ considerably. The one shown in Fig. 7 has a bearing surface as long as the diameter of the plunger. This "square" plunger gives very good satisfaction where it is covered with molten metal, as it is in this case. An extremely long plunger is shown in Fig. 8. The construction of the machine is such that one end of the plunger comes out into the gas chamber and thereore it was extended into the open air in order to overcome the excessive heat of the gas flames. Much trouble has been experienced with this type, from the metal freezing around the surface between it and the cylinder, thus causing the plunger to stick. This is largely due to the great difference in temperature between the two ends, and consequently plungers of this type have to be continually cleaned.

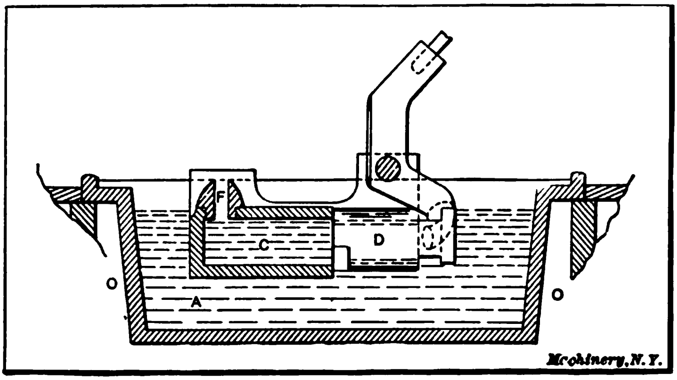


Fig. 10. Pressure Chamber submerged in Melting Pot

To overcome this, the type of plunger shown in Fig. 9 was invented. It is smaller in diameter than the cylinder or pressure chamber and travels in a rack composed of the two rings *I*, which are held together by ribs *J*. One of these rings fits into the end of the cylinder, and holds the rack in position. The molten metal flows into the pressure chamber through port *L*, and a valve closes this port when the plunger is brought forward to force the metal up into the mold. In the cylinder is located an asbestos washer *M* for preventing any leakage of molten metal that might occur. This type of plunger largely overcomes the tendency of metal to freeze on the bearing surface, as its area is greatly reduced. Dross also is not as liable to clog and stick the plunger in the cylinder. This design has, however, added the troubles encountered with an asbestos washer, which, owing to its non-cohesiveness, is continually crumbling away and flaking off.

Around the outlet or nozzle of this machine has been placed an auxiliary heating chamber. Gas enters through pipe *N*, surrounds the nozzle in passage *R*, passes through the perforated ring *P* and fills the inner chamber *Q;* after which the burnt gases pass out. This keeps the molten metal that fills nozzle *F* from chilling when a casting is being made. This is one of the troubles often met with in this style of die-casting machine. Of course, when the sprue-cutter has severed the metal between the mold and the pressure chamber *C*, this passage empties when plunger *D* is pulled back. Passage *F*, however, is filled a large part of the time, as in making a casting it is necessary to bring the plunger forward as hard as possible, and hold it there while the mold is filling with metal and the sprue-cutter is being operated. Metal freezing in this passage causes a great deal of trouble which a heating chamber might abolish.

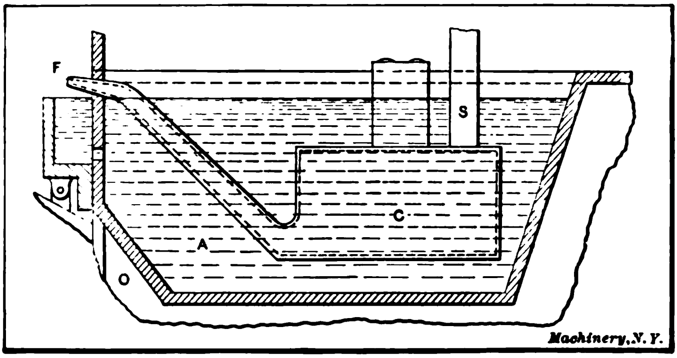


Fig. 11. Melting Pot with Air Pressure Chamber

In Fig. 10 is shown another style of melting pot. This has a pressure chamber submerged in the molten bath, and the plunger is operated by a lever which passes out through the top of the bath. The nozzle also carries the metal through the top of the bath to the mold. In this type the melting pot *A* is surrounded with gas flames at *O*, and the metal in the pressure chamber has to be heated through the mass of metal in the melting pot *A*. It is therefore difficult to keep the

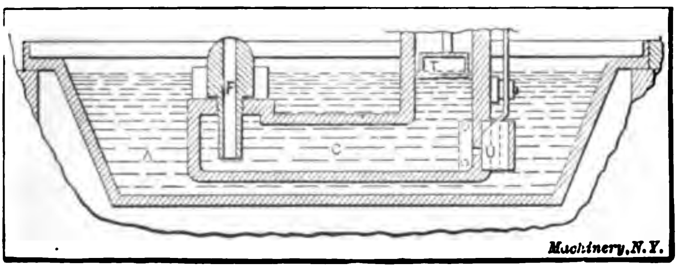


Fig. 12. Another Type of Air Pressure Chamber in the Melting Pot

metal in pressure chamber *C* as hot as that in melting pot *A*. The opposite condition should exist, *i. e.*, the metal should be hottest at the point where it is being forced into the mold. While several die-casting firms have used this type of machine, it has been the cause of much trouble.

Application of Compressed Air to Die casting Machines

In Fig. 11 is shown a pressure chamber submerged in a melting pot, but instead of using a plunger, compressed air is driven into the pressure chamber through pipe *S*. and this forces the molten metal out through nozzle *F* and into the mold. This application of compressed air has appealed to many builders of die-casting machines owing to its simplicity of operation, its positiveness, and the fact that operating troubles, such as the plunger sticking to the cylinder, were overcome in the machine. All those who attempted it, however, were men who understood nothing of metallurgy or the nature of metals. With the exception of a few very rare elements, oxygen unites with every known substance. It has a special affinity for metals when heated, and the

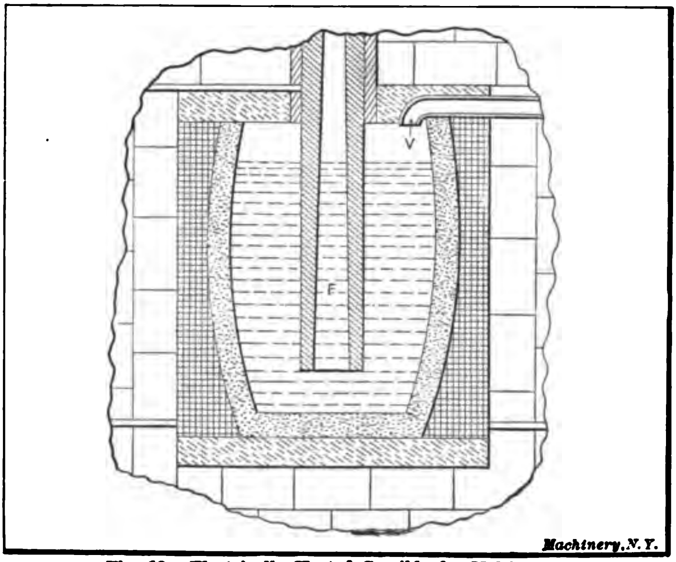


Fig. 13. Electrically Heated Crucible for Melting Pot

higher the temperature, the greater will be this affinity. It is one of the most injurious elements that can be injected into metals. By forcing air under pressure into pressure chamber *C* as is done in this case, it is impinged directly upon the surface of the metal with considerable force, and thus greatly increases the amount of oxygen that the metal will absorb from this air. After the first few castings are made, the metal becomes full of small bubbles which increase in size with the number of castings made, and in a short time there is nothing to the casting but a shell of metal that is filled with bubbles. Many times such castings are marketed because the spongy formation of the center does not show on the outer surface, but the instant they are broken, their worthlessness is apparent.

In Fig. 12 is another type of the pressure chamber that is submerged in the melting pot, and thus has the coldest part of the molten metal passing through nozzle *F*, as in the case in Figs. 10 and 11. In this, air pressure has been used to force the metal up through nozzle *F*, but an attempt has been made to overcome the defects always encountered when using air. Float *T* has been placed in a compartment by itself, and the air is blown into this so that it will impinge upon

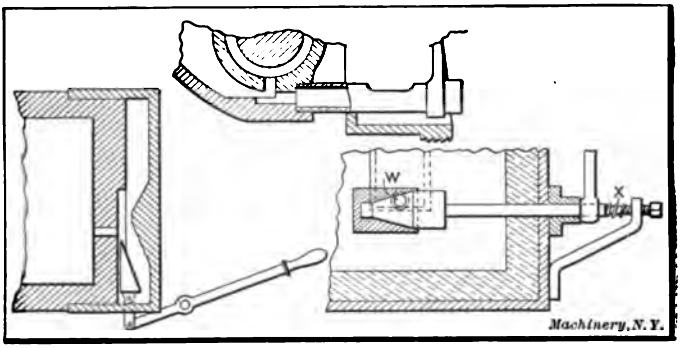


Fig. 14. Three Styles of Valves used

the surface of the float, and only have a small surface of metal around the float to absorb the oxygen. Nozzle *F* was also made of a casting that projected close to the bottom of the bath in order to let out any bubbles and get only the densest metal in the pressure chamber. It

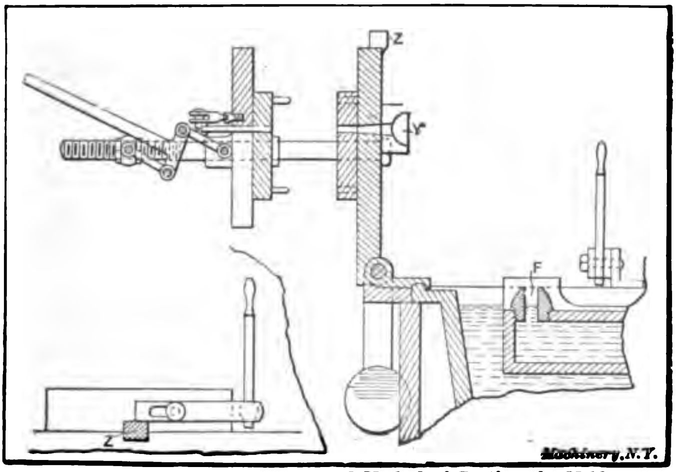


Fig. 15. Tilting Mold Table and Method of Parting the Mold

was thought that the bad effects of air, or the oxygen in the air, would be overcome by causing it to travel downward and then across the pressure chamber to the nozzle *F*. While the bad features of air pressure were overcome to a certain extent, they could not be entirely avoided as long as any part of the surface of the metal was left free to be attacked by the oxygen in the atmosphere. Thus, while this machine will make quite a number of castings before the metal becomes charged with oxygen, it is still only a question of time when that will occur, and then the castings will be weakened and probably spongy and porous. An automatically operating valve was placed at *U*, so that pressure chamber *C* would take metal in as fast as it was injected into the molds.

Electrically Heating the Melting Pot

Another type of melting pot is shown in Fig. 13. In this design an ordinary graphite crucible is surrounded with a resistance coil, and placed in a brick-lined receptacle. An electric current is then turned on to heat the crucible and metal. The top of the crucible is sealed,

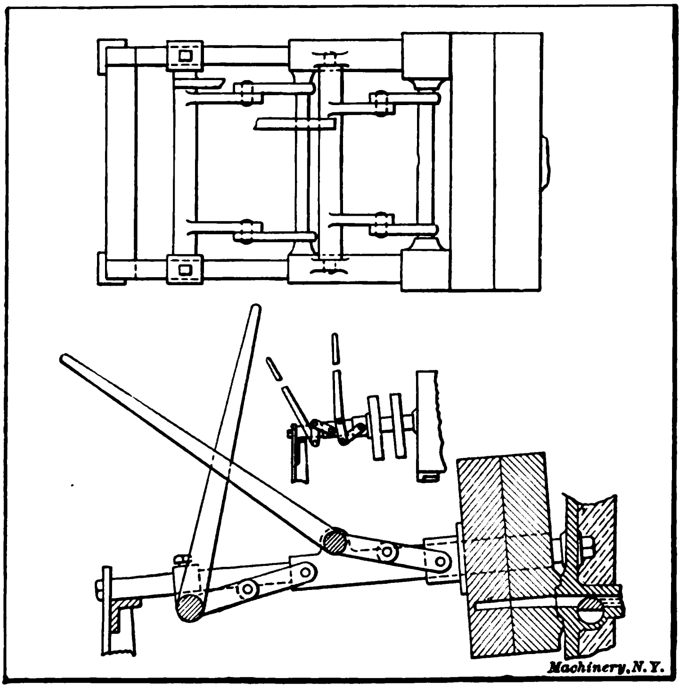


Fig. 16. Toggle-joint Arrangement for Parting the Mold and Drawing it away from the Spout

and air is injected through pipe *V* to force the metal up through the nozzle. While the electric heating arrangement is a good feature, the air pressure attacking the surface of the molten metal makes this type a complete failure.

Valves

In Fig. 14 are shown three styles of valves which are used on die-casting machines. The one to the right, as can be seen, is cone-shaped and opens and closes the hole *W*. A sectional view through this hole is shown in Fig. 7 where the valve is marked *G*, and hole *W* represents outlet passage *F*. This valve is kept a tight fit by a spring located at *X*. It is easy to operate by connecting it to some of the other levers on the machine. The valve shown in the center of the illustration is operated automatically by chain and sprocket wheels, and closes its opening by turning half-way around. The bad feature of this valve is the large amount of surface which the molten metal comes in contact with, thus causing the valve to stick. The valve shown to the left is much more simple and has practically no wearing surface, it being merely a wedge-shaped block that is forced into place by a beveled projection on a frame. This, however, can not be used in all places, and though its design is doubtless the best, its use is limited to the places where it can be operated.

Opening and Closing the Molds

The methods of holding the die-molds vary with the different styles of machines, and a large part of this variation is due to the different constructions previously shown. In the machines that eject the metal

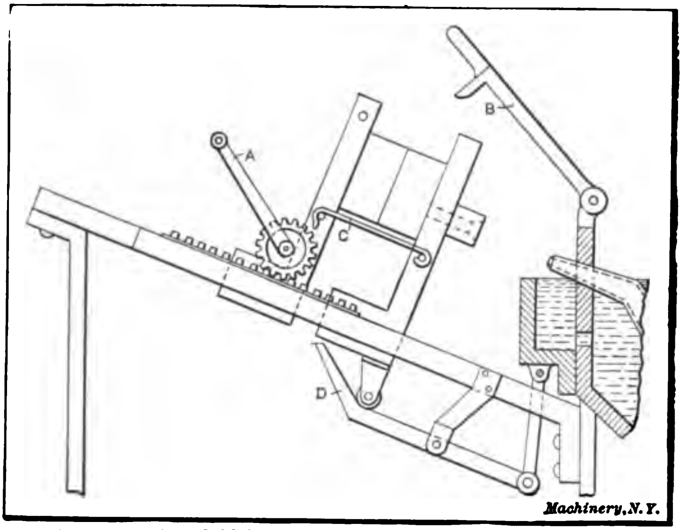


Fig. 17. Rack and Pinion used to part the Mold and draw it away from the Spout

through the top of the bath, platens are used on which to rest the mold, and these are usually fitted with tilting arrangements similar to the one shown in Fig. 15. In this machine, nozzle *F* is ball-shaped, and socket *Y* fits down over it when the table, with its die-mold, is in position for casting. The platen is clamped down by projection *Z* fitting under a piece that is moved by the upright lever, as shown by the sketch in the lower left-hand corner. The mold is divided into two parts. One part is fitted to a plate located on two rods that are bolted to the platen. A toggle-joint is then used to pull the two parts of the mold apart, so that the casting may be removed. This toggle-joint is operated by the lever shown in the inclined position, and as will be seen, arrangements are made to take up any wear that might occur in this joint. The mold will thus be a perfectly tight fit at all times. This is a very important point in making die-castings, as the metal is squeezed into the mold under pressure, and if the joint were not a tight fit, this metal would squeeze out through the sides.

In Fig. 16 is shown a method of holding the mold in position for casting on a machine that takes the metal out through the side. One

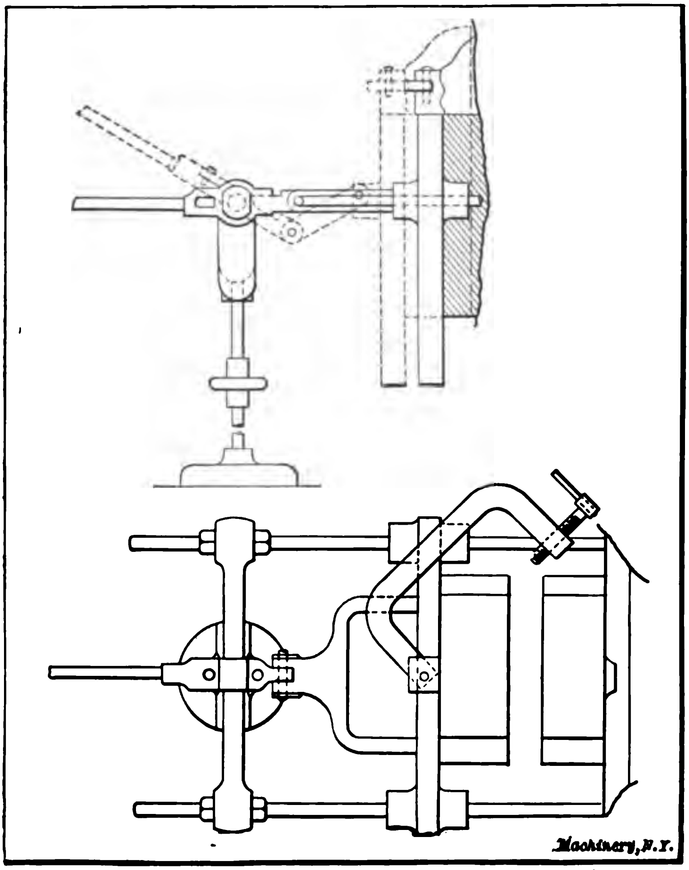


Fig. 18. Another Method of Opening and Closing the Mold

toggle-joint is used to close the two halves of the mold, while a second one is used to force the entire mold up against the nozzle. Why the toggle-joint, with all its faults, is used so much on die-casting machines is really a mystery, and yet it is probably due to the fact that the first machines invented were equipped with toggle-joints, and consequently nearly all designers followed this principle.

In Fig. 17 is shown a rack and pinion which is used for moving the mold away from the nozzle and also for parting it. In this illustration, lever *A* is used to operate the pinion which pulls the mold away from the spout. Hook *B* is then dropped down over the mold to hold it in position, while hook *C* is released and the two halves of the mold are pulled apart by the same gear and rack. In pulling the mold back, lever *D* is tripped and opens a valve that allows enough metal to flow into the pressure chamber to take the place of that which has been

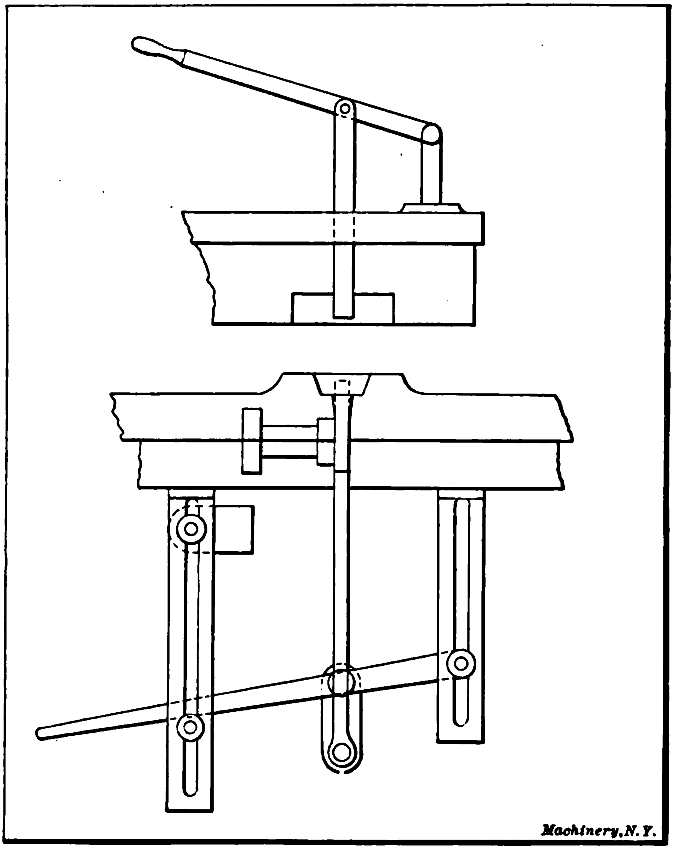


Fig. 19. Two Forms of Sprue-cutters

forced into the mold. While this tripping arrangement is good, and the gear, rack and pinion work successfully, the rest of the design is very crude, and it would mean very slow work in making castings. This machine, however, has not been commercially operated, and probably would not be without considerable re-designing. One of its worst features is the teapot form of pressure chamber with its air pressure. In Fig. 18 is shown still another method of opening and closing the mold, and clamping the two halves together. This also is crude and too slow in its operation.

Sprue-cutters and Ejectors

One of the necessary features on all die-casting machines that turn out perfect castings is the sprue-cutter. Two forms of these are shown in Fig. 19. The upper one is simply a rod that is pushed through the center of the casting. It implies that the casting has a center hole, and is very simple to construct and operate. If this hole is straight, it is

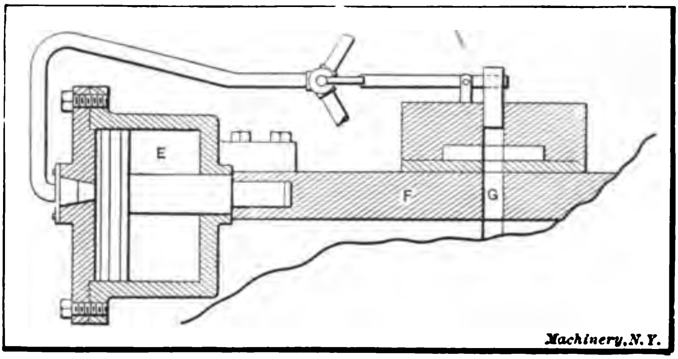


Fig. 20. Moving Platen to cut off the Sprue

immaterial whether it be round, square or any other shape. After the mold is filled, the sprue-cutter is pushed through it to separate the casting from the metal in the melting pot.

When castings have no center hole, the sprue-cutter can be placed at the end of the casting, as shown in the lower view. This mechanism

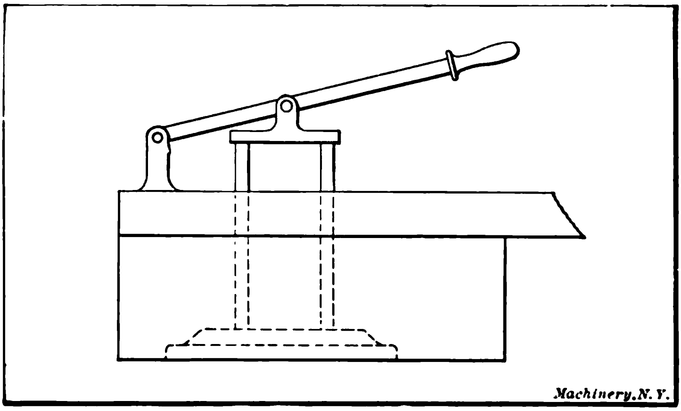


Fig. 21. Casting Ejector

makes it possible to stop the sprue-cutter at both ends of its stroke, the stops being adjustable to any position. The lever also gives the sprue-cutter, which must be a tight fit in the hole in which it operates, a straight push.

In another style of machine the sprue is cut with the platen, as shown in Fig. 20. In this, a piston working in the air cylinder *E* pushes platen *F* over far enough for outlet passage *G* to be out of alignment with the sprue hole in the mold, or the outlet in the lower part of the machine. This cuts off the metal, and leaves a pocket of metal in passage *G* which will equal the thickness of the platen. When it is held long enough for the casting to freeze in the mold, the metal in this passage will freeze and thus put the machine out of commission.

The principle of using air to operate different parts of die-casting machines, such as pressure levers, sprue-cutters, casting ejectors, etc.,

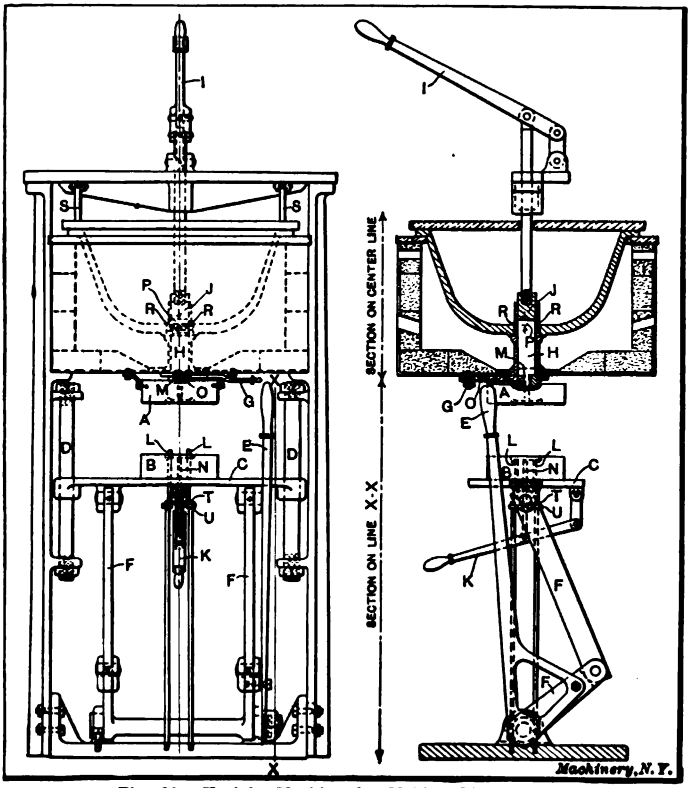


Fig. 22. Upright Machine for Making Die-castings

is very good; but considerable care in designing must be exercised to insure that no metal will be trapped in any part of the machine, and become solid. When this occurs it means that the machine must be taken apart and cleaned before it can be further operated.

In Fig. 21 is shown a casting ejector. This is fastened to one-half of the die-mold, and when the casting is complete and the mold open, the lever is brought down so that the small rods will push the casting out of the mold. The rods, of course, can be placed in any position desired, made of any size or shape, and are a very simple part of the die-casting machine. The casting ejector and the sprue-cutter must occupy positions very close to each other, and the levers that operate each one of these are placed in easy reach of the operator.

Upright Die-casting Machine

In Fig. 22 is shown a complete upright machine that differs quite materially from the others shown. In this, the heating chamber, with its melting pot and pressure chamber, is supported on a cast-steel frame, and the molds are held directly underneath its center. The upper half *A* of the mold is fastened to the bottom of the heating chamber, and the lower half *B* is lowered away from it to get the casting out. The lower half of the mold rides on a cast-iron plate *C* which moves up and down on rods *D*. Lever *E* raises plate *C* with its half-mold, by means of the toggle-joints *F*.

In operating the machine, the two halves of the mold are brought together tightly by pulling lever *E* outward. Lever *G* is then moved out to open outlet *M* of pressure chamber *H*, so that the metal will enter the mold. The lever *I*, which is above the machine, is pulled down to force plunger *J* downward, and thus squeeze the metal filling the cylinder or pressure chamber *H* into the mold. Lever *K* is then pulled up and forces the sprue-cutter *N* entirely through the upper half of the mold *A* and into the nozzle. Lever *G* is now pushed in to close the opening from pressure chamber *H*, sprue-cutter *N* pulled out with lever *K*, and the bottom half of the mold lowered by pushing in lever *E*. As this is done, small plate *T* beneath plate *C*, strikes plate *U*, which is supported from the base of the machine, and this causes casting-ejector *L* to push the casting out of the lower half of the mold. Hinged pieces *S* hold down the cover of the melting pot, so that when the two half-molds are brought together they will not raise the melting pot. One difficulty encountered with this type of machine is that of keeping outlet *M* free from molten metal, so that it will not drop on the casting and spoil it when the mold is opened for its removal. By making sprue-cutter *N* come up close to the metal cut-off *O*, this can be accomplished, but to make a tight fit of these two parts and keep it tight with the continued movements of the machine, while making castings, is not as easy as it looks. A very small drop of metal will often spoil the casting that is being made.

Another bad feature is that the plunger must move the distance shown by *P* before it forces the metal into the mold. While moving this distance it is squirting the molten metal out through ports *R*, and thus churning up the metal in the melting pot. This metal should be kept as quiet as possible. Another bad feature is that four levers must be moved independently for each casting that is made, and this makes the operation of the machine rather slow. These levers should be connected in such a way that the pulling of the two levers would be all that is required.

A machine of this type, however, could very easily be belt- or motor-driven, and thus make its operation a boy's work. The work would consist of removing the castings and starting and stopping the machine.

It could also very easily be made to operate automatically, and thus do away with even that much hand labor. The upright machine appeals to many on account of having the natural phenomena of gravity to assist in getting the metal from the melting pot into the mold. If the liability of molten metal dripping on the finished casting is overcome, this style of machine is very handy and easy to operate.

While many die-casting machines are made for belt or electric drive and semi-automatic or completely automatic, it requires an enormous output to make such a machine a paying proposition, for by gating the castings in molds, a very large output can be obtained with one man's labor on a hand-operated machine, but where thousands of pieces are to be made per day, the automatic machine will save this one man's labor, and can thus be made to pay.

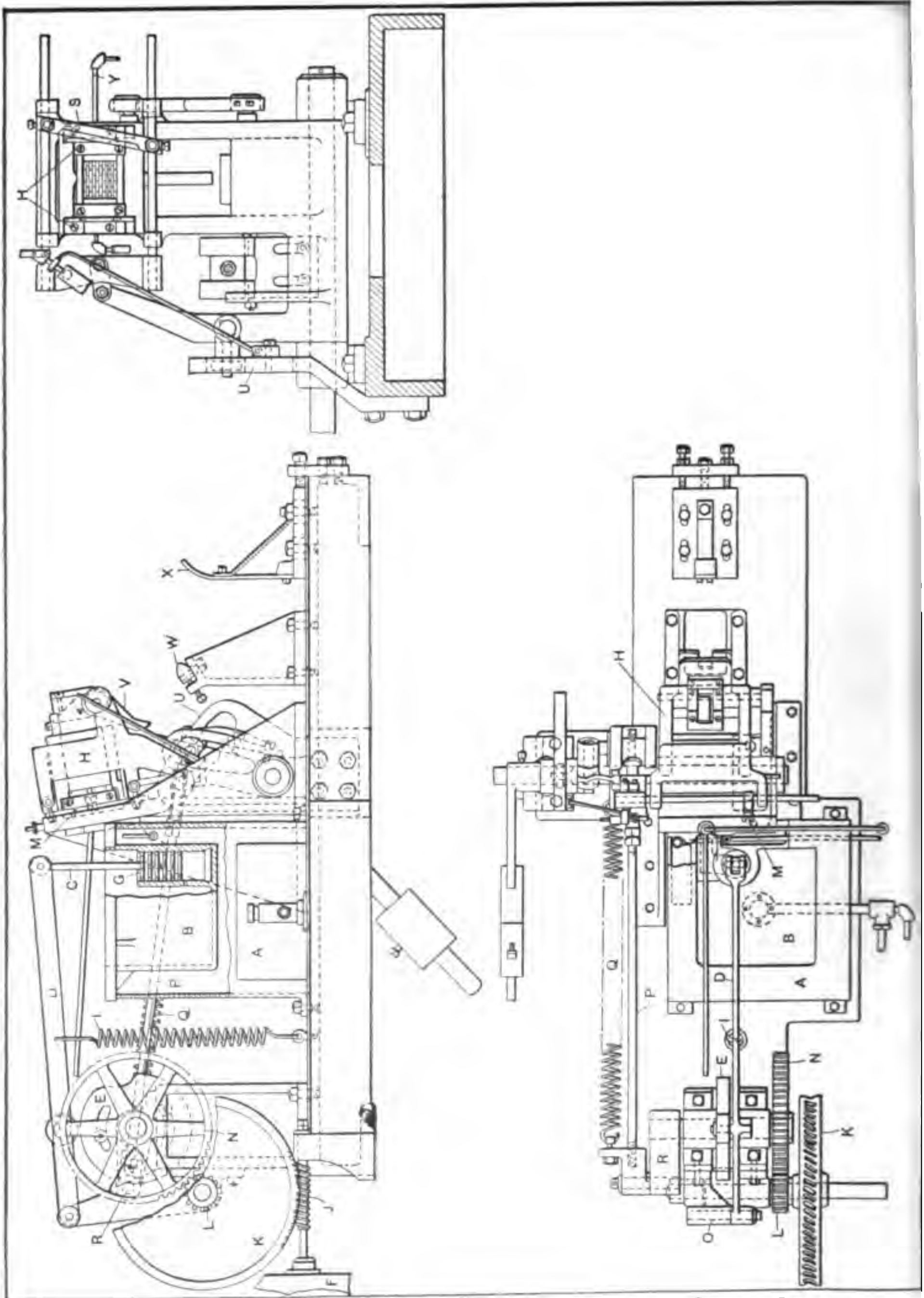
Alloys for Die-castings

Many different alloys are used for die-castings. It is necessary to have an alloy with a fine, close grain that is free from porosity and low in shrinkage. Castings used for some purposes must have a high tensile strength and great hardness, and these can only be obtained at a sacrifice of ductility. Castings with a high ductility can easily be made, but the tensile strength and hardness must be sacrificed. This is also a general rule that applies to the manufacture and production of alloys and metals for all other purposes as well as die-castings.

