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AUTOMATIC SCREW MACHINES AND THEIR TOOLS

# AUTOMATIC SCREW MACHINES AND THEIR TOOLS

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# PREFACE

In the preparation of this book on automatic screw machines and their tool equipment, we have endeavored to embody material which will constitute a comprehensive treatise for tool designers, toolmakers, and machine operators.

The subject-matter of the book divides naturally into two sections, one devoted to various types of machines and their construction, general tool equipments, methods of camming, etc.; the other dealing with tools in detail, and containing specific information on making and using these tools, the speeds and feeds at which they should be operated, and other particulars which it is hoped may be of service to mechanics connected with screw machine work. The chapters on camming and on different types of cutting tools were prepared originally for publication in the columns of the *American Machinist;* they are here arranged in somewhat more convenient form of reference.

It will be noted that in Section I a number of machines are included which, strictly speaking, are of the chucking machine type and "semi-automatic" in their operation, the chucking of the work being accomplished by hand. Aside from this feature, they are, broadly considered, similar in principle to the full automatic machines, although their capacity and the method of holding the material adapt them to the machining of a heavier or otherwise different class of work from that usually produced on "automatics" working entirely from bar stock or on castings and forgings fed to the chuck by means of magazines.

We recognize the fact that the name "automatic screw machine" is hardly broad enough for the designation of a machine which can produce from the bar, from castings or from forgings, almost any symmetrical piece that may fall within the capacity of the chuck and turret traverse. However, the purpose for which this type of machine was originally conceived, naturally determined its title, and, although to-day the making of screws is but a small part of the work it accomplishes, it is still generally known by its original name. A few makers, especially of the medium and larger sizes of machines, refer to them as automatic "turret lathes" and automatic "turret machines," and in the chapter headings we have followed the respective manufacturers' preferences in the matter.

The Authors.

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# SECTION I

## TYPES OF MACHINES

### METHODS OF CAMMING AND TOOL EQUIPMENTS

# CHAPTER I

## The Pratt & Whitney Automatic Screw Machine

The automatic screw machine built by the Pratt & Whitney Company, Hartford, Conn., is of the vertical turret type, with cam drums carried upon opposite ends of a longitudinal shaft for operating the turret and

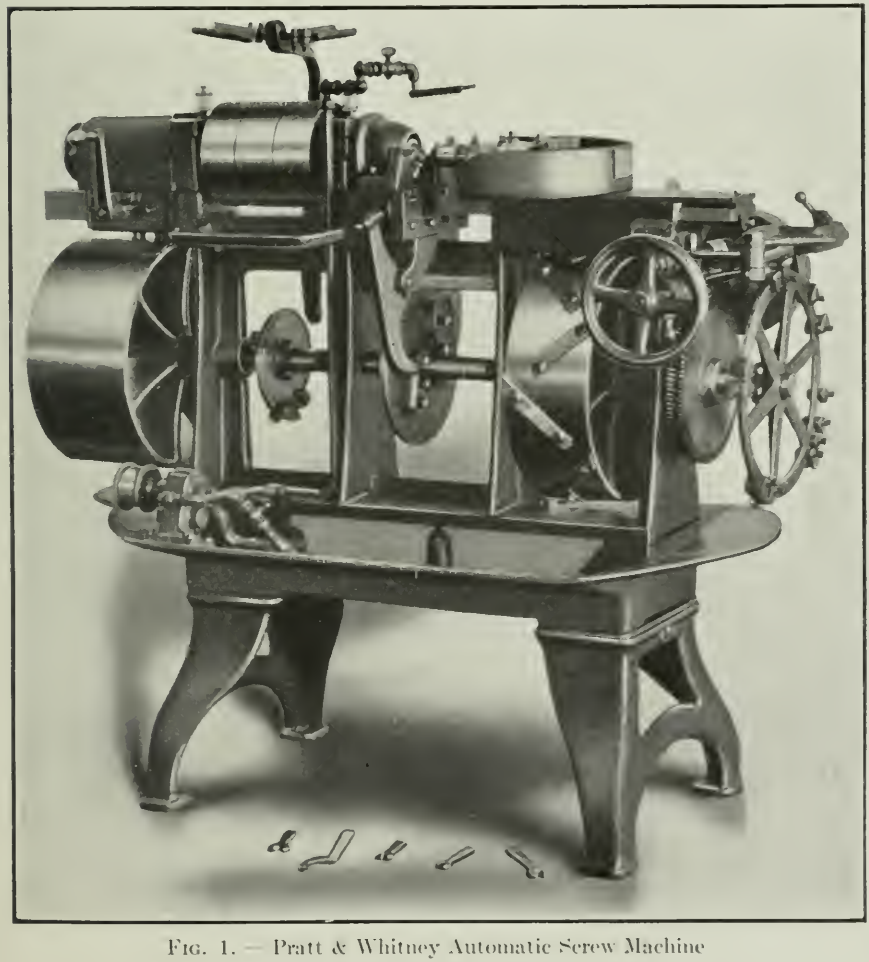


Fig. 1. — Pratt & Whitney Automatic Screw Machine

the chucking and feeding mechanism. This machine is illustrated as a whole by the half-tone engraving, Fig. 1; the line drawings Figs. 2 to 5 showing the principal features of construction.

### ARRANGEMENT OF CAM DRUMS AND DISKS

The drum seen in Fig. 1 near the right-hand end of the main shaft carries a series of plain strap cams arranged obliquely for moving the turret slide to and fro; the drum at the left end is fitted with cams of the same general character for opening and closing the chuck and feeding the stock through the spindle. The disk located at about the middle of the length of the shaft has on its right face ordinarily a pair of flat cams which operate a vertical lever at the front of the cross slide and move the slide toward the rear; the opposite face of the disk is provided with similar cams which act upon a corresponding lever at the rear of the cross slide to move the slide toward the front of the machine. The smaller disk immediately under the head carries a series of dogs adjustable about the disk periphery and adapted to control the shifter lever which moves the open and cross belts on and off the tight and loose pulleys on the spindle. Dogs of similar form are carried on the spider disk at the extreme right-hand end of the machine, for controlling the fast and slow feed-driving mechanism which rotates the cam-drum shaft through the medium of worm and worm wheel, both of which are plainly visible in the half-tone.

### THE SPINDLE AND CHUCK MECHANISM

As will be seen upon examination of Fig. 2, the spindle carries a pair of loose pulleys for the forward and reversing belts, and between them is a third pulley secured to the spindle and driving it in either direction according to which belt is operating on it at the time. The spring collet for holding the bar stock and the feed tube for moving the bar forward when the chuck is opened are plainly shown in the sectional drawing, as is also the mechanism at the rear of the spindle for operating the chuck and feed.

In this illustration, *A* is a sliding block that moves feed tube *B* to and fro, and *C* another sliding block that closes the chuck through the medium of sliding cone *D*, pivoted fingers *E*, and tube *F* which extends through the spindle *G*. Both sliding blocks *A* and *C* are operated by cams on the "chucking" drum directly beneath, and these cams, here shown in outline, will be referred to later. It may be stated here, however, that the distance the stock is fed when the chuck is opened is determined to within close limits by the distance the feed tube is drawn to the rear by its cam while the chuck is closed. Exact feeding to length is of course assured by using a stock-stop in the turret.

The "feed fingers" screwed into the front end of the feed tube *B*

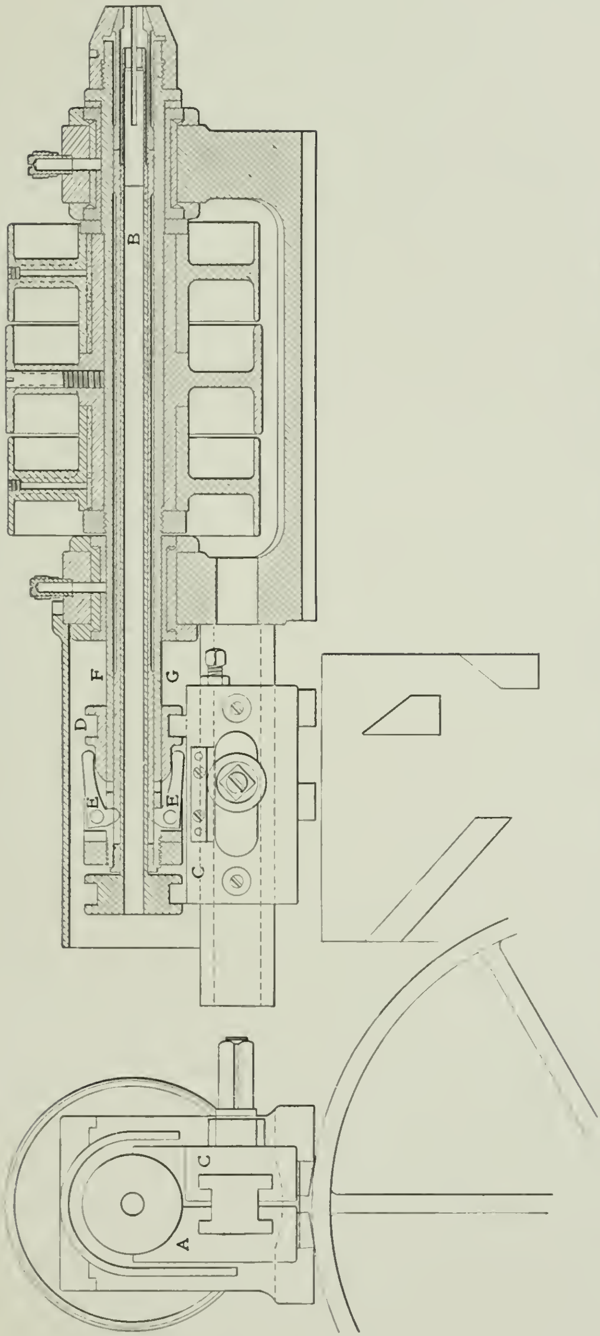



Fig. 2. — Section through Head and Spindle of Pratt & Whitney Automatic Screw Machine

maintain a constant spring grip on the bar of stock and are ready to carry the bar forward the moment the chuck is opened. The latter has sufficient expanding tendency due to the method of spring tempering to release its grip on the stock the instant the operating block *C* is slid forward by its cam to withdraw cone *D* from between fingers *E*. The chuck may be operated by hand at any time in setting up by means of a crank-actuated pinion and rack connected with block *C*. The arrangement of the cams for the chuck and stock feeding mechanism as well as for operating the turret slide are fully described in the next chapter of this book under the general heading of camming.

### THE TURRET SLIDE AND TURRET

The turret and its slide are shown in Fig. 3. The slide is reciprocated by the roll underside which contacts with the cams on the drum below. The turret is indexed step by step at each return of the slide by the four-

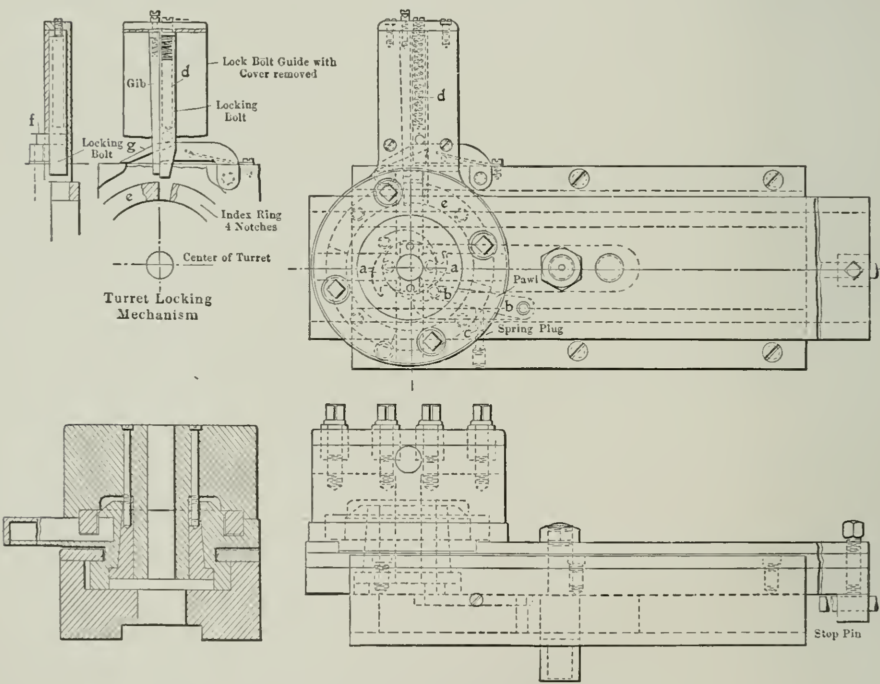



FIG. 3. — Construction of Turret Slide and Turret

toothed ratchet wheel *a*, which is secured to the bottom of the turret and as it is carried to the right comes into engagement with the end of pawl *b*, whose rear end is pivoted in the turret-slide block and whose forward end is kept constantly against the periphery of the toothed ratchet by spring plunger *c*.

Immediately prior to the ratchet coming into contact with the forward end of the pawl, the locking bolt *d* is withdrawn from the notch in the indexing ring *e* by its pin *f* coming in contact with the inclined surface at the forward end of wedge *g* pivoted at the rear of the turret-slide block. As shown in the general plan, and in the sectional view with the locking bolt guide cover removed, the bolt is withdrawn from the index ring. The turret is shown ready to start rotating and upon a slight further movement to the rear the rotary action commences and the locking bolt clearing the heel of the wedge by which it is withdrawn, is forced by its spring against the index ring and drops into the next notch when that notch is brought opposite the bolt end upon the completion of the quarter turn of the turret.

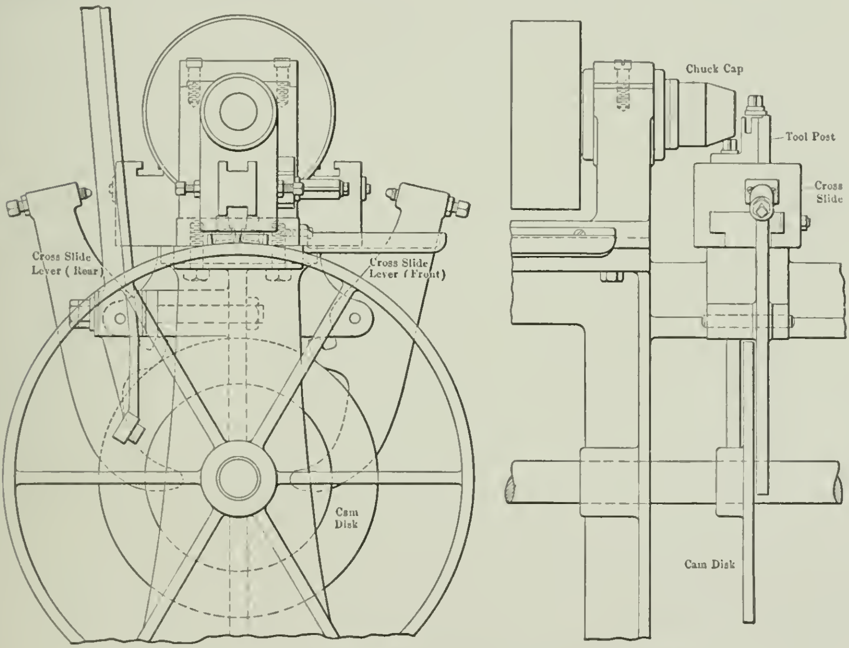



Fig. 4 — The Cross Slide and its Operating Levers

The method of gibbing the locking bolt is shown in the drawing. The bolt itself, as will be noticed, has one radial side sliding against a corresponding side of the notch in the index ring and locates the turret accurately, while the wear due to the thrust is taken on the relatively unimportant bevelled side of the bolt.

## THE CROSS SLIDE

The cross slide, shown in Fig. 4, is adapted to carry front and rear blocks for forming and cut-off tools and is operated by the two levers and the cam disk already mentioned. Both levers carry screws in their upper ends which may be adjusted to feed the cross slide to the desired point in either direction. The cam disk is shown blank in this engraving, but when fitted up for operation it carries cams on either side like those shown in place on the disk in Fig. 1.

### THE FEED DRIVE

Fig. 5 illustrates the fast and slow feed-driving motion which actuates the cam-drum shaft, providing a rapid movement of the cams and tools while the latter are not cutting, and a slow motion during actual cutting operations. The slow motion is obtained through the planetary gears *H*, *I*, *J*, *K*. Gears *H* and *I* are differential drivers mounted on a stud secured in the web of the driving pulley as indicated. Gear *K* is keyed to the worm shaft, and *J* to ratchet *L*, which is locked by pawl *M* during the slow motion, the clutch *N* when thrown into action giving the quick rate of speed to the driving worm which is then driven direct from the pulley instead of through the differential gears *H*, *I*, *J*, *K*. As previously stated, dogs carried on the disk at the right-hand end of the drum shaft control the mechanism, causing the clutch to be engaged and disengaged at the proper intervals. The clutch is normally held out of engagement by latch *O*, which engages with a collar on spring shaft *P*. When arm *Q* is actuated by one of the dogs on the controlling disk, wedge *R* causes latch *O* to lift and release the rod *P*, which is then carried by its spring to the right, throwing in the clutch. The next dog on the disk causes the spring-actuated rod to be drawn back, releasing the clutch and allowing the latch *O* to drop into its original position, and hold the clutch open.

A common ratio of fast to slow motion is 24 to 1 on several sizes of this type of machine (that is, in driving through the planetary gearing Fig. 5 the pulley makes 24 turns to 1 of the worm shaft), but several other ratios are provided for by means of gears, which may be changed in the planetary drive. These ratios, together with the series of feed-driving pulleys for the countershaft, and the drums for driving the spindle speeds, give a wide range of ratios between drum shaft and spindle speeds, and by varying the cam angles a broad range of feeds for the tools varying by very small increments are obtainable. The method of camming this type of machine is described fully in the next chapter.

Various classes of tools for this machine are illustrated in different chapters in Section II.

### COUNTERSHAFT ARRANGEMENT

The countershaft and method of belting to the machine are illustrated in Fig. 6, which shows also the scheme of setting the machine at

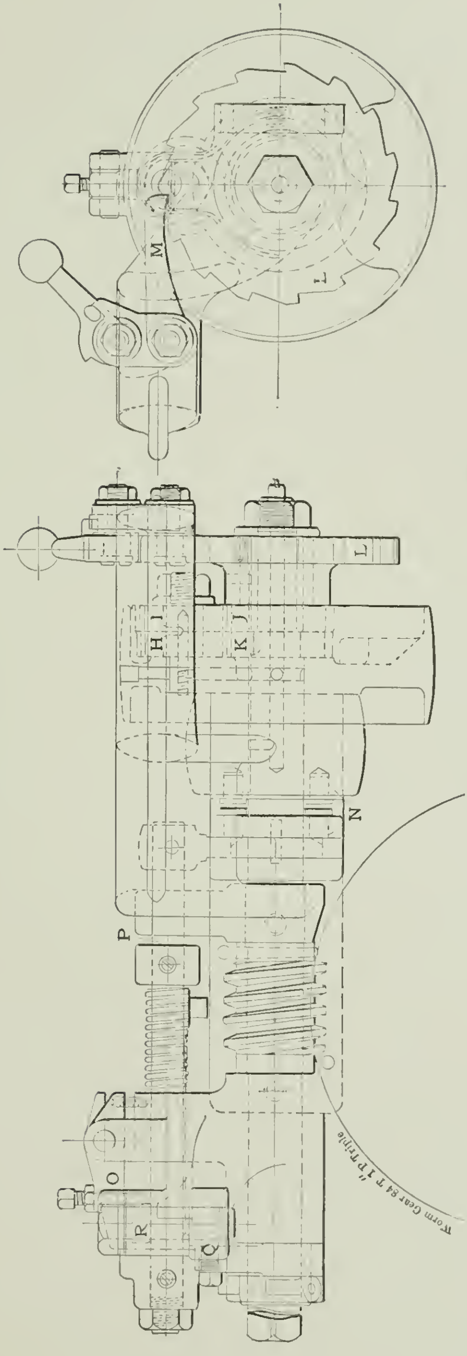



FIG. 5. — Feed Motion for Operating Cam Shaft

an angle with the center line of countershaft. This angular setting which is common to screw machine practice allows the bar of stock to pass behind the machines set immediately to the left, thus permitting all the machines in a row to be placed very closely together. As shown, the end of the machine is swung out of line until the pulley for driving the worm mechanism for operating the cam drum shaft is in proper location

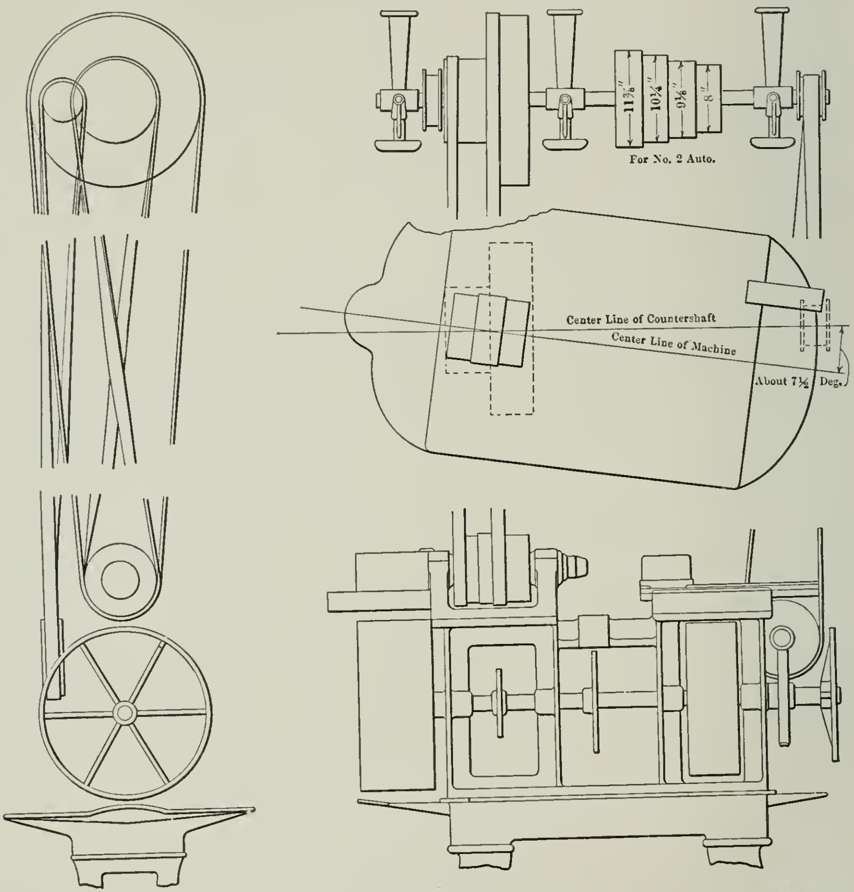



FIG. 6. — Countershaft and Drive for Pratt & Whitney Automatic Screw Machine

relative to the feed pulley on the countershaft, the drive from that pulley to the feed pulley on the machine being by means of a quarter turn belt. The countershaft is represented with two sizes of pulleys for driving the head spindle, and with a pulley to the left for operating the geared oil pump. The speed rates derived for the spindle by the driving method illustrated are discussed in the chapter following on camming.

### CHUCK SIZES AND LENGTH OF FEED

The No. 0 machine of this type takes bar stock up to $\frac{5}{16}$ inch, and turns lengths up to $1\frac{9}{16}$ inch. The No. 1 machine takes stock up to $\frac{1}{2}$ inch and turns up to $2\frac{1}{4}$ inches in length. The No. 2 machine handles stock up to $\frac{3}{4}$-inch diameter and turns lengths up to $2\frac{3}{4}$ inches. The "oversize" machines "1A" and "2A" have increased chuck capacities taking respectively $\frac{3}{4}$ and 1 inch stock.

## CHAPTER II

### Camming the Pratt & Whitney Automatic Screw Machine

A diagram of the Pratt & Whitney automatic screw machine with a set of cams in place is given in Fig. 7, *S* being the chucking drum; *T* the turret-slide drum; *U* the disk for the cross-slide cams; *V* the disk which carries the dogs for controlling the feed motion; *W* the disk whose dogs operate the lever for shifting the spindle-driving belts. Fig. 8 shows the development of the two cam drums with cams arranged for operating on a piece like Fig. 9. It will be seen that the turret cams fill the periphery of the drum, which is a desirable feature in the majority of cases as waste of time is then avoided.

#### CAMMING THE CHUCKING DRUM

As it is essential before camming the turret-slide drum to know what space will be required in unlocking and locking the chuck and feeding out the stock, the chucking drum *S*, Fig. 7, is first cammed without the necessity of a layout on paper, as is required in the case of the turret drum. It is assumed that the piece of work has just been severed from the bar, the chuck being locked firmly. The chuck is now unlocked as a starting point, and the unlocking cam *a* put on, the angle of this cam being about 25 degrees with the edge of the drum. The cam length must be sufficient to move chuck roll *b* far enough to release the spring chuck completely from the work. As soon as the chuck opens, the stock is ready to be fed forward, this movement being accomplished by cam *c*, which should be so put on as to contact with feed roll *d* immediately upon the unlocking of the chuck. An angle of 50 degrees is the usual slope for the stock feed cam; the length is obviously made to give a throw equal to or slightly in excess of the longest piece that the machine will produce. The chuck-locking cam *e* is next to be considered, and this is so located as to contact with chuck roll *b*, and start closing the chuck the instant the feed cam *c* has carried the feed roll *d* to the extreme forward position. Where the work is of a light nature and the chuck easily gripped on the stock, the angle of the chuck-closing cam *e* may be made the same as that of the unlocking cam *a*, namely 25 degrees; for work of a heavier character 20 degrees is a more suitable angle. In locating the feed cam *c* the feed plunger should be pushed forward into the spindle until the grooved

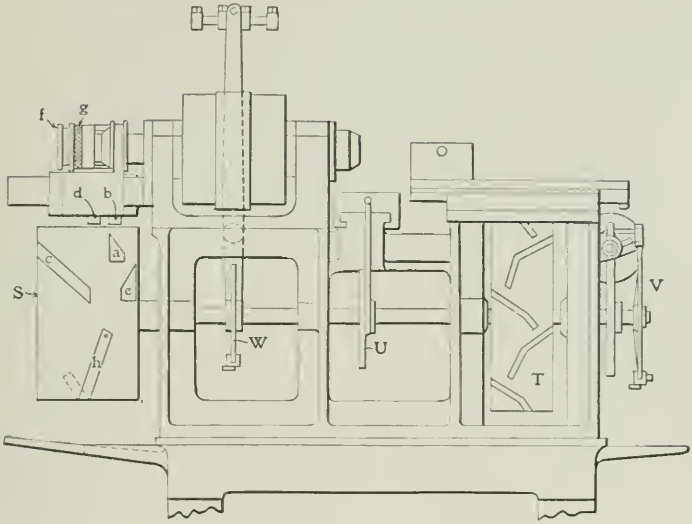



FIG. 7

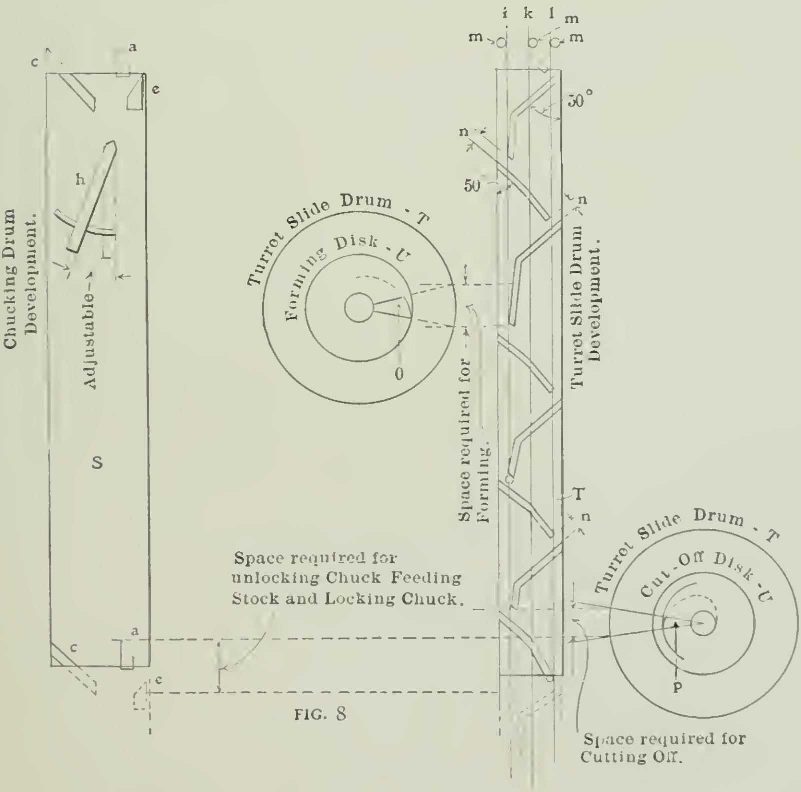



FIG. 8

Cam Arrangement

collar *f* is against the nurled collar *g* at the rear of the chucking finger ring, which limits the forward movement of the feed tube and its roll *d;* it is apparent that this determines the position of the high point of the feed cam, though the left-hand end of that cam may be extended to the edge of the drum or beyond, if desirable, as in the case of extra long feeds.

The feed "draw back" cam *h* is the last one to go on the drum; its function is to draw the feed tube to the rear, bringing the roll *d* into position to be pushed forward again by the feed cam *c* as soon as the chuck again opens. The "draw back" cam is pivoted as indicated, and may be adjusted to give any desired length of feed within the capacity of the machine. In locating this cam its pivoted end must be so positioned as not to strike the chuck-operating roll *b*.

As already stated, the camming of the chucking drum may be done satisfactorily without a layout on the drawing board, though where several machines are being cammed such a drawing may prove of considerable service.

### THE TURRET-SLIDE DRUM

In camming the turret-slide drum a full-size drawing should always be made, the drum periphery being first laid out on paper as a rectangle, whose length and breadth represent respectively the circumference and width of the drum. A development of a turret-slide drum surface is seen in Fig. 8, with three locating lines, *i*, *k*, *l* for the series of cams. The position of these lines may be obtained as follows: A set of tools being placed properly in the turret, the latter is pushed forward as far as required to bring the tools in the right position relatively to the work, after which a scriber is placed at the right side of the roll *m*, which operates the slide, and a line *i* is scribed on the drum to represent the extreme forward position of the turret, hence no cams advancing the turret toward the chuck can project beyond this line. Next the turret slide is moved back to the point where the turret commences to index, and a line *k* is scribed on the drum $\frac{1}{4}$ inch from the left side of the roll *m*, after which the slide is drawn clear back to the right as far as possible, this movement completing the indexing and locking of the turret, and a third line, *l*, is then scribed at the left side of roll *m*. The reason for scribing line *k* (which locates the leading ends of the index cams) one-quarter inch to the left of the point where indexing really commences, is that we then insure the easy index cams coming into contact with the turret-slide roll slightly before the slide actually reaches the indexing point.

We can now draw the three lines scribed on the drum on the full-size layout on the drawing board, as shown in the development, Fig. 8, and thus have the correct distance between the lines *i l* and *k l*. In this case we will call the former distance $2\frac{1}{4}$ inches, and the latter $1\frac{5}{8}$ inches, and may now proceed wth the figuring of the cams for producing the piece, Fig. 9.

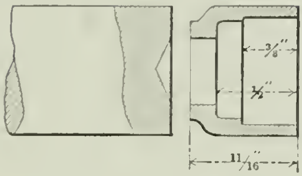



Fig. 9. — The Work

### FEED CALCULATIONS

We will assume a speed of 250 revolutions per minute as suitable for the work, and use a starting or centering-and-facing tool in the first turret hole, a $\frac{7}{16}$ inch twist drill in the second hole, a roughing counterbore in the third hole, and a finishing counterbore in the fourth or last hole. In addition to the length of cutting feed required for each tool we will add $\frac{1}{8}$ inch in each case for safety, and to allow for slight modifications in the character of the piece, thus making it possible for the slow feed to start into action as each tool reaches a point $\frac{1}{8}$ inch away from the actual starting point of its cut. A schedule of the tool feeds may now be laid out as in Table 1.

| | | | | |
|---|---|---|---|---|
| First hole. | Starting tool, | 0.004" feed | $\frac{1}{8}$" deep + $\frac{1}{8}$" allowance | = $\frac{1}{4}$" |
| Second hole. | $\frac{7}{16}$ twist drill, | 0.005" feed | $\frac{13}{16}$" deep + $\frac{1}{8}$" allowance | = $\frac{15}{16}$" |
| Third hole. | Rough counterbore, | 0.010" feed | $\frac{1}{2}$" deep + $\frac{1}{8}$" allowance | = $\frac{5}{8}$" |
| Fourth hole. | Finish counterbore, | 0.015" feed | $\frac{15}{32}$" deep + $\frac{1}{8}$" allowance | = $\frac{19}{32}$" |
| | Finish counterbore, | 0.005" feed | $\frac{1}{32}$" for bottom of cut | = $\frac{1}{32}$" |
| | Combined length of feed of all tools | | | = $2\frac{7}{16}$" |

Table 1. — Tool Feeds for Work Shown in Fig. 9

For carrying the turret forward to the point of cutting and for bringing it back to the point where indexing commences, cam angles of 50 degrees with the edge of the drum are generally used. Sometimes this angle is exceeded by a few degrees, 55 degrees being about the practical maximum limit, while it is very seldom necessary to drop below 50 degrees. The travel of the turret slide while indexing (from $k$ to $l$, Fig. 8) should not generally be much greater than 20 feet per minute, this depending, however, upon the size of machine and tools used. This rate of travel with the work revolving, as stated above, at 250 turns per minute, would be equivalent to 240 inches for 250 turns of the spindle or 0.96 inch per revolution. While the indexing is done with the fast speed of the camdrum shaft, it is desirable in the cases of all turret-slide movements for which cams have to be figured to state the feed per turn of spindle at its equivalent at slow cam-shaft speed. With a feed motion having a ratio of 24 to 1 this means that the indexing movement of 0.96 inch per turn when expressed at the slow cam-shaft rate would be 0.96 divided by 24 = 0.04 inch per revolution.

### HOW THE DRUM SURFACE IS UTILIZED

Before figuring the angles for the cutting and indexing cams we can simplify matters by taking from the total circumference of the drum, which measures, say, 48 inches, the amount of space as measured around the drum periphery utilized by the 50-degree cams, the eight roll spaces, and eight $\frac{1}{4}$-inch flats formed by dressing off the forward ends of the four cutting cams and the rear ends of the four indexing cams to obviate wear of the cam corners. The distance *i* to *l*, Fig. 8, which as already stated is $2\frac{1}{4}$ inches, is temporarily taken, for purposes of calculation, as representing the forward and backward travel of the turret slide. Actually, of course, the travel would be equal to the distance between the centers of roll *m* in the extreme forward and backward positions. However, it is more convenient and in no way affects the result to assume distance *i* to *l* as defining the true length of travel.

That is, we can assume for the moment that the roll is of infinitely small diameter, its travel then being simply from line *i* to *l*. Now if we increase the roll diameter to $1\frac{1}{8}$ inches we merely extend the outer ends of the 50-degree cams sufficiently to overlap the actual roll travel, and at the same time we increase the working space between the cams to allow the roll to pass through. As these roll spaces between the cams are later taken into consideration in our calculations for determining the actual distance around the periphery of the drum consumed by the 50-degree cams, we can disregard altogether the portions of these cams extending outside of lines *i* and *l*. Now, as there are four forward and backward movements to complete the cycle of operations, the total turret travel to and fro may be represented by a quantity equal to 8 × distance *i* to *l*, or 8 × $2\frac{1}{4}$ inches = 18 inches. According to the table giving the feeds of the four tools to be used, $2\frac{7}{16}$ inches of turret travel is required in the cutting operations; the distance from *k* to *l* being $1\frac{5}{8}$ inches the total indexing travel is obviously $4 \times 1\frac{5}{8} = 6\frac{1}{2}$ inches. From the 18 inches which we have taken as representing the total travel of the turret slide, therefore, must be deducted $2\frac{7}{16} + 6\frac{1}{2}$ inches, leaving $9\frac{1}{16}$ inches travel controlled by the 50-degree cams, which, as previously stated, are generally used for non-cutting and non-indexing movements. The peripheral drum space occupied by these cams is then equal to $9\frac{1}{16}$ × cotangent of 50 degrees, or 9.0625 inches × 0.84 = 7.61 inches.

If the cam roll *m* is $1\frac{1}{8}$ inches in diameter, and we allow $\frac{1}{8}$-inch clearance, we have as the peripheral distance occupied by these cam spaces 8 × $1\frac{1}{4}$ inch × cosecant of 50 degrees or 10 inches × 1.3 = 13 inches. The eight $\frac{1}{4}$-inch flats on the ends of the cams = 2 inches peripheral drum space utilized in this fashion. The total circumference of the drum, 48 inches, − 7.61 inches − 13 inches − 2 inches leaves 25.39 inches peripheral space on the drum available for the cams whose angles have to be computed.

### COMPUTING THE CUTTING AND INDEXING CAM ANGLES

We have now this space of 25.39 inches measured lengthwise of the cam drum surface to utilize for the cutting and indexing cams. The next thing to determine is the number of revolutions of spindle required for the several operations on the piece of work. This is calculated as below from the data in Table 2.

| | | | |
|---|---|---|---|
| 1st tool. | Travel of turret, 0.250″ | at 0.004 feed per revolution | = 62.5 rev. |
| 2d tool. | Travel of turret, 0.9375″ | at 0.005 feed per revolution | = 187.5 rev. |
| 3d tool. | Travel of turret, 0.625″ | at 0.010 feed per revolution | = 62.5 rev. |
| 4th tool. | 1st part of travel of turret, 0.5937″ | at 0.015 feed per revolution | = 39.5 rev. |
| | 2d part of travel of turret, 0.0312″ | at 0.005 feed per revolution | = 6.2 rev. |
| | Indexing. Travel of turret, 6.5″ | at 0.04 feed per revolution | = 162.5 rev. |
| | Total number of revolutions necessary | | = 520.7 |

TABLE 2. — Spindle Revolutions Required in Making Piece Shown in Fig. 9

Thus we find that for the 25.39 inches of drum periphery available for the cams to be figured, the spindle should make 521 turns, or 20.5 turns for each inch of cam-drum space. This spindle velocity per inch of drum space will be approximated very closely by using on the countershaft a 10-inch driving drum for the spindle and a 6-inch pulley for driving the feed motion. The question of spindle and feed-pulley ratios is discussed more fully later on.

Knowing the feed per revolution for each tool, we find the angle for the cam for that tool by multiplying the rate of feed by 20.5 which gives the tangent of the desired angle.

The angles for the various cams are then as follows:

| | | |
|---|---|---|
| First tool. | 0.004″ feed × 20.5 = 0.082 | = tangent of 4° 42′ |
| Second tool. | 0.005″ feed × 20.5 = 0.1025 | = tangent of 5° 51′ |
| Third tool. | 0.010″ feed × 20.5 = 0.205 | = tangent of 11° 36′ |
| Fourth tool. | 0.015″ feed × 20.5 = 0.3075 | = tangent of 17° 5′ |
| Fourth tool. | 0.005″ feed × 20.5 = 0.1025 | = tangent of 5° 51′ |
| Indexing. | 0.04″ feed × 20.5 = 0.82 | = tangent of 39° 21′ |

TABLE 3. — Cutting and Indexing Cam Angles

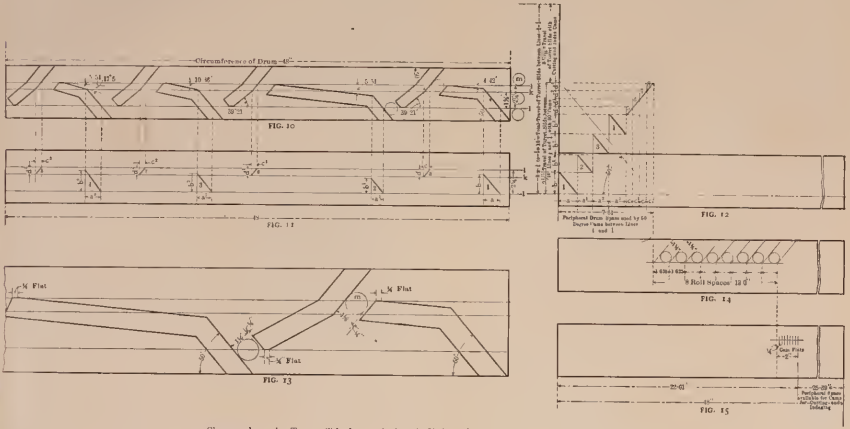
The angles having been determined, the cams may now be laid out on the full-size drawing, a space *n*, Fig. 8, equal to the roll diameter plus $\frac{1}{8}$-inch clearance being left between the adjacent cams, and the flats of $\frac{1}{4}$-inch which prevent wearing of the cam corners being left on the working ends of each cam. A layout of these cams to a larger scale (about $\frac{1}{8}$ actual size) is presented in Fig. 10, and in this drawing the angles of the cams are all shown. While these angles are given in degrees and minutes, the nearest half degree is sufficiently close in practice. It may be of interest at this point, before considering the forming and cut-off cams, to show diagrammatically how the cam-drum surface is divided among the various cams which have been just laid out. For this purpose Figs. 11 to 15 inclusive have been drawn, although of course such diagrams would not be actually used in the working out of the camming problem.

The portions of the 50-degree cams used in the foregoing calculations are here shown transferred below to the similar drum surface in Fig. 11, where a series of triangles 1, 2, 3, 4, 5, etc., are drawn which when arranged in the order shown in Fig. 12 indicate the forward and backward movement of the turret due to that portion of the 50-degree cams which entered into the previous calculation, giving $9\frac{1}{16}$ inches. The 18-inch vertical line on which this $9\frac{1}{16}$ inch travel is laid off represents the total travel of the turret back and forth between the lines *i* and *l* or $8 \times 2\frac{1}{4}$ inches. Hence the $8\frac{15}{16}$ inch portion of that line represents that amount of turret travel due to the cutting and index cams. Fig. 13 is drawn to double the scale of the other diagrams to show more clearly the flats and roll spaces. Figs. 14 and 15 show the eight roll spaces and the cam flats added to the peripheral distance utilized by the 50-degree cams, and the latter sketch indicates the amount of drum space actually left for the cutting cams and the index cams, which has previously been found to be 25.39 inches.

### FINDING THE CAM ANGLES GRAPHICALLY

If preferred, the angles of the various cams may be obtained without reference to tables of trigonometrical functions. Although this method of finding the angles is very convenient, many will prefer the method given below which does not involve the use of trigonometry. A hint of this is given in Fig. 12. Say we draw a perpendicular line *A*, Fig. 16, on the drawing board $9\frac{1}{16}$ inches long, representing the to-an-fro travel between lines *i* and *l* by 50-degree cams, then draw a horizontal base line *B*, to which we draw a line *C*, from the top of the vertical line forming an angle of 50 degrees with the horizontal base line. The portion of the latter thus cut off will indicate the space measured around the drum which the 50-degree cams between lines *i* and *l* occupy, or 7.61 inches which can be measured with a scale accurately enough for all practical purposes.

Next we wish to determine the peripheral distance occupied by each cam-roll space and can find this by a similar process of laying out the roll between the ends of two cams as at *D*, in Fig. 17. If the layout is made double or four times the actual size, the result obtained by scaling will be more accurate and in fact quite near enough to the figured distance. Multiplying the distance *D* by 8 will give us the space required by the




Showing how the Turret-Slide Drum Surface is Utilized by the Various Cams, Roll Spaces, etc.


FIG. 17

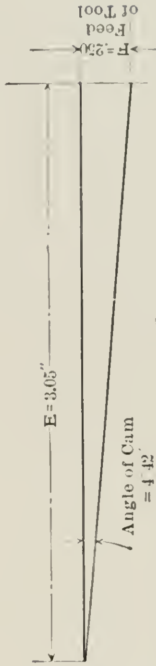



FIG. 18

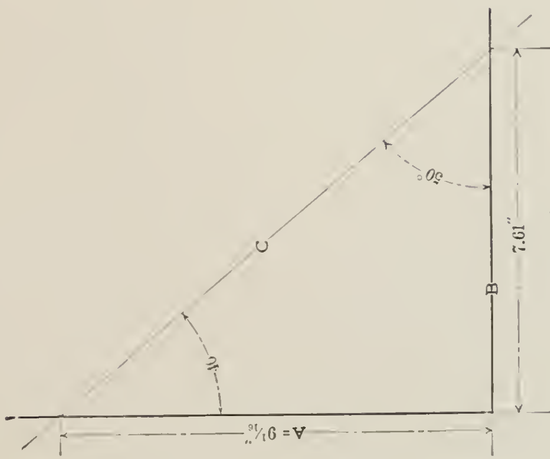



FIG. 16

Finding Cam Angles, and Roll Spaces

eight cam-roll spaces, and adding this to 7.61 inches plus 2 inches for the eight $\frac{1}{4}$-inch flats on the cam ends gives us the total amount to subtract from 48 inches (the circumference of the drum) to obtain the amount left for the cutting and indexing cams (or 25.39 inches). We have already found that the spindle makes 521 turns during the travel of the drum through a distance of 25.39 inches, or 20.5 turns per inch of drum travel. By referring back to our figures in Table 2, we see that the first tool will require 62.5 revolutions in feeding its distance of 0.250 inch toward the chuck at 0.004 inch per revolution. In other words, this tool will require a drum travel of (62.5 divided by 20.5) or 3.05 inches. Laying off a line of this length as $E$, in Fig. 18, and drawing a perpendicular of 0.250 inch to represent the feed distance, we have then merely to measure the angle with the protractor which will give us at once the correct angle for this cam. The angles of all the other cams may be obtained by a similar process, the side $F$ of the triangle laid out representing the total feed or turret-slide travel required for the cam in question, and the length $E$ representing the distance in inches which the drum travels while the spindle is making the number of revolutions necessary for that particular operation, as shown by Table 2. As suggested, it will be well to make the layout double size or larger, thus minimizing the possibility of error in scaling the lines and measuring the angle.

### THE FORMING AND CUTTING-OFF CAMS

Returning now to the forming and cutting-off cams, Fig. 8 shows these members laid out on the opposite sides of their disk. The forming tool cuts down the neck and fillet at the rear of the piece Fig. 9 and should be fed at about 0.002 inch per revolution, the operation being performed at the same time as the drilling. We have found that the spindle makes 20.5 revolutions to every inch of turret-slide drum travel, and this means that in a forming movement of $\frac{1}{8}$ inch or 0.125 inch at 0.002 inch per turn, we require $62\frac{1}{2}$ revolutions, which is equivalent practically to 3 inches of drum travel. Laying off this amount on the drum $T$, we can run the radial lines indicated to the center of the cam disk to define the limits of the forming cam $o$. In drawing the working edge of the cam we strike a curve giving a throw somewhat greater than $\frac{1}{8}$ inch, according to the location of the pin on which the cross-slide operating arms are pivoted. Thus, if the upper end of the rocker arm is $\frac{3}{4}$ the length of the lower, it means practically that for every 0.001 advance of the cam slide the lower end of the arm must move outward about 0.0013 inch. The forming movement of 0.125 inch requires then a cam throw of 0.1625.

In cutting off the completed work a feed of about 0.0025 inch per revolution will be suitable. If the thickness of the metal plus a reasonable amount for clearance, etc., is equal to $\frac{1}{8}$ inch, the work will make

50 revolutions during the operation; at 20.5 revolutions of the spindle per inch of turret-slide drum travel the travel of the drum during the operation of the cut-off cams will be approximately 2½ inches. This operation may commence at or slightly before the completion of the finish counterboring as shown in Fig. 8, where the cut-off cam *p* is drawn in on its side of the disk in the same manner as the forming cam just described. With the cam slide levers pivoted at the point mentioned in connection with the forming cam the cut-off movement of ⅛ inch will require a cam throw of about 0.166 inch.

It will be obvious that the turret-slide drum must have sufficient space between the points where the cut-off operation is completed and the first operation on the next piece is commenced to allow for the opening of the chuck, the feeding of the stock, and the locking up of the chuck on the work.

This distance is indicated clearly in Fig. 8.

In putting the cams on the turret-slide drum the correct starting position for the first cam can be easily located by squaring across from the locking-up cam on the chucking drum, which cam must close the chuck tight before the first tool is brought quite into working position. Where a stop is used in the first hole in the turret the stop cam on the drum is so located relatively to the chucking cams as to bring the stop to its extreme forward position just before the stock is fed completely out and the chuck closed.

## SPINDLE DRUM AND FEED PULLEY CONSIDERATIONS

In the preceding matter it has been shown that after subtracting from the circumference of the turret-slide drum the peripheral space occupied by the 50-degree, or non-cutting and non-indexing cams, the eight cam-roll spaces and the eight ¼-inch flats on the cam ends, we have left a certain distance available for the cutting and indexing cams whose angles have to be figured or obtained by layout and measurement. We have found, too, that during the rotation of the drum through a certain distance equal to the space occupied by these cams, the spindle should make a certain number of revolutions (as per Table 2) determined by adding up the number of turns necessary for taking the different turret-tool cuts at the desired rates of speed, plus the turns during the indexing movements. In order, therefore, that the spindle and cam drum shall be driven at the proper relative speeds, with any given ratio of gearing in the feed motion, the question of the relative diameters of the spindle-driving drum on the countershaft and the feed-motion driving pulley on the same counter has to be taken into consideration. For it is obvious that, both spindle and feed motion being belted from the one counter-shaft, if we are using say a certain diameter of counter drum for driving the spindle, any change in the size of pulley for driving the feed motion will affect the rate of turret-slide feed per revolution of spindle.

### SPINDLE AND FEED-DRIVE RATIOS

In Fig. 19 is shown by diagram the arrangement of pulleys on countershaft, spindle, and feed motion, *A* being the drum for driving the spindle in either direction through reversing belts running on spindle pulley *B*, which is located between two loose pulleys; *C* is the countershaft pulley (known as the "feed pulley") for driving the cam-drum shaft *D* through pulley *E*, which operates the worm shaft and worm gear *F* at slow speed through the planetary gearing indicated at *G*, or directly at high speed by a clutch connecting the pulley directly to the worm shaft. On the No. 1 machine, for example, the spindle pulley *B* has a diameter of $6\frac{5}{8}$ inches, and the feed-motion pulley *E* is 6 inches. The worm gear has 84 teeth meshing with a triple-thread worm, and 28 turns of the worm shaft are required to drive the cam shaft and cam drums through one complete

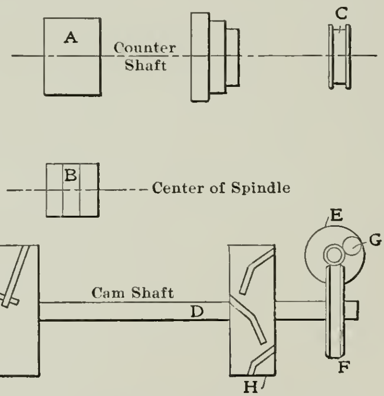



Fig. 19. — Diagram of Spindle and Cam-Shaft Drive

revolution. With a 24 to 1 ratio of gearing in the feed drive at *G*, it is obvious that the pulley *E* must turn 24 × 28 times, or 672 turns to each revolution of the drum shaft — assuming, of course, that the slow motion (24 to 1) is in operation throughout the complete cycle. The circumference of the turret-slide drum *H* carried by the latter being 48 inches, for each inch of peripheral travel of the drum, the pulley *E* on the feed drive must turn (672 ÷ 48) = 14 revolutions. If we have (as found in connection with Table 2) a peripheral distance of 25.39 inches to travel during 521 turns of the spindle in order to give the required feeds with the cams, as figured out, the spindle must make 20.5 revolutions for each inch of drum travel. That is, while pulley *E*, Fig. 19, is making 14 revolutions, pulley *B* must make 20.5 revolutions. If the two pulleys were of the same diameter, the diameter of the countershaft drum *A* and feed pulley *C* would of course be in the ratio of 20.5 to 14 or 1.46 to 1. The spindle pulley, however, is $6\frac{5}{8}$ inches diameter and the worm-shaft pulley *E* 6 inches; therefore the countershaft pulleys will be in the ratio of $(20.5 \times 6\frac{5}{8})$ to $(14 \times 6) = 136$ to 84, or a ratio of 1.62 to 1. This ratio will be approximated very closely by a spindle-driving drum of a diameter of 10 inches and a feed pulley of 6 inches.

The foregoing matter has been presented in order to show the relation existing between the speed of the spindle and the speed of the cam-drum drive. In practice, the diameter of the feed pulley required to be used in conjunction with any given diameter of driving drum for the spindle may be more directly obtained by the aid of a simple table — like Table 4, 5, 6, or 7 on pages 29 to 32. After we have found our cam angles as already described, we may take the angle of any one of the cutting cams and use this in connection with our table for finding the required size of feed pulley.

## USE OF THE TABLES

Referring now to Table 5, this table is arranged with columns for each feed-motion ratio from 24 to 1 down to 2.7 to 1. The quantities in these columns are obtained by dividing the tangent of the angles from 1 to 45 degrees in the second column by the feed-pulley constants 12.7, 5.91, etc., given at the heads of the respective columns. The feed-pulley constant, it should be noted, is equivalent to the number of revolutions of the head spindle to each inch of peripheral travel of the turret drum, with the same diameter of pulleys on the counter for driving the spindle and the feed mechanism. As indicated by the formula at the bottom of the table, the feed per revolution

$$= \frac{\text{tan. of angle}}{\text{feed-pulley constant}} \times \frac{\text{feed pulley}}{\text{counter drum}}$$

and as the six columns under the respective ratios are already worked out giving the equivalent of

$$\frac{\text{tan. of angle}}{\text{feed-pulley constant}}$$

the feed per revolution for any cam angle with any given ratio of gearing in the feed motion is found by multiplying the quantity opposite the angle and in the required column by the feed-pulley diameter and then dividing by the diameter of the counter drum driving the head spindle.

Now, with a given diameter of counter drum for the spindle, and with the angle determined for any cam and the rate of feed given which we wish to produce with that cam, we can find the diameter of feed pulley required to produce that rate of feed by a formula as follows:

$$\text{Dia. feed pulley} = \text{feed per rev.} \times \text{dia. counter drum} \div \left(\frac{\text{tan. of angle}}{\text{feed-pulley constant}}\right).$$

As we have the expression

$$\frac{\text{tan. of angle}}{\text{feed-pulley constant}}$$

already worked out in the table for the various angles, it is merely necessary to multiply the feed per revolution by the diameter of the drum for driving the spindle, and divide by the quantity opposite the cam angle under the proper column. Thus, if one of the cams in the set which we have already figured out is to give a rate of feed of 0.005 inch per turn of spindle (using the 24 to 1 ratio) the cam angle being practically 6 degrees, and if we are using a 10-inch drum on the countershaft for driving the spindle, we can find the size of the feed pulley required by multiplying 0.005 × 10 = 0.05 and dividing by 0.00827 (found opposite 6 degrees and in the 24 to 1 ratio column) = 6. Hence a 6-inch pulley is the proper size to use. It will be obvious that owing to the method used in determining the angles of the set of cams for the turret-slide drum, it makes no difference whatsoever which cam is used as a basis for working out the feed-pulley diameter.

Similar tables which are included for the other sizes of machines should be found of considerable value.

### FEED CHANGES

The figures in the different ratio columns in Table 5 actually show the rates of feed per revolution of spindle which would be obtained if the feed pulley and spindle-driving drum on the countershaft were of the same diameter, and by following across the table on any horizontal line the possible variations obtainable by the six different ratios of gears for use in the feed mechanism will be clearly seen. The actual feed changes produced by different angles of cams and various sizes of feed pulleys and counter drum with a given ratio of gearing are shown by Tables 8 to 11. Table 9, for example, is worked out for the No. 1 automatic and for a 24 to 1 ratio of feed gearing, and it will be apparent from this table that very fine changes of feed are obtained with any given feed pulley and counter drum by slight modification in cam angles; the entire range, of course, being greatly increased when we introduce the gears of other ratios into the feed drive.

It should be borne in mind that after the machine has been cammed in accordance with the method described, the rate of feed per turn of spindle derived from the cam may be increased or decreased by changing the gears in the feed motion without affecting the rate of turret-slide travel during the indexing movement. This is due to the fact that the indexing is accomplished with the feed-motion pulley clutched direct to the cam shaft for driving the cam drum, that is, the "fast motion" is then in operation and this drives at a constant speed unless the feed pulley on the countershaft is changed, or the speed of the counter itself altered by shifting the position of the belt on the three-step driving cone. While the indexing cams are laid out for performing their work with the turret slide traveling at about 20 feet per minute, some departure may be allowed either way from this normal rate, such, for instance, as might be due to a slight change in diameter of feed pulleys.

## THE TWO-SPEED SPINDLE DRIVE

It is quite common practice now, with the Pratt & Whitney automatic, to equip it with a two-step pulley for operating the head spindle in place of the single-diameter drum formerly used for this type of machine. This gives the spindle two rates of speed (ordinarily 2 to 1) and the higher speed is generally employed for the backing belt. Thus, a suitable countershaft speed may be selected for the rough turning cut and for threading, using the forward belt (except in very unusual cases where a left-hand thread is to be cut), and the fast backward speed is then utilized for finish turning and cutting off, a left-hand finishing box tool being used and the cut-off being carried on the rear end of the cross slide. If a forming tool is required, this is carried at the front of the cross slide and operated while the roughing box tool is cutting, with the spindle operating at its slow speed. The spindle then reverses upon the completion of the rough-turning and the forming operation, and runs backward at double the forward speed while the finishing tool is in operation. If the piece is to be threaded, the slower forward speed is utilized while cutting; and after the die has run on, the spindle again reverses to high speed while the die is run off and the cut-off tool severs the work from the bar. This two-speed arrangement is a very advantageous one as it makes it possible to drive the spindle at speeds best adapted for the cuts taken by the different classes of tools used on the work, and thus greatly increases the output.

In plotting out cam angles for use in connection with the two-spindle drive it is advisable to reduce all feeds per revolution to what they actually would be in case only one of the two speeds was used, and thus simplify the problem.

For example, if we have a constant feed of 0.005 inch per revolution at 100 revolutions per minute, and another constant feed of 0.005 inch at 200 revolutions per minute, it is advisable to consider both at the same number of revolutions per minute. To reduce the former to the latter $= 0.005$ inch $\times \frac{100}{200}$ or 0.0025-inch feed at 200 revolutions per minute, while the latter would, of course, remain 0.005. The tangents of the angles for the cams to be used would, of course, be 2 to 1, while the actual feeds per revolution at the speeds used are equal.

Fig. 20 shows a cam layout for a machine using the two-speed spindle drive, the turret-cam drum surface development being shown in two sections for convenience. The forming and cutting-off cams are sketched in at the side of the drum layout with the circles drawn to clearly indicate where the forming and cut-off operations commence and end. The cams shown are suitable for general screw work, the first cam *A* being a plain 50-degree stop cam which holds the turret in its forward position, while the stock feeds out. Cam *B* for the roughing-box tool, and the forming cam on the cross-slide disk, are in operation while the spindle runs at its slow speed, and cam *C* for the finishing cut feeds the finishing-box tool over the work with the spindle operating at its fast speed. The slow spindle speed is used while the die is run on by cam *D*, and the fast speed is again employed during the cutting-off operation. It will be noticed that extra space is left between the end of the die cam *D* and the last draw-back cam. This extra clearance is provided in order that the die may have ample time to run up on the screw and reverse before the draw-back cam comes into action against the turret-slide roll. Where an opening die is used, mounted in a sliding holder, the die cam may be made shorter as indicated by the dotted lines.

The forming tool is used advantageously on regular screw work for necking down at each side of the head while the roughing-box tool is in operation. This reduces the work of the cutting-off tool and on many jobs relieves the box tool of the work of finishing the under side of the head.

## PUTTING ON THE CAMS

A few words regarding the forming and placing of the cams in position on the drums and cut-off disk may not be out of place here. After the angles, lengths, etc., have been found the cams may be cut from the flat stock to the right length and proper angles at the ends by means of a saw in the milling machine, swiveling the vise to give the required angles for the ends, and then the holes for the tap bolts are drilled, after which the cams are bent to conform to the curvature of the drum. Tough steel that will admit of being hardened should be used, and after the pieces are hardened they are located one by one on the drum, and the latter drilled and the holes tapped for the tap bolts which secure the cams in place. The turret-slide cams are located in the right positions relative to the chucking drum cams by squaring across from the chuck-closing cam on that drum, this giving the right location for the first cam on the turret-slide drum. It must be kept in mind that the chuck-closing cam must close the chuck completely before the cutting

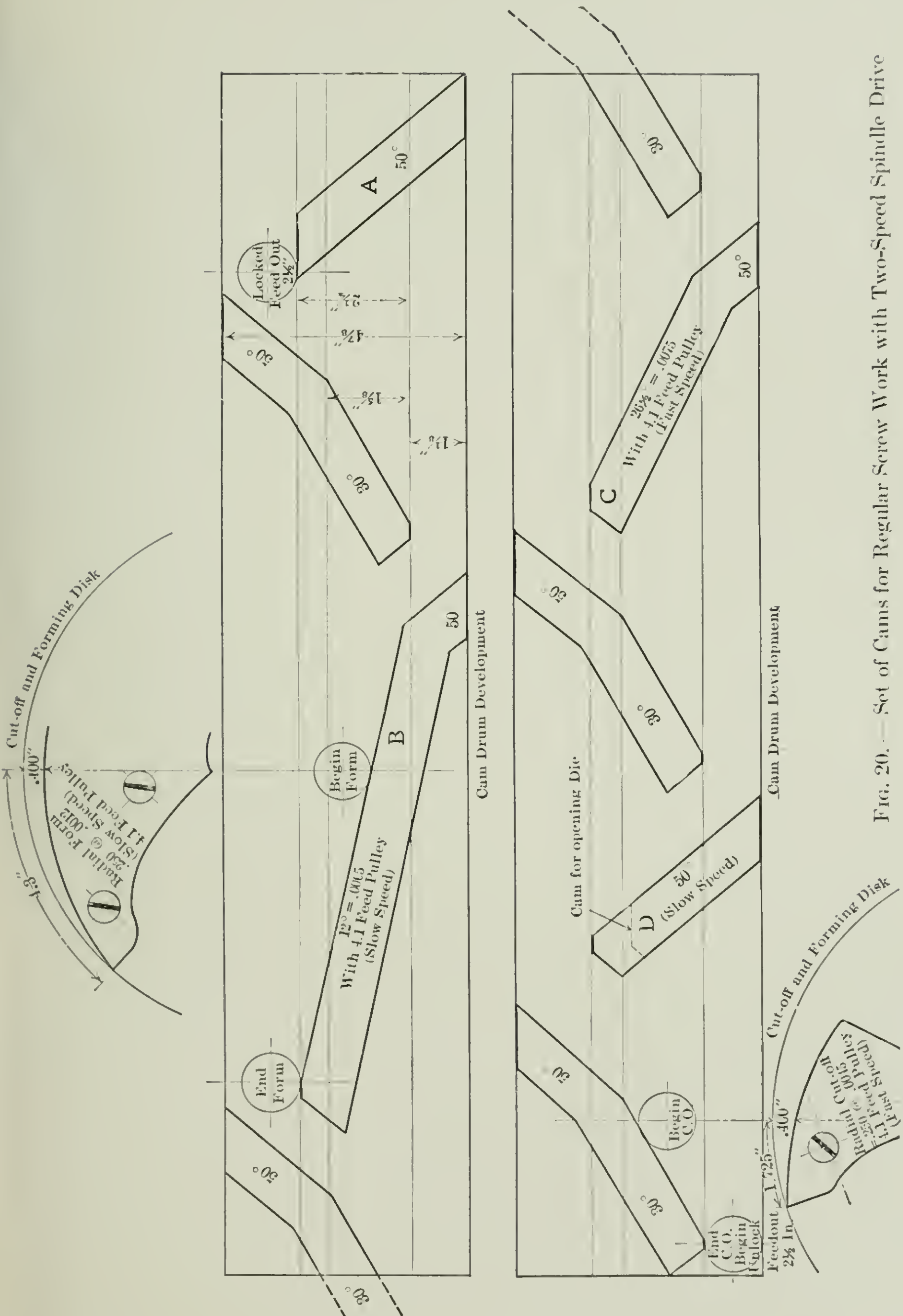



Fig. 20. — Set of Cams for Regular Screw Work with Two-Speed Spindle Drive

part of the first cam on the turret drum comes into contact with the cam roll.