Zinc, tin, copper, antimony. lead, aluminum, nickel, bismuth, magnesium and silver have been compounded in many different percentages to form alloys from which castings for a variety of purposes are made. The first five, namely, zinc, tin, copper, lead and antimony are those most commonly used. Nearly any degree of strength, hardness, toughness, ductility, etc., can be obtained up to those inherent in the combinations that can be made. As yet, no one has marketed castings of the yellow metals or successfully made die-castings, on a commercial scale, from alloys or metals that have a melting temperature much above 1200 degrees F., or that have a strenght equal to the bronzes. Considerable experimenting has been done and success is nearer than it was some years ago, even though the right method may not yet have been discovered.

Aluminum in small percentages is used in many of the die-castings. It acts as a purifier of the alloy, and causes it to flow more freely in the mold. To cast pure aluminium in die-molds or aluminium alloyed with small percentages of zinc or copper, or both, is very difficult. These alloys cannot be cast at all in very thin sections or with very fine detail in figured work, such as is produced in art castings. The lighter aluminum-magnesium alloys have also been experimented with, but these experiments have not met with much success as yet.

Much time and money has been spent by the different die-casting firms to die-cast manganese bronze, but this has been a failure, owing to the zinc oxide which forms on its surface when the alloy strikes the colder metal from which the die-mold is made. It is very doubtful if this feature can be overcome. One of the great difficulties encountered



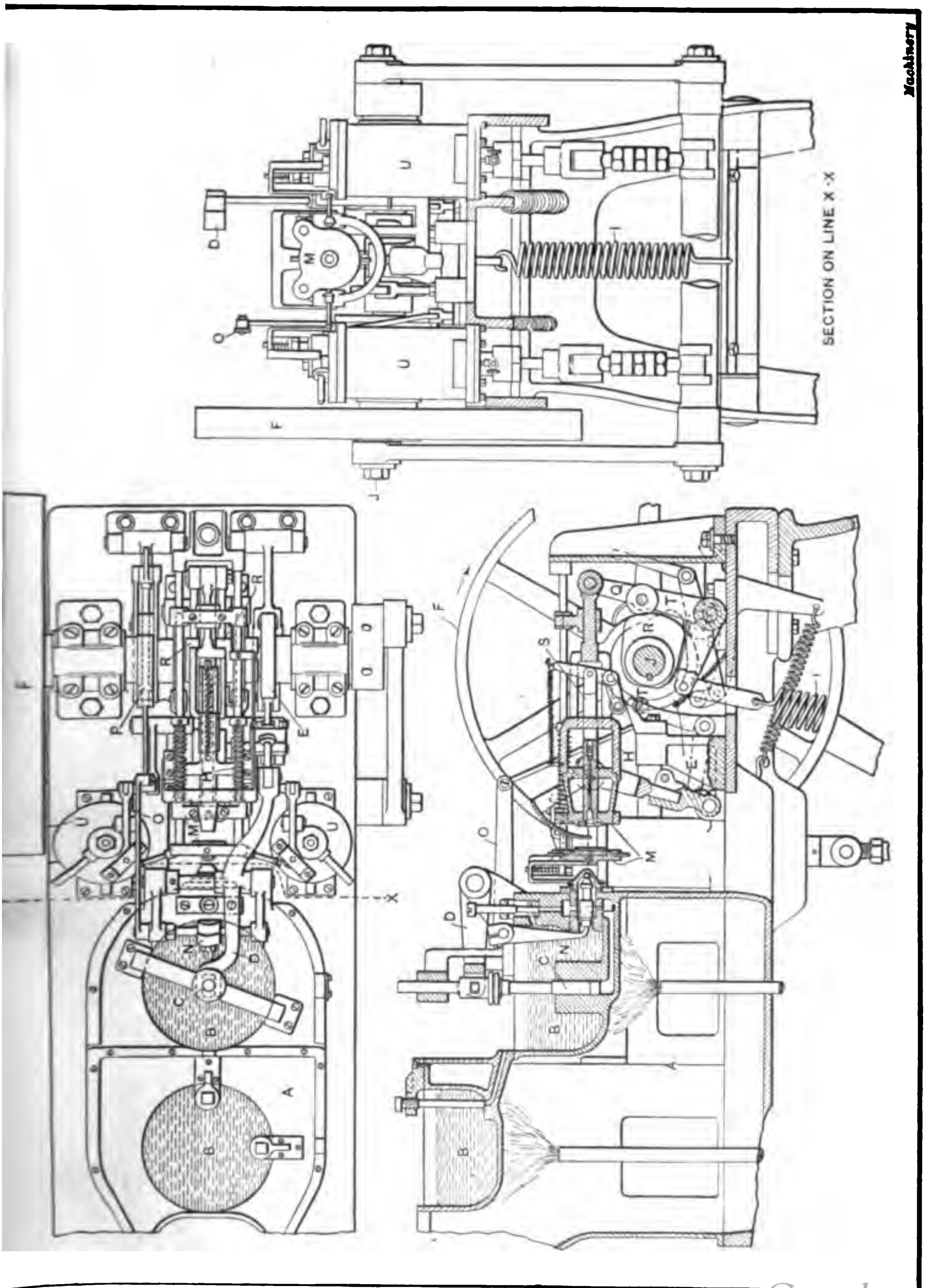


Fig. 24. The Latest Type of Automatic Die-casting Machine

in casting metals of these comparatively high melting temperatures is the oxidization that the casting surface of the steel mold undergoes when its temperature is raised by the molten metal coming in contact therewith. This causes the mold to alter in size and shape, and thus destroys the accuracy of the castings. As this is an expensive way of producing castings, it is only by making them accurate as regards size and shape, and thus saving all machine work, that they can be made a commercial success. When this is done, however, the saving effected is so great that the die-casting machine and its products have become a necessity in manufacturing many parts of machines, instruments, etc., in the modern shop.

Aside from the die-castings made for bearings, zinc is the principal metal in die-casting alloys. An analysis of one of the most prominent makes of die-castings for use where no great strength or hardness was required shows 73.75 per cent of zinc; 14.75 per cent of tin; 5.25 per cent of copper, and 6.25 per cent of aluminum. Another prominent make that is used for similar purposes showed 72.70 per cent of zinc; 19.00 per cent of tin; 5.00 per cent of copper; 2.00 per cent of lead; 1.00 per cent of aluminum, and 0.30 per cent of antimony.

A die-casting that is somewhat harder than the two before given shows on analysis that the alloy is composed of 73.80 per cent zinc; 12.00 per cent tin; 10.60 per cent copper; 3.40 per cent aluminum, and 0.20 per cent iron, the iron being an impurity. Some very hard die-castings analyze as follows: 46.20 per cent zinc; 30.80 per cent tin; 20.40 per cent copper; and 2.60 per cent aluminum. An alloy that is very high in zinc contains 93.00 per cent of zinc; 3.50 per cent tin; 2.00 per cent copper; 1.50 per cent antimony, and 0.40 per cent aluminum.

[The sum of the percentages is 100.40. This anomaly is explained by the fact that after melting 93 pounds zinc, 3.5 pounds tin, 2 pounds copper, and 1.5 pound antimony, 6.5 ounces of aluminum is added as a deoxidizer.]

Another alloy is composed of 90.00 per cent zinc, 6.00 per cent copper, 1.00 per cent tin, and 3.00 per cent aluminum.

While zinc and aluminum in certain percentages and under some conditions might make good die-castings, the aluminum cannot be very high or the alloy shows a tendency to disintegrate. An alloy composed of 50.00 per cent zinc and 50.00 per cent aluminum will disintegrate into a granular mass inside of a year. Such a mixture, even though possessing considerable strength at the time of casting, would very soon lose its strength and crumble up. Some of the die-castings made at present disintegrate, so that their strength is greatly weakened in the course of two or three years. This, however, is due to improper mixtures, as they can easily be made so that practically no disintegration will take place at all.

Zinc and tin mixtures also show an inclination to disintegrate, and hence some other material has to be alloyed with them to act as a binder. They are also inclined to be very brittle unless copper is added, and the molten metal thus given a greater ductility. The zinc and tin mixtures that contain a small percentage of copper are good for wearing parts and also for plating and japanning.

Antimony and bismuth have frequently been used in combination with lead to give the lead a greater hardness. Where no particular strength is desired, such an alloy can be used. The type metals that contain approximately 83 per cent lead and 17 per cent antimony have been cast in machines using steel molds for a number of decades. Practically all of the type metals such as standard, electrotype, linotype, etc., are easily manufactured by die-casting. These contain from 58 to 80 per cent lead, from 4 to 25 per cent antimony, and from 3 to 15 per cent tin. This gives a metal that is fairly hard and has considerable weight, but it is comparatively weak.

Alloys with high percentages of zinc, and a comparatively high copper content are very brittle, with little ductility and strength, while an alloy that is high in zinc and low in copper, *i. e.*, containing 90 to 92 per cent zinc and 8 to 10 per cent copper, shows a good resiliency and strength but no ductility.

Tin alloyed with lead and zinc casts freely and clean, and hence can be made to fill delicate parts of a mold. The zinc in die-castings usually runs from 70 to 90 per cent; the tin from 5 to 30 per cent; the copper from 2 to 20 per cent; the antimony from 1 to 5 per cent; and aluminum as high as 6 per cent has been used. While other metals have been used for making alloys for special castings, the ordinary casting can be produced from alloys made from these metals.

CHAPTER II

AUTOMATIC DIE-CASTING MACHINES

Nearly all die-casting machines in use at the present time are operated by hand, that is, a number of levers are pulled back and forth to perform the different operations of closing the mold, moving the plunger to force the metal into the mold, cutting off the sprue. opening the mold, and ejecting the castings. Nearly all of these machines require two men to operate them, and in some cases it requires five men to operate two machines. With these hand-operated machines a large quantity of castings can be manufactured in a day, and many have not considered it necessary to design and build more expensive machines. Some manufacturers, however, have built completely automatic machines for their own use, in order to save the labor cost of the hand-operated machines. These automatic machines are very successful, and are producing die-castings at a very low cost.

Automatic machines for casting type have been in use for more than sixty years, and these are, in reality, die-casting machines, although only used for the particular purpose of manuacturing type. Like all other die-casting machines, the automatics were devised from ideas and principles adopted in the type-casting machines. and are, in fact, largely improvements of these. The first attempt at applying such machines to the manufacture of castings. other than type, is shown in Figs. 25 and 26. This machine was patented by M. Dimock in 1875 for the manufacture of sewing machine bobbins. By turning crank *F*. all movements were produced that were necessary for the casting of a bobbin and throwing it out of the machine. By putting a pulley in place of the crank, it could be belt-driven and thus made completely automatic. In this machine, *A* is the furnace and *B* the melting pot located over the furnace, in which the metal is melted and held, ready for casting; *C* is the upper end of the pump or plunger that forces the metal into the mold. This plunger is raised and lowered by levers *D*. which in turn are moved by cam *E* located on the driving shaft. which passes through the machine from crank *F* to the flywheel *G*. The mold and the apparatus for opening and closing it and ejecting the casting are located on a framework just above this shaft. The die-mold receives its metal from a nozzle in the side of the melting pot.

The cross-section of the die-mold, with shank *H* on which it is pivoted, is shown enlarged in Fig. 27; the bobbin which is cast in it is shown above the mold. Shank *H* fits into cross-head *I*. and is, by means of this cross-head, pulled back from the spout so that it can be opened. The two halves of mold *M* are opened like an alligator's jaw by turning bar *J*. which is long enough for this purpose and is located on the end of shaft *U* that passes through shank *H* and carriage *I*. The cast bobbin is then thrown out and the mold closed, ready for another casting. The cross-head and mold are moved back and forth by lever *K*. one end of which is pivoted to the frame at the bottom of the machine, while the other end works in a slot in the cross-head. Lever *K* is operated by

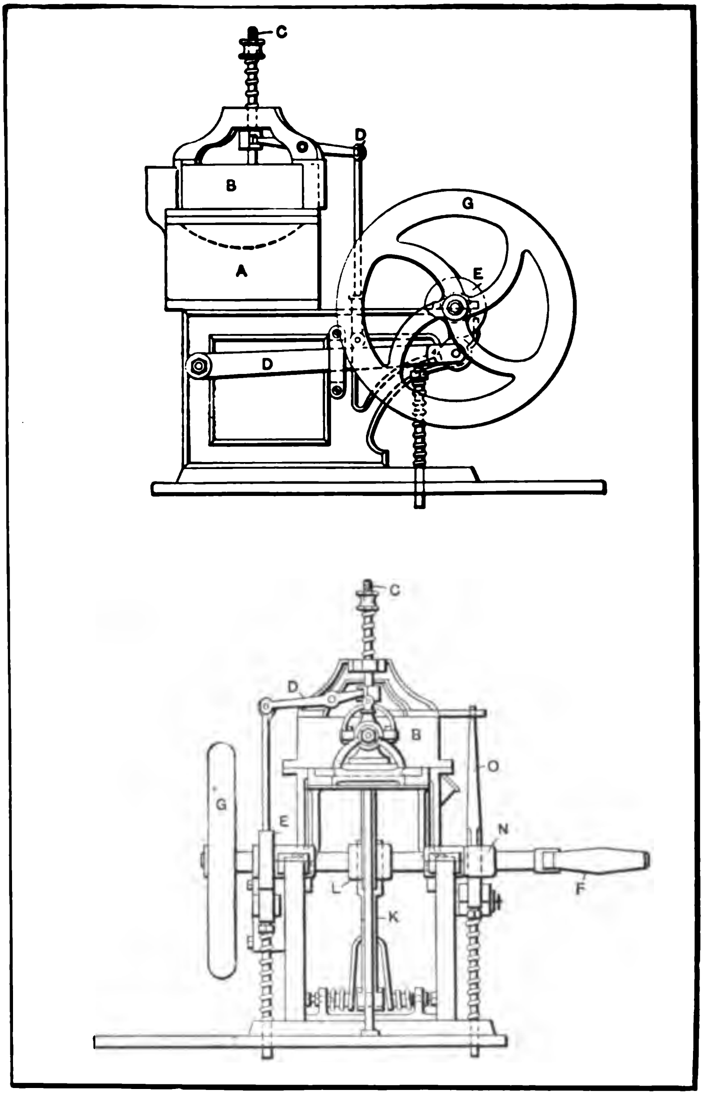


Fig. 25. Side View and End Elevation of First Automatic Die-casting Machine

cam *L* which is located at the center of the main shaft. When mold *M* is moved up to the nozzle of the machine, the tapered end at *V* enters a socket. thus holding the mold firmly closed. As soon as the mold assumes this position, a cam located on the main shaft at *N* operates hinged lever *O*, and this, in turn, moves lever *P*, which opens a valve that allows the molten metal to be injected into the die-mold. This

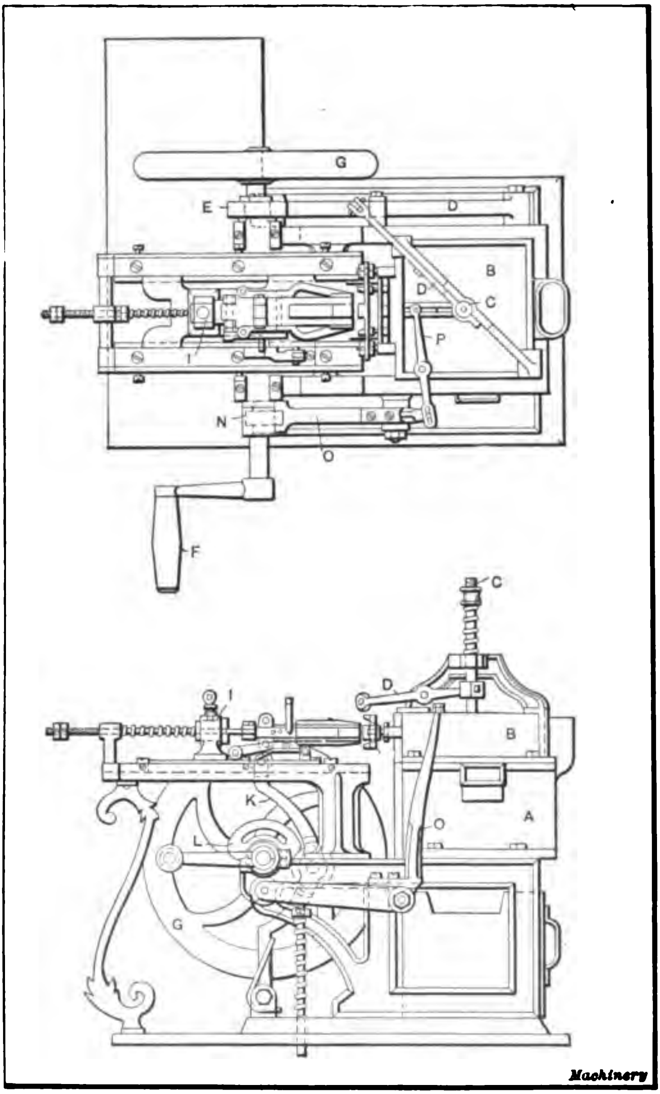


Fig. 26. Plan View and Side Elevation of First Automatic Die-casting Machine

valve operates in practically the same manner as valve *T* in Fig. 28 and valve *L* in Fig. 24, to be described later. In the meantime, plunger *C* has been raised to the top and as soon as the metal cut-off valve opens, the plunger is forced down and fills the mold with metal.

While this machine was simple in design, it worked fairly well, and many castings were made with it. The springs which gave the levers their return motion, however, were not positive enough, and on later machines cams were added for this work. A sprue-cutter, such as is now used, was not provided, and hence the sprue had to be broken off from each casting. These were about the only faults that could be found, and the principles here adopted were developed to a point that enabled automatic die-casting machines to cast pieces very intricate in shape. Movements were devised for pulling out pins, located in the die-molds, as well as other loose pieces that might form any size or shape of hole in the casting.

In 1902, Mr. C. H. Veeder patented the machine shown in Fig. 28. On this he was granted patents on nineteen combinations claims, but it will be seen that, although the machine is greatly improved in its design, the basic principles on which it operates are practically the same as those of the machine patented in 1875. The furnace is located at *A*, the melting pot at *B*, and the upper end of the plunger at *C*, as in the former machine. Lever *D* is operated by cam *E* and moves rod *Q* and lever *R*, which latter causes plunger *S* to travel up and down and squirt

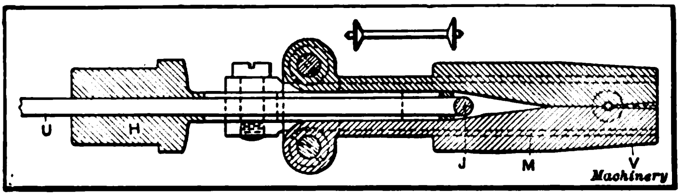


Fig. 27. Die-mold and the Bobbin cast

the molten metal into the die-mold. Another cam moves pivoted lever *O*, which is connected with the valve rod, and opens and closes valve *T* in identically the same manner as did the earlier machine; in fact, the shape of lever *O* is almost the same. This, however, is a design that has been successfully used for years on type-casting machines and is difficult to improve upon.

The manner of parting the mold to remove the casting is altogether different. Instead of opening it like an alligator's jaw, as in the earlier type of machine, a part of the mold is moved back, away from the machine, and the casting is thus allowed to fall out. The mechanism that opens and closes the mold is not shown in Fig. 28, but it is done with a very similar supporting frame and cross-head to that which draws the mold away from the nozzle in the Dimock machine in Figs. 25 and 26; but instead of using rod *U* to turn bar *J* and thus open the mold, as in the Dimock machine, rod *U* is used to form a core in the casting and after the casting has been made, rod *U* is pulled back to free the casting from the mold. This machine has been used for several years, but has also been improved upon. It has been made entirely automatic by putting a pulley in place of the crank wheel.

While in most automatic machines cams have been used to control nearly all of the movements, in others springs and gears have been

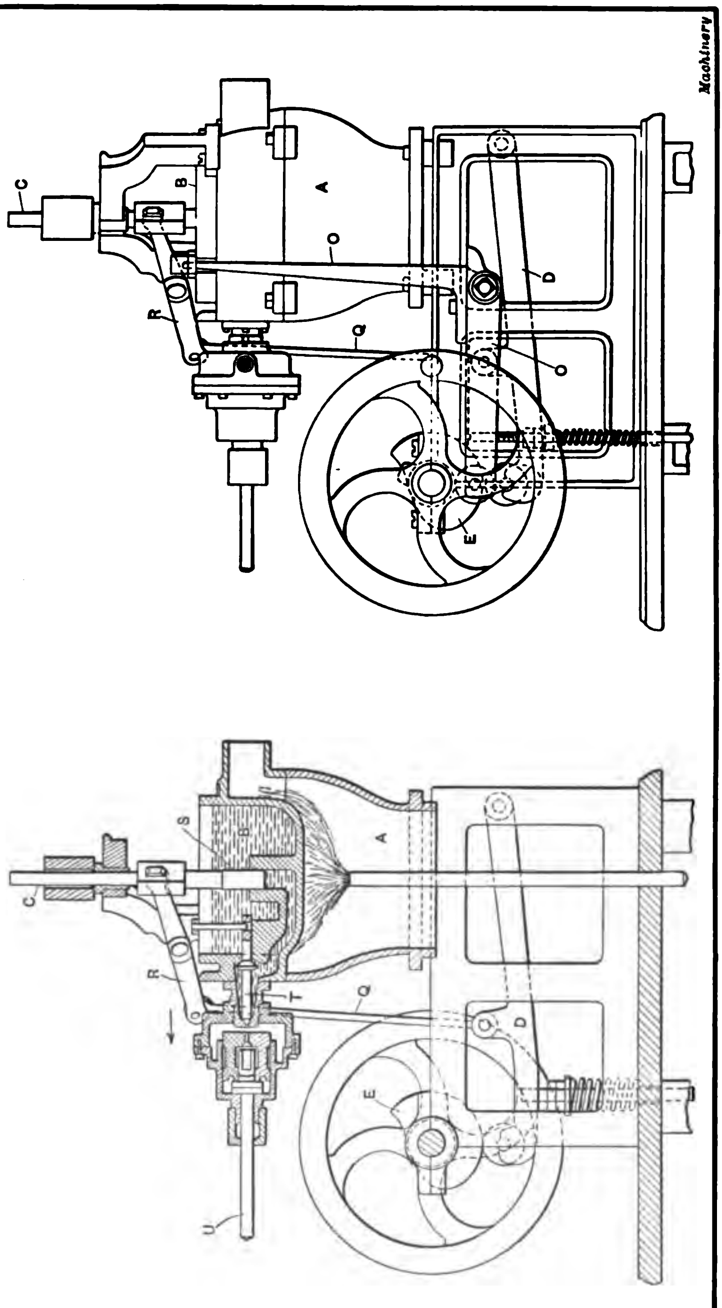


Fig. 28. Modern Die-casting Machine

used in combination with cams. Such a machine is shown in Fig. 23. In this a cam *E* is used to control the motion of the pump plunger and a large spring is used to hold the lever against this cam. The mold is moved up to the spout and away from it by a crank on the end of the shaft that holds the cam. This shaft is driven by a gear *N* that meshes with a pinion *L* driven by a worm-wheel *K* and worm *J;* the worm, in turn, is driven by a pulley *F* and belt. A stationary cam is used to control the motion of a knife which cuts off the sprues and a brush that brushes off the knife. With the exception of the spring for holding the lever that operates the plunger against the cam, this machine works successfully. A spring in this location is liable to fail, owing to the plunger's sticking in the cylinder, due to dross in the molten metal; no metal would then be forced into the mold.

This machine was especially designed for casting electric storage battery grids, but can well be used for making many shapes of castings for machine parts. These grids are thin strips of metal, crossing each other at right angles, the strips being joined together at each intersection; they thus contain a number of square openings, and resemble wire netting, except that the strips are not round. As in the other die-casting machines, *A* is the furnace, *B* the melting pot over the furnace, *C* the plunger rod, and *D* the lever that operates the plunger. A roller attached to lever *D* rides on cam *E*, to guide the up and down motion of plunger *G;* spring *I* holds lever *D* against cam *E*. It would doubtless be better to use another cam to perform the work of this spring and thus make the upward motion of the plunger as positive as is the downward motion. Cam *E* is so shaped and timed in its motion as to cause the plunger *G* to move down only when the mold is closed tightly against the nozzle and ready to receive the metal. To reduce the air pressure in the mold against the action of the plunger, so that all parts are filled with the incoming metal, an air pipe *Y*, with pump, is often connected to the mold. This automatically pumps out the air and creates a vacuum in the cavity of the mold that shapes the casting, just before the molten metal is injected into it by the plunger.

The mold is operated by a mechanism that is as simple, positive and handy as that of any die-casting machine made. Mold *M* is located on rocker arm *H*, which is connected by rod *P* and spring *Q* to crank *R*. Thus, while cam *E* is controlling the operation of plunger *G*, crank *R* is controlling the movements of the mold. Mold *M* is thus brought up to the nozzel and held there while plunger *G* descends and squirts the metal into it. Plunger *G* is then raised for another stroke, while mold *M* is rocking back away from the nozzle. For the grid casting made in this machine many gates are used, and while the rocker is carrying the mold back to the end of its stroke, knife *S* travels across the face of the mold and cuts off the sprues. A brush then travels across the face of knife *S* and brushes off any chips that may have accumulated. These motions are controlled by cam *U*, which is bolted to the side of the frame.

On many kinds of castings for machines or instruments, the shape is such that this knife and brush could not be used for the sprue cutter, but it is easy to take off this mechanism and attach others that would perform the necessary operations, and which might be even simpler in design. The distance through which rocker arm *H* travels can be adjusted by shortening or lengthening rod *P* by the nuts provided. The mold can thus always be kept tightly against the nozzle, and also go back far enough to eject any casting. When rocker arm *H* reaches the end of its backward stroke, arm *V* strikes block *W* and this operates the mechanism that ejects the casting from the mold. To insure no jar, flat spring *X* is provided for rocker arm *H* to strike against.

One of the most complete automatic die-casting machines built is shown in Fig. 24. This machine was patented by Mr. C. H. Veeder and is a vast improvement on the machine shown in Fig. 23. It is supplied with two melting pots and is completely automatic. All that the attendant has to do is to keep the secondary melting pot filled with metal and carry away the finished castings. With each casting that is made, the metal lowers in the melting pot and the secondary melting pot is used for the purpose of keeping the primary melting pot filled. In this machine the air is exhausted from the mold with an air pump before forcing the metal into it, thus insuring the filling of every crevice. The machine differs from nearly all other types in that it has provision for a powerful, positive pressure for forcing the metal into the mold, in addition to the vacuum. Thus, the formation of gas bubbles or air pockets in the cavity that forms the castings is overcome and deformed castings are not produced. The percentage of bad castings has, therefore, been reduced to a minimum.

In this machine also, *A* is the furnace; *B* the melting pots; *C* the plunger; *D* the lever that moves the plunger up and down; *E* the cam that causes the movements of this lever; *F* the pulley that drives the machines; *H* the carriage that holds and operates the mold; and *M* the mold.

A single shaft *J*, driven by pulley *F*, controls all the movements. Cams are located on the central portion of this shaft and cranks on the two ends to give the machine all of its movements. No gears are used. A double-action valve is used to control the injection of the metal into the mold, and to cut off the sprue. This valve is shown at *L*. Before plunger *C* starts moving downward, arm *N* is moved away from valve *L* and the flow of metal due to the downward motion of plunger *C* causes valve *L* to move to the left and close the opening between the passage in which this valve is located and the melting pot. Thus, all of the pressure exerted by the plunger is used to force the molten metal from this valve chamber into the mold. When the die-mold has been filled, arm *N* pushes against valve *L* and causes it to close up the nozzle opening through which the metal flows into the die-mold, and, at the same time, valve *L* cuts off the sprue of the casting. Arm *N* is moved by lever *O*, which, in turn, derives its motion from cam *P*.

Carriage *H*, which holds the mold and controls its movements, is operated by a series of levers that are moved by two cams. Lever *Q*, with its connection levers, is moved by cam *R*, and this pulls carriage *H* to the right to open the die-mold as shown in the lower left-hand view of Fig. 24. By the action of cam *R*, lever *Q* afterwards moves carriage *H* to the left, thus closing the mold and holding it tightly against the nozzle while it is being filled with the casting metal. Spring *I* holds the roller of lever *Q* against cam *R*. This is a weak point of the machine, as the pressure that forces the molten metal into the mold is exerted against this spring, unless a locking device is attached to the mold, and this requires additional mechanism. Another cam could more easily be used to close the mold and hold it against the pressure of plunger *C*. While the mold is opening, bar *S* is moving to the left through carriage *H* to eject the casting from the mold. The movement of bar *S* is controlled by a series of levers moved by cam *T*. While the mold is closed, vacuum tanks *U* are automatically connected with it and draw out all of the air. A vacuum is constantly maintained in these tanks by an air pump.

With all of these movements properly timed, die castings are made as fast as the metal will solidify, and can be ejected from the mold without deforming the castings. Most die-casting machines do not apply much pressure to the plunger, but depend on the suction created by the vacuum to draw the metal into the mold. This does not produce castings with as fine and dense a grain as when a high pressure is applied, and they are more liable to have porous and spongy places. The high pressure, combined with the vacuum in the mold, also makes the casting correspond exactly to the contour of the cavity cut in the mold. One die-mold can be taken out and another, for a different casting, inserted in its place with very little labor. Thus the machine can be made to operate on several kinds of castings in a day's run.

These and other reasons make it one of the most economical machines built, as the cost of the castings has been reduced to little more than the cost of the metals for making the alloys, the gas that keeps the metal molten, interest on original investment, and the expense necessary to keep the machine in repair. Automatic type-casting machines cast one type at a time, at the rate of 240 per minute. This speed is largely due to the fact that cold water is forced through a water-jacket that surrounds the type cavity in the mold; as many as 240 per hour would be a high figure for die-castings for machine or instrument parts, as these are nearly always more intricate in design and have a larger volume of metal to be cooled. Many times, however, more than one casting can be made in a mold. When the mold is water-jacketed, and the machine completely automatic, the output of perfect castings will be many times that of hand-operated machines, and at a very low labor cost.

The formation of coarse crystals is an inherent trait of all metals when they are slowly cooled from the liquid state. This coarse crystallization is more pronounced in some metals than in others, and the alloys from which die-castings are made are composed of the metals that form the coarsest crystals, when so cooled. The most notable example of this crystalline formation is antimony, while zinc is another metal that has a very flaky crystalline structure. This formation of coarse crystals can be overcome to a large extent if the metals are chilled and suddenly solidified from the molten state, when casting them into shape. This is done in the machine shown in Fig. 24, by circulating a stream of cold water through a water jacket formed around the cavity in the mold that forms the casting. While the vacuum created in the cavity of the mold and the pressure used to force the metal in have a tendency to reduce the coarse grain and crystallization, the rapid cooling and solidification that is caused by the current of cold water still further aids in refining the grain.

The action is similar to that which takes place when hardening steel. In this case, the grain is refined by heating cold metal to the desired temperature, and the fine grain is retained by instantly quenching in a liquid, and thus suddenly cooling the metal. If it were allowed to cool slowly, the grain crystals would return to the coarse size of the unheated steel; or if heated to too high a temperature, a coarse grain would be formed that could only be refined by the pressure or hammering applied during forging operations. In the die-casting alloys, this fine grain is produced by melting, and the quicker it can be cooled down from the molten state, the finer will be the grain of the metal in the castings. It is not a difficult matter to surround the casting cavity in all die-molds with a water-jacket. This, of course, will not only give the metal a more dense, homogeneous grain, but will also solidify the castings much more quickly and enable many more castings to be made per hour than can be made in a machine where the mold is not water-jacketed.

CHAPTER III

MODERN HAND-OPERATED DIE-CASTING MACHINE

In the present chapter a simple method for making die-castings is explained, and one of the best machines for casting white metal, or for making "pressure castings," as they are often called, is described. The accompanying illustration, Fig. 29, shows cross-sectional elevations of the machine, which is one of the latest designs of die-casting machines in practical use. No skill is required to operate it; an ordinary laborer can learn how to do it in a very satisfactory way in a short time. When the dies are small and there are only two or three levers to be handled, one man can operate the machine advantageously. But when larger dies are used and a number of levers must be handled, it is more economical to employ two men at the machine. It is important, however, that only one man control the injection of the metal into the dies. This is a very essential point, because two men cannot produce exactly the same results for every pouring. Uniformity in the control of the injection of the metal is one of the basic points in white metal die-casting.

In designing a die-casting machine, it is necessary to so arrange it that the metal will be handled as little as possible, as otherwise part of the metal would oxidize and be wasted. The molten metal should be covered so that the air will not strike it more than is absolutely necessary. In the machine shown in the accompanying illustration, the metal comes into contact with the air only at the nozzle, where it is injected into the die. It may be argued that this would have a detrimental effect on the casting, but experience has shown that it does not; the reason for this is that the surface which comes in contact with the air is so small in comparison to the amount of metal that is pressed out each time, that the few seconds during which the air comes into contact with the surface is not enough to have any serious effect. This is particularly true in the case of large castings. In the case of small castings the metal is poured so much oftener that the surface of the metal at the nozzle is not in contact with the air long enough to injure the casting.

The design of the die-casting machine is, briefly, as follows: In the accompanying illustration *A* is a gas furnace made by the American Gas Furnace Co., this furnace being one of the standard sizes. At *E* are shown the gas burners, four being placed on each side of the furnace. The metal is melted in the pot *B*, and the gas burners can be so controlled that the heat can be directed toward any part of the melting pot. This pot is made of cast iron, and it can be replaced by one of the standard sizes made by the American Gas Furnace Co., at very little cost, when burnt out. The life of the pot depends upon the

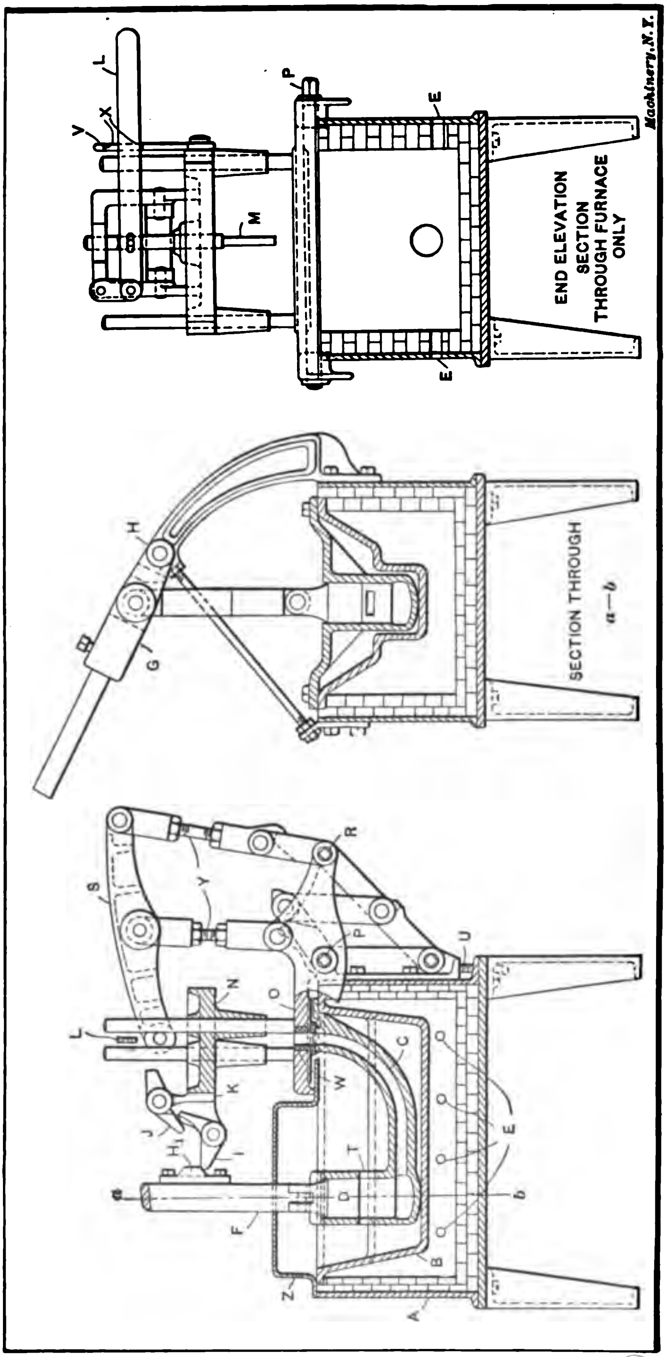


Fig. 29. Die-casting Machine of Recent Design

metal used for making the die-castings. If the metal requires a high degree of heat for melting, the receptacle naturally will not last so long as when less heat is required.

At *C* is shown the part forming the nozzle which is connected to a cylinder in which the metal is compressed by means of the plunger *D*. When the plunger descends, the metal is pressed or pushed out through the nozzle *C*, which is tube-shaped as shown in the illustration. At *F* is shown a connecting-rod which is operated by means of the handle *G* having its fulcrum at *H*. A dog or trip H_1, fastened to the connecting-rod *F*, operates the lever *I* which, in turn, moves the lever *J*, both of these levers being mounted on bracket *K*. The lever *J*, in turn, operates the handle *L*. To the handle *L* is attached a rod *M*, called a "sprue cutter." The part *V* acts as a stop for the motion of lever *L*, this motion being limited between the points *X*. The stop *V* swings out of the way for lever *L*, when the core is being pushed out of the casting.

The dies are fastened between the plates *N* and *O*. The plate *O* is hinged at *P*, and the shaft passing through the lever at *P* is squared on the end as shown, so that a handle may be put on the shaft. In this way plate *O* can be swung away from the nozzle, thus allowing the die to swing away from the furnace through an angle of about 45 degrees. This uncovers nozzle *C*, permitting the pushing out of the so-called "core," which is formed at every pouring. It is advisable to have the core as small as possible, but, of course, the size of the core depends very largely on the size of the casting. When the die-plates are swung away from the nozzle, the operator chills the core by means of compressed air blown through a rubber tube, and when this is done the core is forced out by a forward push of the handle *L*, which at that moment operates the sprue cutter *M*. This action releases the core which is slightly tapered in order that it may be easily removed.

The next operation is to separate the two plates *O* and *N*, thus opening the die, one-half of which is held on the plate *N* and the other on the plate *O*. The die-plates *N* and *O* are separated by operating a handle placed on shaft *R*, which through a set of connecting links and the arm *S* separates the two plates. At *Y* adjustment is provided for setting the two plates properly for any size of die. The top of the furnace is covered by a sheet-iron lid *Z*, lined with asbestos. This cover is left on all the time when the heat is on or when the metal is melted, so as to prevent the latter from coming in contact with the air.

At *T* is a slot in the pressure cylinder through which the metal runs into the cylinder before being pressed into the die. The screw *U* serves the purpose of adjusting the nozzle, so as to get it perfectly tight. This is an important factor, as is also the cleaning of the nozzle, which should be done by the operator after every pouring. This takes but a moment's time and makes it possible to obtain good results. Many times the neglect of this precaution has made it difficult to obtain good castings.

When the die is open, ready to eject the casting, the operator takes the air hose and chills off the casting for a moment. Then he grasps the handle connected to the ejecting pins in the die, and puts one hand under the edge of the die, when a push of the handle makes the piece or pieces fall into the hand of the operator. The air hose is again used for cleaning the die. The reason for this is that after every pouring there is, due to the pressure, a small fin formed on the face of the die, and this must be removed before casting another piece. Blowing the air over the face of the die removes it easily. After the die is cleaned and again closed, plate *O* is closed down over the nozzle and everything is ready for the next pouring. All the operations described require but a part of a minute, especially when the machine and dies are small and light. When a larger machine and larger dies are used, the work cannot be done so rapidly, but will be in proportion to the size and design of the pieces to be cast.

Many experiments have been made to obtain a strong and durable metal for die-castings. When making small parts for machines which require high tensile strength, great care must be exercised to obtain a strong metal and one that flows easily, because when the metal flows easily it is possible to obtain a solid casting. The mixing of the metal must be done in a careful manner, because white metal is very treacherous, and carelessness at this time makes it difficult to obtain good castings. The metal must be carefully handled, and care taken to see tnat it is not too hot when casting. If it is too hot, the operator will have difficulty in obtaining good sound castings.

The dies should be heated slightly before beginning the casting. This is done by closing the die and also closing the plate *O* lightly against the nozzle while the metal is melting. The die will then be of the right temperature for starting the work when the metal is melted. Care should also be taken to keep an even heat in the furnace, so that the temperature of the metal is the proper one for obtaining solid castings. This can be done only by a man experienced in white-metal casting. The metal should not be put into the pot in "pigs," as this chills the melted metal in the pot and causes difficulties. Instead a small furnace should be used alongside of the machine for melting the metal. This melting can be done at a slow heat which is, in itself, a good thing for white metal. When more than one man works the machine it is difficult to obtain castings without blow-holes. A casting may look dense on the outside, and when broken may show such defects as to make it useless for the purposes for which it is intended.

Making Dies for Pressure Castings

When making a die for a pressure casting, the piece to be made should first be considered, as the shape of the piece will govern the point at which the dies should be parted. If the dies are not made and parted correctly, and the sprue not put in the proper place, it will be difficult to obtain good castings. It is therefore desirable to take these points into consideration before attempting to lay out a pair of dies for making pressure castings. Care should also be taken when making tho dies to have them fit together closely, so that there will be no fin left on the casting; this, however, in some cases is unavoidable.

The next point to take into consideration is the weight and character of the castings. If the casting is a thin shell of an odd shape, particular attention should be given to the position of the sprue-cutter, which should be placed so that it will be possible to insure the mold being filled. When the sprue-cutter is not located in the proper position, it will be found that the mold will not fill up properly, which will result in poor castings. It is impossible to lay down any hard and fast rule for the shape or position of the sprue, as the work under consideration is the determining factor. It is well, however, to fill the mold from the bottom, as is the rule in iron molding.

Another factor which enters into the problem for making successful pressure castings is the position in which the dies are set in the machine, the design of the machine, and the conditions under which it works. If the machine has a good pressure, the sprue can be made small, but if the pressure is reduced, which results from various causes,

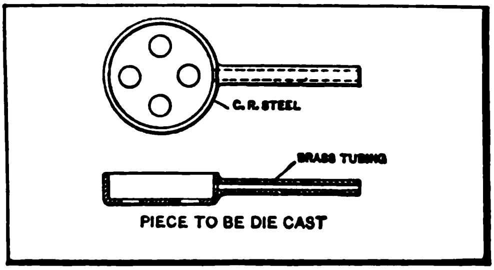


Fig. 30. Work produced on Die shown in Fig. 31

the sprue should be designed to compensate for the loss in pressure. The pressure is sometimes decreased by overheating the metal, which expands the cylinder in the machine, so that the metal squirts out around the sides of the plunger.

The piece shown in Fig. 30 is made from sheet steel and has a brass tube inserted in it. The cost of making this part was so high that it was decided to make the body from white metal and cast the brass tube in it. The end of the brass tube which fits in the body or cap is knurled, so that the tube is held tightly by the metal when cast around it. The die for casting this piece from white metal was made to cast one piece at a time. Of course, if a large quantity had been required it would have been possible to make the dies to cast more than one piece.

The die shown in Fig. 31 consists mainly of a cast-iron frame *A* of box-shape construction. On the top face of the box is fastened the lower die *C*, the other half of the impression being formed in the plate or die *D*. *E* is a circular plug which pushes the brass tube up against the core *F*, forming the inside of the casting. A handle *G*, pivoted on the bracket *H* actuates this plunger *E*, and the coil spring *J* connected to the handle *G* keeps the brass tube tightly up against the core *F*, while the piece is being cast. *K* is a gate through which the metal passes into the dies, while the hole *L* is made to fit the sprue-cutter *B*, the latter removing the metal passing from the pot to the sprue, after the piece is cast. The gate is broken off after the piece is removed from the

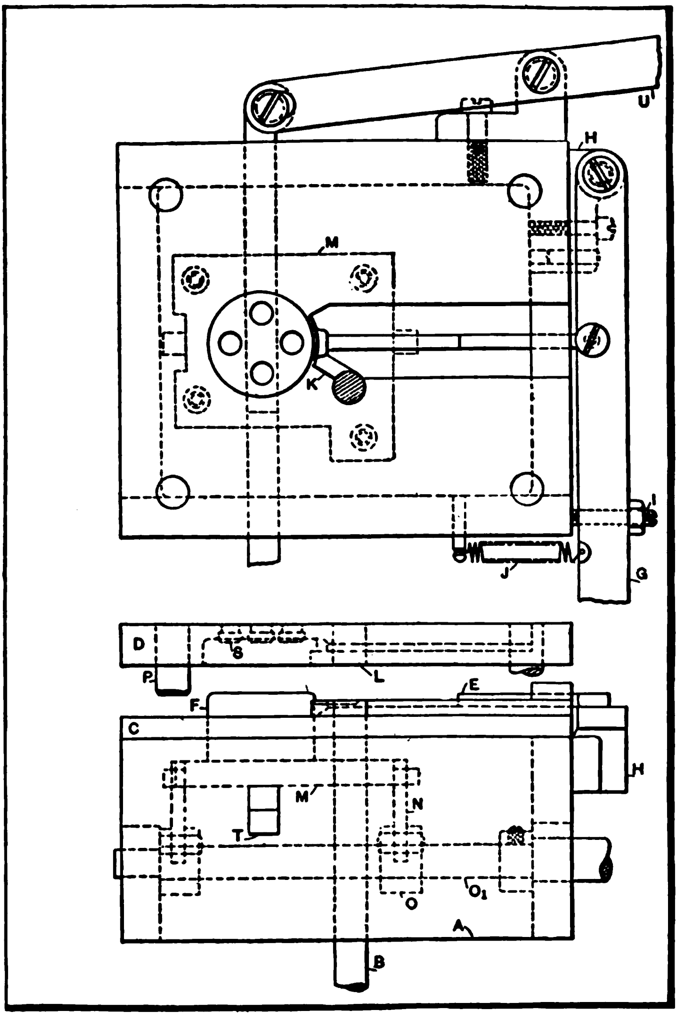


Fig. 31. Die used for producing Work shown in Fig. 30

dies, which can be accomplished with a slight pressure of the hand. The gate should not be made more than 0.010 to 0.015 inch thick, but the width should be made to suit the piece. A plate *M* is held to the lower die by four studs, and acts as a bearing for the links *N*. The studs in the plate *M* are used for guides as well as stops for the up and down movement of the plate, as is shown in the separate view Fig. 32. *O* is an arm which is mounted on a squared portion on the shaft O_1, the arm being bent at one end to form a handle. This arm *O*, through the links *N*, raises and lowers the plate *M*, which, in turn, actuates the core *F*. Dowels *P* are used for lining up the two dies in their relative positions. The dowels should be driven into the thickest die, so that they will be held rigidly.

The holes in the casting are formed by the four core-pins *S*, which

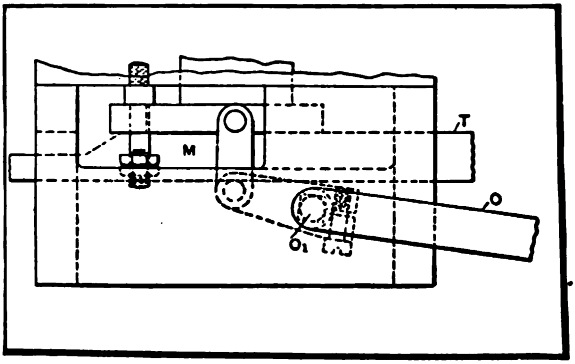


Fig. 32. Side Elevation of Die shown in Fig. 31

are fastened to the upper plate *D*. A slide *T* is pushed in under the plate *M* by means of the lower lever *U*, and is used to prevent the core from blowing out when the pressure is applied for forcing the metal into the dies. The die *D* is held in the die-casting machine on the plate nearest the nozzle, while the other half of the die is fastened to the rear plate. After the plates are separated the piece is ejected by means of a handle, which is pushed forward, allowing the core *F* to go back flush with the plate *C*, when the piece will fall into the hand if placed under the die.

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DIE CASTING

DIES—MACHINES—METHODS

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CONTENTS

CHAPTER I

DIE CASTING

Die-casting, a comparatively recent method for producing finished castings, is rapidly proving itself an important factor in the economical manufacture of interchangeable parts for adding machines, typewriters, telephones, automobiles and numerous other products where it is essential that the parts be nicely finished and accurate in dimensions. The term "die-casting" is self-explanatory, meaning "to cast by means of dies"; described briefly, the process consists of forcing molten metal into steel dies, allowing it to cool in them, and then opening the dies and removing the finished casting. It is the purpose of this treatise to give a general outline of the die-casting process, showing its possibilities and limitations, and also to give a description of the die-casting machinery and its operation, of the fundamental principles involved, and of the methods used in the die-making. Illustrative examples of the best types of dies, based on results obtained from actual experience, will also be given.

Origin of Die Casting

The origin of the die-casting process is somewhat difficult to ascertain. We may look into the history of type founding and find that away back in 1838, the first casting machine for type, invented by Bruce, was a machine that involved the principles of die-casting as it is practiced to-day. More recently, in 1885, Otto Mergenthaler brought out the linotype machine. This machine is a good example of a die-casting machine. However, as we interpret the word to-day, die-casting is a broader term than type-casting or linotyping, although its development without doubt is due to the success of the linotype machine. It is doubtful if die-casting, properly speaking, was originated until about fifteen years ago, and it is certain that it is only during the past few years that the activities in this line have been very noticeable.

One of the first experiments in the direction of die-casting was undertaken to get out some rubber mold parts cheaply enough to leave a profit on a job that was beginning to look dubious from the financial side. The molds were for making rubber plates about three inches square and one-eighth inch thick, the top side of which was decorated with fine raised scroll work; it was this latter feature that gave the trouble. After wasting much time and money trying to stamp the mold parts, a metal-tight box was made as shown in Figs. 1 and 2 with a block screwed in it, the purpose of which was to shape the mold impression and impart to it the scroll design. As shown, the ends of the box were removable, being screwed on. This box was placed under a screw press and a straight plunger that just filled the top of the box was fitted to the head of the press. After the two were lined up, molten type metal was poured into the box, and as soon as the metal had cooled to the "mushy" state, the ram of the press was forced down as shown in Fig. 2. Next, the ends of the box were removed, the screw holding the block taken out, and the die-casting pushed from the box. The object in having the inclined side to the box was to produce a piece shaped with the proper inclination for its position in the final mold used for casting the rubber plates. The illustrations give an idea of the

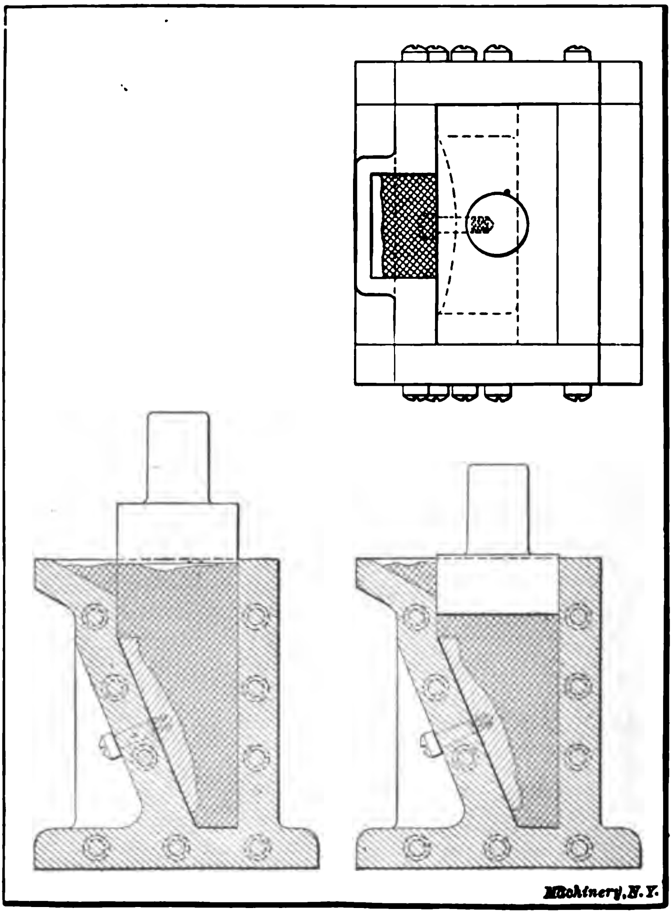


Fig. 1. An Early Experiment in Die Casting – Before Applying Pressure

Fig. 2. An Early Experiment in Die Casting—After Applying Pressure

compression that took place. The die-casting was found to be sharp at the corners and free from flaws, and the scroll work came up in fine shape. Naturally the rest of the mold parts were made in the same way and the job turned from failure into success.

From such simple experiments as these, the die-casting industry has developed to its present stage. In view of the advances that have been made in die-casting, it is singular that there are to-day only about a dozen concerns in the business in this country, but as the subject becomes better understood, and the possibilities of the process are realized, the demand for this class of castings will result in many other firms going into the work, and it is not improbable that a large number of factories will install die-casting plants of their own to aid them in producing better work in a more economical way.

Advantages, Possibilities and Limitations of Die Casting

The greatest advantage of die-casting is the fact that the castings produced are completely and accurately finished when taken from the dies. When we say completely, we mean that absolutly no machining is required after the piece has been cast, as it is ready to slip into its place in the machine or device of which it is to be a part. When we say accurately, we mean that each piece will come from the die an exact counterpart of the last one; and if the dies are carefully made, the castings will be accurate within 0.001 inch on all dimensions, whether they are outside measurements, diameters of holes or radii. All holes are cast and come out smoother than they could be reamed; lugs and gear teeth are cast in place; threads, external and internal, and of any desired pitch can be cast. Oil grooves can be cast in bearings, and, in a word, any piece that can be machined can be die-cast.

The saving in machining works both ways; not only is all machine work eliminated by the one operation of casting, but the machine tools and the workmen necessary for their operation and up-keep are dispensed with, the expense of building jigs and fixtures is stopped; and no cutters, reamers, taps or drills are required for this branch of the production. In addition, the labor required for operating the casting machines may be classed as unskilled. No matter how intricate and exacting the machine work on a piece has been, and how skillful a workman was required to produce the work when machine-made, the same result may be brought about by die-casting, and usually the work is excelled, and, excluding the die-making, unskilled men can make the parts.

From a metallurgical standpoint a die-casting is superior to a sand-casting on account of its density, strength and freedom from blow-holes. Also, when the hot metal comes in contact with the cool dies, it forms a "skin" similar to the scale on an iron sand-casting. As the die-casting requires no machining after leaving the dies, this skin increases the wearing qualities of the casting.

The possibilities of die-casting are numerous. By this method of manufacturing it is possible and practical to cast pieces that could not possibly be machined. It is an every-day occurrence to make castings with inserted parts of another metal, as, for instance, a zinc wheel with a steel hub. It is also possible to make babbitt bearings that are harder and better than can be made in any other way. Often there are two or more parts of a device that have formerly been made separately, machined and assembled, that can be die-cast as one piece. In such cases the saving in production is very great. Figures and letters may be cast sunken or in relief on wheels for counting or printing, and of course ornamentation may be cast on pieces that require exterior finish. As to size, there is no definite limit to the work that can be cast. One job that is being done at the present time is a disk 16 inches in diameter with a round flange 1 inch in diameter, around the rim.

"There is no great gain without some small loss," is just as true of a process like die-casting as it is of anything else. The limitations of this work are few, however, and they are here given so as to state the situation fairly. Generally speaking, a part should not be consid-

Fig. 3. Examples of Die-castings

ered for die-casting if there are but few pieces required, because the cost of the dies would usually be prohibitive. Often, however, it happens that because of the large amount of accurate machine work being done on a machine part, it is economical to make a die for the comparatively small number of parts required and die-cast them. A case illustrating this phase of the matter recently occurred in actual practice. In getting out an order of two hundred vending machines, it was decided to try die-casting on a part that was difficult to machine. The dies were expensive, costing $200, and as there were only 200 pieces to be cast, the die cost per piece was one dollar; but even with that initial handicap, it was found that on account of the difficult machining that had formerly been required, the die-cast parts effected a large saving, and of course the results were superior.

A rough part that would require little or no machining should not be die-cast, because pound for pound, the die-casting metals cost more than cast iron or steel. The casting machine cannot make parts as rapidly or of as hard metals as the punch press or the automatic screw machine. For this latter reason a part that necessarily must be made of brass, iron or steel, cannot be die-cast, although mixtures approximately equal in strength to iron and brass are readily die-cast. To give added strength to a die-cast part it is often advisable to add webs and ribs or to insert brass or iron pins at points that are weak or subject to hard wear. Roughly speaking, it is the part that has required a good deal of accurate machine operations that shows the greatest difference in cost when die-cast, and sometimes the saving is as great as 80 per cent.

The Metals used in Die Casting

The metals that produce the best die-castings are alloys of lead, tin, zinc, antimony, aluminum and copper, and the bulk of the die-castings made at the present time are mixtures of the first four of these metals. From them, compositions may be made that will meet the requirements of nearly any part.

For parts that perform little or no actual work, save to "lend their weight," such as balance weights, novelties and ornaments for show windows, etc., a mixture consisting principally of lead, often stiffened with a little antimony, is used. There is but little strength to this metal, but it is used because of its weight and low cost. For parts that are subject to wear, such as phonograph, telephone, gas-meter and adding machine parts, an alloy composed of zinc, tin and a small amount of copper is used. This alloy may be plated or japanned, and is a good metal to use on general work

Another metal, used chiefly for casting pieces that have delicate points in their design but are not subjected to hard wear, consists principally of tin alloyed with lead and zinc to suit the requirements of the work. This mixture casts freely, and the finished castings come out exceptionally clean. Still another metal, used chiefly for casting pieces that have letters and figures for printing, is similar to the standard type metal—5 parts lead and 1 part antimony; but if there are teeth cast on the sides of the printing wheel a harder mixture will be required to give longer life to the gears.

The following mixtures are typical of die-casting or "white brass" alloys: copper, 10 parts; zinc, 83 parts; aluminum, 2 parts; tin, 5 parts. Another is copper, 6 parts; zinc, 90 parts; aluminum, 3 parts; tin, 1 part. Another containing antimony is copper, 5 parts; zinc, 85 parts; tin, 5 parts; antimony, 5 parts. Shonberg's patented alloy is copper, 3 parts; zinc, 87 parts; tin, 10 parts. Alloys containing 15 to 40 per cent copper and 60 to 85 per cent zinc are brittle, having low strength and low ductility. An alloy of 8 per cent copper, 92 per cent zinc has greater resilience and strength but not the ductility of cast zinc.

Aluminum may be cast, but it is a difficult metal to run into thin walls and fine details; it plays, however, an important part in some good mixtures used for die casting. Experiments are now being conducted for die-casting manganese bronze, and it is said that some very

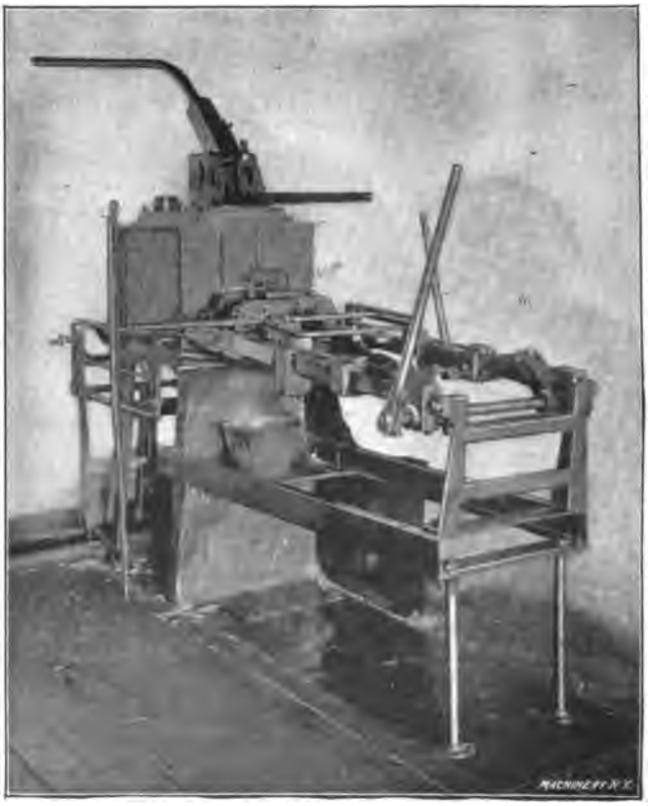


Fig. 4. General View of the Soss Die-casting Machine

good castings have already been made. Its wearing qualities are so valuable that it is particularly desirable for making die-castings.

The Die-casting Machine

The three important requisites for good die-casting are the machine, the dies and the metal. The casting machine is fully as essential as either of the other requisites, and although there are a number of different styles of casting machines in use, each of which has its advantages over the others, especially in the eyes of their respective designers, the fundamental principles upon which they all operate are the same. In each there is the melting pot and the burner, the cylinder and the piston for forcing the metal into the dies, and the dies with the opening and closing device. In some machines pressure is applied to the metal by hand, in others power is used, and in still another class the metal is forced into the dies with compressed air. The provisions for opening and closing the dies vary in the different machines; there are various means employed for cutting the sprue, and the styles of heaters are numerous.

One or two of the largest firms in the die-casting industry have automatic casting machines for turning out duplicate work in large quantities very rapidly. These machines are complicated and are only profitable on large quantities of work, and for that reason their use is not extensive. In general, their operating principles are the same as in the case of the hand machines, but provision is made for automatically opening and closing the dies, compressing the metal, and ejecting the castings.

The Soss Die-casting Machine

The Soss die-casting machine, manufactured and sold by the Soss Manufacturing Co., Brooklyn, N. Y., was the first die-casting machine to be placed on the open market. This machine is shown in Figs. 4 and 5, and in section in Fig. 6. The Soss Manufacturing Co. originally manufactured invisible hinges exclusively. At the advent of the die-casting era, they commenced to make these hinges from die-castings, and placed orders with a leading die-casting concern amounting to thousands of dollars each year. After the die-cast hinges had been on the market for a short time, complaints commenced to come in, some to the effect that the hinges were breaking and others that the hinges were corroding. Either of these faults was serious enough to blast the reputation of the hinge, but the first trouble, breakage, was the more important. Examination of the broken hinges showed that the castings were porous and full of flaws, and as the makers of the castings could not produce castings sufficiently strong for the hinges, Mr. Soss started to experiment for himself. This experimenting led to the production of the Soss die-casting machine.