The forming and cutting-off cams are located on their disk so that the ends of these cams are just passing the ends of the cross-slide levers when the points on the turret cams marked in the layout "end of forming" and "end of cut-off" are just in contact with the turret-slide roll. The idea will be clear from the drawing in Fig. 20.

| P. & W. No. 0 Automatic | | Tangent of Angle / Feed Pulley Constant | | | | | |
|---|---|---|---|---|---|---|---|
| | | Ratios | | | | | |
| | | 24:1 | 11.16:1 | 5.81:1 | 4:1 | 3.14:1 | |
| Degrees | Tangent | Feed Pulley Const. 37.3 | Feed Pulley Const. 17.35 | Feed Pulley Const. 9.03 | Feed Pulley Const. 6.22 | Feed Pulley Const. 4.88 | |
| 1 | .01746 | .00046 | .0010 | .0019 | .0027 | .0035 | ....... |
| 1½ | .02619 | .00070 | .0015 | .0029 | .0042 | .0053 | ....... |
| 2 | .03492 | .00093 | .0020 | .0039 | .0056 | .0072 | ....... |
| 2½ | .04366 | .00117 | .0025 | .0048 | .0069 | .0088 | ....... |
| 3 | .05241 | .00140 | .0030 | .0058 | .0084 | .0107 | ....... |
| 4 | .06993 | .00187 | .0040 | .0078 | .0113 | .0143 | ....... |
| 5 | .08749 | .00234 | .0050 | .0096 | .0140 | .0178 | ....... |
| 6 | .10510 | .00282 | .0060 | .0116 | .0169 | .0215 | ....... |
| 7 | .12278 | .00329 | .0071 | .0136 | .0198 | .0252 | ....... |
| 8 | .14054 | .00376 | .0081 | .0155 | .0225 | .0287 | ....... |
| 9 | .15838 | .00424 | .0091 | .0175 | .0254 | .0324 | ....... |
| 10 | .17633 | .00472 | .0101 | .0195 | .0283 | .0361 | ....... |
| 11 | .19438 | .00521 | .0112 | .0215 | .0312 | .0398 | ....... |
| 12 | .21256 | .00569 | .0122 | .0235 | .0341 | .0435 | ....... |
| 13 | .23087 | .00618 | .0133 | .0256 | .0372 | .0473 | ....... |
| 14 | .24933 | .00668 | .0143 | .0276 | .0401 | .0510 | ....... |
| 15 | .26795 | .00718 | .0154 | .0297 | .0431 | .0549 | ....... |
| 16 | .28675 | .00768 | .0165 | .0318 | .0462 | .0588 | ....... |
| 17 | .30573 | .00819 | .0176 | .0339 | .0493 | .0627 | ....... |
| 18 | .32492 | .00871 | .0187 | .0361 | .0523 | .0666 | ....... |
| 19 | .34433 | .00922 | .0198 | .0382 | .0554 | .0705 | ....... |
| 20 | .36397 | .00975 | .0209 | .0404 | .0586 | .0746 | ....... |
| 21 | .38386 | .01029 | .0221 | .0426 | .0618 | .0787 | ....... |
| 22 | .40403 | .01083 | .0233 | .0448 | .0650 | .0828 | ....... |
| 23 | .42447 | .01137 | .0244 | .0471 | .0687 | .0869 | ....... |
| 24 | .44523 | .01193 | .0255 | .0494 | .0716 | .0912 | ....... |
| 25 | .46631 | .01250 | .0268 | .0517 | .0750 | .0955 | ....... |
| 26 | .48773 | .01307 | .0281 | .0542 | .0786 | .1000 | ....... |
| 27 | .50953 | .01634 | .0293 | .0565 | .0819 | .1043 | ....... |
| 28 | .53171 | .01425 | .0306 | .0590 | .0856 | .1091 | ....... |
| 29 | .55431 | .01486 | .0319 | .0615 | .0892 | .1136 | ....... |
| 30 | .57735 | .01547 | .0332 | .0640 | .0929 | .1183 | ....... |
| 31 | .60086 | .01610 | .0346 | .0667 | .0968 | .1232 | ....... |
| 32 | .62487 | .01675 | .0359 | .0694 | .1006 | .1281 | ....... |
| 33 | .64941 | .01741 | .0374 | .0720 | .1045 | .1330 | ....... |
| 34 | .67451 | .01835 | .0388 | .0748 | .1085 | .1382 | ....... |
| 35 | .70021 | .01877 | .0403 | .0777 | .1127 | .1435 | ....... |
| 36 | .72654 | .01947 | .0418 | .0806 | .1169 | .1488 | ....... |
| 37 | .75355 | .02020 | .0434 | .0836 | .1212 | .1544 | ....... |
| 38 | .78129 | .02094 | .0450 | .0867 | .1257 | .1601 | ....... |
| 39 | .80978 | .02170 | .0466 | .0899 | .1304 | .1660 | ....... |
| 40 | .83910 | .02249 | .0483 | .0931 | .1351 | .1720 | ....... |
| 41 | .86929 | .0233 | .0500 | .0964 | .1399 | .1781 | ....... |
| 42 | .90040 | .0241 | .0518 | .0999 | .1449 | .1845 | ....... |
| 43 | .93252 | .0250 | .0537 | .1034 | .1500 | .1911 | ....... |
| 44 | .96569 | .0259 | .0556 | .1071 | .1554 | .1978 | ....... |
| 45 | 1.00000 | .0268 | .0576 | .1107 | .1608 | .2049 | ....... |

Correct Feed per one Revolution of Head Spindle =

$$\frac{\text{Tan. of Angle}}{\text{Feed Pulley Const.}} \times \frac{\text{Feed Pulley}}{\text{Counter Drum}}$$

Table 4. — For Finding the Correct Feed per Revolution of Spindle or the Diameter of Feed Pulley, for any given Cam Angle. No. 0 Machine.

| P. & W. No. 1 Automatic | | TANGENT OF ANGLE / FEED PULLEY CONSTANT | | | | | |
|---|---|---|---|---|---|---|---|
| | | RATIOS | | | | | |
| | | 24:1 | 11.16:1 | 5.81:1 | 4:1 | 3.1:1 | 2.7:1 |
| Degrees | Tangent | Feed Pulley Const. 12.7 | Feed Pulley Const. 5.91 | Feed Pulley Const. 3.07 | Feed Pulley Const. 2.18 | Feed Pulley Const. 1.64 | Feed Pulley Const. 1.43 |
| 1 | .01746 | .00137 | .00295 | .00568 | .00800 | .01064 | .01220 |
| 1½ | .02619 | .00206 | .00443 | .00853 | .01201 | .01596 | .01831 |
| 2 | .03492 | .00274 | .00591 | .01137 | .01601 | .02129 | .02441 |
| 2½ | .04366 | .00343 | .00738 | .01422 | .02002 | .02662 | .03053 |
| 3 | .05241 | .00412 | .00886 | .01707 | .02404 | .03195 | .03665 |
| 4 | .06993 | .00550 | .01183 | .02277 | .03207 | .04264 | .04897 |
| 5 | .08749 | .00688 | .01480 | .02849 | .04013 | .05334 | .06118 |
| 6 | .10510 | .00827 | .01778 | .03423 | .04821 | .06408 | .07350 |
| 7 | .12278 | .00966 | .02077 | .04000 | .05401 | .07608 | .08586 |
| 8 | .14054 | .01106 | .02378 | .04577 | .06447 | .08569 | .09828 |
| 9 | .15838 | .01247 | .02679 | .05158 | .07265 | .09655 | .11075 |
| 10 | .17633 | .01388 | .02983 | .05687 | .08000 | .10648 | .12200 |
| 11 | .19438 | .01530 | .03289 | .06331 | .08916 | .11852 | .13593 |
| 12 | .21256 | .01673 | .03596 | .06923 | .09750 | .12961 | .14864 |
| 13 | .23087 | .01817 | .03906 | .07520 | .10590 | .14077 | .16144 |
| 14 | .24933 | .01963 | .04218 | .08122 | .11437 | .15203 | .17435 |
| 15 | .26795 | .02109 | .04533 | .08728 | .12291 | .16338 | .18737 |
| 16 | .28675 | .02257 | .04851 | .09340 | .13153 | .17487 | .20053 |
| 17 | .30573 | .02407 | .05173 | .09959 | .14024 | .18642 | .21380 |
| 18 | .32492 | .02558 | .05494 | .10583 | .15863 | .19812 | .22721 |
| 19 | .34433 | .02711 | .05995 | .11216 | .15795 | .20996 | .24078 |
| 20 | .36397 | .02865 | .06158 | .11855 | .16695 | .22193 | .25453 |
| 21 | .38386 | .03022 | .06495 | .12503 | .17608 | .23406 | .26843 |
| 22 | .40403 | .03181 | .06836 | .13160 | .18533 | .24635 | .28253 |
| 23 | .42447 | .03342 | .07182 | .13826 | .19470 | .25882 | .29613 |
| 24 | .44523 | .03505 | .07533 | .14502 | .20423 | .27148 | .31135 |
| 25 | .46631 | .03671 | .07890 | .15189 | .21390 | .28433 | .32609 |
| 26 | .48773 | .03761 | .08252 | .15887 | .22372 | .29739 | .34107 |
| 27 | .50953 | .04012 | .08621 | .16600 | .23373 | .31069 | .35631 |
| 28 | .53171 | .04186 | .08996 | .17319 | .24390 | .32421 | .37183 |
| 29 | .55431 | .04364 | .09379 | .18055 | .25427 | .33800 | .38763 |
| 30 | .57735 | .04545 | .09769 | .18805 | .26483 | .35201 | .40374 |
| 31 | .60086 | .04731 | .10166 | .19572 | .27562 | .36637 | .42018 |
| 32 | .62487 | .04920 | .10573 | .20354 | .28633 | .38101 | .43697 |
| 33 | .64941 | .05113 | .10988 | .21153 | .29789 | .39598 | .45413 |
| 34 | .67451 | .05311 | .11413 | .21971 | .30941 | .41128 | .47168 |
| 35 | .70021 | .05513 | .11837 | .22808 | .32119 | .42695 | .48965 |
| 36 | .72654 | .05720 | .12293 | .23665 | .33327 | .44301 | .50807 |
| 37 | .75355 | .05870 | .12750 | .24545 | .34566 | .45945 | .52695 |
| 38 | .78129 | .06151 | .13219 | .25449 | .35839 | .47639 | .54635 |
| 39 | .80978 | .06297 | .13701 | .26377 | .37147 | .49376 | .56628 |
| 40 | .83910 | .06607 | .14198 | .27332 | .38491 | .51164 | .58678 |
| 41 | .86929 | .06844 | .14709 | .28315 | .39876 | .53005 | .60789 |
| 42 | .90040 | .07089 | .15218 | .29329 | .41302 | .54902 | .62965 |
| 43 | .93252 | .07342 | .15778 | .30375 | .42730 | .56861 | .65211 |
| 44 | .96569 | .07525 | .16338 | .31455 | .44297 | .58884 | .67531 |
| 45 | 1.00000 | .07881 | .16920 | .32573 | .45871 | .60975 | .69930 |

Correct Feed per one Revolution of Head Spindle =

$$\frac{\text{Tan. of Angle}}{\text{Feed Pulley Const.}} \times \frac{\text{Feed Pulley}}{\text{Counter Drum}}$$

TABLE 5. — For Finding the Correct Feed per Revolution of Spindle or the Diameter of Feed Pulley, for any given Cam Angle. No. 1 Machine.

| P. & W. No. 2 Automatic | | Tangent of Angle / Feed Pulley Constant | | | | | |
|---|---|---|---|---|---|---|---|
| | | RATIOS | | | | | |
| | | 24:1 | 11.16:1 | 5.8:1 | 4:1 | 3:1 | 2.6:1 |
| Degrees | Tangent | Feed Pulley Const. 16.9 | Feed Pulley Const. 7.86 | Feed Pulley Const. 4.08 | Feed Pulley Const. 2.81 | Feed Pulley Const. 2.11 | Feed Pulley Const. 1.83 |
| 1 | .01746 | .00103 | .0022 | .0042 | .0061 | .0081 | .0093 |
| 1½ | .02619 | .00154 | .0033 | .0064 | .0093 | .0123 | .0142 |
| 2 | .03492 | .00206 | .0044 | .0086 | .0125 | .0166 | .0191 |
| 2½ | .04366 | .00257 | .0055 | .0105 | .0153 | .0204 | .0234 |
| 3 | .05241 | .00310 | .0066 | .0127 | .0185 | .0246 | .0283 |
| 4 | .06993 | .00413 | .0089 | .0172 | .0249 | .0332 | .0382 |
| 5 | .08749 | .00517 | .0110 | .0213 | .0310 | .0412 | .0474 |
| 6 | .10510 | .00621 | .0133 | .0257 | .0374 | .0500 | .0572 |
| 7 | .12278 | .00726 | .0156 | .0301 | .0438 | .0583 | .0670 |
| 8 | .14054 | .00831 | .0178 | .0343 | .0498 | .0664 | .0763 |
| 9 | .15838 | .00937 | .0201 | .0387 | .0562 | .0749 | .0861 |
| 10 | .17633 | .01043 | .0224 | .0431 | .0627 | .0834 | .0959 |
| 11 | .19438 | .01150 | .0246 | .0475 | .0691 | .0913 | .1057 |
| 12 | .21256 | .01257 | .0269 | .0519 | .0755 | .1005 | .1155 |
| 13 | .23087 | .01366 | .0293 | .0566 | .0822 | .1095 | .1259 |
| 14 | .24933 | .01475 | .0316 | .0610 | .0886 | .1180 | .1357 |
| 15 | .26795 | .01585 | .0340 | .0657 | .0954 | .1270 | .1461 |
| 16 | .28675 | .01696 | .0364 | .0703 | .1022 | .1360 | .1564 |
| 17 | .30573 | .01809 | .0389 | .0750 | .1089 | .1450 | .1668 |
| 18 | .32492 | .01922 | .0413 | .0796 | .1157 | .1541 | .1771 |
| 19 | .34433 | .02037 | .0437 | .0843 | .1225 | .1631 | .1875 |
| 20 | .36397 | .02153 | .0462 | .0892 | .1296 | .1725 | .1984 |
| 21 | .38386 | .02271 | .0488 | .0941 | .1367 | .1820 | .2093 |
| 22 | .40403 | .02390 | .0513 | .0990 | .1438 | .1915 | .2202 |
| 23 | .42447 | .02511 | .0538 | .1039 | .1509 | .2010 | .2311 |
| 24 | .44523 | .02693 | .0565 | .1090 | .1584 | .2109 | .2425 |
| 25 | .46631 | .02759 | .0592 | .1142 | .1659 | .2209 | .2540 |
| 26 | .48773 | .02885 | .0620 | .1197 | .1737 | .2313 | .2660 |
| 27 | .50953 | .03014 | .0646 | .1247 | .1812 | .2413 | .2774 |
| 28 | .53171 | .03146 | .0676 | .1303 | .1894 | .2522 | .2899 |
| 29 | .55431 | .03279 | .0704 | .1357 | .1972 | .2626 | .3019 |
| 30 | .57735 | .03416 | .0733 | .1414 | .2054 | .2735 | .3145 |
| 31 | .60086 | .03555 | .0763 | .1472 | .2140 | .2849 | .3275 |
| 32 | .62487 | .03697 | .0794 | .1531 | .2235 | .2963 | .3406 |
| 33 | .64941 | .03842 | .0824 | .1590 | .2310 | .3076 | .3537 |
| 34 | .67451 | .03991 | .0856 | .1651 | .2399 | .3195 | .3673 |
| 35 | .70021 | .04143 | .0889 | .1715 | .2492 | .3318 | .3815 |
| 36 | .72654 | .04299 | .0922 | .1779 | .2585 | .3431 | .3957 |
| 37 | .75355 | .04458 | .0956 | .1845 | .2681 | .3569 | .4104 |
| 38 | .78129 | .04623 | .0992 | .1913 | .2780 | .3702 | .4256 |
| 39 | .80978 | .04791 | .1029 | .1985 | .2882 | .3839 | .4415 |
| 40 | .83910 | .04965 | .1066 | .2056 | .2987 | .3977 | .4573 |
| 41 | .86929 | .0514 | .1104 | .2129 | .3094 | .4119 | .4776 |
| 42 | .90040 | .0533 | .1143 | .2205 | .3204 | .4266 | .4905 |
| 43 | .93252 | .0552 | .1184 | .2283 | .3318 | .4418 | .5079 |
| 44 | .96569 | .0572 | .1226 | .2364 | .3435 | .4574 | .5259 |
| 45 | 1.00000 | .0592 | .1272 | .2450 | .3560 | .4740 | .5450 |

Correct Feed per one Revolution of Head Spindle =

$$\frac{\text{Tan of Angle}}{\text{Feed Pulley Const.}} \times \frac{\text{Feed Pulley}}{\text{Counter Drum}}$$

TABLE 6. — For Finding the Correct Feed per Revolution of Spindle or the Diameter of Feed Pulley, for any given Cam Angle. No. 2 Machine.

| P. & W. No. 3 Automatic (open belt) | | Tangent of Angle / Feed Pulley Constant — Ratios | | | | | |
|---|---|---|---|---|---|---|---|
| | | 58:1 | 21.9:1 | 16.1:1 | 8.19:1 | 5.7:1 | 4.2:1 |
| Degrees | Tangent | Feed Pulley Const. 32.9 | Feed Pulley Const. 12.4 | Feed Pulley Const. 9.13 | Feed Pulley Const. 4.65 | Feed Pulley Const. 3.23 | Feed Pulley Const. 2.38 |
| 1 | .01746 | .00053 | .00137 | .00186 | .00365 | .00526 | .00714 |
| 1½ | .02619 | .00079 | .00209 | .00285 | .00559 | .00805 | .01092 |
| 2 | .03492 | .00106 | .00282 | .00383 | .00752 | .01083 | .01470 |
| 2½ | .04366 | .00132 | .00346 | .00471 | .00924 | .01331 | .01806 |
| 3 | .05241 | .00159 | .00419 | .00569 | .01118 | .01610 | .02184 |
| 4 | .06993 | .00212 | .00564 | .00766 | .01505 | .02167 | .02940 |
| 5 | .08749 | .00265 | .00701 | .00953 | .01870 | .02693 | .03654 |
| 6 | .10510 | .00319 | .00846 | .01149 | .02257 | .03250 | .04410 |
| 7 | .12278 | .00373 | .00991 | .01347 | .02644 | .03808 | .05166 |
| 8 | .14054 | .00427 | .01128 | .01533 | .03010 | .04334 | .05880 |
| 9 | .15838 | .00481 | .01273 | .01730 | .03397 | .04891 | .06636 |
| 10 | .17633 | .00535 | .01418 | .01927 | .03784 | .05448 | .07392 |
| 11 | .19438 | .00590 | .01564 | .02124 | .04171 | .06006 | .08148 |
| 12 | .21256 | .00646 | .01709 | .02321 | .04558 | .06563 | .08904 |
| 13 | .23087 | .00701 | .01862 | .02529 | .04966 | .07151 | .09702 |
| 14 | .24933 | .00757 | .02007 | .02726 | .05353 | .07709 | .10458 |
| 15 | .26795 | .00814 | .02160 | .02934 | .05762 | .08297 | .11256 |
| 16 | .28675 | .00871 | .02313 | .03142 | .06170 | .08885 | .12054 |
| 17 | .30573 | .00929 | .02466 | .03351 | .06579 | .09473 | .12852 |
| 18 | .32492 | .00987 | .02619 | .03558 | .06987 | .10062 | .13650 |
| 19 | .34433 | .01046 | .02773 | .03767 | .07396 | .10650 | .14448 |
| 20 | .36397 | .01106 | .02934 | .03986 | .07826 | .11299 | .15288 |
| 21 | .38386 | .01166 | .03095 | .04205 | .08256 | .11888 | .16128 |
| 22 | .40403 | .01228 | .03256 | .04424 | .08686 | .12507 | .16968 |
| 23 | .42447 | .01290 | .03417 | .04643 | .09116 | .13127 | .17808 |
| 24 | .44523 | .01353 | .03587 | .04873 | .09567 | .13777 | .18690 |
| 25 | .46631 | .01414 | .03756 | .05103 | .10019 | .14427 | .19572 |
| 26 | .48773 | .01482 | .03933 | .05344 | .10492 | .15108 | .20496 |
| 27 | .50953 | .01548 | .04102 | .05573 | .10943 | .15758 | .21378 |
| 28 | .53171 | .01616 | .04288 | .05825 | .11438 | .16470 | .22344 |
| 29 | .55431 | .01684 | .04465 | .06066 | .11911 | .17151 | .23268 |
| 30 | .57735 | .01754 | .04651 | .06318 | .12405 | .17864 | .24234 |
| 31 | .60086 | .01826 | .04844 | .06581 | .12921 | .18607 | .25242 |
| 32 | .62487 | .01896 | .05037 | .06844 | .13437 | .19350 | .26250 |
| 33 | .64941 | .01973 | .05231 | .07106 | .13953 | .20093 | .27258 |
| 34 | .67451 | .02050 | .05432 | .07380 | .14491 | .20867 | .28308 |
| 35 | .70021 | .02127 | .05642 | .07665 | .15050 | .21672 | .29400 |
| 36 | .72654 | .02208 | .05852 | .07949 | .15609 | .22477 | .30492 |
| 37 | .75355 | .02290 | .06069 | .08245 | .16189 | .23312 | .31626 |
| 38 | .78129 | .02374 | .06295 | .08552 | .16791 | .24179 | .32802 |
| 39 | .80978 | .02461 | .06529 | .08869 | .17415 | .25077 | .34020 |
| 40 | .83910 | .02550 | .06762 | .09187 | .18038 | .25975 | .35238 |
| 41 | .86929 | .02642 | .07004 | .09515 | .18683 | .26804 | .36498 |
| 42 | .90040 | .02736 | .07254 | .09855 | .19350 | .27864 | .37800 |
| 43 | .93252 | .02833 | .07512 | .10205 | .20038 | .28854 | .39144 |
| 44 | .96569 | .02934 | .07778 | .10566 | .20747 | .29876 | .40530 |
| 45 | 1.00000 | .03040 | .08060 | .10950 | .21500 | .30960 | .42000 |

Correct Feed per one Revolution of Head Spindle =

$$\frac{\text{Tan of Angle}}{\text{Feed Pulley Const.}} \times \frac{\text{Feed Pulley}}{\text{Counter Drum}}$$

Table 7. — For Finding the Correct Feed per Revolution of Spindle or the Diameter of Feed Pulley, for any given Cam Angle. No. 3 Machine.

## STEEL CUTTING FEED PER REVOLUTION OF SPINDLE.

P. & W. No. 0 Automatic Screw Machine.

| Angle of Cam. Degree. | For 9″ Counter Drum. Spindle Speeds 905–664–540. Diameter of Feed Pulley. | | | | For 12″ Counter Drum. Spindle Speeds 1207–886–720. Diameter of Feed Pulley. | | | | For 14″ Counter Drum. Spindle Speeds 1408–1033–840. Diameter of Feed Pulley. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2″ | 3″ | 4″ | 5″ | 2″ | 3″ | 4″ | 5″ | 2″ | 3″ | 4″ | 5″ |
| 3 | .00076 | .00114 | .00152 | .00191 | .00057 | .00086 | .00114 | .00143 | .00049 | .00073 | .00098 | .00122 |
| 4 | .00102 | .00153 | .00203 | .00254 | .00076 | .00114 | .00153 | .00191 | .00065 | .00098 | .00131 | .00163 |
| 5 | .00127 | .00191 | .00254 | .00318 | .00095 | .00143 | .00191 | .00239 | .00082 | .00123 | .00164 | .00205 |
| 6 | .00153 | .00229 | .00306 | .00382 | .00115 | .00172 | .00229 | .00287 | .00098 | .00147 | .00197 | .00246 |
| 7 | .00179 | .00268 | .00357 | .00446 | .00134 | .00201 | .00268 | .00335 | .00115 | .00172 | .00230 | .00287 |
| 8 | .00204 | .00307 | .00409 | .00511 | .00153 | .00230 | .00307 | .00383 | .00131 | .00197 | .00263 | .00328 |
| 9 | .00230 | .00346 | .00461 | .00576 | .00173 | .00259 | .00346 | .00432 | .00148 | .00222 | .00296 | .00370 |
| 10 | .00256 | .00385 | .00513 | .00641 | .00192 | .00288 | .00385 | .00481 | .00165 | .00247 | .00330 | .00412 |
| 11 | .00283 | .00424 | .00566 | .00707 | .00212 | .00318 | .00424 | .00530 | .00182 | .00273 | .00363 | .00454 |
| 12 | .00309 | .00464 | .00618 | .00773 | .00232 | .00348 | .00464 | .00579 | .00199 | .00298 | .00397 | .00497 |
| 13 | .00336 | .00504 | .00672 | .00839 | .00252 | .00378 | .00504 | .00629 | .00216 | .00323 | .00432 | .00539 |
| 14 | .00363 | .00544 | .00725 | .00906 | .00272 | .00408 | .00544 | .00680 | .00233 | .00350 | .00466 | .00583 |
| 15 | .00390 | .00585 | .00780 | .00974 | .00292 | .00438 | .00584 | .00730 | .00251 | .00376 | .00501 | .00626 |
| 16 | .00417 | .00625 | .00834 | .01042 | .00313 | .00469 | .00626 | .00782 | .00268 | .00402 | .00536 | .00670 |
| 18 | .00473 | .00709 | .00945 | .01181 | .00354 | .00532 | .00709 | .00886 | .00304 | .00456 | .00608 | .00759 |
| 20 | .00529 | .00794 | .01059 | .01323 | .00397 | .00595 | .00794 | .00992 | .00340 | .00511 | .00681 | .00851 |
| 22 | .00588 | .00881 | .01175 | .01469 | .00441 | .00661 | .00882 | .01102 | .00378 | .00567 | .00756 | .00944 |
| 24 | .00647 | .00971 | .01295 | .01618 | .00486 | .00728 | .00971 | .01214 | .00416 | .00624 | .00832 | .01040 |
| 25 | .00678 | .01017 | .01356 | .01695 | .00509 | .00763 | .01017 | .01271 | .00436 | .00654 | .00872 | .01090 |
| 26 | .00709 | .01064 | .01419 | .01773 | .00532 | .00798 | .01064 | .01330 | .00456 | .00684 | .00912 | .01140 |
| 28 | .00773 | .01160 | .01547 | .01933 | .00580 | .00870 | .01160 | .01450 | .00497 | .00746 | .00994 | .01243 |
| 30 | .00840 | .01260 | .01680 | .02099 | .00630 | .00945 | .01260 | .01574 | .00540 | .00810 | .01080 | .01349 |
| 32 | .00909 | .01363 | .01818 | .02272 | .00682 | .01022 | .01363 | .01704 | .00584 | .00876 | .01168 | .01460 |
| 34 | .00981 | .01471 | .01962 | .02152 | .00736 | .01104 | .01472 | .01839 | .00631 | .00946 | .01261 | .01576 |
| 35 | .01018 | .01528 | .02037 | .02546 | .00764 | .01146 | .01528 | .01909 | .00655 | .00982 | .01309 | .01636 |

Table 8. —Automatic Screw Machine Feeds, Pratt & Whitney No. 0 Machine (24 to 1 feed motion)

STEEL CUTTING FEED PER REVOLUTION OF SPINDLE.

P. & W. No. 1 Regular and No. 1 Special Automatic Screw Machines.

| Angle of Cam. Degree. | For 11″ Counter Drum Spindle Speeds 653-496-396. Diameter of Feed Pulley. | | | | For 12″ Counter Drum Spindle Speeds 713-541-432. Diameter of Feed Pulley. | | | | For 14″ Counter Drum Spindle Speeds 832-631-504. Diameter of Feed Pulley. | | | | For 16″ Counter Drum Spindle Speeds 950-722-576. Diameter of Feed Pulley. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 3″ | 4″ | 5″ | 6″ | 3″ | 4″ | 5″ | 6″ | 3″ | 4″ | 5″ | 6″ | 3″ | 4″ | 5″ | 6″ |
| 3 | .00110 | .00147 | .00184 | .00221 | .00101 | .00135 | .00169 | .00202 | .00087 | .00116 | .00145 | .00173 | .00076 | .00101 | .00126 | .00152 |
| 4 | .00147 | .00196 | .00245 | .00295 | .00135 | .00180 | .00225 | .00270 | .00116 | .00154 | .00193 | .00231 | .00101 | .00135 | .00169 | .00202 |
| 5 | .00184 | .00246 | .00307 | .00369 | .00169 | .00225 | .00282 | .00337 | .00145 | .00193 | .00241 | .00289 | .00127 | .00169 | .00211 | .00253 |
| 6 | .00221 | .00295 | .00369 | .00443 | .00203 | .00271 | .00338 | .00406 | .00174 | .00232 | .00290 | .00348 | .00152 | .00203 | .00254 | .00304 |
| 7 | .00259 | .00345 | .00431 | .00517 | .00237 | .00316 | .00395 | .00474 | .00203 | .00271 | .00339 | .00406 | .00178 | .00237 | .00296 | .00355 |
| 8 | .00296 | .00395 | .00493 | .00592 | .00271 | .00362 | .00452 | .00543 | .00233 | .00310 | .00388 | .00465 | .00204 | .00271 | .00339 | .00407 |
| 9 | .00334 | .00445 | .00556 | .00667 | .00306 | .00408 | .00509 | .00611 | .00262 | .00350 | .00437 | .00524 | .00229 | .00306 | .00382 | .00459 |
| 10 | .00371 | .00495 | .00619 | .00743 | .00340 | .00454 | .00567 | .00681 | .00292 | .00389 | .00486 | .00584 | .00255 | .00340 | .00426 | .00511 |
| 11 | .00409 | .00546 | .00682 | .00819 | .00375 | .00500 | .00625 | .00751 | .00322 | .00429 | .00536 | .00643 | .00281 | .00475 | .00469 | .00563 |
| 12 | .00448 | .00597 | .00746 | .00895 | .00410 | .00547 | .00684 | .00821 | .00352 | .00469 | .00586 | .00704 | .00308 | .00410 | .00513 | .00615 |
| 13 | .00486 | .00648 | 00810 | .00973 | 00446 | .00594 | .00743 | .00890 | .00382 | .00510 | .00637 | .00764 | .00334 | .00445 | .00557 | .00668 |
| 14 | .00525 | .00700 | .00875 | .01051 | .00481 | .00642 | .00802 | .00963 | .00412 | .00550 | .00687 | .00825 | .00361 | .00482 | .00602 | .00722 |
| 15 | .00564 | .00752 | .00940 | .01129 | .00517 | .00690 | .00862 | .01035 | .00443 | .00591 | .00739 | .00887 | .00388 | .00517 | .00646 | .00776 |
| 16 | .00604 | .00805 | .01006 | .01208 | .00554 | .00738 | .00923 | .01108 | .00475 | .00633 | .00791 | .00949 | .00415 | .00554 | .00692 | .00830 |
| 18 | .00684 | .00912 | .01140 | .01369 | .00627 | .00836 | .01045 | .01255 | .00538 | .00717 | .00896 | .01075 | .00470 | .00627 | .00784 | .00941 |
| 20 | .00767 | .01022 | .01278 | .01534 | .00703 | .00937 | .01171 | .01406 | .00602 | .00803 | .01004 | .01205 | .00527 | .00703 | .00878 | .01054 |
| 22 | .00851 | .01135 | .01418 | .01702 | .00780 | .01040 | .01300 | .01560 | .00669 | .00892 | .01114 | .01337 | .00585 | .00780 | .00975 | .01170 |
| 24 | .00938 | .01250 | .01563 | .01876 | .00860 | .01146 | .01433 | .01720 | .00737 | .00983 | .01228 | .01474 | .00645 | .00860 | .01074 | .01289 |
| 25 | .00982 | .01310 | 01637 | .01964 | .00900 | .01200 | .01500 | .01801 | .00772 | .01029 | .01286 | .01543 | .00675 | .00900 | .01125 | 01351 |
| 26 | .01027 | .01370 | .01712 | .02055 | .00942 | .01256 | .01569 | .01883 | .00807 | .01076 | .01345 | .01615 | .00706 | .00942 | .01177 | .01412 |
| 28 | .01120 | .01493 | .01866 | .02240 | .01027 | .01369 | .01711 | .02053 | .00880 | .01173 | .01466 | .01760 | .00770 | .01027 | .01283 | .01540 |
| 30 | .01216 | .01622 | .02027 | .02432 | .01115 | .01486 | .01858 | .02230 | .00955 | .01274 | .01592 | .01911 | .00836 | .01151 | .01393 | .01672 |
| 32 | .01316 | .01755 | .02193 | .02632 | .01207 | .01609 | .02011 | .02413 | .01034 | .01379 | .01723 | .02068 | .00905 | .01206 | .01508 | .01810 |
| 34 | .01421 | .01894 | .02368 | .02842 | .01302 | .01736 | .02170 | .02605 | .01116 | .01488 | .01860 | .02233 | .00977 | .01302 | .01628 | .01954 |
| 35 | .01475 | .01966 | .02458 | .02949 | .01352 | .01803 | .02253 | .02704 | .01159 | .01545 | .01931 | .02318 | .01014 | .01352 | .01690 | .02028 |

Table 9.—Automatic Screw Machine Feeds, Pratt & Whitney No. 1 Machine (24 to 1 feed motion)

## STEEL CUTTING FEED PER REVOLUTION OF SPINDLE.

P. & W. No. 2 Regular and No. 2 Special Automatic Screw Machines.

| Angle of Cam. Degree. | For 12″ Counter Drum. Spindle Speeds 603–426–316. Diameter of Feed Pulley. | | | | For 14″ Counter Drum. Spindle Speeds 703–497–369. Diameter of Feed Pulley. | | | | For 16″ Counter Drum. Spindle Speeds 804–568–422. Diameter of Feed Pulley. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 3″ | 4″ | 5″ | 6″ | 3″ | 4″ | 5″ | 6″ | 3″ | 4″ | 5″ | 6″ |
| 3 | .00076 | .00102 | .00127 | .00152 | .00065 | .00087 | .00109 | .00131 | .00057 | .00076 | .00095 | .00114 |
| 4 | .00102 | .00136 | .00169 | .00203 | .00087 | .00116 | .00145 | .00174 | .00076 | .00102 | .00127 | .00153 |
| 5 | .00127 | .00170 | .00212 | .00255 | .00109 | .00145 | .00182 | .00218 | .00095 | .00127 | .00159 | .00191 |
| 6 | .00153 | .00204 | .00255 | .00305 | .00131 | .00175 | .00218 | .00262 | .00115 | .00153 | .00191 | .00229 |
| 7 | .00179 | .00238 | .00298 | .00357 | .00153 | .00204 | .00255 | .00306 | .00134 | .00178 | .00223 | .00268 |
| 8 | .00204 | .00273 | .00341 | .00409 | .00175 | .00234 | .00292 | .00350 | .00153 | .00204 | .00255 | .00307 |
| 9 | .00230 | .00307 | .00384 | .00461 | .00198 | .00263 | .00329 | .00395 | .00173 | .00230 | .00288 | .00346 |
| 10 | .00256 | .00342 | .00427 | .00513 | .00220 | .00293 | .00366 | .00440 | .00192 | .00256 | .00320 | .00385 |
| 11 | .00283 | .00377 | .00471 | .00565 | .00242 | .00323 | .00404 | .00485 | .00212 | .00283 | .00353 | .00424 |
| 12 | .00309 | .00412 | .00515 | .00618 | .00265 | .00353 | .00442 | .00530 | .00232 | .00309 | .00385 | .00464 |
| 13 | .00336 | .00448 | .00559 | .00671 | .00288 | .00384 | .00480 | .00576 | .00252 | .00336 | .00420 | .00504 |
| 14 | .00363 | .00481 | .00604 | .00725 | .00311 | .00414 | .00518 | .00622 | .00272 | .00363 | .00453 | .00544 |
| 15 | .00390 | .00520 | .00649 | .00779 | .00334 | .00445 | .00556 | .00668 | .00292 | .00390 | .00487 | .00584 |
| 16 | .00417 | .00556 | .00695 | .00834 | .00358 | .00477 | .00596 | .00715 | .00313 | .00417 | .00521 | .00626 |
| 18 | .00472 | .00630 | .00787 | .00945 | .00405 | .00540 | .00675 | .00810 | .00351 | .00472 | .00590 | .00709 |
| 20 | .00529 | .00706 | .00882 | .01059 | .00454 | .00605 | .00756 | .00907 | .00397 | .00529 | .00661 | .00794 |
| 22 | .00588 | .00784 | .00979 | .01175 | .00504 | .00672 | .00839 | .01007 | .00441 | .00588 | .00731 | .00881 |
| 24 | .00648 | .00864 | .01079 | .01295 | .00555 | .00740 | .00925 | .01110 | .00486 | .00648 | .00809 | .00971 |
| 25 | .00678 | .00904 | .01130 | .01357 | .00581 | .00775 | .00969 | .01163 | .00509 | .00678 | .00848 | .01018 |
| 26 | .00709 | .00946 | .01182 | .01419 | .00608 | .00811 | .01013 | .01216 | .00532 | .00709 | .00886 | .01064 |
| 28 | .00773 | .01031 | .01289 | .01546 | .00663 | .00884 | .01105 | .01326 | .00580 | .00773 | .00966 | .01160 |
| 30 | .00840 | .01120 | .01399 | .01679 | .00720 | .00960 | .01199 | .01439 | .00630 | .00840 | .01049 | .01259 |
| 32 | .00909 | .01212 | .01514 | .01817 | .00779 | .01039 | .01298 | .01558 | .00682 | .00909 | .01136 | .01363 |
| 34 | .00981 | .01308 | .01635 | .01962 | .00841 | .01121 | .01401 | .01682 | .00736 | .00981 | .01226 | .01472 |
| 35 | .01021 | .01361 | .01701 | .02042 | .00873 | .01164 | .01455 | .01746 | .00763 | .01018 | .01273 | .01528 |

Table 10. — Automatic Screw Machine Feeds, Pratt & Whitney No. 2 Machine (24 to 1 feed motion)

## STEEL CUTTING FEED PER REVOLUTION OF SPINDLE.
### P. & W. No. 3 Regular Automatic Screw Machine. Plain Head.

| Angle of Cam. Degree. | For 12″ Counter Drum. Spindle Speeds 177–134–94. Diameter of Feed Pulley. | | | | For 14″ Counter Drum. Spindle Speeds 206–156–110. Diameter of Feed Pulley. | | | | For 16″ Counter Drum. Spindle Speeds 236–179–125. Diameter of Feed Pulley. | | | | For 18″ Counter Drum. Spindle Speeds 265–201–141. Diameter of Feed Pulley. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 7″ | 8″ | 9″ | 10″ | 7″ | 8″ | 9″ | 10″ | 7″ | 8″ | 9″ | 10″ | 7″ | 8″ | 9″ | 10″ |
| 3 | .00093 | .00106 | .00119 | .00133 | .00080 | .00091 | .00102 | .00114 | .00069 | .00080 | .00090 | .00100 | .00062 | .00071 | .00080 | .00088 |
| 4 | .00124 | .00142 | .00159 | .00177 | .00106 | .00121 | .00137 | .00152 | .00093 | .00106 | .00119 | .00132 | .00083 | .00094 | .00106 | .00118 |
| 5 | .00155 | .00177 | .00199 | .00222 | .00133 | .00152 | .00171 | .00190 | .00116 | .00133 | .00150 | .00166 | .00103 | .00118 | .00133 | .00148 |
| 6 | .00186 | .00213 | .00240 | .00266 | .00160 | .00182 | .00205 | .00228 | .00140 | .00160 | .00180 | .00200 | .00124 | .00142 | .00160 | .00177 |
| 7 | .00218 | .00249 | .00280 | .00311 | .00187 | .00213 | .00240 | .00266 | .00163 | .00187 | .00210 | .00233 | .00145 | .00166 | .00187 | .00207 |
| 8 | .00249 | .00285 | .00320 | .00356 | .00214 | .00244 | .00275 | .00305 | .00187 | .00214 | .00240 | .00267 | .00166 | .00190 | .00214 | .00237 |
| 9 | .00281 | .00321 | .00361 | .00401 | .00241 | .00275 | .00309 | .00344 | .00211 | .00241 | .00271 | .00301 | .00187 | .00214 | .00241 | .00267 |
| 10 | .00313 | .00357 | .00402 | .00446 | .00268 | .00306 | .00344 | .00383 | .00234 | .00268 | .00301 | .00335 | .00208 | .00238 | .00268 | .00298 |
| 11 | .00345 | .00394 | .00443 | .00492 | .00295 | .00338 | .00380 | .00422 | .00258 | .00295 | .00332 | .00369 | .00230 | .00263 | .00295 | .00328 |
| 12 | .00377 | .00431 | .00484 | .00538 | .00323 | .00369 | .00415 | .00461 | .00283 | .00323 | .00363 | .00404 | .00251 | .00287 | .00323 | .00359 |
| 13 | .00409 | .00468 | .00526 | .00585 | .00351 | .00401 | .00451 | .00501 | .00307 | .00351 | .00395 | .00438 | .00273 | .00312 | .00351 | .00390 |
| 14 | .00442 | .00505 | .00568 | .00631 | .00379 | .00433 | .00487 | .00541 | .00332 | .00379 | .00426 | .00474 | .00295 | .00337 | .00379 | .00421 |
| 15 | .00475 | .00543 | .00611 | .00678 | .00407 | .00465 | .00523 | .00582 | .00356 | .00407 | .00458 | .00509 | .00317 | .00362 | .00407 | .00452 |
| 16 | .00508 | .00581 | .00653 | .00726 | .00436 | .00498 | .00560 | .00622 | .00381 | .00436 | .00490 | .00545 | .00339 | .00387 | .00436 | .00484 |
| 18 | .00576 | .00658 | .00741 | .00823 | .00494 | .00564 | .00634 | .00705 | .00433 | .00494 | .00555 | .00617 | .00384 | .00439 | .00494 | .00549 |
| 20 | .00645 | .00737 | .00830 | .00922 | .00553 | .00632 | .00711 | .00790 | .00484 | .00553 | .00622 | .00691 | .00430 | .00491 | .00553 | .00614 |
| 22 | .00716 | .00818 | .00921 | .01023 | .00614 | .00702 | .00789 | .00877 | .00537 | .00614 | .00691 | .00767 | .00478 | .00546 | .00614 | .00682 |
| 24 | .00790 | .00902 | .01015 | .01128 | .00676 | .00773 | .00870 | .00966 | .00592 | .00676 | .00761 | .00846 | .00526 | .00601 | .00676 | .00752 |
| 25 | .00827 | .00945 | .01063 | .01181 | .00708 | .00810 | .00911 | .01012 | .00620 | .00708 | .00797 | .00886 | .00551 | .00630 | .00708 | .00787 |
| 26 | .00864 | .00988 | .01111 | .01235 | .00741 | .00847 | .00953 | .01059 | .00648 | .00741 | .00834 | .00926 | .00576 | .00659 | .00741 | .00823 |
| 28 | .00942 | .01077 | .01211 | .01346 | .00808 | .00923 | .01039 | .01154 | .00707 | .00808 | .00909 | .01010 | .00628 | .00718 | .00808 | .00898 |
| 30 | .01023 | .01170 | .01316 | .01462 | .00877 | .01002 | .01128 | .01253 | .00768 | .00877 | .00986 | .01096 | .00682 | .00780 | .00877 | .00975 |
| 32 | .01107 | .01266 | .01424 | .01582 | .00949 | .01085 | .01220 | .01356 | .00831 | .00950 | .01068 | .01187 | .00738 | .00844 | .00949 | .01055 |
| 34 | .01196 | .01366 | .01537 | .01708 | .01025 | .01171 | .01318 | .01464 | .00897 | .01025 | .01153 | .01281 | .00797 | .00911 | .01025 | .01139 |
| 35 | .01241 | .01418 | .01596 | .01773 | .01064 | .01216 | .01368 | .01520 | .00931 | .01064 | .01197 | .01330 | .00827 | .00946 | .01064 | .01182 |

Table 11. — Automatic Screw Machine Feeds, Pratt & Whitney No. 3 Machine (58 to 1 feed motion).

## CHAPTER III

### The Brown & Sharpe Automatic Screw Machine

The general design of the automatic screw machine built by the Brown & Sharpe Manufacturing Company, Providence, R. I., is represented in Figs. 21 and 22, the size of machine illustrated in these half-tones being the No. 00, which has a maximum chuck capacity of $\frac{5}{16}$ inch, and a max-

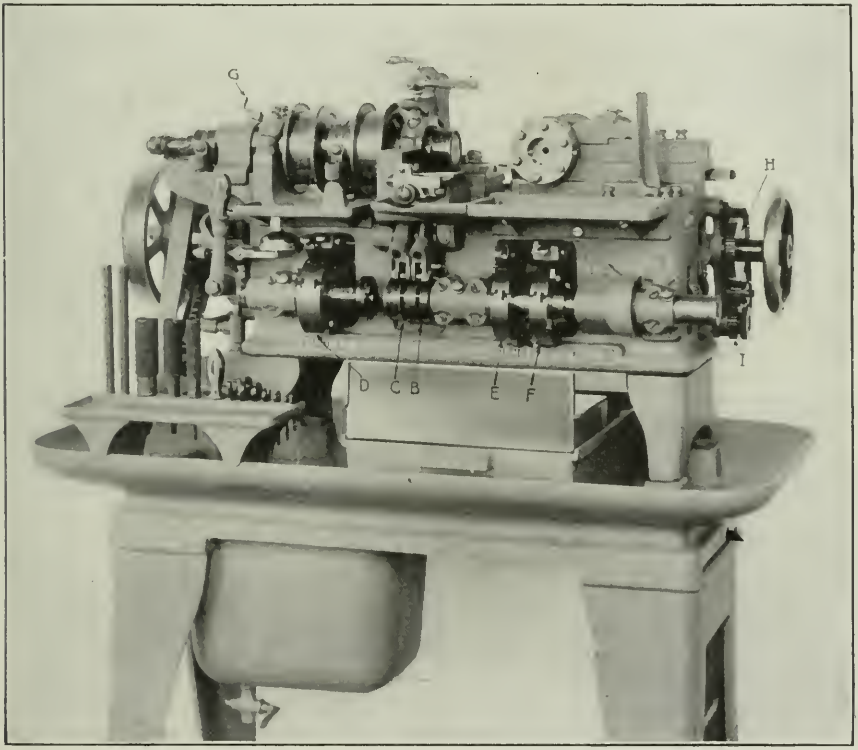



Fig. 21. — Brown & Sharpe No. 00 Automatic Screw Machine

imum feed of 2 inches; the greatest length that it will turn being $1\frac{1}{4}$ inches. Various features of construction are shown clearly in the line drawings, Figs. 23 to 30. Before taking up the construction of the machine in detail, however, it may be well to outline briefly certain features brought out by the half-tone engravings.

GENERAL PRINCIPLES OF CONSTRUCTION

The system of cams employed on this type of machine was adopted by the Brown & Sharpe Manufacturing Company a number of years ago and provides for a set of cams for each piece to be made, so that when a given piece is to be undertaken it is simply necessary to place a set of cams for this piece in position; the machine is then ready to operate, except for the necessary adjustments of the turret tools and cross-slide tools.

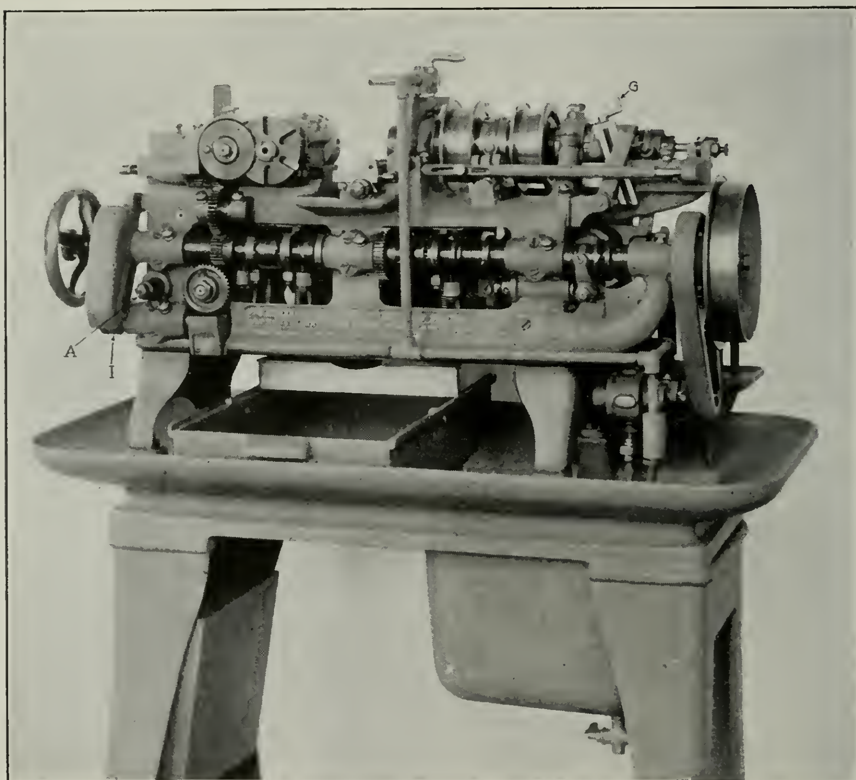



FIG. 22. — Brown & Sharpe Automatic Screw Machine (Rear View)

The turret is arranged for six tools; there are front and rear cross slides, which are operated by edge cams made from blanks $4\frac{1}{2}$ inches diameter with 1-inch center hole and $\frac{1}{4}$-inch locating-pin hole. These locating-pin holes are also placed for positioning the cams and insure their being located in the proper position to give correct timing.

The turret-slide cam is carried on shaft *A*, Fig. 22, the end shown being the shank of the clamp nut. This cam is placed on the shaft through an opening in the rear end of the machine, which gives ready access to this adjustment. The cross-slide cams are carried on the front shaft at *B* and *C*, Fig. 21. The dogs for controlling the mechanism for reversing the spindle, opening and closing the chuck, feeding the stock and rotating the turret, can be adjusted on carriers, *D*, *E* and *F*; this feature gives ease of adjustment for all operations within the capacity of the machine. The turret-rotating mechanism draws the turret slide to the rear position when indexing the turret, irrespective of the hight of the cam position. This does away with the necessity of cutting the cams back to allow the tools clearance when rotating. The reversing shaft, with carrier *D*, can be uncoupled from the front shaft for the purpose of placing the cross-slide cams on carriers *B* and *C*. The stock feed can be adjusted by crank *G*, and the change gears for obtaining different cam-shaft speeds are mounted on shafts *H* and *I*, the gear marked *H* being the driver and that marked *I* the driven. The latter is mounted on a worm shaft at the rear of the machine, which drives through a worm gear a short shaft running crosswise of the bed to the front of the machine where it is connected by bevel gears with the front shaft or cross-slide cam shaft. It also drives by means of spur gears the shaft *A* on which is carried the turret-slide cam.

### THE SPINDLE AND ITS CLUTCHES

The front elevation, Fig. 23, gives a longitudinal section through the spindle and its boxes. This spindle, which has hardened, ground, and lapped bearings, runs in boxes of phosphor bronze, the front box having a tapered exterior, and provision for taking up wear. End play may be taken up by adjusting nuts located at the rear box.

The spindle is driven by friction clutch pulleys having hardened steel bushes and roller bearings operating on the hardened portion of the spindle. Lubricant for the pulleys is supplied from the oil chambers. The friction cones are engaged with the pulleys by sliding sleeve *F′* on levers *G′*. Adjustment for wear is secured by loosening clamp screw *H′* and turning nut *I′*. At *J*, *J*, Fig. 24, is shown a pair of screws by which the clutch sleeves are set central to give equal pressure on the two pulleys.

### THE SPINDLE REVERSE

The reversal of the spindle is secured through the action of spring plunger *K*, Fig. 24, which, upon being released, throws the clutch into instant engagement with the pulley next the chuck. To run forward the clutch is engaged with the other pulley by cam *L*, which is operated by clutch *M*, drawn out at the completion of one revolution by lever *N*. As the spindle is reversed to run forward the plunger spring is compressed by the action of the cam, the plunger being held in place by a wide portion at the rear end of the lever *O*. The carrier *D* shown below

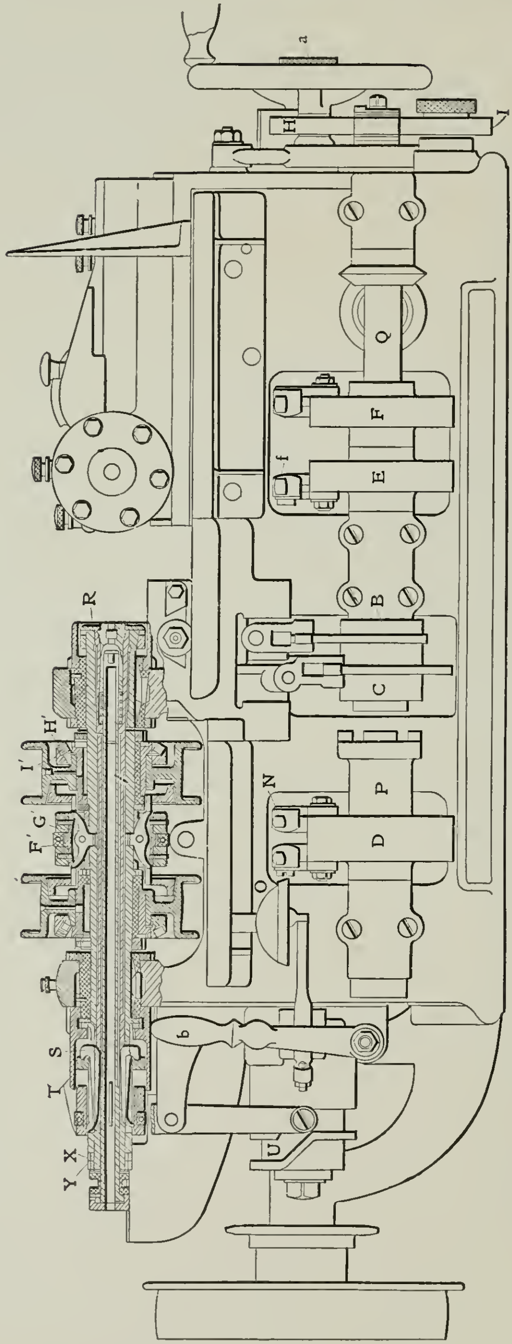



Fig. 23. — Front Elevation and Section through Spindle of Brown & Sharpe Automatic Screw Machine

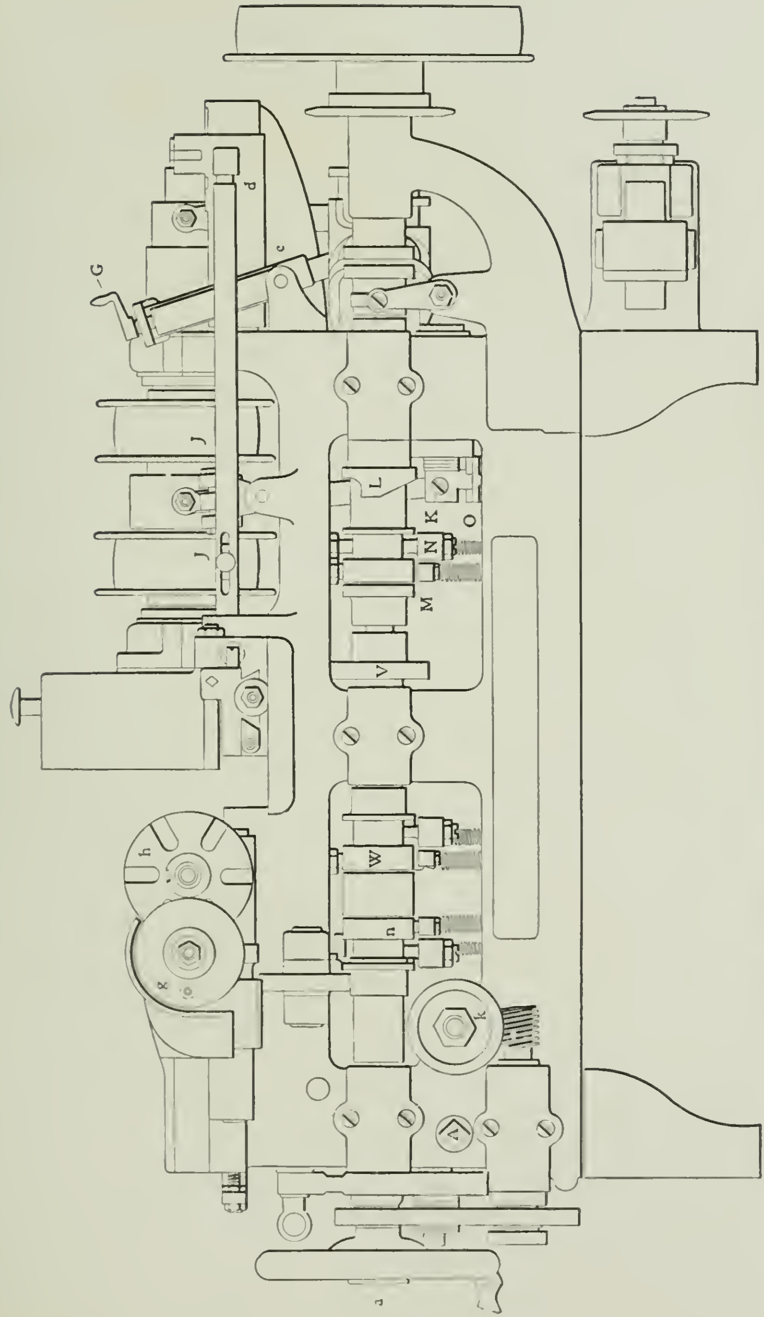



Fig. 24. — Rear Elevation of Brown & Sharpe Automatic Screw Machine

levers *N* and *O* in Figs. 21 and 23 is provided with dogs which may be adjusted to lift the levers at the proper time for reversing the spindle. Where work is to be threaded the positive clutch *P* serves to connect the carrier shaft with the front- or cut-off cam shaft *Q*. This clutch, as already stated, is disengaged when the cross-slide cams are to be changed and need not be connected for work which is not to be threaded. The carrier may be provided with two or more sets of dogs where it is necessary both to thread and tap the work or to cut two threads on it.

## OPERATION OF THE SPRING COLLET

At *R*, Fig. 23, is shown an internally tapered sleeve which slides over the collet and closes it without end movement of the latter, thus assuring accurate stock feeding regardless of any minute variations in diameter. The operation of the sleeve is effected by the chucking tube extending through the spindle to the rear end, where it is controlled by the chuck levers *S*, which are operated by sleeve *T*, which sleeve is actuated by a lever and cam *U*. The stock is also fed through the medium of this cam, which is itself actuated through spur gears *V*, Fig. 24, and a positive clutch *W* on the driving shaft. The gears and clutch are plainly shown on the shaft in Fig. 22. A lever is shown under this clutch in Fig. 24, and when this is depressed by the dog on carrier *E*, Figs. 21 and 23, the clutch is engaged and makes one complete revolution, after which it is again disengaged by a pin in the lever under the clutch which acts upon the cam surface of the clutch and causes the latter to return to its former position.

Adjustment of the chuck is by means of nut *X*, Fig. 23, which may be turned as required after releasing nut *Y*. The collet is removed by taking off the cap with a pin wrench.

## THE STOCK FEED

The pulley at the head end of the machine for driving the main feed shaft *a*, Figs. 23 and 24, is engaged by a clutch actuated by hand lever *b*, which thus forms a means of controlling the feed at all times.

The rear end of the stock-feed tube in the spindle is connected by a latch *c*, Fig. 25, to slide *d*, Fig. 24, which has a slot in which is a sliding block connecting it to lever *e*, Figs. 24 and 25; this lever is operated by cam *U* already referred to. A screw and crank handle *G* are provided, as indicated in Figs. 21, 22 and 24, for adjusting the sliding block; and lever *e* having a constant stroke the length of feed for the stock is varied by changing the position of the sliding block. The length of feed is shown by a scale which is secured to the slide.

By lifting latch *c*, Fig. 25, the feed tube may be withdrawn and the feeding fingers (which are threaded left hand) may be changed. It is, of course, possible to feed more than the regular capacity of the machine by using two or more dogs on the left side of the carrier *E*, Fig. 23, thus operating the feed mechanism several times.

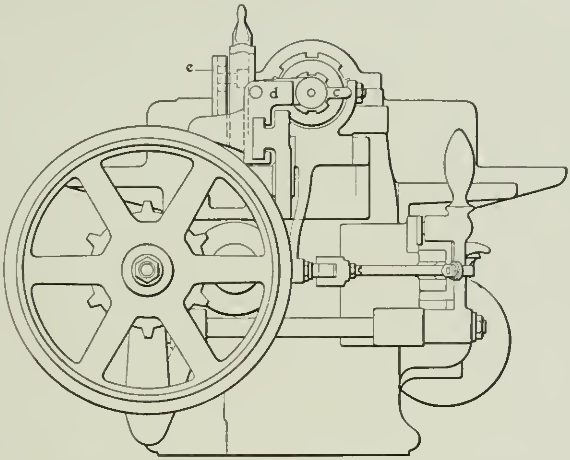



Fig. 25. — End Elevation Showing Chuck Operating Mechanism

When it is desired to stop the stock feed, as in adjusting tools, the dog attached to lever *f*, Fig. 23, can be turned up, thus allowing the dogs on the carrier *E* beneath to pass without lifting the lever.

### THE TURRET SLIDE AND TURRET

As will be observed upon inspection of the various general views, the turret is mounted at the side of the turret slide and rotates in the vertical plane. A long taper shank with which the turret is provided takes a bearing in the turret slide. The indexing movement is accomplished by means of a hardened steel roll in disk *g*, Fig. 24, engaging with grooves cut radially in disk *h*, which is attached to the rear end of the turret spindle. The turret is rotated by this method rapidly and starts and stops without appreciable shock. The taper bolt or pin which locks the turret in its various positions is shown at *i*, Figs. 26 and 27. The locking bolt is withdrawn from the turret by cam *j*.

### TURRET-SLIDE OPERATION

The forward motion of the turret slide for feeding the cutting tools along the work is imparted by a bell-crank lever actuated by the cam mounted on shaft *A*, Figs. 22, 24, and 28, which is itself driven by spur gears from the shaft and worm gear *k*.

While the turret is advancing to the cut and returning after the cut is taken, the movement of the turret slide and the revolving of the turret are controlled independently of the turret-slide feed cam by the crank motion *l*, Fig. 27, while the roll carried by bell-crank lever *m* is passing from the highest point of the cam for the turret-slide feed to the point

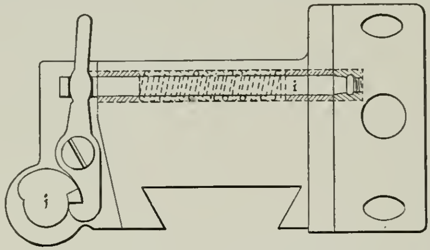



FIG. 26. — End View of Turret Slide Showing Locking Pin for Turret

where the next cut is started. The rapid-motion crank *l* is operated by gears at the rear of the machine which are driven by positive clutch *n*, Fig. 24, on the driving shaft, which clutch is controlled by a lever and suitable mechanism for giving one complete revolution in similar manner to the feed-mechanism control already described. As crank *l* revolves,

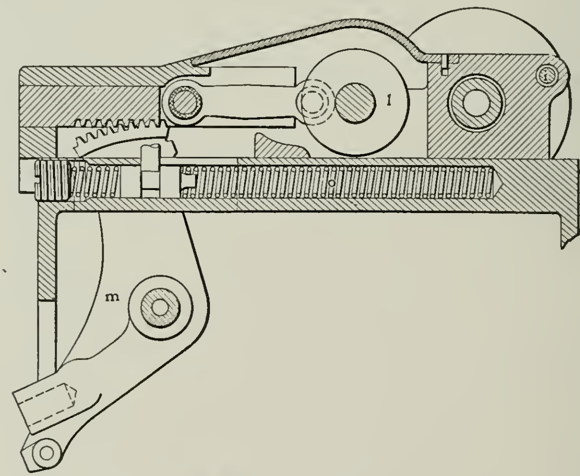



FIG. 27. — Mechanism of Turret Slide

spring *o* is permitted to return the turret slide without the rack. The turret is then revolved in the manner described, and upon the crank *l* coming to rest after it has completed one full revolution, the machine is ready for the next cutting operation.

### THE TWO CROSS SLIDES

The cross slides are shown clearly in Fig. 29. They are operated by cut-off cam shafts *Q*, Figs. 23 and 29, driven from worm-wheel shaft *k*, Figs. 24 and 28, through the medium of bevel gears. The front slide is operated directly by a lever with gear segment formed at the upper end.

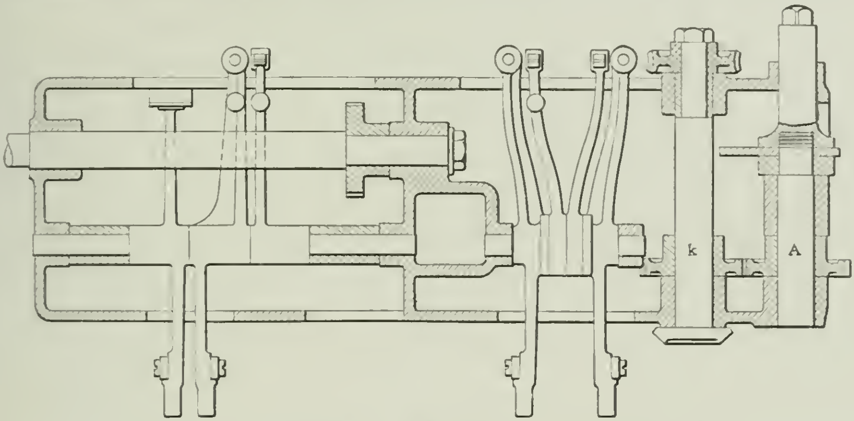



Fig. 28. — Plan Showing Feed Shaft, Tripping Levers, etc.

The rear slide has an intermediate segment gear to reverse the direction of the movement. The cams for the two slides are conveniently placed side by side on their shaft (as at *B* and *C*, Figs. 21 and 23) and the portions which impart motion to the slides are alike in both cams. The racks

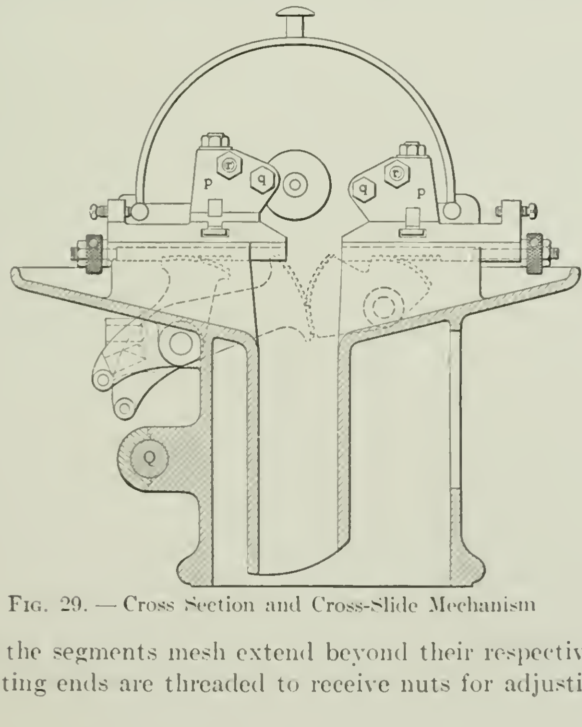



Fig. 29. — Cross Section and Cross-Slide Mechanism

with which the segments mesh extend beyond their respective slides and their projecting ends are threaded to receive nuts for adjusting the tools to their cuts. In addition to these adjusting nuts, stop screws are provided at the rear as in Fig. 29, for insuring accuracy in forming operations.

Circular tools are used on the cross slides and these are held in position on blocks *pp* by screws *qq* and clamped by screws *r r*, Fig. 29.

### DEFLECTOR

In Fig. 30 is shown a deflector which is operated by an adjustable dog on carrier *E* and separates the work from the chips. The oil pump

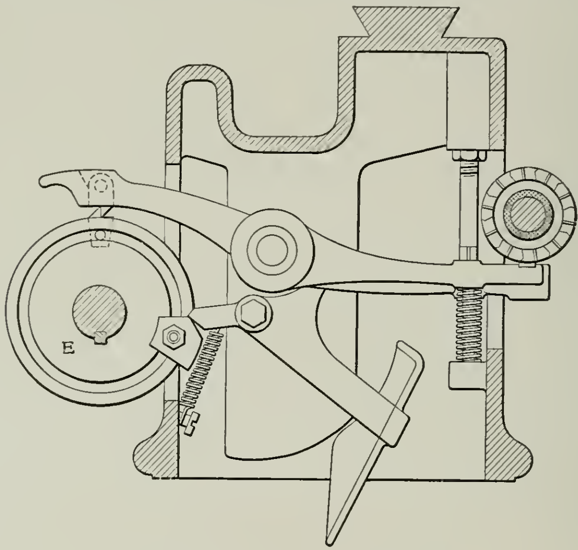


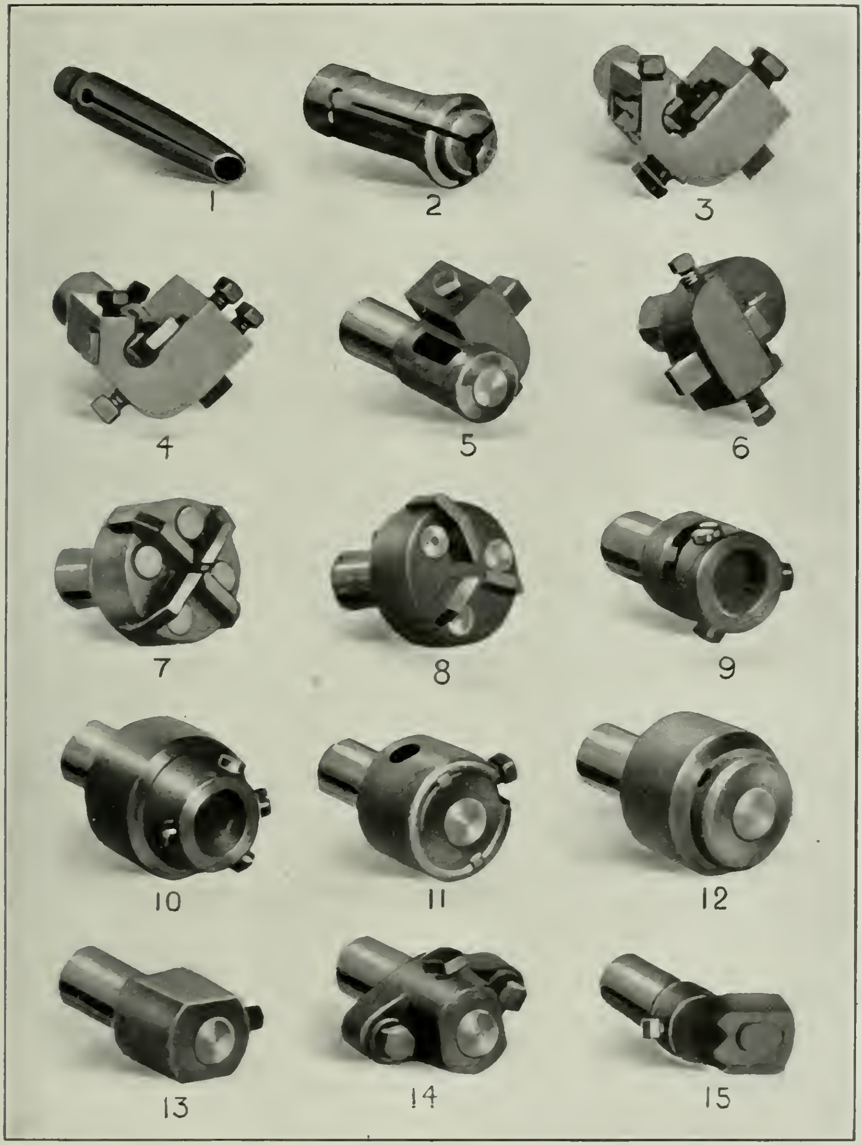

Fig. 30. — Operation of Deflector

is driven by chains from the main pulley and is not stopped when the feed clutch is disconnected; thus an ample supply of lubricant on the work is insured at all times.

### TOOLS AND ATTACHMENTS

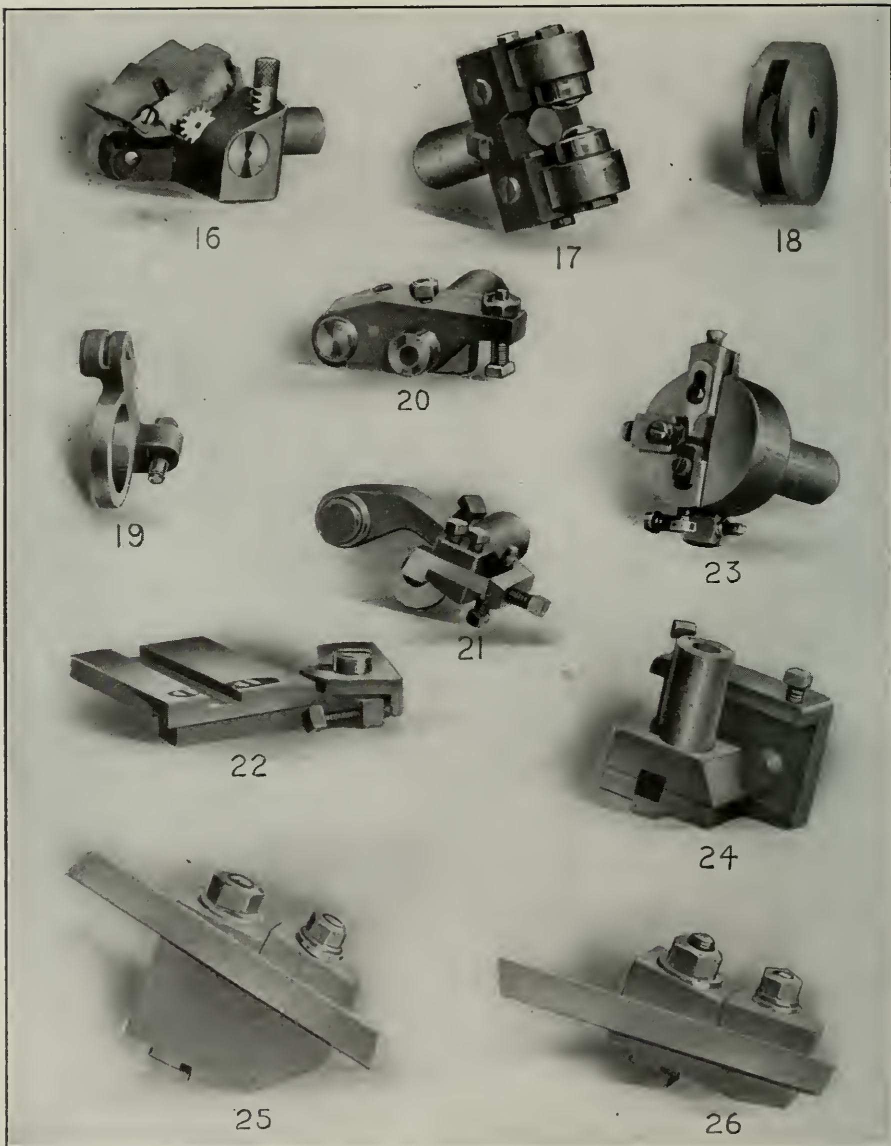
Various tools used on this machine are illustrated in Figs. 31 and 32, the names being given at the bottom of the half-tones. The illustrations are, in most cases, self-explanatory. No. 22 in Fig. 32, it may be stated, is an adjustable guide applied to the cross slide and used for operating recessing tool 20, swing tool 21, and taper turner 23. The latter has two back rests and one cutting tool which are independently adjustable, and the taper given the work is determined by the angle on the guide 22. When the proper taper is obtained, the tool and the back rests are withdrawn radially from the work, thus preventing tool marks on the finished piece.

The construction of the releasing die holder is shown in Fig. 33. *A* is the driving pin and, when it is pulled out of the plate *B*, the die holder




1. Feed Chuck.
2. Spring Collet.
3. Box Tool.
4. Box Tool with Center Drill.
5. Pointing Tool.
6. Centering and Facing Tool.
7. Adjustable Hollow Mill (Finishing).
8. Adjustable Hollow Mill (Roughing).
9. Die Holder.
10. Die Holder (Releasing).
11. Tap Holder.
12. Tap Holder (Releasing).
13. Drill Holder.
14. Floating Holder.
15. Back Rest for Turret.

FIG. 31. — Brown & Sharpe Automatic Screw Machine Tools




16. Angular Cutting-off Tool.
19. Nurl Holder for Cross Slide.
22. Adjustable Guide used with Tools 20, 21, 23.
25. Cutting-off Tool Post (High).
17. Nurl Holder for Turret.
20. Recessing Tool.
21. Swing Tool.
18. Nurl Holder for Cross Slide.
23. Taper Turning Tool.
24. Tool Post for Square Tools.
26. Cutting-off Tool Post (Low).

Fig. 32. — Brown & Sharpe Automatic Screw Machine Tools

releases and, when the spindle is reversed, the ball $C$ drives the die off. One ball recess is for right-hand threads and the other for left-hand threads. With this die holder the turret slide can move back some distance after the holder is released and still, as soon as the spindle is reversed, the die will be backed off the thread.

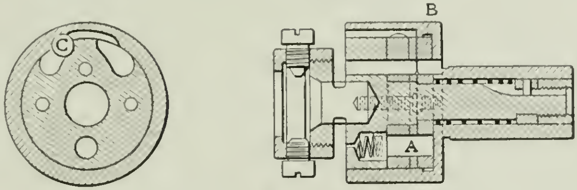



Fig. 33. — Releasing Die Holder

No circular forming tools are included in the groups in Figs. 31 and 32, but in Fig. 34 two circular tools and their holders are plainly shown. This illustration also represents clearly the tap and die revolving attachment which rotates the tap or die in the same direction as the spindle, but at one-half the spindle speed. It is of service where the work requires no other slow movement except that for threading and enables the spindle to be run at its maximum speed for satisfactory production of the work, while the tap or die is revolved at a suitable speed for threading.

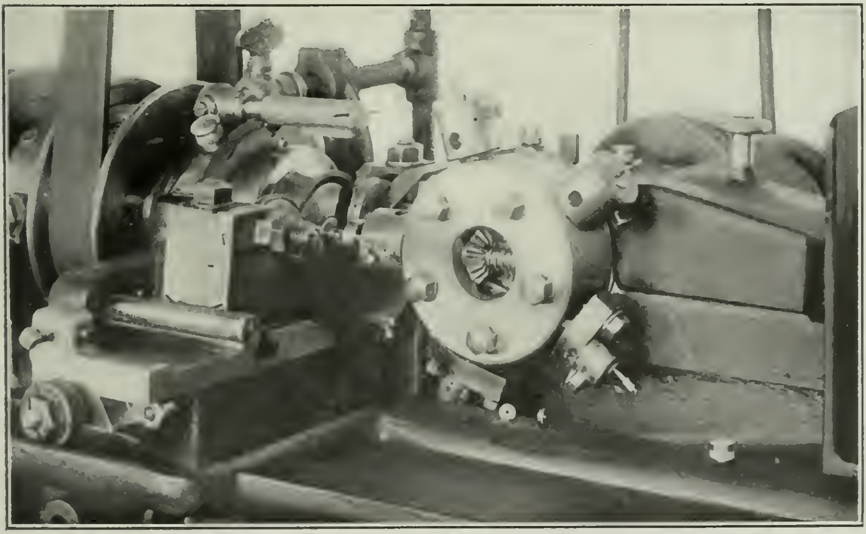


Fig. 34. — Tap and Die Revolving Attachment

Fig. 35 shows the screw-slotting attachment which takes the screws as they are left by the machine and slots them automatically. The saw is mounted on a slide and driven by a round belt from the countershaft. It can be adjusted for depth of cut by a screw at the back of the slide.

The screw to be slotted is held in a bushing carried in a floating holder mounted in a swinging arm which can be adjusted radially by a screw and nut on the rotating lever. The device is operated by cams that are mounted as indicated on the front shaft of the machine. The forward and upward movements of the arm are positive and the return movements are controlled by springs.