Referring to the illustrations Figs. 5 and 6, *A* is the base and frame of the machine, *B* is the heating chamber located at one end of the machine, and within this heating chamber is the tank *C*, shown in Fig. 6. This tank contains the metal from which the die-castings are made, and the metal is heated by the burners *D*. These burners are fed by air and gas through piping on the side of and beneath the furnace. To facilitate lighting the burners and inspecting their condition at any time, there is an opening (not shown) through the firebrick lining of the furnace and the outer iron wall, on a level with the top of the burners. There is also another opening through the furnace wall to allow the gases due to the combustion to escape. Through the bottom of the tank, well to the inner side of the furnace, runs the cylinder *E*. Below the bottom of the tank, the cylinder makes a right-angle turn, extending through the furnace wall and terminating just outside of the wall. The orifice of this cylinder is controlled by gate *F*. In that part of the cylinder that extends upward into the tank, there is an opening *G* that allows the molten metal to run into the cylinder from the tank. Working in this cylinder, is the piston *H*, that is used in forcing the metal into the dies. The compression lever *I*, hinged over the inner furnace wall, is kept normally raised by spring pressure, and is connected to the piston by means of the link *J*.

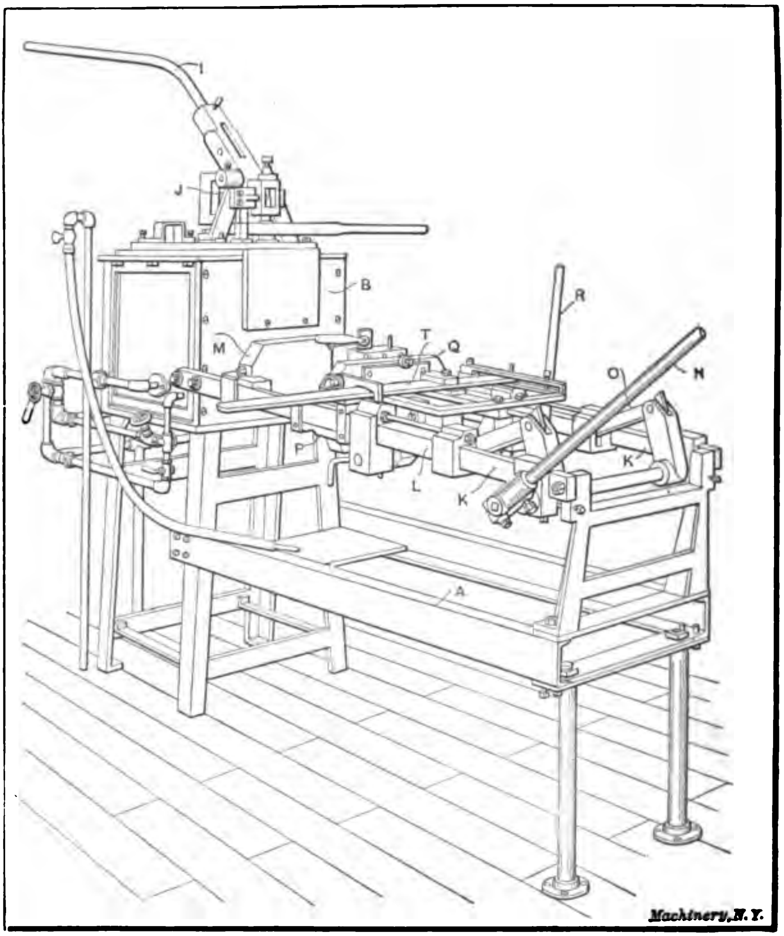


Fig. 5. Working Parts of the Soss Die-casting Machine

At the opposite end of the machine from the furnace, is the mechanism for operating the dies. This mechanism consists of a pair of square rods *K*, upon which are mounted the sleeves *L*. These sleeves have a long bearing surface and are attached to the die-plate *M*. Lever *N* at the end of the operating mechanism controls the movement of these sleeves by means of links *O*. Upon these sleeves is mounted a secondary set of sleeves *P*, attached to the other die-plate *Q*, and whose movement is controlled by lever *R*, through links *S*. This second set of sleeves is free to travel with the first set, and in addition has an independent movement of its own on the primary sleeves. It is the function of lever *R* to bring die-plate *Q* up to die-plate *M* by means of links *S* and sleeves *P*; and it is the function of lever *N* to bring both of the die-plates up to the outlet of the cylinder by means of links *O* and sleeves *L*. This system of sleeve-mounting is one of the distinctive patented features of the Soss machine. The orifice of the cylinder *E* is conical in shape and exactly fits the cup-shaped opening in die-plate *M*, so that when the two are brought together, the joint is metal tight. At the center of this opening, and extending through the die-plate *M*, is an opening that leads to the dies mounted on the inner faces of the two die-plates, and a continuation of this opening extends through die-plate *Q* in which the sprue-cutter *U* works. Attached to the outer side of this die-plate are two slotted brackets. In the slot of one of these is pivoted the lever *T*, and in the slot in the opposite bracket are bolted two stops that limit the motion of the lever. This lever operates the sprue cutter *U*, that works through the opening in die-plate *Q*. The sprue-cutting mechanism is best shown in Figs. 5 and 6. At the left of Fig. 5 may be seen a rubber hose connected to the air piping. This hose is used for cleaning out the dies after each casting operation.

Operation of the Die-casting Machine

The metal for the die-casting machine is mixed in the proper proportions for the work in hand by means of a separate furnace, before being poured into the tank of the machine itself. The burners are lighted and the dies are set up on the two die-plates. As soon as the machine has "warmed up," so that the metal is in a thoroughly melted condition, the sprue-cutting lever *T* is thrown back, leaving a clear passageway to the die cavities. Lever *R* is pulled backward, thus bringing die-plate *Q* up to die-plate *M*, which operation closes the two halves of the die. Then lever *N* is thrown forward, thereby bringing the closed die up to the body of the machine, with the nozzle in close contact with the outlet of the cylinder. Next, the gate *F* is opened, and the man at the compression lever *I* gives the lever a quick, hard pull, forcing the metal in the cylinder downward and into the dies. The molten metal literally "squirts" into the dies. Gate *F* is now closed; lever *N* is pulled back to remove the dies from the cylinder outlet; and the sprue-cutting lever *T* is pushed forward, cutting off the sprue and pushing it out of the nozzle into the kettle placed beneath it. The lever *R* is pushed forward, and a finished casting is ejected from the dies.

An important advantage that this machine has over other die-casting machines is the fact that the metal for the castings is taken from the *bottom* of the melting pot, whereas most other machines use metal from the top of the tank. At the bottom of the tank the metal is always the best, as it is free from impurities and dross; hence, there is little chance for the formation of blow-holes. A handful of rosin thrown into

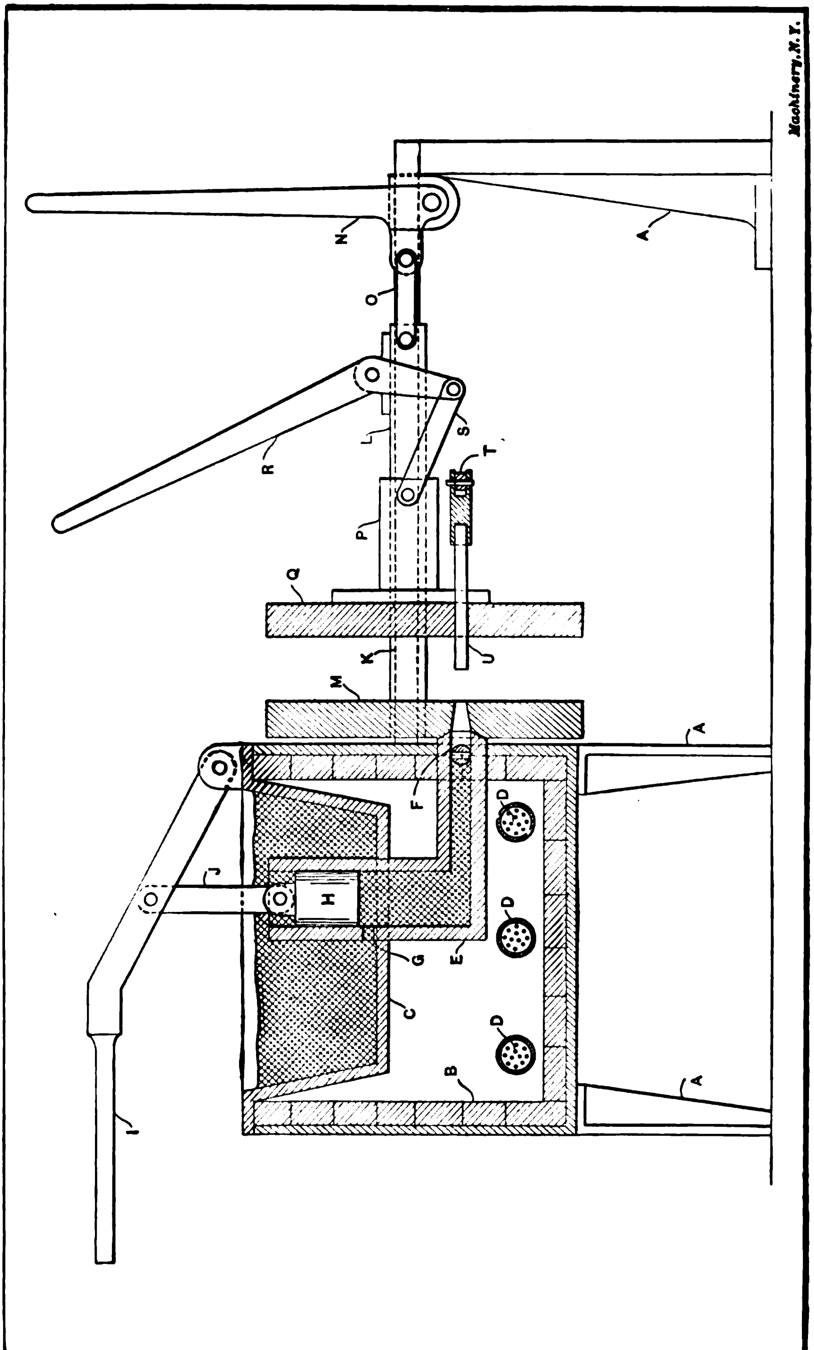


Fig. 6. Section of Soss Die-casting Machine

the melting tank occasionally helps to keep the metal clean, but the metal nearest the surface always contains more or less foreign matter.

While this description of the operation of the die-casting machine may convey the idea that the process is a slow one, as a matter of fact, the time required is, on the average, not over a minute and a half for turning out a finished casting. With the ejection of the casting from the dies, the product is completed, in theory; but in practice there are always a few small thin fins, caused by the air vents or by improperly fitted portions of the dies. It is, however, but the work of a few seconds to break off these fins, and unless there are many of them, or they are excessively thick, they are detrimental neither to the quality nor the quantity of finished castings.

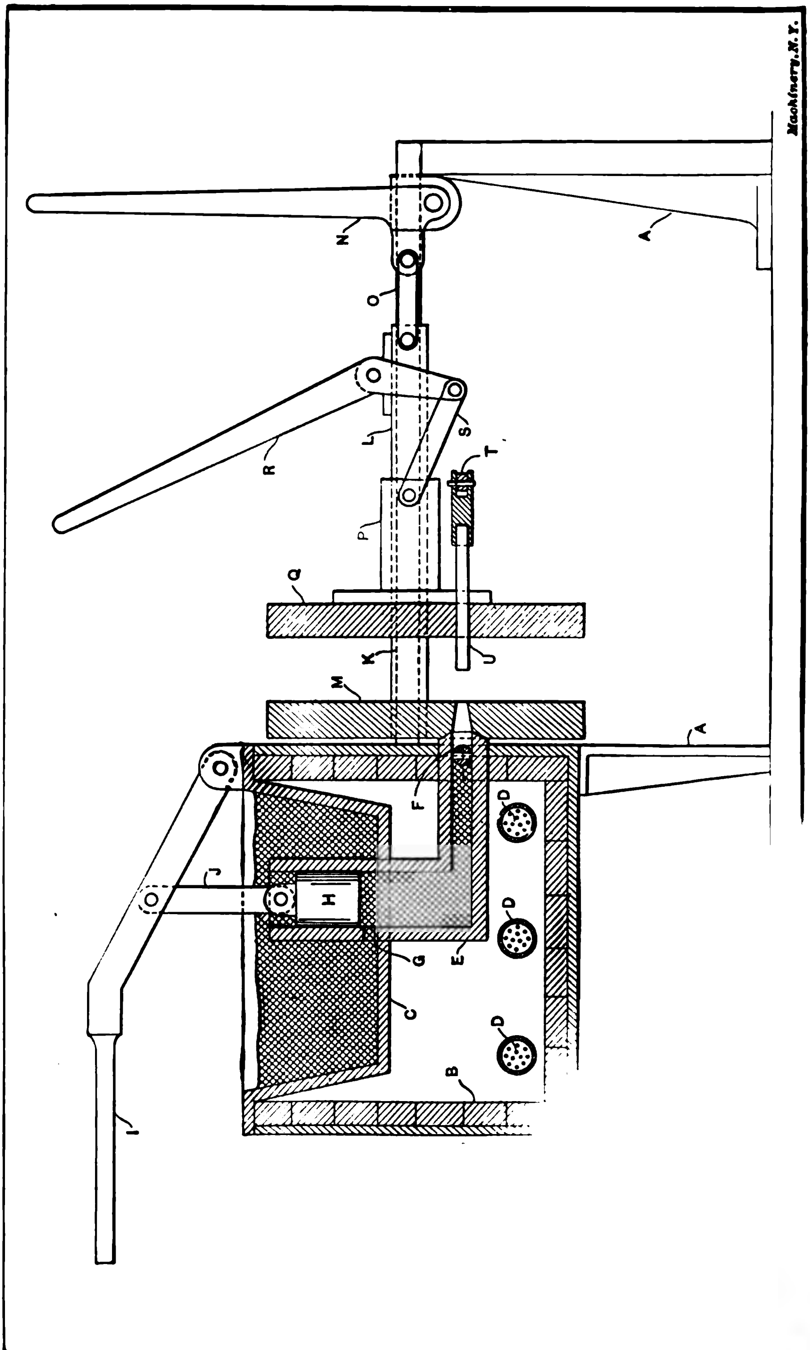
Points on the Operation of the Die-casting Machine

We have now taken up the description and general operation of the die-casting machine, but like every other machine, there are numerous little kinds and practices in its working the observing of which makes the difference between good and poor die-casting. Some of these points are here given.

The casting machine is best operated by three men, one of whom attends to the compression lever and the metal supply in the tank. The other two men stand on each side of the die-end of the machine, and it is their duty to operate the sprue-cutter, open the dies and remove the finished casting, clean the dies with air and close them, throw back the die-plates to their casting position over the cylinder outlet, and do any other work incident to the operation of the machine. While it requires three men to operate a die-casting machine in the best manner, the man who attends to the compression lever has a good deal of spare time between strokes, and if two or even three of the machines are conveniently placed, one man can easily pull levers for all three.

The metal should be kept just above the melting point and at a uniform temperature. If the metal is worked too cold, the result will manifest itself in castings that are full of seams and creases, and it will be difficult to "fill" the thin places in the dies. If, on the other hand the metal is allowed to get too hot, the die will throw excessively long fins, the castings will not cool as quickly in the die, and consequently they cannot be made as rapidly. On account of the importance of keeping the metal at a uniform heat, the fresh metal that is added to that in the tank from time to time, is kept heated in a separate furnace. Therefore, when the metal in the tank gets low, the new supply does not reduce the temperature of the metal being worked. Some casters use a thermometer to indicate the heat of the metal.

Casting-dies require lubrication frequently. Just how often they should be lubricated depends on the shape of the die, the composition of the casting metal, and the general performance of the dies. Beeswax is the common lubricant, and the lubrication consists in merely rubbing the cake over the surfaces of the dies that come in contact with the casting metal. In die-casting large parts, the dies must be kept cool by some artificial means, for hot dies are conducive to slow



Section of Soss Die-casting Machine

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In the Soss machine, the burners are so placed that the metal in the cylinder is kept at a slightly higher heat than that in the tank proper. This condition is brought about by having the cylinder directly over the burners. The value of this feature lies in the fact that gas is not wasted in heating the entire tank full of metal to this higher heat, but still the metal under compression is at the required temperature. The gas consumption of the average die-casting machine is about 100 cubic feet per hour.

The speed at which die-castings may be produced varies with the size of the castings being made, the composition of the metal being cast, and the style of dies that must be employed. In many cases, in die-casting, separate brass or steel pieces are used, that must be placed in the dies before each operation so that they will be inserted in and become a part of the finished casting. The dies may be difficult of operation on account of draft problems or pins and screws that must be inserted in the dies and removed from each casting before another can be made. These different types of dies will be more fully described in the next chapter. Taken as a whole, from ten to sixty pieces per hour are the maximum limits for speed in die-casting, and with a well-working die, of simple construction, a speed of forty pieces per hour is considered good production. It is possible, however, when the castings to be produced are small in size and simple in shape, to gate a number of them together, or rather to construct the dies so that six or more castings may be made at once. By this means it is often possible to cast five or six thousand pieces per day of ten hours, on a hand die-casting machine.

CHAPTER II

MAKING DIES FOR DIE-CASTING MACHINES

The making of casting dies calls for ingenuity and skill of the highest order on the part of the die-maker. There is probably no class of die-making in which the work produced is more faithful to the dies, both in showing up the little details in the making that reflect credit on the dies, and in exposing the defects and shortcomings in the workmanship, if there be any. The castings from casting-dies or molds as they are sometimes called, may be produced in dimensions down to ten-thousandths for accuracy if necesasry, and once the dies are made the castings will not vary in the slightest degree, if the working conditions are kept uniform.

In spite of the close work required in making casting-dies, the work is very fascinating. Perhaps it is on account of this accuracy; possibly it is on account of the fact that they are made from machine steel; but most likely it is because there are no hardening troubles to be contended with. Another factor that makes the work interesting is the ingenuity required in the work, for almost every die-maker, if he is worthy of the name, likes to figure out and plan for the best way of building a die for a difficult job.

General Principles of Casting-die Making

Casting-dies, or molds, have little in common with sand molds. It is true that the dies for die-casting are composed of two parts corresponding to the cope and nowel of the sand mold, but they are so different in every other way that no benefit would result from a comparison.

Generally speaking, casting-dies are made of machine steel; the parts which are exceptions are the heavy bases and frames, which are made of cast iron, and the dowel pins and small cores, usually made of tool steel. Except in rare instances, there are no hardened parts about a casting-die; this is the case because the melting points of some of the alloys that are die-cast are high enough to draw the temper from any hardened parts of the dies.

The ideal die is simple in construction, with as few parts as practicable; the castings should be easily ejected and should come from the dies as nearly free from fins as possible. To meet these requirements in the best way is the proposition that confronts the ingenuity of the die-maker. As the die is primarily in two parts, there must be a parting line on the casting. This line is always placed at the point that will permit the casting to be ejected from the dies in the easiest manner possible, bearing in mind the effect the joint will have on the appearance of the finished casting; this is a point far less important than with sand casting, for, if the dies are properly made this seam will be barely perceptible. When it is practicable to do so, it is wise to have the parting line come on an edge of the die-casting. Draft is unnecessary on the straight "up-and-down" places, but of course it is impossible to draw any parts that are undercut. Means must be provided for ejecting the casting from the dies after completion and it is usually done by means of ejector pins, though frequently it is better to have the bottom of the die or some other section movable and do the ejecting on the same principle that is used on drawing dies of the compound type. On close work, shrinkage plays an important part, and the amount of shrinkage varies from 0.002 to 0.007 of an inch per inch. Aluminum shrinks the greatest amount, Parsons white brass shrinks considerably, while tin shrinks but little. Thus, it may be easily seen that to figure the shrinkage allowance for an alloy that contains three or four metals with different shrinkages, requires judgment. To prevent the air from "pocketing," air vents are necessary at frequent intervals around the die-cavity. These vents are made by milling a flat shallow cut from the die-cavity across the face of the die to the outside edges of the block. From ¼ inch to ½ inch is the usual width and from 0.003 to 0.005 of an inch, the customary depth, varying with the size and shape of the die in question.

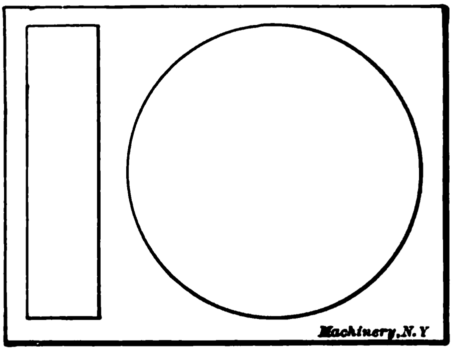

Fig. 7. Disk cast in Simple Casting-die

The dies or molds for die-casting are of various styles, as are also punch-press dies, and it would be difficult to lay down specific rules for their classification. There are the plain dies, without complications of any kind; slide dies with one or more slides; dies for bearings, both of the "half-round" and of the "whole-round" types; dies for gated work; and many other less important classes. Then there are dies that have features that belong to more than one of these types, so that it is easily seen that to decide upon the style of die that would be best for a given piece of work requires a good deal of experience. Some of the most important of these types can best be shown by illustrating dies made in the various styles, showing, step by step, how the dies are made and assembled. To begin with, consider the making of a casting-die of the very simplest form.

In Fig. 7 is shown a plain flat disk made by die-casting. In actual practice, a die would not be made for such a simple piece, unless there were some features about it that would prevent it being made on a screw machine or with press tools. It might have a cam groove cut in one of its flat sides, the sides might be covered with scroll work, there might be gear teeth around its circumference, or a hundred and one other conditions to make die-casting a desirable method of manufacturing. All these complications are omitted for the sake of simplifying this initial description of a casting-die.

Fig. 8 shows the die for this piece in plan and sectional elevation. *A* is a square cast-iron frame, made from a single casting. This frame or box, as it is generally called, is planed on the top and bottom only. Next, the two die-halves *B* and *C* are shaped up from machine steel. In this casting-die, and in the majority of others, these die blocks are

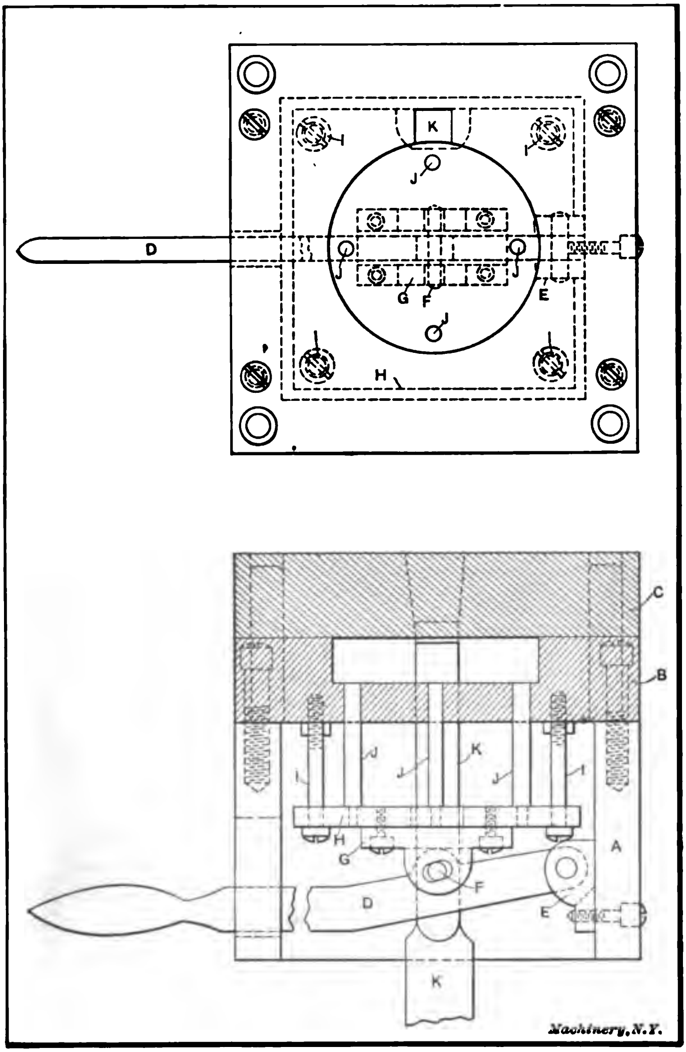

Fig. 8. Simple Casting-die for Casting Block shown in Fig. 7

square. The lower half of the die *B* is held to the cast-iron frame by fillister head screws, set in counterbored holes, thus sinking the screw-heads under the surface of the block. The upper half of the die *C* is located upon *B* by dowel pins driven into *B* which have a sliding fit in the reamed holes in *C*. This being done, the die-half *B* is fixed to the faceplate of the lathe and the recess bored for the die-cavity. This operation is a simple one in this case, for it is merely a straight hole one-half inch deep and three inches in diameter. Of course this recess must be carefully finished with a tool that has been stoned up to a sharp edge, using lard oil. Emery cloth should be used as little as possible. It is unnecessary to give this hole draft, but it must be free from ridges or marks that would prevent the casting from being pushed out. If the faces of the dies are spotted with a small piece of box wood or rawhide held in the drill press and kept charged with flour emery, the die-casting will reproduce this "bird's-eye" finish and the appearance will well repay the few minutes additional time that it will take. The spotting should be done with dry emery (without oil) to get the brightest finish. The upper die-half *C* is simply ground on its working face. The outside corners and edges of the faces of both die-halves should be well rounded off so as to insure the absence of slight dents or rough places that might prevent the dies from fitting perfectly.

The ejecting mechanism must next be considered. Lever *D*, pivoted from bracket *E*, has a steel pin *F* that engages in the elongated hole in bracket *G*, so that an upward pull of the lever *D* raises bracket *G*, which is attached to ejector-pin plate *H*. This plate is a loose fit over the guide screws *I* that are attached to the lower die-half *B*. The ejector pins *J*, four in number, in this die, are riveted into the ejector-pin plate, and they work through holes drilled and reamed through the lower die-half. The ends of these pins must be finished off so as to lie perfectly flush with the inside of the die when ready for operation and, of course, they must be a sliding fit in the holes in the die.

An important feature of a casting-die is the sprue cutter, shown in this die at *K*. If the disk for which this die was made, had had a hole or central opening of any kind, the sprue cutter would best be operated at that point; but, as this disk is plain, the sprue cutter must be placed at the edge. At the outside of the die-cavity, as shown in Fig. 8, the opening for the sprue cutter is laid out, drilled and filed to shape. It is obvious that the side of the sprue cutter adjacent to the die must fit the outline of the die perfectly, so that there will be no break in the appearance of the casting. The opening for it is extended through the upper die-half, and from a point ¼ of an inch from the inside face of the die this hole is flared out nearly as large as the opening through the die-plate of the machine. Of course the apperture in the upper die-half must be no larger than the opening through the die-plate; otherwise the sprue could not be pushed out. The sprue cutter itself is a long rod, whose section is of the same shape and size as the openings just made, and it is connected to the sprue cutting mechanism of the machine. Of course it is unnecessary to shape the entire length of the sprue cutter to size; after the working end is milled to shape for a distance of six or eight inches, the rest of the rod may be left round. The sprue cutter is finished first, after which both the openings in the die are fitted to it; and while the fit should be metal tight, it must be perfectly free to slide.

The dies are mounted on the die-plates of the casting machine by means of straps, much the same as bolsters are held on punch press beds. The position of the die on the die-plate must be such that the opening for the sprue cutter will line up with the nozzle at the outlet of the cylinder. At the time of casting, the position of the sprue cutter is as shown in the illustration of this die, Fig. 8. In this position there is room for the metal to enter the die-cavity, and yet there is but a small amount of metal to be cut off and pushed back after the die has been filled with metal.

With slight modifications, the above style of die may be used for die-casting any piece that will draw or pull out of a two-part die. If holes must be cast through the piece, it is only necessary to add core pins to the lower die *B*, a point that will be more fully described later. It is unnecessary to add that both halves of the die may be utilized in making the cavity for the die, should they be needed. Also, it is often easier to machine out the recess larger than is needed, and set in pieces in which parts of the outline of the die-casting have been formed. Gear teeth are put in the die in this way; a broach is cut similar to the gear desired, then hardened and driven through a piece of steel plate which is afterward fitted to its place in the die.

Slide Dies

The die illustrated in Fig. 9 is one of the most successful of the various types of casting-dies, and if properly made is an interesting piece of die work. The prinicpal use of this particular style of die, called a slide die, is to cast parts like the one shown in Fig. 10, which is a disk similar to the one which the last die described was to cast, except that it has raised letters at the edge and a hole in the center. It is obvious that the die last described, (Fig. 8), would not do for disks or other pieces having projections or depressions around their edges, as, for instance, printing or counting wheels with raised or sunken characters, or grooved pulleys. Briefly, this style of die is similar to the simple casting-die, except that slides are provided, to the required number, which form the edge of the casting. A die for a plain grooved pulley would require but two slides, while a die for a printing wheel with forty letters around its edge would necessitate forty slides, one for each of the letters. The die about to be described, shown in Fig. 9, was made to cast a wheel with six raised letters.

Referring to Fig. 9, *D* is the cast-iron box or frame, *E*, the lower die, and *F* the upper die. In making the lower die-half, the stock is first shaped to size and doweled to the blank for the upper die-half, and the holes for attaching to the frame are drilled. For the sake of clearness, these holes and screws are omitted from the illustration as are also the vents, since they have been fully explained. The lower die is next strapped to a face plate, trued up, and bored out nearly to the diameter of the body of the piece to be cast, exclusive of the raised letters. The depth of this recess is equal to the thickness of the printing wheel plus 3/16 inch to allow for the cam ring *G* that is used to reciprocate the slides of the die. The cam ring is made large enough to cover the die-cavity as well as the slides that surround it, with an allowance of an inch or two for the cam slots *H*. The six slides *I* are made long enough to have good bearing surfaces. With the size of the cam ring determined, the die is next bored out to receive this cam ring and the last inch of the recess is carried down to the depth of the die cavity so as to make an ending space for the slots that the slides are to work in.

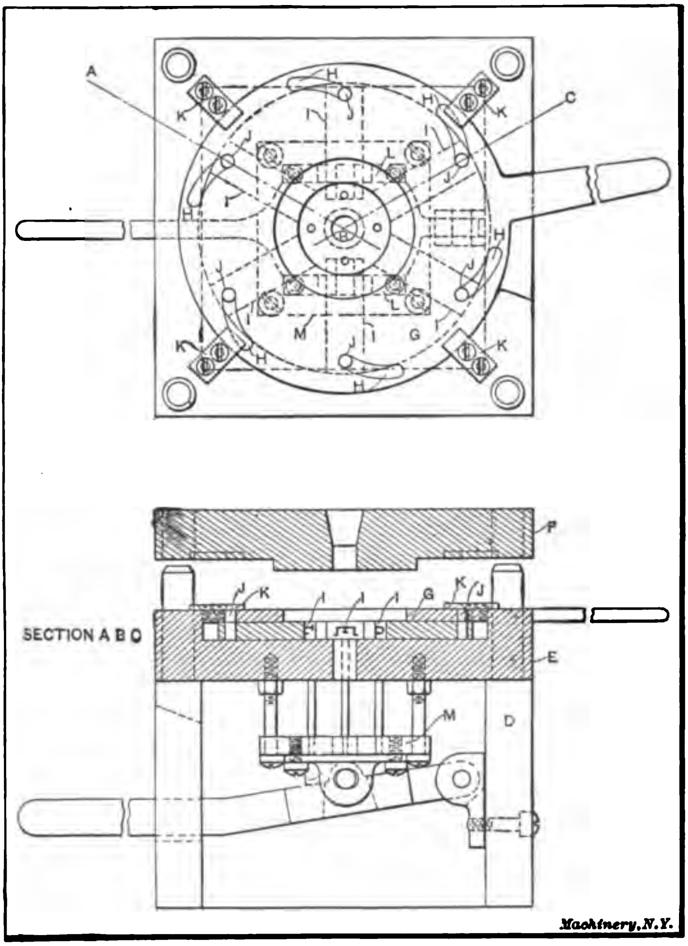

Fig. 9. Slide Die for Casting the Printing Wheel shown in Fig. 10

The die is now taken from the faceplate and the slots for the slides laid out.

These slots may be milled or shaped, but milling is to be preferred. The next step is the making and fitting of the slides, which are of machine steel, having a good sliding fit in the slots. The six slides are fitted in position and left with the ends projecting into the die proper.

The slots *H* are next profiled in the cam ring *G*, and the pins *J* that work in them are made and driven into the holes in the slides. With the slides and cam ring in place, the cam ring is rotated to bring all the slides to their inner position where they are held temporarily by means of the cam ring and temporary screws. The die-half with the slides thus clamped in the inner or closed position, is set up on the lathe faceplate and the die-cavity indicated up and bored out to the finish size, which operation also finishes the ends of the slides to the proper radius. The die may now be taken down and the slides removed to engrave the letters upon their concave ends. The engraving can be done in the best manner on a Gorton engraving machine, but if such a machine is not available they may be cut in by hand. Stamping should never be resorted to for putting in the letters, because the stock displacement would be so great that it would be impossible to refinish the surface to its original condition. Before fitting the cam ring, an opening must be milled in the die to allow the handle to be rotated the short distance necessary. After the cam ring has been fitted, it is held in by the four small straps *K*, attached by screws to the lower die-half at the corners.

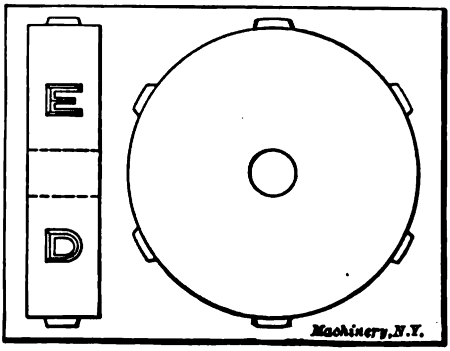

Fig. 10. Printing Wheel cast in a Slide Die

The sprue cutter, which is not shown, is operated through the hole in the center of the piece and is, of course, round in this die. Its action is the same as was the one previously described, and the ejecting device is similar, with the exception that the brackets *L* that are attached to the ejector-pin plate *M*, are widely separated so as to make room for the sprue cutter that works through a hole in the plate *M*.

Die for Casting with Inserted Pieces

For making die-castings that are to have pieces of another metal inserted, it is necessary to have a die with provisions for receiving the metal blank and holding it firmly in position while the metal is being cast around it, and of course the piece must be held in such a manner that it can be easily withdrawn from the die with the finished casting.

The die illustrated in Fig. 11 is for a part that is used as a swinging weight, shown in Fig. 12. The upper part of the piece is made from a sheet steel punching, so as to lighten this part of the piece as well as to give increased strength, especially at the hole at the pivoted end of the work. The cast portion of the piece is slotted lengthwise, as the illustration shows; and three holes pass through the casting, piercing the sides of the slot. In addition to showing the method of making dies for inserted pieces, this die shows the principles of simple coring.

In making this die, two machine-steel blanks are planed up for the upper and lower halves of the die, *A* and *B*, the lower die being made nearly twice as thick as the upper die because it is in this part that the most of the die-cavity will be made. In this lower half of the die

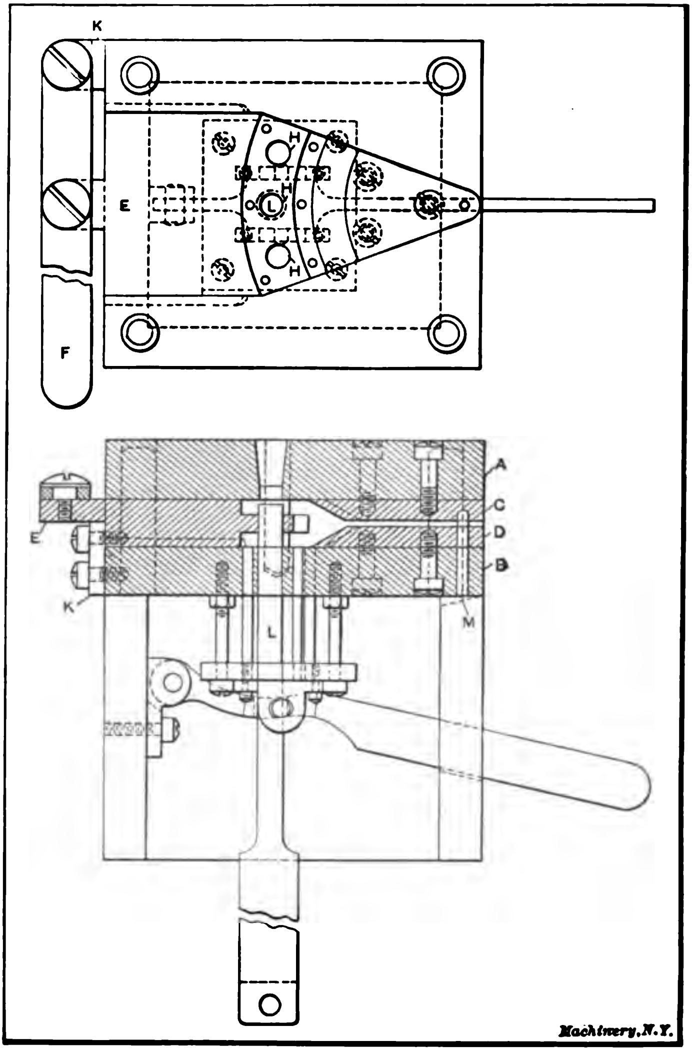

Fig. 11. Casting-die for Making Castings with Inserted Pieces like that shown in Fig. 12

the stock is milled out to the same shape as the outline of the plan view of the casting, being carried down to the exact depth of the thickness of the casting. From the wide end of this recess the stock is milled or shaped out in a parallel slot to the outside of the die-block.

At the bottom of the side of this wide slot are T-slots to guide the slide *E* that is to work in this opening. The side is milled and fitted to the T-slots and opening in the die, but is left considerably longer than the finish size. Next, the slide is mounted on the faceplate of a lathe and turned out on the end with the proper radius and a tongue to form the slot that is to be in the curved end of the casting. At the outer end of the slide is left a lug that is drilled and tapped for the operating lever *F* that reciprocates the slide, using the stud in bracket *K* as a fulcrum.

Two pieces of machine steel are next shaped and finished up to form the chamfered part of the casting and to locate the inserted steel punching in the die. The combined thickness of these pieces *C* and *D* is equal to the thickness of the casting, less the thickness of the inserted piece. It is now an easy matter to seat section *D* in the bottom of the milled part of the lower die-half, and to locate section *C* in its proper position on the upper half. A pilot pin *M* is fitted in *D* to hold the steel punching in position by means of the hole that is in the extreme upper end of the punching. The pilot pin extends through this hole into a corresponding hole in section *C*. At the lower end of the steel part that is inserted, there are two holes the object of which is to secure the punching to the die-casting, for the molten metal runs through these holes, practically riveting the die-casting to the inserted piece.

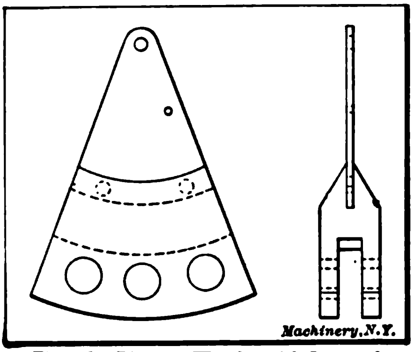

Fig. 12. Die-cast Weight with Inserted Sheet-steel Punching

Provision has now been made for holding the sheet-metal part that is to be inserted, and the cavity has been completed for the casting, including the tongue at the end; it now remains to describe the manner of forming the holes that pierce the casting through the slotted portion. In the lower die-half the positions of the three holes *H* are laid out, drilled and reamed. Then, with the two die-halves together and the slide clamped at its inner position, the holes are transferred through the slide and the upper die. This being done, it is an easy matter to make core pins and drive them into the upper die at the two end holes, the center hole being taken care of by the sprue cutter *L* that will be described later. The core pins should be a nice sliding fit through the slide and in the holes in the lower die, into which they should extend from a quarter to half an inch. In addition to coring the holes, these pins act as a lock to hold the slide *E* in its proper position at the time of casting.

The sprue cutter *L* is most conveniently operated in the center hole, thus doing away with the core pin that would otherwise be required. The sprue cutter needs little description in this die, for as in the slide die, it is merely a plain round rod that fits closely in the holes through the dies and slide. The ejector mechanism is the same in this die as in the dies already described; therefore further description is unnecessary.

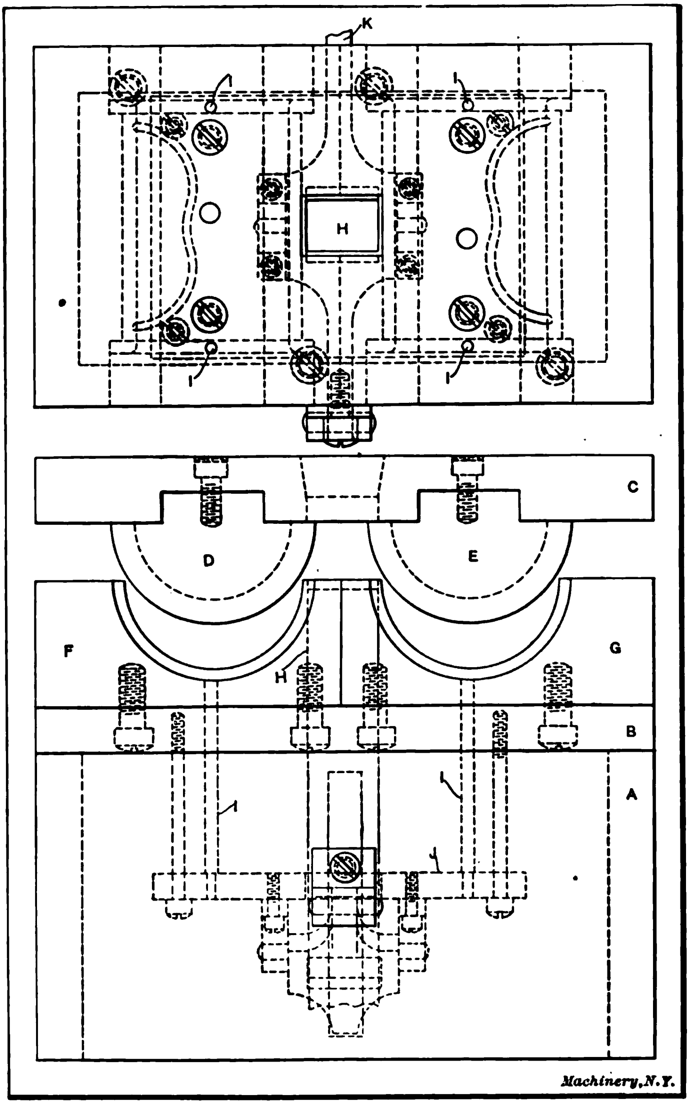

Fig. 13. Casting-die for the Half-round Bearing shown in Fig. 14

The operation of this die is very simple. The sheet-steel piece is laid in the recess in the open die, being located by the pin *M*. Slide *E* is thrown in by means of lever *F*, and the dies are closed. At the time of casting, the sprue cutter in is the position shown in the sketch, being nearly through the die-cavity. As before explained, this position admits the molten metal to pass into the die-cavity, but still leaves very little sprue to be cut off after the die-casting is completed. It should be stated that the steel piece that is inserted must be perfectly flat and free from burrs that would prevent the die-halves from coming together properly.

Bearing Dies

Bearing dies are one of the most important of the various classes of casting-dies. The bearings produced by die-casting are so far superior to those made by other casting methods and machining that their use is now very extensive. Dies are made for "half-round" and "whole-round" bearings. There is little out of the ordinary about a whole-round die, but the half-round die involves many interesting methods of die-making, and for that reason is here described.

Fig. 13 shows a casting-die for half-round bearings. Half-round bearing dies are usually made to cast two bearings at a time, for the reason that it is just as easy to cast two pieces of such a shape as it is to cast one, and, in addition, the die is balanced in a better manner. As with other dies, the first step is to machine up the frame *A* and the

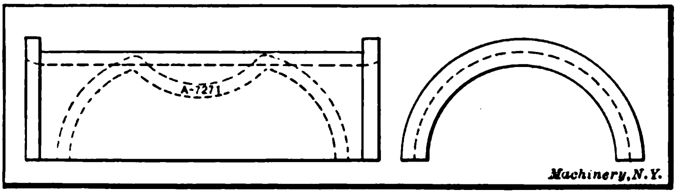

Fig. 14. Die-cast Half-round Bearing, Showing the Cast Oil Grooves

two die-halves *B* and *C*. The pieces *D* and *E* that are to form the insides of the bearings are then turned up and one side of each shaped and keyed to fit the slots that have previously been milled in die-half *C*. These parts are held in place by dowels and screws. One of the bearings produced by this die is shown in Fig. 14, and it will be noticed that there is an oil groove within that covers the length of the bearing. To produce this groove in the die-castings, a shell must be turned up and bored out whose inside diameter is that of the inside of the bearing, and whose thickness equals the depth of the oil groove. This being done, the oil grooves are laid out upon the shell and cut out by drilling and filing. After rounding the outside corners, these little strips are pinned to the cores *D* and *E* in their proper places.

Another little kink in this connection is worthy of noting. So many different styles and sizes of bearings are made by a concern doing much die-casting that it is essential that the die-cast bearings should bear some distinguishing number to identify them. As this number is of no consequence to the user it is well to have the number in an inconspicuous place, but it must be where it will not be effaced by scraping, etc. Bearing in mind that it is much easier to produce raised lettering by die-casting than to produce sunken lettering, it will be readily seen that the oil groove affords a good place in which to put the bearing number. This is easily done by stamping the figures upon the narrow strip that forms the oil groove. In this place on the bearing it may be easily found if needed, and of course there is no danger of its being taken out by machining.

The lower die consists of two blocks *F* and *G*, each of which contains an impression of a bearing. The best way to make these parts is to lay out the ends of each of the blocks with the proper radius, taking care to have the center come a little below the surface of the face of the block. Then the blocks should be shaped out to get the bulk of the stock out, before setting up in the lathe. After the lathe work is done

Fig. 15. Interesting Examples of Die-castings

on each piece, which of course is usually done separately, the faces of the two blocks are faced down just to the exact center of the impression. It will be noticed that two blocks are used for the lower part of the die. The reason is to facilitate the locating of the female parts of the die in proper relation to the male parts. After properly locating, they may be doweled and screwed to baseplate *B*.

The sprue cutter *H*, better shown in the plan view, is square in shape and connects with the die-cavities in a thin narrow opening on either side of the sprue cutter. The ejector pins, *I*, two to each die, are at the ends of the bearings. The ejector-pin plate *J* is necessarily large, and is operated by lever *K*.

Fig. 15 shows a number of interesting examples of die-castings.

CHAPTER III

VAN WAGNER MFG. CO.'S DIE-CASTING PRACTICE

In 1907, Mr. E. B. Van Wagner, of Syracuse, N. Y., established the E. B. Van Wagner Mfg. Co. for the production of die-castings. The factory comprises the office section, the machine shop where the dies and casting machines are built, the metallurgical laboratory where the metals are alloyed, the casting department shown in Fig. 17 where the die-castings are made, and the trimming department.

Possibilities and Limitations of Die Casting

At the outset we may say that it is possible to die-cast almost any piece, but it is not by any means practicable to do so. It must be remembered that to die-cast on a practical basis the dies must be con-

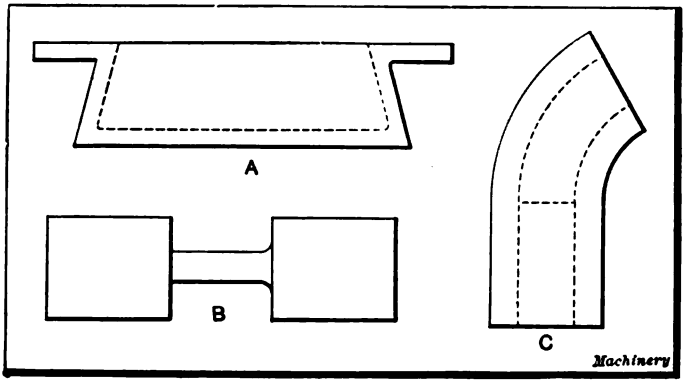

Fig. 16. Die-casting Constructions to be avoided

structed in such a manner that the cost of their operation and up-keep will be light, or there will be no profit in die-casting. It is impracticable to produce under-cut work, that is, work having no draft and which is therefore impossible to draw from the die. Such an instance is that illustrated at *A*, Fig. 16, and by the internal section of *M*, Fig 21, and the internal groove in *O*, also shown in Fig. 21. If absolutely necessary, work of this kind can be done by the use of collapsible cores; but here, again, we meet resistance in maintaining the dies in proper condition, and, moreover, this method is commercially impracticable, owing to the difficulty of operating these cores rapidly. Hollow work, requiring curved cores, like faucets and bent piping of the character illustrated at *C* in Fig. 16, are difficult to produce. If, in designing the piece, it can be planned to have the parts of such a shape that the cores can be readily withdrawn, employing a two-piece core with a slight draft in each direction, the division coming as indicated by the core line of *C* in Fig. 16, the problem becomes simpler. Oftentimes this work can best be done by casting in a straight piece,

Fig. 17. View of the Casting Room

afterward bending the die-casting. It does not pay to cast rough heavy work that can be made just as efficiently by sand casting. Generally speaking, the greatest saving can be effected by die-casting small pieces which have previously required a large amount of machining to produce. On large plain work the amount of metal required for the casting makes the cost excessive on account of the difference in cost of the metals. If, however, the large work must be finely finished by polishing, etc., it is oftentimes found of advantage to die-cast. Corners, especially those joining thick and thin sections, as at *B*, Fig. 16, should be heavily filleted as shown on one side of this piece. Regarding the casting of thin sections, it is not practicable to try to cast sections under 3/64 inch in thickness, as the metal runs with difficulty into such narrow places. A casting having walls 1/16 inch, like that shown at *X*, Fig. 24, is easily cast. Threaded sections, if the threads are fine, say, under twenty-four to the inch, should not be die-cast, because under moderate pressure they will strip. A good way to treat constructions of this kind is to enclose brass or steel bushings in the die-castings in which the threads are required.

As to the accuracy with which die-castings may be produced, it is possible to keep dimensions within 0.0005 inch of standard size, but to do so requires considerable expense in keeping the dies in condition. A limit of 0.002 inch, however, is entirely practicable, and can be maintained easily. In specifying the accuracy with which die-castings are to be made, only those parts which are absolutely essential should be held to size, in order to keep the cost of the work nominal. One of the great advantages of the use of die-castings is that no finishing is required after the pieces leave the molds. Finish requirements should be plainly stated in ordering die-castings, as the alloy must be suited to these requirements.

Another great saving is effected on lettered work, either raised or sunken. One of these jobs is illustrated at *Q*, Fig. 22, which shows an

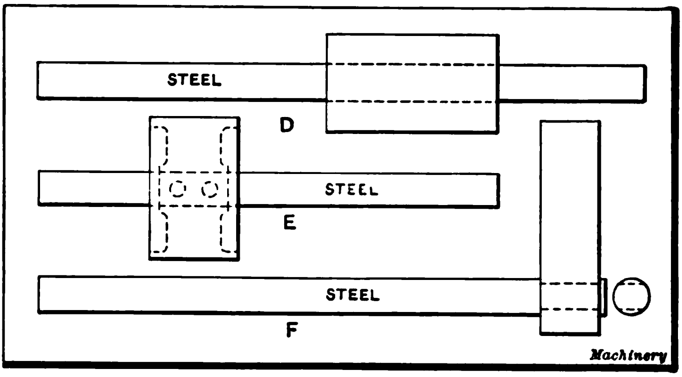

Fig. 18. Methods of attaching Die-cast Gears, etc., to Shafts

example of die-cast lettering. Sunken lettering is to be preferred to raised lettering, as the latter is more easily injured. Knurled work may be produced easily, if straight knurls are used, and threaded sections over ¼ inch in size are entirely practicable, either internal or external. External die cast threads are illustrated at *R* and *S*, Fig. 22. The casting of gears and segments is a familiar appliction of die-casting; this is illustrated by the large gear at *N*, Fig. 21, and the segment at *W*, Fig. 23, which give an idea of the general character of this class of work. The casting of pulleys, gears, and similar parts on shafts may be easily effected as shown by the gear on the shaft at *N*, in Fig. 21. The views shown in Fig. 18 are intended to convey an idea of three methods of die-casting around shafts. At *D* is shown a die-casting cast around a steel shaft. If the surface of the shaft coming within the pulley has been previously knurled, the pulley will grip it much better, but for ordinary purposes the shrinkage of the die-cast metal around the shaft is sufficient. If any heavy strain is to be imposed on the work, it is better to provide anchor holes through the shaft, like those indicated at *E*. It will be readily seen that the die-cast metal runs through these holes in the shaft, forming rivets which are integral with the casting. For locating levers upon the ends of shafts, etc., a good way is to flatten opposite sides of the shaft and cast around them, as shown at *F*, Fig. 18. The screw seen projecting beneath the piece at *Q*, Fig. 22, was die-cast in place. Any of these

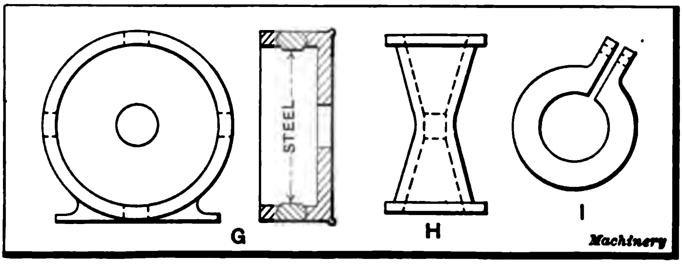

Fig. 19. A Few Possibilities of Die Casting

methods are to be recommended, and a proper knowledge of possibilities of this kind will increase the scope of die-casting.

Another phase of die-casting which can well be borne in mind is the possibility of inserting steel or other parts in the die-casting. Such an instance is shown at *G* in Fig. 19— a die-casting which was made by the Van Wagner Co. as a part of an electrical apparatus, the steel inserts being contact points. Oftentimes it is found advisable to include brass bearing rings to give additional durability at points where the die-cast metal would not stand up. The die-casting shown at *U*,

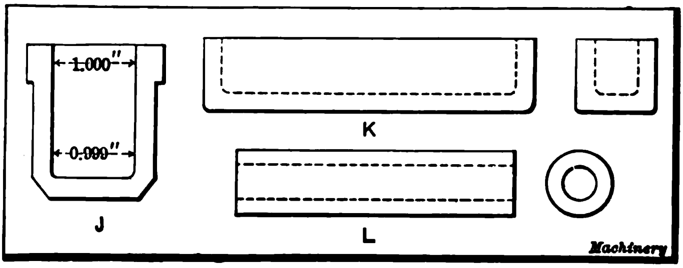

Fig. 20. Castings which illustrate Points of Shrinkage and Draft

Fig. 23, in which the brass ring at *T* has been incorporated, is typical of such cases. To die-cast pieces like those shown at *H* in Fig. 19, and similarly at *V* in Fig. 23, having inverted conical openings, might at first thought seem difficult, but this is entirely practicable. Similarly, split bushings like those shown at *I*, Fig. 19, and at *W*, Fig. 23, may be cast with projecting lugs for the reception of screws for clamping upon shafts, etc., but this construction should not be used if frequent tightening or loosening will be necessary.

The shrinkage problem mainifests itself in die-casting in the same measure that it does in other casting operations. Different metals shrink in different degrees, as will be explained later on. However, one important point can be mentioned at this time: that is, the amount of shrinkage is often dependent upon the shape of the piece. For in-

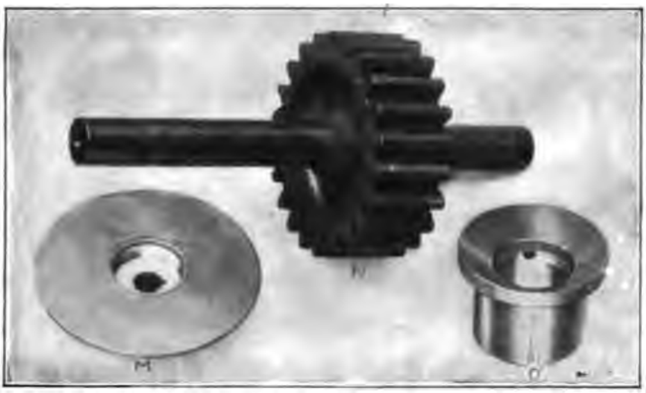

Fig. 21. Die-castings showing Impractical Under-cut Sections; also a Large Gear die-cast on Shaft

stance, pieces like those shown at *K* in Fig. 20 or at *X* in Fig. 24, will shrink very little on account of the fact that the steel mold is of such shape that the central core will prevent the die-casting from shrink-

Fig. 22. Die-castings which show Lettering and Thread Castings

ing. However, pieces like those shown at *L* in Fig. 20, or at *V* in Fig. 24, which have nothing to hold them from pulling together as they cool, will shrink to the greatest extent. All of these points must be taken into consideration when designing work for die-casting. Practically no draft is necessary on a die-casting, except on very deep sections, as indicated at *J* in Fig. 20, where a draft of 0.001 inch to the inch is desirable. Perfectly straight sections, however, can be cast, as the shrinkage of the metal is usually enough to free it from the die.

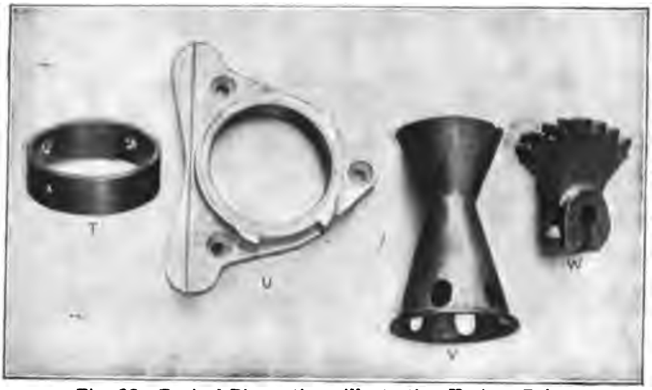

Fig. 23. Typical Die-castings Illustrating Various Points

It is the opinion of the Van Wagner Co. that die-casting costs can be materially reduced if designers will bear this point in mind when bringing out new designs. Even though it is often possible to cast special pieces, incorporating several parts in one, and thereby accomplishing what seems to be a great stunt to the designer, it is sometimes more practicable to make the piece in several sections and later

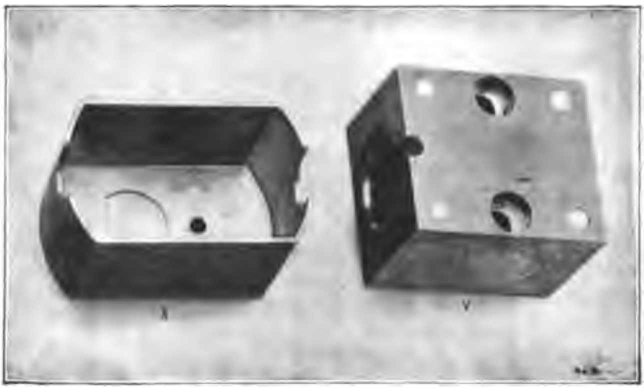

Fig. 24. Die-castings Illustrating the Extremes of Shrinkage

assemble it. Not only is this simpler for the die caster, but it is also more economical for the customer. Such points as avoiding thin sections, including large fillets at corners, as well as taking account of the under-cut problem, are simply matters of common sense, but they can profitably be considered by the designer.

The Van Wagner Die-casting Machine

The first essential to good die-casting is a good casting machine. Perhaps the best known types of casting machines are of the familiar plunger type, of which there are several varieties, the pneumatic type and the rotary or automatic type. (For descriptions of various types of die-casting machines, see "Die Casting Machines," MACHINERY'S Reference Book No. 108.) For the economical production of die-castings, however, the hand-operated machines are rather too slow, and automatic machines are applicable only to a class of work which may be made in very large quantities. For these reasons, therefore, the Van Wagner Co. employs the compressed air type of die-casting machine which was patented by Mr. E. B. Van Wagner in 1907. In the casting department of the Van Wagner shop, illustrated in Fig. 17, there are installed about thirty machines. Fig. 27 shows a die-casting

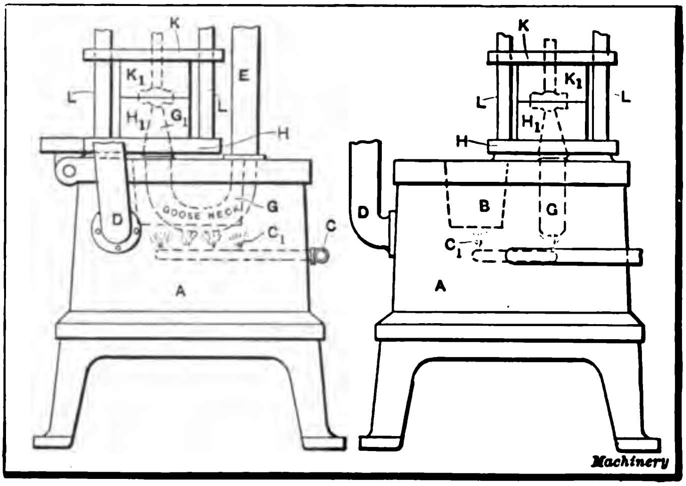

Fig. 25. Drawing illustrating Principle of Van Wagner Die-casting Machine

machine in the open position. Fig. 26 shows a closer view of the die-operating mechanism and Fig. 25 is presented to give a general idea of the construction of the entire machine.

By referring to the line illustration Fig. 25, which shows the Van Wagner pneumatic die-casting machine in part, and comparing this illustration with Fig. 26, which shows the general appearance of the die-operating and other mechanism of the casting machine, a good idea may be obtained of its construction and working. At *A* may be seen the base of the machine in which is located the melting pot *B*. This melting pot is heated by means of fuel oil passing through the supply pipe *C* to the burners C_1. A vent pipe *D* is provided to take away the gases incident to combustion. The pressure for "shooting" the metal into the die cavity is supplied by air through the supply pipe *E*. A valve controls this air supply. The pressure is regulated to suit the particular casting or die, the proper amount being determined by experiment. Similarly, an air exhaust pipe *F*, which may be seen directly above the supply pipe, sub-divides into two tubes which extend to the die cavity to exhaust the air before the metal is admitted. There are two methods of overcoming the presence of air in the die cavity—the exhaust method and the venting method, and it is the former that is here described.

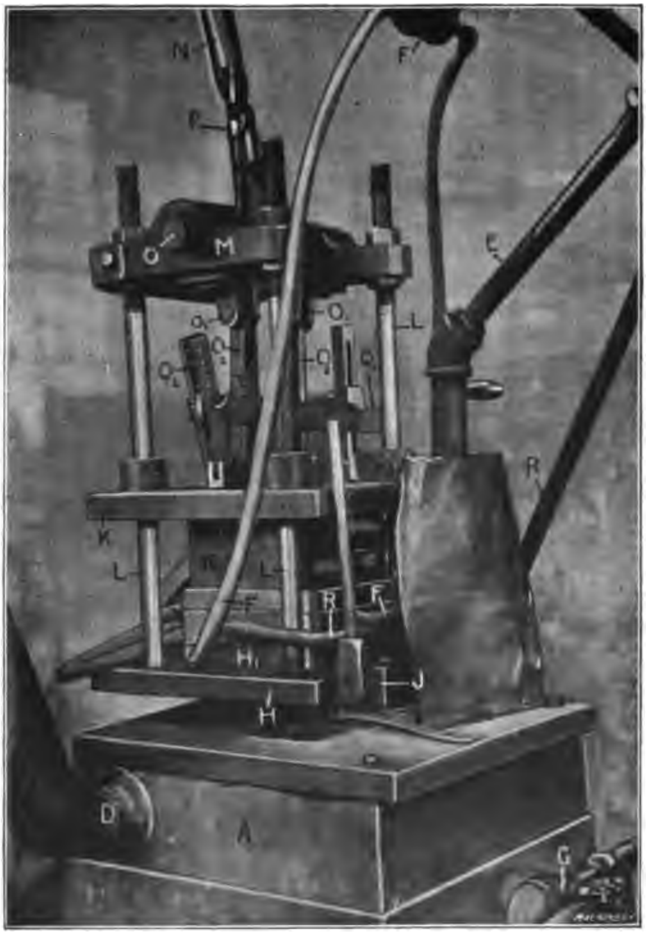

Fig. 26. View of Machine showing Die-operating Mechanism

A "goose-neck" *G*, shown in Fig. 25, serves to temporarily contain the metal which is forced into the mold. An amount of metal slightly in excess of that required for one die-casting is placed in this goose-neck with a hand-ladle, previous to each operation of the machine. One end of the goose-neck is connected to the air pipe, *E*, while the other end terminates in the nozzle G_1. This nozzle may best be seen by referring to the illustration of the machine shown in Fig. 27, in connection with Fig. 25. One of the advantages in using this goose-neck is that the entire air pressure is expended upon the metal in the goose-neck, and, by reason of its isolated position, the goose-neck and its contents are kept slightly hotter than the contents of the melting pot.