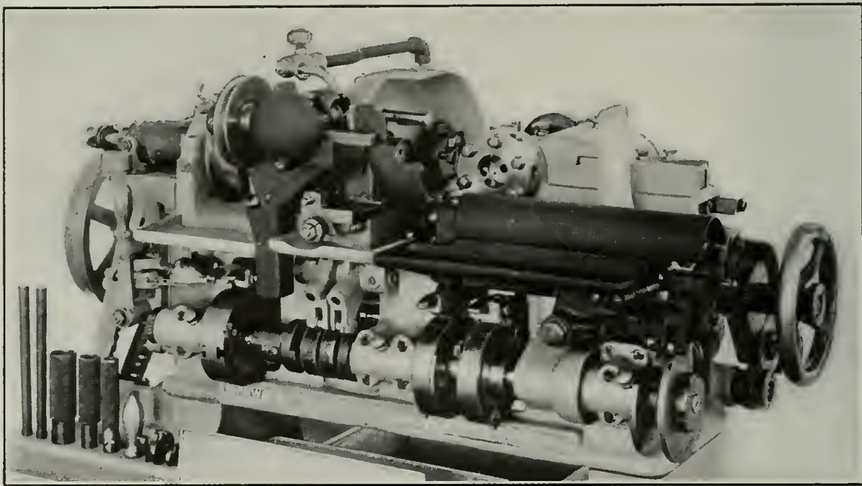


Fig. 35. — Screw-Slotting Attachment

Another attachment (not shown) is for running a drill at high speed where small holes are required in the work. This attachment is also driven by a round belt from the counter.

### COUNTERSHAFT ARRANGEMENT

Figs. 36 and 37 show the overhead works for the No. 00 automatic. As will be observed, there are two countershafts; the first one having 8-inch fast and loose pulleys taking 3-inch belts. This shaft should run at about 450 turns per minute. The second countershaft is driven by a six-step cone pulley and has a drum $14\frac{3}{4}$ inches diameter, and two smaller pulleys $10\frac{3}{4}$ and $5\frac{1}{2}$ inch diameter respectively for operating the spindle pulleys.

A double pulley running freely on the end of the shaft serves as an intermediate between the first counter and the feed-driving pulley on the machine. Thus a constant rate of speed is provided for the feed mechanism regardless of the spindle speed.

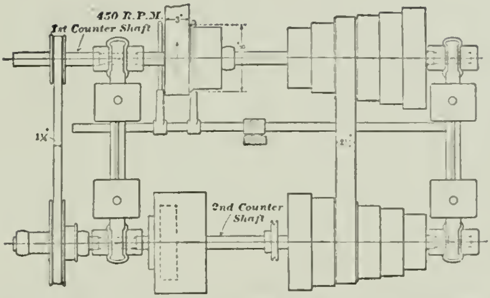



FIG. 36. — Plan of Overhead Works for Brown & Sharpe No. 00 Automatic Screw Machine

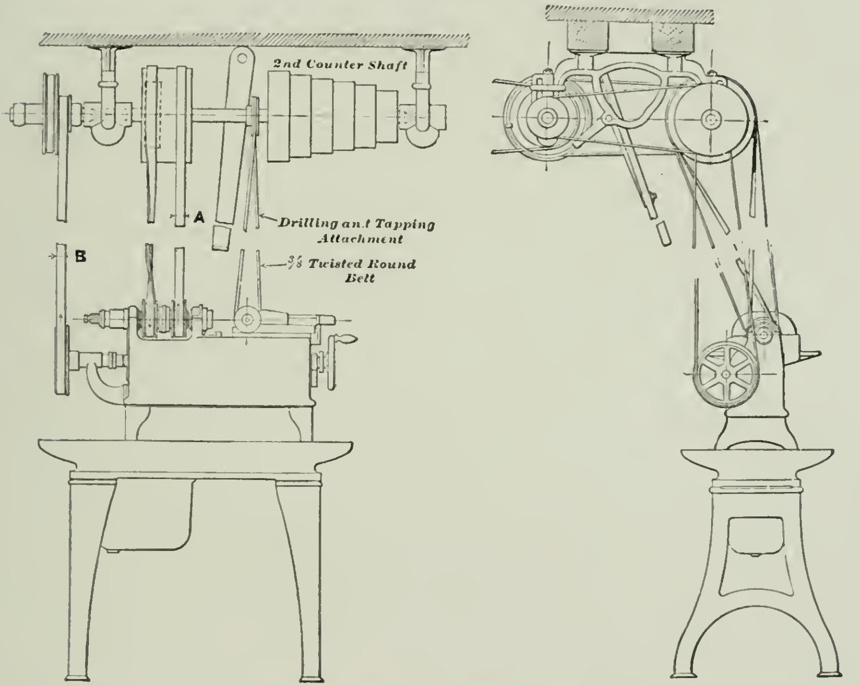



FIG. 37. — Front and End Elevations of Overhead Works for Brown & Sharpe No. 00 Automatic Screw Machine

## SIZES OF MACHINES

The chuck and turning capacity of the No. 00 machine, as already stated, is $\frac{5}{16}$ by $1\frac{1}{4}$ inch, the maximum length that can be fed being 2 inches. The No. 0 machine receives stock up to $\frac{1}{2}$ inch in the chuck, turns lengths up to $1\frac{3}{4}$ inches and has a maximum feeding movement of 3 inches. The No. 2 machine handles material up to $\frac{7}{8}$-inch diameter, turns lengths up to $2\frac{1}{2}$ inches and feeds any length up to 4 inches.

# CHAPTER IV

## Laying Out Brown & Sharpe Screw Machine Cams

This chapter on camming, prepared by F. E. Anthony, of Providence, R. I., gives a practical idea of the method employed in laying out the cams for the Brown & Sharpe automatic screw machine. The example taken is a simple screw, but the laying out of the cams and the methods employed are practically the same for a more complicated piece, excepting that the lobes of the cams would necessarily have to be designed to suit the various operations on more complicated work.

### ORDER OF OPERATIONS

Assuming that a screw as shown in Fig. 38 is to be made from common yellow brass and the requirements are such that it is necessary to take roughing and finishing cuts to produce the desired blank size before threading, the following order of operations would be selected: rough turn with hollow mill; index turret; finish turn with box tool; index turret; thread; cut-off screw; feed stock to stop; index turret.

The facing of the under side and the removing of the bur on the outer diameter of the head, as well as the indexing of the turret three times to bring the stop into position for feeding the stock for the next blank, are not considered in the above operations, as usually these operations can be performed during the time required for parting the screw from the bar.

The spindle speed, length of cuts, feed per revolution of spindle for the various cuts, the time consumed by the idle movements, such as feeding the stock, indexing the turret and reversing the spindle, also the clearance between the turret and cross-slide tools, are taken into consideration to determine the total number of revolutions of spindle required for completing the screw. The fastest spindle speed for the machine, which is 2400, can be used for brass.

### DETERMINING THE NUMBER OF SPINDLE REVOLUTIONS

To determine the number of revolutions of the spindle required for the various cuts, divide the length of cut by the feed or advance of the tool per revolution of the spindle. Calculating on a feed of 0.012 inch for roughing, which cut is 1 inch long, 83 revolutions and a fraction of a revolution will be required. As it is not practicable to consider fractions of revolutions, the roughing cut will be given 84 revolutions. After the roughing cut, the turret is indexed to bring the finishing tool into position. The mechanism that rotates the turret maintains a constant speed, and the indexing of the turret, to bring another tool to the cutting point, requires one-half second in all cases. With the spindle running 2400 revolutions per minute, each change consumes 20 revolutions. It is an advantage, however, to allow extra revolutions for the operation to facilitate adjusting the dogs that control the mechanism; allowing 22 revolutions for the change will give the desired result.

For the finishing cut, which is 1 inch long, and calculating a feed of 0.012 inch per revolution, 84 revolutions will have to be allowed as for roughing.

The pitch of the thread on the screw being 60 per inch, the number of revolutions required for running the die on the screw (which has a thread ½ inch long) will be one-half of 60, or 30, actual revolutions. To this amount should be added extra revolutions for clearance; allowing 33 revolutions for running the die on to the screw and the same number for backing the die off will give a total of 66 revolutions for threading.

### SPINDLE REVOLUTIONS REQUIRED DURING CROSS-SLIDE MOVEMENTS

A certain amount of the cam circle must be allowed between the threading and cutting-off operations, so that the cross-slide tools will not begin to advance to the cutting point until the die holder has dropped back beyond the interfering point. The drop for each cross slide is 1 inch, giving a distance of 2 inches from edge to edge of the cross-slide tools, with the slides in the backward position.

The die-holder cap with adjusting screws requires approximately 1½ inches space to pass through; as there are 2 inches between the cross-slide tools, should these tools begin to advance to the cutting point as soon as the die reaches the end of the screw (when backing off), there would be a trifle more clearance than actually required.

Consulting the templet shown in Fig. 39, it will be noted that 5 hundredths of the cam circle are taken up in advancing the cross slide from its backward position (which is determined by the low portion of the cam) to the point where the tool commences the cut. The revolutions of the spindle during this clearance can be determined after finding the total revolutions required for the different operations and idle movement.

The cutting-off tool, as shown in Fig. 38, is arranged with a parting blade that has a 23-degree angle on the cutting edge; this is for the purpose of making the parting close to the head of the screw, to avoid leaving a large teat on the piece when dropped.

Using an angular blade, it is necessary to allow extra travel so that

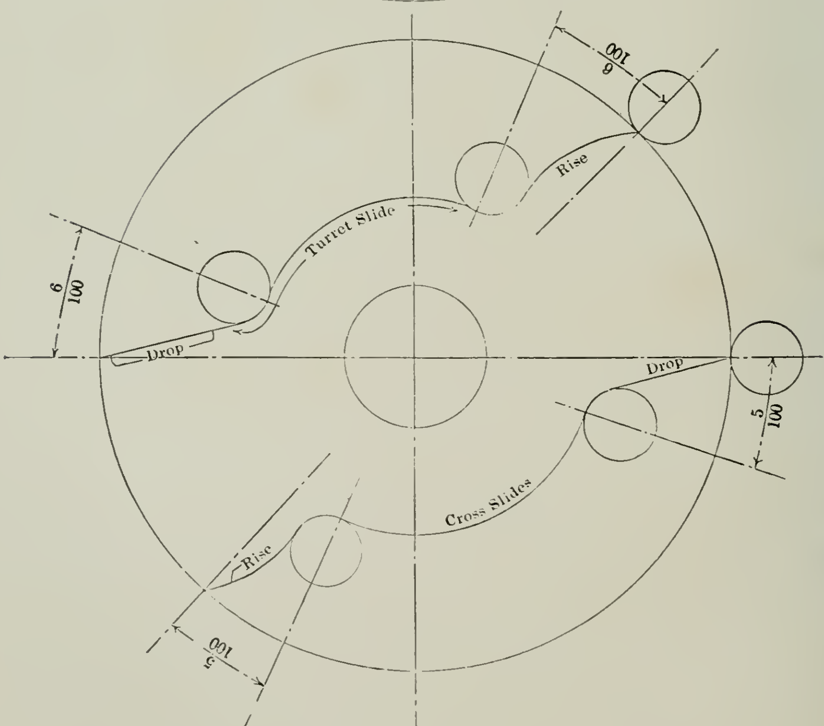



Fig. 39. — No. 00 Cam Templet (about $\frac{3}{4}$ size)

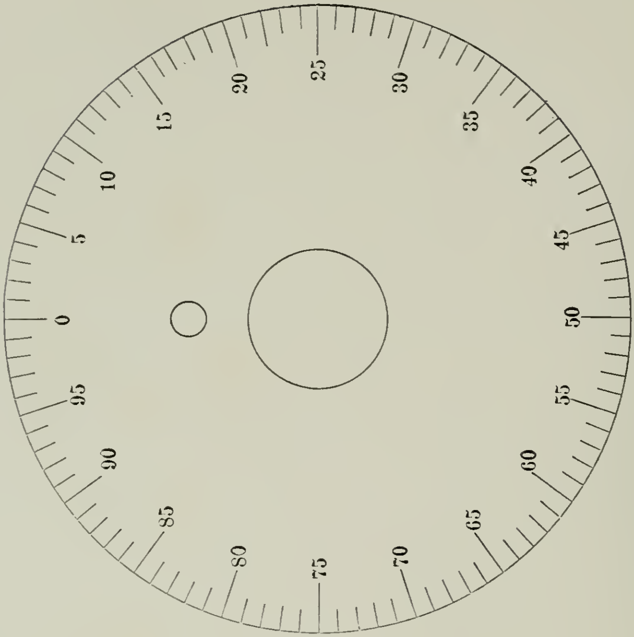
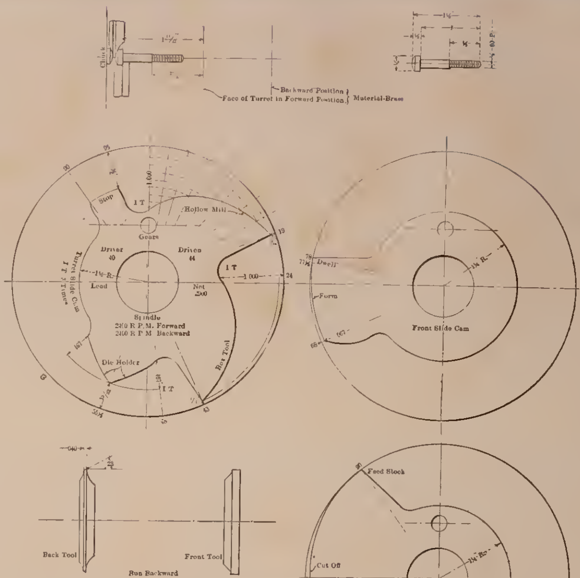



Fig. 40. — Graduated Index for Laying Out No. 00 Cams (about $\frac{3}{4}$ size)





| REV'S | ORDER OF OPERATIONS | | FEED |
|---|---|---|---|
| 84 | Rough Turn, Hollow Mill, and Float, Hold | | .012 |
| 22 | Index Turret. | | |
| 84 | Finish Turn, - Box Tool | | .012" |
| 22 | Index Turret. | | |
| 66 | Thread, Die Holder and Die | | |
| 22 | Clearance. | | |
| | Form - Front Slide = 44 Rev's | Same Time | .0016" |
| 56 | Cut Off, - Back Slide and Index Turret, | 3 Times | .0015" |
| 22 | Feed Stock to Stop. | | |
| 22 | Index Turret. | | |
| 440 | Total Revolutions. | | |

FIG. 38. — Cam Layout (about ½ size)

the low point of the angle can be carried a trifle by the center of the spindle to insure removing the teat on the bar, which is termed "by travel." Add to the radius (0.125 inch) of the bar used 0.019 inch, the amount of "by travel" required for the cutting-off tool plus 0.003 inch clearance to allow for variations in material, and we have a total of 0.147 inch travel for the cutting-off tool; considering a feed or advance of 0.0015 inch per revolution, approximately 97 revolutions will be required for cutting off.

The facing of the under side of the head (the tool for which travels from $\frac{1}{4}$ inch diameter of stock to $\frac{1}{8}$ diameter of finished size) requires a travel of 0.067 inch, including clearance to allow for variation in material; this cut carried at a feed of 0.0016 inch will require approximately 42 revolutions. As this cut can begin at the same time as the cutting-off operation and will be completed by the time the screw is partially cut off, the revolutions required need not be considered when determining the total number.

### INDEXING AND STOCK-FEEDING ALLOWANCE

As there are but four turret tools used in making the screw, it will be necessary to index the turret three times after the threading operation to bring the stop into position for feeding the stock for the following screw. The 97 revolutions allowed for cutting off will give ample time for these changes.

An allowance of 22 revolutions must be added for feeding the stock to the stop after cutting off and indexing the turret, to bring the roughing tool into position for the following screw.

The following table shows the total number of revolutions required for actual operations:

| | Revolutions. |
|---|---|
| Roughing cut | 84 |
| Index turret | 22 |
| Finishing cut | 84 |
| Index turret | 22 |
| Threading | 66 |
| Clearance | |
| Cutting off | 97 |
| (Index turret three times; face under side of head.) | |
| Feed stock | 22 |
| Index turret | 22 |
| | 419 |

As 5 hundredths of the cam circle must be allowed for clearance between the die holder and cross-slide tools, the above total of 419 revolutions represents 95 hundredths of the cam circle. Dividing 419 by 95, the quotient, 4.41 (the number of revolutions in 1 hundredth), multiplied by 100 gives a total of 441 revolutions of the spindle to complete the screw.

### SELECTING CHANGE GEARS

With each machine a number of change gears are furnished to allow the cam-shaft speeds to be varied from 3 to 30 seconds per revolution. These gears allow variations of one second to be made. As the spindle makes 40 revolutions per second, selecting a train of gearing from the gear table (see Table 12, page 61) accompanying the machine, that will give a revolution of the cam shaft in 11 seconds, the spindle will make 440 revolutions to one of the cam shaft. It will, therefore, be necessary to take away a revolution from one of the operations, the total being 441. Allowing 96 revolutions for cutting off, instead of 97, as previously calculated upon, will not make any material difference to the feed for this cut.

### DIVISION OF THE CAM CIRCLE

As it is not convenient to divide the cam blanks into various numbers of parts equal to the number of revolutions required for making different pieces, it is the general practice to divide the cam circle into 100 equal parts, as shown in Fig. 40. The number of hundredths for the lobes and spaces on the cams is obtained by dividing the number of revolutions for each operation by the total number, taking the nearest decimal with two places. For example: The number of revolutions for the roughing cut is 84; dividing 84 by 440, the result, 0.19, is the number of hundredths of the cam circle required for the first cut. Reducing the remainder of the operations in the same manner the cam circle is divided as follows:

| | Revolutions. | Hundredths. |
|---|---|---|
| Rough turn | 84 | 19 |
| Index turret | 22 | 5 |
| Finish turn | 84 | 19 |
| Index turret | 22 | 5 |
| Thread | 66 | 15 |
| Clearance | 22 | 5 |
| Cut off | 96 | 22 |
| Feed stock to stop | 22 | 5 |
| Index turret | 22 | 5 |
| | 440 | 100 |

### THE TURRET AND CROSS-SLIDE CAMS

Commencing at the line opposite the $\frac{1}{4}$-inch hole in the cam blank, as shown in Fig. 38, the turret-slide cam is divided as follows:

0 to 19, lobe for roughing cut;

19 to 24, space for indexing turret;

24 to 43, lobe for finishing cut;

43 to 48, space for indexing turret;

48 to 63, lobe for threading;

63 to 90, reduced to diameter ($2\frac{1}{4}$ inches) of cam carrier, allowing turret to dwell in rear position during the time taken up for clearance and the cutting-off and facing operation;

90 to 95, lobe for feeding stock;

95 to 0, space for indexing turret.

A clearance of 5 hundredths has been calculated on after threading to avoid interference of the cross-slide tools with the die holder, in which case the cross-slide cam for cutting off will commence at 68 and extend to 90. The parting of the piece from the bar will occur before the complete portion of the lobe has passed the roll on the cross-slide lever, due to the extra amount of throw on the cam necessary for removing the teat on the bar which has previously been termed "by travel," in which case the stop for feeding the stock can be in position as soon as the cutting-off tool commences to drop back after cutting off. The travel of the facing tool, which commences at $\frac{1}{4}$ diameter and is carried forward to $\frac{1}{8}$ diameter, will be approximately 0.067 inch, including clearance; advancing the tool at 0.0016 inch per revolution, 42 revolutions will be required. To this number are added 2 revolutions for dwell of the tool at the finishing point, making a total of 44 revolutions, which takes up 10 hundredths of the cam circle. As 2 revolutions for dwell will require $\frac{1}{2}$ hundredth, the throw of 0.067 inch will take $9\frac{1}{2}$ hundredths of cam surface.

The facing operation commences at the same time as the cutting off; consequently the spacing of the front-slide cam will be from 68 to $77\frac{1}{2}$ for advance of tool, $77\frac{1}{2}$ to 78 for dwell.

The hight of the various cam lobes is determined by the lengths of the tools to be used. The face of the turret is approximately $1\frac{5}{8}$ inches from the face of the chuck, with the turret-slide lever on a cam portion $4\frac{1}{2}$ inches diameter.

## THE LAYOUT

On the cam layout sheet, Fig. 38, three perpendicular, parallel lines, approximately 1 inch long, should be drawn, with a distance of $1\frac{5}{8}$ inches between the first and second, and $1\frac{1}{8}$ inches between the second and third lines. The first line represents the face of the chuck; the second, the face of the turret with the lever on a cam $4\frac{1}{2}$ inches diameter; and the third, the face of the turret with the slide in the rear position. A line drawn at right angles through the center of these lines represents the center of the spindle. The cross-slide tools and sample should be drawn to scale close to the chuck line. The line representing the center of the spindle is necessarily the center of the piece to be made. The roughing and finishing cuts are carried close to the under side of the head of the screw. The hollow mill and the head portion of its holder, which extends beyond the face of the turret, is $1\frac{3}{8}$ inches long, as shown in Fig. 41;

as the under side of the head is approximately $1\frac{1}{32}$ inches from the line, representing the face of the turret in the forward position on a $4\frac{1}{2}$-inch cam diameter, it will be necessary to arrange for the high point on the lobe to stop at least $\frac{1}{32}$ inch below the $4\frac{1}{2}$-inch circle on the layout sheet, so that the cut will not be carried forward to such a point that the proper

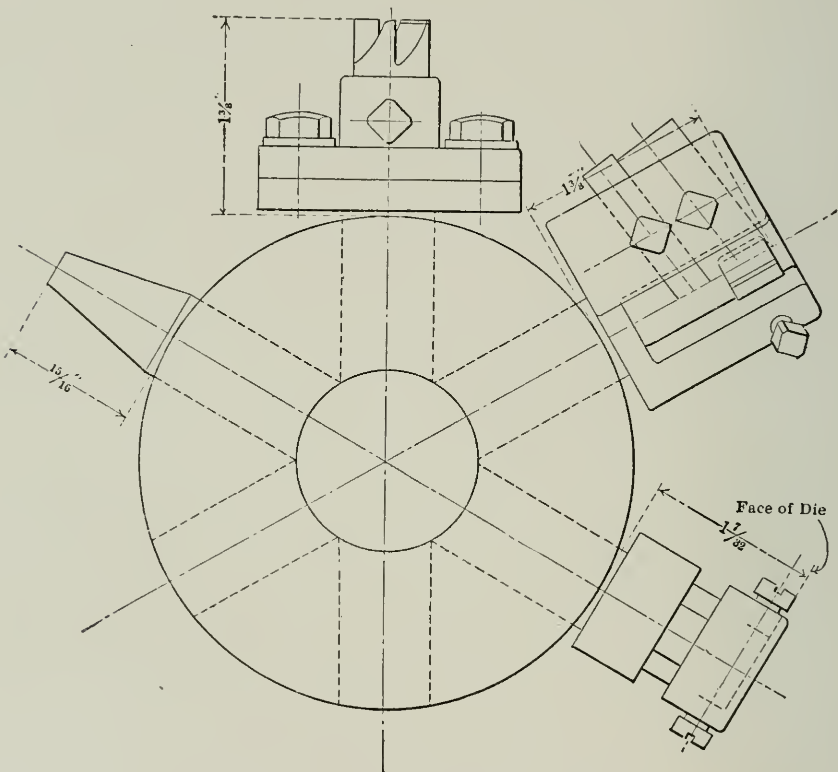



Fig. 41. — Diagram of Turret and Tools

thickness of head cannot be obtained. An extra thirty-second of an inch should be allowed to facilitate adjusting the tool, in which case the high point of the roughing lobe should stop $\frac{1}{16}$ inch below the $4\frac{1}{2}$-inch circle; as the rise on that lobe is 1 inch (the length of the cut), the low point will be $1\frac{1}{16}$ inches below the $4\frac{1}{2}$-inch circle.

### THE TURRET-SLIDE CAM LOBES

From the zero line to 19 hundredths of the cam circle, construct an increase curve, with a rise of 1 inch for the roughing cut. The method of laying out the increase curve, approximately, is shown in Fig. 38. With a templet as shown in Fig. 39 draw the line of drop, beginning at 19 hundredths, and draw an arc equal to the radius ($\frac{1}{4}$ inch) of the turret-slide lever roll, tangent to the drop line, with the low point of the arc about $\frac{1}{16}$ inch below the starting point of the following lobe. The lobe for the finishing cut is a duplicate of the roughing.

In constructing the threading lobes, it is the usual practice to allow the die head, which is arranged to slide on the holder, to draw away from the turret to prevent crowding the die on to the work.

As 33 revolutions are allowed for running the die on to the screw, the advance of the die would be $\frac{33}{60}$ (0.537 inch). From this, deduct 0.060 inch to allow the die to draw away from the turret. The result, 0.467 inch, is the rise for the lobe, and the drop for backing the die off of the screw must necessarily be the same.

When determining the hight of the lobe, the amount of "pull out" allowed for the die must be taken into consideration.

The length of the die-holder head, as shown in Fig. 41, is $1\frac{7}{32}$ inches plus 0.060 inch allowed for "pull out." The result, which is approximately $1\frac{9}{32}$ inches, is the total length of holder to be considered.

The threading begins at 48 hundredths and requires 15 hundredths of cam surface. The rise for following the die on the screw would be 0.467 inch ($7\frac{1}{2}$ hundredths). Locating the high point of the lobe at $55\frac{1}{2}$ hundredths, the length of the holder plus $\frac{1}{32}$ inch for clearance makes it necessary to cut the high point $\frac{15}{32}$ inch below the $4\frac{1}{2}$-inch circle.

Construct the increase curve for the drop and rise in the same manner as shown in Fig. 38 for the roughing cut.

The die will have backed off the screw at 63 hundredths and the portion of cam surface from this point to the starting point of the stop lobe should be cut down $1\frac{1}{8}$ inches from the $4\frac{1}{2}$-inch circle to allow the turret to remain in the rear position during the cutting off and facing operations. Allowance should be made for the drop from the point on the threading lobe and the rise for the stop lobe, using the templet, Fig. 39, for constructing the lines.

## THE CROSS-SLIDE CAM LOBES

The cross-slide cam blanks are $4\frac{1}{2}$ inches diameter. It is not necessary to cut the high point of the lobes on the cams below this diameter when using forming and cutting-off tools, as the slides are arranged with suitable adjustment for producing any diameter within the capacity of the machine.

Tne rise and drop on the cross-slide cams are constructed from the templet, Fig. 39, and should be spaced in the same manner as the turret-slide cam, using the locating-pin hole for the zero line, in order to time the cams properly when placed in the machine.

The cutting off commences at 68 and is completed at 90 hundredths; the facing is from 68 to 78 hundredths.

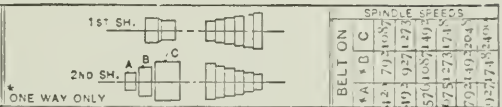
STOCK STOP, SPINDLE REVERSE, ETC.

The stop lobe from 90 to 95 hundredths is without advance to produce a dwell of turret slide while feeding the stock. From 95 hundredths to zero, a drop necessary to bring the turret-slide lever roll $\frac{1}{16}$ inch below the starting-point for the roughing cut is constructed.

The reversing of the spindle does not consume time enough to make it necessary to allow on the threading lobe for this change. The reversing of the spindle from backward to forward after cutting off can be carried on during the operation of feeding the stock or revolving the turret.

# No. 00 AUTOMATIC SCREW MACHINE.

## Table for Laying Out Cams.



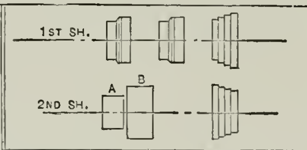

| Time in seconds to make one piece. | Gross product in 10 hours. | Net product in 10 hours gross minus 10% | Gear on driving shaft. | Gear on worm shaft. | Hundredths of cam surface to feed stock. | | Spindle speeds. | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Min. | 420 | 492 | 576 | 675 | 792 | 927 | 1087 | 1273 | 1492 | 1748 | 2048 | 2400 |
| | | | | | | | Sec. | 7 | 8.2 | 9.6 | 11.2 | 13.2 | 15.4 | 18.1 | 21.2 | 24.8 | 29.1 | 34.1 | 40. |
| | | | | | | | ½ Sec. | 3.5 | 4.1 | 4.8 | 5.6 | 6.6 | 7.7 | 9.1 | 10.6 | 12.4 | 14.5 | 17.1 | 20. |
| | | | | | | | Number of revolutions to make one piece. | | | | | | | | | | | | |
| 3 | 12000 | 10800 | 70 | 21 | 17 | | | 21 | 25 | 29 | 34 | 40 | 46 | 54 | 64 | 75 | 87 | 102 | 120 |
| 4 | 9000 | 8100 | 50 | 20 | 13 | | | 28 | 33 | 38 | 45 | 53 | 62 | 72 | 85 | 99 | 117 | 137 | 160 |
| 5 | 7200 | 6400 | 60 | 30 | 10 | | | 35 | 41 | 48 | 56 | 66 | 77 | 91 | 106 | 124 | 146 | 171 | 200 |
| 6 | 6000 | 5400 | 50 | 30 | 9 | | | 42 | 49 | 58 | 67 | 79 | 93 | 109 | 127 | 149 | 175 | 205 | 240 |
| 7 | 5142 | 4600 | 60 | 42 | 8 | | | 49 | 57 | 67 | 79 | 92 | 108 | 127 | 149 | 174 | 204 | 239 | 280 |
| 8 | 4500 | 4000 | 60 | 48 | 7 | | | 56 | 66 | 77 | 90 | 106 | 124 | 145 | 170 | 198 | 233 | 273 | 320 |
| 9 | 4000 | 3600 | 60 | 54 | 6 | | | 63 | 74 | 86 | 101 | 119 | 139 | 163 | 191 | 224 | 262 | 307 | 360 |
| 10 | 3600 | 3200 | 40 | 40 | 5 | | | 70 | 82 | 96 | 112 | 132 | 154 | 181 | 212 | 249 | 291 | 341 | 400 |
| 11 | 3272 | 2900 | 40 | 44 | 5 | | | 77 | 90 | 106 | 124 | 145 | 169 | 199 | 233 | 274 | 320 | 375 | 440 |
| 12 | 3000 | 2700 | 40 | 48 | 5 | | | 84 | 98 | 115 | 135 | 158 | 185 | 217 | 255 | 298 | 350 | 410 | 480 |
| 13 | 2769 | 2400 | 40 | 52 | 4 | | | 91 | 107 | 125 | 146 | 172 | 201 | 236 | 276 | 323 | 379 | 440 | 520 |
| 14 | 2571 | 2300 | 30 | 42 | 4 | | | 98 | 115 | 134 | 157 | 185 | 216 | 254 | 297 | 348 | 408 | 478 | 560 |
| 15 | 2400 | 2100 | 40 | 60 | 4 | | | 105 | 123 | 144 | 169 | 198 | 232 | 272 | 318 | 373 | 437 | 512 | 600 |
| 16 | 2250 | 2000 | 30 | 48 | 4 | | | 112 | 131 | 154 | 180 | 211 | 247 | 290 | 339 | 398 | 466 | 546 | 640 |
| 17 | 2117 | 1900 | 20 | 34 | 3 | | | 119 | 139 | 163 | 191 | 224 | 263 | 308 | 361 | 423 | 495 | 580 | 680 |
| 18 | 2000 | 1800 | 30 | 54 | 3 | | | 126 | 148 | 173 | 202 | 238 | 278 | 326 | 382 | 448 | 524 | 614 | 720 |
| 19 | 1894 | 1700 | 20 | 38 | 3 | | | 133 | 156 | 182 | 214 | 251 | 294 | 344 | 403 | 472 | 554 | 649 | 760 |
| 20 | 1800 | 1600 | 20 | 40 | 3 | | | 140 | 164 | 192 | 225 | 264 | 309 | 362 | 424 | 497 | 583 | 683 | 800 |
| 21 | 1714 | 1500 | 20 | 42 | 3 | | | 147 | 172 | 202 | 236 | 277 | 324 | 380 | 446 | 522 | 612 | 717 | 840 |
| 22 | 1636 | 1450 | 20 | 44 | 3 | | | 154 | 180 | 211 | 247 | 290 | 340 | 399 | 467 | 547 | 641 | 751 | 880 |
| 23 | 1565 | 1400 | 20 | 46 | 3 | | | 161 | 189 | 221 | 259 | 304 | 355 | 417 | 488 | 572 | 670 | 785 | 920 |
| 24 | 1500 | 1350 | 20 | 48 | 3 | | | 168 | 197 | 230 | 270 | 317 | 371 | 435 | 509 | 597 | 699 | 819 | 960 |
| 25 | 1440 | 1300 | 20 | 50 | 3 | | | 175 | 205 | 240 | 281 | 330 | 386 | 453 | 530 | 622 | 728 | 853 | 1000 |
| 26 | 1384 | 1250 | 20 | 52 | 3 | | | 182 | 213 | 250 | 292 | 343 | 402 | 471 | 552 | 647 | 757 | 887 | 1040 |
| 27 | 1333 | 1200 | 20 | 54 | 3 | | | 189 | 221 | 259 | 304 | 356 | 417 | 489 | 573 | 671 | 787 | 922 | 1080 |
| 28 | 1285 | 1150 | 20 | 56 | 3 | | | 196 | 230 | 269 | 315 | 370 | 433 | 507 | 594 | 696 | 816 | 956 | 1120 |
| 29 | 1241 | 1100 | 20 | 58 | 3 | | | 203 | 238 | 278 | 326 | 383 | 448 | 525 | 615 | 721 | 845 | 990 | 1160 |
| 30 | 1200 | 1050 | 20 | 60 | 3 | | | 210 | 246 | 288 | 337 | 396 | 463 | 543 | 636 | 746 | 874 | 1024 | 1200 |

The number of hundredths given is always sufficient for feeding stock, but it is usually best to add 1-100 for revolving the Turret.

TABLE 12. — For Laying Out Cams for Brown & Sharpe No. 00 Automatic Screw Machine.

## No. 0 AUTOMATIC SCREW MACHINE

### Table for Laying Out Cams.



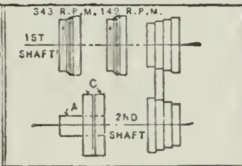

| Spindle speeds | Belt to machine on pulley A | | | | Belt to machine on pulley B | | | |
|---|---|---|---|---|---|---|---|---|
| FAST | 445 | 543 | 663 | 810 | 988 | 1207 | 1474 | 1800 |
| SLOW | 200 | 244 | 298 | 364 | 445 | 543 | 663 | 810 |

| Time in seconds to make one piece | Gross product in 10 hours | Net product in 10 hours gross minus 10% | Gear on driving shaft | Gear on worm shaft | Hundredths of cam surface to feed stock | Spindle speeds: Min. 200, Sec. 3.3, ⅔ Sec. 2.2 | Min. 244, Sec. 4.1, ⅔ Sec. 2.7 | Min. 298, Sec. 4.9, ⅔ Sec. 3.3 | Min. 364, Sec. 6.1, ⅔ Sec. 4. | Min. 445, Sec. 7.4, ⅔ Sec. 4.9 | Min. 543, Sec. 9.1, ⅔ Sec. 6. | Min. 663, Sec. 11.1, ⅔ Sec. 7.3 | Min. 810, Sec. 13.5, ⅔ Sec. 9. | Min. 988, Sec. 16.4, ⅔ Sec. 10.9 | Min. 1207, Sec. 20.1, ⅔ Sec. 13.4 | Min. 1474, Sec. 24.5, ⅔ Sec. 16.3 | Min. 1800, Sec. 13., ⅔ Sec. 20. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | NUMBER OF REVOLUTIONS TO MAKE ONE PIECE | | | | | | | | | | | |
| 5 | 7200 | 6400 | 120 | 20 | 14 | 17 | 20 | 25 | 30 | 37 | 45 | 55 | 67 | 82 | 101 | 123 | 150 |
| 6 | 6000 | 5400 | 120 | 24 | 12 | 20 | 24 | 30 | 36 | 44 | 54 | 66 | 81 | 99 | 121 | 147 | 180 |
| 7 | 5142 | 4600 | 120 | 28 | 10 | 23 | 28 | 35 | 42 | 52 | 63 | 77 | 94 | 115 | 141 | 172 | 210 |
| 8 | 4500 | 4000 | 120 | 32 | 9 | 27 | 33 | 40 | 49 | 59 | 72 | 88 | 108 | 132 | 161 | 197 | 240 |
| 9 | 4000 | 3600 | 120 | 36 | 8 | 30 | 37 | 45 | 55 | 67 | 81 | 99 | 121 | 148 | 181 | 221 | 270 |
| 10 | 3600 | 3200 | 120 | 40 | 7 | 33 | 41 | 50 | 61 | 74 | 90 | 110 | 135 | 165 | 201 | 246 | 300 |
| 11 | 3272 | 2900 | 120 | 44 | 7 | 37 | 45 | 55 | 67 | 82 | 100 | 122 | 148 | 181 | 221 | 270 | 330 |
| 12 | 3000 | 2700 | 60 | 24 | 6 | 40 | 49 | 60 | 73 | 89 | 109 | 133 | 162 | 198 | 241 | 295 | 360 |
| 13 | 2769 | 2400 | 120 | 52 | 6 | 43 | 53 | 65 | 79 | 96 | 118 | 144 | 175 | 214 | 262 | 319 | 390 |
| 14 | 2571 | 2300 | 60 | 28 | 5 | 47 | 57 | 70 | 85 | 104 | 127 | 155 | 189 | 231 | 282 | 344 | 420 |
| 15 | 2400 | 2100 | 60 | 30 | 5 | 50 | 61 | 74 | 91 | 111 | 136 | 166 | 202 | 247 | 302 | 368 | 450 |
| 16 | 2250 | 2000 | 60 | 32 | 5 | 53 | 65 | 79 | 97 | 119 | 145 | 177 | 216 | 263 | 322 | 393 | 480 |
| 17 | 2117 | 1900 | 60 | 34 | 4 | 57 | 69 | 84 | 103 | 126 | 154 | 188 | 229 | 280 | 342 | 418 | 510 |
| 18 | 2000 | 1800 | 60 | 36 | 4 | 60 | 73 | 89 | 109 | 133 | 163 | 199 | 243 | 296 | 362 | 442 | 540 |
| 19 | 1894 | 1700 | 60 | 38 | 4 | 63 | 77 | 94 | 115 | 141 | 172 | 210 | 256 | 313 | 382 | 467 | 570 |
| 20 | 1800 | 1600 | 60 | 40 | 4 | 67 | 81 | 99 | 121 | 148 | 181 | 221 | 270 | 329 | 402 | 491 | 600 |
| 22 | 1636 | 1450 | 60 | 44 | 4 | 73 | 89 | 109 | 133 | 163 | 199 | 243 | 297 | 362 | 443 | 540 | 660 |
| 24 | 1500 | 1350 | 40 | 32 | 3 | 80 | 98 | 119 | 146 | 178 | 217 | 265 | 324 | 395 | 483 | 590 | 720 |
| 26 | 1384 | 1250 | 60 | 52 | 3 | 87 | 106 | 129 | 158 | 193 | 235 | 287 | 351 | 428 | 523 | 639 | 780 |
| 28 | 1285 | 1150 | 60 | 56 | 3 | 93 | 114 | 139 | 170 | 208 | 253 | 309 | 378 | 461 | 563 | 688 | 840 |
| 30 | 1200 | 1050 | 60 | 60 | 3 | 100 | 122 | 149 | 182 | 222 | 271 | 331 | 405 | 494 | 603 | 737 | 900 |
| 32 | 1125 | 1000 | 30 | 32 | 3 | 107 | 130 | 159 | 194 | 237 | 290 | 354 | 432 | 527 | 644 | 786 | 960 |
| 34 | 1059 | 950 | 30 | 34 | 3 | 113 | 138 | 169 | 206 | 252 | 308 | 376 | 459 | 560 | 684 | 835 | 1020 |
| 36 | 1000 | 900 | 30 | 36 | 3 | 120 | 146 | 179 | 218 | 267 | 326 | 398 | 486 | 593 | 724 | 884 | 1080 |
| 38 | 947 | 850 | 30 | 38 | 3 | 127 | 155 | 189 | 231 | 282 | 344 | 420 | 513 | 626 | 764 | 934 | 1140 |
| 40 | 900 | 800 | 30 | 40 | 3 | 133 | 163 | 199 | 243 | 297 | 362 | 442 | 540 | 659 | 805 | 983 | 1200 |
| 44 | 818 | 725 | 30 | 44 | 3 | 147 | 179 | 218 | 267 | 326 | 398 | 486 | 594 | 725 | 885 | 1081 | 1320 |
| 48 | 750 | 675 | 20 | 32 | 3 | 160 | 195 | 238 | 291 | 356 | 434 | 530 | 648 | 790 | 966 | 1179 | 1440 |
| 52 | 692 | 620 | 30 | 52 | 3 | 173 | 211 | 258 | 315 | 385 | 471 | 575 | 702 | 856 | 1046 | 1277 | 1560 |
| 56 | 642 | 575 | 30 | 56 | 3 | 187 | 228 | 278 | 340 | 415 | 507 | 619 | 756 | 922 | 1127 | 1376 | 1680 |
| 60 | 600 | 525 | 30 | 60 | 3 | 200 | 244 | 298 | 364 | 445 | 543 | 663 | 810 | 988 | 1207 | 1474 | 1800 |
| 65 | 553 | 490 | 30 | 65 | 3 | 217 | 264 | 323 | 394 | 482 | 588 | 718 | 877 | 1070 | 1308 | 1597 | 1950 |
| 70 | 514 | 450 | 24 | 56 | 3 | 233 | 285 | 348 | 424 | 519 | 633 | 773 | 945 | 1153 | 1408 | 1720 | 2100 |
| 75 | 480 | 430 | 24 | 60 | 3 | 250 | 305 | 372 | 455 | 556 | 679 | 829 | 1012 | 1235 | 1509 | 1842 | 2250 |
| 80 | 450 | 400 | 30 | 80 | 3 | 267 | 325 | 397 | 485 | 593 | 724 | 884 | 1080 | 1317 | 1609 | 1965 | 2400 |
| 90 | 400 | 350 | 20 | 60 | 3 | 300 | 366 | 447 | 546 | 667 | 814 | 994 | 1215 | 1482 | 1810 | 2211 | 2700 |
| 100 | 360 | 300 | 24 | 80 | 3 | 333 | 407 | 497 | 607 | 742 | 905 | 1105 | 1350 | 1647 | 2012 | 2457 | 3000 |
| 110 | 327 | 290 | 30 | 110 | 3 | 367 | 447 | 546 | 667 | 816 | 995 | 1215 | 1485 | 1811 | 2213 | 2702 | 3300 |
| 120 | 300 | 270 | 20 | 80 | 3 | 400 | 488 | 596 | 728 | 890 | 1086 | 1326 | 1620 | 1976 | 2414 | 2948 | 3600 |

TABLE 13. — For Laying Out Cams for Brown & Sharpe No. 0 Automatic Screw Machine.

# No. 2 AUTOMATIC SCREW MACHINE.

## Table for Laying Out Cams.




| SPINDLE SPEEDS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | BELT TO MACHINE ON PULLEY A | | | | BELT TO MACHINE ON PULLEY C | | | |
| FAST | 277 | 342 | 421 | 519 | 640 | 789 | 973 | 1200 |
| SLOW | 120 | 148 | 182 | 225 | 277 | 342 | 421 | 519 |

| TIME IN SECONDS TO MAKE ONE PIECE. | GROSS PRODUCTION IN 10 HOURS. | NET PRODUCTION IN 10 HOURS GROSS MINUS 10% | GEAR ON DRIVING SHAFT. | 1st GEAR ON STUD. | 2nd GEAR ON STUD. | GEAR ON WORM. | HUNDREDTHS OF CAM SURFACE TO FEED STOCK. | SPINDLE SPEEDS. PULLEYS. SEC. / MIN | 2 / 120 | 2.47 / 148 | 3.033 / 182 | 3.75 / 225 | 4.6167 / 277 | 5.7 / 342 | 7.0167 / 421 | 8.65 / 519 | 10.67 / 640 | 13.15 / 789 | 16.2167 / 973 | 20 / 1200 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 6000 | 5400 | 80 | 32 | 80 | 40 | 17 | | 12 | 15 | 18 | 22 | 28 | 34 | 42 | 52 | 64 | 79 | 97 | 120 |
| 7 | 5142 | 4600 | 80 | 32 | 72 | 42 | 15 | | 14 | 17 | 21 | 26 | 32 | 40 | 49 | 61 | 75 | 92 | 114 | 140 |
| 8 | 4500 | 4000 | 80 | 32 | 72 | 48 | 13 | | 16 | 20 | 24 | 30 | 37 | 46 | 56 | 69 | 85 | 105 | 130 | 160 |
| 9 | 4000 | 3600 | 80 | 32 | 72 | 54 | 12 | | 18 | 22 | 27 | 34 | 42 | 51 | 63 | 78 | 96 | 118 | 146 | 180 |
| 10 | 3600 | 3200 | 80 | 32 | 72 | 60 | 10 | | 20 | 25 | 30 | 37 | 46 | 57 | 70 | 86 | 107 | 131 | 162 | 200 |
| 11 | 3272 | 2900 | 80 | 32 | 84 | 77 | 10 | | 22 | 27 | 33 | 41 | 51 | 63 | 77 | 95 | 117 | 145 | 178 | 220 |
| 12 | 3000 | 2700 | 80 | 32 | 60 | 60 | 9 | NUMBER OF REVOLUTIONS TO MAKE ONE PIECE. | 24 | 30 | 36 | 45 | 55 | 68 | 84 | 104 | 128 | 158 | 195 | 240 |
| 13 | 2769 | 2400 | 80 | 32 | 72 | 78 | 9 | | 26 | 32 | 39 | 49 | 60 | 74 | 91 | 112 | 139 | 171 | 211 | 260 |
| 14 | 2571 | 2300 | 80 | 32 | 60 | 70 | 8 | | 28 | 35 | 42 | 52 | 65 | 80 | 98 | 121 | 149 | 184 | 227 | 280 |
| 16 | 2250 | 2000 | 80 | 32 | 60 | 80 | 7 | | 32 | 39 | 49 | 60 | 74 | 91 | 112 | 138 | 171 | 210 | 259 | 320 |
| 18 | 2000 | 1800 | 80 | 32 | 48 | 72 | 6 | | 36 | 44 | 55 | 67 | 84 | 103 | 126 | 156 | 192 | 237 | 292 | 360 |
| 20 | 1800 | 1600 | 80 | 32 | 48 | 80 | 5 | | 40 | 49 | 61 | 75 | 92 | 114 | 140 | 173 | 213 | 263 | 324 | 400 |
| 22 | 1636 | 1450 | 80 | 32 | 42 | 77 | 5 | | 44 | 54 | 67 | 82 | 102 | 125 | 154 | 190 | 235 | 289 | 357 | 440 |
| 24 | 1500 | 1350 | 80 | 32 | 40 | 80 | 5 | | 48 | 59 | 73 | 90 | 111 | 137 | 168 | 208 | 256 | 316 | 389 | 480 |
| 26 | 1384 | 1250 | 80 | 32 | 36 | 78 | 4 | | 52 | 64 | 79 | 97 | 120 | 148 | 182 | 225 | 277 | 342 | 422 | 520 |
| 28 | 1285 | 1150 | 80 | 32 | 36 | 84 | 4 | | 56 | 69 | 85 | 105 | 129 | 160 | 196 | 242 | 299 | 368 | 454 | 560 |
| 30 | 1200 | 1050 | 60 | 60 | 80 | 80 | 4 | | 60 | 74 | 91 | 112 | 138 | 171 | 210 | 259 | 320 | 394 | 486 | 600 |
| 35 | 1028 | 925 | 60 | 60 | 72 | 84 | 3 | | 70 | 87 | 106 | 131 | 162 | 199 | 246 | 303 | 373 | 460 | 568 | 700 |
| 40 | 900 | 800 | 60 | 60 | 54 | 72 | 3 | | 80 | 99 | 121 | 150 | 185 | 228 | 281 | 346 | 427 | 526 | 649 | 800 |
| 45 | 800 | 700 | 60 | 60 | 48 | 72 | 3 | | 90 | 111 | 136 | 169 | 208 | 256 | 316 | 389 | 480 | 592 | 730 | 900 |
| 50 | 720 | 625 | 60 | 60 | 48 | 80 | 3 | | 100 | 124 | 152 | 187 | 231 | 285 | 351 | 432 | 533 | 657 | 811 | 1000 |
| 55 | 654 | 575 | 60 | 60 | 42 | 77 | 3 | | 110 | 136 | 167 | 206 | 254 | 313 | 386 | 476 | 587 | 723 | 892 | 1100 |
| 60 | 600 | 525 | 40 | 80 | 60 | 60 | 3 | | 120 | 148 | 182 | 225 | 277 | 342 | 421 | 519 | 640 | 789 | 973 | 1200 |
| 70 | 514 | 450 | 40 | 80 | 60 | 70 | 3 | | 140 | 173 | 212 | 262 | 323 | 399 | 491 | 605 | 747 | 920 | 1135 | 1400 |
| 80 | 450 | 400 | 40 | 80 | 54 | 72 | 3 | | 160 | 198 | 243 | 300 | 369 | 456 | 561 | 692 | 853 | 1052 | 1297 | 1600 |
| 90 | 400 | 350 | 40 | 80 | 48 | 72 | 3 | | 180 | 222 | 273 | 337 | 415 | 513 | 631 | 778 | 960 | 1183 | 1459 | 1800 |
| 100 | 360 | 300 | 40 | 80 | 48 | 80 | 3 | | 200 | 247 | 303 | 375 | 462 | 570 | 702 | 861 | 1067 | 1315 | 1622 | 2000 |
| 110 | 327 | 290 | 40 | 80 | 42 | 77 | 3 | | 220 | 272 | 334 | 412 | 508 | 627 | 772 | 951 | 1173 | 1446 | 1784 | 2200 |
| 120 | 300 | 270 | 40 | 80 | 40 | 80 | 3 | | 240 | 296 | 364 | 450 | 554 | 684 | 842 | 1038 | 1280 | 1578 | 1946 | 2400 |
| 135 | 266 | 240 | 36 | 72 | 40 | 90 | 3 | | 270 | 333 | 409 | 506 | 623 | 769 | 947 | 1168 | 1440 | 1775 | 2189 | 2700 |
| 150 | 240 | 210 | 36 | 80 | 40 | 90 | 3 | | 300 | 370 | 455 | 562 | 692 | 855 | 1052 | 1297 | 1600 | 1972 | 2432 | 3000 |
| 165 | 218 | 190 | 36 | 77 | 35 | 90 | 3 | | 330 | 407 | 500 | 619 | 752 | 940 | 1158 | 1427 | 1760 | 2170 | 2675 | 3300 |
| 180 | 200 | 180 | 36 | 84 | 35 | 90 | 3 | | 360 | 444 | 546 | 675 | 831 | 1026 | 1263 | 1557 | 1920 | 2367 | 2919 | 3600 |

TABLE 14. — For Laying Out Cams for Brown & Sharpe No. 2 Automatic Screw Machine.

# CHAPTER V

## The Brown & Sharpe Automatic Screw Machine with Constant-Speed Drive

The Brown & Sharpe, No. 2 G, automatic as equipped with constant-speed drive is illustrated in Figs. 42, 43, and 44. The general form of

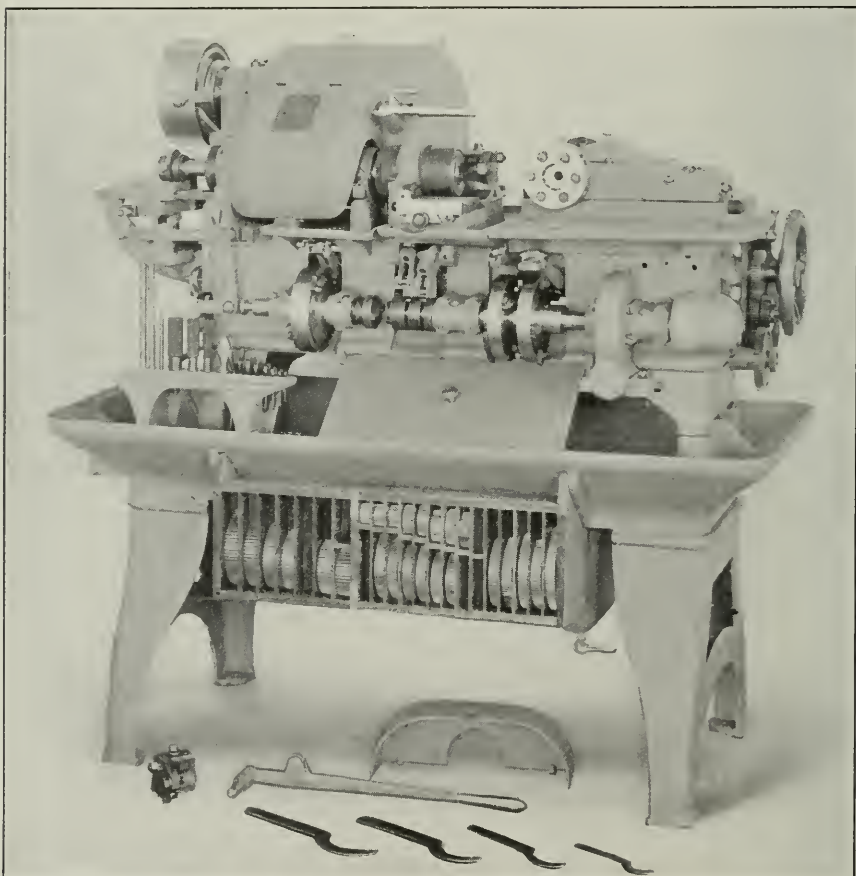


Fig. 42. — Brown & Sharpe Automatic Screw Machine with Constant-Speed Drive

the machine itself is practically unchanged from the design illustrated in Chapter III, the new features being detailed in Fig. 43.

A friction clutch is located in the driving pulley *A*, allowing the machine to be driven direct from the main line. Any standard constant-speed motor can be mounted upon the machine.

The spindle is driven by silent-running chains. Variations of the spindle speeds are obtained by means of change gears and friction clutches, each pair of change gears giving two spindle speeds one slow and one fast, automatically changed by the friction clutches. There is also a friction clutch located on the spindle for reversing, so that with the whole combination it is possible to obtain twelve forward changes and twelve backward changes of speed for the spindle.

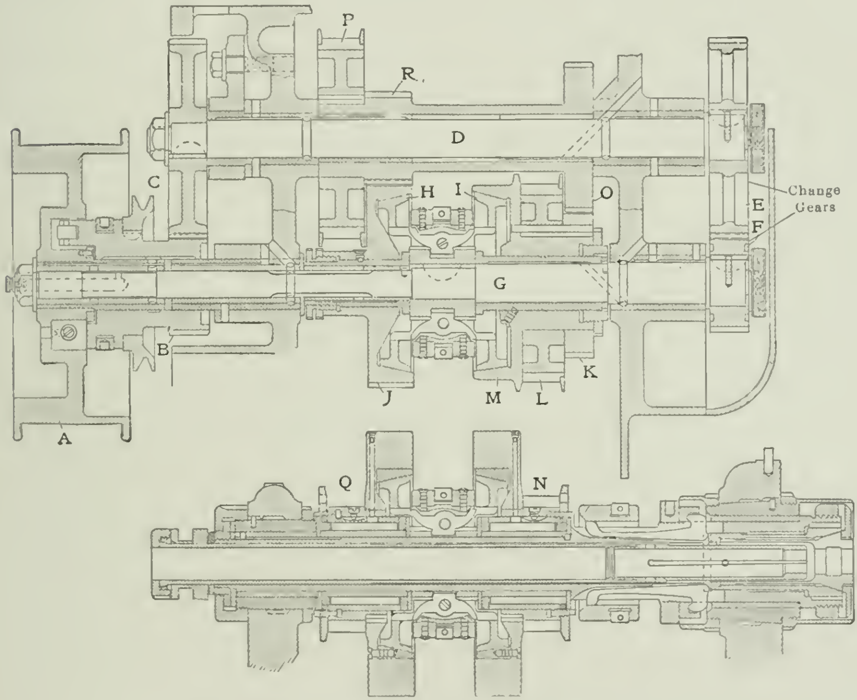



Fig. 43. — Details of the Constant-Speed Drive

The feed-driving mechanism is positively connected with the spindle-driving mechanism. The power is taken by the driving pulley *A*, to which the sliding gear *B* is connected by a friction clutch. By means of this friction clutch the machine is started or stopped, and there is, in addition, independent means provided for starting and stopping the feed when desired.

The sliding gear *B* through gear *C* drives back shaft *D*, which in turn drives the clutch shaft *G* through the change gears *E* and *F*. Keyed to the shaft *G* is the friction body with faces *H* and *I*, and mounted loosely on shaft $G$ is the gear $J$ on one side of the friction body, and on the other side of the body the gear $K$ and chain sprocket $L$, both of which are fastened to the friction back $M$.

Mounted loosely on shaft $D$ is a quill on which are the gears $O$ and $B$ and the sprocket $P^1$. When the clutch face $I$ engages the friction back $M$, the spindle is driven back at a slow speed through the sprocket $L$ and the chain and sprocket $N$ and the spindle is driven forward at a slow speed through gears $K$ and $O$, the sprocket $P$, and chain and sprocket $Q$.

When the clutch face $H$ engages the gear $J$ the spindle is driven forward at a fast speed through gear $B$, the sprocket $P$, and the chain and sprocket $Q$, and is driven backward at a fast speed through gears $R$, $O$, and $K$, the sprocket $L$ and chain and sprocket $N$.

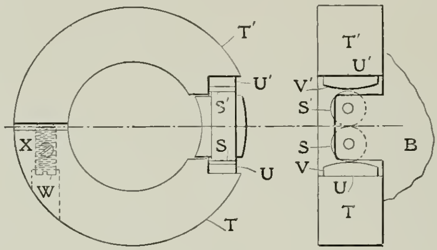



Fig. 44. — Details of Clutch

The direction of the spindle rotation depends upon whether the clutch body on the spindle is engaged with sprocket $N$ or sprocket $Q$, both of which are loose on the spindle and are provided with roller bearings. All bearings in the driving mechanism are bushed with bronze and oiled from pockets on the outside of the case.

The friction clutch in the machine driving pulley is of novel design. The driving pulley $A$ carries a split friction ring $T$ and $T^1$, which is expanded by the two hardened rolls $S$ and $S^1$ on the end of the sliding gear $B$. These rolls operate against the hardened shoes $U$ and $U^1$, the inner surfaces of which are arcs of circles. The sliding gear $B$ is operated by a conveniently located hand lever.

To operate the friction, the rolls are forced in between the shoes a little beyond the centers of the arcs, thus expanding the ring and clamping it to the pulley. As the rolls are beyond the centers of the arcs, they remain locked in position. To compensate for wear, the friction ring is adjusted by the screw $W$, and clamped by the set screw $X$.

## CHAPTER VI

### The Cleveland Automatic Turret Machine and its Cam Adjustments

One of the types of turret machines made by the Cleveland Automatic Machine Company, Cleveland, Ohio, is illustrated in Figs. 45, 46, and 47. The latter is in reality a plan view of a different size of machine than that shown in Figs. 45 and 46, but the construction is essentially the same.

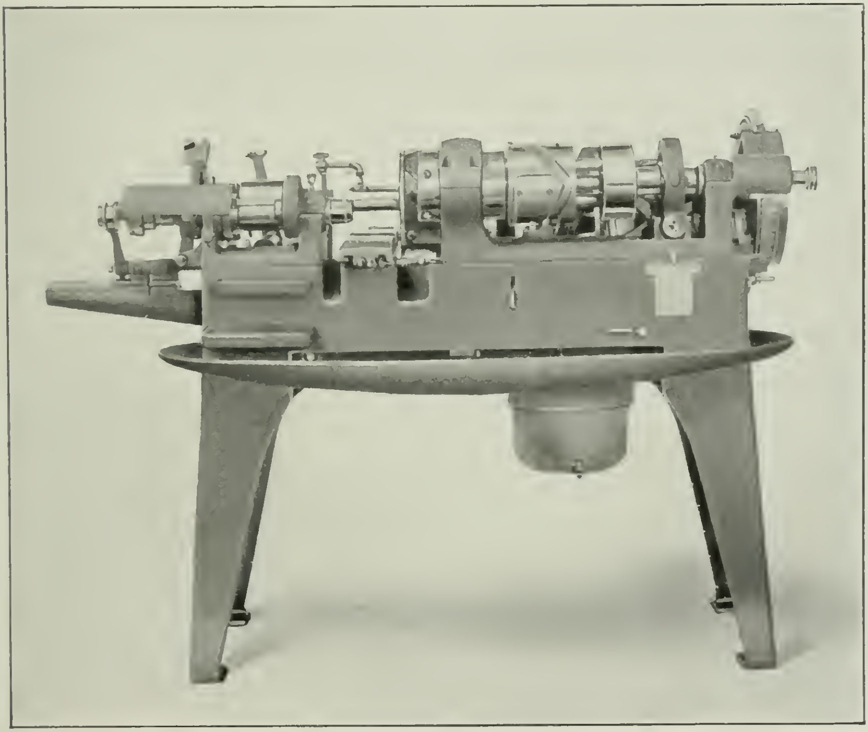


Fig. 45. — Cleveland Automatic Turret Machine

#### SPINDLE DRIVE

On the Cleveland machines, except in the cases of those built for light forming and brass work, which are direct driven, the spindle is driven by gears arranged on the shaft parallel to and behind it, so that a single belt running continuously in one direction will, when shifted from one

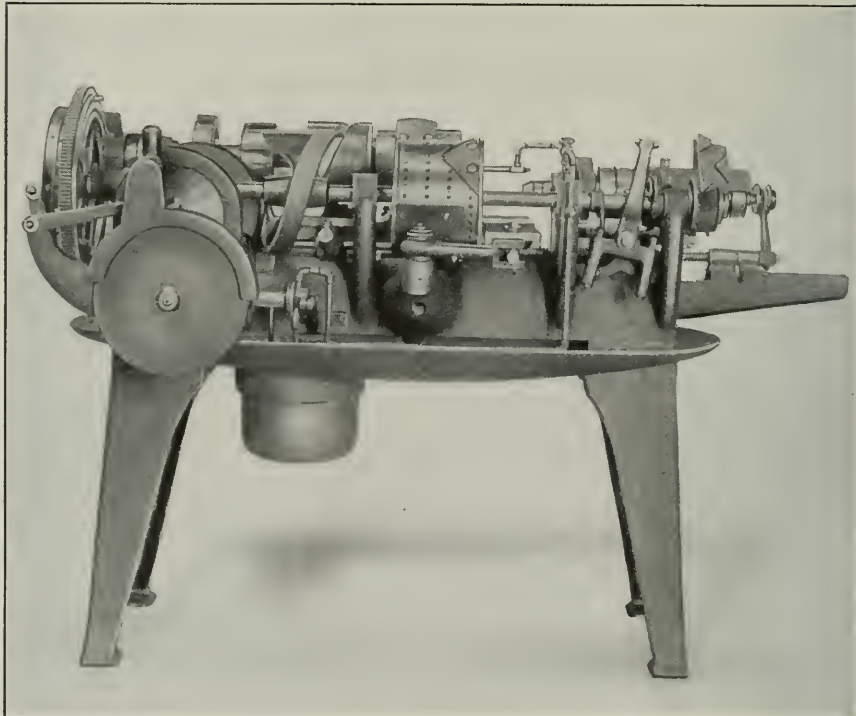


Fig. 46. — Cleveland Automatic Turret Machine (Rear View)

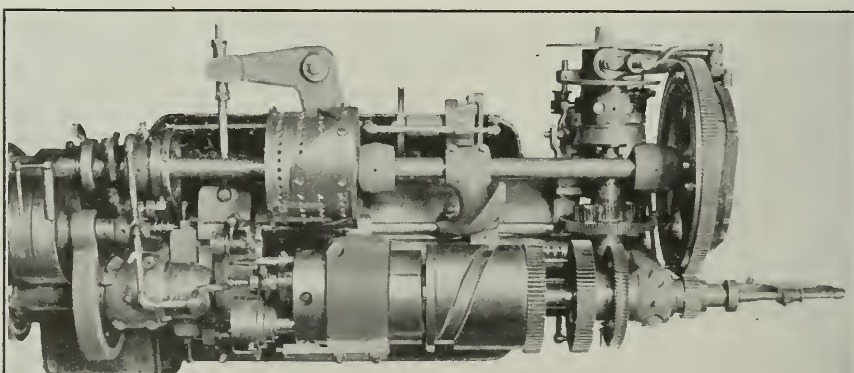


Fig. 47. — Cleveland Automatic Turret Machine (Plan View)

pulley to another, drive the spindle alternately in opposite directions, as is required in threading a screw and backing off the die. These gears are usually so proportioned that the speed of the spindle is greater when running in one direction than the other, so that in threading the die may be run off the screw at a much higher speed than is used in cutting the thread. Other operations, including cutting off, may also be run at the higher rate of speed. The movement for reversing the spindle when threading is practically an instantaneous one and the full width of the belt is used until the operation of threading is completed. The spindle carries the usual type of spring chuck and feed tube for the bar stock.

### TURRET AND CROSS SLIDE

The turret for carrying the tools is mounted on a horizontal shaft located parallel to the spindle. The tools are held in a concentric position in the front end of the turret and the latter is indexed and locked at its periphery on a radius larger than that of the circle in which the tools are disposed, thus serving to maintain proper alinement of the tools with the work spindle. The means of supporting the turret during its forward and backward movements in the head, and the location of the longitudinal indexing notches in its periphery, are shown clearly, as is also the arrangement of the cross slide which ordinarily carries two tool posts, one or both of which may be used as operations require.

### GENERAL SYSTEM OF OPERATION

The mechanism for operating the turret and the cross slide, as well as the stock feed and chuck, is driven through speed-changing friction disks, by a quarter-turn belt from the countershaft which drives the work spindle. This feed-driving mechanism, by means of planetary gears and suitable clutch connections, provides an automatically controlled rapid traverse for the turret and cross slide during the non-cutting movements and a slow, readily regulated rate of travel during the actual cutting operations. The method of controlling this feed drive will be referred to later. It will be understood, of course, that turret and cross slide, feed mechanism, etc., may be conveniently operated by hand by means of crank handle and lever, when setting up for a given piece of work.

An inspection of the half-tone engravings and the line drawing, Fig. 48, will reveal the location and character of the various cams, the means of controlling the spindle-driving belts, and other features of importance.

### ARRANGEMENT OF CAMS

The cams may be classed under the following names: Turret cams, feed-regulating cams, cross-slide cams, chuck opening and closing cams, stock-feed cams. These cams are all clearly shown in position, in the half-tone engravings, and are represented also in the drawing, Fig. 48, which is a plan view of the operating mechanism.

The turret cams located just to the rear of the turret, as seen in Figs. 45 and 47, are shown at *C* and *D* in the diagram, Fig. 48. These cams are fixed and are never changed. The forward and back movements of the turret *E*, controlled by these cams, are constant for all kinds of work; the idle travel of the turret, before the tools reach the work, is made at high speed, the cutting feed being tripped in just as the tool

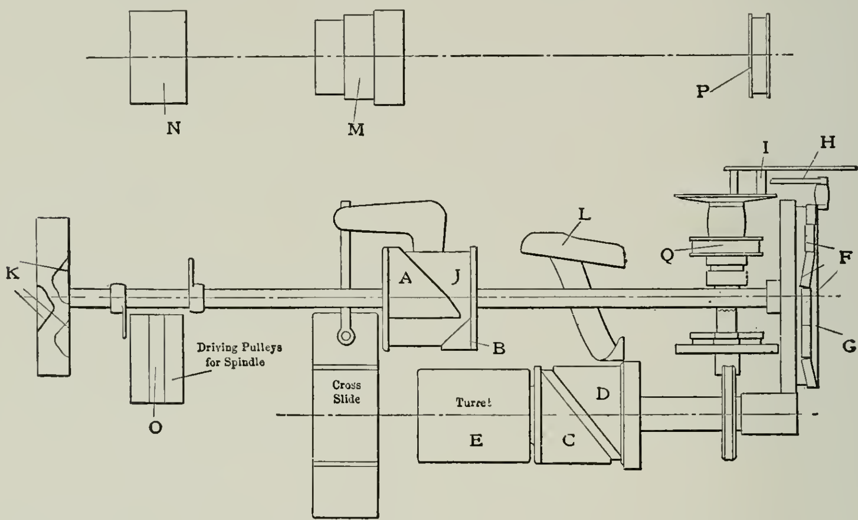



Fig. 48. — Camming Diagram, Cleveland Automatic Turret Machine

reaches the point at which it is to start cutting. The feed of the turret to every revolution of the spindle is variable to suit the conditions of each individual tool held in the turret. That is, if there are five cutting tools in the turret and each tool requires a different feed from any of the others, each individual rate of feed is obtainable by means of the adjustable feed-regulating cams.

### FEED-REGULATING CAMS

These cams, as seen in the general views, and at *F*, Fig. 48, are strips of flat steel $\frac{1}{4}$ x 1 inch, and each cam is held in place by two screws. The cams may be moved across the face of the drum *G*, this movement being provided for by slots milled in the drum, where the screws clamp the cams; also, they may be set at slight angles, taking peculiar staggered positions, as may be seen in the drawing. There are two of the cams for each hole in the turret, and the amount of feed per revolution of spindle is controlled by these cams to suit the individual requirements of each tool.

In setting these cams the operator watches the cutting tools and adjusts the cams until the tools are removing the desired amount of stock per revolution of spindle. A slight change of angle on any of the cams produces a noticeable difference in the turret feed. The cams act through the medium of the levers *H*, which raise and lower the friction roll *I* between the friction disks and so give the variable feed. The disks are clearly shown in Figs. 46 and 47, as well as in the drawing just referred to. The cams *F* that are set at an angle, or staggering, as they appear in the drawing, are in most cases intended for carrying the roll from one cam to another; that is, from the cam set back to the one forward, or vice versa. There are, however, occasional cases when a cam may be used at an angle, say in drilling certain holes. Thus the drill can start in with the feed decreasing, or increasing, as it advances. When using a drill that is not an oil feed, the lubricant does not reach the cutting edge as the drill advances; for this reason it may be desirable not to feed the drill so rapidly, and in such instances it is advisable to use the feed-regulating cam set at an angle.

### CROSS-SLIDE CAMS

The drum *J*, carrying the cross-slide cams, has (as will be noticed in Figs. 46 and 47) a number of rows of tapped holes around the periphery. The cams *A* and *B* are standard for all work and are adjustable around the drum. The rate of feed of the cross slide is variable, this also being controlled through the regulation of the cam-shaft speed by the feed-regulating cams *F*, in combination with the turret feed. If a forming tool is working in conjunction with a drill, the feed is set for the heaviest cut each tool will stand. If a cut-off tool is working either in conjunction with another tool or individually, the cams that take care of this tool are adjusted without interfering with other tools in the different operations.

### CHUCK OPENING AND CLOSING CAMS

These cams are shown at *K*, and are also visible in the half-tone illustrations. As there shown they are cast solid on the face of a segment for bar work, while for magazine and double-camming work a drum is used. For bar work adjustment is unnecessary, as the cams are cast in the correct position to allow ample time for chucking the longest piece within the capacity of the machine.

### STOCK-FEED CAM

The stock-feed cam *L*, which answers for all work except where double feed is required, is cast to the required shape and clamped to the cam shaft. The general form is well illustrated in the rear view, Fig. 46, where the cam is shown just to the left of the cross-slide drum. Its adjustments are either around the cam shaft or lengthwise upon it.

In case double feed is desired, that is, if it is required to feed the stock twice to one revolution of the cam shaft, a drum is put on the shaft in place of this segment, and two cams, which are cast to the same outline as the segment, are fastened to the drum.

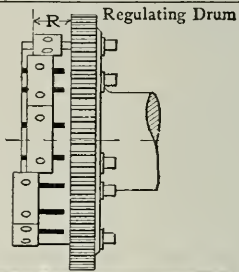
### THE SETTING-UP FORM

Fig. 49 illustrates a printed form that accompanies machines that are tooled and covers all adjustment necessary in doing any class of work.

**POSITION OF TOOLS AND CAMS ON THE CLEVELAND AUTOMATIC**

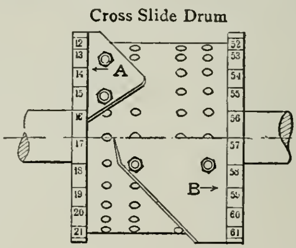
Sample No.________ Order No.__________ Mach.No.________

| Position of Tools in Turrent | | Position of Regulating Cams at R | |
|---|---|---|---|
| 1 | | 1 | |
| | | 2 | |
| 2 | | 3 | |
| | | 4 | |
| 3 | | 5 | |
| | | 6 | |
| 4 | | 7 | |
| | | 8 | |
| 5 | | 9 | |
| | | 10 | |
| 6 | | 11 | |
| | | 12 | |




Position of Cross Slide Cams

| | |
|---|---|
| A | |
| B | |
| C | |
| D | |
| E | |
| F | |
| G | |
| H | |
| I | |
| J | |
| K | |




Tools on Front of Cross Slide

Tools on Back of Cross Slide

| | |
|---|---|
| Pieces per Hour________ | Extra Tools and Attachments |
| Revolutions of Countershaft per Minute________ | |
| Size of Flange Pulley ________ | |
| Size of Spindle Pulley ________ | |
| Pins in Regulating Drum outside________ | |
| Pins in Regulating Drum inside________ | |
| Remarks. ________ | |

Fig. 49. — Setting-up Chart for Cleveland Automatic. (Actual Size 6 × 12 inches)

The feed-regulating drum, shown at *G*, Fig. 48, and the cross-slide drum *J* are both represented on this sheet, which is designed to simplify the setting up of the machine when changing from one job to another.

### SPEEDS, FEEDS, ETC.

The countershaft diagram is included in the drawing, Fig. 48, *M* being a three-step cone belted from the main line; *N* the drum from which the spindle-operating pulleys *O* are driven; *P* a pulley for driving the feed mechanism through the medium of a quarter-turn belt passing over pulley *Q*.

In setting up a job on the machine, the speed at which the spindle must revolve in order to get the peripheral speed of work best adapted to the tools is the first consideration and is obtained by placing the belt from the line shaft on the most suitable of the three steps of countershaft pulley *M*, giving a fast, medium, or slow countershaft speed. As the tool feed is variable between widely separated extremes of feed, the changing of the speed of the countershaft does not affect the feed of the tools, as the feed-regulating cams *F* are adjusted to accommodate the faster or slower speeds of the countershaft and produce the desired rate of feed of the cutting tools per revolution of work.

### ATTACHMENTS AND TOOLS

A number of useful attachments are made for this machine and two of these are shown in Figs. 50 and 51. The independent cut-off attachment is designed to be used in cases where the forming to be done is too long for one forming tool and without this attachment would have to

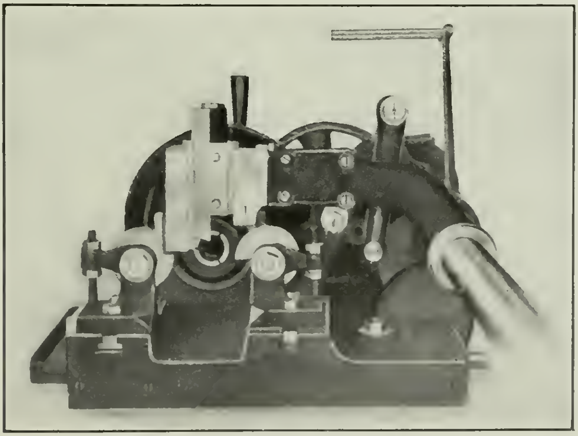


FIG. 50. — Independent Cut-off Attachment

be partly formed on the automatic machine and finished by a second operation in another machine. By using the independent cut-off device two forming tools can be used; one on the front of the cross slide and one on the rear; the piece being cut off by the attachment which is in no way connected with the cross slide, but rests on the hood of the live spindle and the cam shaft, and is operated by a cam on the latter. In this way the piece is completely finished on the automatic machine.

### THIRD SPINDLE-SPEED ATTACHMENT

Another important device is the third spindle-speed attachment by which a slow spindle speed forward is obtained in addition to the regular forward and reverse speeds. This attachment is of service especially when taking heavy cuts or threading work of large diameter and coarse pitch. With the belt on pulley *A*, Fig. 51, the normal speed is obtained; with the belt on pulley *B* and clutch *C* in operative position, the slow

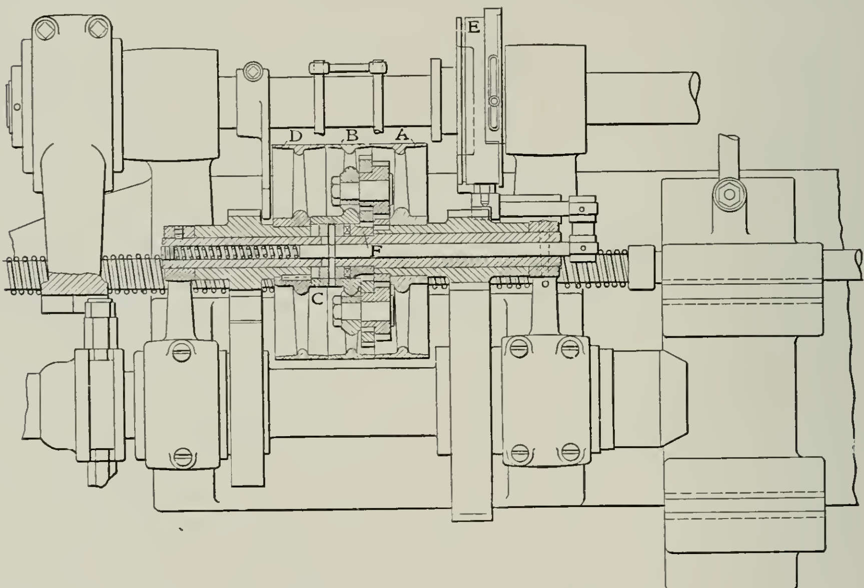



Fig. 51. — Third Spindle-Speed Attachment

spindle speed is derived through the medium of the planetary gears. When the belt is on pulley *D* the rapid reverse speed is secured for backing off the die or for cutting off the stock. Clutch *C* is controlled by cams on drum *E* and is engaged with pinion *F* to hold the pinion fast when the spindle is to be driven at slow speed by operating the belt on pulley *B*. When the clutch is disengaged, releasing pinion *F*, *B* becomes a loose pulley.

The magazine attachment is not illustrated here as it is shown in position on a Cleveland machine in Chapter XIV.

### TURRET TOOLS

A few typical turret tools are illustrated in Figs. 52 to 57. The first of these is a roller rest box tool with independently adjustable rolls to accommodate different sizes of stock, and with three turning tools adapted to be adjusted in the manner indicated. The block nearest the inner end of the box tool carries an auxiliary steady rest with a roll at its end which may be applied when the work is reduced to such a small diameter that it is liable to spring away from the cutting tool which is shown

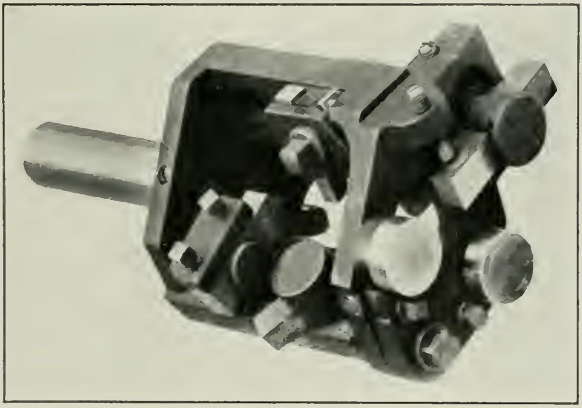


FIG. 52. — Roller Rest Box Tool

opposite the rest in a vertical position. Fig. 53 shows a combination drilling and chamfering tool. Fig. 54 is an adjustable boring tool which may be used where it is necessary to secure perfect concentricity with the exterior of the work. Fig. 55 is a die and tap holder in which the socket for the die or the tap is connected with the holder proper by a

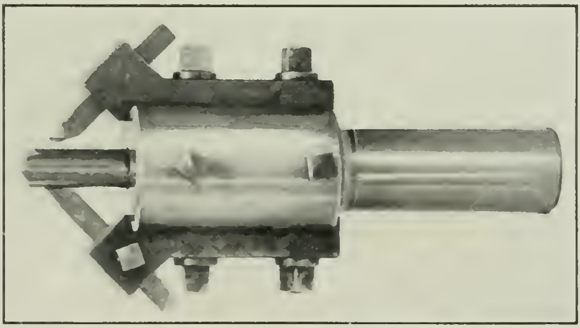


FIG. 53. — Combination Drilling and Chamfering Tool

pair of rolls operating in oppositely located slots. This gives the threading tool considerable freedom longitudinally and assures accurate results even though the turret itself is not fed forward at the exact speed with which the die is drawn onto the work. Fig. 56 is a roller steady rest used where it is advisable to support a piece of work undergoing forming operations. The method of adjustment is sufficiently clear to require no explanation.

### COMBINATION UNDERCUT FORMING AND CUT-OFF TOOL

This style of tool, shown in Fig. 57, is used very extensively on the Cleveland machines. It will be noticed that it has an adjusting wedge so that the work diameter can be varied more or less. In using the form-

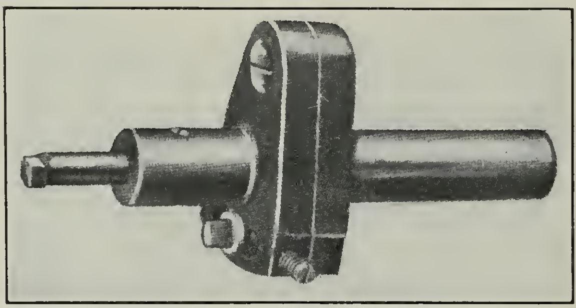


Fig. 54. — Adjustable Boring Tool.

ing tool in combination with a cut-off tool, the undercutting tool is set in advance of the cut-off; in other words, it passes under the work, completing the outside of the piece and keeps in advance while the cut-off

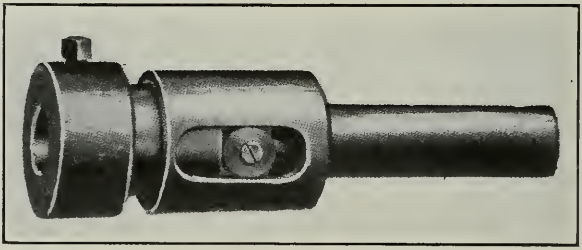


Fig. 55. — Tap and Die Holder

tool is severing the piece from the bar. In combination with the forming tool it rounds the corner or produces any shape desired before the cut-off tool on the opposite side of the slide has advanced to sever the piece.

### MACHINE CAPACITIES

The regular turret machines of the type illustrated in this chapter are built in a wide variety of sizes; the smallest having a chuck capacity of $\frac{1}{4}$-inch and turning lengths up to $1\frac{1}{8}$ inches, while the largest, which is intended for handling tubing of large diameter and for forming bevel gears and other parts from the bar, admits 6-inch material through the chuck and is capable of turning lengths up to $6\frac{3}{4}$ inches. A line of "plain automatics," operated on the same principle, as the machine described, are built with a single tool head in place of the regular turret. These are intended especially for manufacturing studs, rollers, short screws,

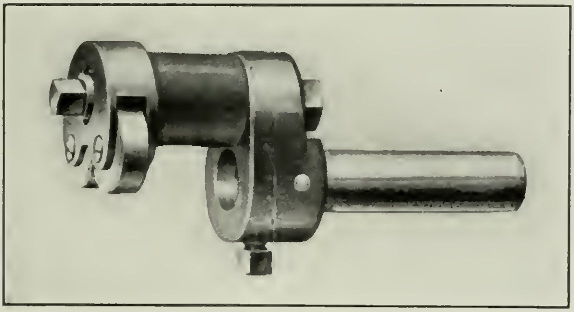


Fig. 56. — Roller Steady Rest

taper pins, etc., where the forming may be done entirely with the cross-slide tools. Several sizes of automatic chucking machines are also built by this company, these being adapted for finishing castings and forgings

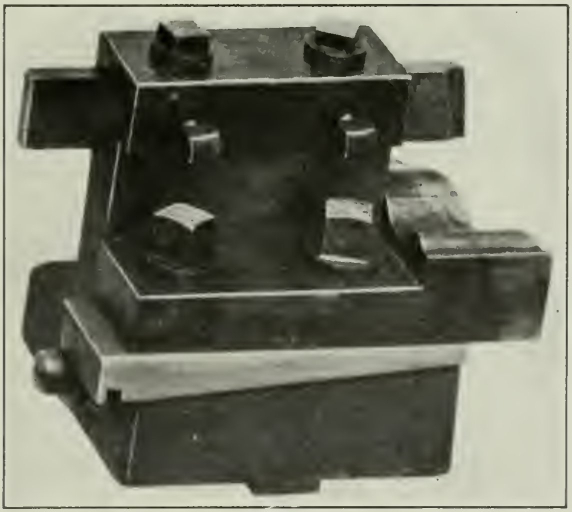


Fig. 57. — Combination Undercut Forming and Cut-off Tool

which are handled in jaw chucks or on face plate fixtures. These machines, in general design and operation, are similar to the regular turret machine illustrated.

# CHAPTER VII

## The Gridley Single-Spindle Automatic Turret Lathe

This machine, built by the Windsor Machine Company, Windsor, Vermont, is designed for handling bar stock up to 2 inches diameter and for turning lengths of 8 inches, the feed of the turret tools being

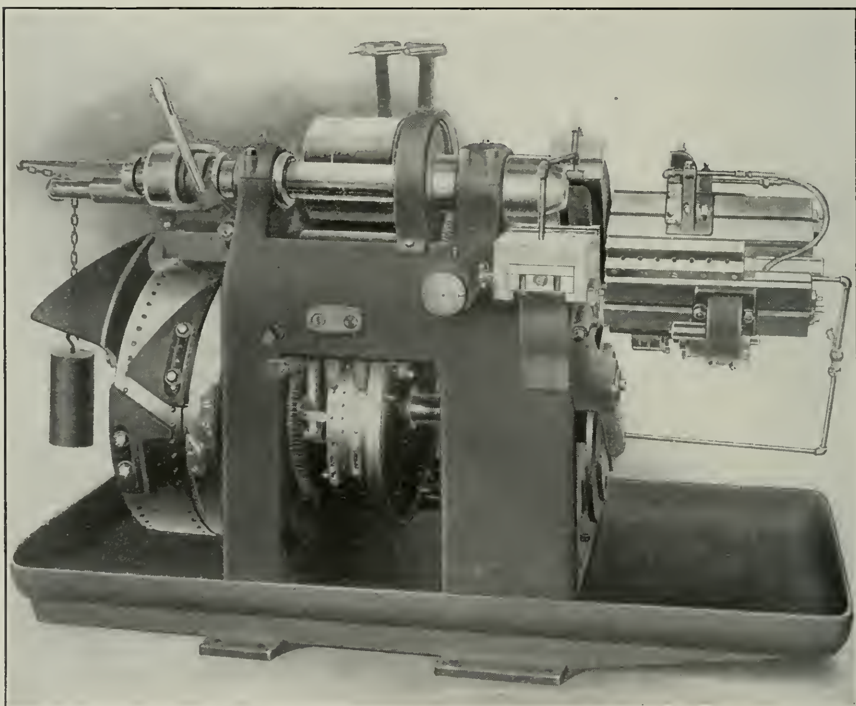


Fig. 58. — Gridley Automatic Turret Lathe

slightly in excess of the latter figure. It is equipped with a spindle geared from a back shaft in the ratio of 3 to 1 and driven by $2\frac{3}{4}$-inch belts operating on 11-inch pulleys. The pulleys are driven at two different speeds by open belts, except when it is necessary to reverse the spindle, then one is driven by cross belt in opposite direction.

### THE SPINDLE AND CHUCK

The spindle is fitted with the usual type of spring collet and feed chuck, and the chuck is operated by cams at the inner edge of the drum shown to the left in the general view, Fig. 58, while the feeding of the stock is accomplished by a weighted sliding block engaging the rear end of the feed tube, the weight drawing the stock forward as the chuck is opened (which movement takes place just as the high point of the large cam at the outer edge of the drum passes the contacting roll under the feed

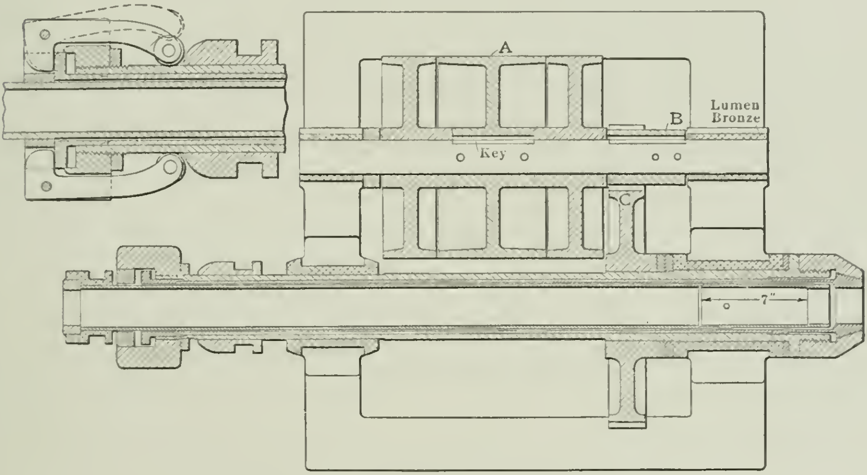



FIG. 59. — Gridley Spindle Construction

block), but the incline on the heel of the cam preventing abrupt throwing of the bar against the stock stop carried by the turret. The construction of the spindle and its driving mechanism is shown in the sectional drawing, Fig. 59.

### THE TURRET

The turret is four-sided, with as many longitudinal gibbed slides for the tools, and, as shown in Fig. 60, is cast integrally with a long hub of large diameter extending through the bed of the machine. This hub or spindle is hollow and through it passes a shaft which at the rear end carries a crosshead and roll *A*, which in connection with the cams *B* and *C* on the face of the feed drum reciprocate the shaft and operate the tool slides on the turret. Only that tool which is in working position is affected by the movement of the shaft, however, as connection between the shaft and any tool slide is made only when that particular slide swings up into line with the work spindle. This connection is effected by a pin *D* under the slide, and which at the proper moment enters a notch in a dog carried by the shaft *E*. As the turret makes its next partial rotation, the connecting pin clears the engaging dog and the pin under the succeeding slide enters that notched member. Feed cams of three angles are regularly included, these being suitable for fine, medium, and coarse feeds. The cams are readily located about the drum in any required position.

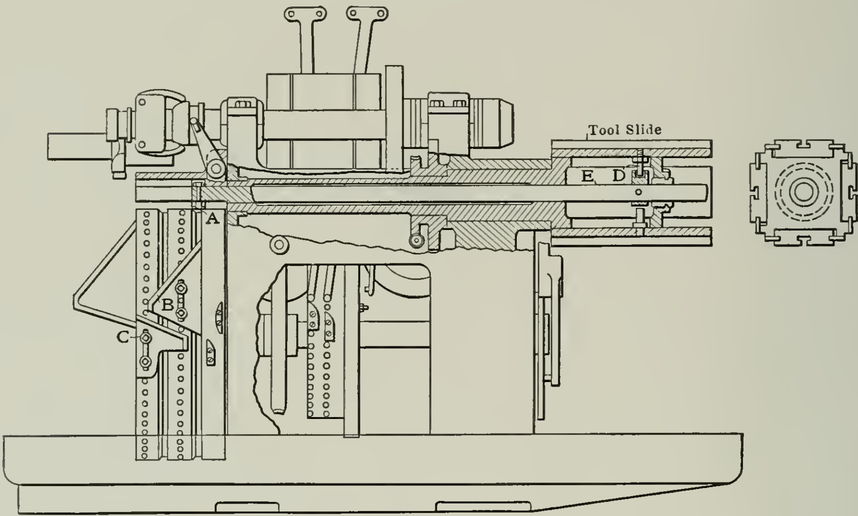



FIG. 60. — Gridley Turret Construction

### CAM-SHAFT DRIVE

The cam shaft is driven by worm wheel and worm shaft actuated by the well-known differential gear or "sun and planet" mechanism, the quarter-turn belt being shifted at the proper moment from fast to slow driving position, or vice versa, by a forked guide operated through the medium of adjustable dogs carried by a disk on the cam or main shaft. This feed, as seen in Fig. 61, may be thrown out of action at any time by turning a small handle at the front of the bed, this handle being attached to a shaft carrying at its rear end the pawl which locks the ratchet wheel in this form of drive. Of the two pulleys, *F* is the one driving through planetary gears, the pulley making 70 revolutions to one turn of the worm *G*. When the belt is shipped onto pulley *H*, which is pinned to the worm shaft, the cam shaft is rotated rapidly for moving the tools to or from their cuts at high speed.

### TURRET REVOLVING AND LOCKING MECHANISM

The turret rotating mechanism is driven, as in Fig. 62, by an independent worm and worm-wheel, also rotated by a quarter-turn belt at the rear of the bed.

The locking disk *A* is keyed to the stem *B* of the turret and carries

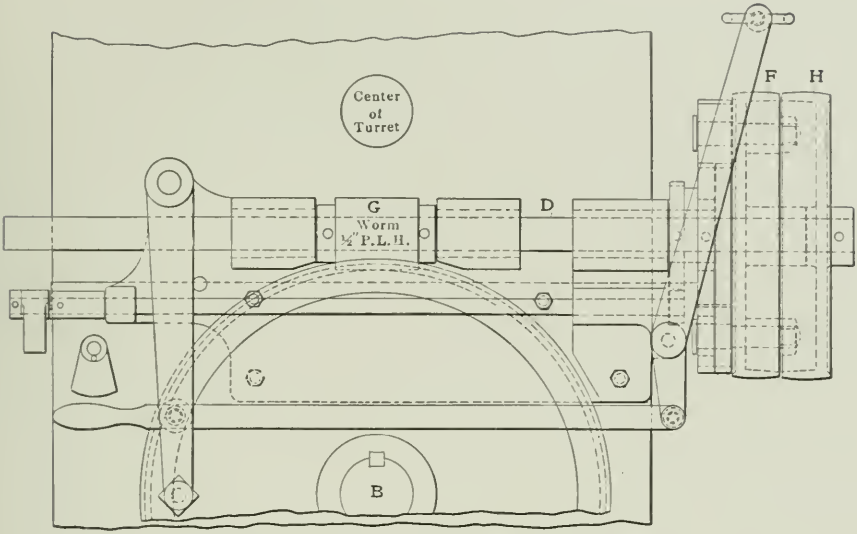



Fig. 61. — Feed Drive for Cam-Drum Shaft

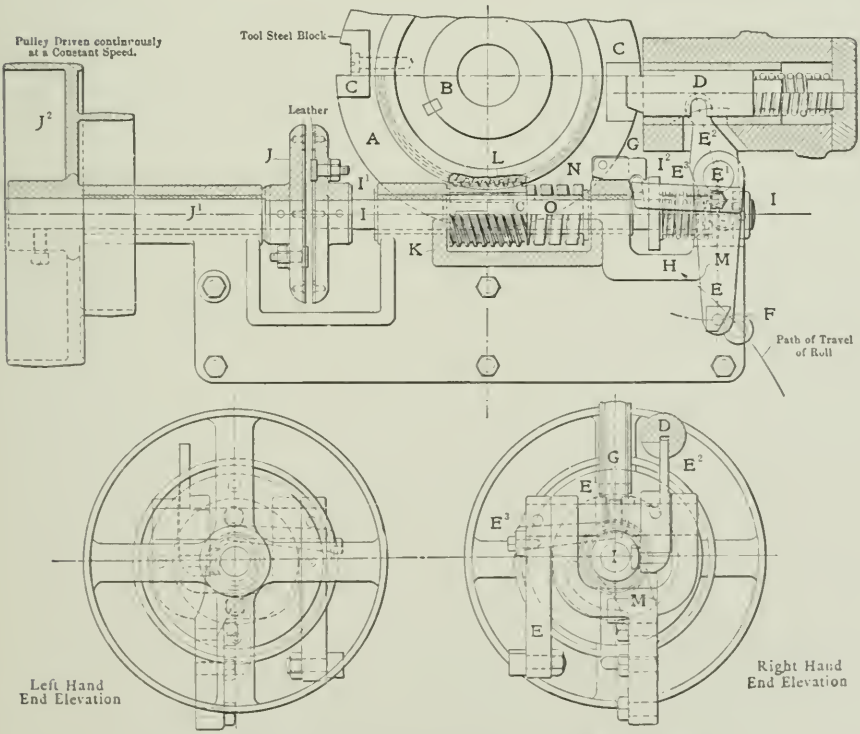



Fig. 62. — Turret Revolving and Locking Mechanism

4 tool steel shoes *C* into which the locking pin *D* enters. The locking pin is withdrawn by the lever *E* with its shaft $E^1$ and arm $E^2$, the upper end of which enters a hole in the locking pin. The lever *E* is operated by the roll *F*, which is fastened in the edge of the cam drum. This is the cam drum between the columns of the frame. When this lever *E* has been moved forward far enough to draw the locking pin clear from the seat *C*, the arm $E^3$, attached to the lever *E*, raises the latch *G*, and the spring *H* slides the shaft *I* with its clutch member $I^1$ into engagement with the other clutch member *J*, which is driven constantly by the shaft $J^1$ and its pulley $J^2$; this causes the shaft *I* to revolve, and that in turn revolves the worm *K*, thus causing the turret through the worm *K* and worm gear *L* to revolve.

It will be noticed that the end of the locking pin rides on the periphery of the locking disk *A* after the roll *F* has passed the projection on *E*. When the turret has revolved so that the locking pin drops into the notch in seat *C*, the shaft *I* with its clutch is moved endwise out of engagement with the constantly revolving member *J*, by the pin *M* in the lower end of the lever $E^2$. In order to take care of the momentum of the revolving parts and clutch $I^1$, which is geared with the turret through the worm *K* and worm gear *L*, a spring *N* is interposed, one end of which bears against the bracket which carries the revolving parts, and the other end against the worm *K*, so that when the turret stops revolving, the spring *N* allows the worm *K* to act as a screw, the worm gear *L* acting as a nut, so that it is not necessary to stop the movement of the revolving parts instantly.

The worm *K* is splined to a bushing *O*, but is free to move endwise on the bushing, the latter being splined to the shaft *I*. The object of the latch *G* and the spring *H* is to prevent the engagement of the clutches $I^1$ and *J* until the locking pin *D* has been entirely withdrawn from the inserted shoe *C*, then the further movement of the lever *E* with its arm $E^3$ raises the latch *G* out of engagement with the collar $I^2$ on the shaft *I*. The movement of the lower end of the lever $E^2$ compresses the spring *H*, so that when the latch *G* is clear of the collar $I^2$, shaft *I* is given a quick endwise motion to bring the two clutch parts together. There is a leather ring on each of the clutch parts so that when they are brought together by the spring *H* the turret is operated by the frictional contact between the leather rings. In fact the frictional engagement oftentimes accomplishes the revolving of the turret without the necessity of the steel clutches.

### THE CROSS SLIDE

The cross slide is operated by a cam under the turret. It is fitted to a heavy guide and a broad, taper, adjustable shoe is fitted to the top of this guide to take up any play. The slide may be utilized for either forming or cutting-off operations. When it is used for forming, the cut-off tool is carried in the pivoted arm at the back, this arm also being operated by a cam on the disk beneath.

### THE TURRET TOOLS

The slides carried by the turret give plenty of room for tools of any class or size likely to be required; each slide is provided with a longitudinally placed screw for adjusting the tools accurately to and from the spindle. Where desired, the stock stop may be clamped in one of

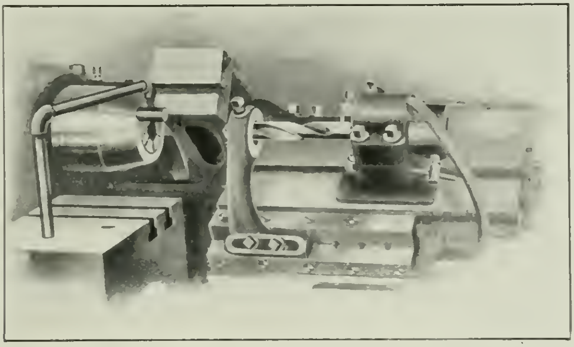


Fig. 63. — Turret with Drill and Guide in Position

the corners of the turret, thus leaving all four faces clear for cutting tools, and when so arranged, an extra notch is provided in the index disk to stop the turret in an intermediate position. By dropping a block into one or more notches in the index disk the turret may be allowed to skip one or more stations, thus turning quickly through two or more points in its rotation before it is again locked.

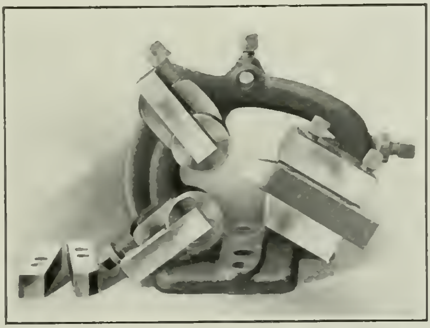


Fig. 64. — Turner with Roller Back Rests

Two tools may be placed in tandem order on any slide, and when drilling long holes the drill may be secured — as in Fig. 63 — in a holder at the rear while an auxiliary block at the front carries a supporting bush. The turning tools are equipped with roller back rests as in Fig. 64, and to each tool, as well as to drills, there is an oil supply which can flow to the tool only when the latter is in operating position. The oil piping will be seen in the various illustrations.

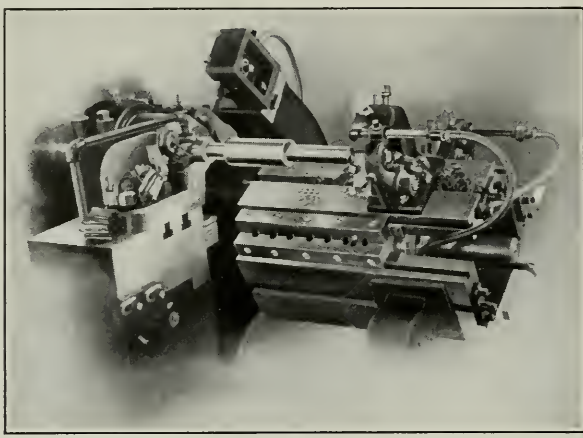


Fig. 65. — Turning and Forming

Fig. 65 shows a turner and cross-slide tool in operation, and Fig. 66 illustrates a 12-inch finishing slide.

### TWELVE-INCH FINISHING SLIDE

The object of this tool, which is primarily a finishing device, is to take a longer cut than the cams or the turret itself will admit. The regular feed cams will give only an $8\frac{1}{2}$-inch movement, but with this tool a straight cut 12 inches in length can be taken, and allow $\frac{3}{4}$-inch clearance. This is accomplished by having a rack under the slide operated by the regular

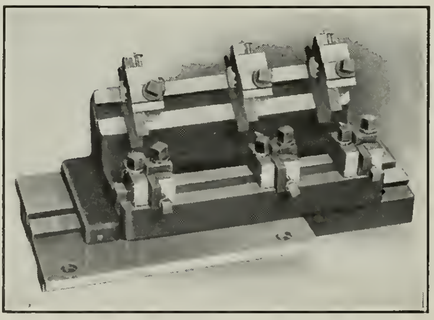


Fig. 66. — Twelve-inch Finishing Slide

draw bar in the usual manner. This rack runs in a pinion, onto which is fastened a large gear which in turn runs in a rack attached to the tool slide, and the rack operated by the draw bar thus gives an increased movement to the rack attached to the tool slide. To use the tool the regular slide is taken out of the turret and the 12-inch slide put in its place.

### TAPER TURNER

A taper turner is shown in Fig. 67. It carries two tools, one of these carried in post *A* preceding the back rest jaws *B*, giving the work a true

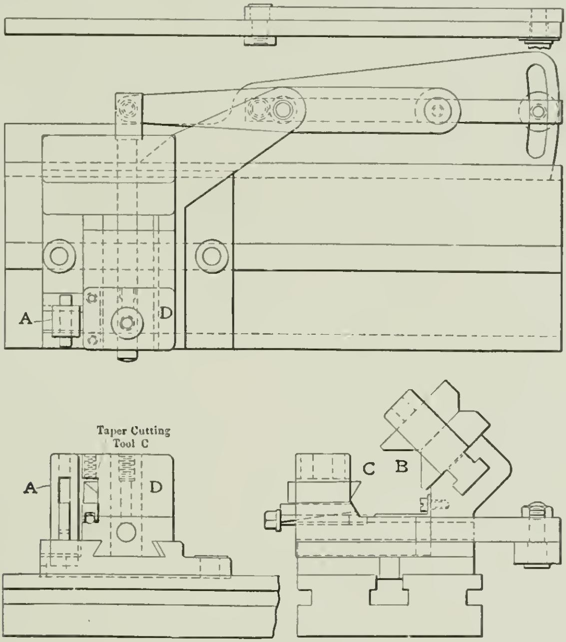



Fig. 67. — Taper Turner

cylindrical surface, while the tool *C* following the back rest is carried by a cross slide *D* whose movements are controlled by the taper bar shown at the rear.

### DIE HOLDER

A method of mounting an opening die on the turret is shown in Fig. 68, where the die is mounted in a sliding sleeve which is held back in normal position by a light spring, the head in this position resting against a cushioning compression spring which prevents the die striking the work abruptly as it feeds forward. The die once started on the cut, the turret slide stops and the sliding carrier then moves forward in its holder until an opening lever on the die head strikes an adjustable stop bar shown just below the die proper. This opens the chasers, and, as the turret slide returns, the bent lever at the side of the die comes into contact with another stop secured in the corner of the turret, and by turning the die head slightly closes it for the next cut.

The method of belting from the countershaft will be understood from Fig. 69, no explanation being called for.

### MOTOR DRIVING AND CONTROLLING ARRANGEMENT

An interesting form of the Gridley automatic turret lathe, in which both the work spindle and cam-drum shaft are driven by variable-speed

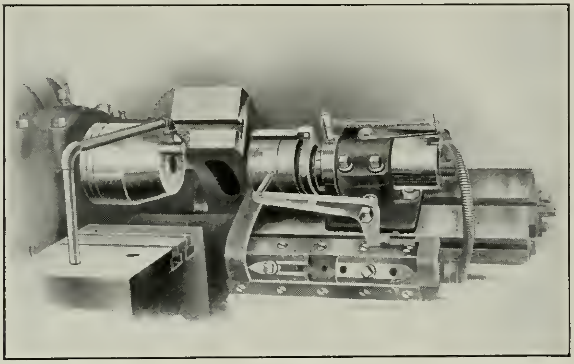


Fig. 68. — Turret with Opening Die in Place

motors the controllers of which are operated automatically by cams on one of the drums, is shown in Figs. 70 and 71. This arrangement gives a very flexible control of cutting speeds and feeds throughout the cycle of operations required to produce any given piece of work.

This type of motor-driven machine is made in two sizes, one taking bar work up to $3\frac{1}{4}$ inches, and the other up to $4\frac{1}{4}$ inches diameter. The variable-speed motor for the spindle is mounted as represented in the engravings, at the top of the head-stock and behind the spindle. The motor shown is a General Electric 3-horse-power machine geared 10 to 1 to the spindle.

### CAM-SHAFT DRIVE AND MOTOR CONTROL

The variable-speed motor operating the drum shaft and the turret-revolving mechanism is fixed to a bracket which is attached to the oil pan and the rear column of the machine, as shown in Fig. 71. Both motors are operated by controllers placed near the floor at the front side of the machine. The metal tubing incasing the armature and field wires from the spindle motor to its controller is shown in Fig. 70, while in the end view the wires from the feed motor to its controller are seen following the top of the oil pan. The controllers themselves are operated automatically by a small gear beneath the controller handle meshing with a segment gear pivoted on the frame holding the controllers, the segment gear being moved as desired by cams bolted to the operating drum. By using different cams any desired speed may be obtained for the spindle motor, or it may be entirely stopped while the tools are withdrawn from finished work.

### SPEED AND FEED VARIATION

In threading work, inside and out, advantage is gained by slowing the spindle motor to the proper threading speed, and then reversing at full speed for backing off or out solid dies or taps. This not only saves considerable time, but by having the proper cutting speeds better threads are obtained. The variable-speed feed motor in combination with the four sets of feed cams in the machine equipment gives the proper range

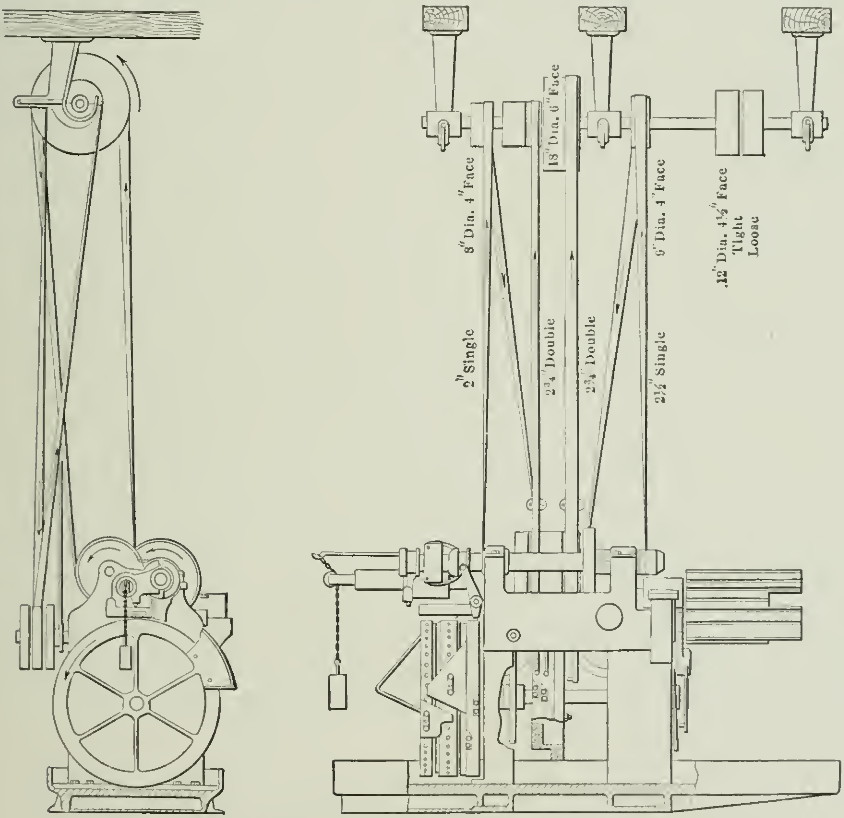



Fig. 69. — Countershaft and Drive for Gridley Automatic Turret Lathe

of feeds, from that required in drilling tool steel to the coarsest roughing cut a ½ x 1 inch high-speed roughing tool flooded with oil will stand. The wide range in both speeds and feeds instantly obtainable for every operation, with also a variable reverse speed of the spindle, enable the machine to handle to advantage any work within its capacity. The fast and slow motion for the drum shaft is obtained by driving the worm direct from the feed-shaft motor or back-geared through planetary gears, operated by the same cams as are used on the belt-driven machines for this purpose.

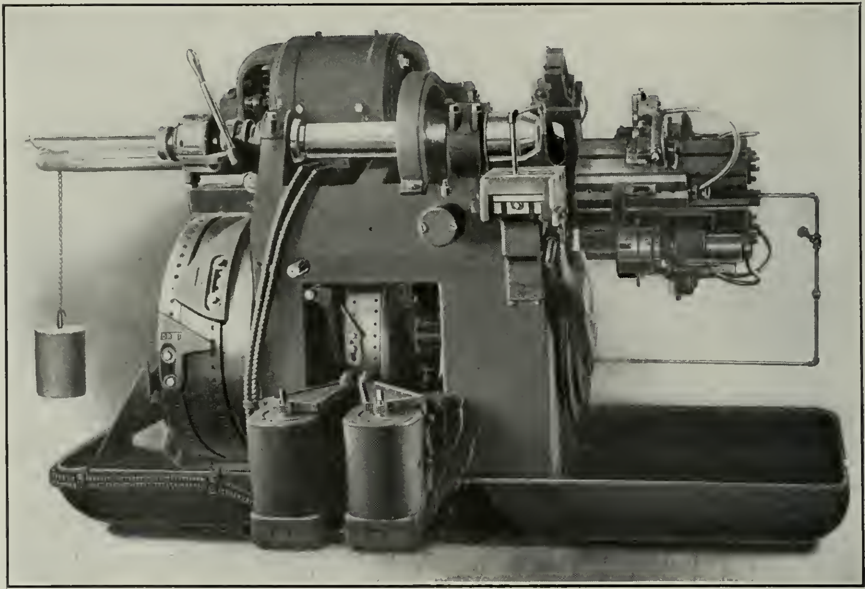


Fig. 70. — Gridley Motor Operated Turret Lathe

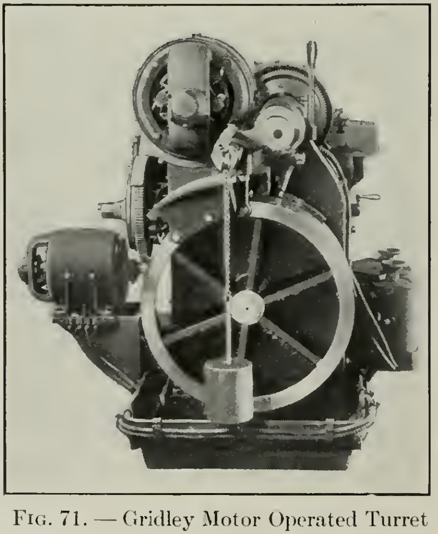


Fig. 71. — Gridley Motor Operated Turret Lathe (End View)

The tools used on this machine are of the same general type as already shown in connection with the Gridley belt-driven automatic.

# CHAPTER VIII

## The Alfred Herbert Automatic Screw Machine

The accompanying half-tone, Fig. 72, illustrates the automatic turret machine built by Alfred Herbert, Ltd., Coventry, England. The machine shown, which is one of the larger sizes made by this concern, will admit a $3\frac{1}{2}$-inch bar through the spindle and will turn up to a length of 8 inches. It is illustrated as fitted up for producing shells for quick-firing guns.

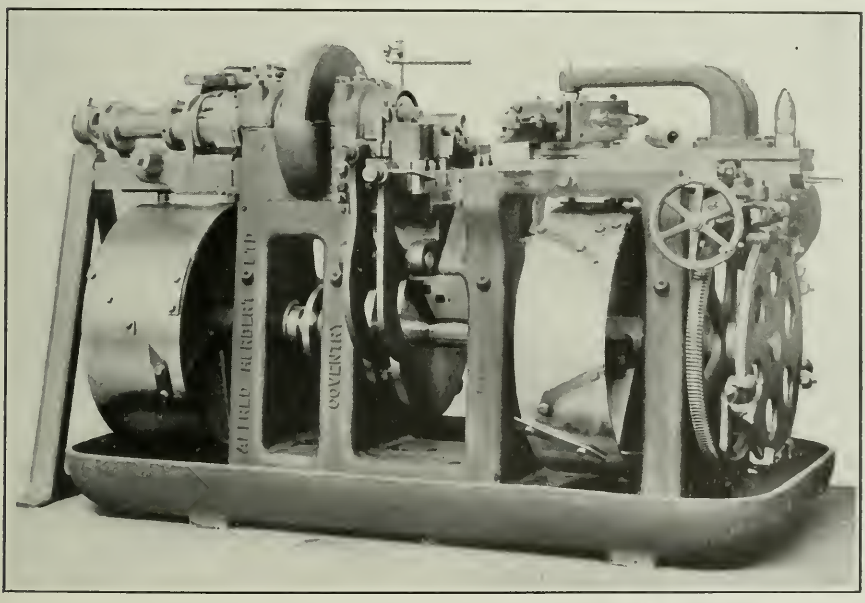
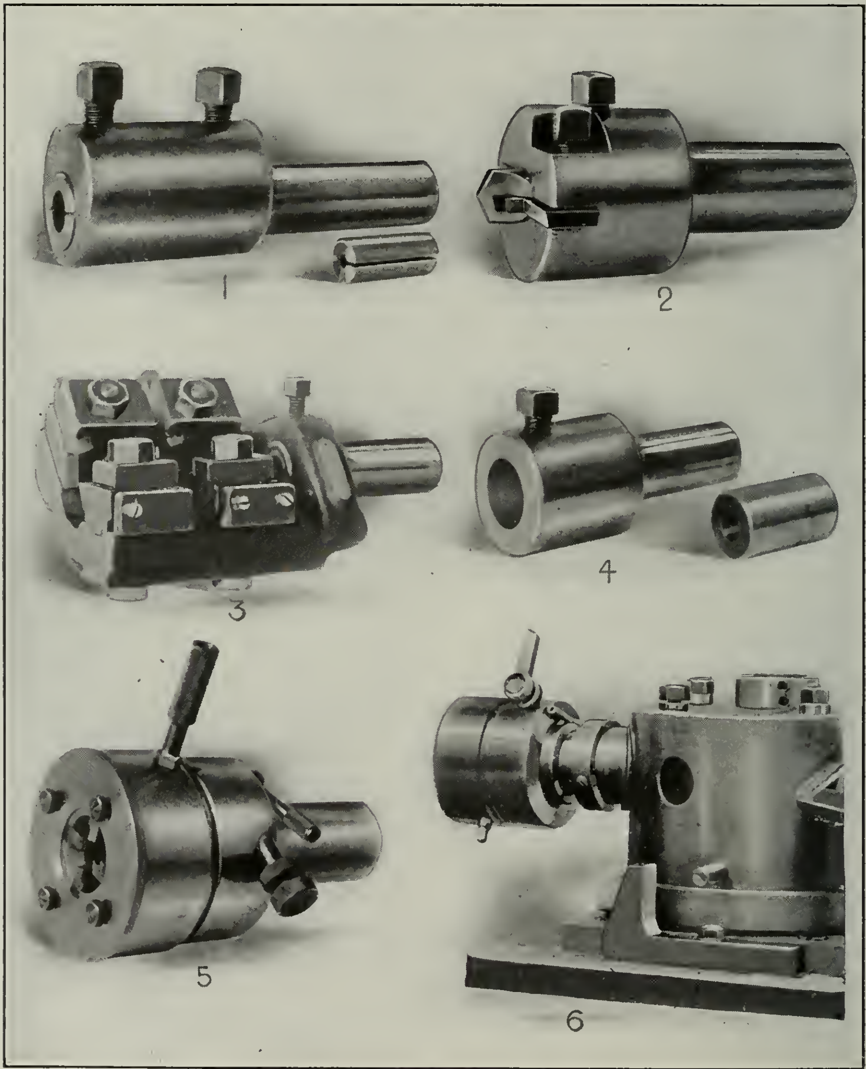



Fig. 72. — Alfred Herbert Automatic Screw Machine

The arrangement of the cam-shaft drive, and cam drums, the cross-slide mechanism, etc., are clearly brought out in the general view. The spindle with its spring collet and stock-feeding apparatus is driven by a shaft at the rear to which it is connected by gear and pinion, the driving shaft being operated by a pair of belts from the overhead works. The arrangement is such that both of the belts can be open and one of them faster than the other where it is desirable to change the speed of the work during its progress, as for tapping or external threading, the speed changing automatically the same as though it were reversing.

The type of tools used in turret and cross slides is shown clearly. A number of turret tools are also illustrated in Fig. 73. One of the tools in the group is the Coventry opening die, and this die is also illustrated mounted in a spring holder in the turret and with the operating cam at the side of the latter. The magazine machines built by this company are described in Chapter XV.




1. Drill Holder and Bushing.
2. Centering and Facing Tool.
3. Box Tool with Two Cutter Blocks.
4. Steady Bush Holder.
5. Coventry Opening Die.
6. Opening Die in Turret.

Fig. 73. — Tools for Herbert Automatic Screw Machine

# CHAPTER IX

## New Spencer Double-Turret Automatic Screw Machine

The Spencer screw machine, with its two turrets, as now built by the Mack Manufacturing Company, Jersey City, N. J., is illustrated in Fig. 74. It handles stock up to $1\frac{5}{8}$ inches through the hollow spindle and finishes both ends of a piece without removing it from the machine.

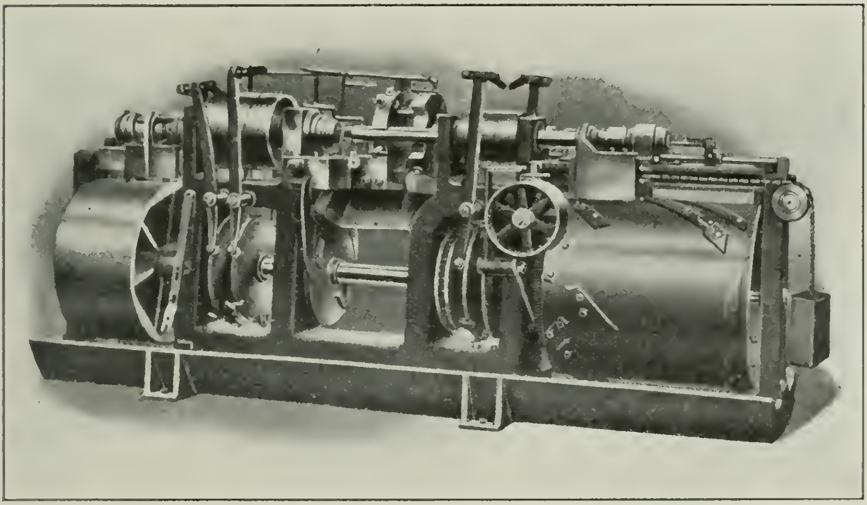


Fig. 74. — Spencer Double-Turret Automatic Screw Machine

The drum at the left carries the cam strips which control the stock feed and the chuck of the main spindle. Next come the two disks with cams for controlling the belt movement in either direction; then the cut-off and forming-tool cam disk under the cut-off slide; the friction disk which revolves the turrets at the proper time; two more belt-shifter disks; the worm-feed mechanism for revolving the drum or cam shaft and the large drum with the cams for the first or left-hand turret; the cams for the secondary spindle movement, and for controlling the chuck in this spindle.

The two turrets are mounted on spindles at the back of the machine, the spindle for the left-hand turret telescoping through the quill on which the right-hand turret is mounted. The latter does not move endwise, but the work is fed to the tools of this turret.

The first turret is fed to the work through the quill, and both turrets are made to revolve together by two studs, fastened in one turret and sliding in the other, as can be seen above the secondary spindle.

The stops are carried in the outer edge of the first turret and rest against the plate shown, which also guides the tools in line to their work. The cams draw the stop off the end of the plate when it is time to revolve, the friction disk with the chain which is constantly pulling the turret forward revolves it, the cam throws the next stop over the plate and the next tool goes to work.

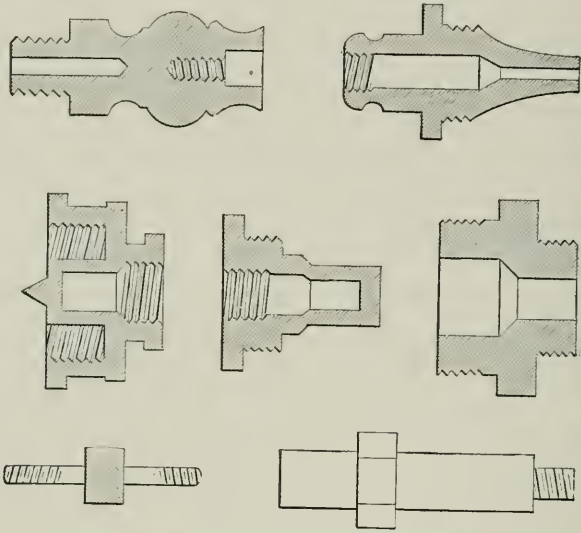


Fig. 75. — Work Done on Double-Turret Machine

In operation the bar is fed in through the left or main spindle to a stop in the first turret, the chuck is closed and the tools in the left turret commence operations on the piece. Taking any one of the pieces shown in Fig. 75, the making of the first end is, of course, regular screw-machine work. When ready to cut off, however, the long slide throws the secondary spindle forward, past the open side of the second turret, till the chuck closes over the end of the work already finished. As both the work and the secondary spindle are revolving at the same rate, there is no difficulty in gripping it firmly and without injury.

Then the second spindle recedes, carrying the work, and the turrets revolve; while the first turret is at work on the beginning of a new piece, the second turret is finishing the back end of the piece in the second spindle. In this case the work is fed to the tools.

When the last operation is done, the secondary chuck opens, the ejector controlled by the spring at the extreme right pushes the work out of the chuck, and it is ready to go forward again, to take a new piece which the first turret has finished and is ready to cut off.

# CHAPTER X

## The Cleveland Double-Spindle Plain Automatic Machine

The two-spindle machine illustrated in Fig. 76 is designed primarily for forming and shaving both ends of the work, thus obviating the necessity for a second operation. It has, in place of the usual Cleveland turret, a second head carrying a spindle in line with the main or left-hand spindle through which the stock is fed in the customary manner. After the end of the bar is fed through the left-hand or main spindle and is gripped in

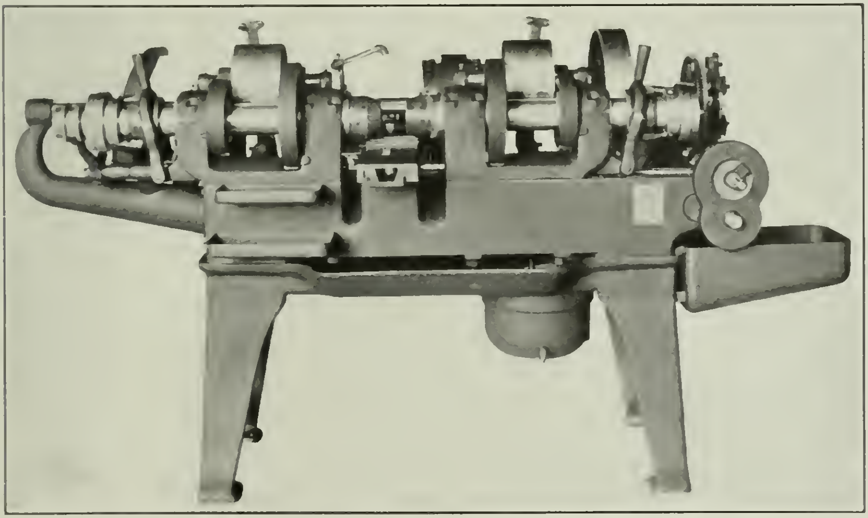


Fig. 76. — Cleveland Double-Spindle Plain Automatic

the chuck, a combination cutting-off and forming tool advances and completes the outer end of the piece; it is then fed through the right-hand spindle hood, the chuck mechanism on both spindles acting simultaneously. The piece then partly finished is gripped in the right-hand chuck and the forming tool advances, finishing both ends as seen in Fig. 77. After the forming tool has advanced far enough to separate the two pieces it still continues to feed forward for a short distance until both ends are shaved clean and exact to size. As these operations take place on one piece after another, the finished parts are moved through the right-hand spindle head, finally dropping into the pan fastened to the end of the machine. The spindle and cross-slide operations are controlled in practically the same manner as on the regular turret machine built by the same company and illustrated in Chapter VI.

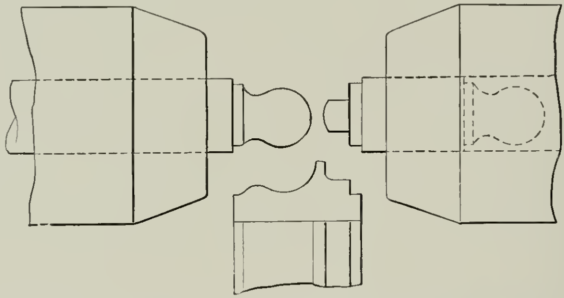


Fig. 77. — Work on Cleveland Double-Spindle Machine

## CHAPTER XI

### The Acme Multiple-Spindle Automatic Screw Machine

The multiple-spindle automatic screw machine built by the National Acme Manufacturing Company, Cleveland, Ohio, is illustrated in its latest form with single-belt drive in Figs. 78 and 79. When equipped for motor drive the single driving pulley is replaced with a spur gear and the motor connected to this is carried on a bracket placed at the left of the gear.

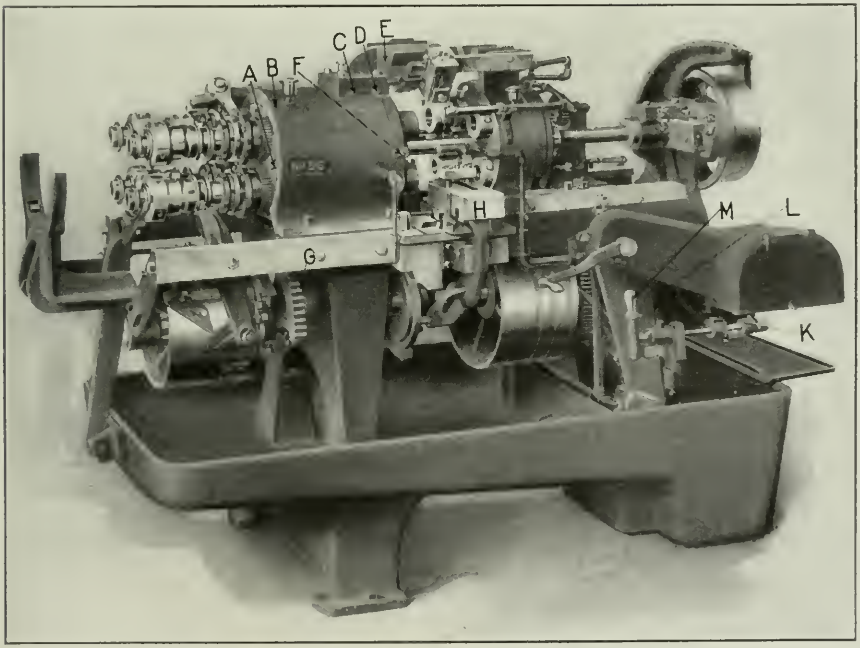



Fig. 78. — Acme Multiple-Spindle Automatic Screw Machine

The machine as shown consists primarily of a cylinder A, Fig. 78, holding four stock-carrying spindles and a series of slides carrying tools which operate on all four bars from the side, top, and end at one time.

As there are two slides operating from opposite sides of the machine, two from the top and one (the main slide, which is capable of carrying four tools, one for each spindle) from the end, it is possible to use eight separate tools at one time — two on each bar, one from the end and one from the side.

After a bar has been operated upon in the first position by one pair of tools, it is carried on to the next pair by the cylinder which is indexed by quarter turns. In this manner, after three sets of tools have finished their work upon the piece, it is carried to the fourth position where the final tools (one of which is a cutting off blade) operate upon it. This

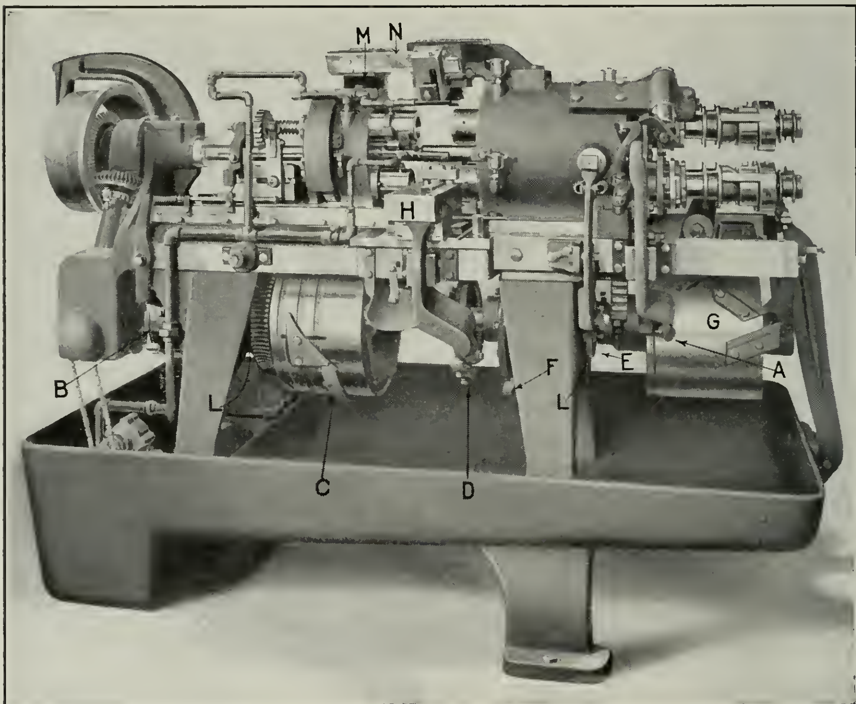



Fig. 79. — Acme Multiple-Spindle Automatic Screw Machine (Rear View)

gives a finished piece at each quarter turn of the cylinder. As all tools work simultaneously, the time required for the longest single operation is the time necessary to finish the piece.

It is frequently possible to combine two or more tools, such as a box tool and a drill, two dies, die and tap, drill and countersink, etc., or to use special attachments, described later. In such cases more than eight operations are readily performed.

The stock is fed in the manner generally adopted on automatic screw machines, all movements being cam controlled and positive. The length of feed and position of the gage stop are easily changed to meet the requirements of the work in hand. The gage stop on this machine does not occupy one of the end tool positions, but is so arranged that the stock is fed against it during the quarter turn of the cylinder on the smaller machines, and just before the tools engage the stock in the first position on the larger sizes, the stop being swung back to allow the tools to come into contact with the stock.

### DRIVING AND SPEED CHANGE MECHANISM

The drive to the four work spindles is transmitted by the longitudinal shaft and connecting gearing as illustrated in the general views and in Fig. 80, and the speed-changing mechanism and cam-shaft drive are arranged as represented in Fig. 81.

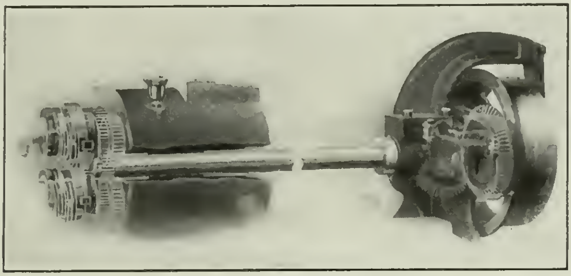


Fig. 80. — Acme Spindle Drive

A change-gear system is used in connection with these mechanisms in order to transmit driving power, as well as facilitate rapid changes in the spindle speeds and tool feeds.

The stock-spindle speeds are controlled by back gears *A*, Fig. 81. When running direct, gears on the stud *B* are slipped out of engagement with those on the pulley hub and top shaft, or removed entirely.

Direct drive is obtained by first sliding gears on the stud out of mesh, then binding together thimble *C* and pulley (or gear, if motor driven), with the two screws furnished for this purpose. When changing from direct speed, the two thimble screws are removed before placing the gears on the stud in mesh with the gears on the pulley hub and shaft. To change the spindle speed, the vertical section of overhanging arm *D* is removed by removing screw *E*, after which thimble *C* is removed, the pulley (or gear, if motor driven) slipped off of the top shaft and the gears slipped from the hub of the pulley and stud, replacing with the gears to be used.

### FEED CHANGES

Feed-rate changes are controlled by gears *F*, Fig. 81 through which the cam shaft is operated. The idle movements of the machine (those which occur when the tools are not operating on the work, such as feeding in of the rods, indexing of cylinder, movement of tool slide toward and from the work, etc.) occur when the machine is running at the constant or direct speed, or when sliding clutch *G* is engaged with the teeth in clutch collar *H*. Through the use of roller clutch *J* the feed-change gears remain idle during these movements. Various classes of work can be produced at a higher rate than is provided by the direct feed drive. This is accomplished by the use of certain combinations of change gears and is clearly set forth in a gear table, supplied with the machine. The shifting of

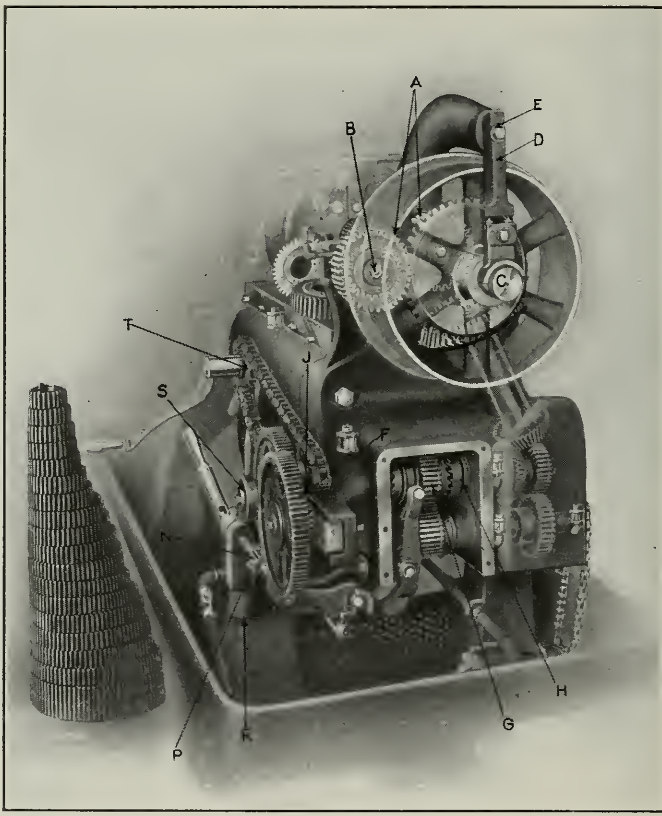



FIG. 81. — Spindle and Cam Shaft Change Gear and Driving Mechanism

sliding clutch *G* is controlled automatically by arm *K*, Fig. 78, operated by dogs or cams on drum *L;* also by hand lever *M*. With the hand lever to the extreme right, arm *K* is removed from the zone of the dogs or cams on drum *L*, and the feed mechanism is rendered inoperative, except on the slow or cutting speed. The lever cannot be moved in this direction during the idle movements, or when the feed mechanism is being operated on the direct or fast speed, and when in this position cannot be moved to throw the sliding clutch in engagement with the teeth of the direct-drive clutch, thereby eliminating the possibility of trouble which might be caused by jamming the tools against the work on the fast or direct speed. This hand lever will be found very convenient during the work of setting up the machine, as by its use the amount of hand cranking can be very materially reduced.

Clutch *G*, Fig. 81, should always be in the neutral position when the hand crank is being used. The shifting action of this clutch may be regulated by slight adjustment of angular cam *N*, and its proper engagement with the stationary clutches is assured by tension on the spring which operates plunger *P*, this tension being increased if found necessary by turning nuts *R* to the right.

Frictions *S* and *T* are employed in connecting the feed-change gears to the sprocket shaft and the small sprocket to the worm shaft, their use being a safety measure as they will slip in case of accident causing unusual strain on the machine, and thus prevent the breakage or distortion of the more vital parts of the mechanism.

### CAMS AND CAM SHAFT

The cam shaft carries the drums and disk to which are attached the cams which control the several movements of the machine, and in addition the indexing segment for the cylinder carrying the four work spindles. The proper indexing of the cylinder depends upon the indexing segment, and especially upon the last tooth, which is made adjustable to compensate for such wear as may occur at this point.

To drum or disk *B*, Fig. 79, are attached the cams or dogs which operate the lever controlling the change from the idle to working speeds of the machine, and with the exception of machines Nos. 51, 515, and 52 the lever operating the thread-starting mechanism.

Cam drum *C*, Fig. 79, operates the main tool slide, and on machines Nos. 51, 515, and 52 the thread-starting mechanism. The grooves in this drum are for what are known as the "backing-up" strips, which are used to relieve the strain on the screws that hold the lead cam — the cam which feeds forward the main tool slide. The cross slots in this drum provide for adjustment of the cam which controls the rapid movement of the tool slide toward the work before the cuts are started.

Disk *D*, Fig. 79, carries the cams which operate the cutting-off and forming tool slides. There are two sets of screw holes in this disk for locating the cutting-off cam, one set of holes to be used when there is no operation to be performed from the fourth position of the main tool slide, the other when this position is used. It is necessary to use the extra set of holes when an operation is being performed in the fourth position from the main tool slide in order to delay the cutting-off operation until the tool slide recedes sufficiently to allow the tools in the fourth position to clear the work before the piece is entirely cut off.

Disk *E*, Fig. 79, operates the cylinder-locking levers. On the small machines this disk is outside the leg. Disk *F* operates the oscillating gage stop on machines Nos. 53, 54, 55, and 56. Machines Nos. 51 to 52 are equipped with stationary gage stop and this disk will, therefore, not be found on these machines. Cam drum *G* carries the cams which operate the frictions, chucking and un-chucking levers, and feeding mechanism. Cam shaft end play is taken up by collars at *L*.

### THE WORK-SPINDLE CYLINDER AND CYLINDER CASING

The cylinder *A*, Fig. 78, for the work spindles is of gray iron, the bearing surface of which is ground to size. The internal surface of the cylinder casing *B* is also ground to size; compensation for wear of either the casing or cylinder being provided by a slot in the casing. Contraction and expansion of the casing is controlled by screws *C* and *D*. To contract the casing loosen the screws in top bracket *E*, turn screw *C* to the left, and screw *D* to the right. When proper adjustment is secured turn screw *C* to the right. To expand the casing turn screw *D* to the left, then screw *C* to the right, after which screw *D* to the right. Longitudinally the cylinder is held in position in the cylinder casing by a flange on the cylinder and adjustable clips *F*. When the cylinder is indexed by the segment gear *G*, Figs. 78 and 82, it is brought into correct position by plunger *M*, Fig. 82. When in proper alinement adjusting screw *N*, Fig. 82, is resting upon half-round plunger *P*. Plunger *M* is designed to enter only a short distance into bushing *R*, the tapered portion of the plunger striking the upper wall which, with the assistance of springs *S*, insures perfect contact between adjusting screw *N* and half-round plunger *P*.

### WORK SPINDLES, BEARINGS, ETC.

The work spindles are of steel, chucks of the push type being used. Each nose piece is ground in place on its spindle. Bronze parallel bearings are used in the cylinder. The front and rear tapered bearings are of bronze, both running in hardened and ground steel bushings. The longitudinal movement of the spindles is adjusted for end play by turning collars *N*, Fig. 83. To adjust the chucks to the rods, finger-holder *O*, Fig. 83, should be turned to the right (after first unscrewing the set screw) if it is desired that the chucks grip the stock tighter, or if less tightly, to the left, the set screws being tightened after the proper adjustment has been secured. The feed chucks are threaded to turn right-handed and fit closely in the feed tubes to prevent their coming loose when the machine is in operation. As the work spindles rotate to the left the nose pieces have left-hand threads.

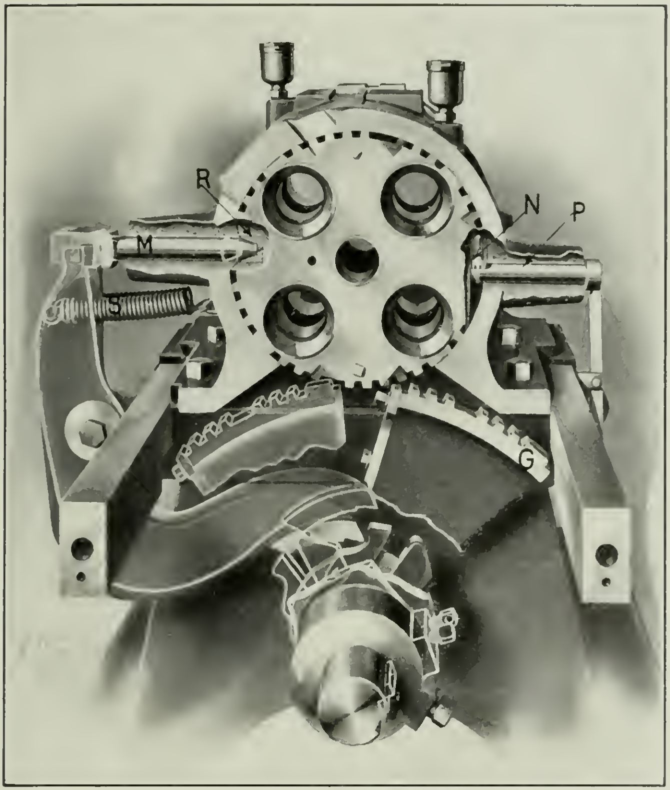


FIG. 82. — Indexing and Locking Mechanism

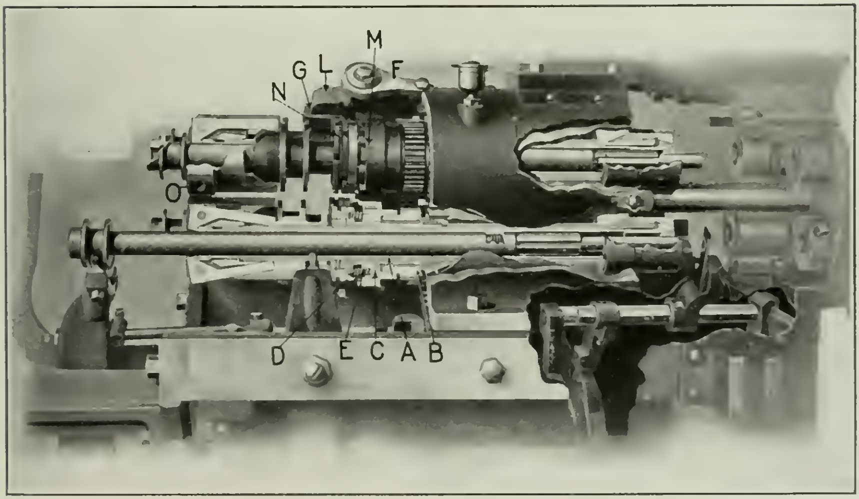


FIG. 83. — Spindle Construction

### FRICTIONS

The spindle frictions, Fig. 83, which make it possible to hold one work spindle stationary while the remaining three continue to rotate, are made up of four principal parts, viz.: sleeve *A*; male tapered section and gear *B*; female tapered section *C*; spring seat *D*. The work spindles as already stated are driven by a gear attached to the spindle-driving shaft meshing with the geared portion of the male tapered section *B*, engaging female tapered section *C*, which is keyed to sleeve *A*; sleeve *A* being keyed to the work spindle. Sections *B* and *C* are held in engagement by springs *E*. When sections *B* and *C* are not engaged, section *B* not being keyed to sleeve *A* rotates freely on it, and section *C*, sleeve *A*, and the work spindle remain stationary. Disengagement of members *B* and *C* resulting in the work spindle being held stationary is necessary, while threading, cross-drilling, side milling, or other special operations of this nature are being performed. Where the friction caused by lever *F* compressing springs *E* is insufficient to hold the work spindle stationary, which may be the case when cutting coarse threads, adjustable plunger *G* located on the under side of bracket *L* (which bracket is attached to the cylinder casing) is brought into contact with lug *M* inserted in section *C* of the friction. This will prevent rotation of the work spindle during the threading operation. The length of time the work spindle must be held stationary is determined by the duration of the threading or special operations. The opening and closing of the friction is controlled by cams on cam drum *G*, Fig. 79, operating through a roll, lever *A*, and a toggle-locking device. The opening cam is positive, while the closing cam is adjustable on the cam drum. In the larger machines positive clutches are used in place of frictions to provide against slipping; these are operated in the same manner as the frictions on the smaller machines.