The Die-operating Mechanism

The die-operating mechanism of the machine is contained within a hinged framework, shown in position for the removal of the die-casting in Fig. 27. Referring to Fig. 26, in connection with the line illustration Fig. 25, it will be seen that the die-holding mechanism is all supported upon the lower die-holding plate *H*, which is hinged to the edge of the base of the machine. A lock *J* serves to hold the dies and operating mechanism in the upright operating position, and by means of a counterbalance, suspended from an overhead rope which connects with the top of the mechanism at *P*, the changing of the posi-

Fig. 27. Die-casting Machine in Position for Removal of Casting

tion of this mechanism is easily effected, and when thrown into the horizontal position, as indicated in Fig. 27, it rests upon a support while the dies are being opened and the castings ejected.

The lower die is shown at H_1, and the upper die K_1 is mounted upon the upper die-holding plate *K*. Four rods *L* act as guiding members for the upper die-holding plate to slide upon. These rods *L* are mounted in fixed positions at the corners of the lower die-holding plate *H*, and at their upper ends the operating shaft supporting plate *M* is located in a fixed position, serving to support the upper ends of these rods. The position of this plate *M* is adjustable upon the rods by means of check-nuts, thus providing for the accommodation of thick as well as thin dies. A shaft *O* is supported in this top plate, and by means of the operating lever *N* working through slotted levers O_1, and links O_2, the upper die-holding plate and die can thus be removed from contact with the lower die at will.

The metal enters the die cavity through the nozzle G_1, and after setting, it is necessary to cut the sprue formed by the surplus metal that remains outside the die cavity. For this purpose, a sprue-cutter, operated by means of hand-lever Q_1, is employed. This sprue-cutting lever is hinged in the fulcrumed link Q_2, and is held in its casting position by means of an adjustable stop on bracket Q_3.

In many dies, it is necessary that water be circulated through the die-blocks to keep them cool during the die-casting operation. In Fig. 26, the water pipe may be seen at R, and hose pipes run from this supply to each side of the die-blocks, thus providing a cooling circulation. In this illustration, the pipes used for exhausting the air from the die cavity are apt to be confused with the cooling pipes, but by following

Fig. 28. General View of Trimming Department

the two pipes leading vertically down to the machine, the exhaust pipes may be seen and kept distinct from the water pipes.

Making a Die-casting

In order to clearly understand the operation of the die-casting machine, let us follow the sequence of events that takes place in producing a casting. Two men are required to operate the machine. In Fig. 27, the operators may be seen in their working positions. The first step is taken by the operator at the left who, with a hand-ladle, dips enough metal for one casting from the melting pot and pours it through nozzle G_1 into the goose-neck. The second operator in the meantime is replacing the cores in the dies, adjusting the position of the sprue-cutter and closing the dies preparatory to making a casting. This being done, he elevates the dies and their operating mechanism, which are hinged and counterbalanced, as previously described, bringing them to an upright position. The die operator now mounts the box, raises the sprue-cutter to its open position to admit the metal; after which the machine operator turns the air valve with his left hand. The operation of this air valve admits the air behind the metal, forcing it into the die, and the same movement opens the exhaust valve slightly in advance. The exhaust valve is located upon the second length of piping just above the air valve, and as a link connects the two valves, the single motion exhausts the air from the die cavity and immediately afterward the air is admitted behind the metal, thereby "shooting" the metal into the die. This being done, the air is shut off and the die operator cuts the sprue by means of lever Q_1, withdraws the cores in the die, throws the dies to the open position (which is indicated in Fig. 27), and operates the ejecting mechanism, thus removing the casting from the die. In the meantime, the machine operator is tending to his metal supply and getting a ladle full of metal ready for the next die-casting operation. By referring to the machines shown in Fig. 17, it will be noticed that

Fig. 29. Trimming Die-castings on a Filing Machine

only a few are provided with exhaust piping for venting the dies. Another venting method will be described later.

The number of die-castings which can be made on one machine per day of ten hours varies with the character of the pieces being die-cast, the number of pieces made at each operation of the machine and the ease with which the dies may be worked, which depends, of course, upon the number of cores and parts to be handled at each die-casting operation. The dies shown in the machine in Fig. 26, produce four bearings at each operation.

Trimming Die-castings

At the end of each run the operators of the machines go over their work, breaking the castings from the sprues and throwing out all that are defective. No matter how carefully the die-casting molds have been made, there is always a certain amount of trimming to be done on the finished die-castings, on account of the crevices left in the die for air

Fig. 80. General View of E. B. Van Wagner Co.'s Die making Department

vents, or which exist from improper fitting of the parts of the dies. These "fins," as they are called, are trimmed by hand operators in a special department. A general view of this trimming room is shown in Fig. 28. Usually it is sufficient to scrape these fins off with a scraping knife, but if the casting is especially difficult to produce, so that a large opening is required to admit the metal, it is sometimes necessary to

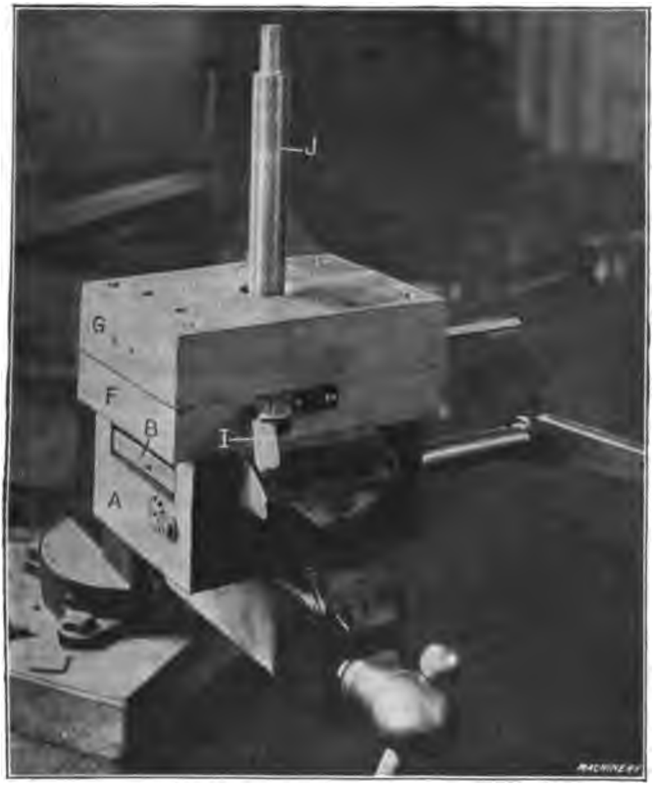

Fig. 31. A Typical Die-casting Mold

trim unusually thick sprue sections by filing. Fig. 29 illustrates the method of trimming such die-castings on a filing machine.

The Dies Used

Next to the casting machine. the dies or molds are the most important necessary factor. A general view of the Van Wagner Co.'s die-making department is shown in Fig. 30. In order to gain a proper conception of the work required in producing a high-grade die-casting mold, we will follow the different steps which are necessary in making the mold. The first and most important step is the proper planning of the die. Before any work at all can be done, it is necessary to plan the die, *i. e.*, to decide just where the parting lines will come; just what method will be used for ejecting the piece; what alloy will be used; where the casting will be gated; and a hundred and one minor points, all of which have a direct bearing upon the performance of the finished dies. All these decisions have to be made by the diemaker, and in Fig. 37 he is shown, micrometer in hand, computing the shrinkage allowances that he will make in the dies. This is a very important factor on accurate work as the shrinkage varies from 0.001 to 0.004 inch, according to the alloy and the general shape of the piece.

Before taking up the actual machining operations of the mold-making as conducted in this factory, it will be well to take a typical die-casting mold and note its general construction. Fig. 31 shows a typical die-casting mold closed, while Fig. 32 shows the same mold disassembled on

Fig. 32. Die-casting Mold shown in Fig. 31, disassembled

the bench to show its construction. The piece for which the mold has been made is also shown. Fig. 33 shows a similar die in section. From the three illustrations a good idea of an average die-casting mold can be obtained. Referring to these illustrations, the principal parts of this die are the ejector box *A*, and the ejector plate *B* which is operated by the racks *C*. For operating the ejector plate, the pinion shaft *D* having a handle suitable for turning, is furnished. This, of course, fits into a bored hole in the ejector box, bringing the pinion into mesh with the racks for raising the ejector plate. In the ejector plate are three ejector pins *E* for removing the casting from the mold. The ejector pins operate through holes *F*. Beyond the pinion shaft may be seen the casting for which this mold has been made. It will be noticed that the top side of the casting has three projecting lugs through which are small holes. Provision for forming this side of the die-casting is made in the lower half of the mold *G*, while the upper half of the die-casting is taken care of by the top plate *H*. One of the toggles for operating the core pins through these three lugs is shown at *I*. These parts will be described more fully later. The sprue cutter is shown in position in the die at *J*.

Machining the Die Cavities

As will be noticed from Fig. 30, the machinery in the die-making department is of modern design, for no other class of work demands as good tool equipment and as much skill in the making as die-casting molds. The die-blocks are made of machinery steel. Fig. 34 illustrates the first step in making a die-casting mold after the die-block has been shaped approximately to size. This operation consists in carefully facing off the die surfaces on a vertical-spindle grinding machine. This, of course, is a quick method of surfacing the die-block, and it insures that the top and bottom surfaces of these plates will be parallel, permitting the die-faces to come together properly.

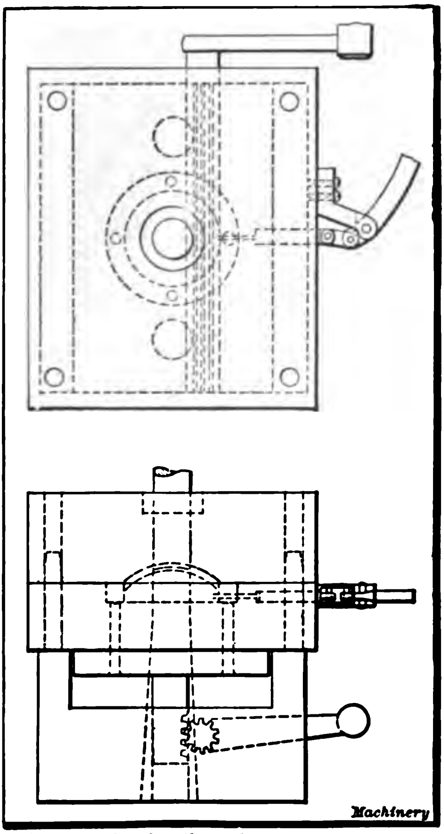

Fig. 33. Section through a Die-casting Mold

The next step consists of laying out the die, as shown in Fig. 36. This is done in the usual manner, by working on a coppered surface, using dividers, scales, and a center punch. When laying out the die, the necessary allowances are made for shrinkage and finish, these points having been planned before actual work on the die has been started. As in other phases of die-work, the machining operations are performed, as far as possible, before any hand-work is done. In Fig. 38 may be seen a die-maker turning the cavity in a part of the die-casting mold. The highest type of skilled workmanship is called for on this machine work, and as may be surmised from Fig. 38, where the die-maker is shown measuring the die with a vernier caliper, the measurements must be exact, for no grinding operations follow the machine work.

Figs. 35 and 39 show typical milling operations being performed on die-casting molds. In Fig. 39 the diemaker is shown indicating a pin in one corner of the mold cavity, preparatory to doing additional mill-

Fig. 34. First step in making the Mold—Grinding Surfaces of Blocks

ing. The block is held in the usual manner by being clamped on the bed of the milling machine, and after it has been properly located under the cutter head, tools are substituted for the indicator and the milling

Fig. 35. A Milling Operation on a Die

of the cavity is completed. Fig 35 shows one of the sections of the die-casting mold which is to be used in producing the casting shown at the right of the work. In this case the diemaker is milling the recess

Fig. 36. Laying out One of the Mold Parts

Fig. 37. Planning the Die-casting Mold

Fig. 38. Turning out a Die-casting Mold

for the steel arbor which may be seen directly in the foreground. This will be fitted in place to provide for the forming of the hole in the side of the piece.

Fig. 40 illustrates several important points in the making of a die-casting mold. This illustration shows the ejector box with the lower half of the mold on it, the ejector plate being held against the under side of the die-plate by means of the pinion shaft. The operation being done is the drilling of the ejector pin holes. Referring back to Fig. 32, which by the way shows the die here illustrated disassembled, the holes being drilled are those shown at *F* for the reception of the pins *E*. The method employed is to drill the holes through the die and into the

Fig. 39. Indicating a Mold on the Milling Machine

ejector plate, afterward reaming all holes to size and driving the pins into position in the ejector plate, while they are allowed to slide freely through the die-plate. We will now assume that the ejector box and plate have been completed and fitted, a pinion shaft for operating this plate also fitted, the lower and upper dies completed by the machining operations previously described, and all assembled. The final operation of the fitting of the pins is shown in Fig. 41 in which the die-maker may be seen filing off the ends of these pins so that when dropped to the lower position they will lie flush with the surface. If of uneven lengths, these pins will cause irregular spots in the casting. It now remains to describe the toggles used for operating the cores which form the holes through the three lugs in the casting. One of these toggles, of which there are three, is shown at *I*. in Fig. 31, and also in Fig. 32.

These toggles consist of brackets which are attached to the die-plate, and levers which are fulcrumed at the ends of the brackets so that their operation works the core pins. It is necessary to remove these core pins after each casting has been made and position them before another casting can be produced.

The fitting of the parts of a die-casting mold is one of the most important parts of the work. It demands the highest type of workmanship, for a poorly fitted die means a die which works hard in addition to producing poor castings. It is very important that all movable parts should work freely. Fig. 42 shows the assembling operation on a die-casting mold, the casting which is to be duplicated being shown in the immediate foreground. These parts must all be screwed into their respective places, making the joints as nearly air-tight as possible. One cause of poor die-castings arises from the trapping of air in the die, and different methods are employed for overcoming this trouble.

Fig. 40. Drilling the Ejector-pin Holes

Venting the Dies

There are two methods of preventing air from being trapped in die-casting molds; either by constructing the dies so that the air may be exhausted from the mold cavity before admitting the metal, or by venting the die so that the air may be forced out by the inrushing metal. In the first of these methods it is necessary that the joints in the mold be made as close as possible, otherwise it will be impossible to produce anything like a vacuum in the mold cavity. If, however, it has many parts which must be fitted, it is usually considered advisable to provide the die with vents consisting of milled recesses a few thousandths inch deep. Several vents are provided, from which the air can

Fig. 41. Fitting Ejector-pins

escape when the metal is admitted to the dies. The hot metal, of course, "shoots" through them in thin ribbons, but not enough escapes to affect the pressure on the metal which goes into the casting.

No matter how carefully a die may have been constructed, or how carefully it has been assembled, there is always a certain amount of "babying" to be done before it will work satisfactorily. The casting may stick a little here, or there may be a rough spot there, and it is the successful elimination of these troubles which constitutes the production of a good die-casting.

Die-casting Metals

One of the purposes of this book is to correct several erroneous impressions which are prevalent in regard to die-casting possibilities. Many people seem to think that nearly all metals can be die-cast, but as a matter of fact, those metals which can be successfully die-cast can be numbered on the fingers of one hand, being alloys of lead, zinc, tin, copper and antimony. The tin base metals shrink very little, while the zinc base metals shrink considerably, and those with a large per cent of aluminum have a very high shrinkage. Without doubt, the most used die-casting metals are the zinc base metals. A typical metal of this class contains about 85 per cent zinc; 8 per cent tin; 4 per cent copper and 3 per cent aluminum. The melting point of this metal is

Fig. 42. Assembling a Die-casting Mold

about 850 degrees F. While this alloy is one of the most common, it is not by any means the best, as there is too little tin employed, but it is a comparatively cheap metal, which probably accounts for its large use. This metal is easily affected by heat and cold, and rapidly deteriorates with age. The lead base metals may be typified by an alloy containing 80 per cent lead; 15 per cent antimony; 4 per cent tin; and 1 per cent copper. This composition melts at approximately 550 degrees F. and is used for castings subjected to little wear and where no great strength is required. The weight of this metal is its greatest objection, and it is also quite brittle because of the large percentage of antimony.

For the best class of die-castings, the tin base metals are employed. These range from 60 to 90 per cent tin, and from 2 to 10 per cent copper, together with a little antimony. The melting point of a mixture of this composition is about 675 degrees F. The castings have a good color and they are much better in quality than any of the other alloys.

It is absolutely essential that tin base metals be used for carbureter parts or other parts coming in contact with gasoline. Also, the tin base metals must be used for parts which come in contact with food products, as the lead or zinc alloys have a contaminating effect.

Aluminum alloys have been cast in France and Germany in limited quantities, but very seldom in this country on account of their high melting point, as well as their effect upon the die. After aluminum alloys have been run in the dies for a short time, the surfaces of the molds become pitted. Through some unexplained cause, the metal seems to flake out particles of the steel in the molds. When an aluminum alloy is to be used, a good mixture is 80 per cent aluminum, 3 per cent copper and 17 per cent zinc. This alloy has a high shrinkage and it has also the same deteriorating effect upon the dies, but to a much less degree than pure aluminum.

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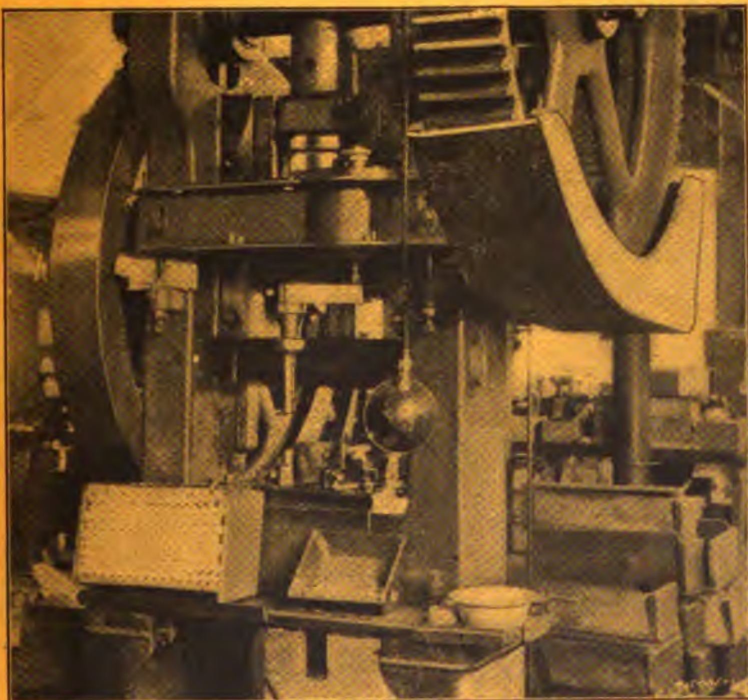

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NUMBER 110

THE EXTRUSION OF METALS

CONTENTS

INTRODUCTION

Although it had been found possible as early as 1850 to extrude such metals as lead and tin and thus form pipes and bars, the extrusion process had not, at that time, been successfully applied to the shaping, by means of extrusion, of such metals as copper, delta-metal, etc. It was when Alexander Dick, the inventor of the delta-metal, made some experiments with this material under high pressure and at high temperature, during the latter part of the eighties, that it was first shown that this material could be extruded in a heated state. There were, however, several difficulties to overcome. The extrusion process, as is well known, consists of hot plastic metal being pressed through a form or die at high pressure, so that a continuous bar or pipe of the cross-section of the die or form is produced. Lead and tin can be extruded at comparatively low temperatures (250 degrees F.), but copper and similar metals require temperatures all the way up to 1750 or 1800 degrees F.

The main difficulties to be overcome are to maintain the high temperature and plasticity of the metals during the extrusion, and to make press cylinders and dies which will be able to withstand the effect of the high temperatures and pressures. The first condition was met by Dick by filling the press cylinder with molten metal and by surrounding it with heat insulating material, such as ground granite. In order to prevent the heated metal from forcing itself between the plunger and the cylinder, when the pressure was applied, a spherical steel piston was employed which spread when the pressure was applied, and in this way effectively closed the cylinder behind the metal.

The advantages of the extrusion process, as compared with the ordinary rolling and drawing process, soon became apparent. The extrusion process permitted parts of unusual cross-section to be produced in great quantities. In fact, sections could be extruded which could not be rolled under any circumstances. In Fig. 26 is shown a number of special sections which have been produced by extrusion. On account of the high pressure under which the metal is extruded it becomes more compact and its strength is increased. The extruded shapes, therefore, possess those qualities which make them especially useful in machine design The surfaces are smooth, and free from flaws and other defects. The dimensions of the extruded shapes can be gaged with great accuracy, so that they may be used either directly or with very little additional finishing. After the advantages of the new method had become known, it was soon adopted and further developed by many different individuals and concerns.

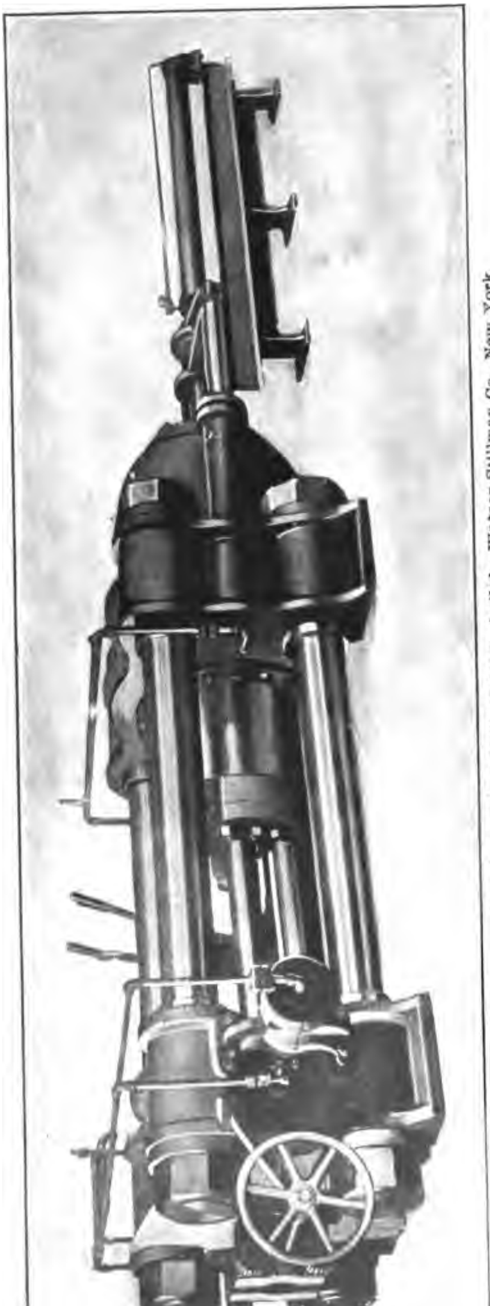

Fig. 1. Two-thousand-ton Hydraulic Extrusion Press, built by Watson-Stillman Co., New York

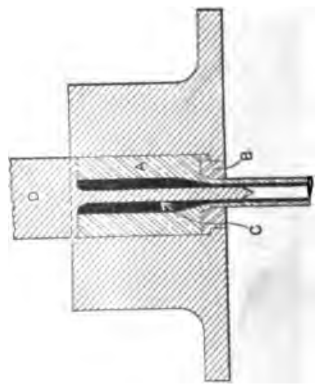

Fig. 2. Making Tin-lined Lead Pipe

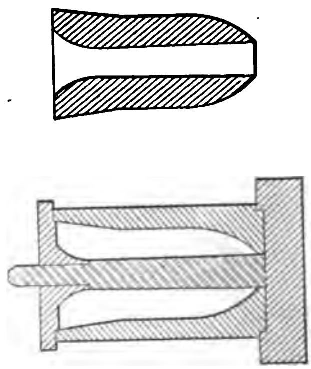

Fig. 3. Improved Ingot Mold and Lead Ingot

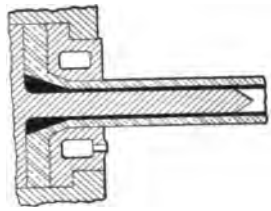

Fig. 4. Jacketed Die

Machinery

CHAPTER I

THE EXTRUSION PROCESS

The extrusion process for manufacturing metal shapes for various purposes is rapidly growing in favor. Intricate shapes can be made by this process that would be impossible to roll and that would be very expensive to machine; and shapes that could be rolled can be produced more accurately to size by the extrusion process than by rolling, and can also be made from various kinds of metals. While the principle on which this process operates is a very old one, it was not a commercial success until the hydraulic press was enough developed to be used for this purpose. During the past two decades many improvements have been made that have enabled shapes to be made quicker and cheaper, and of metals that are stronger, harder and tougher than those formerly used. The great progress in metallurgy also has produced strong alloys that could be more easily extruded.

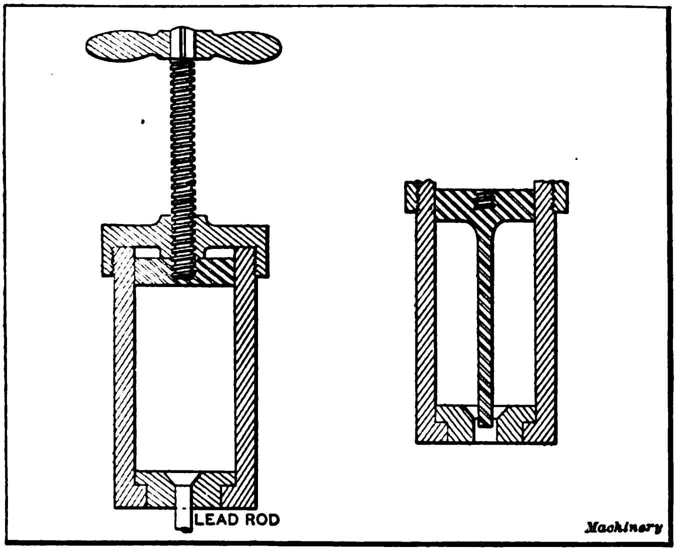

Fig. 5. Early Press for Making Lead Rods

Fig. 6. Principle of Press for Making Lead Pipe

In Fig. 1 is shown one of the latest types of machines used for extruding or squirting solid metal alloys through metal dies into the required shapes. Like most other machines of the present day, the one shown has evolved, or gradually grown, from a crude, simple device. It has required the services of many engineers and mechanics and over a century of time, to develop it to its present state. The alloys and the methods of extruding them have also passed through the same evolution. Notwithstanding this, some manufacturers very zealously guard 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.

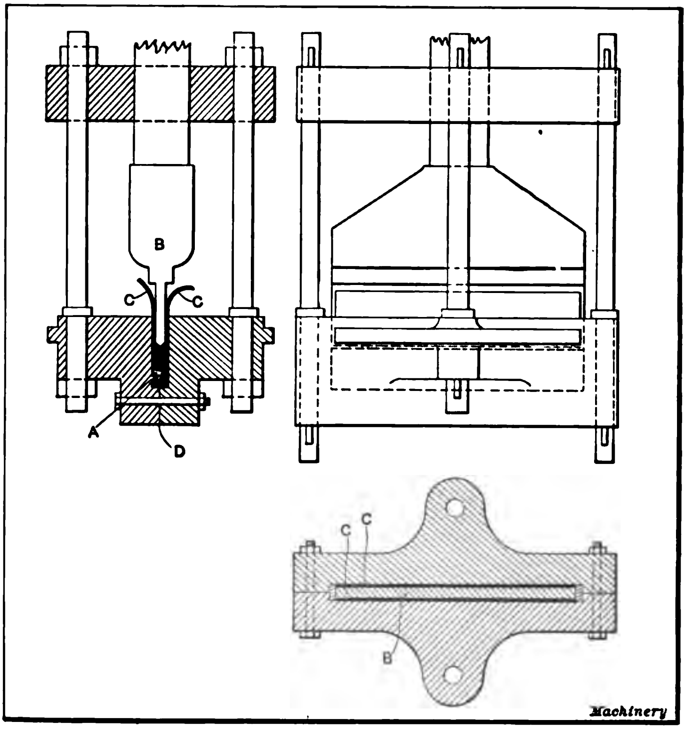

Fig. 7. Machine for Making Lead Sheets

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

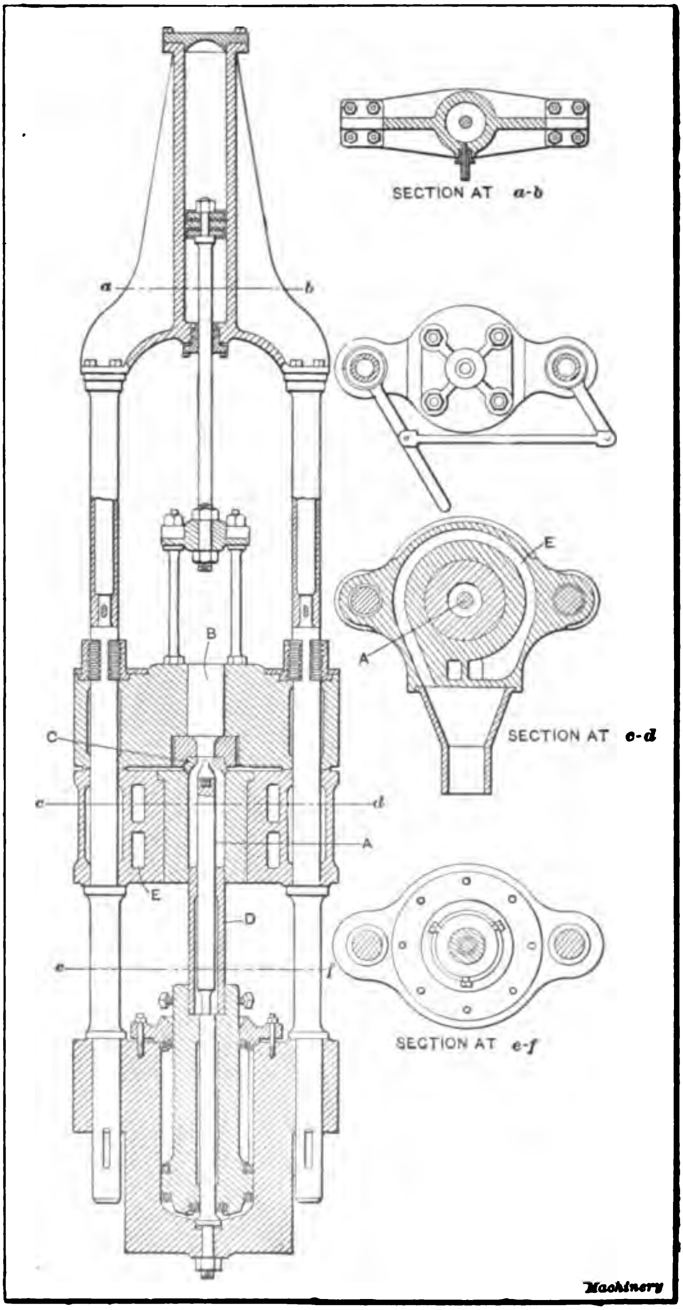

Fig. 8. Hydraulic Press for Making Tin-lined Lead Pipe

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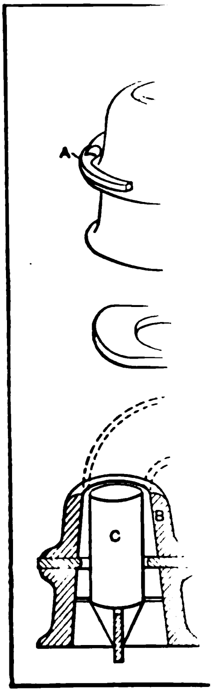

Fi...

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and dies inserted at *D*. ...
and sheets of different ...