### MAIN TOOL SLIDE

The main tool slide, Fig. 84, carries the tools usually carried in the turret of single-spindle machines, *i.e.*, those worked from the end. Four is the maximum number of tools it will accommodate, although by the use of combination tools in these positions, more than four operations may frequently be performed. The locations of the several tools are designated as "positions." The first is the position from which the tools engage the bar on which the forming tool is operating. The second, that above and vertically parallel to the first position; the third, opposite to and horizontally parallel to the second position; the fourth, below and vertically parallel to the third position.

The tool slide is moved toward and from the work by cams bolted to cam drum *A*, Fig. 84, operating on a roll attached to adjustable slide *B*, which is bolted to the body of the main tool slide.

It is good practice to have the shanks of tools extend as far back in the tool spindles as possible in order to secure increased rigidity. To make this possible two methods of adjustment are provided when changing from long to short work and vice versa, viz., the changing of the position of the lead cam on the cam drum, also that of adjustable slide *B*, Fig. 84.

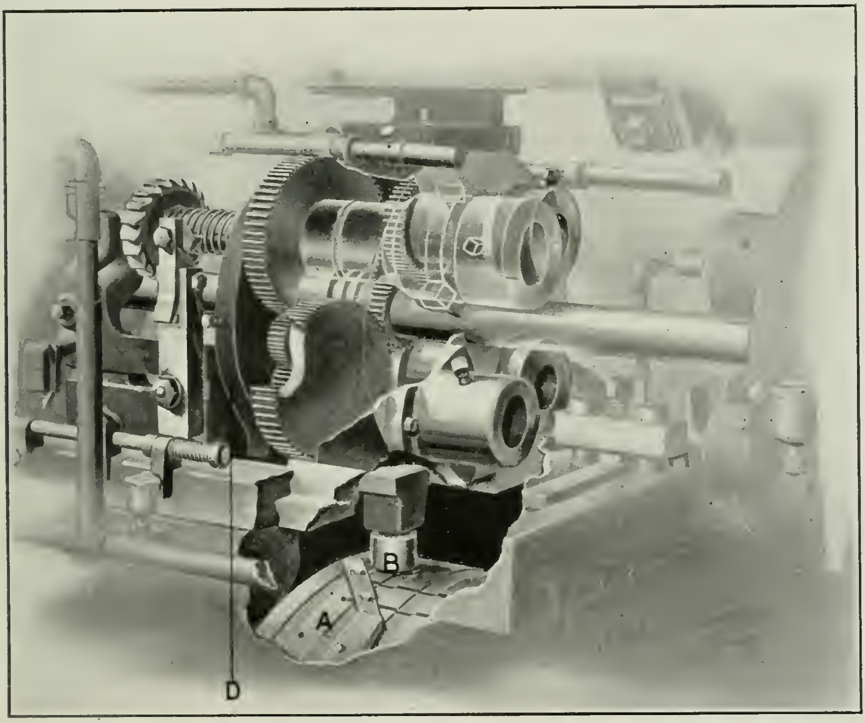



Fig. 84. — Main Tool Slide

When it is necessary to perform an operation from the fourth position in the tool slide, about 4 inches should be taken off the wide end of the lead cam on Nos. 53 to 56 machines inclusive, and about 3 inches on the Nos. 51 to 52 machines. This is done to allow the tool in this position to clear the work before the piece is cut off.

If desirable, the tool spindle in the second position can be rotated by means of the gears driven by the sliding gear keyed to the spindle-driving shaft for driving the threading spindle. The back plate attached to the rear of the vertical portion of the tool slide with screws and spacing collars carries a stud upon which the intermediate gear that drives the tool spindle in this position rotates. This spindle may be driven by loosening a collar at the rear sufficiently to allow it to rotate freely, unscrewing a nut on the stud and moving the stud sufficiently to bring the intermediate gear into mesh with the gears on the spindle-driving shaft, then tightening the stud again by screwing up the nut. The rotation of the second position tool spindle is found very convenient in cases where a very small hole is to be drilled. Screws are provided for use in adjusting the position of the individual tools in the tool slide and also serve as a gage stop in re-setting tools in their original positions after they have been removed from the slide.

### THREADING MECHANISM

The threading mechanism is so constructed as to allow for the threading operation as much time as is consumed in the longest milling, drilling, or forming operation, thus insuring good threads, and long life for the threading tools.

Oil is forced through the die spindle into the die from the rear, thus providing ample lubrication. The die spindle is rotated by means of sliding gear *E*, Fig. 85, which is keyed to and driven by the top shaft.

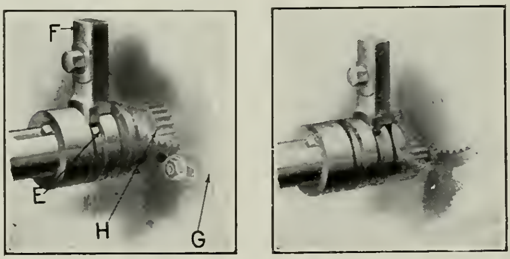



Fig. 85. — Speed Change Gear for Threading Spindle

When the die spindle is not in use clip *F* can be raised and the gear slipped out of mesh with the threading-spindle gears. When clip *F* is in engagement with the groove nearest the teeth in gear *E* the threading spindle sleeve will be driven direct and at its highest rate of speed. When clip *F* is in engagement with the groove farthest from the teeth in gear *E* the sleeve will be driven through the intermediate and compound gears *G* and *H* at its lowest rate of speed. The threading-spindle sleeve rotates about seven times as rapidly when driven direct as when driven through intermediate and compound gears. In threading brass or cutting very fine threads on soft steel, the direct drive may be used. In most other cases it is advisable to use the intermediate drive.

The threading spindle is driven by pins *A*, Fig. 86, attached to the threading-spindle sleeve, engaging pin *B* in the spindle. Pin *B* is adjustable for length, this adjustment being used when the pitch of the thread is such that the forward travel of the tool must be faster than that of the tool slide. These pins are furnished in various lengths. When the tool becomes slightly dulled, or when the die has a shallow throat (which is necessary when the thread is to be cut close up to the head or shoulder of the work), the device in Fig. 86 is brought into use. This is known as the thread starter and operates as follows.

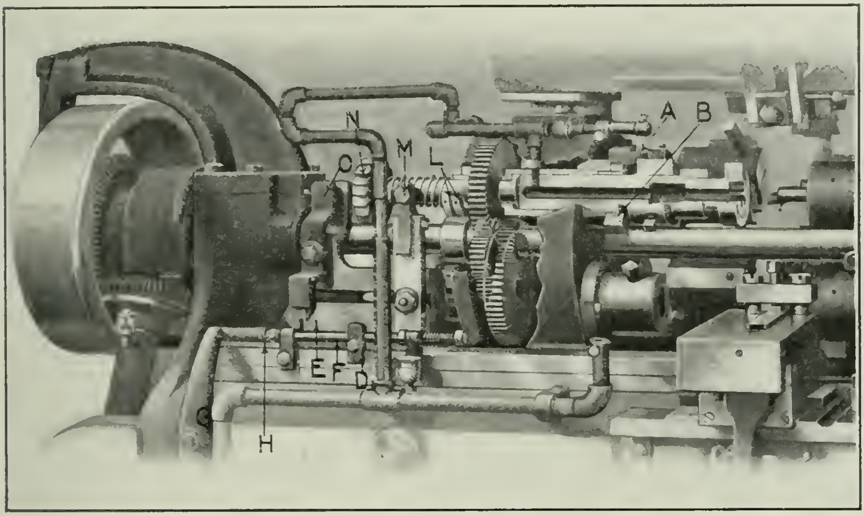



FIG. 86. — Threading Mechanism

At the time the tool is in position where it just touches the end of the blank to be threaded, roll *D* should be adjusted so as to be brought into contact with swinging pawl *E*, the roll holder being adjustable on rod *F*, which is operated by an adjustable cam on cam drum *B* (Fig. 79), through lever *G*, Fig. 86. Spring *H* compensates for any slight variation there may be in the length of the blank, making the starting of the tool positive, but the operation of the mechanism flexible. End play in the threading-spindle sleeve is taken up by collars *L*.

After the tool has completed the operation of threading, the work spindle is released (as explained in connection with the operation of the frictions) and the tool runs off when the ratchet *N* on the rear end of the die spindle engages flexible pawl *M*, all receding with the tool slide. In setting tools for threading, before starting the machine the ratchet should clear flexible pawl *M* from $\frac{1}{8}$ to $\frac{3}{16}$ inch when pins *A* and *B* on the threading-spindle sleeve and spindle are placed end to end. With the regular threading mechanism only right-hand threads can be cut, but the machine can be equipped with left-hand threading attachment when so desired.

### FORMING AND CUTTING-OFF SLIDES

These slides are made adjustable for position lengthwise of the machine. This makes it possible to change the longitudinal position of the cutting-off and forming tools without disturbing the tools themselves. The cutting-off tool when of the blade variety is adjustable for hight by means of a screw in the slide. A gage for setting the forming tool to the proper hight is furnished with each machine.

On machines Nos. 52, 55, and 56 both the levers which operate the forming and cut-off slides *H*, Figs. 78 and 79, and the bracket in which they are pivoted, are drilled in two separate locations. This double drilling makes it possible to form deeper and cut off larger diameters of stock when the levers are pivoted in the lower holes without substituting cams of a greater throw or travel, as designated in a table accompanying the machine.

### TOP SLIDES

Two of these slides are provided, operating in second and third positions as represented in Figs. 78 and 79. They are adjustable lengthwise of the machine and are used for nurling, thread-rolling, shaving, light forming, etc., and are very useful in producing many varieties of work. Their operation is provided for through bar cams attached to the tool slide. Cam *M*, Fig. 79, moves the top slide toward, and cam *N* from the work. These cams can be readily filed to any angle, thus providing whatever feeds may be deemed desirable for the tools in use. In operating tools in these top slides, care must be exercised in having cam *M* notched and the tools so set that the slides will be in their original position and the tools out of the way before the indexing of the cylinder carrying the work spindles takes place.

The cams rarely need changing as the set provided with the machine covers a wide range of work; extreme cases, however, require a faster or a slower feed.

### TOOLS AND ATTACHMENTS

Fig. 87 illustrates the machine as it appears equipped with tools for each position for operation on four rods at the same time. Fig. 88 is a group of collets, feed chucks, and jaws. Fig. 89 illustrates various types of box tools with back rest jaws, roller rests, etc. Fig. 90 shows die, tap and drill holders with button dies, tap and drill bushings, die extensions, etc. The die holder at the top of the group is a telescopic device used in cutting two threads. A tap is frequently used in place of the second die. At the center and left of the group is a friction die holder used for threading close to a shoulder on small work; a button die holder and extension being shown just to the right.

Fig. 91 is a set of tools for machining a stud shown at the center of

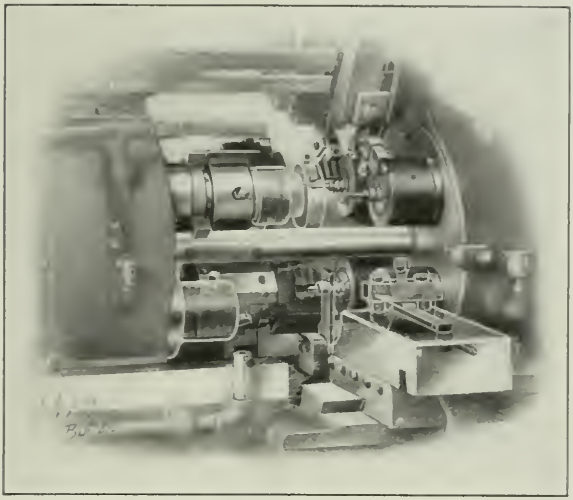


Fig. 87. — Four Spindles and Tool Positions

the group. As this work is indexed through the four positions, the tools operate as follows: Forming tool and lower box tool in the first position; shaving tool and box tool with roller rest, second position; die in the third and cut-off tool in the fourth position. The shaving tool shown just above the die is similar to a number shown in Fig. 92, which also includes several types of nurls, and a thread-rolling tool. The shaving tool is mounted in the machine as illustrated in Fig. 93. It consists of a holder carrying a rest and a shaving blade, the holder being pivoted to allow

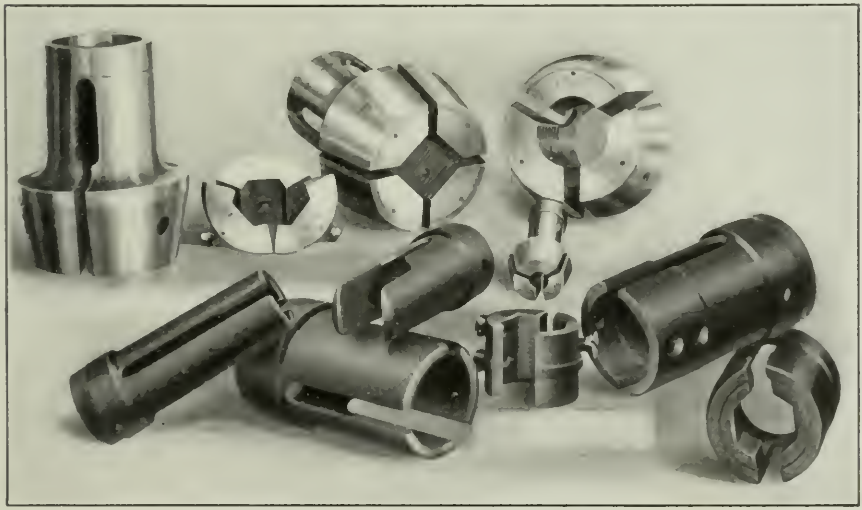


Fig. 88. — Spring-Collets and Feed Chucks

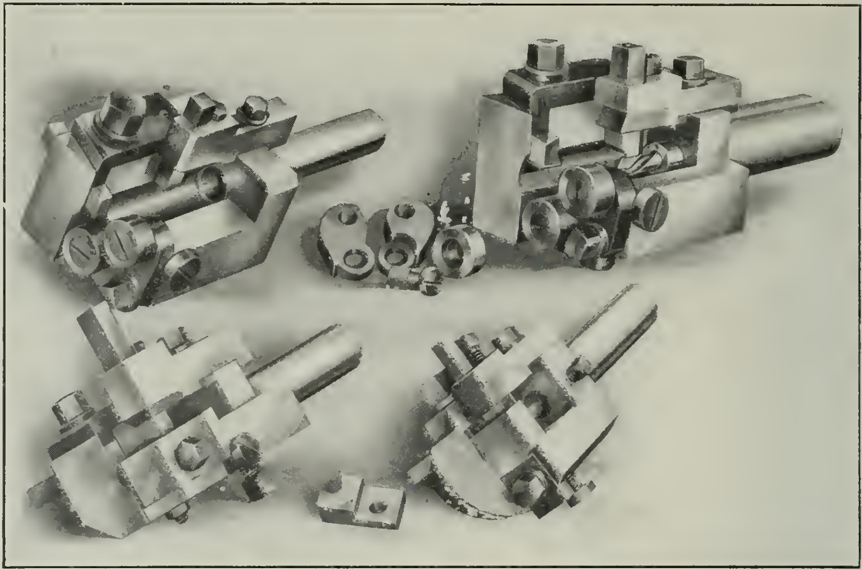


Fig. 89. — Box Tools of Various Types

the blade and rest to find their own center. As the distance between blade and rest when once set is positive, and as the tool is allowed to find its own center, it produces very accurate results.

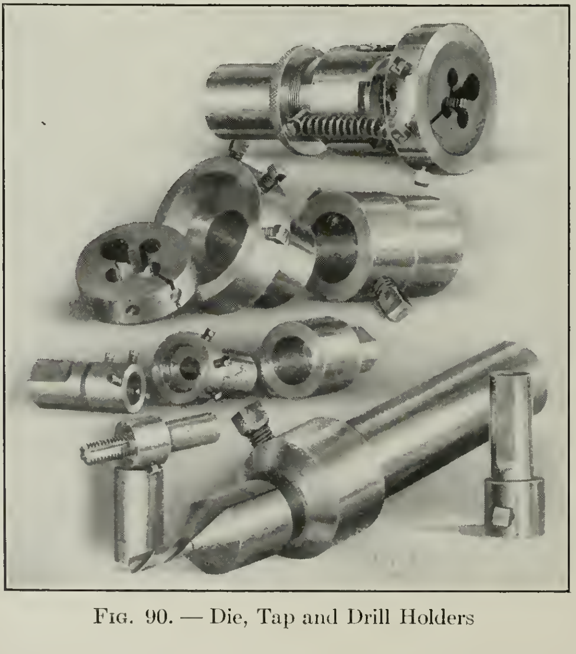


Fig. 90. — Die, Tap and Drill Holders

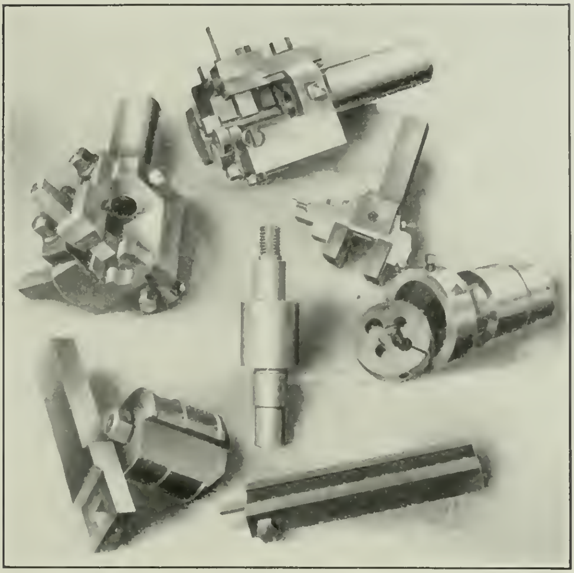


Fig. 91. — Set of Tools for Machining a Stud

The thread-rolling tool mounted as shown in Figs. 93 and 94 is especially adapted for rolling a thread at the back of a shoulder. It consists of a thread roller mounted in a holder which is secured in the rear top

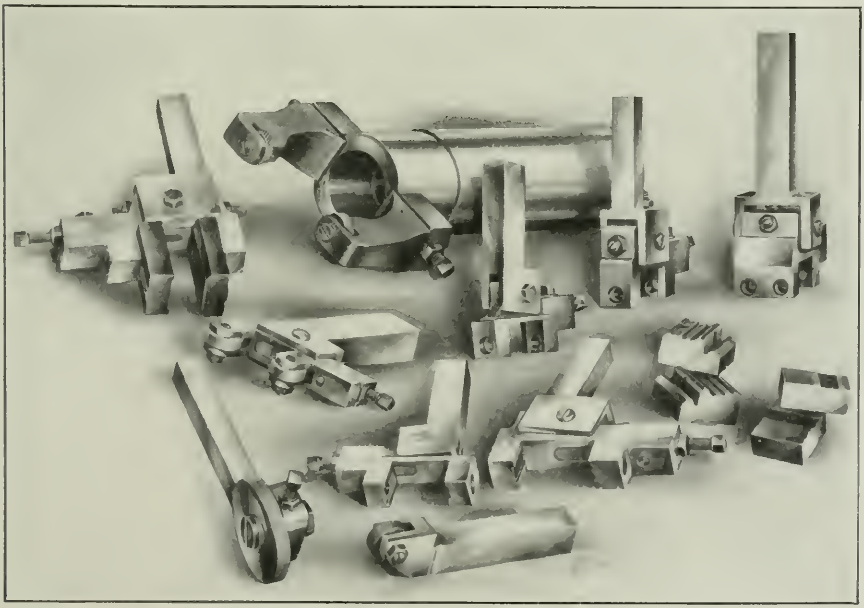


Fig 92. — Shaving, Thread Rolling, and Knurling Tools

slide. It produces smooth, accurate threads and is obviously applicable to many cases where a die cannot be operated. At the same time it may be used satisfactorily at the front side of a shoulder where ordinarily a die would be employed. Fig. 94, which is a rear view, shows a

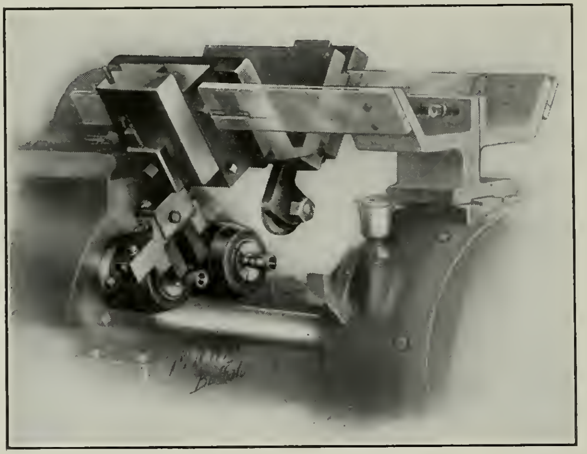


Fig. 93. — Shaving and Thread-Rolling Tools in Position

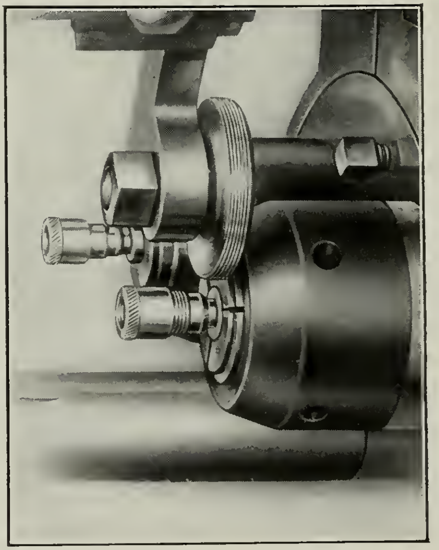


Fig. 94. —Work Before and After Threading with Roller

piece of work before and after threading and clearly illustrates the manner in which the threading roll can be applied between a shoulder on the work and the face of the chuck.

### CROSS-DRILLING ATTACHMENTS

The cross-drilling attachment shown in Fig. 95 is operated in the third position, where provision is made for stopping the rotation of the stock to allow for threading and other operations. The attachment is secured to the cutting-off slide and actuated by the cutting-off lever. On the larger sizes of machines sufficient feed for the drill is obtained by an auxiliary lever at the side of the attachment, which increases the throw of the cam. Adjustments are provided for governing the depth and position of the hole in the work. The drill spindle is operated by a belt from a countershaft. By using a combination tool it is possible to drill and countersink a hole at the same time.

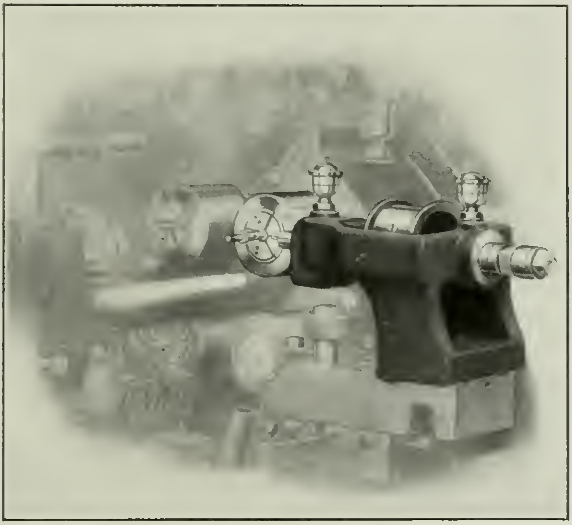


Fig. 95. — Cross-Drilling Attachment

Cross drilling from the top of the piece may be accomplished by means of an attachment used in place of the top slide over the third position. This attachment may also be used in conjunction with the one on the cutting-off slide, the holes being drilled at a given angle to each other. Also, when required, the machine may be modified to allow the two holes to be positioned at any angle with each other between 90 degrees and a few degrees from parallel.

### MILLING ATTACHMENTS

There are two forms of end milling attachments for the machine, one being driven by belt; the other by gears. The latter type is illustrated in Fig. 96, and is adapted to the heavier classes of work; for example, where two cutters are required. These attachments are operated from the main tool slide, opposite the third stock position owing to the necessity of having the stock stationary during the drilling operation. Either

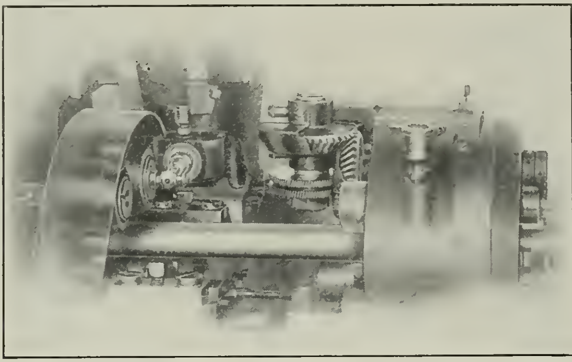


Fig. 96. — End-Milling Attachment

attachment can be used in conjunction with cross-drilling or side-milling attachments, but are not applicable where threading operations are required as their position on the machine is then occupied by the threading spindle.

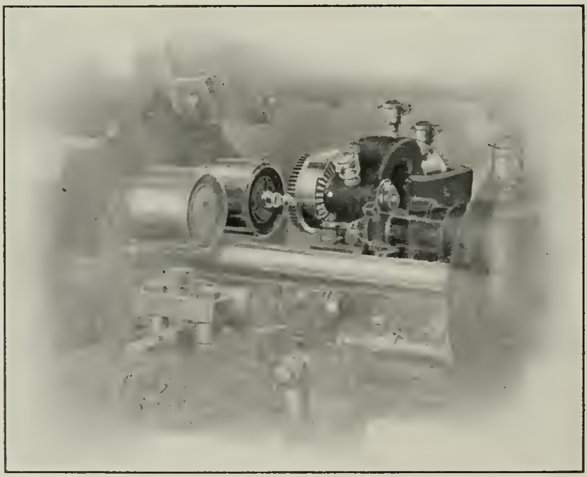


Fig. 97. — Side-Milling Attachment

A side-milling attachment is shown mounted on the cross slide in Fig. 97; and in Fig. 98 a slotting attachment is illustrated, the work handled in this device being received from the spindle by a turret holder and carried around in front of the saw or saws as the case may be. After the operation the piece is ejected in the manner indicated.

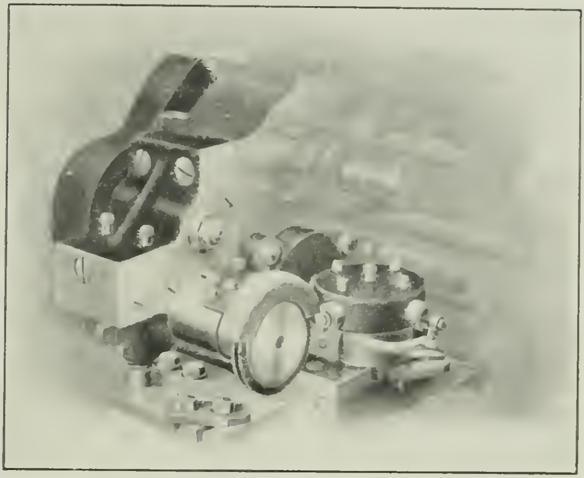
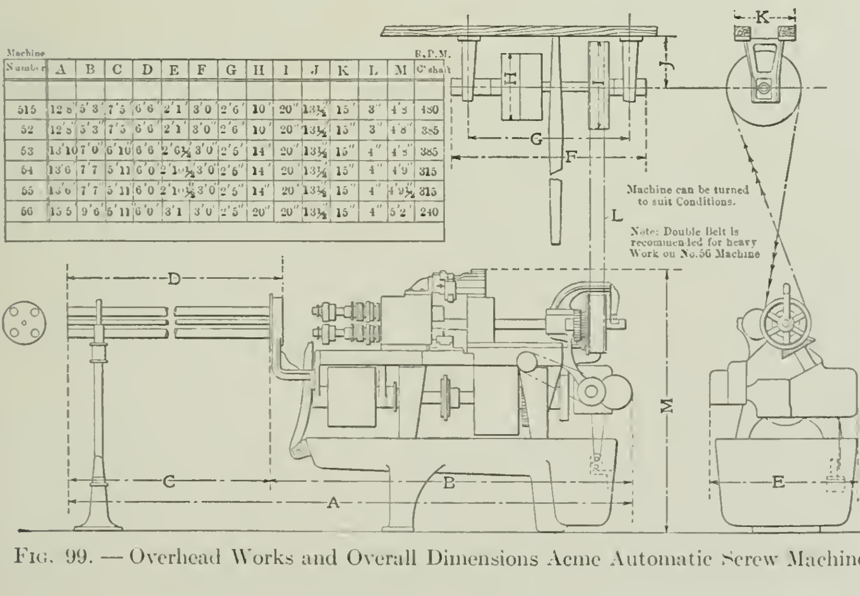


FIG. 98. — Slotting and Milling Attachment

MACHINE SIZES

A setting-up print for the different sizes of Acme machines is reproduced to small scale in Fig. 99 with the leading over-all dimensions, belt widths, etc. The several sizes in which the machine is built range from a chuck capacity of ¼-inch and feed length of 2½ inches to a chuck capacity of 2¼ inches and feed length of 10½ inches.




| Machine Number | A | B | C | D | E | F | G | H | I | J | K | L | M | R.P.M. C'shaft |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | |
| 515 | 12'8" | 5'3" | 7'5" | 6'6" | 2'1" | 3'0" | 2'6" | 10" | 20" | 13½" | 15" | 3" | 4'3" | 480 |
| 52 | 12'8" | 5'3" | 7'5" | 6'6" | 2'1" | 3'0" | 2'6" | 10" | 20" | 13½" | 15" | 3" | 4'8" | 385 |
| 53 | 13'10" | 7'0" | 6'10" | 6'6" | 2'6½" | 3'0" | 2'5" | 14" | 20" | 13½" | 15" | 4" | 4'5" | 385 |
| 54 | 13'6" | 7'7" | 5'11" | 6'0" | 2'10½" | 3'0" | 2'5" | 14" | 20" | 13½" | 15" | 4" | 4'9" | 315 |
| 55 | 13'6" | 7'7" | 5'11" | 6'0" | 2'10½" | 3'0" | 2'5" | 14" | 20" | 13½" | 15" | 4" | 4'9½" | 315 |
| 56 | 15'5" | 9'6" | 5'11" | 6'0" | 3'1" | 3'0" | 2'5" | 20" | 20" | 13½" | 15" | 4" | 5'2" | 240 |

FIG. 99. — Overhead Works and Overall Dimensions Acme Automatic Screw Machine

# CHAPTER XII

## The Universal Multiple-Spindle Automatic Screw Machine

The general design of this machine, which is built by the Universal Machine Screw Company, Hartford, Conn., is well shown in the front and rear views, Figs. 100 and 101.

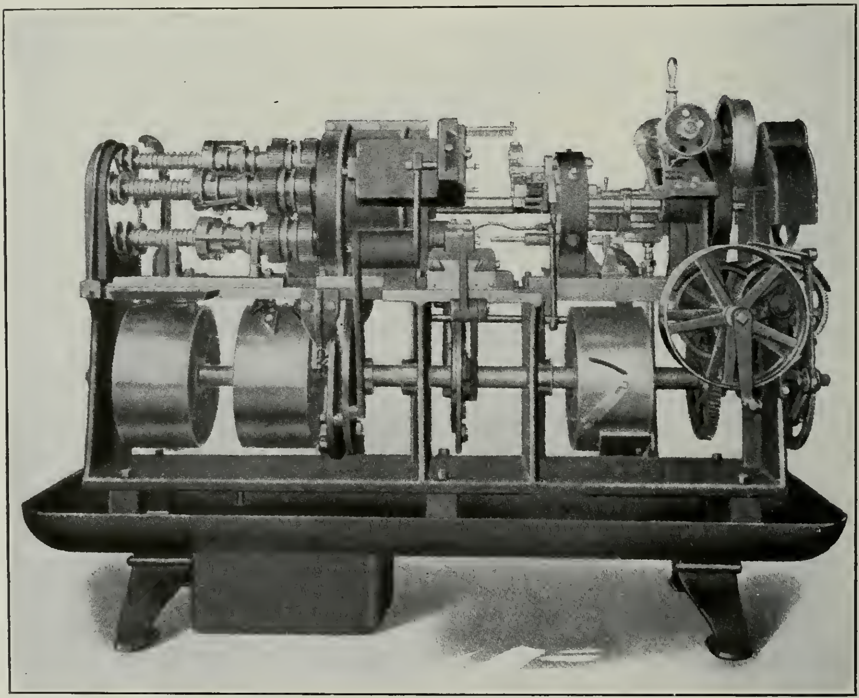


Fig. 100. — Universal Multiple-Spindle Automatic Screw Machine

The machine has five spindles and is operated from the countershaft by a single belt passing over the plain driving pulley shown at *A*, Fig. 102. The five spindles are carried in a cylinder which is indexed to bring one spindle after another in front of each of the five tools in the tool slide. The latter is fed forward by the cam underneath, bringing all the tools into action simultaneously, and a piece is completed at each advance of the tool slide.

OPERATION OF THE SPINDLES

For ordinary turning, forming, drilling, and other operations, the spindles run in a left-hand direction; for threading, the spindle with the work is run slowly to the right during the operation and upon the die reaching the proper distance the spindle is reversed and the die rapidly drawn off the work. As will be seen, each spindle has at its rear end two spur gears. The one nearest the turret is operated by a gear on a central sleeve passing through the turret and supported at its right-hand

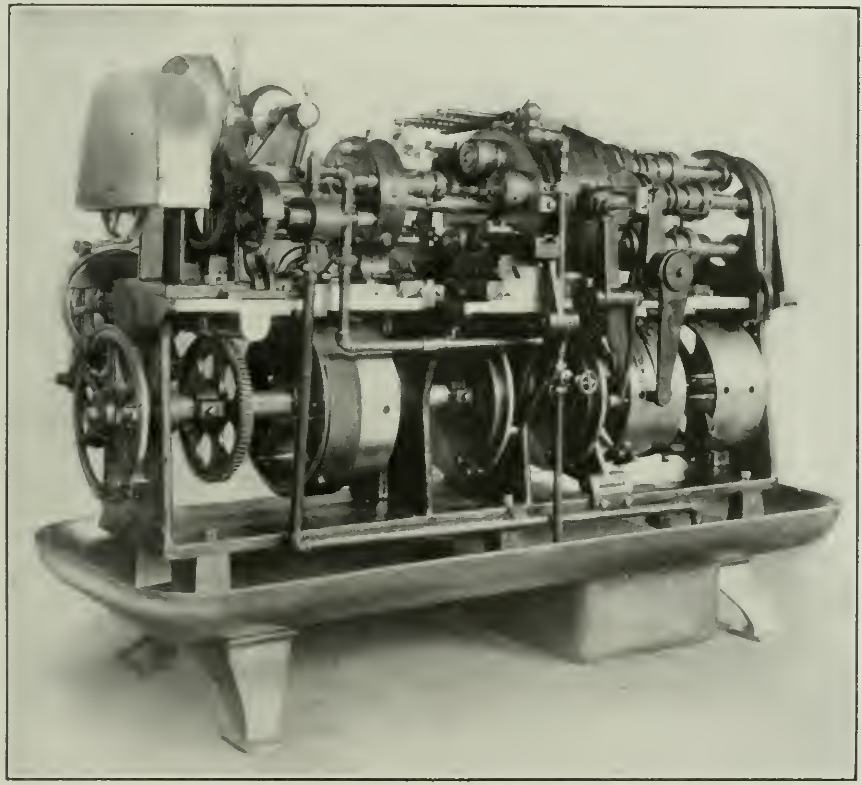


FIG. 101. — Universal Multiple-Spindle Automatic Screw Machine (Rear View)

end as shown at *B*, Fig. 102, the gears *C* and *D* serving to drive this sleeve or hollow shaft, through which passes shaft *E*. This latter shaft carries at its left end gearing engaging the outer gears on the spindles for driving them during threading operations. The drive for shaft *E* is transmitted through the medium of change gears in train *F* at the outer end, connecting with the right-hand end of the short driving shaft *G*. It is obvious that by the series of change gears suitable spindle speeds for threading may always be obtained. An important feature in this spindle-driving mechanism is a positive type of clutch (operated by an arm at the rear) for connecting the spindles with either the left-hand turning or right-hand threading motion.

### THE CAM-SHAFT DRIVE

The cam shaft is also driven from short shaft *G*, Fig. 102. This shaft by means of bevel gears *H* drives shaft *I* upon which is mounted freely pulley *J*, which may be secured to *I* by operating lever *K* and so engaging the conical clutch with the pulley. This pulley is belted to the pulleys below for driving the cam-shaft gearing, the arrangement of which is shown clearly in Fig. 103, and when the lever *K*, Fig. 102, is moved to the right the friction clutch in *J* is disengaged and a brake *L* applied to the pulley, stopping it and the cam shaft instantly.

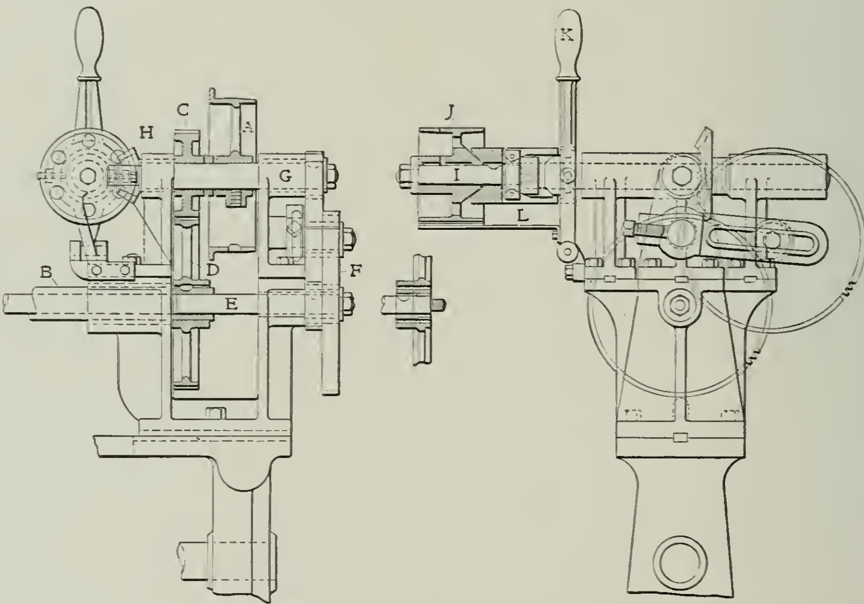



Fig. 102. — Driving Mechanism of Universal Automatic Screw Machine

This is a convenience especially when setting up for a piece of work as the feed motion may be started and stopped at will without stopping the spindle.

Of the two pulleys placed side by side as in Fig. 103, on the worm shaft for operating the cam-drum shaft, the outer one drives the worm shaft direct for rapid traverse of the tools during idle or non-cutting movements, while the inner one drives the shaft through change gearing, by which the requisite rate of feed is always readily obtainable. The short belt is of course automatically shifted from one pulley to the other during the cycle of operations; the shifter lever and dogs for controlling it being plainly seen in Figs. 101 and 103. The outer end of the worm shaft is squared to receive a crank handle which facilitates hand operations of the cam shaft during the setting-up process.

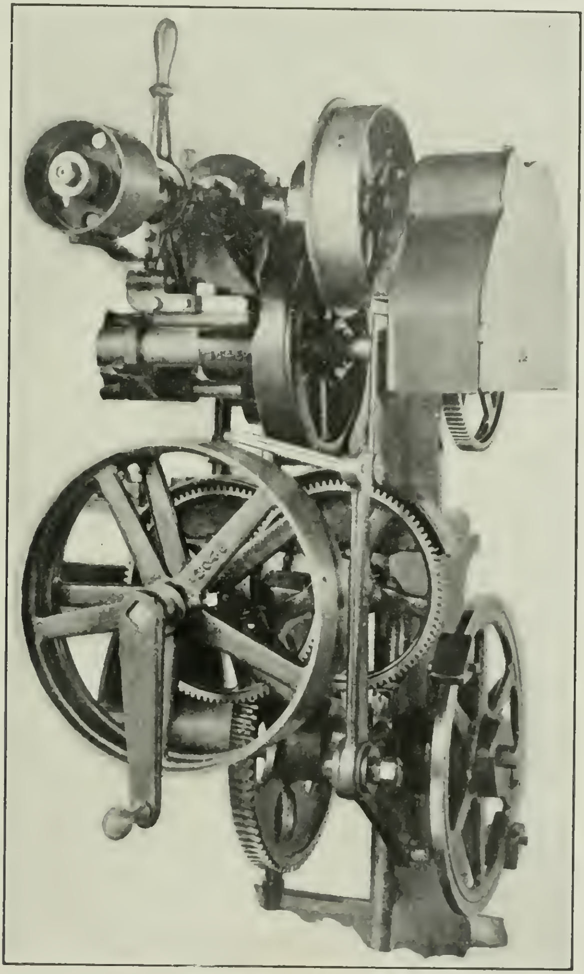


FIG. 103. — Mechanism for Operating Cam Shaft of Universal Automatic Screw Machine

### THE LOCKING BOLT FOR THE SPINDLE TURRET

The turret-locking bolt is shown in Fig. 104 and needs little description, as its general form and mode of operation are indicated in this engraving and the half-tone, Fig. 101. This latter view also shows in conjunction with the front view, Fig. 100, the method of operating the three independent cross slides, the arrangement of oil pump and piping, and the gearing by which the pump is positively driven from the large spindle-driving gear represented at *D*, Fig. 102. The countershaft is a single-speed affair fitted with tight and loose pulleys.

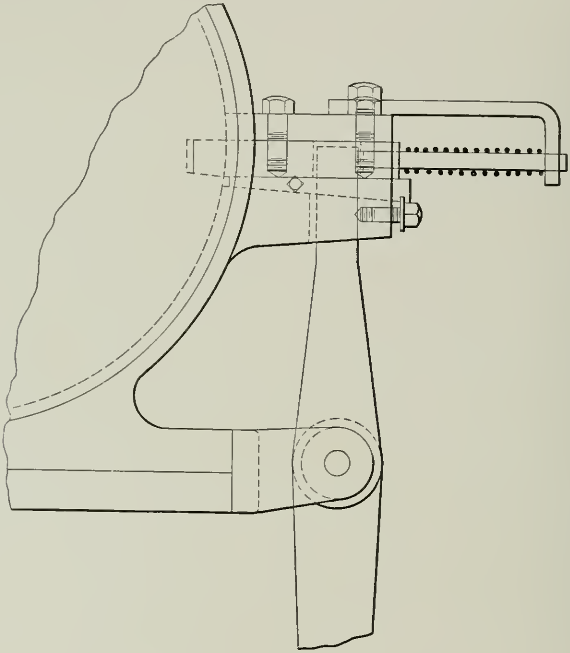


Fig. 104. — Locking Bolt Detail

This machine is known as the No. 3 and takes work up to $1\frac{1}{2}$ inches in diameter, feeds lengths up to 6 inches, and machines a maximum length of 5 inches. Two smaller sizes take work $\frac{3}{8}$ and $\frac{3}{4}$ inch diameter respectively.

# CHAPTER XIII

## The Gridley Multiple-Spindle Automatic Turret Lathe

In the accompanying engravings is illustrated the Gridley multiple-spindle automatic turret lathe built by the Windsor Machine Company. The single-spindle automatic built by this concern is illustrated in Chapter VII.

The four-spindle machine forming the subject of the present chapter is well illustrated by the general views, Figs. 105, 106, and 107; its con-

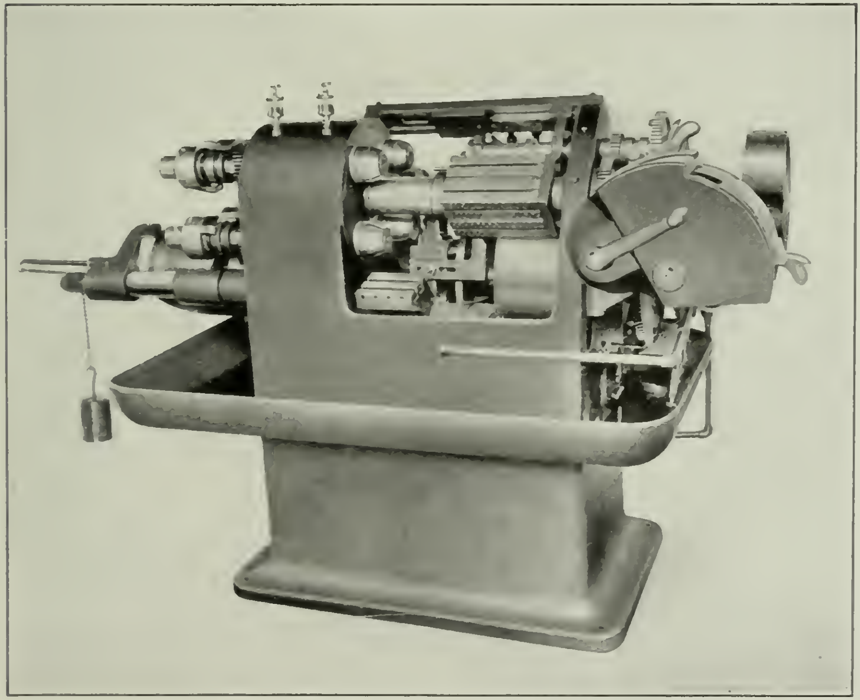


Fig. 105. — Gridley Multiple-Spindle Automatic Turret Lathe

struction will be understood by referring to these half-tones and to the details presented in the line drawings. Like the single-spindle machine referred to, this automatic has a four-sided slide for carrying the "turret" tools; the tool slide in this case, however, is not rotated to bring the tools one after another into position for the successive cuts, as the four spindles themselves are carried in a cylinder that is indexed step by step to bring each spindle successively into position for the bars of stock to be operated upon by the various tools.

All of the tools held by the tool slide are fed forward together, one tool rough-turning the bar in one spindle, another tool taking a finishing chip on the piece held in the next spindle, a die threading the piece in the next spindle, and the finished piece being cut off and a new length of

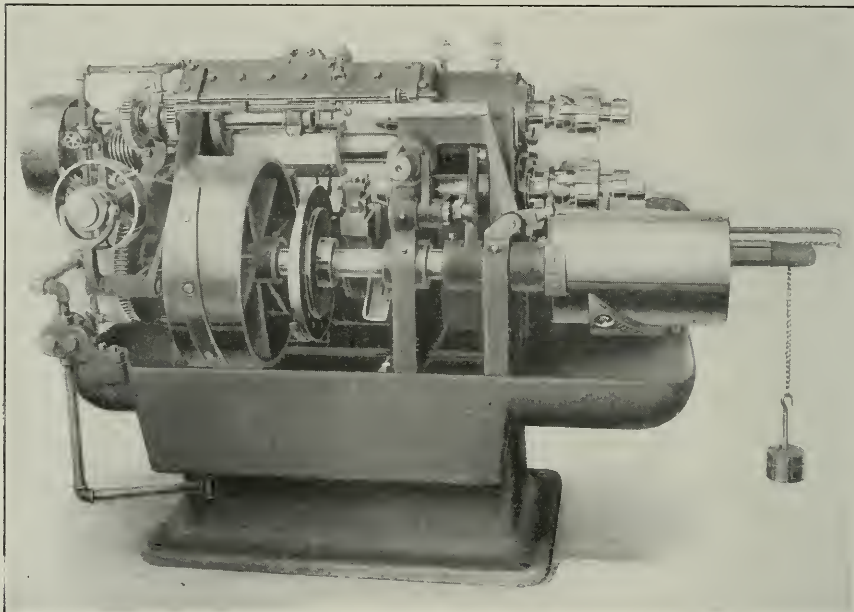


Fig. 106. — Gridley Multiple-Spindle Automatic Turret Lathe (Rear View)

stock fed through the chuck at the fourth position of the spindle, or such other operations being performed as the piece may require. As all of these operations are performed simultaneously, it will be seen that the time to make a completely finished piece and cut it off will be only the time required to perform the longest operation plus the time required to return the tool slide, revolve the spindle cylinder, and move the tools back to their cutting position.

### THE SPINDLE AND TOOL SLIDE

The spindles, their carrying cylinder, and the tool slide are shown in Fig. 107 removed bodily from the machine; this half-tone reveals also a number of other interesting features of construction. A horizontal section through one of the spindles is given in Fig. 108, and it will be noticed that the spindle takes a long, straight bearing in a lumen-bronze sleeve which admits of ready renewal as a whole in the event of sufficient wear occurring to make this necessary. The hub of the cylinder around which the four spindles are located is extended, as represented in Fig. 105, to form a long bearing for the tool slide, this feature of mounting spindles and tool slide on the same member having been adopted in conjunction with the feature of large bearing areas to insure permanent alinement of spindles and tools. The bearings of the spindle-carrying cylinder are on the large diameters *A* and *B*, Fig. 107. In the event of any wear taking place between these surfaces at either end and the bearings formed in the main frame of the machine, the alinement of spindles and tool slide need not be affected, as both will simply move together.

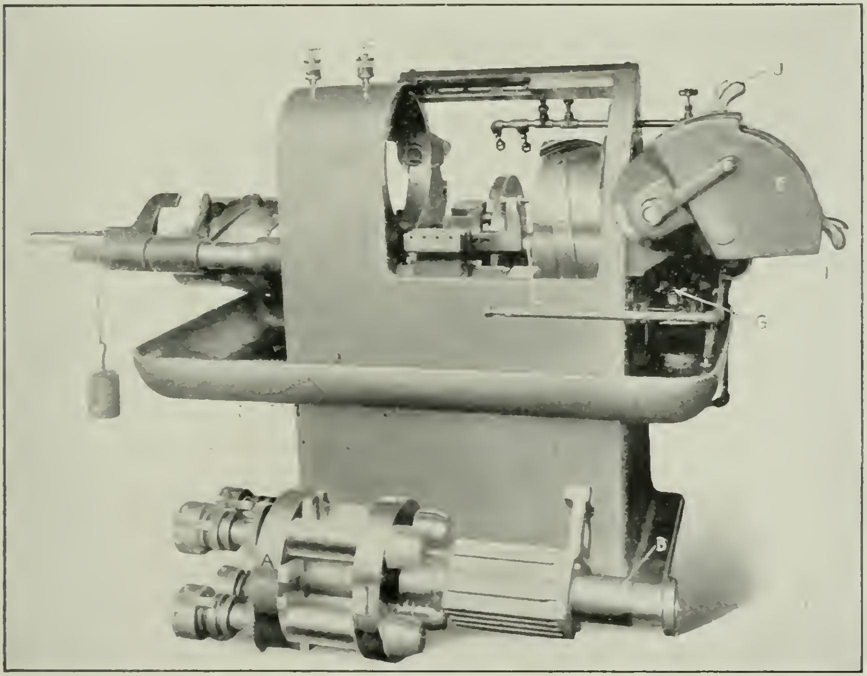



FIG. 107. — Gridley Multiple-Spindle Automatic Turret Lathe with Spindles and Tool Slides Removed

In addition to the features just described, Figs. 105 and 107 show clearly the method of preventing the tool slide from rotating, the arrangement consisting of an arm attached to the tool slide and machined at the outer end to fit a longitudinal guide bar located as represented at the top of the machine.

The spindles have the usual collets and stock-feed device, and are driven by the pulley shown at the right-hand end of the machine in Fig.

105. This pulley is keyed to one end of a driving shaft running through the center of the spindle-carrying cylinder as in Fig. 108, and carrying on its other end a gear meshing with a gear keyed on each of the spindles at the rear end of the bearing. The spindles are run constantly in one direction without stopping or reversing for the purpose of threading, that operation being taken care of by the threading mechanism to be referred to later.

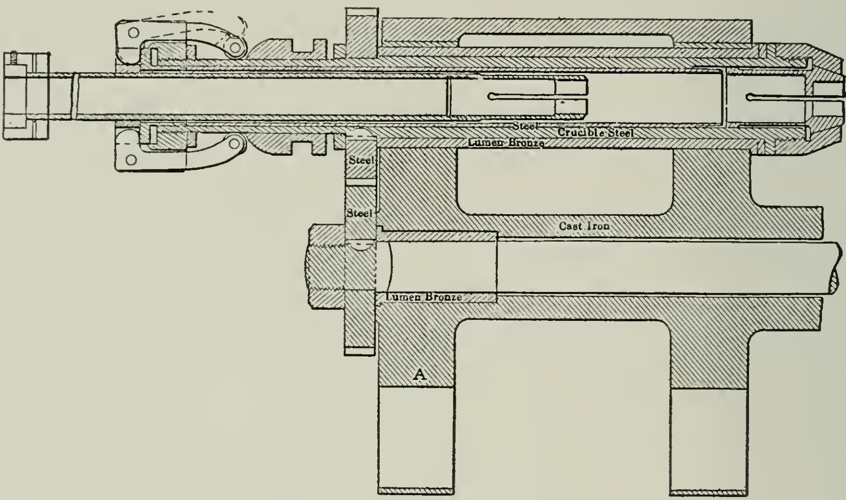



Fig. 108. — Spindle Construction

### OPERATION OF THE TOOL SLIDE

The cam shaft *C*, Figs. 107 and 109, carries the cams for operating the tool slide and the forming and cutting-off tools; the cams for operating the chuck and feeding the stock; and the mechanism for revolving the cylinder. It is driven at two speeds, one of which is comparatively slow for use during the time the tools are cutting, the other a high speed, for returning the tool slide and revolving the spindle cylinder. During the slow movement (while the tools are cutting) it is driven by a worm *D*, Fig. 109, on the spindle-driving shaft, through the change-gear box *E*, worm shaft *F* and worm gear *G* keyed on cam shaft *C*. When the tools have finished cutting, the loose pulley *H*, which runs at a constant speed, is clutched to the worm shaft *F*. The drawing shows a toothed clutch for this connection, but a friction is now used instead. This method of driving the cam shaft gives a quick change feed for the cutting tools and a constant maximum speed for what are termed "idle movements," irrespective of the rate of speed during the cutting period. The quick-change gears in the feed box *E* are controlled by two handles, the lower one *I* having three locations, corresponding to the feed cam used, there being three of these cams furnished, one for work not over 2 inches long, one for work between 2 and 4 inches and the other for work ranging between 4 and 6 inches in length. Although the 6-inch cam can be used for the shortest work, there is of course an appreciable loss of time in moving the tool slide its full travel when working short pieces. When the lower

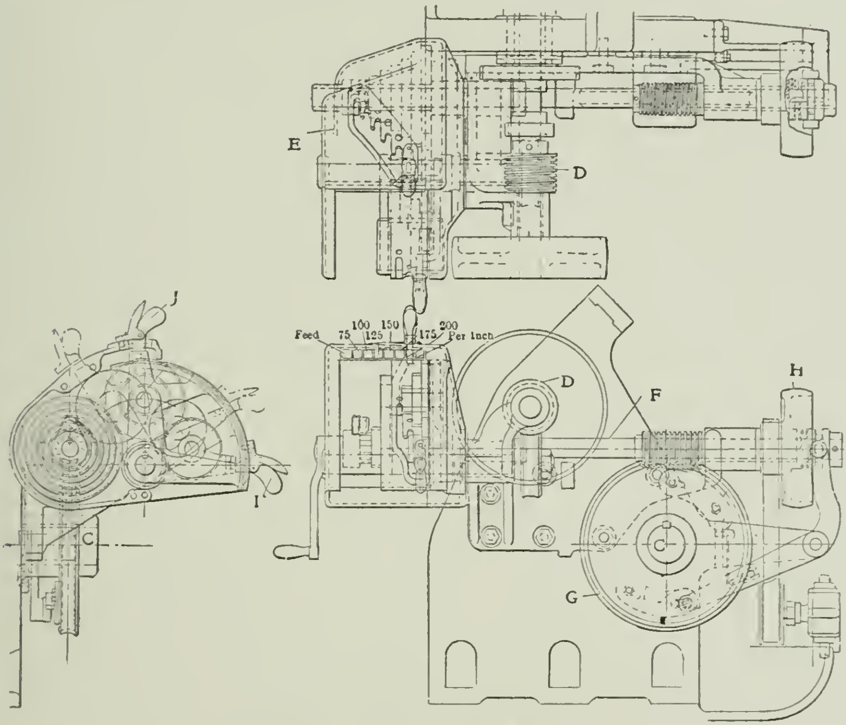



Fig. 109. — Feed-Driving Mechanism

handle is in the position corresponding to the feed cam which is being used, the upper handle *J* can be placed in any one of the six positions to give the feed desired, the figures 75, 100, 125, 150, 175 and 200 representing the revolutions of the spindle to one inch of travel of the tool slide.

## TURNING AND THREADING APPARATUS

The form of tool slide allows a turning tool to be used identical with that employed on the Gridley single-spindle automatic turret lathe. The tool slide has sufficient room to allow of one tool being placed back of another.

As the spindles are driven constantly in one direction, as stated above, and in order that a high cutting speed for the turning tools and a low cutting speed for the die can be used, it is necessary to rotate the die at a speed slightly less than the speed of the spindle while threading, and at a higher speed when running the die off the piece. This is accomplished by means of two gears on the spindle-driving shaft, these gears meshing with two loose gears on the threading shaft, which in Figs. 105 and 106 is shown immediately above and to the rear of the tool slide. These gears are of such ratio that when one of them is clutched to the die shaft it will rotate the die at a speed slightly less than that of the spindle; when the other gear is clutched to the shaft, the die will rotate at a higher speed so as to run off. When a left-hand thread is being cut, the die rotates faster than the spindle during the threading operation and slower when running off.

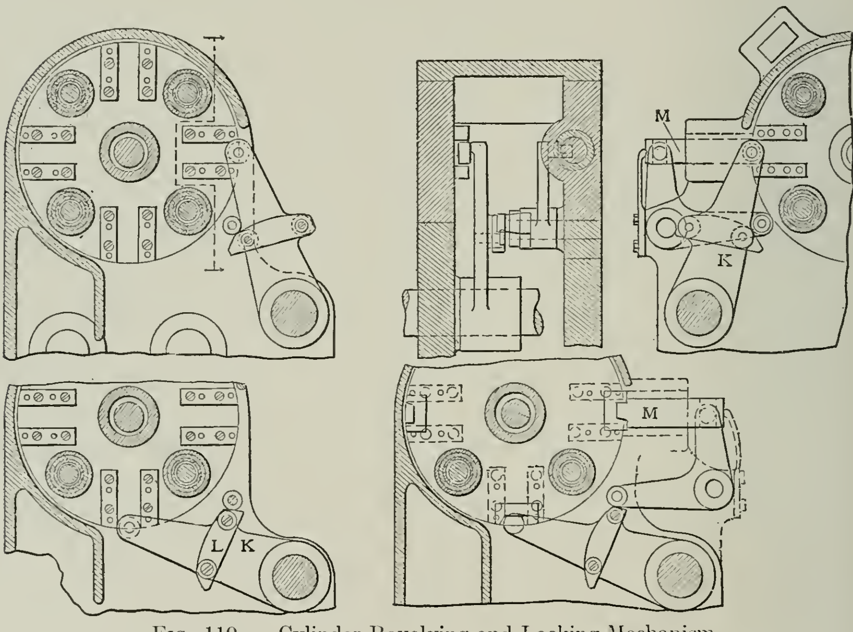


Fig. 110. — Cylinder Revolving and Locking Mechanism

## THE INDEXING MECHANISM

The mechanism for revolving the spindle cylinder is illustrated by Fig. 110, which also shows the method of operating the locking bolt. Arm $K$ mounted on the cam shaft carries a cam $L$ for withdrawing the locking bolt $M$ and has at its inner end a roll which at each revolution of the arm enters the channel in the face of the cylinder flange and rotates the cylinder one quarter turn, the locking bolt then dropping back into the next notch. The various sections show the cylinder just before the rotary movement commences and just after it has taken place, the locking bolt being shown in place in one view and withdrawn in another.

Further explanation of the mechanism is unnecessary as the drawings illustrate the scheme fully. It may be stated, however, that the index notches for the lock bolt are formed in tool-steel shoes, secured in rectangular pockets in the periphery of the cylinder.

The machine illustrated has a capacity for $1\frac{1}{8}$-inch round stock, 1-inch hexagon, and $\frac{3}{4}$-inch square stock.

# CHAPTER XIV

## The Cleveland Automatic Machine with Magazine Feed

The magazine attachment for enabling the Cleveland automatic turret machine to handle small castings and forgings requiring operations on one or both ends is represented in Fig. 111, which illustrates

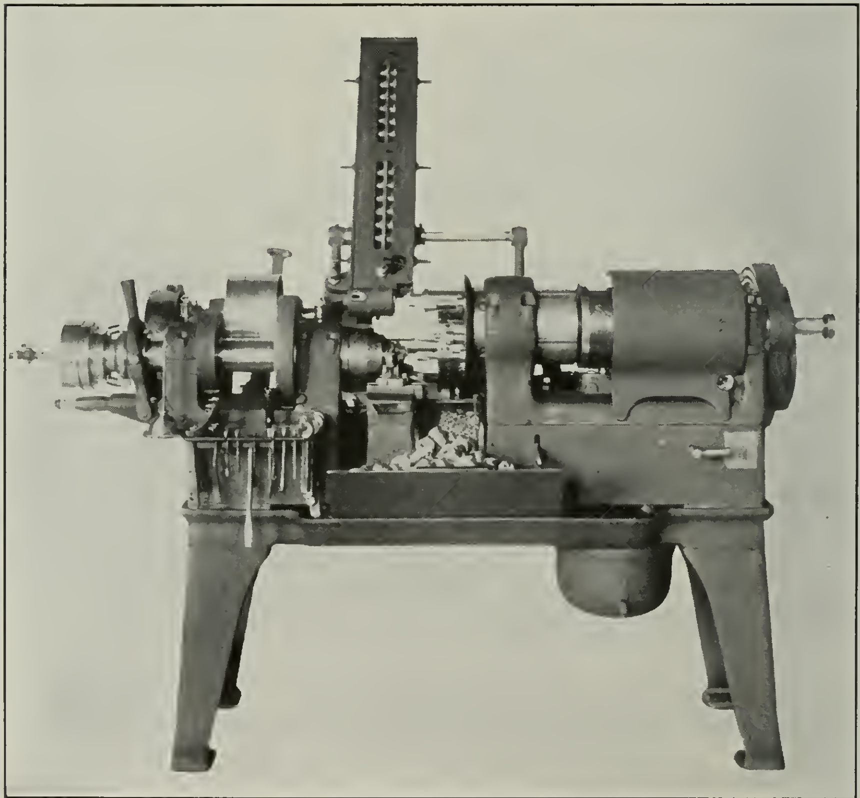


Fig. 111. — Cleveland Automatic Turret Machine with Magazine Attachment

the appliance in working position. The attachment is made in two forms, the older model being placed on the rear of the cross slide and operated by a cam on the regular cam shaft engaging with levers at the rear of the magazine. The later design or tilting magazine, as illustrated, is mounted on a shaft held horizontally by two upright brackets fastened to arms on the bed of the machine, and is tilted in front of the turret when the conveyor or transfer device is in position to take a piece out to be chucked; it is then tilted back avoiding interference with tools in the turret or on the cross slide. It is operated in the same manner as the older model. The conveyor is held in one of the tool holes of the turret. It grips the part in the magazine at the proper moment and carries it in line with the spindle, where the work is chucked, machined, and ejected to make way for the next piece removed from the magazine.

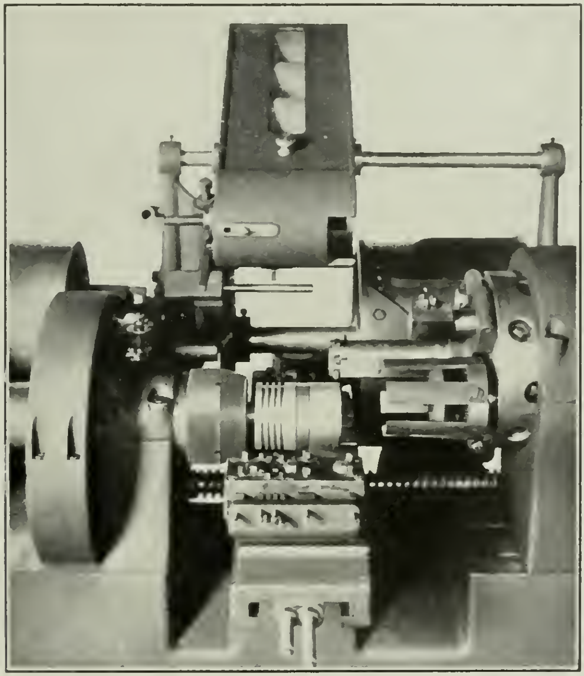


Fig. 112. — Machining a Piston in a Cleveland Magazine Machine

Fig. 112 shows a method of handling, in the magazine of a large Cleveland machine, a piston for automobiles. The piston is about $5\frac{1}{4}$ inches diameter and 6 inches long. The engraving illustrates plainly the turning tool fastened to the face of the turret. This tool takes a roughing cut on the outside of the piston and, as the turret revolves, it brings the tool on the opposite side in contact and takes a finishing cut. The conveyor is made with blades fastened to a holder in the turret. The short tool shown above it is for boring out and chamfering the end of the piston, preparing it for the grinding operation. The tools on the cross slide in front rough out the ring grooves and the clearance in the center, and face down the end; the tool on the slide at the rear finishes the ring.

## CHAPTER XV

### The Alfred Herbert Magazine Automatic Screw Machine

In Fig. 113 is illustrated an automatic magazine screw machine built by Alfred Herbert, Ltd., for handling castings. The castings shown are

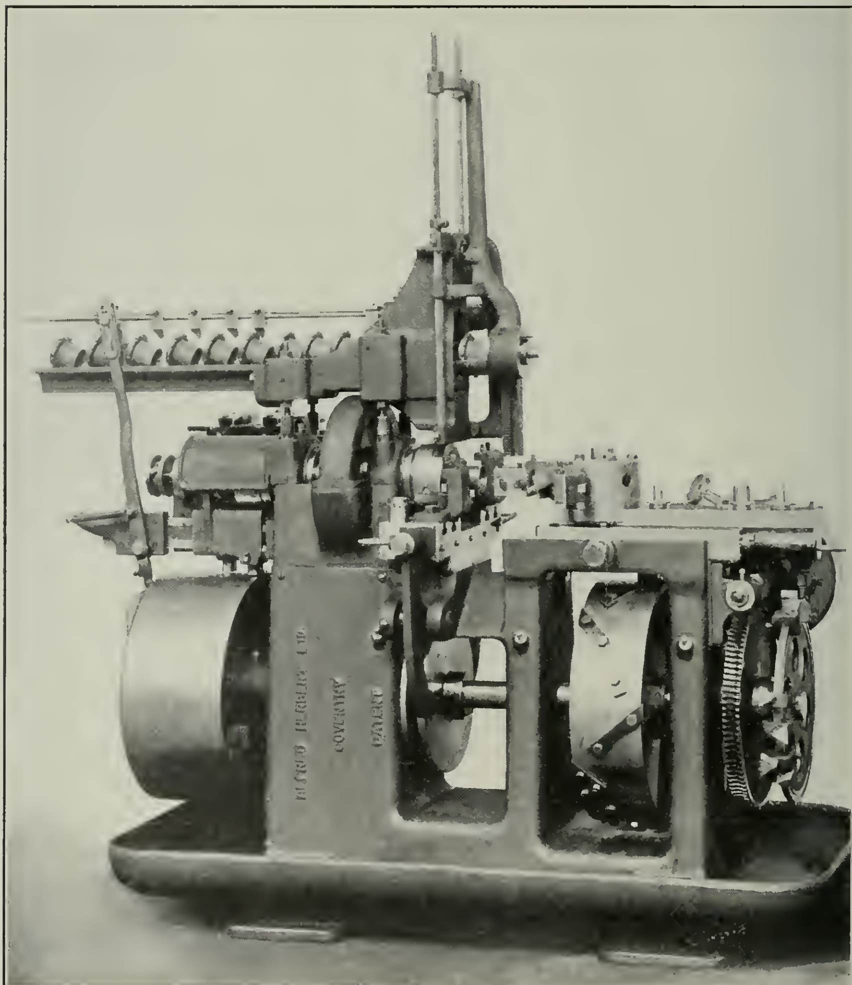


Fig. 113. — Alfred Herbert Magazine Machine

used for electric cable connections. The machine is illustrated with the magazine full, ready for work and with a finished piece in the chuck, and upon the turret slide will be seen several sizes and types of castings for which the machine is fitted up.

### SPINDLE AND CHUCK

Fig. 114 shows the spindle and chucking mechanism, and Fig. 115 the construction of the magazine. The chuck is of the three-jaw type

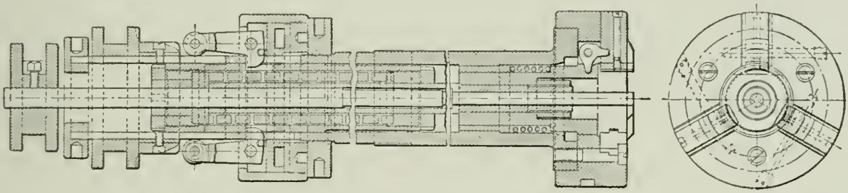


Fig. 114. — Spindle and Chuck

and operates against a stiff steel spring in the spindle, thus allowing for variations in the rough castings. The jaws are provided with liners to suit different sizes, these liners being readily changed. The manner in which

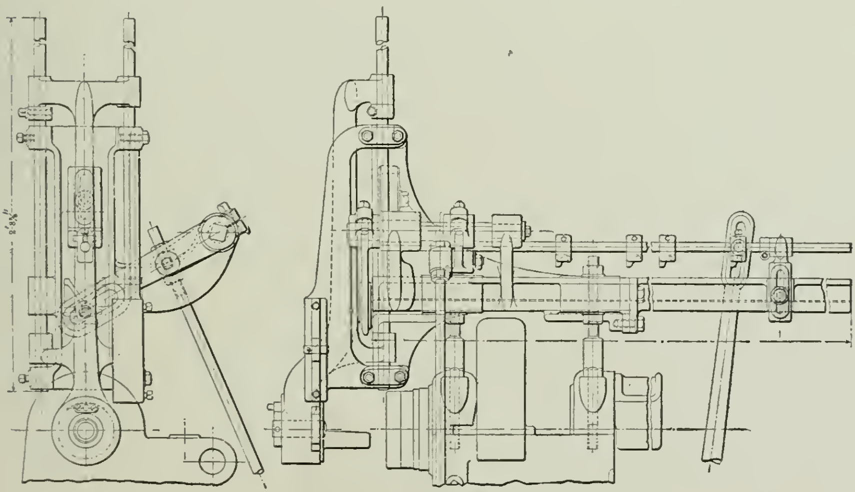


Fig. 115. — The Magazine

the chuck is opened and closed is clearly shown in the drawing and needs no explanation. The rod at the center of the spindle ejects the work when it is completed.

### MAGAZINE FOR SHELLS

The manner in which the work is fed from the magazine into the chuck is more clearly seen in Figs. 116, 117, and 118. In this case the machine is shown fitted up for one-pounder shells for quick-firing guns. Although the work is of a somewhat different nature from that in the machine in Fig. 113, the magazines are practically alike. The shells, which are made from a high grade of cast steel, have been bored out straight, formed outside and cut off in a previous operation in another machine, and the function of the machine here shown is to chamber out the interior of the shell and thread the hole. The spindle carries a draw-back chuck, and in this chuck is a bushing which forms a stop for the shells and also admits the end of the ejector.

### THE SHELL FEED

The upper trough of the magazine is kept filled with shells which are fed forward periodically by means of the long bar carrying the small adjustable pawls shown immediately above the trough, the feed bar being moved by a lever operated by a cam on the drum below. From the trough the shells are fed one at a time into a rotating carrier attached to a rising and falling slide. In Fig. 116 a shell has just been fed into the carrier. After the shell already being operated upon has been completed it is ejected. The carrier then descends to the position shown by Fig. 117, where the next shell is just about to enter the chuck. It is pushed into the chuck by means of a plunger in the carrier, this plunger being moved by a spring plunger in the turret. At the same time another small plunger is pushed in by an adjustable projection on the turret and releases the carrier, which turns over under the action of a flat spring like a clock spring, and assumes the position shown in Fig. 118. In this view the shell is chucked and ready for machining.

The carrier is now raised to its original position in Fig. 116, and on its way up is turned over to its proper position by means of a rack which engages with a gear ring on the carrier hub.

### THE CARRIER MECHANISM

The carrier mechanism is shown in Fig. 119, in which *A* is the carrier proper and *B* the gear ring, which is a free fit upon the hub. At *C* this hub is provided with a series of ratchet teeth which engage with a pawl *D* upon the gear ring. *E* is a small plunger carrying a tooth *F* which engages with clutch teeth at the back of the carrier and holds it in the position shown, against the action of the clock spring *G*. It will be seen from this drawing that when the carrier descends, the gear ring will rotate freely upon the carrier without turning it, the pawl slipping over the ratchet teeth. When the carrier rises, however, after having been turned

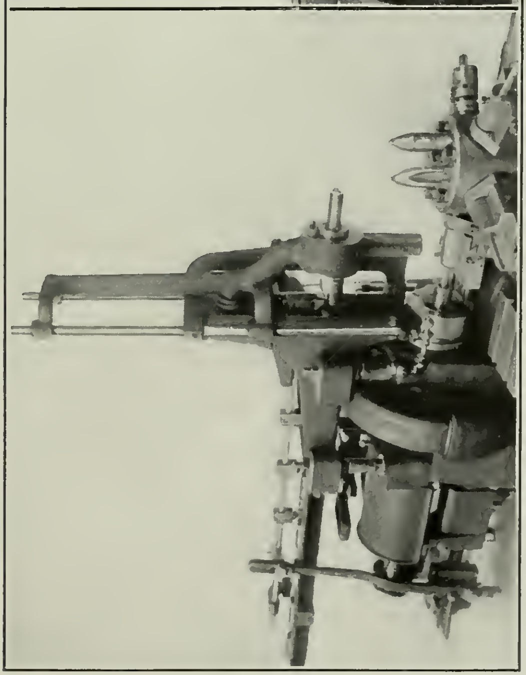


Fig. 116

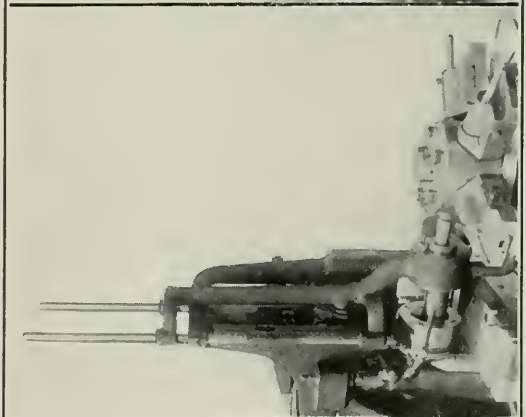


Fig. 117

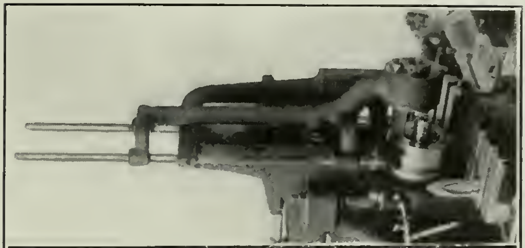


Fig. 118

Herbert Magazine Machine Equipped for Handling Shells over by the clock spring, on the release of the plunger *E*, the rack on the magazine rotating the gear wheel transfers this motion through the pawl to the carrier and thus rotates it back into its original position.

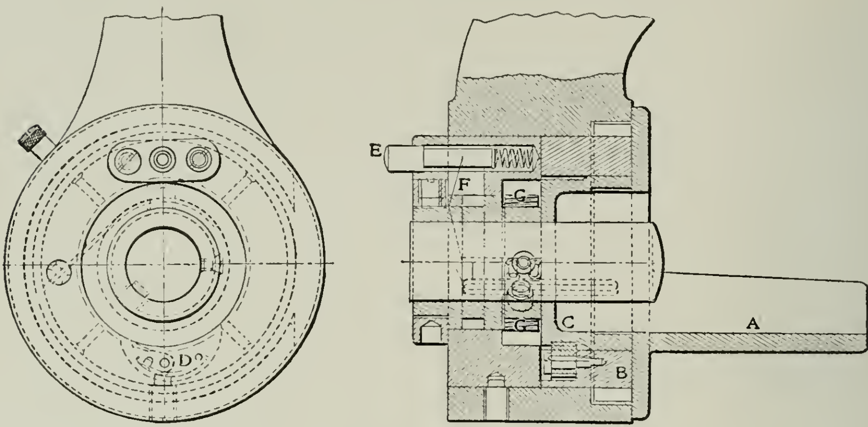



Fig. 119. — Rotating Carrier

### OPERATION OF THE CARRIER

The lever for moving the vertical slide in which the carrier is mounted, is clamped on a square shaft shown at the back of the attachment. This shaft is rocked by a short lever which is connected by an adjustable rod with the cam lever hung below in the frame of the machine. This lower lever, being moved by a cam, has a fixed stroke; but by adjusting the nuts on the connecting rod, the position of the slide — when the cam lever roll is on the highest point of the cam — may be varied to bring the carrier into correct alinement with the work on the magazine. On the downward movement the slide is stopped, with the work in line with the chuck, by means of an adjustable stop collar placed on one of the vertical rods. This adjustment at top and bottom is very important, as the position of the carrier must vary with the diameter of the work. In addition to the vertical adjustment, the magazine has an adjustment endwise to and from the chuck.

### ADVANTAGE OF THE MAGAZINE

This type of magazine has been used by the firm for chucking all kinds of pieces where the length is greater than the diameter, one of its advantages being that the same form of trough can be used for a great variety of work. In cases where the pieces will not lie in the trough in such a position that they can be easily chucked, small shoes are made to carry them. These shoes hold the pieces level until they are chucked and then drop off into the tray. They can afterwards be collected and used over again.

THE CHAMBERING TOOLS

In forming the chamber in the steel shells three turret tools are used, each tool being adjusted to do its share of the work. The construction of the tools is shown in Fig. 120. The body *A*, provided with a shank fitting the turret hole, is cut out dovetailed at the bottom to receive a slide *B*. On this slide is secured a former *C*, which is shaped to suit the

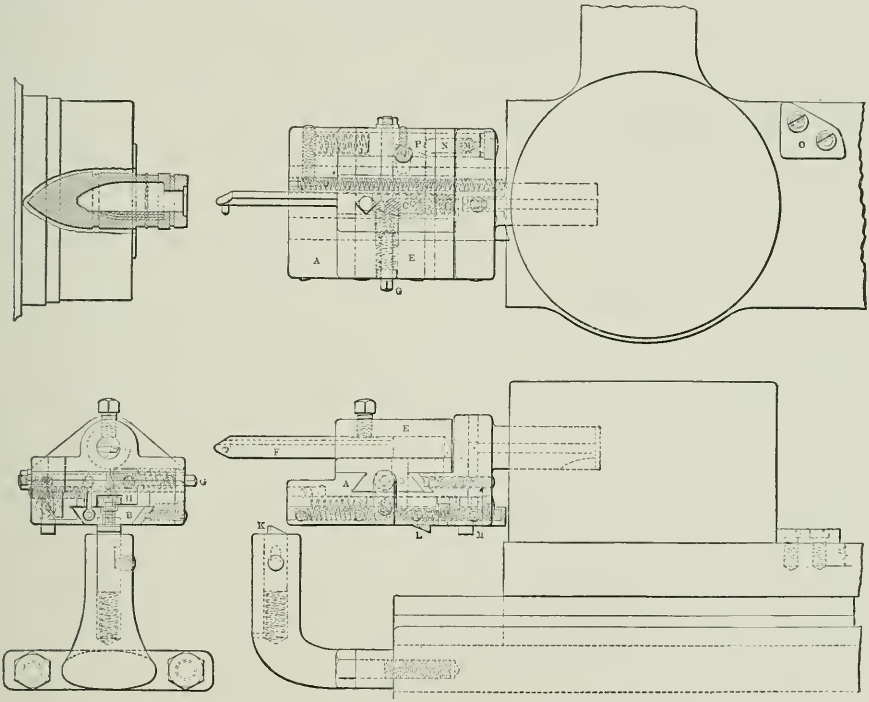



FIG. 120. — Tool for Forming Chamber in Shell

chamber in the shell. A long spring *D* holds the slide back in place on the body *A*. The cross slide *E*, fitted to the top of *A*, carries the tool bar *F*, this bar being provided with a hole for admitting oil to lubricate the tool and wash out the chips. In the cross slide is a screw *G* carrying a shoe *H*, which is held against the former *C* by means of the spring *J*. By turning the screw *G* the tool can be adjusted to the cut.

CUTTING THE CHAMBER

The tool is run in to the bottom of the hole and cuts on the return. When the turret moves up, carrying the tool into the shell, a spring plunger *K*, fitted in a holder secured to the front end of the turret-slide block, engages with a tooth *L* on the bottom of the former slide *B*. The slide is thus kept from moving when the turret is drawn back. The former being held in position, the shoe *H*, as it slides along, moves the cross slide *E*, and the cutting tool forms the chamber in the shell.

When the shoe reaches the back of the former it snaps over the end, the spring returning the cross slide to its central position, so that the cutting tool — as it is withdrawn by the turret — will clear in the smaller hole in the outer end of the shell. When the turret rotates, a pin *M* in a spring plunger *N* in the back of the body *A*, strikes a steel plate *O* behind the turret and forces the plunger ahead. This plunger is milled out at *P* and in the notch rests a pin *Q* carried in the bottom of the cross slide *E*. When the plunger is forced ahead by the plate *O* the inclined surface at *P* moves the pin *Q* and slide *E*. The shoe *H* thus being withdrawn from behind the former *C*, the slide *B* is forced back by the spring *D* into its original position in the holder.

### THE TAP HOLDER

The tap for the hole at the back of the shell is carried in a self-releasing holder shown in place in Fig. 116. The teeth on this holder disengage when the tap has reached the required depth. When the spindle reverses, a spring pin in the holder engages with a ratchet on the shank of the socket, holding it stationary while the tap is withdrawn. The holder is carried in a socket provided with a spring which gives the pressure necessary for starting the thread when the tap is brought up to the work.

# CHAPTER XVI

## The Potter & Johnston Automatic Chucking and Turning Machine

The "manufacturing automatics" made by Potter & Johnston, Pawtucket, R. I., are adapted for handling castings, forgings, and bar stock up to large diameters; all operations after the chucking of the piece being performed automatically. The machine sizes are $5\frac{1}{2}$ x 10 inch and $8\frac{1}{2}$ x 16 inch; and both are built with triple-geared and direct belt

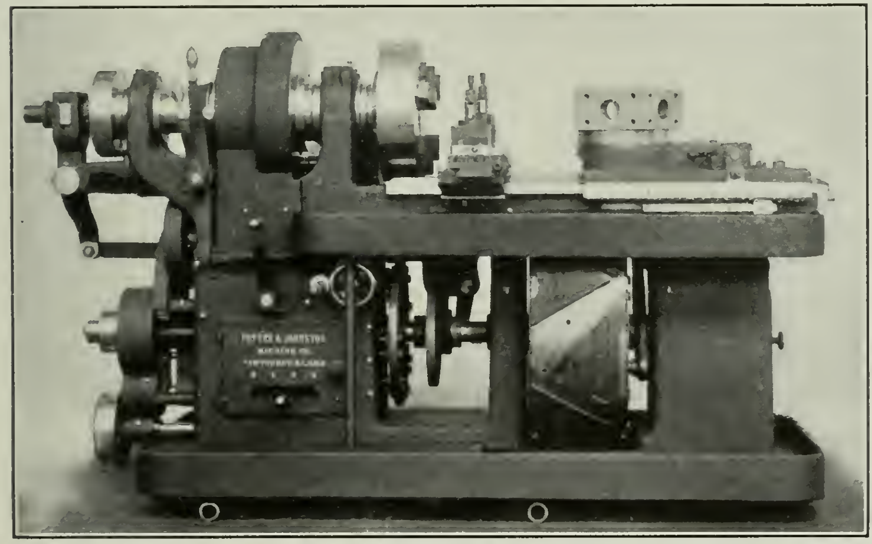


Fig. 121. — Potter & Johnston Manufacturing Automatic

driven heads and with various sizes of spindles ranging from a diameter of 3 inches with a $1\frac{9}{16}$-inch hole, for operating on small work at high speeds, to $7\frac{3}{4}$ inches diameter with $6\frac{1}{4}$-inch hole for taking bar stock up to 6 inches and machining heavy castings and forgings. The machine illustrated in Figs. 121 and 122 and known as the $8\frac{1}{2}$ x 16 inch model has a spindle diameter of $5\frac{3}{4}$ inches, the hole through the spindle having a diameter of $4\frac{1}{2}$ inches.

### THE SPINDLE DRIVE AND SPEEDS

As will be seen upon examining the rear view in Fig. 122 the machine is driven by a plain pulley mounted on the back shaft which is geared to the spindle. Two rates of speed are obtained through the gearing, the spindle revolving always in one direction; right- and left-hand tapping, however, can be done by special arrangement, without reversing. The two speed changes are obtainable automatically, thus making it practicable to run at a suitable speed for drilling say a small hole and turning the hub of a piece, and then drop to a reduced speed for machining the larger periphery of the work. A set of change gears for the spindle drive are provided for giving the correct speeds for any work within the capacity of the machine, the speeds of course being determined prior to starting operations on the work.

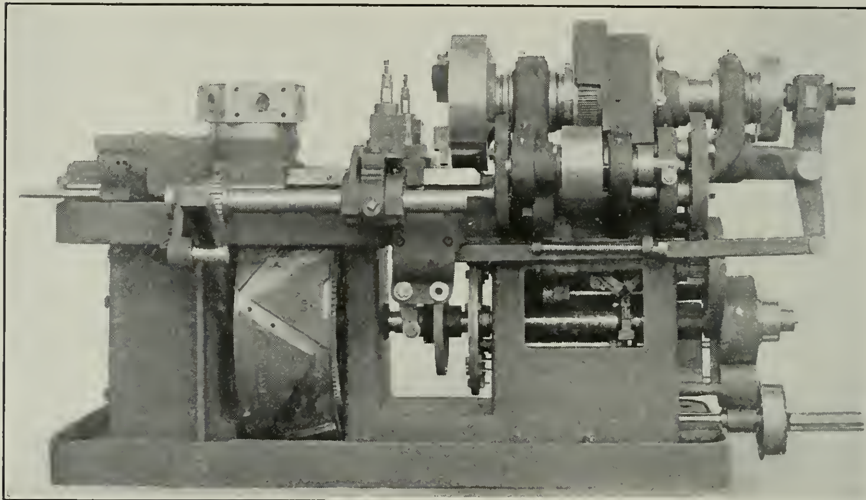


Fig. 122. — Potter & Johnston Manufacturing Automatic (Rear View)

The speeds are controlled by adjustable dogs on the right-hand side of the cam disk shown directly underneath the chuck. The dogs actuate at the predetermined moment a horizontal rod connected to the vertical clutch lever at the left-hand end of the head and thus cause either the fast or slow speed to be thrown into or out of action. The vertical crank handle at the front of the head and to the right of the speed-clutch lever connects the driving pulley at the back of its shaft or releases it, thus forming a convenient means of starting and stopping the machine without interfering with the countershaft.

### THE FEED MECHANISM

Both turret and cross slides are operated automatically from the main cam shaft placed longitudinally of the machine. This shaft is driven from the spindle by a belt leading over the pulleys shown at the end of head and bed. The lower pulley operates through spur gears an epicyclic train connected to the cam shaft, and by means of this epicyclic gearing and suitable clutches the cam shaft may be given a slow speed for the cutting travel of the tools and a rapid velocity for quickly withdrawing the tools, indexing the turret and bringing it forward again to cutting position.

The speed changes of the cam shaft are controlled by dogs on the opposite side of the disk which carries the spindle-controlling dogs referred to above. A dog carried by this disk also stops the feed when the work is finished.

Four rates of feed for cutting operations are provided by a quick change gear in the base. Having determined upon the proper feed for handling a job, the change-feed gear lever is dropped into the notch to correspond with the feed desired. It frequently happens, however, that a finer or coarser feed than that originally provided for should be used, the operator then simply moving the change-feed gear lever which projects through the door at the front of the machine either to the right or left, and dropping it into one of the notches which are numbered "2–1–3–4." When the handle is placed in the notch bearing no number, the feed is thrown out.

### THE TURRET AND CROSS SLIDES

The turret is five-sided and the slide on which it is mounted is operated by the large cam drum on the main shaft. The turret is clamped in each position as it indexes around and is thus held rigidly while the tools are at work.

The form of the cam is plainly seen in the two general views. The cams in the regular equipment are suited to all ordinary work up to 9 inches in length and special cams can be used for pieces of unusual character.

The cross slide has front and rear tool posts and the tools may be arranged to work at the same time the turret tools are cutting or independently of these tools. The slide is adjustable longitudinally on the bed and the cams which operate it are placed at the right-hand end of the cam drum for the turret slide where they are readily adjusted from the front of the machine.

Fig. 123 shows the cross-slide cams, the oblique rack which they operate and the gear which meshes with the rack and turns the back shaft which is in turn connected by a similar gear with a rack under the cross slide. This line drawing and the rear view, Fig. 122, show the means of operation clearly.

### BACK-FACING BAR

The automatic back-facing bar through the spindle is an important feature. The end of the bar is provided with a taper hole to carry drills, cutters, facing tools, either singly or in combination, and by their use a large variety of pieces, such as gears, pulleys, etc., may be finished complete at one holding, the back-facing tools finishing the inner end of the hub and turning it, while the turret and cross-slide tools are turning the periphery, facing down both edges of the rim, the outer hub, and boring the hole. By this arrangement it is possible to have as many as

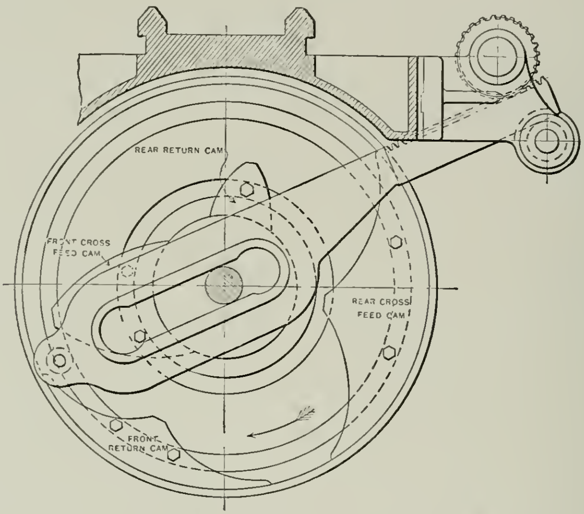



Fig. 123. — Cross-Slide Cams and Connecting Mechanism

eight cutting tools in simultaneous operation, thus completing the work expeditiously. Where extreme accuracy is required, a double back-facing bar with cutters for roughing and finishing chips may be applied. The arrangement of the back-facing bar and the method of operation will be understood from the illustrations.

### MACHINE WITH LARGER SPINDLE

The engraving, Fig. 124, is presented to illustrate the $8\frac{1}{2}$ x 16-inch machine as constructed with $7\frac{3}{4}$-inch spindle adapted for receiving bar stock up to 6 inches diameter. This view shows in addition to other interesting details, the centering chuck at the rear end of the head for gripping and supporting the stock.

### TOOL EQUIPMENT

The general character of the tools used on this type of machine is indicated in Figs. 125 and 126, which show the machine set up for turning, boring and facing operations. The combination tools and their functions will be understood without explanation. Another interesting job is represented in Fig. 127, which illustrates the method of machining

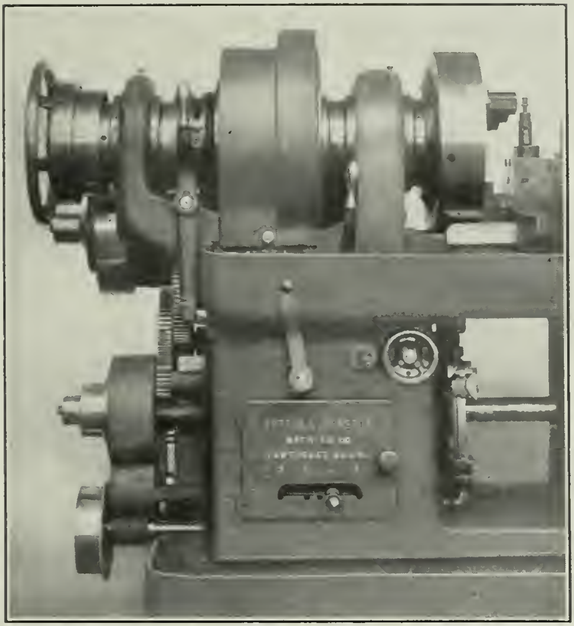


Fig. 124. — $8\frac{1}{2} \times 16$ inch Potter & Johnston Manufacturing Automatic

gas engine pistons and is also self-explanatory. A few specimens of the completed work produced on the machines are shown in Fig. 128, which suggests the range of diameters falling within the scope of the machine.

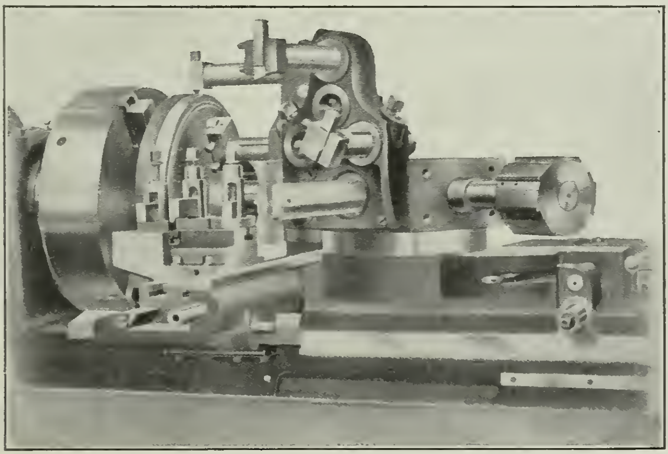


Fig. 125. — Turning, Boring, and Facing

### TOOL RECORD

Figs. 129 to 132 show the four pages of a convenient tool record sheet issued by the manufacturers and on which are recorded the tool and dog settings, change gears, etc., for a piece after the work has been set

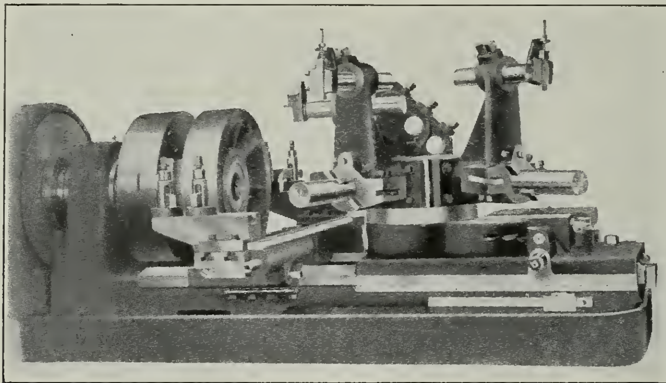


Fig. 126. — Turning a Spoked Fly-wheel

up. At any time afterward the settings may be readily duplicated by simply referring to the sheet, the features and advantages of which are well brought out in the illustrations.

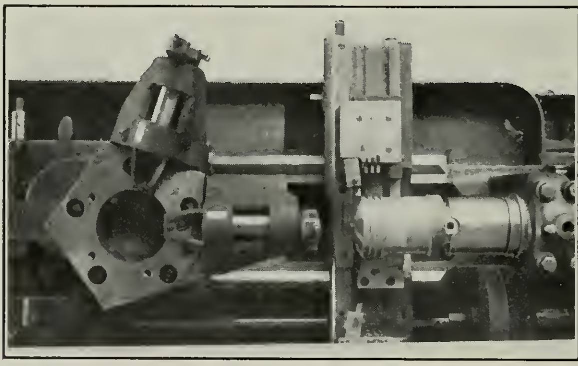


Fig. 127. — Machining a Gas Engine Piston

### MACHINE CAPACITIES, ETC.

The $8\frac{1}{2}$ x 16 inch machine illustrated swings 20 inches over the bed and 10 inches over the cross slide. The travel of the cross slide each way is $5\frac{1}{2}$ inches. The $5\frac{1}{2}$ x 10 inch machine swings 17 inches over the bed and 10 inches over the cross slide. The gear-driven heads of the type shown are operated from a single-speed countershaft driven by a pair of tight and loose pulleys and carrying a plain pulley belted to the machine. The countershaft for the machines with direct-belted head is operated by three-step cone pulleys. When the machines are equipped for motor drive the motor is mounted on a bracket directly behind the head.

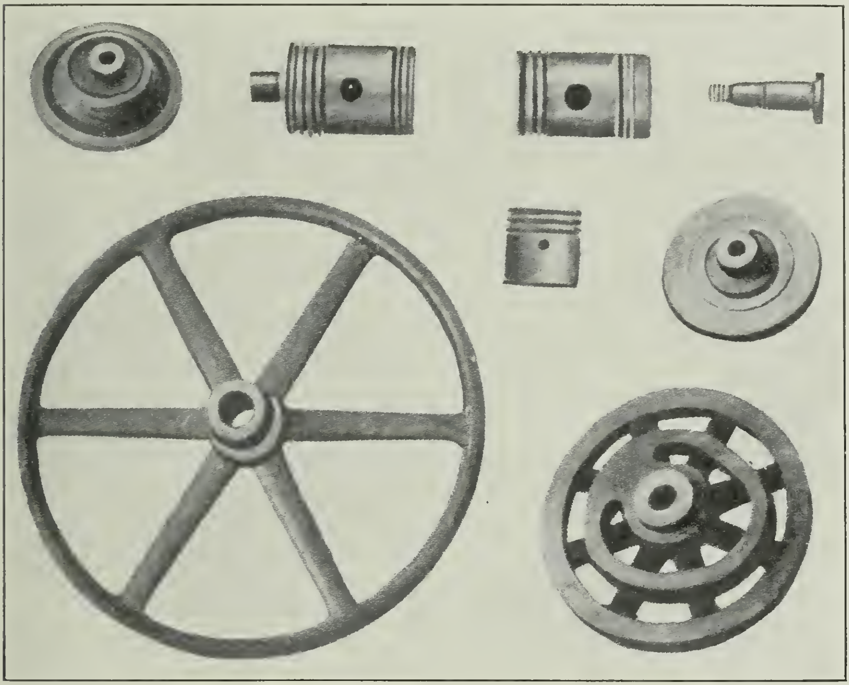


FIG. 128. — Some of the Work done on the Potter & Johnston Machine

Either size of machine with the smaller spindles may be equipped with a lever chuck which can be operated to admit or release work without stopping the spindle, this being of especial advantage when machining small work from the bar or handling comparatively light castings and forgings.

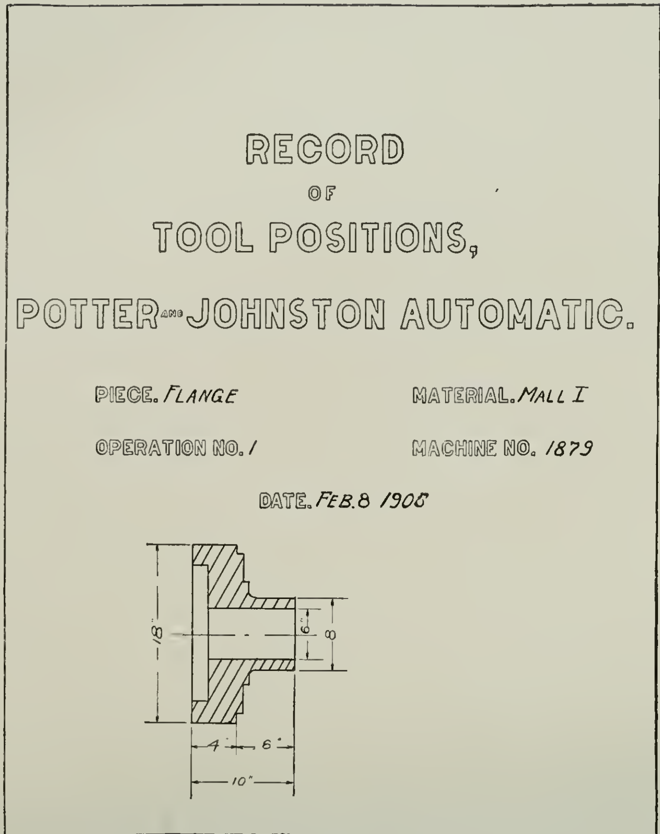



Fig. 129

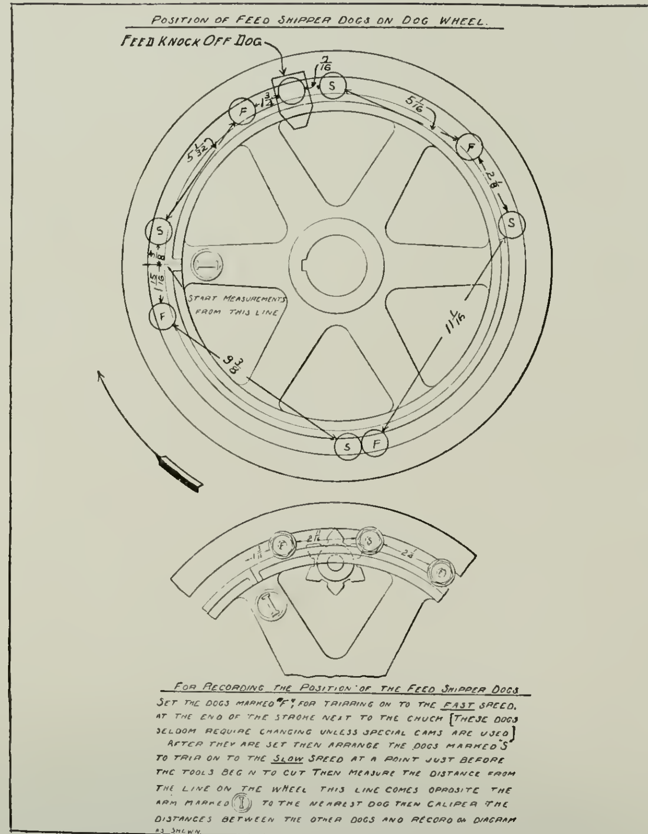



Fig. 130

First and Fourth Pages of Tool Record

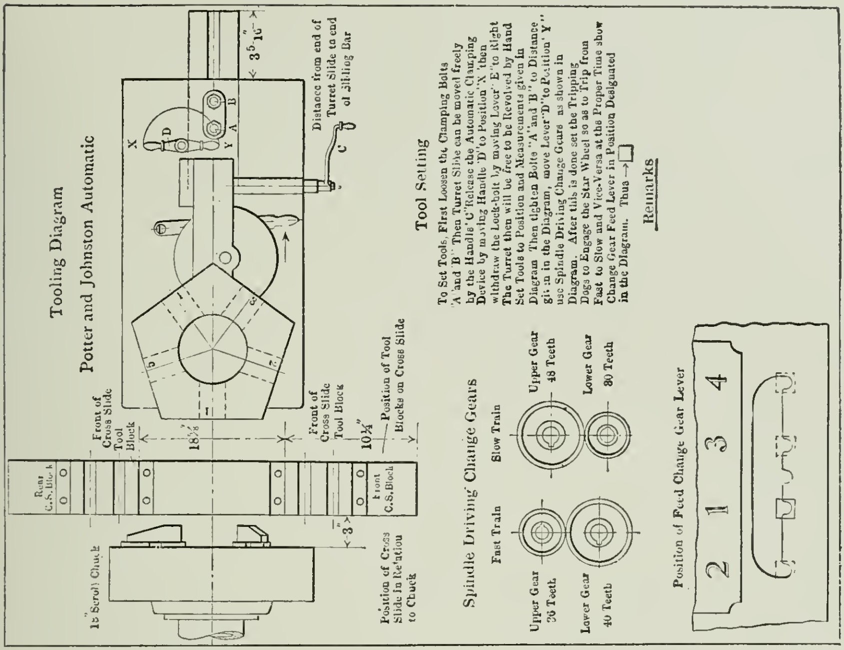



Fig. 132

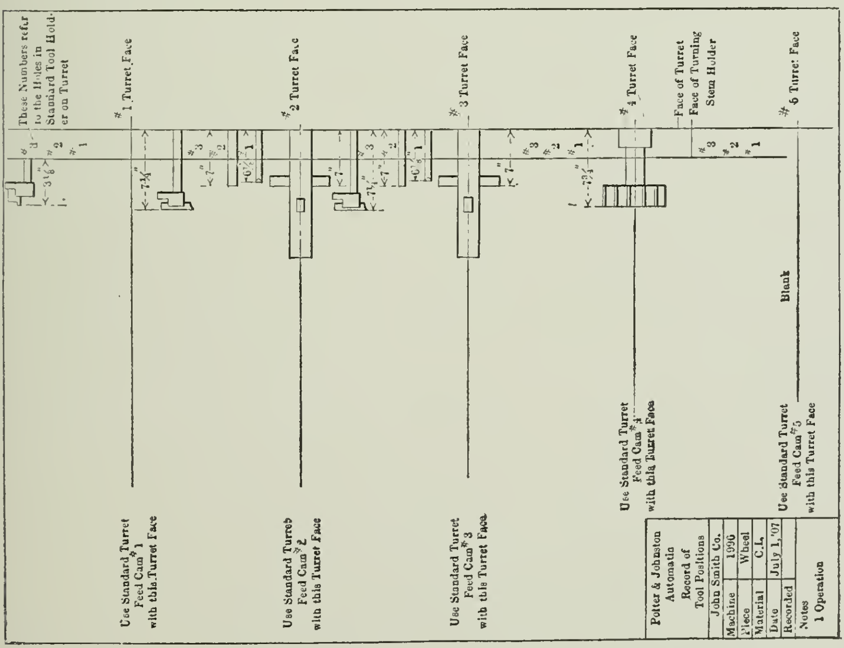



Fig. 131

Second and Third Pages of Tool Record

# CHAPTER XVII

## The Gridley Semi-Automatic Piston Ring Machine

This machine is in general design quite similar to the Gridley automatic machine for bar stock described in Chapter VII. It is constructed especially for making from the casting piston rings ready for grinding on the edge. The operator secures the casting to the studs in the face plate and the machine then bores the inside, turns the outside eccentric, and cuts the ring off from the casting automatically. Fig. 133 shows

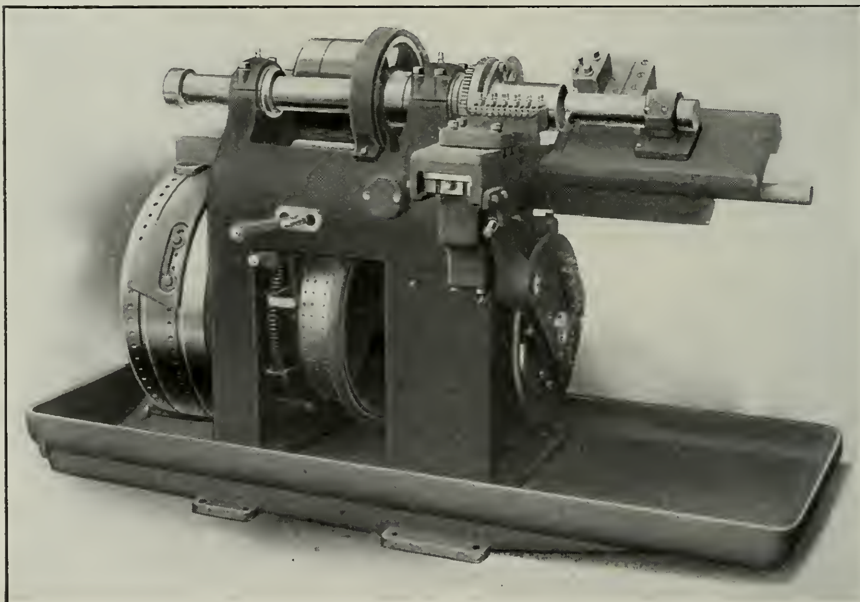


Fig. 133. — Gridley Semi-Automatic Piston Ring Machine

the machine as a whole; Fig. 134 illustrates the method of holding the special casting to the face plate and shows the means of operating the tools; Fig. 135 is a drawing of the casting from which the piston rings are made.

### ECCENTRIC TURNING MECHANISM

Fig. 136 is a construction drawing of the eccentric turning mechanism. In this engraving *A* represents the head of the machine carrying the spindle

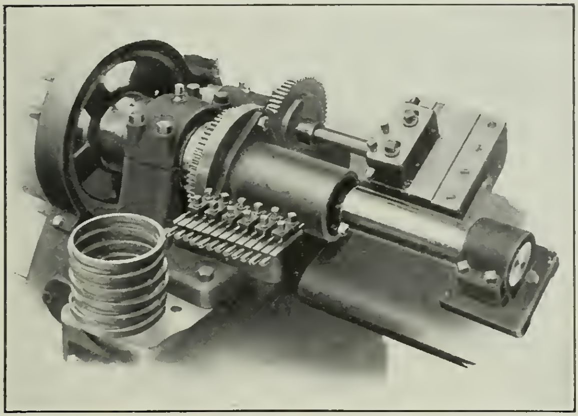


FIG. 134. — Boring, Turning, and Cutting Off Piston Rings

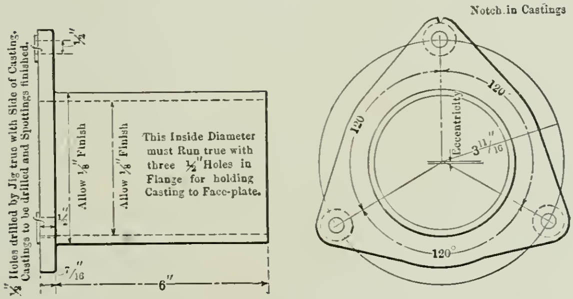



FIG. 135. — Casting from which Piston Rings are Made

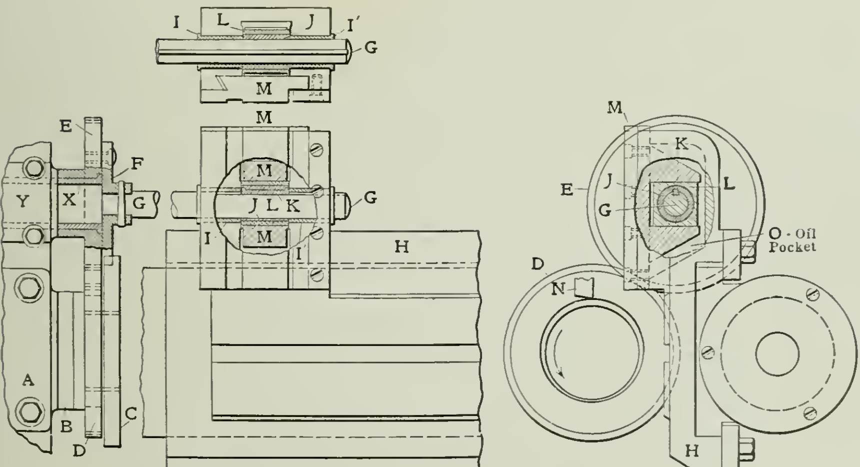



FIG. 136. — Eccentric Turning Mechanism for Piston Rings

*B* to which is attached the face plate *C*. This face plate carries the gear *D* which meshes with the driving gear *E*, to which is attached the coupling *F* pinned to the shaft *G*. This shaft is supported in the slide *H* by the two bushings *I* and *I′*. It carries the eccentric *J* and drives it by the key *K* which is free to move endwise in the keyway in the shaft *G*. The eccentric *J* is free to revolve in the square block *L*, and the latter is free to move vertically in the guideway in the auxiliary slide *M*. This arrangement gives the slide *M* a reciprocation for each revolution of the spindle; the gears *D* and *E* being of even diameter. It will be noticed that the construction provides an oil pocket at *O*, which keeps the parts thoroughly lubricated. The gear *E* runs free on the bushing *X* held in the frame of the machine by the cap *Y*. The same bushing *X* acts as a bearing for the back-gear shaft which drives the spindle.

## CHAPTER XVIII

### The Prentice Multiple-Spindle Automatic Turret Machine

The multiple-spindle automatic built by the Geo. G. Prentice Co., New Haven, Conn., is shown in the accompanying illustrations. This machine is designed for performing boring, turning, threading, and other operations on castings, forgings, and similar parts, also on pieces that

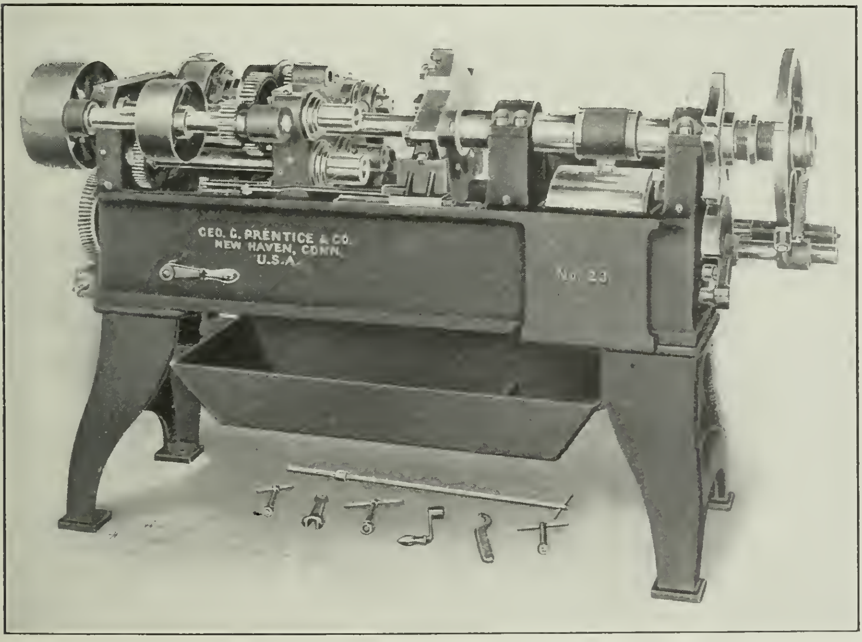



Fig. 137. — Prentice Multiple-Spindle Automatic Turret Machine

have been finished on one end in a bar-stock machine. It is especially adapted to the handling of such parts as air-brake-valve bodies, couplings and nuts, globe valves, grease cups, compression hose and fuller bibbs, gage- and ball-cock bodies, valve stems, etc. The machine shown has four spindles, these being arranged in the manner indicated in Figs. 137 and 138. Each of the spindles carries a tool for a different operation, and the work is automatically indexed and fed up to the tools by a cam drum, which will be seen in Fig. 137, near the right-hand end of the machine. The work carrier, or turret, consists of a chuck provided with five distinct sections or sets of jaws, each pair of jaws except the upper one being in line with one of the spindles; the upper section forms the point at which the operator feeds the work to the chuck.

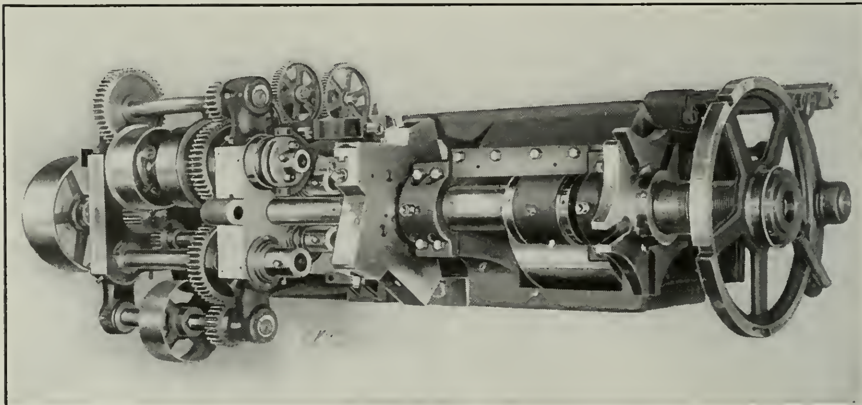


Fig. 138. — Prentice Multiple-Spindle Automatic Turret Machine

### THE DRIVING MECHANISM

The drive for the four spindles and cam drum will be understood from the general views. The first spindle — the one in front — is geared, as shown, to a shaft driven independently from the counter, while the two lower spindles are geared together and driven by the large pulley at the end of the head. The threading spindle is provided with friction reversing pulleys and back-geared, the ratio in the case of the machine illustrated (which is known as the No. 23) being 4 to 1, while the lower spindles are geared from their driver in a 2.7 to 1 ratio, and the front spindle in a ratio of 2 to 1. The cam shaft which feeds the work carrier up to the tools is driven from either the third or fourth spindle by change gearing extending to a shaft at the rear of the bed, this shaft being connected with the cam shaft — which extends the full length of the machine — by bevel and worm gearing.

### THE FEED

The feed drum is adapted to receive a cam strip fixed at the required angle, this being determined by the length of the longest cut required on the piece of work. An adjustable ring on the threaded end of the chuck shaft, or turret bar, forms a positive stop for each forward movement of the work to the tools. This stop collar will be noticed just to the rear of the indexing mechanism which brings the work into alinement with one spindle after another until completed. The feed clutch may be thrown out of gear and the feed instantly stopped by shifting the lever shown near the left-hand end of the machine. The chuck may be fed up by hand, when adjusting tools for new work, by turning to the left the worm shaft at the end of the bed.

### OPERATION OF THE CHUCK

The construction of the chuck is shown in Fig. 139. Each section forms a two-jaw chuck opened and closed by a right- and left-hand screw, and special false jaws are, of course, fitted to hold any shape of piece. As already stated, the work is placed in the uppermost section of the chuck, and the first indexing movement then brings it into line with the tool in the first spindle, where the first operation is performed. In the meantime a second piece of work has been placed in the following section of the chuck, which is then in the upper position, and when the first piece

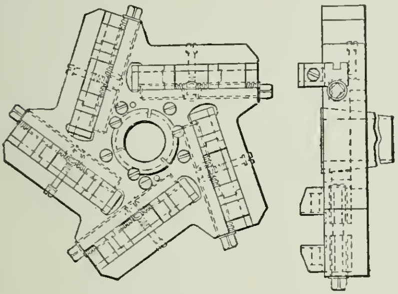


Fig. 139

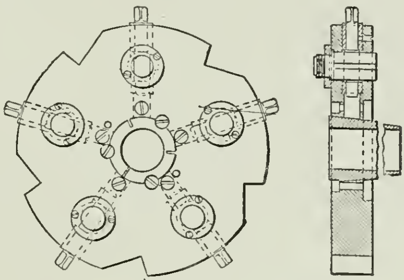


Fig. 140

Chuck and Face Plate for Prentice Turret Machine

is brought into line with the second tool, the first tool is operating on the second piece; thus each indexing movement presents each piece of work to a different tool and four operations may be carried on simultaneously; the operator simply takes out the finished parts and puts in the rough work without stopping the machine, and ordinarily can attend to two or more machines. While the tools are cutting the chuck is supported and relieved of strain by a bracket which slides under the ledge of the chuck at the front of the machine. This bracket is visible in Fig. 137, and, as there shown, is attached to a lever which automatically draws it back out of the way of the chuck before the latter indexes, and then moves it to supporting position again before the tools start cutting. A taper bushing in the chuck body forms a means of compensating for wear between chuck and turret bar.

### INDEXING FACE PLATE

For holding work that has been finished on one end and requires a second operation, an indexing face plate is used in place of the chuck.

This face plate, as shown in Fig. 140, has five drawback studs or work arbors, which are threaded to receive work having internal threads, or provided with threaded collets for externally threaded work. After a piece of work has been screwed on a few turns by hand, a half turn of an eccentric stud draws it back tight against a hardened collar.

The spindles of this machine are ground and run in bronze bearings, the front bearings being taper, and all but the threading spindle have tool holders forged solid on the spindle. The frictions on the threading spindle are of an expanding ring type and controlled by a lever contacting with a tripping disk on the cam shaft. When an automatic opening die or collapsing tap is used, the threading mechanism is locked in the forward position, and the reversing belt removed.

## TOOL EQUIPMENT

Fig. 141 illustrates some of the tools adapted to this machine. The one in the upper left-hand corner is for cutting external and internal

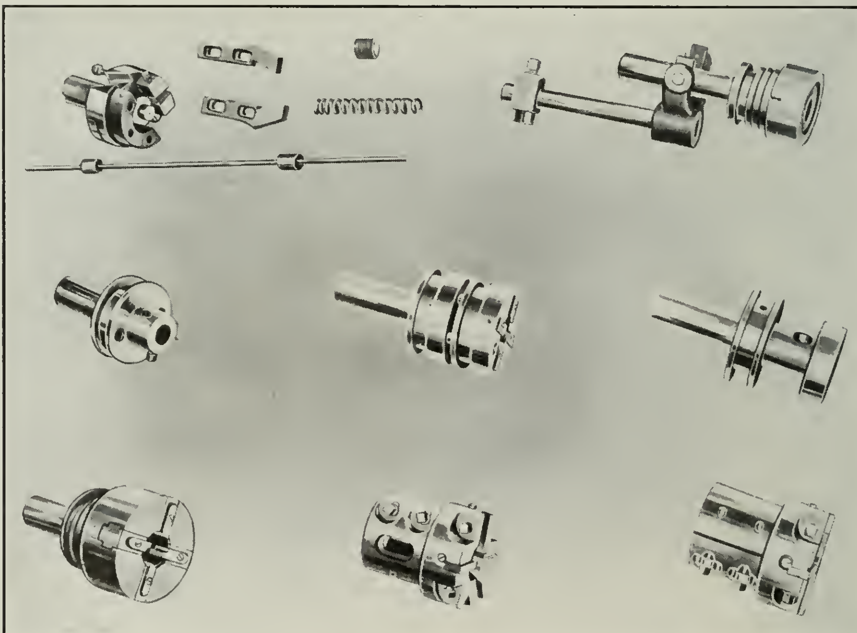


Fig. 141. — Prentice Turret Machine Tools

annular grooves, and consists of a shank and head with a cross slide and cutter moved at right angles by two wedges. For internal grooves the tool is carried at the center of the slide. A spring-actuated rod returns the slide as soon as the pressure on the work is removed. The tool at the right is a hollow mill which automatically opens upon the completion of the cut. The three tools in the second row are tap and die holders, the middle one being a combination floating affair for cutting external and internal threads at the same time. The tap holder proper slides on two studs in the threading spindle, and the die holder on two studs in the tap holder, thus allowing a tap and die of different pitch to be used together. Both types of tap and die holders shown are arranged to be led on the work by feed mechanism. An automatic opening die is shown in the lower left-hand corner, and at the right are a pair of adjustable roughing and finishing turning tools. Among other tools used are boring and turning tools, counterbores, etc., made of flat bar stock dressed on the grinder and inserted in holders.

### UNDERCUTTING TOOLS

Some details of the tools for cutting external and internal grooves of any desired form are presented in Figs. 142 to 149 inclusive. The tool, Fig. 142, is placed in one of the spindles of the machine and operated by an angular wedge and cross-slide mechanism, the wedges being made with the proper angle to give fast or slow cross motion to the cutter head. For external cuts, a ball-bearing pilot receives the thrust of the piece of work as the chuck is fed up to the tools, and this pressure forces the cutter head back on the wedges and draws the cutter down into the work. When the advance of the work ceases, and the chuck starts to back off, the spring in the hollow spindle forces the cutter head out on the wedges and the tool is drawn out of the work. For cutting internal grooves, the cutter is placed on the opposite side of the head from where placed for external work, and the same taper wedges are used for both forms of cutting.

### INTERNAL OPERATION

Fig. 143 shows the shape of the wedges, Fig. 144 the ball-bearing pilot. In Fig. 145, neck *a* is an external cut made with this tool. For internal cutting a circular or single-point tool is mounted on a special head used in place of the cutter head shown in Fig. 142. Fig. 146 is the cutter used for the inside groove *b* in Fig. 145. Fig. 147 is the cutter used for simultaneously forming the two inside grooves *c d* in the work, Fig. 148. On this work the cross motion of the cutter head does not begin until the cutter has entered the work and the face of the work comes in contact with the steel-thrust washer mounted on the cutter head.

### ROTARY CUT-OFF

There are certain classes of work, such as valve, gage, and compression-bibb spindles, which are cast with a chucking lug, from which the finished piece is severed after all the operations are performed. For this work

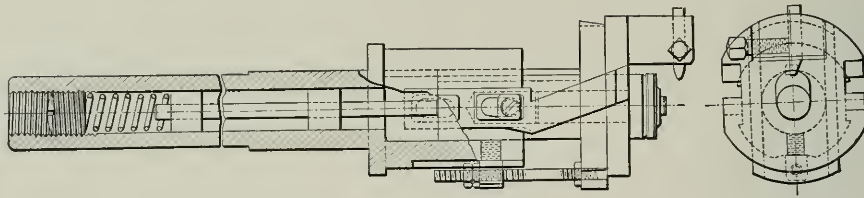
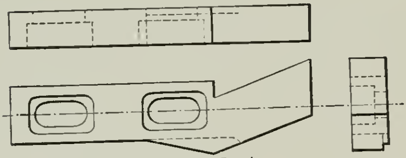


FIG. 142



Make Right and Left Hand

FIG. 143

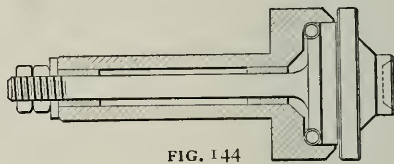


FIG. 144

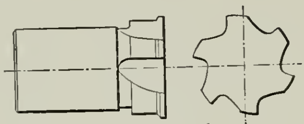


FIG. 146

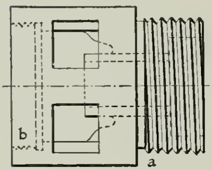



FIG. 145

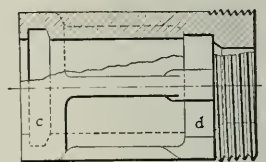



FIG. 148

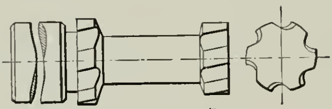


FIG. 147

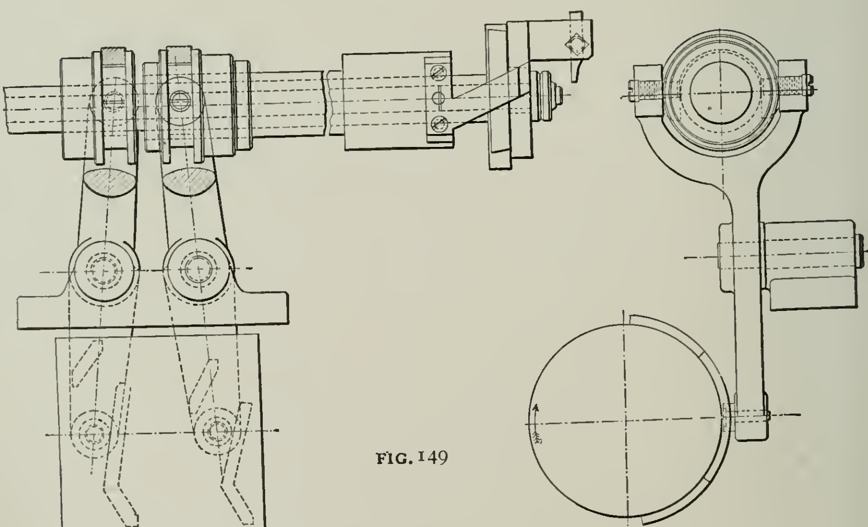


FIG. 149

Undercutting Tools for Turret Machine

a rotary cut-off tool is mounted in place of one of the regular spindles of the machine. As the tool must traverse a considerable length over the finished surface of the work to bring the cutting-off tool to the point of operation, the cutter head is fed out by means of the rear lever and cam as shown in Fig. 149. The advance of the chuck brings the work in contact with the ball-bearing pilot in the cutter head, and at the same time the forward lever and cam feed the cutter into the work, the feed being accelerated by means of the angle of the cam as the tool enters the work. When the operation is completed a return cam on the forward drum shifts the lever and withdraws the cutter from the work, and a similar cam shifts the rear lever and the tool is drawn back ready for the next operation.

### COUNTERSHAFT, MACHINE SIZES, ETC.

The arrangement of the countershaft and driving belts is represented in Fig. 150.

The machine illustrated will turn a length of 5 inches and swing 5

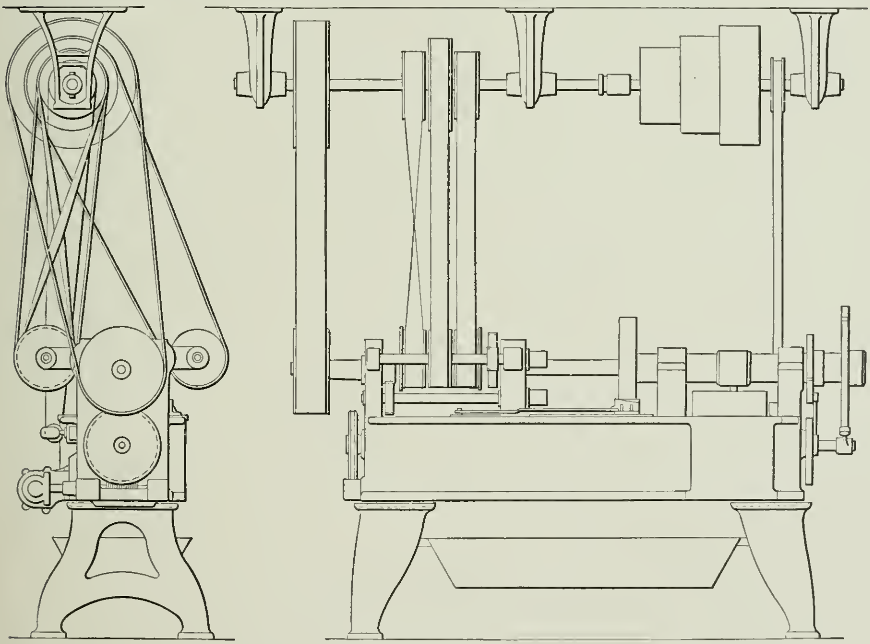


FIG. 150. — Countershaft and Drive for Prentice Automatic Turret Machine

inches outside of the chuck jaws. The false jaws open $3\frac{1}{4}$ inches. The threading spindle receives shanks $1\frac{1}{16}$ inches diameter by $4\frac{1}{4}$ inches long, and the other spindles have $1\frac{1}{2}$ x 3-inch holes. The threading capacity is up to $\frac{3}{4}$-inch pipe or $1\frac{1}{2}$ inches straight. There are three other sizes, the largest swinging 7 inches outside of chuck jaws, turning a length of 7 inches, and having a threading capacity for pipe up to 2 inches and straight work up to 4 inches diameter.

### DOUBLE-HEAD MULTIPLE-SPINDLE TURRET MACHINE

As will be seen by referring to Fig. 151 this machine is built on very similar lines to the single-end machine by the same company, but is double-ended and, therefore, performs boring, facing, drilling, turning, threading, and other operations on both ends of a piece at one setting in the chuck. The standard machine has three spindles in each end, between which is

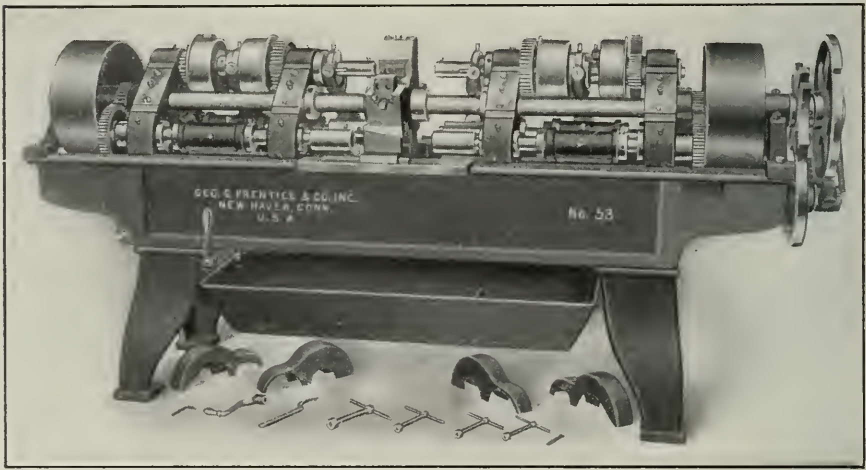



Fig. 151. — Prentice Six-Spindle Double-Head Automatic Turret Machine

a chuck having four sections or sets of chuck jaws. The spindles, carrying the tools, are in line with the different sections of the chuck, except the upper section, where the operator removes finished work and inserts an unfinished piece while the machine operates constantly on a piece of work in each of the other sections of the chuck.

### SPINDLE OPERATION

The spindles revolve and are fed up to the work by means of yoke and lever connections with cams on drums inside of the bed, the cam shaft extending the entire length of the machine. The forward-feed cams are set at the proper angle to give the required advance or cutting feed to the tools on the work, and the reverse cams draw the tools back from the work when the operations are completed. While the tools are backing off, the chuck is automatically indexing so that each piece of work is brought in line with the spindles which perform the succeeding operations.

The movements of the machine are timed so that the indexing occurs as soon as the longest single operation on any piece of work is completed. All the shorter operations are completed within this time, hence the time of finishing a piece of work on both ends is the time necessary for the longest single operation plus a few seconds taken in the indexing of the chuck and the advancing of the tools.

### THREADING MECHANISM

As the chuck indexes toward the front of the machine, the first or roughing spindles are at the front, and the finishing and threading spindles follow. The threading mechanism consists of a sliding tap or die holder with a fork lever connecting with a cam to start the lead of the thread. The driving mechanism consists of forward and reverse friction pulleys with expanding rings. The tap is driven the required number of turns into the work, then the reverse is automatically engaged and the tap withdrawn.

The proper cutting feed for different kinds of metal is obtained by change gears, a worm and worm gear connecting with the main feed shaft on which all cam drums are placed. The spindles are back-geared and have ample driving power for work within the rated capacity of the machine.

### GENERAL DATA

Three sizes of the six-spindle machines are built: One for light work, one with capacity for ¾-inch pipe size threads and smaller, and one for 2-inch down to ¾-inch pipe threads. The same design of machine is also built with four spindles in each head and a five-section chuck, the three sizes of this design corresponding in threading capacity with the three six-spindle machines. The eight-spindle type is adapted especially to handling bicycle hubs and gas and electric fixture work. All these machines have the same chuck-steadying bracket as the single-head machine illustrated.

# SECTION II

## SCREW MACHINE TOOLS

### METHODS OF MAKING AND USING THEM

# CHAPTER XIX

## Points In Setting up and Operating Automatic Screw Machines

In the following pages a few general suggestions are given which may be of interest to operators before considering in detail the different types of tools, determination of speeds, feeds, etc., treated fully in Chapters XX to XXVII.

It should be borne in mind that the automatic screw machine necessarily has more complicated mechanism than a hand-operated machine, as many movements must be performed automatically, which in the hand type of machines are accomplished by the operator. The automatic machines must, therefore, have the more careful attention in setting up for turning out work. When, however, the machines are properly adjusted, very little attention over that required on a hand machine is needed, although the use of dull tools must be particularly guarded against. The machines must be carefully erected and leveled up so as to avoid poor alinement between head spindle and turret, etc.

### operator's duties

Ordinarily a workman will readily attend to six machines and on very simple straightforward work may economically look out for more. He should become thoroughly familiar with the machine operations and adjustments before putting in tools or starting up, and it is generally well first to operate the machine by hand before putting on power.

Assuming that a new piece of work is to be produced on an automatic screw machine, it is well to consider first the various ways in which the work may be machined, and to give due consideration to the tool equipment available and to the quantity of pieces to be made, and then decide upon a satisfactory method.

### tools and collets

The making of special tools and the changing of the camming of the machine (if any) must then be attended to. All tools and holders must be made accurately to give correct results, and in addition it is always advisable to check the first few pieces produced, by gages or otherwise, to see that the pieces are of the correct dimensions. The collet should grasp the rod the entire length of the bearing surface, and have a tendency to bite harder on the front end than at the rear. This affords rigidity to the work when a cross-forming operation is being performed. The front end of the collet should likewise have a good bearing in its seat. The collet when closed must firmly grip the rod so as to prevent any slipping under the action of the cutting tools.

### HANDLING MATERIAL

The feeding chuck must have sufficient grip to feed the rod accurately without undue marring of the material upon its return stroke. It is generally considered well to straighten the bars of stock if they are bent, and also to gage them for diameter and to stack them into separate bundles if there is an appreciable variation which would cause difficulty when machining, and afterwards to make adjustment of the collets, etc., to suit the various sizes as worked up.

Where different qualities of steel are being used, extreme care must be taken to prevent mixing in a hard tool steel bar with the soft steel stock from which the work is supposed to be made; as the speed of the spindle and the feed may be such as to ruin expensive tools.

### TOOL AND OTHER ADJUSTMENTS

It is, of course, obvious that the lubricating pump should be known to be properly working and all cutting tools properly set with regard to the work and their cutting edges properly ground in order to get good results.

The head spindle bearings must be adjusted so as to permit running of the spindle at satisfactory speed without unreasonable freedom — else trouble will arise from this source. The cross slide, turret and turret-slide bearings must also be carefully adjusted and kept in good condition.

The selection of the proper spindle speeds for various jobs, as well as the determining of satisfactory feeds should be considered carefully. In the next chapter are tables which should be helpful in this connection.

### PRODUCTION

The rate of production is dependent not only on the rate of feed and spindle speed, but also on the tool equipment. The production of threaded work especially is facilitated by employing tools so designed as to take advantage of two speeds and to cut when the spindle is reversed.

The camming should be such as to permit the performing of several operations simultaneously, such as drilling from the turret and forming from the cross slide.

### MANIPULATION OF TOOLS

When changing the tool equipment from one piece to another the seat in the head spindle for the collet must be thoroughly cleaned as well as the collet, so as to avoid eccentricity in the operation of the rod due to foreign matter, when the stock is grasped by the collet.

It is well before dismantling tools to make a model on the automatic screw machine for convenience in setting up in the future. This model should be complete in all respects, but should not be fully cut off to its usual length, but should be left intact, with sufficient length of the bar to

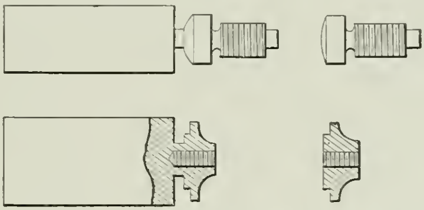


FIG. 152. — "Setting Up" Models for the Screw Machine

permit grasping by the collet allowing the model to be the proper working distance from the end of the spindle. The illustration in Fig. 152 shows two models with the piece of stock by which they are held when setting up for the production of similar work.

## BELTS, OILING, ETC.

It is recommended that belts without rivets be used for the spindle drive as they run smoothly at high speed. Laced wire also makes a smoother running belt than where leather lacing or hooks are used for coupling the ends together. On machines where the belts are shifted to change a spindle speed or the direction of rotation, double belts will be found superior to single belts as the former being of stiffer cross section may be more quickly moved and the results desired more quickly obtained.

The workmen in charge of machines should be instructed to lubricate all bearings frequently with good machinery oil and should be thoroughly familiar with the location of each hole and its function. Too much attention cannot be given to this if satisfactory continuous service is to be expected from an automatic screw machine.

The chapters that follow in this section describe in detail various classes of tools for screw machines and illustrate methods of making and using them. It is hoped that the information contained therein, with the chapters on camming and illustrations of tools in Section 1, may be of special interest and service to toolmakers, draftsmen and operators.

## CHAPTER XX

### Speeds and Feeds for Screw Machine Work

The ordinary class of screw machine tools, suitable speeds and feeds for which have to be determined when camming automatics, includes the various turning tools such as box tools (adjustable and non-adjustable), hollow mills, drills, reamers, counterbores, taps and dies, forming and cutting-off tools. The accompanying tables of speed and feeds for different types of tools used on materials commonly worked in the automatic have been compiled from data accumulated and thoroughly tested during extended experience in this class of work and have proved of value in the screw machine department, not only in connection with the handling of automatics, but also, to a considerable extent, on hand machines, although, naturally, the matter of feeds on the latter class of apparatus is largely regulated by the personal equation; the question of spindle speeds, however, is quite as important and as readily settled for hand machines as for automatics.

It is of course, impossible, where a series of tools is used on an automatic machine providing say two rates of speed for the spindle for any given job, to select speeds theoretically correct for each and every tool carried by the turret and cross slide. A compromise is necessary and therefore speeds are selected which will fall within the range suitable for the different tools; in determining these surface speeds and the rates at which to drive the spindle to approximate closely the desired surface velocities, the tables should be found of service.