In 1863 tin-lined pipe ...
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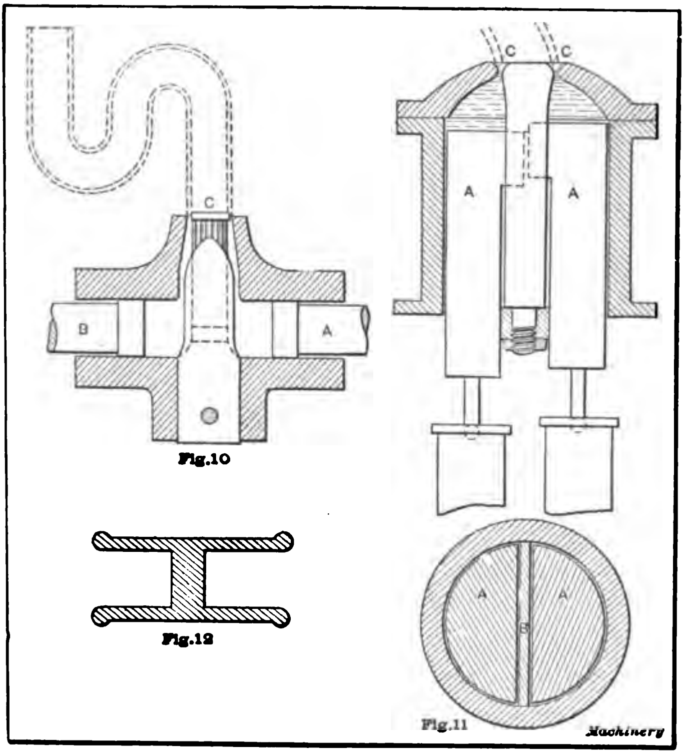
in Fig. 2. In this, *A* is th...
B, the die; and *D*, the ...
Previous to this, lead pipe ...
the pipe, but it was very ...
interior of the pipe, and it ...
unequal in thickness. While ...

presented other difficulties due to the sharp corners in the cylinder. Therefore, the lead ingots were cast in a mold of the shape shown in Fig. 3, and the tin ingots were cast in another mold that would make them fit the inside of the lead ingot. Another difficulty encountered was due to the uneven heating of the dies, and they were jacketed as shown in Fig. 4, so that steam or water could be circulated through them. In this way the die could be heated up to the required temperature before starting to make pipe, and maintained at this temperature while running.



Figs. 10 and 11. Other Devices for Making Curved Pipe. Fig. 12. Extruded Shape used for Leaded Glass Windows

In 1869, A. H. Hamon of Paris, France, patented the hydraulic press shown in Fig. 8 for manufacturing tin-lined lead pipe. In this the lead ingot that surrounded the hollow tin ingot was placed in the cylinder at *A*, and ram *D* was operated to force the metal through the die at *C* and the opening at *B*, where it was coiled onto a reel. A blast of hot air or steam was sent through the ports *E* to bring the metal to the correct temperature for extrusion. This temperature was below the melting point of the tin, but high enough to make the mass pasty, so that it could easily be extruded through the die. This design is practically the same as that of the extrusion machines of the present day.

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

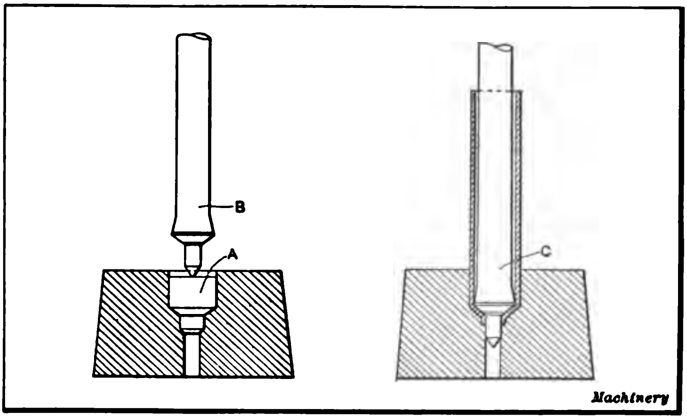


Fig. 13. Method of Tube Making

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 two halves, each of which can be driven at a different speed. Hence, the metal on either side of partition *B* can be forced through the opening around core *C* in varying volumes. This causes the lead pipe to curve in either direction as much as desired, or extrudes it in a straight line.

The softer metals were also extruded in other shapes for various purposes, such as printers' leads, shapes for holding glass in leaded glass windows (as shown in Fig. 12), etc. Very thin metals used for metal foil were also produced. These latter were made from lead-tin alloys, and many different compositions were used to get stronger, tougher and better wearing metals than pure lead. Very thin tubes,

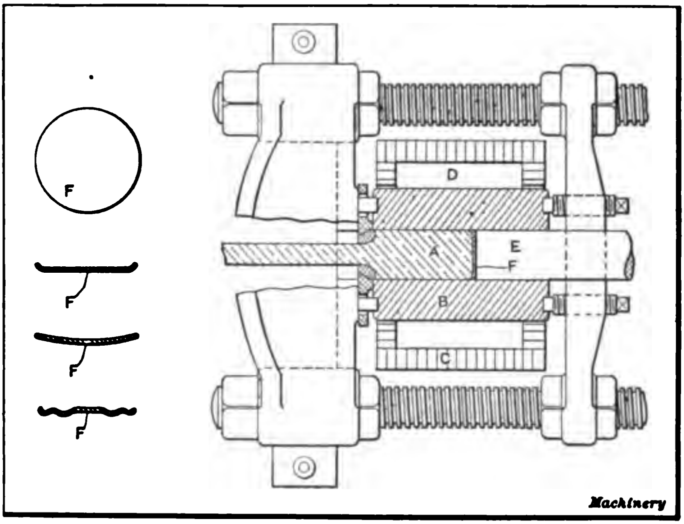


Fig. 14. Coke-fired Ingot Container

such as are used for artists' paints and similar materials, were also made by a similar process. At *A* in Fig. 13 is shown a disk of metal with plunger *B* in position to be forced down into it. At *C* the plunger is shown at the bottom of its stroke and the tube is completely formed. The grids or plates for secondary batteries were made by the extrusion process as much as twenty-five years ago. These consist of narrow strips of metal crossing each other, and joined at the intersections so as to form hollow squares. They often have more than one hundred squares in them. They were made by extruding a long cellular mass which was later cut up into thin grids.

When metals or alloys with a higher melting temperature than the lead and tin first used were formed into various shapes by the extrusion process, several problems other than that of a powerful machine presented themselves. One of the greatest of these problems was that of the temperature. It was very desirable to be able to extrude brasses and bronzes, as they were much stronger than alloys with a lead or tin base. It was necessary to keep the temperature below the fusion 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,

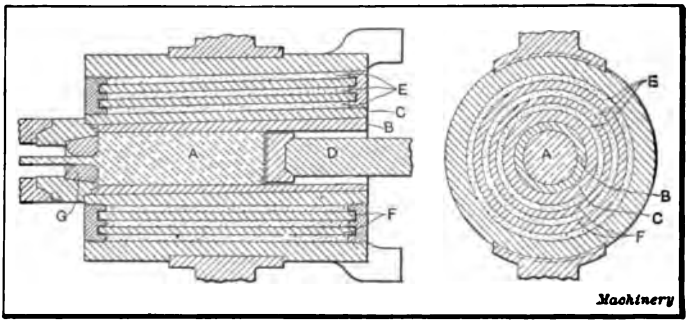


Fig. 15. Steel and Asbestos Container

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.

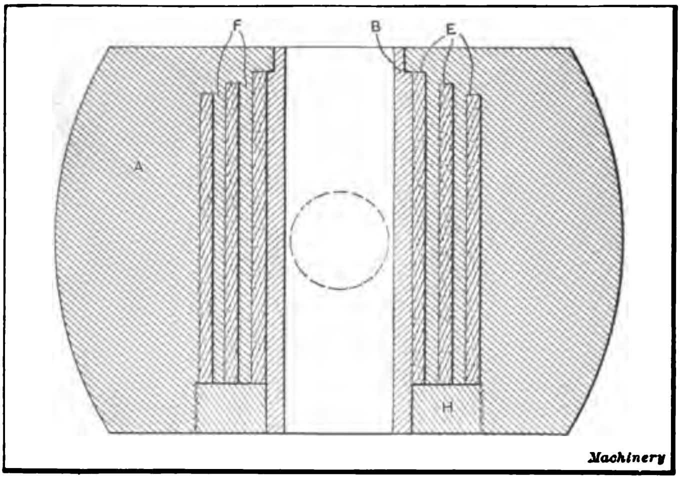


Fig. 16. Cast Container with Layers of Heat-insulating Materials

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 special billet containers, and these are now a part of all extruding machines.

Billet Containers

One of the first designs of this type was patented by George A. Dick in England in 1893. This device is shown in Fig. 14, in which *A* is the billet of metal that is being extruded; *B*, the cylinder or billet container; *C*, a case built around the container; and *D*, a passage through which the flames from a coke or coal fire were passed. With this apparatus, copper and zinc alloys that were red hot and plastic at

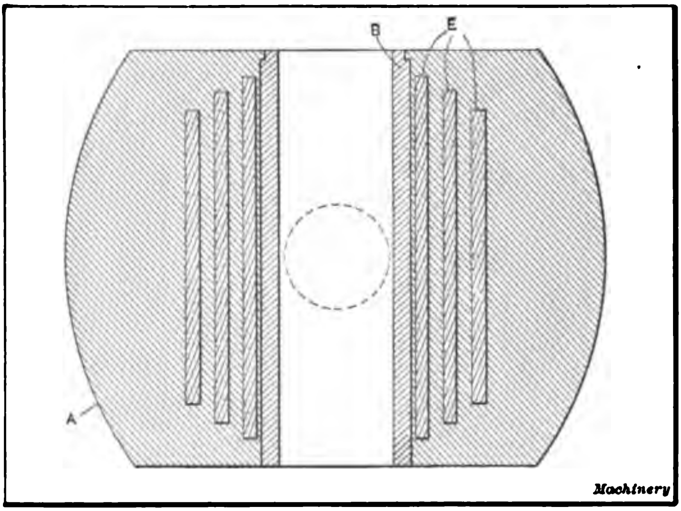


Fig. 17. Another Type of Cast Container

from 800 to 900 degrees F., were successfully extruded. When the billet was inserted in the container, a disk similar to those shown at *F* was placed over the end of the ram *E*. This disk will spread, fit the wall of the container tightly, and prevent the metal in the billet from squeezing back past the ram and wedging it. These disks were made from metal with a higher melting temperature and less plasticity than the metal being extruded.

While this device worked better than anything previously used, it was difficult to control the coke fire so as to maintain a uniform temperature. Another difficulty was met with in trying to conduct the heat away from the head, owing to the thickness of the metal that had to be used to withstand the pressure exerted by the hydraulic ram. As considerable heat was given out by the billet, and the penetration through the thick cylinder wall was slow, the exterior would be much cooler than the interior. This caused unequal expansion and contraction, and frequently resulted in cracks and fractures. Hence, a built-up head or billet container was designed, having alternate layers of steel and 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

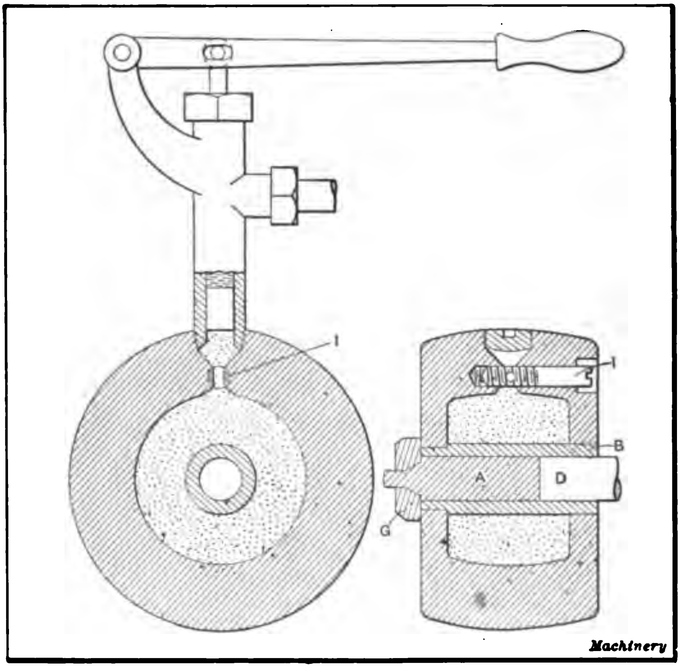


Fig. 18. Heat Insulation forced into Place by Pump

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 openings were packed with heat-insulating materials, and ring *H* was screwed into the case. In Fig. 17 cores were made from broken granite, scrapstone, trap-rock or other suitable heat-insulating materials, and these were located in the mold and the case cast solidly around them. Billet container *B*, however, was inserted as a separate piece, because this part wears and must be replaced, while the container proper may last indefinitely. It is not always possible to manufacture cylinders in this way, as the metal from which they are cast may shrink much more than the refractory material in the cores. This is almost sure to cause a fracture in the casting when it is solidifying. A style in which the cylinder is cast hollow is shown in Fig. 18. After the billet container *B* has been placed in position, the hollow space

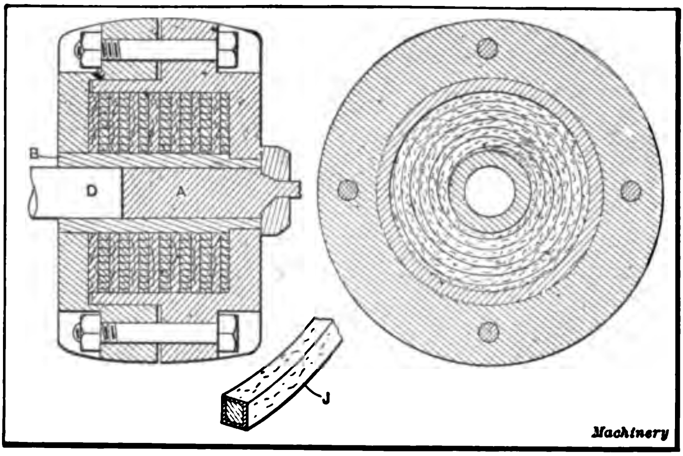


Fig. 19. Container wound with Wire and Asbestos Insulation

is filled with refractory materials like glass, sand, etc., by forcing these materials through valve *I*, with a force pump, as shown.

In Fig. 19, lining *B* is wound with asbestos-covered flat wire and the cylinder clamped together over this with bolts. The form of wire shown at *J* is used, and the coils are separated by rings of asbestos. This retains the heat and strengthens lining *B* enough to prevent it from bulging or cracking under the pressure transmitted by the ram. The rings of asbestos may be left out, and the covered wire wound in solid, or it may be wound alternately with strips of asbestos of the same size, staggered. A sectional view would then present the appearance of a checker board.

Electrically-heated Container

One of the latest types of cylinders is arranged so that the ingot to be extruded can be electrically heated. Not only the cylinder, but the die-block and the end of the ram also can be similarly heated. This is shown in Fig. 20. Here *A* is the ingot that is being extruded; *B*, the billet container; *C*, the cylinder; *D*, the ram or plunger; and *E*, the winding of metallic tape which has enough resistance to impede the

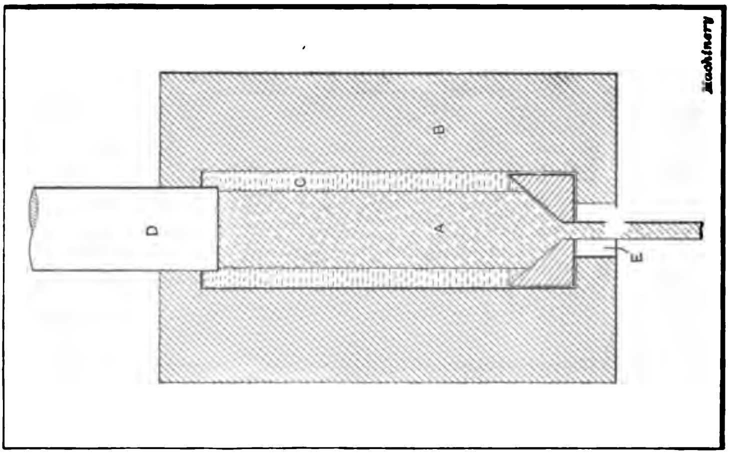


Fig. 21. Liquid-surrounded Ingot

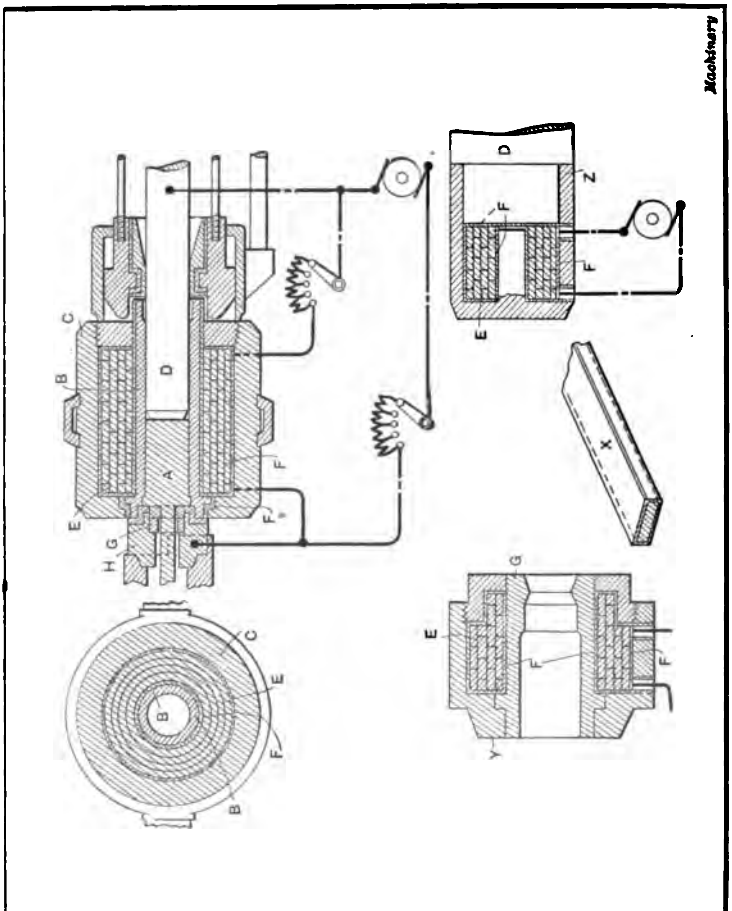


Fig. 20. Electrically-heated Container

current and generate the heat. A section of this tape is shown at *X*. It is usually made of copper and covered with some insulating material. The insulation that confines the electric current and prevents it from entering other parts of the machine is shown at *F*; *G* is the die, and *H* the die block, which may also be electrically heated by constructing it as shown at *Y*. The end of the ram *D* may be electrically heated by constructing it as shown at *Z*. This would entirely surround the billet with electric heating apparatus.

In extruding-machines or processes, the billet is heated to the proper temperature before it is placed in the cylinder, and hence the only thing required is a maintenance of this temperature until the metal has been extruded. If, therefore, the cylinder were electrically heated, it might be all that would be required. The ram would seldom require heating, and it would weaken it to place a resistance in the end of the ram. For metals with higher melting temperatures, however, it might be desirable to heat the die-block electrically, and this could readily be done as shown. The electric current is by far the best means of heating the metal and maintaining it at a steady temperature. With rheostats, the current can be easily controlled, and, consequently, the amount of heat required to maintain an alloy at a certain temperature is easily regulated to within a few degrees.

Special Forms of Containers

An attempt was made to abolish the troubles caused by billets adhering to the container walls, by using the design in Fig. 21. Here billet *A* is much smaller in diameter than container *B* and is surrounded with some kind of liquid at *C*. Thus, when ram *D* forces the metal through die *E*, liquid *C* is supposed to keep the ingot from gripping the walls of the container and wedging therein. It is claimed for this method that aluminum or metals of similar ductility can be extruded at atmospheric temperature, this being due to the fact that the billets can be made much smaller in diameter than the interior of the containers; that the ram *D* need only be a tight fit at the extreme end of the container; and that the liquid acts as a lubricant, and the adhesive force is thus entirely overcome. Thus a greater power can be applied to the ram, and the extruded metal be made more dense. The heat can also be done away with, except that which is caused by friction when the metal passes through die *E*. The liquid *C* can be oil when metals are extruded cold, and this will lubricate the apparatus and aid in overcoming the friction as it passes through the die. Water also might be used. Metals of a higher melting temperature could be extruded, and consequently greater strengths obtained. When it became necessary to heat metals for extrusion, fused caustic potash or other materials might be used.

In attempting to press cold metals through a contracted hole like the die of an extrusion press, the billet spreads under the compression and grips the side walls. To overcome this adhesive force and make it less than the forward pressure of the ram, billets are softened and made plastic by raising their temperature. This also reduces the strain

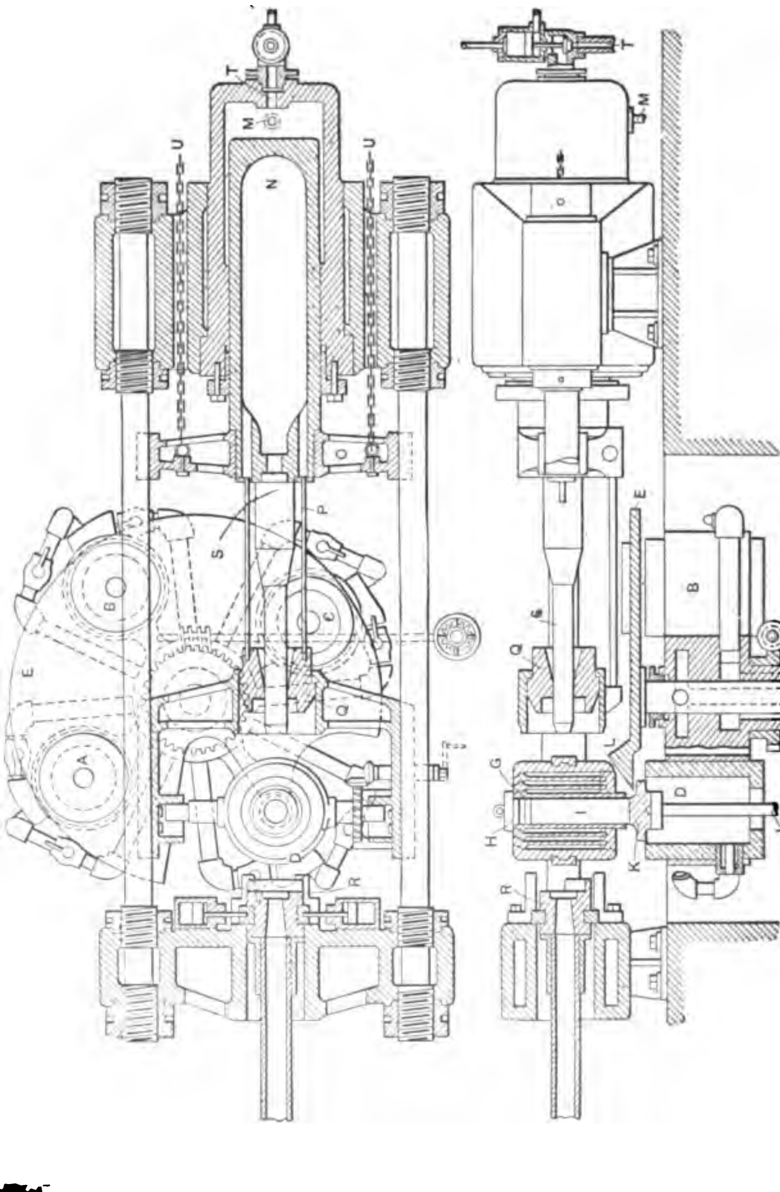


Fig. 22. Main Features of a Modern Extrusion Machine

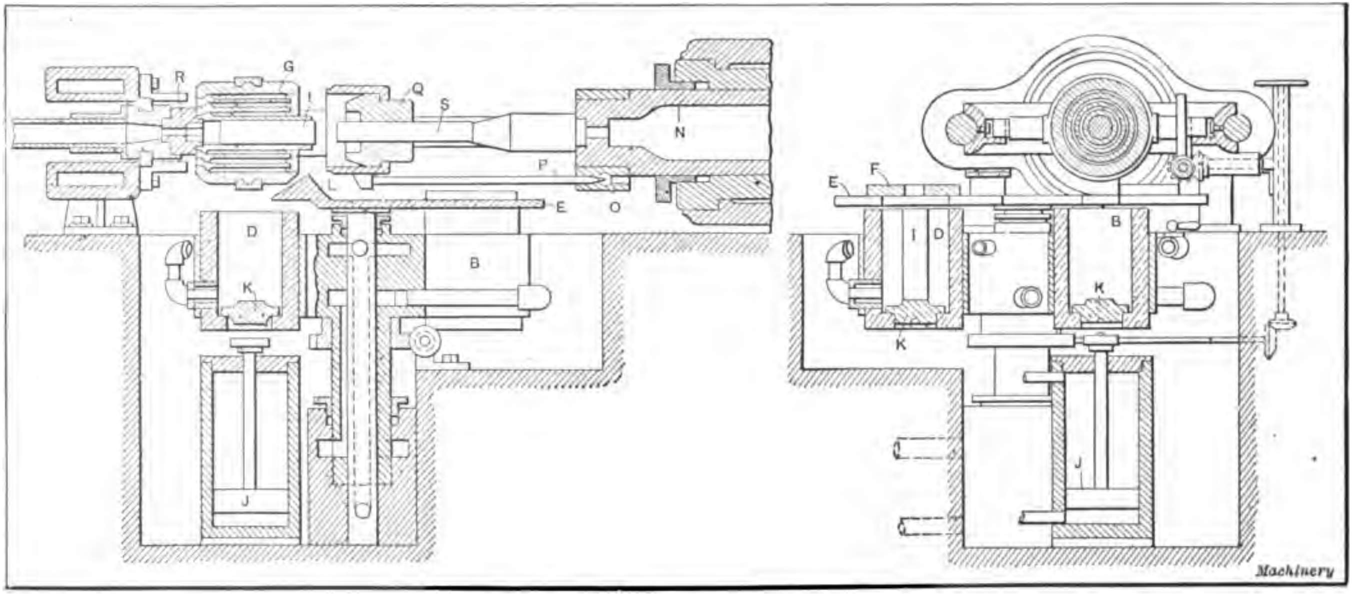


Fig. 28. Main Features of a Modern Extrusion Machine

against the die. If the extruding metal is heated too high it will be too soft, and its grain will be coarsened. The design of cylinders requires that the ram or plunger shall fit the billet container so tight that no metal from the billet can force its way between the ram and the container wall. At the same time it must be loose enough not to score the sides of the container. These requirements also put a limit upon the pressure which can be employed. This limit is not very high, owing to the fact that the die spreads in proportion to the strain put upon it. The higher the temperature to which it is heated, the more it will give way to this strain.

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

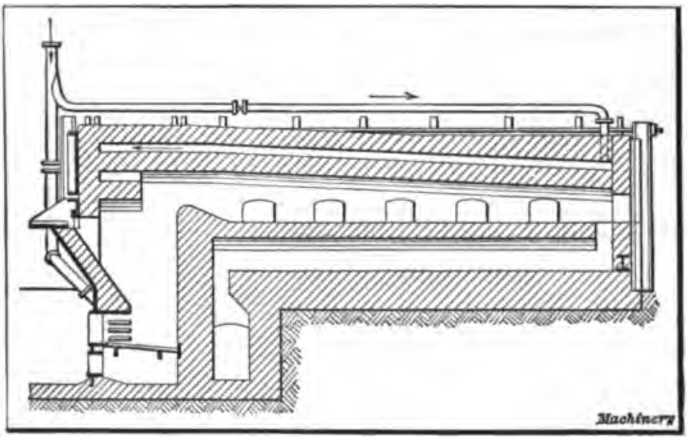


Fig. 24. Section through the Heating Furnace

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

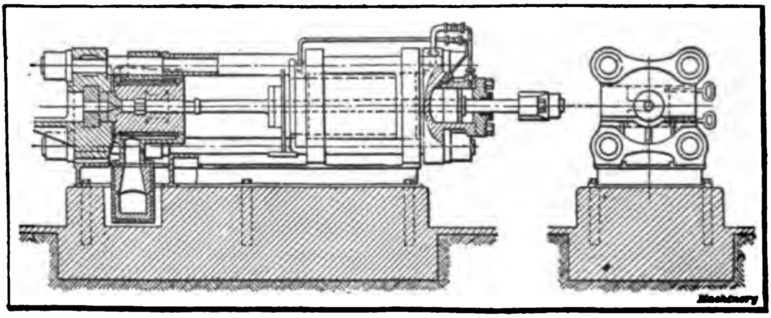


Fig. 25. General Arrangement of Krupp Extrusion Press

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	5⅛
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-

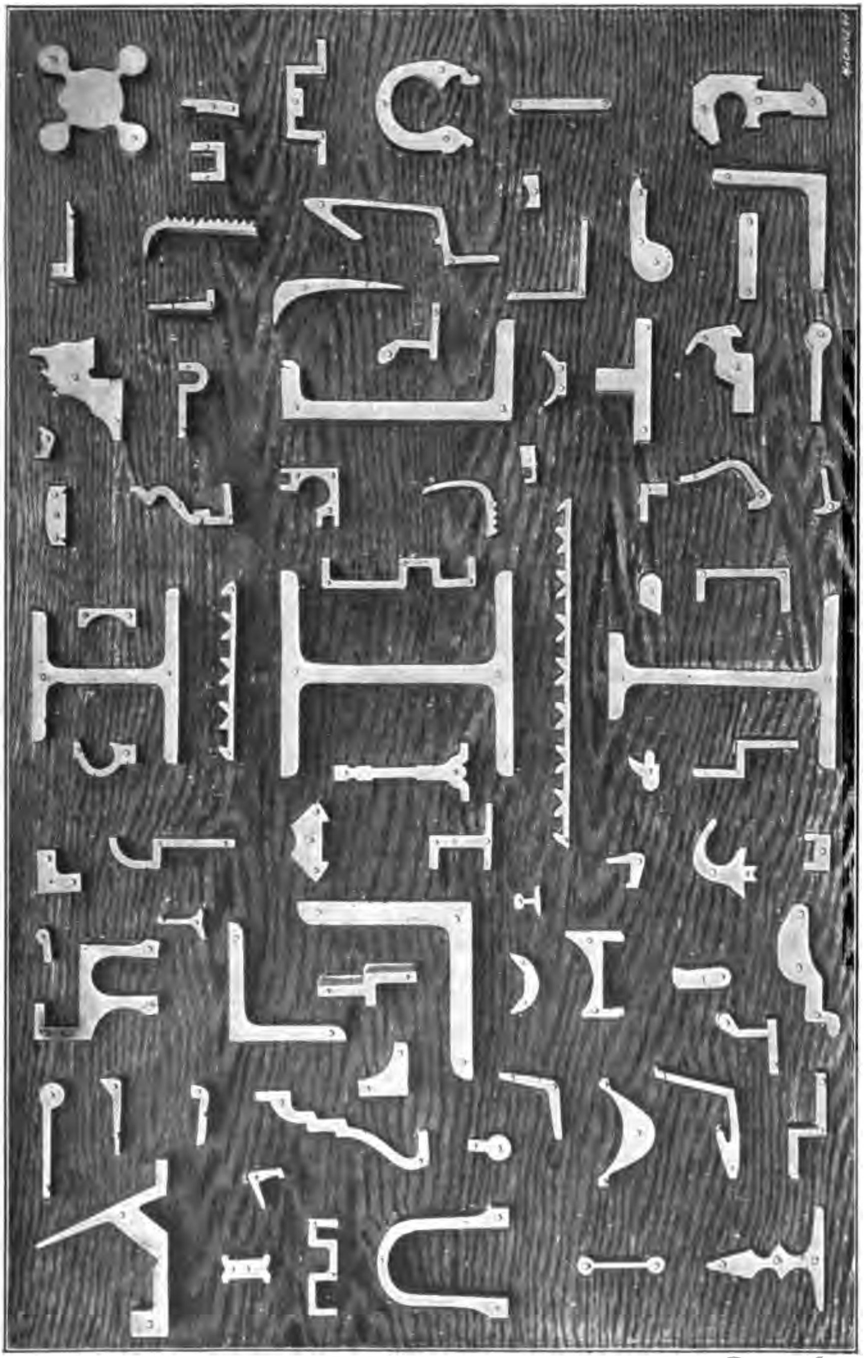


Fig. 26. Examples of Extruded Metal Shapes produced by the Coe Brass Mfg. Co.