#### SPEEDS AND FEEDS FOR TURNING

Tables 15 and 16 cover turning speeds and feeds for bright-drawn stock (screw stock) and brass, with various depths of chip (that is, stock removed on a side) from $\frac{1}{32}$ inch up to $\frac{3}{8}$ inch. These feeds and speeds and depths of cut are figured more especially for such tools as roughing boxes where the cut, though frequently heavy, is taken by a single cutting edge, the work being well supported behind the cutter during the operation. Table 17 covers the same range of steel work as Table 15, but is laid out for hollow-mill operations; it will be noticed that, the cut being divided with this tool among three or more cutting edges, coarser rates of feed are provided for than with the box tool. With both classes of

| CUTTING SPEEDS AND FEEDS FOR SCREW STOCK. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1/32 Inch Chip | | | | 1/16 Inch Chip | | | | ⅛ Inch Chip | | | |
| Dia. of Stock | Feet Surface Speed | Rev. per Min. | Feed per Rev. | Dia. of Stock | Feet Surface Speed | Rev. per Min. | Feed per Rev. | Dia. of Stock | Feet Surface Speed | Rev. per Min. | Feed per Rev. |
| ⅛ | 80 | 2445 | .002 | ¼ | 60 | 916 | .0035 | ⅜ | 55 | 560 | .004 |
| 3/16 | 70 | 1426 | .003 | ⅜ | 60 | 611 | .004 | ½ | 55 | 420 | .005 |
| ¼ | 70 | 1069 | .004 | ½ | 60 | 458 | .005 | ¾ | 55 | 280 | .006 |
| ⅜ | 70 | 713 | .005 | ¾ | 55 | 280 | .006 | 1 | 50 | 191 | .007 |
| ½ | 60 | 458 | .006 | 1 | 55 | 210 | .007 | 1¼ | 50 | 152 | .007 |
| ¾ | 60 | 305 | .007 | 1¼ | 55 | 168 | .007 | 1½ | 45 | 114 | .007 |
| 1 | 60 | 229 | .008 | 1½ | 50 | 127 | .008 | 1¾ | 45 | 98 | .007 |
| 1¼ | 60 | 183 | .008 | 1¾ | 50 | 109 | .008 | 2 | 40 | 76 | .008 |
| 1½ | 50 | 127 | .009 | 2 | 45 | 86 | .009 | 2¼ | 40 | 68 | .008 |
| 1¾ | 50 | 109 | .010 | 2¼ | 45 | 76 | .009 | 2½ | 40 | 61 | .008 |
| 2 | 50 | 95 | .010 | 2½ | 45 | 68 | .009 | 3 | 40 | 51 | .008 |
| 2¼ | 50 | 85 | .010 | 3 | 45 | 57 | .009 | 3½ | 40 | 44 | .008 |
| 3/16 Inch Chip | | | | ¼ Inch Chip | | | | ⅜ Inch Chip | | | |
| Dia. of Stock | Feet Surface Speed | Rev. per Min. | Feed per Rev. | Dia. of Stock | Feet Surface Speed | Rev. per Min. | Feed per Rev. | Dia. of Stock | Feet Surface Speed | Rev. per Min. | Feed per Rev. |
| ½ | 50 | 382 | .004 | ¾ | 50 | 254 | .004 | 1¼ | 45 | 137 | .005 |
| ¾ | 50 | 254 | .005 | 1 | 50 | 191 | .005 | 1½ | 45 | 114 | .005 |
| 1 | 50 | 191 | .005 | 1¼ | 45 | 137 | .005 | 1¾ | 45 | 98 | .005 |
| 1¼ | 45 | 137 | .006 | 1½ | 45 | 114 | .006 | 2 | 40 | 76 | .006 |
| 1½ | 45 | 114 | .006 | 1¾ | 45 | 98 | .006 | 2¼ | 40 | 68 | .006 |
| 1¾ | 45 | 98 | .006 | 2 | 40 | 76 | .005 | 2½ | 40 | 61 | .007 |
| 2 | 40 | 76 | .007 | 2¼ | 40 | 68 | .007 | 3 | 40 | 51 | .007 |
| 2¼ | 40 | 68 | .007 | 2½ | 40 | 61 | .007 | 3½ | 40 | 44 | .007 |
| 2½ | 40 | 61 | .007 | 3 | 40 | 51 | .007 | 4 | 40 | 38 | .008 |
| 3 | 40 | 51 | .007 | 3½ | 40 | 44 | .007 | 4½ | 40 | 34 | .008 |

TABLE 15. — Speeds and Feeds for Screw Machine Work

| CUTTING SPEEDS AND FEEDS FOR BRASS | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1/32 Inch Chip | | | | 1/16 Inch Chip | | | | ⅛ Inch Chip | | | |
| Dia. of Stock | Feet Surface Speed | Rev. per Min. | Feed per Rev. | Dia. of Stock | Feet Surface Speed | Rev. per Min. | Feed per Rev. | Dia. of Stock | Feet Surface Speed | Rev. per Min. | Feed per Rev. |
| ⅛ | 180 | 5500 | .003 | ¼ | 180 | 2748 | .004 | ⅜ | 165 | 1680 | .004 |
| 3/16 | 180 | 3668 | .004 | ⅜ | 180 | 1833 | .005 | ½ | 165 | 1260 | .006 |
| ¼ | 180 | 2748 | .005 | ½ | 180 | 1374 | .0065 | ¾ | 165 | 840 | .007 |
| ⅜ | 180 | 1833 | .006 | ¾ | 165 | 840 | .0075 | 1 | 150 | 573 | .008 |
| ½ | 180 | 1374 | .008 | 1 | 165 | 630 | .0085 | 1¼ | 150 | 456 | .009 |
| ¾ | 180 | 915 | .010 | 1¼ | 165 | 504 | .010 | 1½ | 135 | 342 | .010 |
| 1 | 180 | 687 | .011 | 1½ | 150 | 381 | .012 | 1¾ | 135 | 294 | .010 |
| 1¼ | 180 | 549 | .012 | 1¾ | 150 | 327 | .012 | 2 | 120 | 228 | .011 |
| 1½ | 150 | 254 | .014 | 2 | 135 | 258 | .014 | 2¼ | 120 | 204 | .011 |
| 1¾ | 150 | 218 | .014 | 2¼ | 135 | 228 | .014 | 2½ | 120 | 183 | .012 |
| 2 | 150 | 190 | .015 | 2½ | 135 | 204 | .014 | 3 | 120 | 153 | .012 |
| 2¼ | 150 | 170 | .015 | 3 | 135 | 171 | .014 | 3½ | | | |
| 3/16 Inch Chip | | | | ¼ Inch Chip | | | | ⅜ Inch Chip | | | |
| Dia. of Stock | Feet Surface Speed | Rev. per Min. | Feed per Rev. | Dia. of Stock | Feet Surface Speed | Rev. per Min. | Feed per Rev. | Dia. of Stock | Feet Surface Speed | Rev. per Min. | Feed per Rev. |
| ½ | 150 | 1146 | .005 | ¾ | 150 | 762 | .005 | 1¼ | 135 | 411 | .007 |
| ¾ | 150 | 762 | .006 | 1 | 150 | 573 | .006 | 1½ | 135 | 342 | .008 |
| 1 | 150 | 573 | .007 | 1¼ | 135 | 411 | .007 | 1¾ | 135 | 294 | .008 |
| 1¼ | 135 | 411 | .008 | 1½ | 135 | 342 | .008 | 2 | 120 | 228 | .009 |
| 1½ | 135 | 342 | .009 | 1¾ | 135 | 294 | .008 | 2¼ | 120 | 204 | .009 |
| 1¾ | 135 | 294 | .009 | 2 | 120 | 228 | .009 | 2½ | 120 | 183 | .010 |
| 2 | 120 | 228 | .010 | 2¼ | 120 | 204 | .009 | 3 | 120 | 153 | .010 |
| 2¼ | 120 | 204 | .010 | 2½ | 120 | 183 | .010 | 3½ | 120 | 131 | .010 |
| 2½ | 120 | 183 | .010 | 3 | 120 | 153 | .010 | 4 | 120 | 114 | .010 |
| 3 | 120 | 153 | .010 | 3½ | 120 | 131 | .010 | 4½ | 120 | 102 | .010 |

TABLE 16. — Speeds and Feeds for Screw Machine Work

| SPEEDS AND FEEDS FOR HOLLOW MILLS. SCREW STOCK. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1/32 Inch Chip | | | | 1/16 Inch Chip | | | | 1/8 Inch Chip | | | |
| Dia. of Stock | Feet Surface Speed | Rev. per Min. | Feed per Rev. | Dia. of Stock | Feet Surface Speed | Rev. per Min. | Feed per Rev. | Dia. of Stock | Feet Surface Speed | Rev. per Min | Feed per Rev. |
| 1/8 | 80 | 2445 | .0026 | 1/4 | 60 | 916 | .0045 | 3/8 | 55 | 560 | .0052 |
| 3/16 | 70 | 1426 | .0039 | 3/8 | 60 | 611 | .0052 | 1/2 | 55 | 420 | .0065 |
| 1/4 | 70 | 1069 | .0052 | 1/2 | 60 | 458 | .0065 | 3/4 | 55 | 280 | .0078 |
| 3/8 | 70 | 713 | .0065 | 3/4 | 55 | 280 | .0078 | 1 | 50 | 191 | .0091 |
| 1/2 | 60 | 458 | .0078 | 1 | 55 | 210 | .0091 | 1¼ | 50 | 152 | .0091 |
| 3/4 | 60 | 305 | .0091 | 1¼ | 55 | 168 | .0091 | 1½ | 45 | 114 | .0091 |
| 1 | 60 | 229 | .0104 | 1½ | 50 | 127 | .0104 | 1¾ | 45 | 93 | .0091 |
| 1¼ | 60 | 183 | .0104 | 1¾ | 50 | 109 | .0104 | 2 | 40 | 76 | .0104 |
| 1½ | 50 | 127 | .0117 | 2 | 45 | 86 | .0117 | 2¼ | 40 | 68 | .0104 |
| 1¾ | 50 | 109 | .013 | 2¼ | 45 | 76 | .0117 | 2½ | 40 | 61 | .0104 |
| 2 | 50 | 95 | .013 | 2½ | 45 | 68 | .0117 | 3 | 40 | 51 | .0104 |
| 2¼ | 50 | 85 | .013 | 3 | 45 | 57 | .0117 | 3½ | | | |
| 3/16 Inch Chip | | | | 1/4 Inch Chip | | | | 3/8 Inch Chip | | | |
| Dia. of Stock | Feet Surface Speed | Rev. per Min. | Feed per Rev. | Dia. of Stock | Feet Surface Speed | Rev. per Min. | Feed per Rev. | Dia. of Stock | Feet Surface Speed | Rev. per Min. | Feed per Rev. |
| 1/2 | 55 | 420 | .0052 | 3/4 | 50 | 254 | .0052 | 1¼ | 45 | 137 | .0065 |
| 3/4 | 55 | 280 | .0065 | 1 | 50 | 191 | .0065 | 1½ | 45 | 114 | .0065 |
| 1 | 55 | 210 | .0065 | 1¼ | 45 | 137 | .0065 | 1¾ | 45 | 93 | .0065 |
| 1¼ | 50 | 152 | .0078 | 1½ | 45 | 114 | .0078 | 2 | 40 | 76 | .0078 |
| 1½ | 50 | 127 | .0078 | 1¾ | 45 | 93 | .0078 | 2¼ | 40 | 68 | .0078 |
| 1¾ | 50 | 109 | .0078 | 2 | 40 | 76 | .0078 | 2½ | 40 | 61 | .0078 |
| 2 | 40 | 76 | .0091 | 2¼ | 40 | 68 | .0091 | 3 | 40 | 51 | .0078 |
| 2¼ | 40 | 68 | .0091 | 2½ | 40 | 61 | .0091 | | | | |
| 2½ | 40 | 61 | .0091 | 3 | 40 | 51 | .0091 | | | | |
| 3 | 40 | 51 | .0091 | | | | | | | | |

TABLE 17. — Speeds and Feeds for Screw Machine Work

tools the feeds are, of course, increased as the diameter of the stock increases, the peripheral speeds being reduced as the feeds grow coarser and the chip greater in depth.

The speeds and feeds for finishing box tools as used on different materials are given in Table 18, the last column indicating the amount of stock which, generally speaking, it is advisable to remove in order to produce a good surface.

CUTTING SPEEDS AND FEEDS FOR FINISH BOX TOOL

| Finished Diameter of Work | Screw Stock | | | Brass Rod | | | Cast Iron | | | Tool Steel | | | Amount advisable to remove on a Side |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Feet Surface Speed | Rev. per Min. | Feed per Rev. | Feet Surface Speed | Rev. per Min. | Feed per Rev. | Feet Surface Speed | Rev. per Min. | Feed per Rev. | Feet Surface Speed | Rev. per Min. | Feed per Rev. | |
| 1/16 | 80 | 4889 | .003 | 180 | 11000 | .003 | | | | 40 | 2445 | .002 | .002 |
| 1/8 | 80 | 2445 | .0045 | 180 | 5500 | .0045 | | | | 40 | 1222 | .003 | .0025 |
| 3/16 | 70 | 1426 | .0055 | 180 | 3668 | .0055 | 70 | 1426 | .0055 | 40 | 815 | .003 | .0025 |
| 1/4 | 65 | 993 | .0075 | 180 | 2750 | .0075 | 70 | 1069 | .0075 | 35 | 581 | .004 | .0045 |
| 1/2 | 60 | 458 | .011 | 180 | 1375 | .011 | 65 | 496 | .011 | 35 | 267 | .005 | .006 |
| 3/4 | 60 | 305 | .012 | 180 | 917 | .012 | 65 | 331 | .012 | 35 | 178 | .007 | .006 |
| 1 | 60 | 229 | .012 | 175 | 668 | .012 | 60 | 229 | .014 | 30 | 115 | .009 | .0065 |
| 1 1/2 | 55 | 140 | .014 | 170 | 433 | .014 | 60 | 153 | .016 | 30 | 76 | .009 | .007 |
| 2 | 50 | 95 | .014 | 170 | 325 | .014 | 60 | 115 | .016 | 30 | 57 | .009 | .008 |

TABLE 18. — Speeds and Feeds for Screw Machine Work

### FORMING-TOOL SPEEDS AND FEEDS

Speeds and feeds for forming tools are given in Table 19, the widths covered here ranging from $\frac{1}{16}$ inch to 2 inches, and the smallest diameter of form from $1\frac{1}{2}$ inches down to $\frac{1}{16}$ inch. It will be seen that the tool about $\frac{1}{8}$ inch wide is adapted to take the coarsest feed, tools from this width up to about $\frac{3}{16}$ (such as are commonly employed for cutting-off purposes) admitting of heavier crowding, as a rule, than either the narrower or wider tools. Thus we see the rate of feed drop off as the tool narrows to $\frac{1}{16}$ inch, which obviously is too thin a cutting device to admit of taking much of a chip, while similarly as the width of form and chip increases above about $\frac{3}{16}$ or $\frac{1}{4}$ inch the rate of feed must again be diminished to give the best results. Naturally, other things being equal, the greater the diameter of the section formed, the coarser the feed which can be taken economically. This is also indicated by the figures in the table.

### DRILLING AND REAMING DATA

Drilling speeds and feeds are given in Table 20. While these speeds are based on much higher peripheral velocities than drillmakers as a rule recommend for general purposes, it should be remembered that conditions for drilling in the automatic on the usual run of work are nearly ideal so far as lubrication of drill and work, steadiness of feed, etc., are concerned, and it is possible under these conditions where the holes drilled as a rule are

| SPEEDS FOR FORMING | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Dia. of Work | Screw Stock | | Brass Rod | | Cast Iron | | Tool Steel | |
| | Feet Surface Speed | Rev. per Min. | Feet Surface Speed | Rev. per Min. | Feet Surface Speed | Rev. per Min. | Feet Surface Speed | Rev. per Min. |
| ⅛ | 75 | 2292 | 200 | 6112 | | | | |
| 3/16 | 75 | 1528 | 200 | 4074 | | | | |
| ¼ | 70 | 1069 | 185 | 2827 | 75 | 1146 | 45 | 688 |
| ⅜ | 65 | 662 | 185 | 1885 | 70 | 713 | 40 | 407 |
| ½ | 65 | 497 | 185 | 1414 | 70 | 535 | 40 | 306 |
| ¾ | 60 | 305 | 175 | 882 | 65 | 331 | 35 | 178 |
| 1 | 60 | 229 | 175 | 667 | 65 | 248 | 35 | 134 |
| 1½ | 60 | 153 | 170 | 432 | 60 | 153 | 30 | 76 |
| 2 | 50 | 96 | 170 | 324 | 60 | 115 | 30 | 57 |

| FEEDS FOR FORMING TOOLS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| With of Form | Smallest Diameter of Form. | | | | | | | |
| | 1/16 | ⅛ | 3/16 | ¼ | ⅜ | ½ | ¾ | 1½ |
| 1/16 | .0007 | .0008 | .001 | .0012 | .0012 | .0012 | .0012 | .0012 |
| ⅛ | .0005 | .0008 | .001 | .0012 | .0015 | .0020 | .0025 | .0025 |
| ¼ | | .0007 | .001 | .001 | .0015 | .0015 | .0018 | .0018 |
| ⅜ | | | .0009 | .001 | .001 | .0012 | .0015 | .0015 |
| ½ | | | .0008 | .0009 | .001 | .001 | .0015 | .0015 |
| ¾ | | | | .0008 | .0009 | .001 | .0011 | .0012 |
| 1 | | | | | .0008 | .0009 | .001 | .0012 |
| 1½ | | | | | .0007 | .0007 | .0009 | .0011 |
| 2 | | | | | | | .0007 | .001 |

TABLE 19. — Speeds and Feeds for Screw Machine Work

comparatively shallow and the drill has ample opportunity for cooling during the operations carried on by the other tools, to maintain speeds that would be considered too high to be attempted in general shop practice.

Table 21 is made up of speed and feed data for reamers. In this table

## DRILLING FEEDS AND SPEEDS

| Screw Stock | | | Brass Rod | | Cast-Iron | | Tool Steel | | Screw Stock | | | Brass Rod | | Cast-Iron | | Tool Steel | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dia. of Drill | Feed per Rev. | R.P.M. at 60 Ft. Peripheral Speed | Feed per Rev. | R.P.M. at 175 Ft. Peripheral Speed | Feed per Rev. | R.P.M. at 60 Ft. Peripheral Speed | Feed per Rev. | R.P.M. at 35 Ft. Peripheral Speed | Dia. of Drill | Feed per Rev. | R.P.M. at 55 Ft. Peripheral Speed | Feed per Rev. | R.P.M. at 165 Ft. Peripheral Speed | Feed per Rev. | R.P.M. at 55 Ft. Peripheral Speed | Feed per Rev. | R.P.M. at 33 Ft. Peripheral Speed |
| 1/32 | .0006 | 7333 | .0008 | 21390 | .0006 | 7333 | .0005 | 4278 | 1/2 | .005 | 420 | .0065 | 1260 | .005 | 420 | .0037 | 252 |
| 3/64 | .0008 | 4889 | .0010 | 14260 | .0008 | 4889 | .0006 | 2852 | 9/16 | .0057 | 373 | .0074 | 1120 | .0057 | 373 | .0043 | 224 |
| .059 | .001 | 3884 | .0013 | 11329 | .001 | 3884 | .0008 | 2265 | 19/32 | .0057 | 353 | .0074 | 1067 | .0057 | 353 | .0043 | 212 |
| 1/16 | .0013 | 3667 | .0017 | 10696 | .0013 | 3667 | .0010 | 2139 | 5/8 | .0059 | 336 | .0077 | 1008 | .0059 | 336 | .0044 | 202 |
| 5/64 | .0016 | 2093 | .002 | 8555 | .0016 | 2093 | .0012 | 1658 | 11/16 | .006 | 305 | .0078 | 917 | .006 | 305 | .0045 | 183 |
| 3/32 | .0018 | 2445 | .0023 | 7130 | .0018 | 2445 | .0014 | 1430 | 3/4 | .0065 | 280 | .0084 | 840 | .0065 | 280 | .0049 | 169 |
| .105 | .002 | 2186 | .0026 | 6366 | .002 | 2186 | .0015 | 1305 | 13/16 | .007 | 258 | .0091 | 776 | .007 | 258 | .0052 | 155 |
| 1/8 | .0025 | 1833 | .0033 | 5348 | .0025 | 1833 | .0018 | 1070 | 7/8 | .0075 | 240 | .0097 | 702 | .0075 | 240 | .0056 | 144 |
| .150 | .003 | 1528 | .0039 | 4456 | .003 | 1528 | .0022 | 891 | 15/16 | .008 | 224 | .0104 | 672 | .008 | 224 | .006 | 134 |
| 5/32 | .003 | 1421 | .0039 | 4144 | .003 | 1421 | .0022 | 828 | | | 50 Ft. | | 150 Ft. | | 50 Ft. | | 30 Ft. |
| 3/16 | .004 | 1222 | .0052 | 3565 | .004 | 1222 | .003 | 713 | 1 | .0085 | 191 | .0110 | 573 | .0085 | 191 | .0064 | 115 |
| 7/32 | .004 | 1048 | .0052 | 3050 | .004 | 1048 | .003 | 611 | 1 1/8 | .009 | 169 | .0117 | 509 | .009 | 169 | .0067 | 102 |
| 1/4 | .0045 | 916 | .0058 | 2674 | .0045 | 916 | .0033 | 535 | 1 1/4 | .0095 | 152 | .0123 | 458 | .0095 | 152 | .0071 | 92 |
| 9/32 | .0045 | 815 | .0058 | 2377 | .0045 | 815 | .0033 | 475 | 1 3/8 | .010 | 139 | .0130 | 416 | .010 | 139 | .0075 | 83 |
| 5/16 | .0045 | 733 | .0058 | 2139 | .0045 | 733 | .0033 | 427 | 1 1/2 | .011 | 127 | .0143 | 382 | .011 | 127 | .0082 | 76 |
| 3/8 | .0045 | 611 | .0061 | 1783 | .0045 | 611 | .0035 | 356 | 1 5/8 | .012 | 118 | .0156 | 352 | .012 | 118 | .009 | 70 |
| 7/16 | .005 | 524 | .0065 | 1528 | .005 | 524 | .0037 | 305 | 1 3/4 | .013 | 109 | .0169 | 327 | .013 | 109 | .0097 | 65 |
| | | | | | | | | | 2 | .014 | 96 | .0182 | 294 | .014 | 96 | .0105 | 57 |

TABLE 20. — Speeds and Feeds for Screw Machine Work

the feed for different classes of material has been considered as constant for any given diameter of reamer, although it is conceivable that with

| REAMING FEEDS AND SPEEDS | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dia. of Reamer | Feed per Rev. | Amount to Remove on Dia. | Rev. per Min. | | | | Dia. of Reamer | Feed per Rev. | Amount to Remove on Dia. | Rev. per Min. | | | |
| | | | Screw Stock at 40 Ft. | Brass Rod at 130 Ft. | Cast Iron at 45 Ft. | Tool Steel at 25 Ft. | | | | Screw Stock at 40 Ft. | Brass Rod at 130 Ft. | Cast Iron at 45 Ft. | Tool Steel at 25 Ft. |
| ⅛ | .005 | .0045 | 1222 | 3972 | 1375 | 764 | 1¼ | .018 | .010 | 122 | 397 | 138 | 76 |
| 3/16 | .006 | .0045 | 815 | 2648 | 917 | 509 | 1½ | .020 | .010 | 102 | 331 | 115 | 63 |
| ¼ | .007 | .006 | 611 | 1986 | 688 | 382 | 1¾ | .022 | .010 | 87 | 284 | 98 | 54 |
| ⅜ | .0085 | .006 | 407 | 1324 | 458 | 254 | 2 | .024 | .013 | 76 | 248 | 86 | 48 |
| ½ | .0105 | .008 | 306 | 993 | 344 | 191 | 2¼ | .026 | .013 | 68 | 220 | 76 | 42 |
| ⅝ | .012 | .008 | 245 | 795 | 275 | 153 | 2½ | .028 | .013 | 61 | 199 | 69 | 38 |
| ¾ | .014 | .008 | 204 | 662 | 229 | 127 | 2¾ | .030 | .013 | 56 | 181 | 63 | 35 |
| 1 | .016 | .010 | 153 | 497 | 172 | 95 | 3 | .032 | .013 | 51 | 165 | 57 | 32 |

TABLE 21. — Speeds and Feeds for Screw Machine Work

certain materials, especially on brass alloys, etc., the feed per revolution might be increased somewhat, to advantage, over the rates given. These feeds have been tabulated, however, as representing highly satisfactory practice in reaming the materials listed.

| SPEEDS FOR DIES - STANDARD THREADS. | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Dia. of Thread | Screw Stock | | Brass Rod | | Cast Iron | | Tool Steel | | Cast Brass | |
| | Feet Surface Speed | Rev. per Min. | Feet Surface Speed | Rev. per Min. | Feet Surface Speed | Rev. per Min. | Feet Surface Speed | Rev. per Min. | Feet Surface Speed | Rev. per Min. |
| ⅛ | 40 | 1222 | 135 | 4126 | 40 | 1222 | 25 | 764 | 120 | 3666 |
| ¼ | 40 | 611 | 125 | 1909 | 40 | 611 | 25 | 382 | 110 | 1680 |
| ⅜ | 35 | 356 | 120 | 1222 | 35 | 356 | 20 | 204 | 100 | 1019 |
| ½ | 35 | 267 | 120 | 917 | 35 | 267 | 20 | 153 | 100 | 764 |
| ¾ | 35 | 178 | 115 | 586 | 30 | 153 | 20 | 102 | 100 | 509 |
| 1 | 30 | 115 | 110 | 420 | 30 | 115 | 20 | 76 | 90 | 344 |
| 1¼ | 30 | 92 | 100 | 306 | 25 | 76 | 15 | 46 | 90 | 275 |
| 1½ | 30 | 76 | 90 | 229 | 25 | 64 | 15 | 38 | 90 | 229 |
| 2 | 25 | 48 | 85 | 162 | 20 | 38 | 15 | 29 | 90 | 172 |

TABLE 22. — Speeds and Feeds for Screw Machine Work

THREADING, COUNTERBORING, ETC.

Table 22 explains itself and, while giving speeds for threading work with dies, should be of equal value in establishing speeds for tapping. It should be noted that the speeds in this table are proper for *high speed* dies. For *carbon steel* dies the speeds used should be from 50 to 75 per cent of the rates given.

For feeds for counterbores from $\frac{3}{8}$ inch to 2 inches diameter, Tables 15 and 16 for turning may be followed where the counterbores cut to a depth from one-half to three-quarters their diameter. Where cutting deeper than about one diameter, the feeds should be decreased; in such depths it is well to withdraw the counterbore during the cutting operation to free it from chips.

It is not expected that the speeds and feeds laid down in these tables will coincide exactly with the ideas of everybody engaged in screw machine operations. Conditions as to materials, lubricants, clearances of cutting edges, quality of tools, etc., all have an important bearing upon the question of efficient cutting speeds and feeds. It is believed, however, that the foregoing information should be of service to a good many readers, representing as it does the practice commonly followed by one of the largest tool shops with its carbon-steel screw machine tools.

# CHAPTER XXI

## Spring Collets and Feed Chucks

Spring collets and feed chucks or feed fingers as they are frequently called, are the first tools to be considered in connection with screw machine work as upon these appliances devolve the operations of feeding the bar of material through the spindle and the holding of it while the different machining cuts are taken by the various cross-slide and turret tools.

When manufactured in large quantities the collet blanks are produced in the turret machine by the aid of forming tools for machining the exterior surface and by suitable internal tools of the drill and reamer order for finishing the interior to the required dimensions. In making a few collets at a time, however, as is generally the practice in the smaller shops, a few simple appliances suffice for the satisfactory handling of the work during the different operations.

### LATHE OPERATIONS

The collet blank may first be roughed out in the lathe and the inside chucked out and reamed taper from the rear end to leave the walls of the collet body of suitable proportions and to allow the collet to be slipped onto a taper arbor the rear end of which is fitted to the taper hole in the lathe spindle. While mounted on this arbor the outer end of the collet is centered and center reamed to allow it to be supported by the tail center, and the body may then be turned and bored to correct shape and size without removing from the arbor. It is sometimes advantageous to rough out two collets on the same piece of stock and then cut apart and mount on the taper plug arbor for finishing separately. This method gives a longer and handier piece of material to work in the lathe.

The work is readily removed from the taper arbor on which it is turned, by means of a nut on a threaded portion of the arbor body adjacent to the taper section. Before taking the chuck blank off from its arbor the conical nose should be gaged carefully to make sure that it will fit properly in its seat in the screw machine spindle. The hole, bored in the front end for the bar material, should be true and straight — especially if grinding is not to be resorted to after hardening. Of course where absolute truth is essential in the running of the collet it is important that the hole be ground after hardening with the collet seated in a grinder fixture in precisely the same way as it will later be operated in the screw machine.

### HOLDING WHILE SLITTING

The taper arbor referred to is of the general form indicated in Fig. 153, which shows the method also of carrying the work between the dividing head and tail center on the milling machine, while the slots are being cut to allow the collet to open and close on the material when in service. There are numerous methods of mounting collets for this slitting operation, but the one indicated is as simple as any and entirely satisfactory where collets are put through in small lots and more elaborate fixtures are therefore uncalled for. If a small piece of flat stock is centered as shown and introduced between the end of the work and the foot center of the dividing head, and the center itself flatted on top, sufficient clearance will be obtained for the slitting saw which is run into the work from the front end.

### COLLET INTERIOR

It is well to shape the interior of the collet about as illustrated in Fig. 154, the long curve or fillet *b* at the front end of the chamber where it joins the cylindrical hole, forming in conjunction with the fillet at *a* a strong section not likely to break away in the operation of the collet. The internal sloping surface at *b* also facilitates the passing of a fresh bar of stock into the collet upon the finishing up of the previous length of material.

### PREPARING FOR HARDENING

Before hardening collets it is common practice to open them somewhat to insure their having a given tension after hardening and tempering so that they will open and release the stock the instant they are themselves freed by the cam-operated chucking mechanism. This opening of the collet must be carefully attended to or an eccentric and unsatisfactory job will be the result. Sometimes a simple fixture having a cone-pointed spindle is used for this purpose, the collet or chuck being held centrally while the cone plunger is forced between the chuck jaws sufficiently to open them evenly the necessary amount. However, no matter how much care is taken in this operation, the effect is lost unless the hardening is properly attended to, and the only sure way of producing a perfectly true collet with certainty is to grind it as a final operation.

### PREVENTING DISTORTION

Some toolmakers take the precaution of leaving a thin fin of metal at the front end of the collet in each saw slot, as in Fig. 155, in order that when hardened there shall be no chance of distortion due to unequal springing of the prongs or jaws. This metal tie or bridge at the ends of the jaws is readily removed by grinding out with a thin slitting wheel or lap. Still another scheme is illustrated in Fig. 156, which comprises in addition to

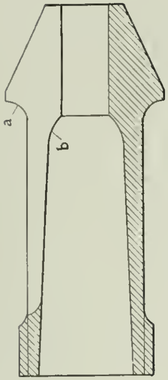



FIG. 154

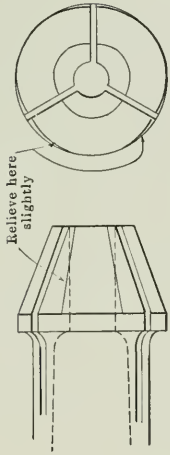



FIG. 157

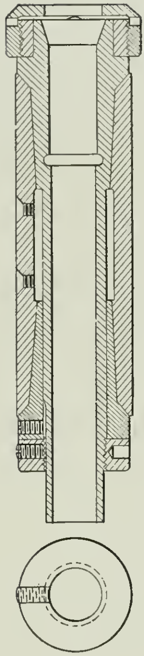


FIG. 159

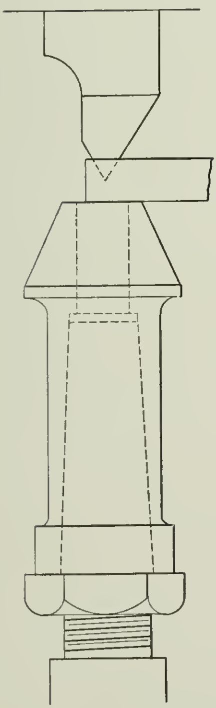


FIG. 153

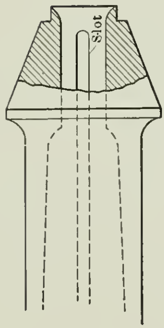



FIG. 156

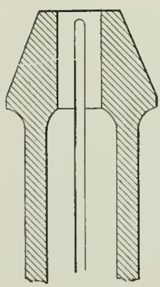


FIG. 155

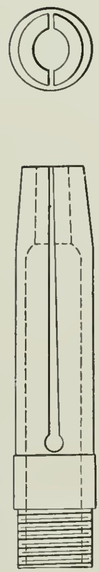


FIG. 158

Spring Collets and Feed Chucks

the thin wall of metal at the front ends of the saw slots, a narrow ring or nose adapted to be carried on a grinder center while the collet is ground externally. Thus inequalities introduced in the hardening process may be rectified by grinding and afterward the superfluous metal at the end of the collet nose may be ground off leaving the appliance ready for service.

Another method of preventing trouble in hardening collets is to insert a piece of sheet metal (say $\frac{1}{32}$ inch thicker than the slot width) in the front ends of the slots and then wire the nose of the chuck tightly so as to retain the steel pieces during the hardening operation. The collet must be heated uniformly and dipped so as to insure all three prongs being cooled simultaneously, otherwise they will be of different lengths and twisted, resulting in an untrue collet. With the best of care, a collet that is hardened, but not ground afterward, will generally require touching up on the conical portion of one or two of the prongs to insure its running true. It is not a difficult undertaking, however, to make a chuck run true within 0.002 inch by polishing one or two prongs.

In order that the collet may close parallel, it must be fairly long, and the exterior of each prong, or jaw, may be relieved by filing, as in Fig. 157, so as to insure its bearing along the center. After hardening, the collet should be carefully tempered at the ends of the slots to prevent breaking at this point.

## FEED CHUCKS

The feed chucks or feed fingers need no such refinements in their production. They are usually closed after slitting on opposite sides, and thus after hardening they will maintain a constant grip upon the stock sufficient to feed the bar forward the moment it is released by the chuck. The idea is indicated in Fig. 158, which represents a typical feed chuck. Ordinarily the hole for the stock should be bored out a little over size, otherwise the corners of the feed chuck jaws when drawn back over the stock will mar the surface.

## A GRINDING FIXTURE FOR CHUCKS

A handy grinding appliance for spring collets is shown in Fig. 159, this sketch being made from a device in use at the E. Howard Watch factory, Waltham, Mass. This particular tool is adapted to receive an automatic screw machine collet after it is hardened, and hold it during the grinding operation in precisely the same manner in which it will later be held in the screw machine when in operation. The quill in which the spindle is carried is slipped into a regular quill rest on the bench lathe or grinder, and the collet to be ground out is readily inserted and as easily removed when the grinding or lapping operation is completed.

All parts of this fixture, including quill, spindle, rear bearing, cone, cap, and adjusting nut, are of steel, hardened, ground and lapped.

# CHAPTER XXII

## Box Tools and Other External Cutting Appliances

The accompanying engravings, Figs. 160 to 179, illustrate a variety of so termed box tools and hollow mills which are used in automatic screw machines, and in much the same form in hand machines also. It is the purpose of this chapter to point out some of the reasons for different designs and to show for what particular cases each type of tool illustrated is best adapted.

### GENERAL PRINCIPLES

Practically all box tools consist primarily of a frame or body which is clamped to the turret of the screw machine. The box-tool frame is utilized for holding the cutting tools and, usually, a work-supporting device commonly known as a back rest. In the frame there is also in some instances provision made for holding internal cutting tools such as drills, counterbores, etc.; in this latter case outside turning and boring may be accomplished simultaneously. The cutting tools are usually adjustable so as to be suitable for turning various diameters; the back rests or work-supporting devices are made both adjustable and solid or non-adjustable. Both cutting tools and back rests are preferably mounted in sub-holders permitting of longitudinal adjustment. The most common turning tools in use are for cylindrical work, but taper work can also be successfully produced by box tools designed for the purpose.

### CONDITIONS OF SERVICE

The type of box tool in general, as well as such features as the work-supporting device and the manner in which the cutting-tool edge is presented to the work, are dependent upon various conditions, among which may be mentioned:

1. Length of work being turned;
2. Uniformity of diameter of stock used (bright drawn or rough stock);
3. Cross-section of stock (circular or otherwise);
4. Character of material;
5. Reduction in diameter to be made;
6. Character of longitudinal cut (cylindrical, taper, or other).

Before explaining the reasons why the foregoing conditions should influence the design of tool, it may be well to understand precisely by name the various parts which are frequently referred to later on. To this end a few of the different types of box tools and component parts, as shown by Figs. 160 to 167, will first be briefly described.

### TYPES OF BOX TOOLS

Figs. 160 and 161 illustrate a box tool with movable blocks holding the cutters and with a back rest of the non-adjustable open type. The cutting edge of the tool is practically radial, but longitudinally the cutter

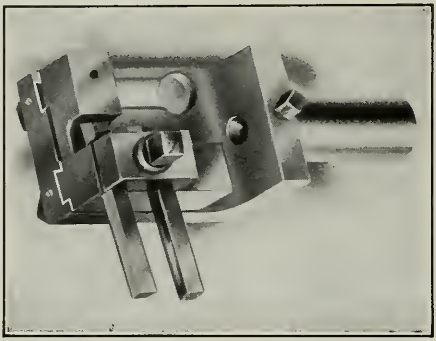


Fig. 160. — Non-Adjustable Roughing Box Tool

lies tangent to the circle representing the work. This tool is commonly called a roughing box and is recommended for heavy cuts as there is less danger of springing, due to the strain on the tool in cutting, than in the case of the radial tool in Figs. 162 and 163. The latter tool has movable

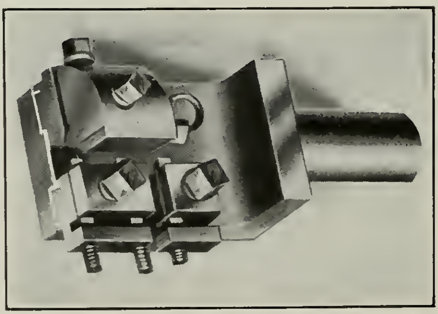


Fig. 162. — Adjustable Finishing Box Tool

blocks holding the cutters, and movable blocks carrying the back-rest jaws. Both cutters and back-rest jaws may be adjusted to suit different diameters of work. The cutting edge of the cutter is radial to the work and is parallel with the longitudinal section of the cutter. The tool is

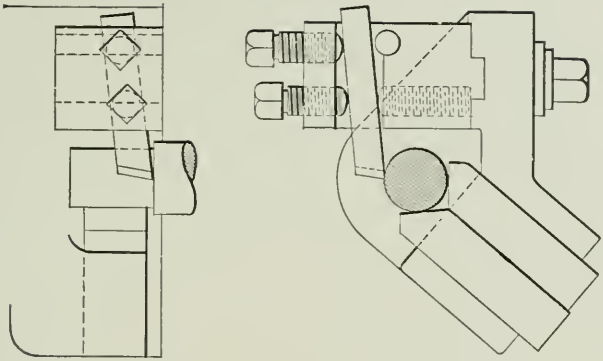


FIG. 164

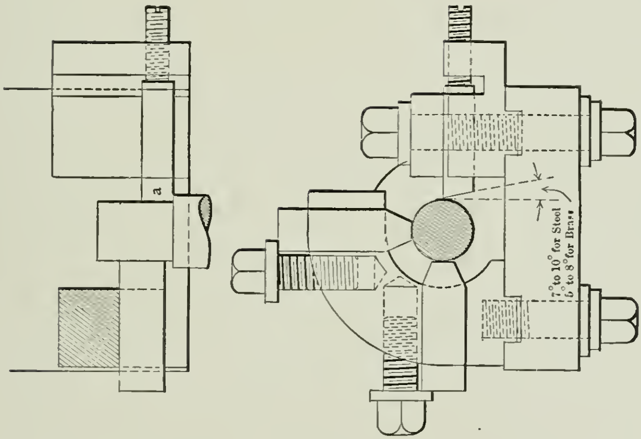



FIG. 163

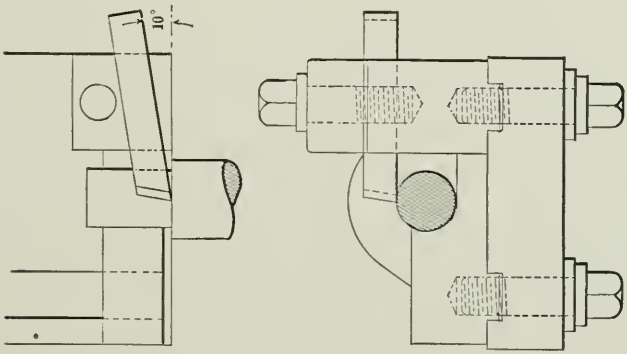



FIG. 161

Box-Tool Rests and Cutters

used mostly for brass and similar material and for light cuts on steel, and is in this general form commonly known as a finishing box. On very free-cutting materials such as brass, the edge of the cutting tool is generally presented to the work without any rake, as shown in Fig. 163. In cutting the harder materials, steel, etc., and especially in taking roughing cuts on such material, rake is desirable; hence the tool of the roughing box is presented to the work in the manner shown by Fig. 161.

The tangent cutter used in the box tool shown in this view and in Fig. 160 is sharpened by grinding on the end, and compensation for the grinding away of the metal is made by adjusting the cutter forward, whereas in the radial type of cutter in Figs. 162 and 163, frequent sharpening cannot be done without resulting in lowering the cutting edge of the tool below the center of the work, unless a substantial part of the tool be sacrificed. The radial tool, however, is easily ground accurately on face *a*, which is the particular edge governing the finish; while the corresponding face on the tangent type of tool is rather difficult to grind so as to produce as smooth work.

### OTHER FORMS OF BOX TOOLS

Fig. 164 outlines the general scheme of a box tool with tangent cutter having means of radial adjustment for various diameters, the back rests being adjustable also, as indicated.

In Fig. 165 we have a box tool with a back rest of the bushing type

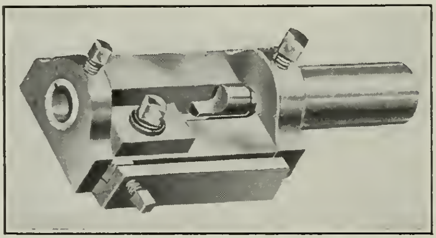


Fig. 165. — Bushing Box Tool

which fully envelops the work. A bushing like that shown in Fig. 166 is frequently used in the bushing type of box tool. This bushing is tapered externally and drawn into a conical hole, and is thus suitable for slight variations in stock sizes. Fig. 167 shows another "solid" rest, but without a bushing. The question of chip room frequently makes it necessary to abandon the bushing and bore the hole for the stock directly in the back rest. Quite often the back rest is cut away to allow the tools to operate on a second shoulder cut; then the bushing as ordinarily made interferes. As a rule, it is preferable to use the bushing where possible, owing to the ease with which it may be replaced when worn out of shape, and also because of the facility with which any changes due to hardening may be corrected.

Other types of work-supporting devices, such as internal stem rests, etc., are very commonly used. Fig. 168 illustrates such a combination. Frequently, too, revolving stem rests are used in place of the stationary type shown. Quite often a drill or counterbore is held in the shank of the box tool in a similar manner and acts as a support, and also, as before stated, enables turning and boring operations to be accomplished simultaneously.

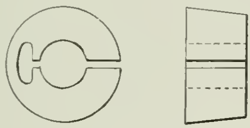


FIG. 166. Bushing

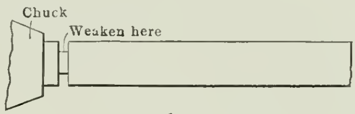


FIG. 169. Long Work

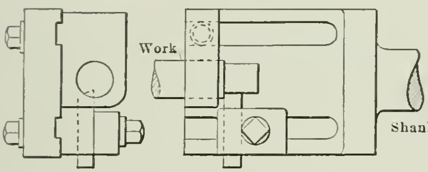


FIG. 167

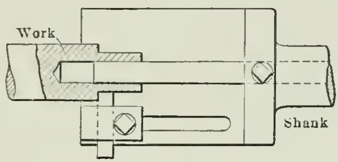


FIG. 168

Other Turning Methods

## SELECTION OF BACK RESTS

Generally speaking, work that projects over one and one-half times its diameter from the spindle chuck cannot be turned accurately or rapidly without the aid of a support which will prevent the work springing away from its proper radial relation to the edge of the cutting tool.

Usually on work which does not project over five diameters from the chuck, the back rest is located so as to support the work by the diameter produced by the first cutting tool in the box tool, the back rest being set from about $\frac{1}{64}$ inch to $\frac{1}{32}$ inch back of the cutting tool, as in Figs. 161 and 163. While any of the types of back rests shown in Figs. 160 to 167 may be used, on work of the length mentioned an enveloping back rest is not required. The type of back rest used in the tool in Figs. 162 and 163 is adjustable for wear and preferable on this account. The non-adjustable open back-rest, Figs. 160 and 161, is recommended only when the design of the tool makes it difficult to utilize an adjustable type. All back rests should be of tool steel. They should be very hard and smooth; otherwise when used on fast-running material such as brass, a welding action takes place. They should be ground and lapped on the bearing face so as to bear more strongly on the forward end of the work than at the rear. The clearance need not be more than 0.003 or 0.004 inch to the foot. Should the back rest be bell mouth, the work turned will be rough and covered with ridges.

### TOOL POSITION, LUBRICATION, ETC.

Also it is quite important, where using such rests, that the work be not turned too large if roughing up of the surface is to be avoided. About 0.0005 inch freedom should be allowed for work up to ½-inch diameter, and about 0.001 inch freedom for 1-inch diameter. Proper lubrication of the bearing is also essential in preventing roughing up of the work. Lack of alinement of solid or half-open rests with the spindle of the machine may also cause the production of poor surfaces on the work, owing to the heavy crowding action under such conditions.

In setting adjustable back-rest jaws it will be found conducive to good work to hold a bar in the head spindle, turn a true running piece of work from 0.0004 inch to 0.0008 inch oversize and then adjust the jaws so that they will bear snugly on the turned part. The closer this is to the spindle the better. In using solid or non-adjustable open-back rests, as shown by Figs. 160, 161, 165, and 167, it is recommended that they be bored out while held in the turret hole of the machine that they are to be used in. This insures the hole being in alinement with the head spindle; these conditions, as well as having the turret slide travel parallel with the axis of the head spindle, are necessary in order to produce accurate work.

Burnishing of stock generally results from the pressure of the cutting tool forcing the work against a closely adjusted, smooth back rest, and is usually considered an evidence of proper adjustment. Frequently, however, this is found not to be the case.

### LONG AND SHORT WORK

On very long work, when bright-drawn cylindrical stock of uniform diameter is being turned, the solid back rest is found very satisfactory. The rest is in this event set ahead of the cutting tool and fully enveloping the work. It obviously prevents any tendency for the work to spring away. Where heavy stock which does not run true is to be machined, it is necessary before turning partly to cut off, as shown by Fig. 169, thus permitting the back rest to pull the bar into central position. In case there are short bends in the bar, trouble will be met, so that for long work machined in this manner it is necessary to select straight bars. It is also important where a back rest is used ahead of the cutting tool (that is, where the unmachined bar rotates directly in the back rest) to select practically uniform diameters of stock, not varying in size over 0.0004 inch to 0.0008 inch. In many large screw factories all bright-drawn stock is carefully gaged as soon as received and sorted out in this manner;

in setting up the machine a back rest is selected to suit a particular bundle of gaged stock.

### IRREGULARITY OF STOCK SECTION

Where bright-drawn stock is used which is slightly out of round, as is very frequently the case, the use of a full enveloping back rest preceding the cutting tool will be found superior to the jaw type, giving a two-point bearing. In the former case the pressure of the tool cannot force the work away and the turned part will be cylindrical; whereas with the jaw type of back rest the pressure of the cut will keep the irregular contour of the bar against a jaw and consequently reproduce a similar cross-section to the turned part. This emphasizes the value of using back-rest jaws so as to follow the cutting tool; but as before noted, their use is limited to short work and work of medium length. In such work, if the back-rest jaws are properly set and the turret slide travels parallel with the axis of the head spindle, true work will result irrespective of the collet or turret hole being out of line with the spindle.

### CAST-IRON WORK

In machining cast iron, as on the magazine automatic, box tools with the ordinary types of rests are not satisfactory, owing to the fact that the cast-iron dust is apt to become ground between the rest jaws and the turned part of the work, thus causing the latter to become roughed up. The use of water, however (with just enough oil to prevent rusting), or any thin solution under pump pressure, effectually overcomes this trouble; oil seems to increase the difficulty.

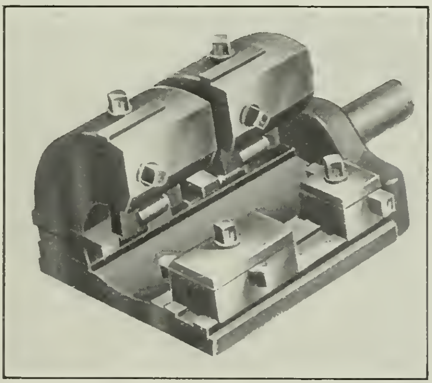


FIG. 170. — Box Tool with Roller Rest

A box tool with roller back rests, which is excellent on cast-iron work when used in conjunction with an air blast to keep dust from accumulating between the rollers and work surface, is shown in Fig. 170. This box tool as sometimes used on the Pratt & Whitney magazine machine, may be stiffly supported at the bottom by a hardened-steel plate carried on a bracket attached to the front end of the turret slide and traveling with the slide. Another satisfactory way of turning cast iron is by means of hollow mills.

## HOLLOW MILLS

Hollow mills are also very suitable for turning long work from bar stock. These tools with multiple teeth support the work centrally, cut very rapidly, and if held concentric with the head spindle and properly cleared will produce excellent results.

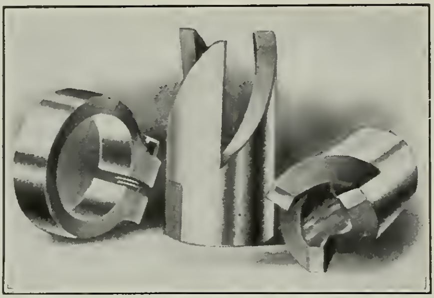


Fig. 171. — Hollow Mills and Clamp Collar

Fig. 171 illustrates a form of hollow mill. The clamp collar shown in the group is commonly used for slightly adjusting the teeth to cut to correct diameter. Another good form of clamp ring is shown in Fig. 172.

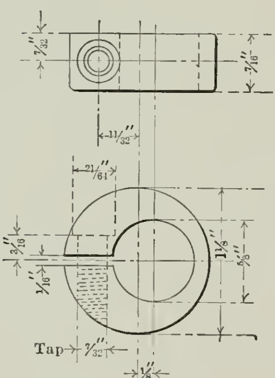
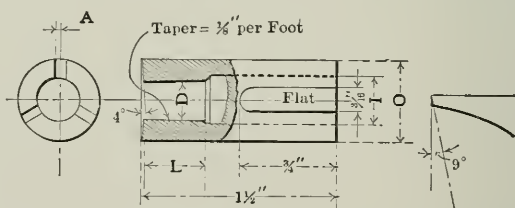



FIG. 172




| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| D = Finishing | 1/16 | 3/32 | 1/8 | 5/32 | 3/16 | 7/32 | 1/4 | 9/32 | 5/16 | 3/8 | 1/2 | 5/8 | 3/4 |
| D = Roughing | .072 | .104 | .135 | .166 | .197 | .229 | .26 | .291 | .322 | .385 | .510 | .635 | .760 |
| L = | 1/4 | 1/4 | 5/16 | 5/16 | 3/8 | 3/8 | 7/16 | 7/16 | 1/2 | 5/8 | 3/4 | 7/8 | 1 |
| $A = \frac{D}{10}$ = | .006 | .009 | .012 | .015 | .019 | .022 | .025 | .028 | .031 | .038 | .050 | .063 | .075 |
| I = | 3/13 | 3/16 | 3/16 | 5/16 | 5/16 | 3/8 | 3/8 | 3/8 | 3/8 | 7/16 | 9/16 | 11/16 | 13/16 |
| O = | 3/8 | 3/8 | 3/8 | 5/8 | 5/8 | 5/8 | 5/8 | 5/8 | 5/8 | 1 | 1 1/4 | 1 3/8 | 1 5/8 |

FIG. 173

Clamp-Collar and Hollow-Mill Dimensions

This is made with sufficient metal at one side to admit the clamping screw, while the opposite side of the ring is weak enough to allow it to close properly upon the mill when adjusted by the screw.

The teeth of hollow mills should be radial or ahead of the center. With the cutting edge ahead of the center, as in Fig. 173, the chips as produced are caused to move outward away from the work and prevented from disfiguring it. With the cutting edge below the center, rough turning will result. With the cutting edge greatly above the center, chattering is produced. About one-tenth of the cutting diameter is found a good average amount to cut the teeth ahead of the center. When the chips produced from any turning or boring cut curl nicely, it is indicative of a free cutting action; but these chips are very troublesome on the automatic screw machine. In making hollow mills for the automatic, part or all of the rake to the cutting edge is generally sacrificed.

### HOLLOW-MILL PROPORTIONS

The table under the hollow-mill sketch in Fig. 173 gives proportions of mills from $\frac{1}{16}$ to $\frac{3}{4}$ diameter, showing the amount to cut the teeth ahead of the center, the amount of taper in the hole, etc.

Besides the type of mill shown made in one piece, hollow mills are often used with inserted blades of high-speed steel. These tools are especially useful on the larger sizes of work.

### TAPER-TURNING TOOL

So far we have discussed conditions where cuts are cylindrical and where box tools with stationary cutting tools and back rests are suitable. On taper work the cutting tool must move radially; the back rest, unless it precedes the cut, must be so constructed as to adjust itself to the increase or decrease in diameter.

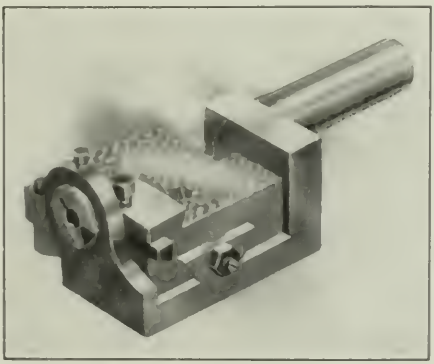


FIG. 174. — Taper-turning Box Tool

Fig. 174 illustrates a type of box tool for taper work which is suitable when uniform bright-drawn stock is used. The back rest consists of a stationary bushing fully enveloping the bar. The hole should be about

0.0005 oversize and nicely lapped. The cutting tool is held in a transverse sliding member, the cross movement to the slide being controlled by a taper bar mounted on the cross slide of the screw machine. The taper bar is sometimes made in two pieces which may be adjusted in such a manner as to permit varying angles of tapers to be produced. This tool allows only one cut to be taken over the work unless the support from the back rest is dispensed with.

### SOME POINTS IN BACK-REST CONSTRUCTION

Having now illustrated various types of box tools and their rests, hollow mills, etc., a few words relative to the actual making of certain box-tool parts may be of interest.

In making back rests of the quarter-bearing type, as shown by Figs. 160 and 161, the usual custom is first to bore out the solid block from 0.0005 to 0.001 inch over the size that is to be turned, and plane away the portion indicated at *A*, Fig. 175. The hole should be very smooth and cylindrical. Low-carbon tool steel is very good for the purpose, providing the work is pack hardened; otherwise it is preferable to use high-carbon steel and harden in an open fire.

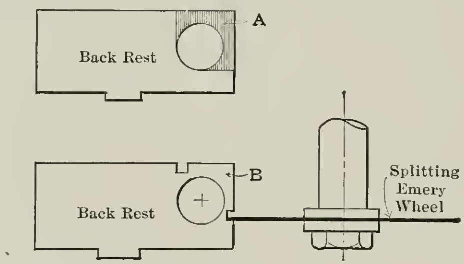



FIG. 175. — Cutting Out Corner of Back Rest

After the back rest has been hardened and assembled in the box-tool frame, the bearing may be slightly lapped with emery by holding a cylindrical piece of brass of correct diameter in the screw machine chuck. The turret slide being moved back and forth will very quickly cause the lap to correct any slight crookedness due to the hardening.

When an exceptionally nice job is required, the back rest may be hardened after cutting in, as at *B*, Fig. 175; afterward, by using a slitting emery wheel the corner may be removed entirely, leaving a little over the quarter bearing.

It is found good practice to give back rests a width equal to one or one and one-half times the diameter of the work they are used on. It often happens, of course, that the positions of the cutting tools necessitate the employment of two rests in one box tool.

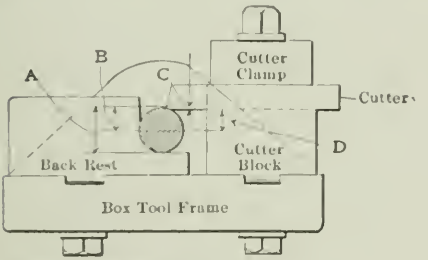
### BOX-TOOL CUTTERS

It may be stated that present-day practice favors the use of high-carbon steel for the radial type of tools and high-speed steel for tangent cutters on heavy roughing cuts.

Sections recommended for box-tool cutters are as follows: For box tools used for stock diameters up to $\frac{5}{16}$ inch, $\frac{3}{16}$ inch square; up to $\frac{3}{8}$ inch diameter, $\frac{7}{32}$ inch square; up to $\frac{1}{2}$ inch diameter, $\frac{1}{4}$ inch square; up to $\frac{3}{4}$ inch diameter, $\frac{5}{16}$ inch square; up to 1 inch diameter, $\frac{3}{8}$ inch square; up to $1\frac{1}{2}$ inches diameter, $\frac{1}{2}$ inch square.

### THE "TANGENT" CUTTER

While the box tool shown in Figs. 160 and 161 has been called the tangent tool, actually the cutter should not be exactly tangent to the diameter to be turned, as it is then impossible to adjust this type of cutting




A = Full Diameter of Work
B = Half " "
C = Amount Cutting Edge of Cutter is below a Line Tangent to Diameter of Work. (.002" to .003")
D = B - C

FIG. 176

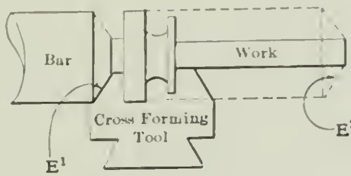
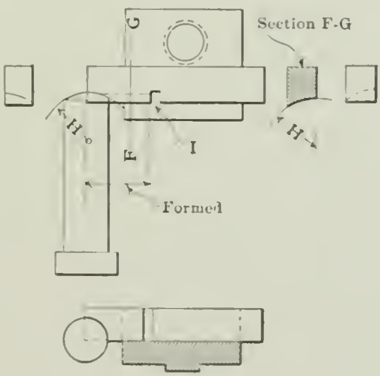



FIG. 178



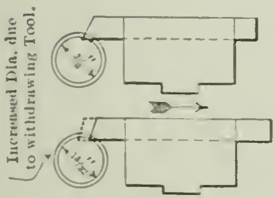




FIG. 177

FIG. 179

Box-Tool Cutters

tool so as to cut under size, although by withdrawing the tool oversize work can be turned. In order to be able to compensate for slight errors and to insure that work may be turned to fit the non-adjustable back rest, it is the practice to plane the cutter block so that the cutting edge of the tool is about 0.002 inch to 0.003 inch below a line tangent to the diameter actually to be turned, as at *C*, Fig. 176.

The effect of in-and-out adjustment of the cutter is clearly shown by Fig. 177.

### AN OPERATING SUGGESTION

In order to facilitate the "starting on" of the box tool, it is well to have the end of the work beveled, as in Fig. 178. The forming tool in finishing the head of the work simultaneously bevels a portion of the bar at $E^1$ which, when a new piece of work is being produced, becomes $E^2$. The first cut of the box tool is thus made light and does not become heavy until after the support of the back rest has been secured.

Fig. 179 illustrates an end-pointing tool used on the type of box tool just referred to. The form is planed in the end of the cutter as indicated, thus permitting frequent grinding without altering the form. Sometimes for pointing work a special pointing box tool is employed, carrying merely a back rest and a pointing cutter; frequently a regular roughing-box tool is utilized and the pointing cutter held in the hollow shank and prevented from moving by a set screw.

## CHAPTER XXIII

### Drills, Counterbores and Other Internal Cutting Tools

The design of internal cutting tools is largely governed by the character of the material to be cut, the depth of hole, and, in tools for finishing, the amount of material left by the roughing tool for removal.

As with external cutting tools the clearance and rake of the cutting edges, the number of cutting edges, and the means of avoiding accumulation of chips must be considered in connection with the nature of the material to be cut.

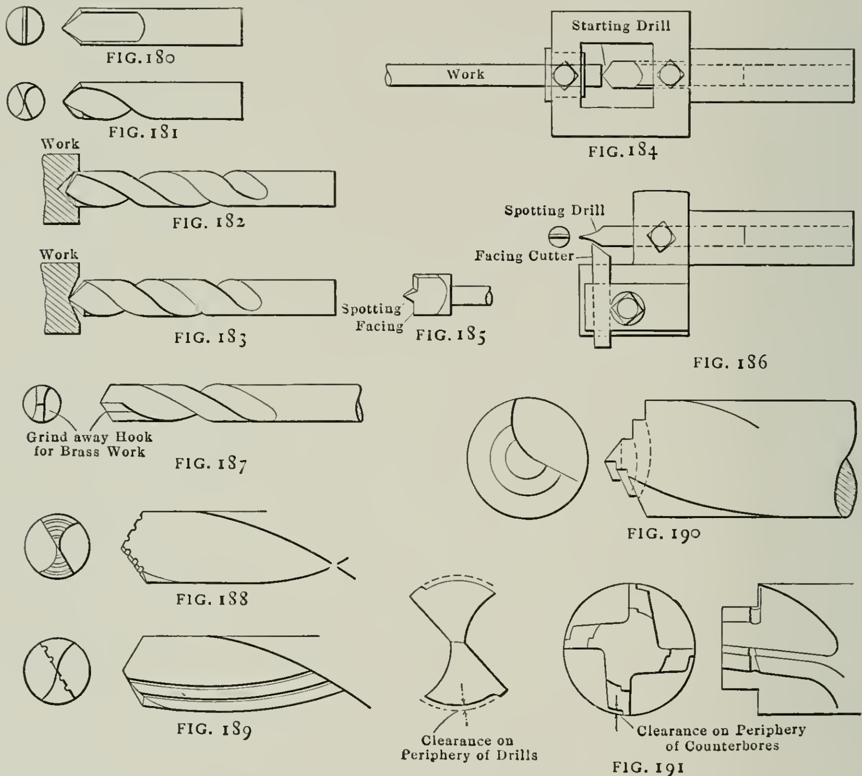
#### STARTING DRILLS

It is generally advisable before attempting to drill a long hole to use what is termed a starting drill, which tool is usually either of the flat type, as shown in Fig. 180, or somewhat similar to a twist drill, only having short flutes like Fig. 181. The point should be quite thin and the lip angles more acute than the drill that is to follow, as in this event the outer diameter of the drill is permitted to cut before its blunt non-cutting center web comes in contact with the work. Fig. 182 illustrates a twist drill entering a piece of work that has previously been spotted with a starting drill, and the twist drill will be found to run true under these conditions. When the blunt center web of a drill is allowed to come in contact with the work first, as in Fig. 183, the value of the starting drill is not nearly as great as under the conditions in Fig. 182. For starting drills under ¼ inch in diameter the flat starting tool, Fig. 180, is very satisfactory, while for larger work, except brass and similar materials, the type illustrated by Fig. 181 is more commonly used.

#### SPOTTING AND FACING TOOLS

On long, slender work made of smooth stock close to size and which projects some distance from the head spindle it is generally found necessary to support the end of the work close to the point being spotted, and in such cases the starting or spotting drill is held in a holder which is also suitable for guiding the outer end of the work. Fig. 184 illustrates a tool of this type.

In some cases combination spotting and end-facing tools like Fig. 185 are used. This type of tool is very satisfactory on brass work, etc., but on harder materials, such as steel, which is more destructive to the cutting edges and thus makes frequent regrinding necessary, a tool holder having separate starting and facing cutters, as shown in Fig. 186, is preferable, as the independent adjustments allow frequent sharpening to be more economically accomplished.




Spotting Tools and Drills

## TWIST AND STRAIGHT FLUTE DRILLS

In drilling cylindrical holes standard commercial tools are preferred owing to the convenience of replacement when they become worn out or broken. Ordinary twist drills are very satisfactory in steel and cast iron, although in very deep holes the chips are sometimes difficult to get rid of, and clogging up of the flutes and occasional breakage will then occur unless frequent withdrawing of the drill is resorted to. On brass and all free cutting stock the rake given to the cutting edges of twist drills generally causes excessive curl to the chips and thus makes the automatic removal of the chips from the hole difficult. On automatic screw machines oftentimes a long curled chip is very objectionable as some machine functions may be interfered with. For these reasons, when twist drills are used in brass, it is good practice to reduce this rake by grinding in the lips at the front end, as in Fig. 187.

A two-lip, straight-fluted drill commonly known as a "Farmer" drill is generally superior to the twist drill in cases where the curling of the chips is troublesome, and in shops where brass work predominates, this drill is used much more commonly than the twist drill.

### SERRATED, FLUTED AND STEPPED LIPS

The cutting edges of drills are sometimes serrated as indicated in Fig. 188 to produce narrower chips than would otherwise result and facilitate their easy removal. A similar effect is produced by fluting the drill, as shown by Fig. 189. Still another method of producing narrow chips is to step the end of the drill. It may be of interest to mention that this latter scheme is very commonly used in the one-lip drills for drilling long holes in gun barrels, spindles, etc. Fig. 190 will give an idea of this type of tool. When such a drill is carefully guided and advanced at a low rate of feed it is possible to drill a distance of 30 or 40 inches with not more than 0.010 inch curvature in the length of the hole. There is no center web to prevent free cutting as in the two-lip twist drill, and oil is forced under pressure to keep the cutting cool and conduct away chips. The use of oil in this manner is found very effective with all classes of internal cutting tools, except when operating in cast iron. It makes possible the running of work at a high peripheral speed without excessive heat, results in rapid cutting and insures long life to the cutting edges of the tool.

The center edge of all twist- and straight-flute drills should be thinned down at the cutting point, as the drill will then cut more freely and less power be required for the work.

### BACK AND LAND CLEARANCES

Drills should have some back clearance, from 0.007 to 0.015 inch per foot being common practice. The land back of the cutting edge should be quite narrow as little land is required to support the drill and prevent chattering, while an excessive width increases friction and heat, resulting in the welding of chips to the drill along these surfaces and the consequent production of rough holes of varying diameter. Fig. 191 represents the manner in which drills and counterbores should be cleared on their peripheries.

The milling cutters used to flute twist and other drills should be of such form as to produce a straight cutting edge on the drill. If there is a curve to the cutting edge curved chips are produced which are difficult to bend or curl and such chips not only cause excessive heat, but severe strain on the cutting tool and frequent breakage of the latter.

The various steps on short internal cylindrical cutting tools should be tapered back about 0.020 inch per foot, and the peripheral contact reduced to a minimum so as to give ample chip clearance and avoid welding of chips.

### FLAT DRILLS AND COUNTERBORES

Fig. 192 illustrates a type of tool commonly termed a flat drill, which is extensively used on brass work; it is especially recommended for such material where there are numerous shoulders or forms to be cut out. The tool has a cylindrical shank which fits a turret tool holder. On large work it is customary to make the flat drill of rectangular stock and utilize a special holder, as shown in Fig. 193.

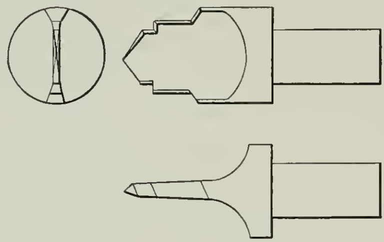


FIG. 192

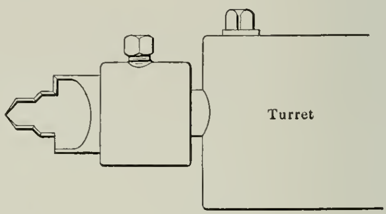



FIG. 194

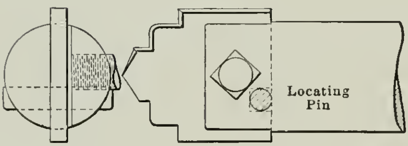



FIG. 193

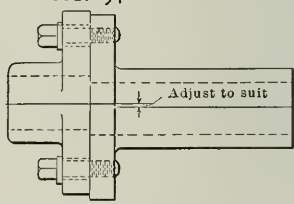



FIG. 195

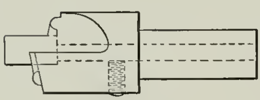


FIG. 196

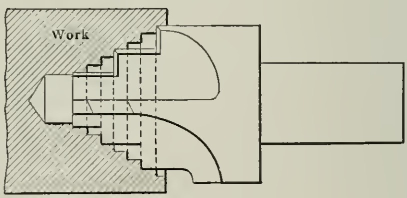



FIG. 197

Flat Drills and Counterbores

Such tools when held in the turret, as in Fig. 194, should be placed with the faces vertical so as to prevent them from cutting appreciably oversize if the indexing of the turret, due to wear, is not perfect. In the event of the turret holes after long usage being badly out of line, an adjustable holder should be used. A tool of this character is illustrated in Fig. 195.

A one-lip drill or counterbore with a helical cut, as represented in Fig. 196, is found superior in many cases as it permits of grinding the cutting edge without changing the form of the hole produced.

Counterbores as well as drills should have sufficient back and peripheral clearance but should not have too many cutting lips. A back clearance of about 0.020 inch per foot is satisfactory. For counterbores up to 1 inch three flutes or cutting lips are ample; more flutes are apt to result in insufficient chip space.

### STEPPED COUNTERBORES

In making stepped counterbores where chips bother, it is conducive to good results to provide only one cutting edge for each step and to have successive cutting edges arranged spirally on adjacent cutting lips. Fig. 197 illustrates a stepped counterbore for roughing a hole that is afterward to be finished by a taper reamer. The advantage of this stepped counterbore lies in its producing a hole with a number of slight steps without an undesirable quantity of chips to wedge and cause trouble. For brass work the flutes of counterbores should generally be parallel with the body of the tool, while on steel the flutes should be cut so as to give a positive rake angle of 10 to 15 degrees; the deeper the hole to be counterbored the less the angle of the tool. For steel, and particularly in deep holes, internally lubricated counterbores are effective in keeping the edges cool and in forcing out chips. The various effects produced by counterbores with their cutting edges ahead or behind center, the value of proper rake and lubricants, are discussed in Chapter XXVII on clinging of chips to screw machine tools.

### MACHINE REAMERS

Machine reamers are generally used for finishing holes smoothly and to size, and consequently it is advisable not to leave too much stock for these tools to remove. On steel work from $\frac{3}{8}$ to 1 inch in diameter, from 0.004 to 0.008 inch is generally satisfactory, while in brass from 0.006 to 0.012 is a suitable amount. It is well to have the teeth of all reamers unevenly spaced, as there is then less liability of chattering than where even spacing is adopted.

Cylindrical reamers should only cut on the front end in entering a hole; they cut back of the front end, on the lips, only when the material being reamed alternately expands and contracts through undue pressure or variation in temperature produced by the cutting action. This latter is particularly noticeable in brass tubing. Most cylindrical reaming tools like Fig. 198 are cleared the entire length of their cutting lips as well as having a back taper of about 0.004 inch per foot. For reaming steel where it is desired to produce an accurate smooth hole the so-termed rose reamer, Fig. 199, is excellent. This tool can cut only on the front end, and must be well lubricated and not forced so as to expand the work. It will ream holes under these conditions that are satisfactory to the most exacting. For this work a rose reamer is better than a reamer with peripheral clearance, as its weight is more satisfactorily supported and there is thus more certainty of a round hole being reamed. A rose reamer, as intimated, has no peripheral clearance on the flutes, but should be back-tapered about 0.004 inch per foot.

FIG. 198

FIG. 199

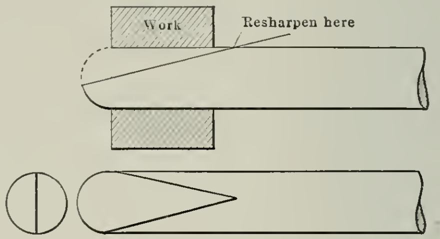



FIG. 200

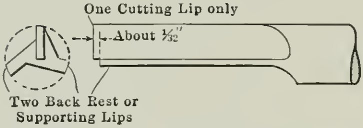



FIG. 201

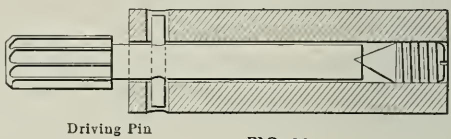



FIG. 202

Reamers and Reamer Holder

### THE CUTTING EDGES

The cutting edges of reamers are seldom undercut and are generally on center, although for brass it is considered by many advisable to mill the cutting edge ahead of center and so secure a scraping cut. The flutes are generally milled parallel with the body of the reamer, but in many cases a spiral-fluted reamer has been the means of obviating chattering.

The spiral should be cut left-hand to prevent drawing in. In small work, particularly brass, a flat reamer like Fig. 200 gives good results. It is inexpensive to make, and may be readily re-sharpened as indicated.

Reamers or, more correctly, boring tools with three flutes and with only one cutting edge as shown by Fig. 201 are found very useful for producing straight, deep holes.

### REAMER HOLDERS

Usually reamers for cylindrical holes (and sometimes finish counter-boring tools) are carried in holders permitting of a floating action of the reamer. When a reamer is held rigidly in the turret hole there is almost a certainty of its cutting an oversize and tapering hole due to the impracticability of retaining the turret hole in perfect alinement with the work spindle. There are a variety of floating reamer holders used. A simple form is illustrated in Fig. 202. With a reamer held in a suitable floating holder and providing the end of the hole that is to be reamed has been bored out so as to run true, and from 0.003 to 0.015 undersize, there should be produced a hole true to size and concentric.

### NUMBER OF FLUTES IN REAMERS

The number of flutes cut in ordinary reamers should be as indicated by the following table:

| Hand. | Fluted Chucking. |
|---|---|
| $\frac{1}{8}$ to $\frac{7}{32}$ diameter 4 flutes. | $\frac{1}{8}$ to $\frac{7}{16}$ diameter 6 flutes. |
| $\frac{1}{4}$ to $\frac{15}{32}$ diameter 6 flutes. | $\frac{1}{2}$ to $1\frac{1}{4}$ diameter 8 flutes. |
| $\frac{1}{2}$ to $1\frac{1}{4}$ diameter 8 flutes. | $1\frac{5}{16}$ to $1\frac{11}{16}$ diameter 10 flutes. |
| $1\frac{9}{32}$ to $1\frac{23}{32}$ diameter 10 flutes. | $1\frac{3}{4}$ to $2\frac{3}{16}$ diameter 12 flutes. |
| $1\frac{3}{4}$ to $2\frac{7}{32}$ diameter 12 flutes. | $2\frac{1}{4}$ to $2\frac{3}{4}$ diameter 14 flutes. |
| $2\frac{1}{4}$ to $2\frac{3}{4}$ diameter 14 flutes. | $2\frac{3}{16}$ to 3 diameter 16 flutes. |
| $2\frac{25}{32}$ to 3 diameter 16 flutes. | |

### TAPER REAMERS

Taper or formed reamers should be provided with clearance the entire length of their cutting lips. The lips or lands instead of being continuous are in the case of long reamers usually serrated by means of a narrow left-hand spiral groove, and this breaks up the chip into a number of curled strips instead of producing a single wide one. The flutes in taper reamers are sometimes milled left-hand so as to prevent pulling in, and sometimes right-hand to assist in cutting. On slight tapers any tendency to draw in must be obviated owing to the risk of breaking the tool, while on steep tapers which resist the feeding in of a tool an opposite effect is desired.