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 Delta metal, manganese bronze and similar alloys can be used in the extrusion process. Aluminum, when used in small percentages, makes copper harder than when 8 to 10 per cent is used, and hence the aluminum bronzes with from 8 to 10 per cent of aluminum are the most easily extruded. An alloy containing 90 per cent copper and 10 per cent aluminum, or one with 85 per cent copper, 10 per cent zinc, and 5 per cent aluminum is also used, but ordinarily the copper content is kept lower than this. With these aluminum bronzes, however, a tensile strength of from 65,000 to 85,000 pounds per square inch is obtained, with an elastic limit of from 40,000 to 60,000 pounds, an elongation in 8 inches of about 18 per cent, and a reduction of area of about 20 per cent. Some tests on extruded shapes made for the Government have shown even better results than this.

Pure zinc can be greatly strengthened by an extrusion process conducted in the proper way. If the area of the die opening in relation to the area of the zinc billet to be extruded is in the ratio of 1 to 15, the temperature of the metal is kept between 85 and 180 degrees F., and the extruded metal is submitted to a pressure of not less than 90,000 pounds per square inch, the coarse crystalline structure of the ordinary zinc is transformed into a fine grain, and the zinc assumes the properties of brass. A tensile strength of 29,000 pounds per square inch can be obtained in this way and an elongation of from 26 to 70 per cent. For comparison, ordinary zinc only has a tensile strength of 5000 pounds per square inch and almost no percentage of elongation. Zinc in the extruded condition can also be readily worked with machine tools and it is quite malleable and flexible.

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

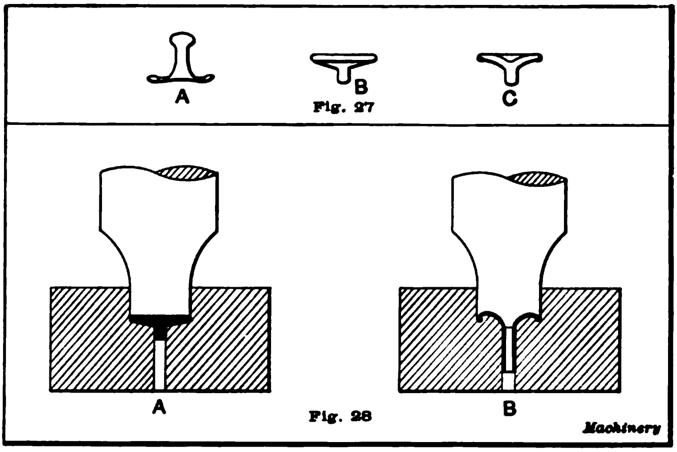


Fig. 27. A, Collar Button; B, Fastener; C, Improved Fastener. Fig. 28. A, Die for Fastener, with Work in Place; B, Die intended to produce a Fastener of Improved Design, showing Piece actually produced.

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

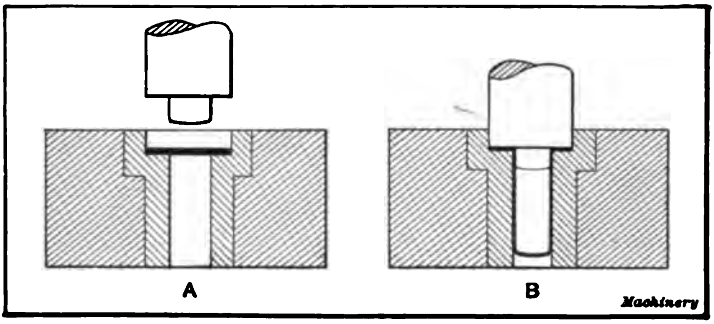


Fig. 29. Lee's Method of Making Tubular Articles, Patented in 1906. A, the Die with Blank in Position; B, the Extruded Shell

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

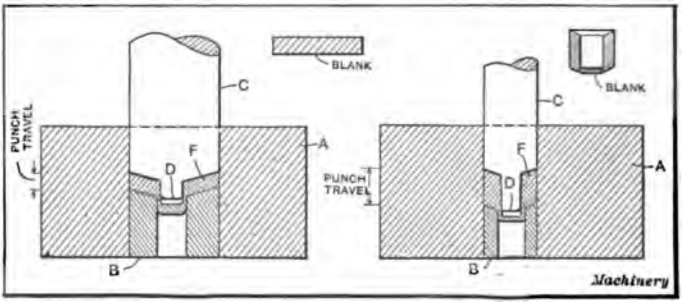


Fig. 30. Extruding from a Flat Blank **Fig. 31. Extruding from a Cup-shaped Blank**

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-

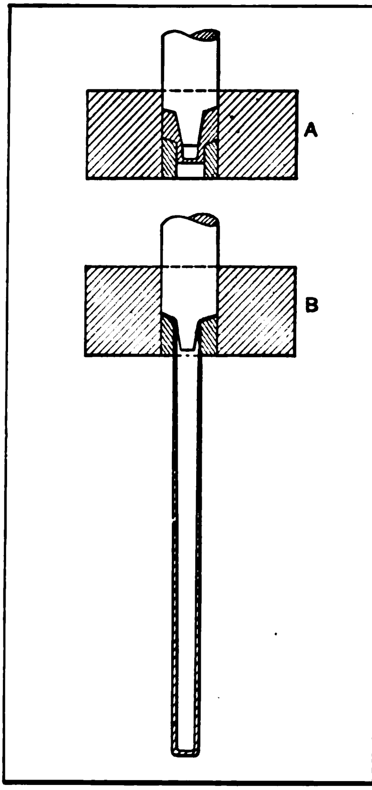


Fig. 32. Making Tubes with Taper Walls

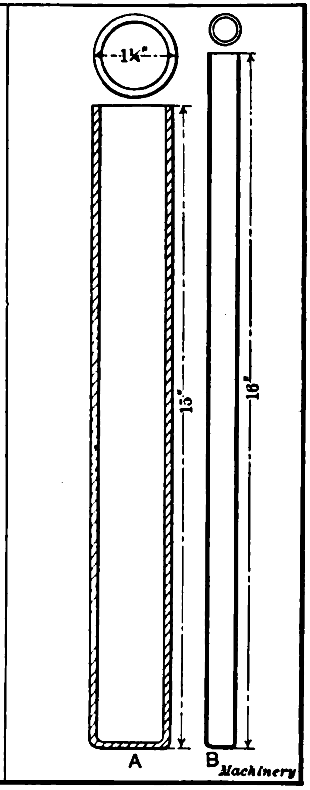


Fig. 33. Comparison of Tube-making Methods

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.

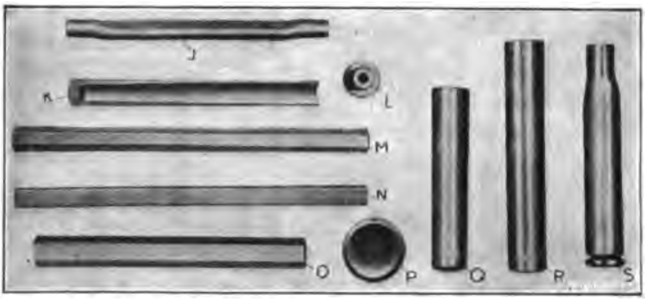


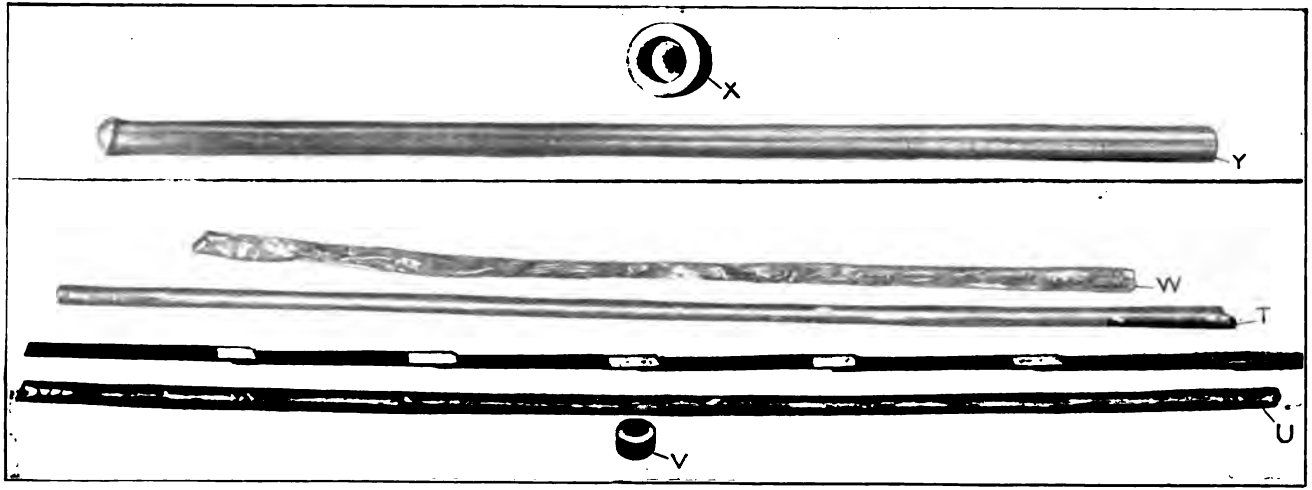
Fig. 34. Miscellaneous Examples of Extruded Work

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. 85 and 86. Lead Tubes for Torpedo Work. Examples of Difficult Extrusion

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 extruded article reduced. A particularly valuable alloy is one that contains 98 per cent aluminum and 2 per cent zinc. Not only is this a strong alloy, but it can be extruded easily. The best lubricant known in the press-working of aluminum is soapy water

Pure zinc is a soft metal, but contrary to the general rule, is a poor metal to work in this process. It can be extruded easily enough, for it flows very nicely, but its effect on the former and die is to roughen them in a very short time, and after several hours' work the dies will be unfit for use. Minute particles seem to separate from the zinc and are forced into the surfaces of the dies.

Copper is a very satisfactory metal to extrude. Some of the best examples of extrusion have been produced from 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

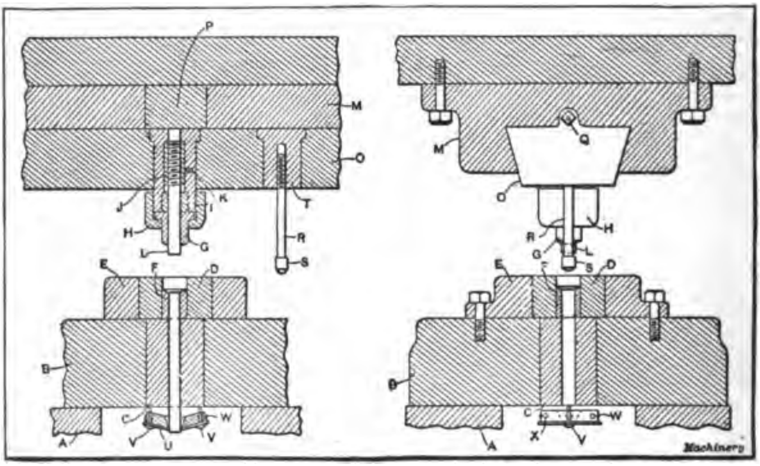


Fig. 37. A Modern Die for Extruding Tubular Shapes

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

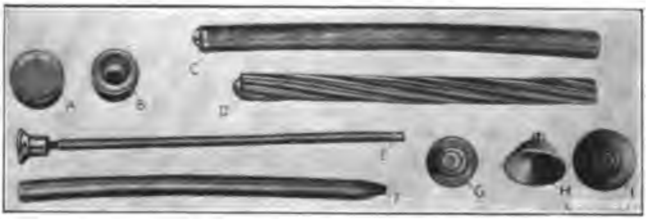


Fig. 38. A, B, C, and D, Steps in Making an Instrument Case by Extrusion; E and F, Extruded Parts for Automatic Pencils; G, Bullet Jacket; H and I, Hat-pin Guards

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

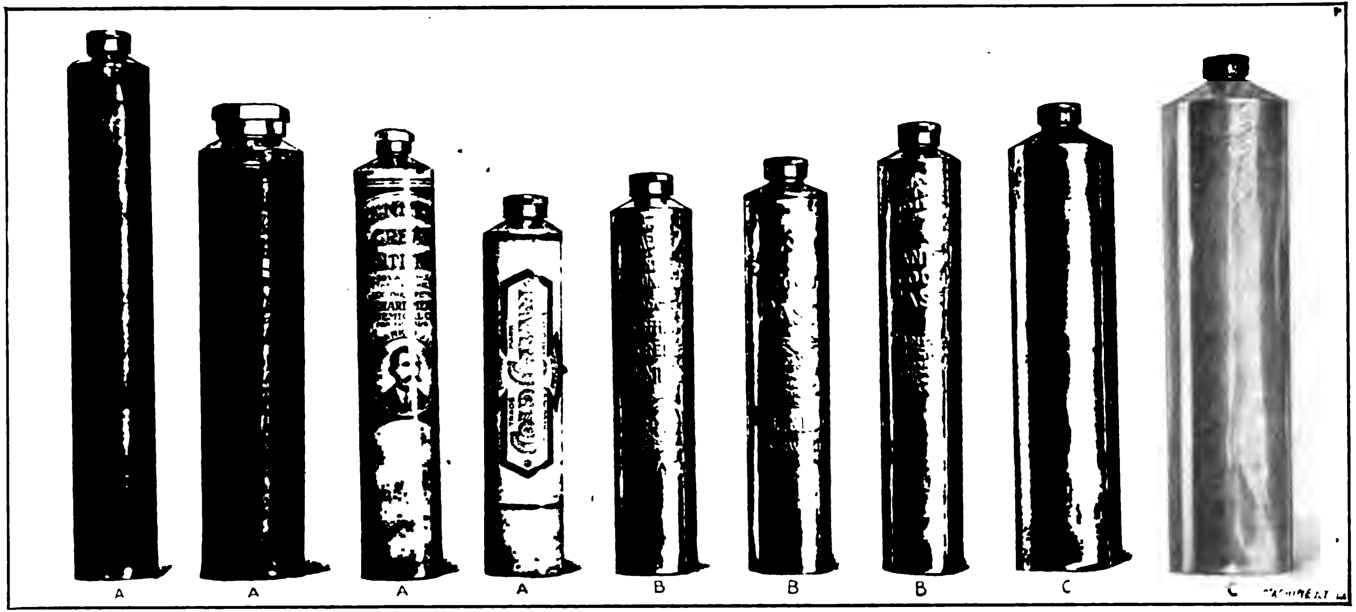


Fig. 39. Collapsible Tin Tubes made by Extrusion

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.

The general method of making collapsible tubes is illustrated in Fig. 40, which shows the operator just completing a gross of 5-inch tubes, representing about fifteen minutes' work. This illustration also gives a good idea of the size of the press.

Preparing the Stock

The particular grade of tin used by this company for collapsible tube making comes from the Straits of Malacca and is known as

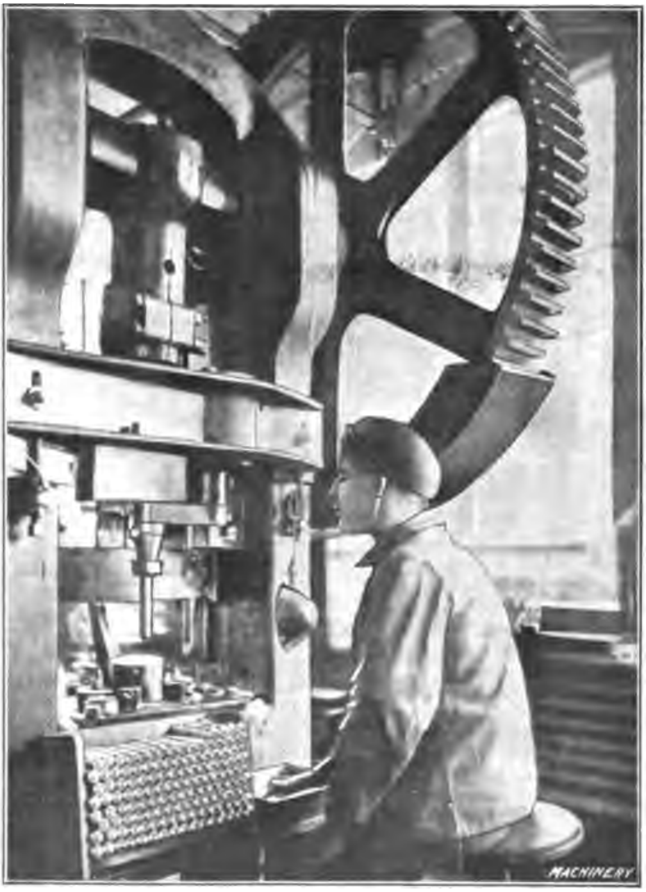


Fig. 40. Making Collapsible Tubes at the Rate of 600 per Hour

Penang tin. It reaches the factory in the form of 130-pound pigs, and is then re-melted in the furnaces shown in Fig. 41 and cast in slabs weighing nine pounds each. These slabs are about six inches wide, fifteen inches long and one-half inch thick.

The slabs are taken to a pair of rolls and reduced to a thickness ranging from 0.110 to 0.220 inch, varying with the length of tube that is to be made. For a five-inch tube, the metal is rolled to 0.190 inch. The next operation consists in blanking the disks for the tubes. These disks, three of which appear at *P*, Fig. 42, are cut to the same diameter as the diameter of the tube that is to be made, and in blanking they are slightly "crowned" to conform to the inclined shoulder of the tube. This crowning is accomplished by merely chamfering the end of the blanking punch to the proper bevel; the die is perfectly flat. The blanking press is equipped with a roll-feed, and the rolls are knurled, so as to grip the sheets firmly. In Fig. 41 may be seen some of the sheets from which blanks have been cut, and which are sent back to the melting room for re-casting into slabs.

The Extrusion Presses

The operation of extruding collapsible tubes and the presses used are without doubt the most interesting features of the work. In Fig. 45 the details of the press and dies are well illustrated. For the large tubes, one-inch diameter and over, the E. W. Bliss Co.'s No. 63 press

Fig. 41. Furnaces where the Tin Ingots are cast into Nine-pound Slabs

is used, and Figs. 45 and 46 show representative Bliss presses for making collapsible tubes and their caps. The No. 63 press is rated as a five-ton press, and its chief point of distinction, aside from its powerful construction, is its peculiar punch action, which will be described later. Referring to Fig. 45, *D* shows the die-shoe held to the bolster *E*, which latter is bolted to the bed of the press; *F* shows the end of the knock-out rod operated by lever *G*. The punch *H* is held in the arm *I*, which turns upon shaft *J*. Front plate *K* is adjustable, and its inner side is recessed for the cam that swings the punch-arm and punch away from the die. As the ram descends, this arm slowly swings so as to bring the punch in alignment with the die. It reaches the point of alignment just before the end of the stroke, so that at the time the end of the punch strikes the blank, the punch descends vertically. In Fig. 40 the arm has just started to swing outward on the upward stroke, and in Fig. 45 the arm is shown at the end of its outward swing, giving the operator ample room to withdraw the tube from the punch. Knock-out rod *F* frees the end of the tube from the die, allowing the tube to remain on the punch as it ascends.

In operating an extrusion press of this character, the operator places

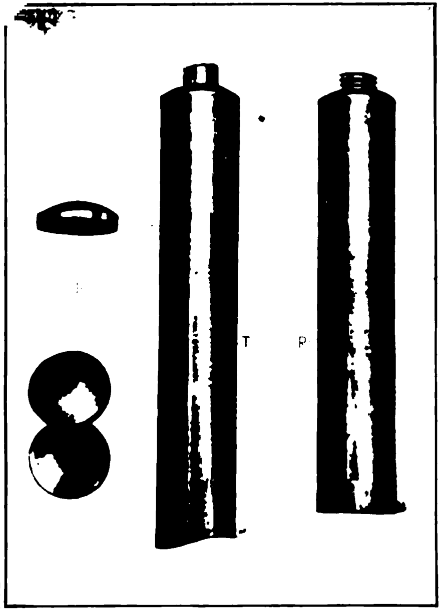


Fig. 42. The Three Operations in making a Collapsible Tube

Fig. 43. Punch and Die in Position in Press

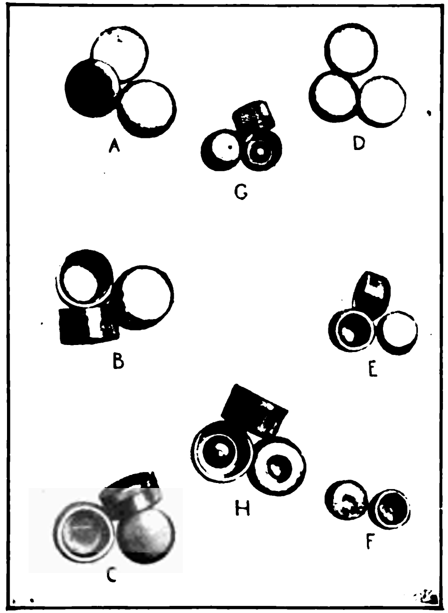


Fig. 44. Caps of Different Sizes and Styles at Various Stages of Competion

the blanks in the die with his right hand and removes the tubes from the punch with his left hand. The speed with which the metal "crawls" up the punch is surprising, but it must be remembered that the extrusion of a five-inch tube must take place while the punch is descending the last one-eighth inch. The operator is obliged to wear a glove upon his left hand on account of the heat imparted to the tube by the extrusion. A skilled operator is able to "catch" nearly every stroke of the press. When making these 1-inch by 5-inch tubes he will turn out 600 tubes per hour, and on the smaller tubes, ½-inch by 2½-inch, using a smaller press of the same type, the average production is 1500 tubes per hour.

Dies for Extruding Collapsible Tubes

Figs. 43 and 47 illustrate the parts of the dies and punches. Fig. 43 shows a close view of the tools in the press and Fig. 47 shows the tools

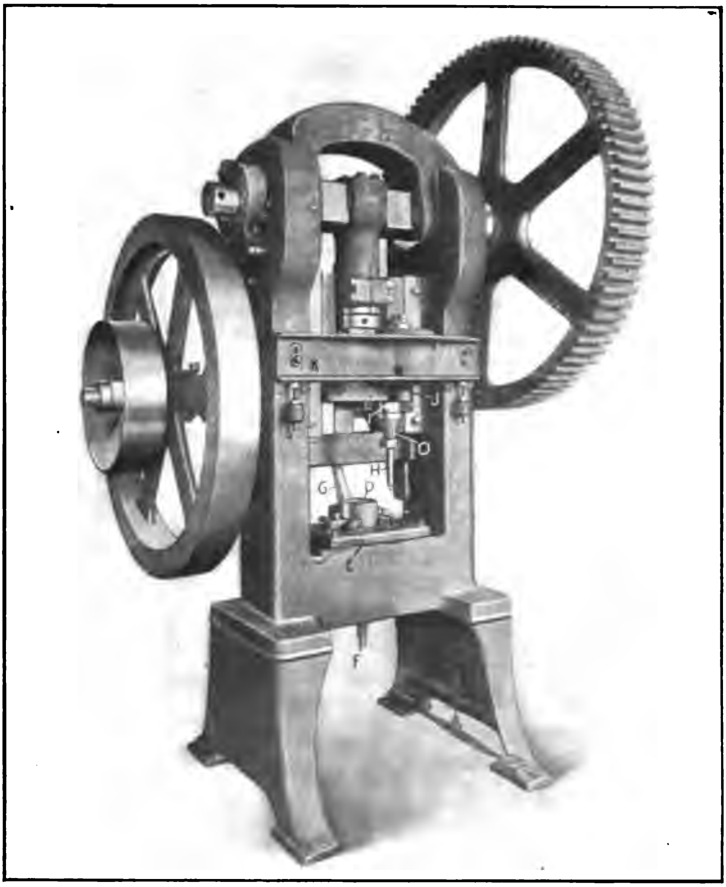


Fig. 45. Details of Arrangement of Extrusion Press

as they appear out of the press. At *D* is shown the die-shoe, held to the press by the two ears shown in Fig. 47, and adjusted laterally by the four screws *L* indicated in Fig. 43. Within this die-shoe rests the die-ring *M*, made of tool steel and carefully hardened and tempered. This ring acts as a support to strengthen the die *N* shown within the ring; this die is also separately shown at the front of Fig. 47.

The die *N* is made of the best tool steel and its cavity is made just the size and shape of the outside of the head of the tube, except that the hole that sizes the neck extends clear through this die to admit the knock-out. Thus the knock-out is employed to form the bottom of the die as well as to eject the finished tube. If the shoulders of the tubes require lettering, a hob is made with the lettering raised. By placing this hob in the die-cavity, the letters are all stamped into the

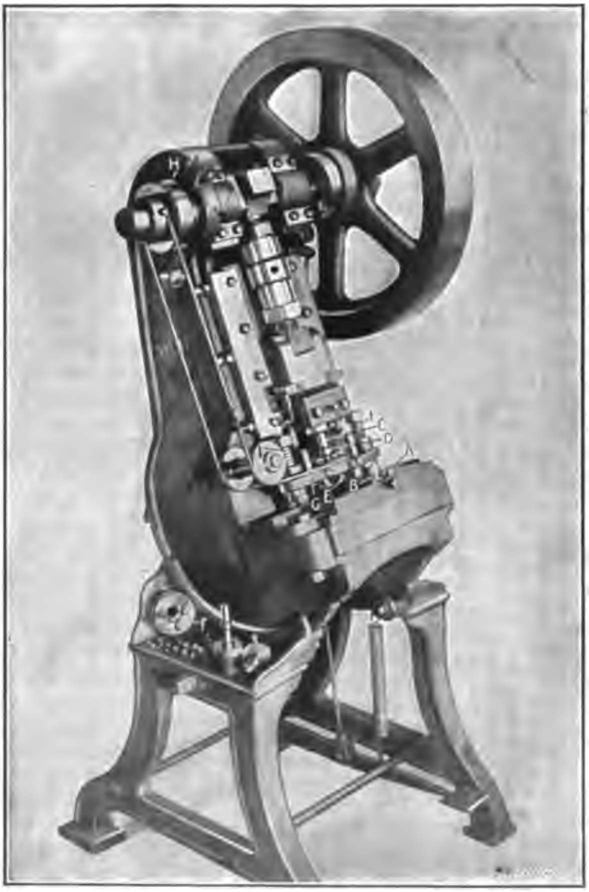


Fig. 46. Bliss Cap-forming Press with Unscrewing Attachment

die at the same time. A collapsible tube die must be very smooth and highly polished in order that the metal will flow easily and take on a bright finish. This polishing is started with fine emery and oil and the final high polish is obtained with crocus and oil. The final polishing must be done after the die has been hardened and tempered to a faint straw color.

The punch used in extruding collapsible tubes has several distinctive features that are peculiar to this line of work. Two of these punches are shown at *H* in Fig. 47. The working part of the punch is made about one inch longer than the tube that is to be produced, and two inches additional length is left for the shank. The shank of the punch is held in the punch-holder O by tightening the nut upon the tapered sleeve. The part of the punch that does the actual work is

Fig. 47. The Press Tools used in Collapsible Tube Making

the tip end, having the largest diameter. To illustrate this more clearly, Fig. 48 shows two collapsible tube punches and dies; in one case the blank is shown in position in the dies, and in the other the result of the operation is indicated. From these it will be seen that

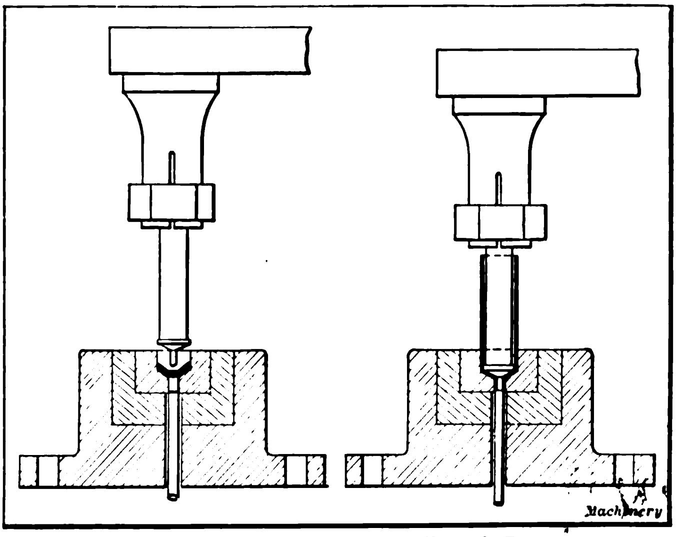


Fig. 48. Principle of Making a Collapsible Tube

the long pilot forms the hole at the shoulder and outlet. As the pressure upon the blank is increased, the recess in the die becomes filled with metal and the excess metal is squeezed up past the end of the rib on the punch. As the pressure is continued, the shoulder of the tube constantly becomes thinner; the displaced metal is forced into the walls of the tube, thus increasing its length. It is obvious that after

...squeezed past the ribbed end of the punch, its ...upper part of the punch is considerably smaller ...e inside of the tube. For a one-inch tube, the die ... inch; the ribbed end of the punch would measure ...nd the body of the punch would be approximately ...eter. The punches are made of Jessops steel, hard- ...emper drawn to a light straw color, except the ...ch is drawn very much lower. The punch-holder *O* ...the swinging arm *I* shown in Fig. 45.

Fig. 49. Cap-blanking and Cap-making Presses

Trimming the Tubes

When the tubes come from the extrusion presses they appear as shown at *T* in Fig. 42. As will be noticed, the opening in the head is not cut through, nor is the head threaded. Better results are obtained by cutting the thread at the time the tube is trimmed. The trimming and threading is done in tube trimming and threading machines of a type designed especially for the work and patented by this company. At *R* in Fig. 42 the tube is shown completed.

Cap-making

The caps for collapsible tubes are made in an entirely different manner from the tubes, although the blanking and finishing operations are very much the same as those employed in the tube making. The metal for the caps for 5-inch tubes is rolled to a thickness of 0.140 inch; the blanks are cut ½ inch in diameter, and the punchings are not crowned as were the tube blanks. In the background of Fig. 49 may be seen a cap-blanking press, while in the foreground are shown the working parts of two cap-forming presses.

Forming the Caps

The operation of forming the caps is an interesting piece of presswork, and the principles should be applicable to other lines of manufacturing. By referring to Fig. 46, the operation of the tools may be clearly followed. The die is shown at *A*, and upon its top surface there is a slide *B* that facilitates the feeding of the blanks to the working part of the die, without danger to the operator's fingers. The punch *C* has its tip end threaded with the same size thread as that on the tube that the cap is to be used with. The die-cavity is of the same diameter as the outside of the cap to be formed. Thus, when the punch strikes the blank, the tin is "crowded" around the sides of the punch, being confined on the outside by the limits of the die-cavity. This operation wedges the blank tightly into the die-cavity, but as the metal is just as tightly pressed into the threads upon the punch, the cap is readily withdrawn when the punch ascends.

The manner in which the cap is removed from the threaded punch is of interest. As the punch rises from the die, a beveled shoulder *D*, on the upper part of the punch body, comes into contact with the ends of three set-screws, located at the upper ends of the gripping fingers *E*. As these fingers are centrally hinged, the effect of this contact of the bevel-edged shoulder against the set-screws on the upper ends of the gripping fingers is to throw the tips of the fingers together, causing them to grip the cap as it rises on the punch. These gripping fingers are pivoted in a circular plate that is fitted to a bearing in stripping plate *G*. One of these circular plates, of the two-finger style, is shown at *F* at the side of the press. By means of a pulley *H* on the driving shaft, run independently from above, so as to make possible a higher speed, the gripping finger plate is kept constantly revolving. Thus, as soon as the cap is gripped by the fingers, it is rapidly unscrewed from the punch. During this operation, the punch is rising, and in order that the cap will not be pulled away from the gripping fingers, the stripping plate *G* that supports this mechanism is arranged to slide upward upon pins *I*, thus keeping pace with the ascending punch. When the cap has been unscrewed, the punch continues to rise until the set-screws slide off the shoulder at the bottom, thus releasing the fingers and allowing the cap to slide into a box at the rear of the press. Some caps have a monogram embossed upon the top; this part of the work is easily included in the forming operation by engraving the design in the bottom of the die.

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