In practice, therefore, it is found satisfactory from the cutting point of view, to make the flutes left-hand in reamers producing holes tapering from 0 to about $1\frac{1}{2}$ inch per foot. From $1\frac{1}{2}$ to $2\frac{1}{4}$ inches taper per foot the flutes may be straight, while on tapers greater than this a right-hand flute is satisfactory. This latter gives a positive rake to the cutting edge, and less end pressure is required to force the tool to the cut than with straight or left-hand flutes.

The cost of making tools with right- or left-hand flutes is somewhat greater than for straight flutes, and grinding is not so readily accomplished with ordinary equipment, hence straight-flute taper reamers are more commonly used.

### RECESSING TOOLS

Recessing tools constitute still another class of internal cutting appliances used on screw machine work for forming grooves and chambers in pieces after they have been drilled or bored out as required. There are many types of recessing appliances, and one is illustrated in Fig. 203. The body *A* has a shank fitting the turret hole, and carries a stud upon which is pivoted the tool holder *B* in which is inserted the cutting tool. This swinging member *B* is held normally in central position by loop spring *C*. In operation, after the tool has entered the hole in the work to the required point the cross slide advances, and, acting upon adjusting screw

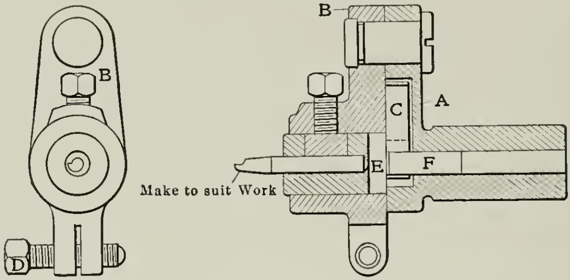



Fig. 203. — Recessing Tool

*D*, presses the holder *B* toward the rear and causes the tool to cut the internal channel in the work. If a chamber or recess of some length is to be formed, the turret slide then advances and the tool takes a boring cut along the side of the hole. Upon completing its work, the tool is relieved by the cross slide receding, and is returned to central position by spring *C* which presses the pivoted tool holder *B* forward until a stop plug *E* contacts with stop pin *F* in the shank. The turret then withdraws the tool from the work.

# CHAPTER XXIV

## SCREW MACHINE TAPS AND DIES

TAPS and dies form a very interesting topic for discussion among toolmakers, and as the conditions under which they are used have quite a bearing on their correct design, it is the case that ideas as to their specific design are greatly at variance. Possibly the selection of the steel used and the manner in which the hardening is accomplished have a more important bearing on results than in the case of any other class of cutting tools. This chapter is not intended to cover this phase of the subject, but it may be opportune to state that in our experience it has been found best from an economical standpoint to temper a tap quite a little lower than a die. Exceedingly hard, brittle taps are liable to frequent breakage on account of their relatively weak cross-section and small chip space as compared with a die.

Keeping taps sharp is more economical than continually making new ones to replace those breaking on account of being unduly hard. A die, however, may be so designed as to have ample metal for strength and much more chip room than the tap, and consequently breakage from this cause is not so liable to occur as with the tap. Furthermore, re-grinding of a die is considered more difficult than re-grinding a tap, and therefore the die is generally left harder than the tap. The speed of work while external threading operations are performed may be higher than for internal threading on account of the foregoing reasons and also because of greater facility for properly lubricating. Tables of speeds for dies and suggestions on lubricating are given in Chapters XX and XXVII.

### TYPES OF DIES AND TAPS

Fig. 204 represents what is commonly known as a spring screw-threading die, with its clamping or size adjusting ring, and Fig. 205 a button die Both of these tools are used extensively in the automatic screw machine. On large work dies with inserted chasers, one form of which is shown in Fig. 206, are found very satisfactory. Various types of opening dies are also being successfully used on different classes of work.

Taps are generally made solid, although there is doubtless economy in the inserted blade type of tap when of large dimensions. Collapsing taps are also made for some lines of work.

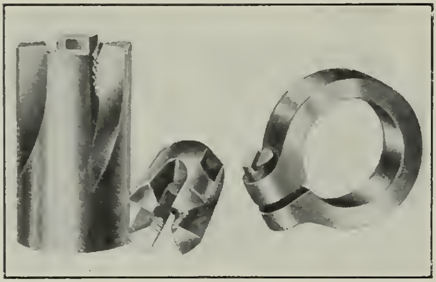


Fig. 204. — Spring-Screw Threading Dies

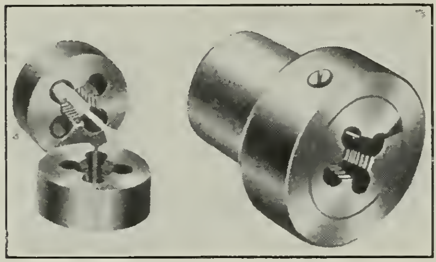


Fig. 205. — Button Dies

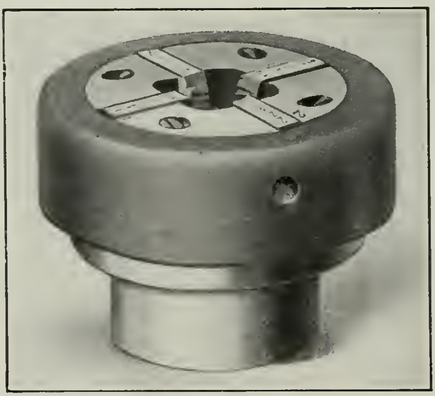


Fig. 206. — P. & W. Inserted Chaser Die

SPRING DIES

Owing to the movable parts which may affect perfect alinement between the turret hole and the head spindle of turret machines, it is found impracticable to hold dies or taps, even if perfectly true and concentric, directly in a turret hole or in a rigid non-adjusting tool holder. Ordinary commercial spring screw-threading dies, even when mounted in holders permitting of side play, are apt to produce better results if made with three cutting edges, as in Fig. 207, than if provided with four or more cutting edges. With the latter, the result due to changes in hardening or imperfect workmanship is apt to be that only two diametrically opposite teeth are simultaneously cutting, as shown in Fig. 208. This causes the die to vibrate and produce a rough thread, with chatter marks. With commercial dies having three cutting edges and providing that they are mounted in a free holder these troubles are greatly reduced. On one

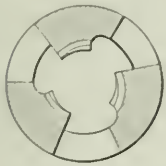


FIG. 207

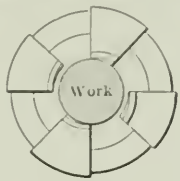



FIG. 208

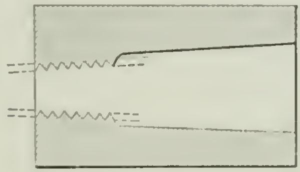


FIG. 210

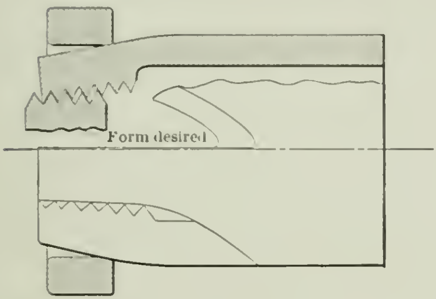



FIG. 209

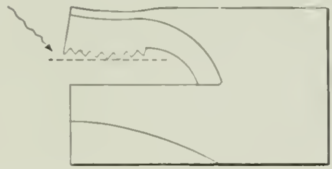


FIG. 211

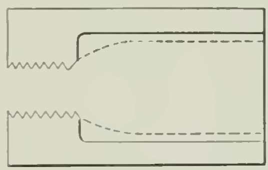


FIG. 212

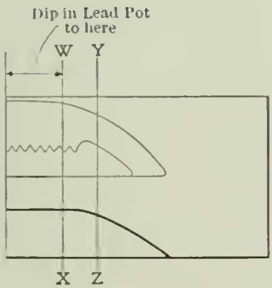



FIG. 213

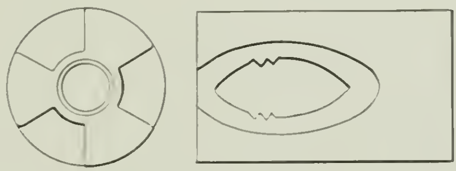


FIG. 214

Spring Dies

occasion, in the designing and tooling of 76 turret machines for a foreign order, about half of which machines were automatics, it was decided to make all of the spring screw-threading dies with *three teeth only*. The diameters of work to be threaded were from 3 millimeters (approximately $\frac{1}{8}$ inch) to 32 millimeters (approximately $1\frac{1}{4}$ inches) and the threads per inch, with the exception of the large sizes, somewhat less in number than United States standard. The parts to be machined were of low-carbon tool steel, cold drawn machinery steel, brass, and also some copper.

Excellent results were obtained in hardening, and only three dies were cracked or ruined by the fire. *There was not a single die which gave any trouble whatsoever* when setting up and testing the equipment. This record would have been impossible with four-tooth dies.

### TAPPING OUT THE DIE

It is good practice in making spring screw dies to either hob out the thread with a hob tap 0.005 to 0.015 inch oversize, according to size, and in use to spring the prongs to proper cutting size by a clamping ring as shown in Fig. 204, or to tap the die out from the rear with a hob tap tapering from $\frac{3}{16}$ inch to $\frac{1}{4}$ inch per foot, leaving the front end about 0.002 inch over cutting size, and in this case also to use a clamping ring, Fig. 204. Both of these schemes are for the purpose of obtaining back clearance and are effective. Theoretically, the use of the taper hob is the best, and is to be preferred especially when work is to be cut with threads of included angle less than 40 degrees, as the shape of thread produced by clamping the prongs of the die to a size below that at which it is hobbed may then be affected enough to be decidedly unsatisfactory. Fig. 209 illustrates this bad feature.

Fig. 210 illustrates the die with the taper somewhat exaggerated, as made with a taper hob and the general internal form of a very satisfactory spring screw-threading die.

### HARDENING

In hardening a die it frequently happens that curves to the lips are produced as in Fig. 211. When clamping the prongs of an oversized hobbed die (with such curvature) down to size, this will still result in a bell mouth die. With a die hobbed out with a tap of sufficent back taper, as in Fig. 210, the curve, if it exists, will not result in a bell mouth; the clearance angle being more pronounced than with an oversize tapped die, neutralizes the curvature. The internal form shown by full lines in Fig. 212 is bad, as the thickness of metal varies so that in hardening trouble will result. In Fig. 210, and as shown by dotted lines in Fig. 212, is a more satisfactory internal form.

Probably the best practice in hardening is to dip the prongs into the lead pot not further than dotted lines *W-X*, Fig. 213, in which case less trouble will result, and the heat will still be sufficient to cause the remaining portion of the prongs to be sufficiently hard when chilled, to prevent welding of chips, etc.

In case the hardening effect extends back into the curve as at *Y-Z*, side-twisting of the prongs is almost a certainty, and the cutting edge of the die in this event will not be in contact with the work, but a portion back of the cutting edge will be dragging on the work which will cause a ragged thread and oftentimes break off the piece being threaded.

In spite of care there is much risk in the *length* of the prongs being at variance after hardening, and it is conducive to good results to leave a tie to the prongs as shown in Fig. 214. This tie can be removed in two or three minutes by the use of a slitting emery wheel.

With a three-prong die it is possible to provide lips of generous cross section, giving rigidity. The undesirable friction due to too much thread in contact with the work is overcome by milling out as in Fig. 207, to suit the material being threaded.

### CUTTING EDGES

The cutting edge of a spring screw die is generally radial for brass, and it is permissible for the edge to point a trifle below center, particularly when there is any possibility (owing to the ease of cutting) of there being a strong chip produced which may cause a "hogging in" action. On steel or material not free cutting, and which opposes the cutting action, it is desirable to have a positive rake to the cutting edge so as to make the cutting action easier, hence the cutting edge is generally above center. The amount is only limited by the chip curling so as to be objectionable on account of clogging, or by the rake being so much as to cause too free cutting, and consequently the production of a big, strong chip and the "hogging in" action which in this event, owing to the cutting edge being above center, produces very bad results.

It should be observed that where large diameters of brass are to be threaded and where the die is so rigid that no springing action can take place, the radial-cutting edge is not as desirable as where there is positive rake to the edge.

Chattering, etc., on large work is generally due to weakness of tool or tool holder, and increased rigidity in these oftentimes makes possible an increase of clearance and particularly an increased positive rake to the cutting lip angles of all tools, with the result of better cutting action.

It is desirable in spring screw dies to make the outside true with the axis of the thread and cutting edges, and consequently it is found desirable to grind the outside diameter from the thread. This is of particular value in connection with the outside clamping or sizing ring, as it assists in adjusting the several prongs of the die equally, as well as making it unnecessary to provide undue freedom in the die-holding device.

On large work, where inserted chaser dies may be utilized, it is evident that more than three cutting edges can be used with very little of the difficulty common to the spring screw die, as distortion due to hardening is less, and if it exists at all, it can be compensated for if necessary. Furthermore, the desirable side clearance to each chaser may be readily given to this type. Where more than three teeth are found desirable it is always better to have an odd than an even number of teeth, as the possibility of only two teeth cutting is then avoided.

### MAKING INSERTED CHASERS

With inserted chaser "opening dies" it is becoming quite common practice to mill the threads of the chasers with a milling cutter, thus giving straight and ample clearance, instead of hobbing with a master tap, which latter gives very little clearance unless greatly oversize.

A feature emphasized by those milling chasers, instead of hobbing, is that when dies or chasers are cut by a master tap there are three inherent errors which if accumulative may be sufficient to make it impossible to obtain perfect pitches. There is first the error of the lead screw in the lathe used in cutting the master hob; second, the error in the hob due to hardening; third, the error in the die or chasers due to hardening. If these three errors act cumulatively the result is that an inaccurate die is produced. By milling the chaser the first two errors may be eliminated, leaving only the error caused by hardening the chaser, and this last error may be kept small by hardening only the cutting edge, the unhardened material at the rear having an important effect in preventing distortion.

It is furthermore advanced by some that in milling the thread of a chaser the metal is not compressed as it is with a tap; that with a tap the metal is not really cleanly cut, but is, so to speak, more or less pushed off as the tap has no clearance and the resulting surface is left in a state of strain which relieves itself when hardening, thus increasing the distortion both in form and in pitch.

### BUTTON DIES

The shape of the round button die gives it an advantage over the spring screw die in hardening, and this type of die is in considerable favor with many on small work. It is not considered as convenient to re-sharpen correctly as the spring screw die, but the low original cost of button dies permits them to be discarded when dull. Chips on coarse pitches are not so easily gotten rid of with the button die as with other types. It has, however, when correctly made, some very good features, and when fully understood and made in proper manner it is very satisfactory for screws $\frac{5}{16}$ inch diameter and under. Owing to the rigidity of the button die the cutting edge of the tooth may always be ahead of the center for brass, as well as for steel, and good results follow.

This type of die should be made substantially as in Fig. 215, and instead of hobbing with an oversize hob, an undersize hob is superior, the die being expanded to proper cutting size. The reason for this is that, with the cutting edge of the teeth *ahead* of center and providing an oversize hob be used, the relation of the cutting edge to the work would be as shown in Fig. 216, when *closing down* the die which, when exaggerated as shown, emphasizes the bad cutting action which exists under normal conditions to an objectionable extent. When the die is *expanded*, as shown by Fig. 217, the clearance of the threaded portion of the die is in the center, where it is desirable that it should be, and the cutting action is excellent. When reversing the work for the removal of the die there is no danger of the wedging in of chips.

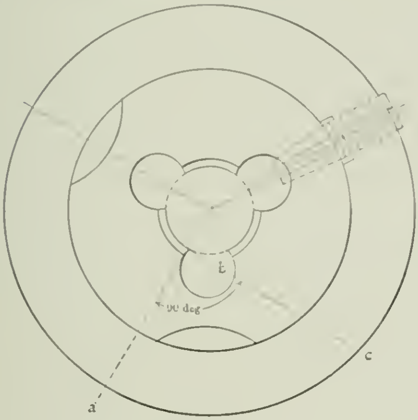



FIG 215

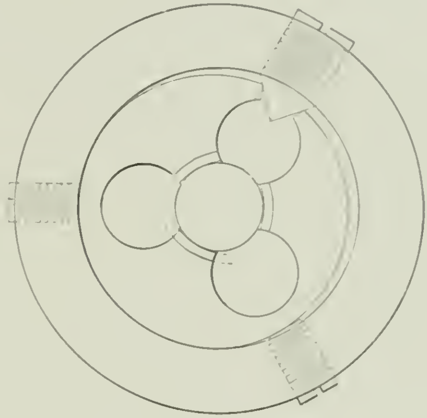


FIG. 216

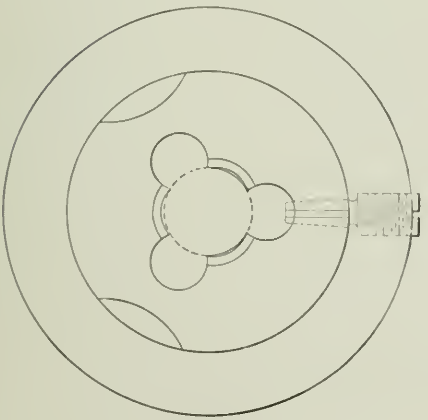


FIG. 217

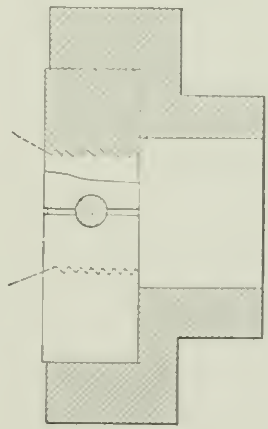


FIG. 218

Button Dies

This type of die, on account of the chance it affords for what would ordinarily be considered an excessive rake without springing, is found very satisfactory for cutting copper.

In the button die, as shown in Fig. 215 and Fig. 218, it should be noted that the expanding wedge is a taper pin which acts as a tie and prevents a twist to the die which might occur from hardening if a wedge were used as in Fig. 216. The line *a*, Fig. 215, representing the cutting edge of the die, may be pointed on center or above, as desired, and then the center of hole *b* is located on line *c* so that the edge of the hole is tangent to the line *a*.

APPLICATION OF DIE TO WORK

Most dies are chamfered, so as to cut smoothly and to assist in starting on to the work, as in Fig. 218, but it sometimes is necessary to cut very closely to a shoulder with one die only, and in this event there can

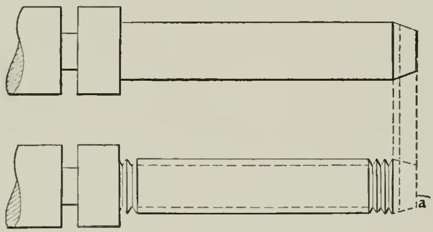



FIG. 219

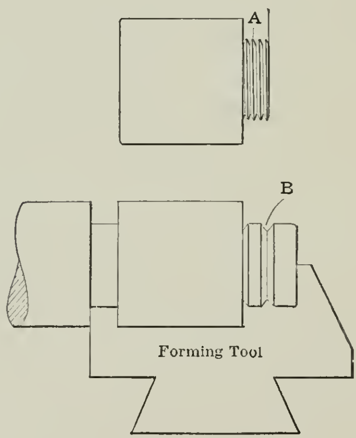



FIG. 220
Threading Work

be but little chamfer. It will be of assistance in starting the die under these conditions, when work permits, to bevel the end of the work as indicated in Fig. 219, prior to running the die on, and afterward remove the bevel at *a*, if objectionable.

It sometimes happens that very short threads have to be produced, as shown at *A*, Fig. 220. An effective method of producing such work is to first cut a long thread and afterward face off the extra portion between neck *B* and the end of the piece. The nicking at *B*, previous to cutting the thread, is necessary to prevent a bur, which would otherwise be produced by the facing tool.

### INTERNAL THREADING

Thus far this chapter has been confined to the external threading of work; it should be remembered that many of the conditions are common to internal threading operations also.

Taps have their cutting edges cut radially in most cases, though on brass it is desirable to cut below center, thus breaking up the chip for its more easy removal. A free curling chip is undesirable when tapping, unless the stock is of such a nature that tearing of work will result in case the cutting edge is not such as to produce such a chip. Copper is a material of this nature, and a tap made like Fig. 221 with a big rake to its cutting edge works out nicely. On copper and similarly acting material, cutting out every other tooth, as is done on the Echols patent tap made by the Pratt & Whitney Company, is found an efficient means of producing clean threads. Fig. 222 illustrates this tap and also shows it entered in a piece of work; Fig. 223 represents an ordinary tap.

In the former (which is always made with an odd number of flutes), each alternate tooth is omitted, the arrangement being so carried out that each of the cutting teeth is followed by a space and each space by a tooth. This arrangement gives a freedom of action to each cutting tooth not obtainable with the ordinary form of tap. In tapping holes with ordinary taps in copper and similar material the tendency is to tear the threads, owing to the wedging action of the cutting teeth, and the slight resistance offered by the metal to the pressure of the continuous row of cutting edges. The chips are carried forward in a mass in front of the cutting teeth, and unless the tap is frequently reversed, thus breaking up the mass of chips, the thread will either be mutilated or the tap broken.

It will be seen upon examination of Fig. 222 that only one side of the thread that is being formed with the tap there shown is operated upon at once. It is thus relieved of one-half the pressure and wholly of the wedging action, and because of the absence of the next adjacent threads, a slightly lateral movement of the thread being formed is possible, owing to the mobility of the metal. It is probable that under similar conditions the removal of alternate teeth in a die would be of value.

### LENGTH AND NUMBER OF LANDS

The number of teeth in regular taps and width of land should be regulated by the diameter and pitch of work as well as the nature of the material being cut. On "sticky" material both dies and taps should have relatively short land. On fine threads, where a drunken thread is to be insured against, more teeth are required than on a coarser pitch of

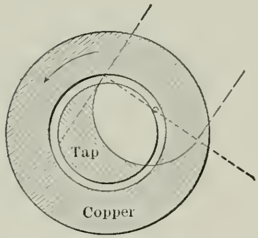



FIG. 221

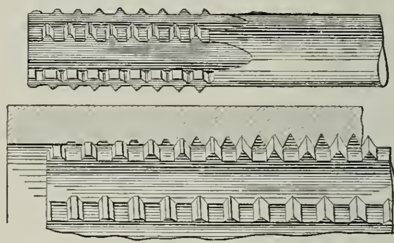


FIG. 222

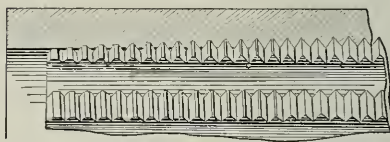


FIG. 223

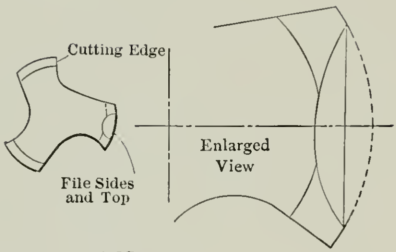



FIG. 224

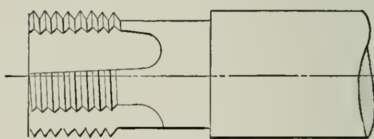


FIG. 225

Taps

the same diameter. A good average number of teeth on taps for United States standard threads is given in the following schedule. Too few teeth

| Outside Diameter. | No. of Flutes. | Width of Land. |
|---|---|---|
| 3/16 | 4 | 3/64 |
| 1/4 | 4 | 1/16 |
| 5/16 | 4 | 5/64 |
| 3/8 | 4 | 3/32 |
| 7/16 | 4 | 7/64 |
| 1/2 | 4 | 1/8 |
| 5/8 | 4 | 5/32 |
| 3/4 | 4 | 3/16 |
| 7/8 | 4 | 7/32 |
| 1 | 4 | 1/4 |
| 1 1/4 | 4 | 5/16 |

and too short land afford very little support and may cause chattering; too much land in contact causes heat due to excessive friction and welding of chips, torn threads, etc.

### TAP RELIEF

Taps for use in the screw machine should permit reversing of the work without any chance of chips wedging at this point, and consequently are not cleared the same as hand taps which go entirely through the work and are thus removed without reversal.

Fig. 224 illustrates the way to relieve the top and sides of the teeth of screw machine taps. A tap for long cylindrical threading should in addition be slightly tapering toward the back so as to free itself. This taper should be about 0.020 to 0.030 inch per foot, although conditions may make it desirable to vary this somewhat.

Where a tap is used on steep triple and quadruple threads it is customary to cut the flute on a spiral so as to present a square cutting face like Fig. 225, which is self-explanatory.

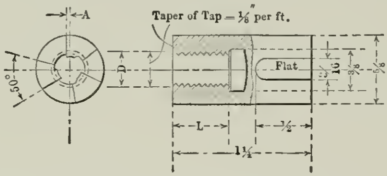
### SIZING WORK FOR THREADING

In boring holes previously to tapping they should be somewhat larger than the theoretical diameter at bottom of thread, as the crowding action of the tap will cause the metal to flow some and compensate for this. Where no allowance is made, frequent tap breakage is liable to occur and torn threads in the work also. On external work it is for the same reasons advisable to turn the work undersize; the following table gives good average allowances for both internal and external work:

| Threads per Inch. | External Work. Turn Undersize. | Internal Work. Increase over Theoretical Bottom of Thread. |
|---|---|---|
| 28 | 0.002 | 0.004 |
| 24 | 0.002 | 0.0045 |
| 22 | 0.0025 | 0.005 |
| 20 | 0.0025 | 0.0055 |
| 16 | 0.003 | 0.006 |
| 14 | 0.003 | 0.0065 |
| 13 | 0.0035 | 0.007 |
| 12 | 0.0035 | 0.007 |
| 11 | 0.0035 | 0.0075 |
| 10 | 0.004 | 0.008 |
| 9 | 0.004 | 0.0085 |
| 8 | 0.0045 | 0.009 |
| 7 | 0.0045 | 0.0095 |
| 6 | 0.005 | 0.010 |

### SPRING DIE SIZES

It may be of value to include a table of suitable dimensions for spring screw dies, and the data in the sketch, Fig. 226, should prove of service, particularly for steel. For brass the cutting edge is radial, thus eliminating dimension *A*. The width of land at bottom of thread is usually




| D = | 1/16 | 3/8 | 3/16 | 1/4 | 5/16 | #3 | #4 | #6 | #8 | #10 | #12 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Th'ds P.I. = | 64 | 40 | 32 | 20 | 18 | 56 | 40 | 32 | 24/32 | 24/32 | 24/32 |
| $A = \frac{D}{10}$ | .003 | .012 | .019 | .025 | .031 | .010 | .011 | .014 | .016 | .019 | .021 |
| L = | 3/16 | 9/32 | 3/8 | 1/2 | 1/2 | 7/32 | 1/4 | 9/32 | 5/16 | 11/32 | 3/8 |

| D = | 3/8 to 1/2 | 1/2 to 3/4 | 3/4 to 1 |
|---|---|---|---|
| Th'ds P.I. = | Std. | Std. | Std. |
| A = | D ÷ 10 | D ÷ 10 | D ÷ 10 |
| L = | 3/4 | 1" | 1 1/2 |
| O.S.Dia. | 1" | 1 3/8 | 1 5/8 |
| Length | 2" | 2 1/4" | 2 1/2" |

Fig. 226. — Spring Die Dimensions

made about $\frac{1}{4}$ O. D. of cut, the milling between flutes being 70 degrees for the flute and 50 degrees for the prong in the case of three-flute dies.

## SIZING DIES AND TAPS

As most all dies have means for slight adjustment, it is not necessary to use the same care in sizing them as in the case of taps which are generally non-adjustable. Dies may be "chased out" to fit a male-threaded plug and a tap to suit a female gage. In the event of having only a plug or a sample to work to, the ball-point micrometer is very convenient in comparing diameters when cutting the thread on a tap. In making taps to a drawing or specification, it is of assistance to turn a portion of the tap to the theoretical bottom of the thread and then with properly formed threading tools, to use this part as a gage when sizing the tap, either copper plating with blue vitriol and burnishing the plate with the thread tool or dispensing with the plating and using a good eye-glass to detect when actual contact between the threading tool and tap blank at gage-point takes place.

## TESTING THREADING ACTION

When in doubt as to the proper cutting action of a die or tap it is advisable to carefully turn or bore a piece of work, then thread the work under normal conditions, but to stop the work with the cutting action taking place, then in the case of external threading, note whether all the cutting edges are producing an even clean chip, or pushing the thread off. In case the thread in the die is smooth and the cutting edges are sharp and have been properly lubricated and the work is poor, the chances are that the angle of rake or the clearance is at fault.

To examine the hole tapped out the work must be carefully sawed into two pieces.

## DIE HOLDERS

Holders for die and taps for the automatic have much to do with the success of these tools. Fig. 227 shows a very satisfactory holder made by the Pratt & Whitney Company. This appliance was developed for use in a screw machine whose spindle reverses very rapidly.

Among the important features of this particular die holder are the following: The backward movement of the sliding die holding head *a*, which, as usual, occurs in running off the die or tap from the work, is never opposed by the guide fingers *b b′*, should they strike against the ends of driving pins *c c′*, as the guide fingers being pivoted at *d d′* swing out in this event. This prevents stripping of the thread. The spiral springs *e e′* serve to return and retain the guide fingers in their normal parallel position which is required when the die or tap is cutting a thread.

The edges of the guide fingers which come in sliding contact with the driving pins as shown are beveled to an angle of 15 degrees with the line of travel of the die head. This angle obviously results in a freer forward movement to the die head than when there is a parallel sliding action, and also insures the lead of the thread conforming very closely to that of the die or tap. The angle could be carried to such a spiral as to tend to push the sliding head forward immediately the die has caught. The 15-degree slope, however, has proved very satisfactory.

At *f* is shown a spring cushioning plunger which prevents undue shock when catching the first thread on the work, and is especially efficient when cutting threads finer than 32 per inch.

## ADJUSTMENT FOR LENGTH OF THREAD

Positive and uniform length of the thread being cut is insured by adjusting the self-locking stop screw *g*. This stop screw determines the amount of travel which the die head *a* may have without rotating with the work. For instance, should it be desired to cut a $\frac{3}{8}$-inch length of thread, it is only necessary to adjust the nut forward until the amount of lap which the driving pins *c c′* have on guide fingers *b b′* is equal to $\frac{3}{8}$ inch, as indicated at *h*.

After the die head has traveled forward enough to free the driving pins, no further thread cutting occurs, as the die head, then being free, revolves with the work. When the spindle and work are reversed the die head usually reverses also until the lip on the groove in the die head at *i* comes in contact with the spring-actuated pawl *j*. This, of course, prevents further reverse rotation of the die head, and as the work continues to rotate the die is unscrewed.

In case the die head due to its inertia does not reverse with the work

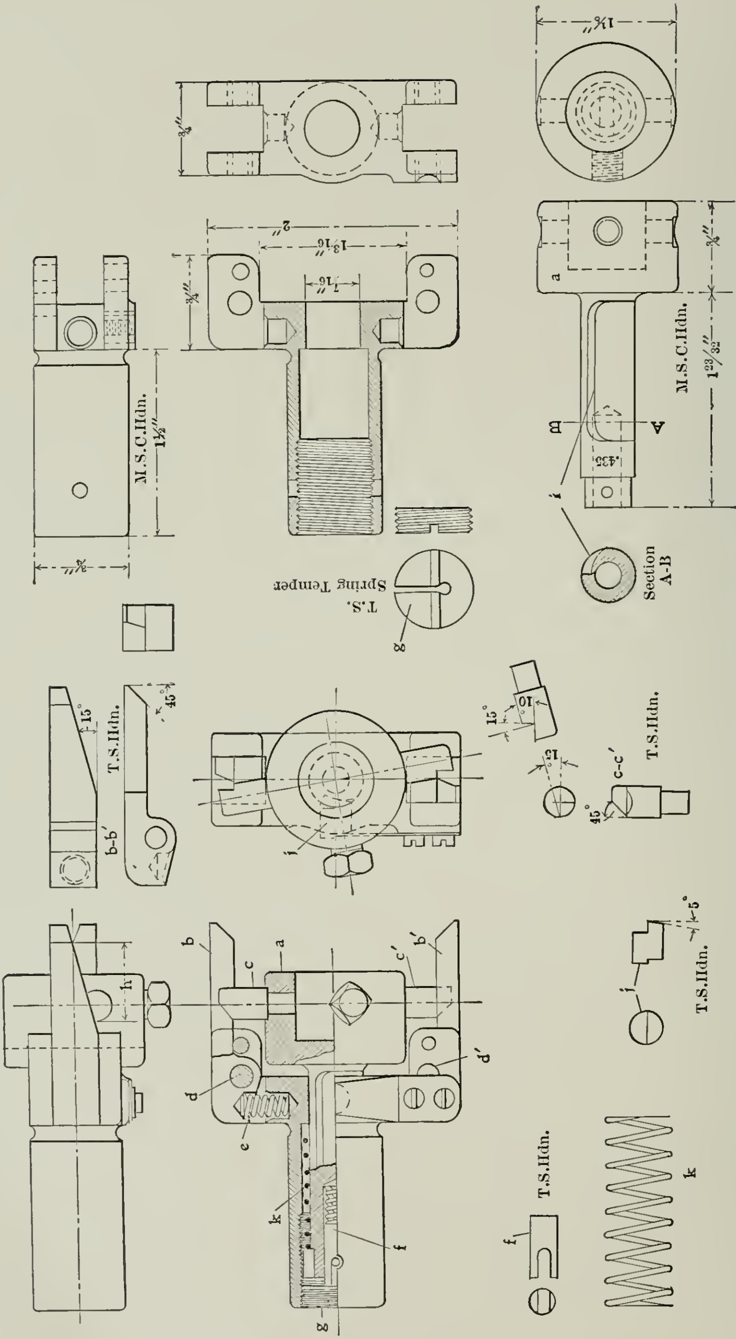



Fig. 227. — Releasing Die Holder

(as does happen occasionally), and should the driving pins and fingers in this event be in direct line, there is no danger of stripping the threads, for the guide fingers as before mentioned will under these conditions be caused to swing outward during the backward movement of the head by the driving pins.

A light spiral spring *k* serves, when the die is not cutting threads, to hold the die head back in the body with cushioning plunger against the stop screw, and in use has the advantage of preventing the marring of the first few threads on the work when backing off the die providing after the thread has been cut, and previous to reversal of the work, the turret, together with the holder, be pulled backward a distance equal to a couple of threads. This causes the spring to be in tension, and, after the spindle has been reversed and the die unscrewed from the end of the work, the spring brings the die head and die clear of the end of the piece that has been threaded.

On account of the fact that absolute alinement of turret and spindle is not always retained and as dies spring in hardening, a slight floating action between the sliding die head and body is allowed. Referring to the detail of the head, it will be seen that the shank is 0.435 inch diameter while the hole in the body is 0.4375 inch.

In some cases where old machines are used, considerably more than this freedom may be advisable; too much freedom, however, is bad, for then trouble may result in starting on the die.

# CHAPTER XXV

## Forming Tools and Methods of Making Them

Quite a variety of types of cutting tools and holders have been developed for cross forming work on the automatic screw machine.

For brass work flat-formed blades such as shown in Fig. 228 or solid forged tools as in Fig. 229 are found very satisfactory, owing to its being possible to obtain with these perfect side and peripheral clearances.

Where frequent sharpening of the tool is required and where the form produced must be kept uniform, these tools are not always satisfactory, and a tool whose cutting edge can be sharpened without any alteration to its contour is generally preferred. Fig. 230 illustrates what is usually known as a circular forming tool. The grinding is done on face *a b c d*, the form as indicated extending entirely around the periphery. Fig. 231 illustrates another type of forming tool which admits of the cutting edge being re-ground without alteration of its contour. This is known by various names, a very common one being " dovetail forming tool " from the fact of its generally having a dovetail to fit into its holder. To prevent any confusion this tool will be referred to as a dovetail forming tool hereafter in this chapter. These tools are generally held and fed in such a manner that the cutting edge is on a radial line with the work being formed. In some special cases, however, it is found more satisfactory for the tool to travel tangentially to the work instead of radially.

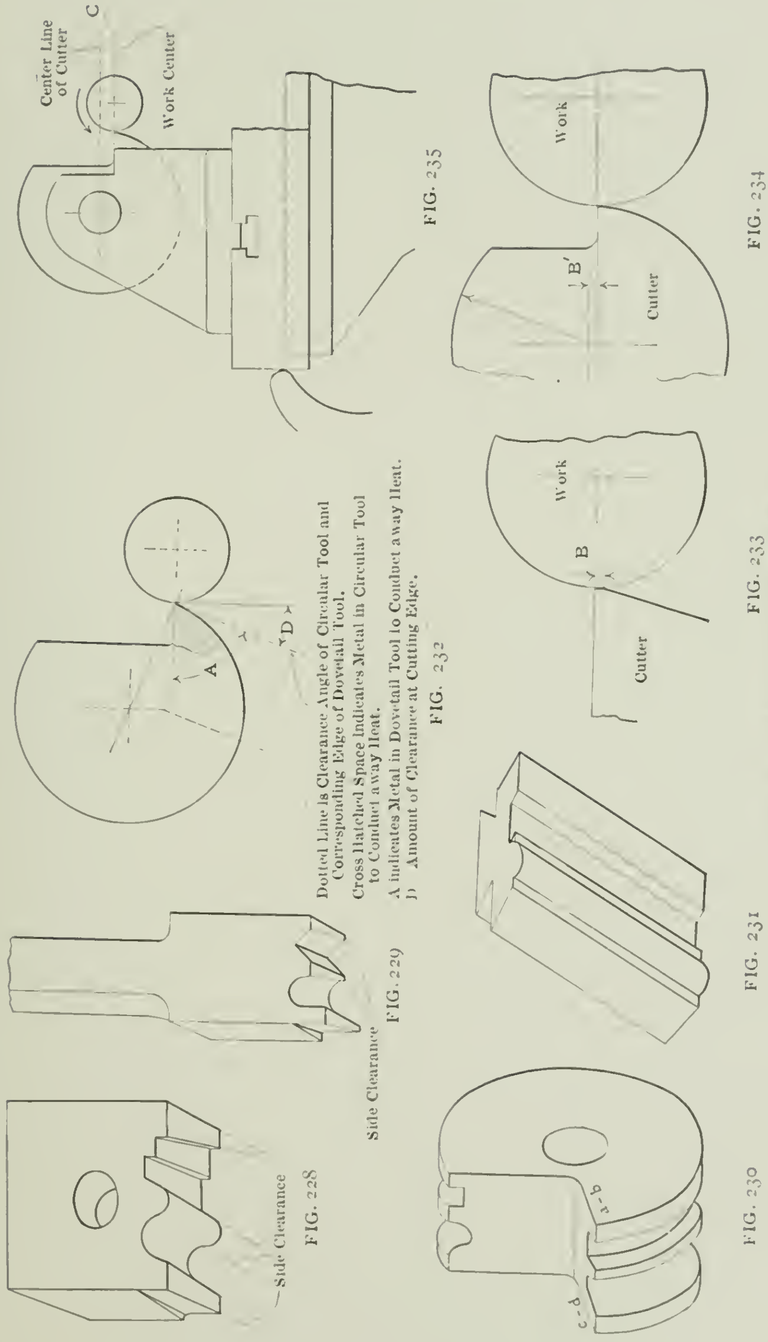
### COMPARISON OF TYPES

There are various things to be taken into consideration when determining whether to use a circular or a dovetail forming tool, and the following points may be of assistance when making the decision:

1. The peripheral clearance angle being constant in both circular and dovetail tools, as shown by Fig. 232, it is clear that in the dovetail type there is more metal directly under the cutting edge than in the circular tools to conduct away the heat which is produced while forming.

2. The difficulty and cost of producing an accurate and smooth form leave much in favor of the circular forming tool.

3. The type of tool post required for a circular forming tool oftentimes interferes with turret tools simultaneously operating on work with the cross-slide tools. The dovetail type of tool permits of the use of holders which do not thus interfere.




Forming Tools and Their Clearances

4. The increasing peripheral clearance of a circular forming tool permits a lesser angle to be utilized at the point of cutting than with the dovetail type, and this lesser angle has a tendency to prevent chattering on account of the support afforded. With the dovetail type, stoning the clearance face is sometimes resorted to, which in effect gives a lesser angle at the cutting point, as indicated in Fig. 233 at *B*.

A similar result with the circular tool *without* stoning the clearance edge is obtained by properly determining the relation of the center of the cutter to the center of the work as shown at *B'*, Fig. 234. Raising or lowering the cutting edge of the tool changes the clearance angle and incidentally changes the form produced. Consequently the clearance angles and the relation of the center of the cutter holding bolt to the work center are points which it is necessary to consider carefully.

### DIAMETERS AND CLEARANCES

With a given material the larger the diameter of the work the greater the angle of clearance required. Clearance angles are seldom less than 7 degrees and seldom over 12 degrees except on work out of the ordinary run.

The diameter of circular forming tools is an important point to consider. A small diameter has a more pronounced change of clearance angle than a large diameter. In fact, when of an exceedingly large diameter the circular tool approaches in cutting action the dovetail type of tool.

On the Pratt & Whitney automatic screw machines the standard outer diameters of circular forming cutters are as follows:

No. 0 machine, $1\frac{3}{4}$-inch O. D. cutter.

No. 1 machine, 2-inch O. D. cutter.

No. 2 machine, $2\frac{1}{8}$-inch O. D. cutter.

No. 3 machine, 3-inch O. D. cutter.

In order to obtain suitable peripheral clearance the practice is to locate the center of the cutter above the center of the work as at *C*, Fig. 235; the tool holder being bored out above the center as indicated and the forming tool milled out below center a corresponding amount so that its flat cutting surface is level with the center of the work. A very satisfactory amount to locate the circular tools above center and cut their working edges below for the machines just referred to is as follows: For No. 0 machine, $\frac{1}{8}$ inch; No. 1, $\frac{3}{16}$ inch; No. 2, $\frac{3}{16}$ inch; No. 3, $\frac{3}{16}$ inch.

### GETTING THE TOOL DIAMETERS AT DIFFERENT POINTS

In order to produce a circular or a dovetail type of tool so that the contour of its cutting edge is such as to produce correct work, the amount a circular tool is off center as *C* in Fig. 235 and the clearance angle of a dovetail tool as at *D*, Fig. 232, must be known. In connection with the circular type of tool the diagrams Figs. 236, 237, 238 and 239 will be

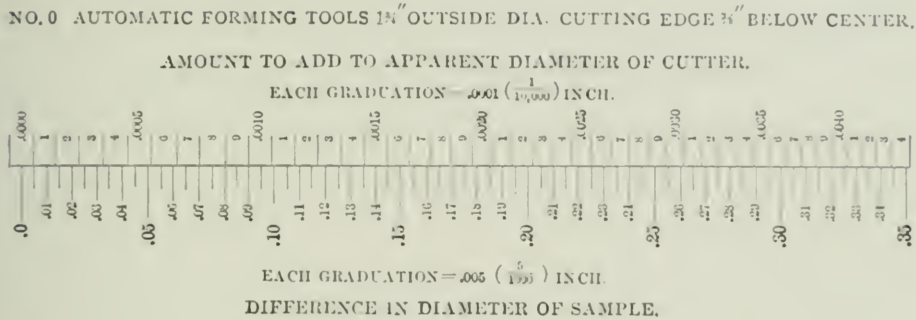



FIG. 236. — Diagram for Finding Actual Diameter of Circular Forming Tools for P. & W. No. 0 Automatic

found convenient for quickly ascertaining the diameters of the various sections of the tool. The method of using these diagrams is given in Fig. 237.

Where different diameters than those given in the diagrams are used, or when the amount the cutter center is set off from the work center varies from the diagrams, the following formula may be used in connection with Figs. 240 and 241:

$$f = g - \sqrt{g^2 + a^2 - (2a\sqrt{g^2 - c^2})}$$

To compute the measurement *T* on dovetail tools, Figs. 240 and 242, the formula would be:

$$T = a \text{ (cosine } A)$$

Ten degrees is a very common clearance for dovetail tools; cosine 10° = 0.98481.

## TOOL-MAKING METHODS

There are various methods employed by the toolmaker in accurately making circular and dovetail forming tools. The form of tool has considerable to do with the scheme selected. For instance, if the work is entirely without curved or irregular outline the tool, if circular, would be simply turned up in an engine lathe to the correct dimensions, sometimes making allowance for grinding, and then milling out a section for the cutting edge. In case the cutter in question is of the dovetail form and has been correctly dimensioned, no difficulty will be experienced in accurately planing to dimensions if the toolmaker has proper dimensioned size blocks. The depth micrometer also is of value in this work. Sometimes fly cutters are also used for making these dovetail tools.

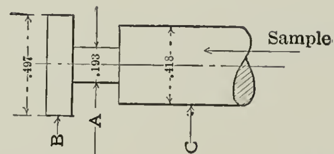
NO. 1 AUTOMATIC FORMING TOOLS 2″ OUTSIDE DIA. CUTTING EDGE 3/16″ BELOW CENTER.

AMOUNT TO ADD TO APPARENT DIAMETER OF CUTTER.

EACH GRADUATION = .0001 $\left(\frac{1}{10,000}\right)$ INCH


EACH GRADUATION = .005 $\left(\frac{5}{1000}\right)$ INCH.

DIFFERENCE IN DIAMETER OF SAMPLE.



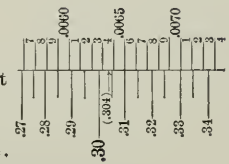

Example: to find the Actual Diameter of Circular Forming Tool at B for #1 Auto. Screw Machine.

Diameter at A = Standard Outside Diameter of Forming Tool = 2.00″

Difference in Diameter of Sample = .497 − .193 = .304. Apparent Diameter of Cutter, or Diameter if Cutting Edge were on Radial Line = 2.00 − .304 = 1.696.

Opposite .304 (Difference in Diameter of Sample) on Lower Scale Read on Upper Scale the Amount to be Added to Apparent Diameter = .0064.

Therefore Actual Diameter of Circular Forming Tool at B = Apparent Diam. (1.696) + .0064 = 1.7024.




Example; —
To Find Actual Diam. of Forming Tool at C

| | |
|---|---|
| .418 Diam. Sample at C | 2.000 Diam. Tool at A |
| .193 " " " A | .225 Dif. in Diam. of Sample |
| .225 Dif. in Diam. of Sample | 1.775 Apparent Diam. of Tool |
| | .0046 Amt. to Add (from Scale) |
| | 1.7796 Actual Diam. of Tool at C |

FIG. 237. — Diagram for Finding Actual Diameters of Circular Forming Tools for P. & W. No. 1 Automatic

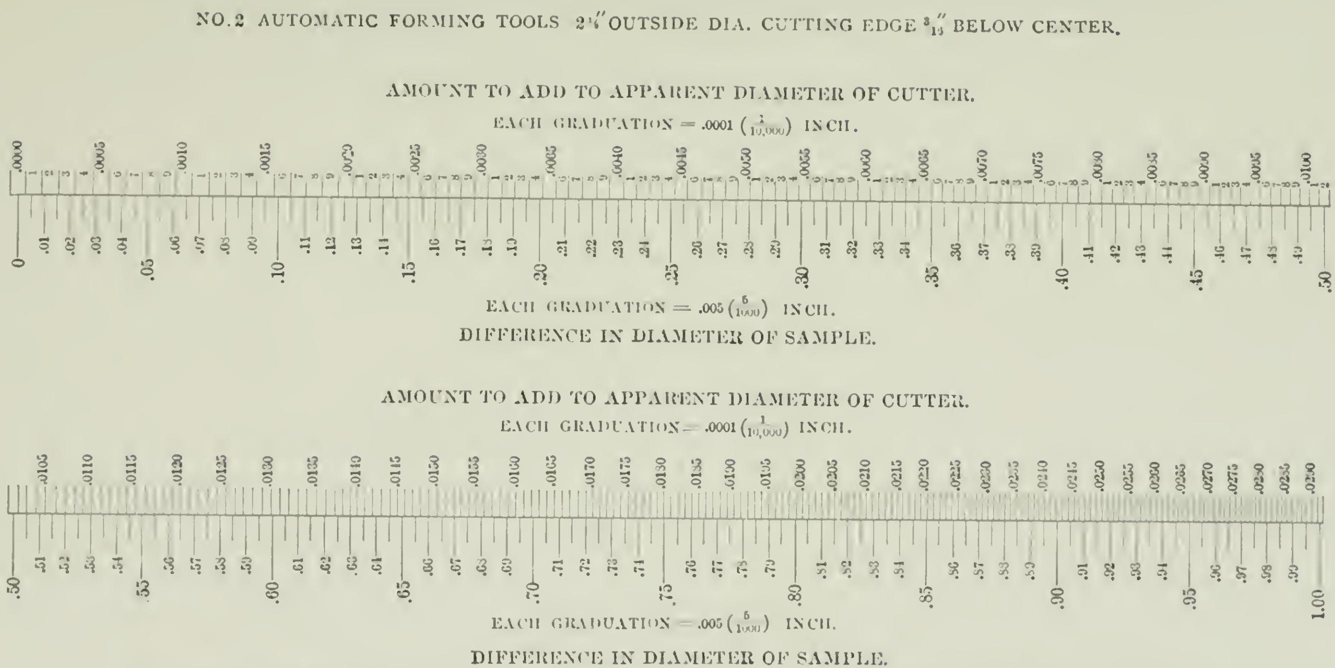



FIG. 238. — Diagram for Finding Actual Diameters of Circular Forming Tools for P. & W. No. 2 Automatic

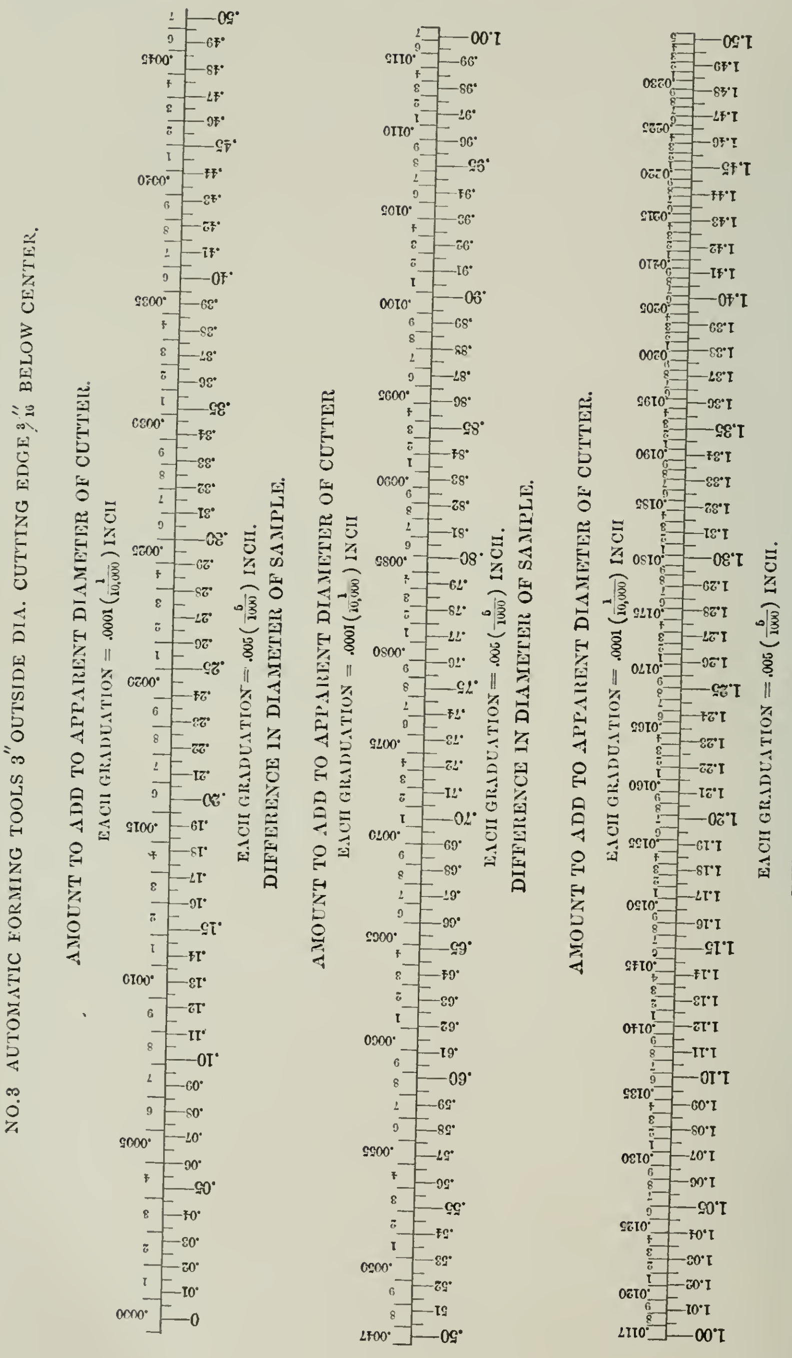
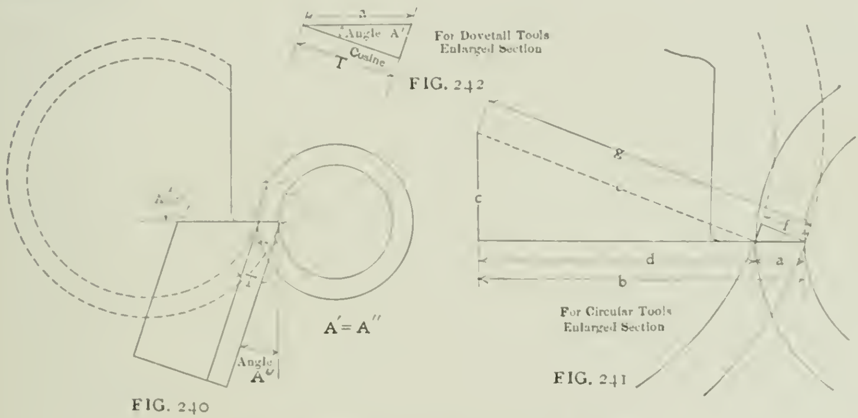



FIG. 239. — Diagram for Finding Actual Diameters of Circular Forming Tools for P. & W. No 3 Automatic

THE TRANSFER SCHEME

It sometimes happens that circular cutters are to be made which are very difficult to caliper; it is then quite frequently advisable to turn a tool-setting gage of the correct diameter and copper plate the gage (using blue vitriol), and then to size the cutter correctly by first bringing a master tool into contact with the gage, noting the graduation on the micrometer collar on the feed screw of the lathe, then moving the carriage longitudinally and bringing the master tool down upon the cutter to the same position. This scheme admits of several master tools being used, and in connection with micrometer stops or suitable size blocks for the longitudinal movement of the carriage accurate circular tools can be economically made.




Finding Cutting Depths of Forming Tools

Fig. 243 illustrates this transfer scheme, corresponding numbers indicating corresponding diameters of model and cutter. By simultaneously using a fixed dead tool arranged as a stop on center against the gage before referred to and a master tool off center the amount the circular cutter is off from the work-center, the gage may be made of such diameters as would be correct with the cutting edges of the circular cutter on the radial line instead of being off center. Another modification of the scheme is to dispense with the dead tool or stop referred to and use a rigid master-tool-holding block capable of rapid vertical adjustment which will permit of setting the master tools to the gage while on center and then allow them to be dropped below center an amount equal to the amount the cutting edge of the cutter is off center. This permits very accurate cutters to be produced. Fig. 244 will give an idea of this method.

Sometimes it is found convenient first to rough out the circular forming tool and next mill out the space for the cutting edge, and thus permit the master tool to be used without the chance of error creeping in which might occur on account of the necessity of moving the cross slide of the carriage in and out.

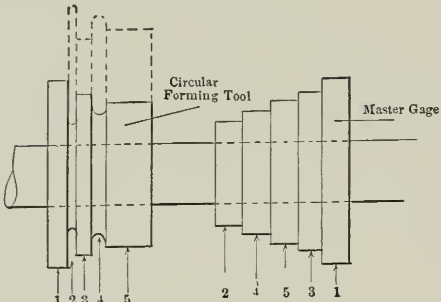



FIG. 243

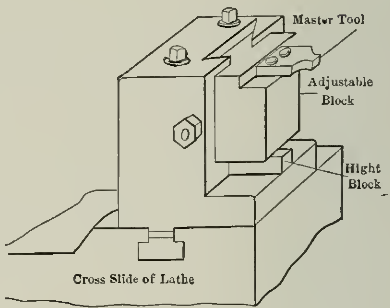



FIG. 244

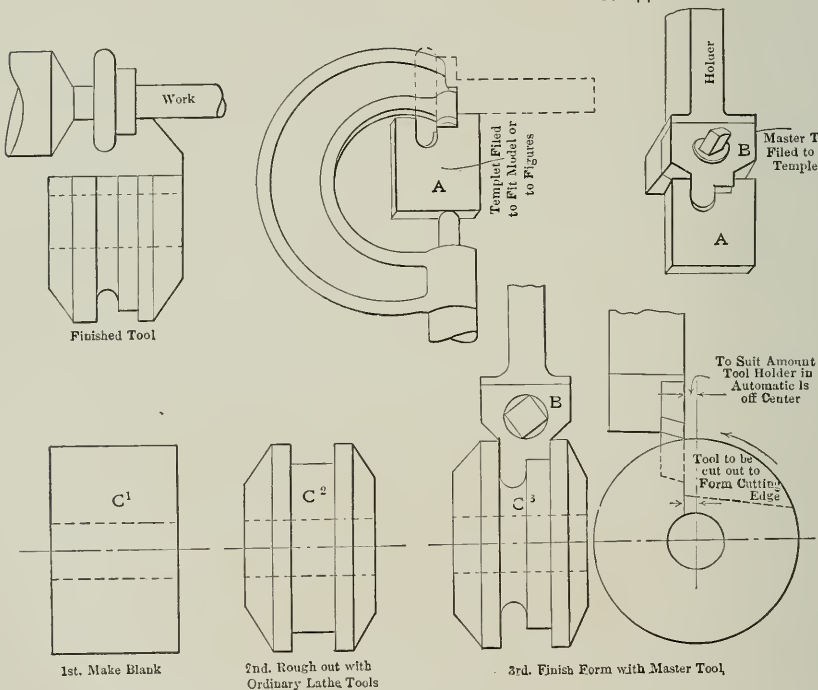



FIG. 245

Making Circular Forming Tools

It will be found of advantage to use tissue-paper feelers between the master gages and the tools in these transfer methods. Some toolmakers prefer merely copper plating the master and just burnishing the copper surface to show contact previous to transferring.

### MASTER TOOLS AND TEMPLETS

When irregular shaped circular forming tools are produced by direct micrometer measurements, the master tool is generally made of the same contour as the work that is to be produced; consequently the master tool when finishing the circular tool must be held off center an amount equal to the amount the cutting edge of the circular tool is off center. The sequence of operations in making a circular tool from a given model or drawing is shown in Fig. 245. First is prepared a master tool templet *A*, and then a master tool *B*. The templet is of sheet steel and should be made from a rectangular piece that is perfectly square to facilitate measuring with a micrometer. Considerable skill is required to file complicated forms accurately. The master tool *B* is shaped exactly to fit the master tool templet *A*, and is also made perfectly square to permit measuring with a micrometer.

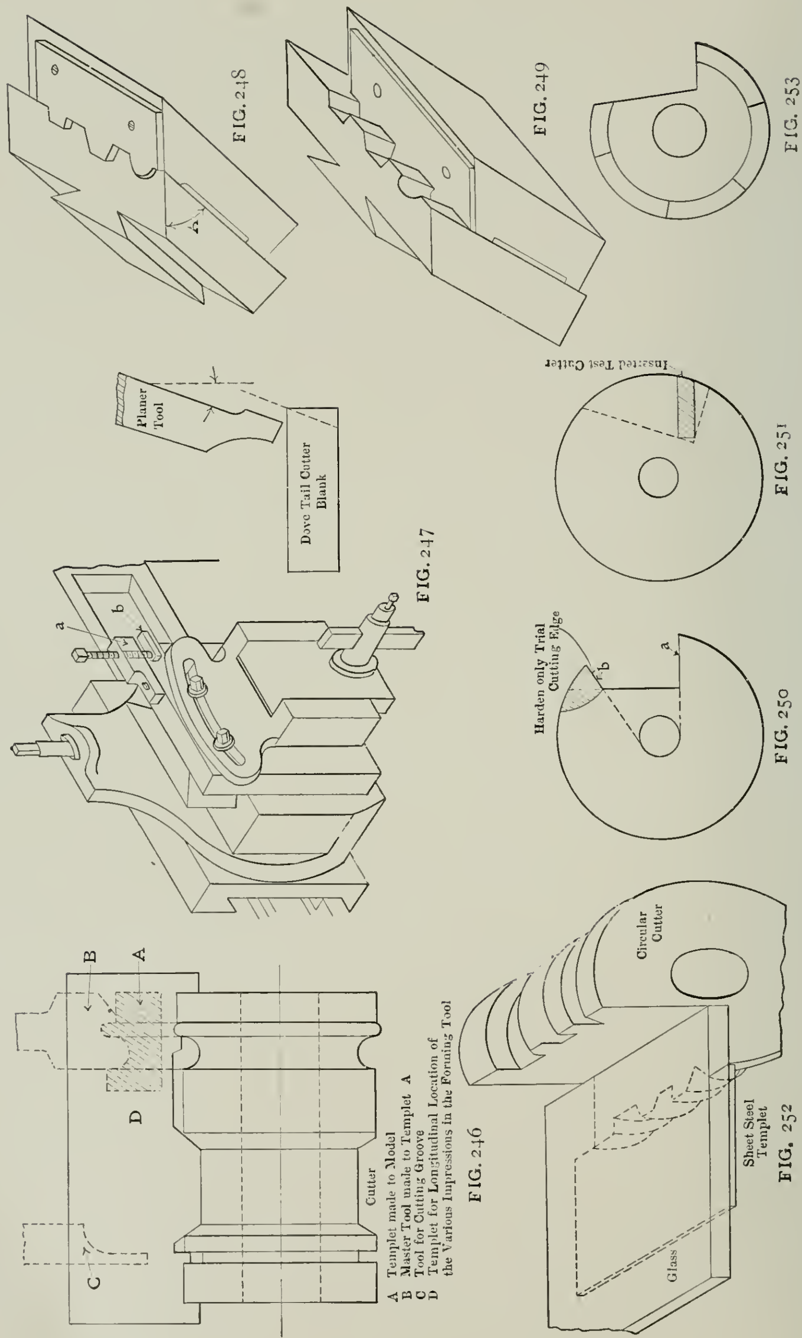
The circular tool is formed by the latter as previously outlined and as shown in Fig. 245. Owing to the thin scraping chips taken when finishing a cutter to exact size the master tool may have a tendency to glaze instead of cutting. The use of turpentine prevents the glazing by assisting the tool to take hold on very thin chips. In some cases two or more master tools are found more convenient than the one, especially in making wide circular forming tools, and in this event it is customary to make a male sheet-steel gage *D*, Fig. 246, for convenience in testing the longitudinal positions of the various cuts in the circular tool. This latter gage does not require the complete form as it is commonly used for longitudinal work only.

### MAKING DOVETAIL TOOLS

In planing dovetail tools size blocks may be used as already mentioned for setting the planer or shaper tool to the various hights required. A stop screw may be located as at *a*, Fig. 247, and size blocks used as at *b* for regulating the setting of the head. Or a depth micrometer may be used instead of the stop screw, tissue-paper feelers being used in either case. Size blocks may also be used directly on the plate in many cases, the tool being brought down into contact with the different blocks for getting the depths of the various grooves, etc., in the cutter blank.

In using a formed tool of same contour as the model in planing the dovetail tool as in the enlarged sketch in Fig. 247, the formed tool is held in the post at the same angle as the dovetail tool will afterward be used on the work. The dotted lines indicate the angle to which the working edge will be finished and the planing tool is shown set at the same angle.

In planing the dovetail form of tools it will sometimes be found of advantage to plane the face of the cutting edge of the blank to the




Making Circular and Dovetail Forming Tools correct angular relation to the clearance face as at *A*, Fig. 248, and then scribe the contour desired on this cutting face from a templet.

If the templet is fastened to a block as shown, the shape of the finished soft cutter may also be nicely tested as in Fig. 249.

As frequent hardening and annealing of tool steel is liable to affect its quality, various expedients are resorted to in order to test the correctness of tools without undue waste.

### TESTING OUTLINE OF FORMING TOOLS

A common scheme is to mill the circular tool as in Fig. 250, where *a* is the actual cutting edge and *b* a trial cutting edge. The cutter is hardened at *b* only and a piece of work is formed by this edge. If incorrect, the cutter edge is annealed at that point and then corrected. Another method is to insert a flat piece of steel as in Fig. 251, and after forming, the test piece is removed and hardened to test the accuracy of the form in the cutter.

A glass plate is frequently found convenient when testing the outline of a circular tool with a templet, the sketch, Fig. 252, showing the application clearly.

Narrow circular cutting-off tools and in fact almost all delicate circular forming tools which are apt to be cracked by hardening are benefited by having radial slots milled as shown in Fig. 253, they are then less liable to crack than when left solid.

### TOOL POSTS

There are many types of tool posts for holding cross-forming and cutting-off tools. Fig. 254 is a form of post made by the Pratt & Whitney Company for holding circular forming tools. This has an adjustable swivel tongue or guide *A* which is controlled by an eccentric pin *B*. The cutter is doweled to the tool holder *C* by pin *D* and the holder after the cutter has been brought in to correct position is firmly clamped to the tool post. There are a number of holes in the tool holder *C* which permit the cutter to be doweled until entirely worn out. The holder is clamped by screw *E*, and being considerably further from the center of the cutter than the cutting edge insures rigidity in this respect. The cutter and holder furthermore are clamped by the center tool binder *F*. A gage for quickly locating the cutter edge on center is part of this equipment. Fig. 255 illustrates a pair of these posts in position and a gage is shown at *g* in the drawing.

Fig. 256 illustrates a circular forming-tool holder with two varying diameters of tools which has been used on automatics equipped with magazines for cast-iron sewing-machine hand wheels and similar work where considerable variation in diameters would require a very large

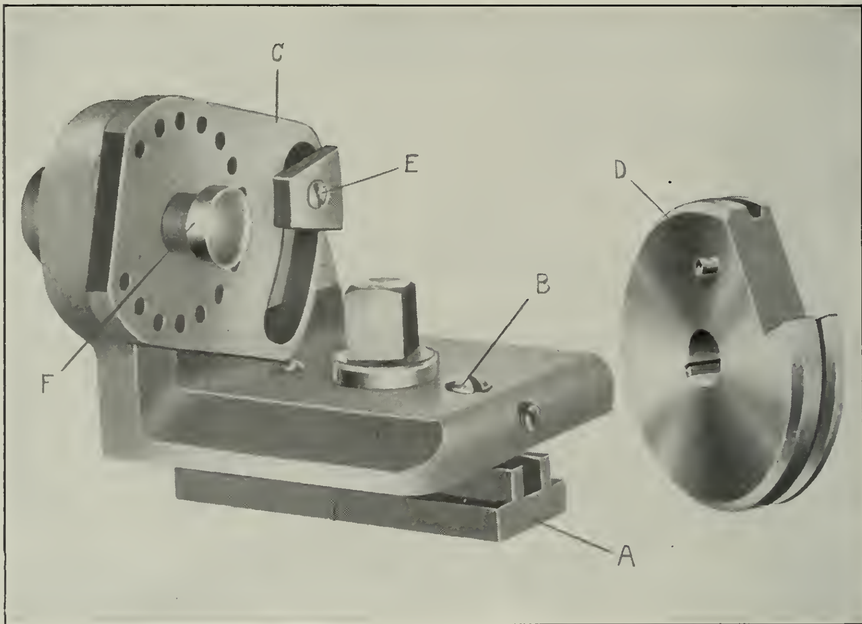



FIG. 254. — Adjustable Tool Post for Circular Forming Tools

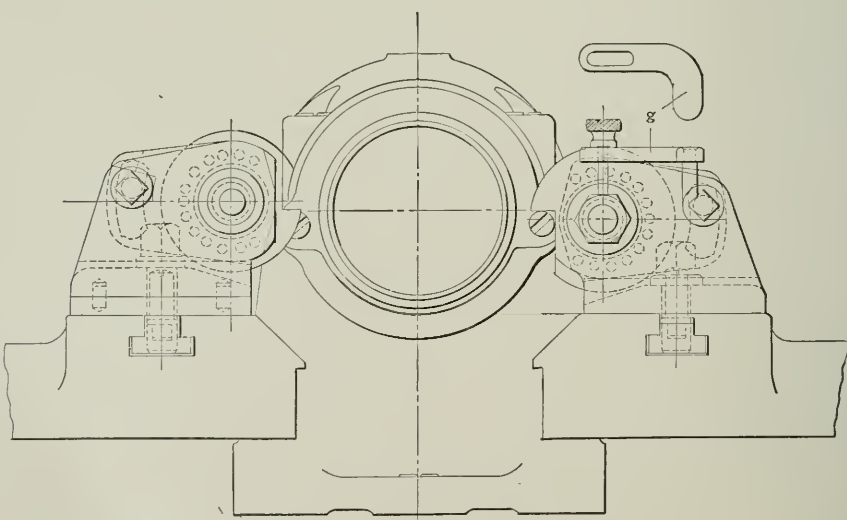



FIG. 255. — Adjustable Tool Posts for Circular Forming Tools

circular tool of the ordinary type, which would be unsatisfactory as regards peripheral clearances.

Fig. 257 is a common dovetail tool holder and post. Fig. 258 represents another style of tool post for holding the dovetail type of tool.

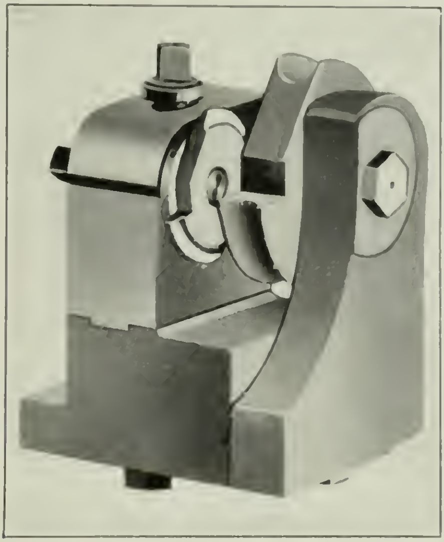


FIG. 256. — Tool Posts for Two Circular Tools

Fig. 259 shows a tool post for holding flat tools. The tool is clamped by screws *a* in swinging block *b* which is adjusted by screws *c* and clamped

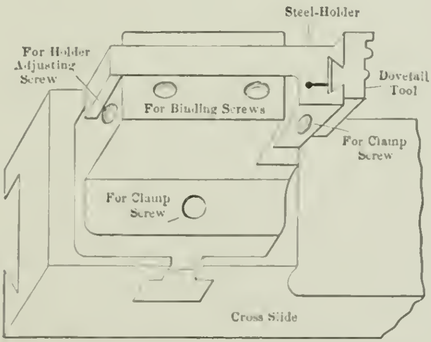



FIG. 257. — Post for Dovetail Tool Holder

fast with the tool post to the cross slide by nut *d*. An eccentric pin *e*, adjusts the tool to position vertically, and the swinging block gives the required adjustment for side clearance.

There are numerous other types, where provision is made for adjusting the tool vertically by wedges, swinging anvils, etc. Fig. 260 illustrates one of these posts with swinging anvil.

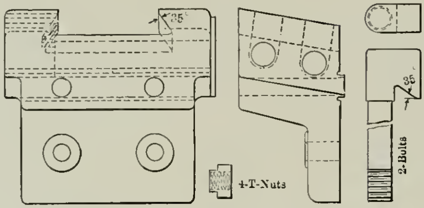



Fig. 258. — Dovetail Forming Tool Post

## APPLICATION OF TOOLS TO WORK

Generally, circular dovetail-forming tools do not have perfect side clearance. This feature is discussed in Chapter XXVII on "Why Chips Cling to Screw Machine Tools."

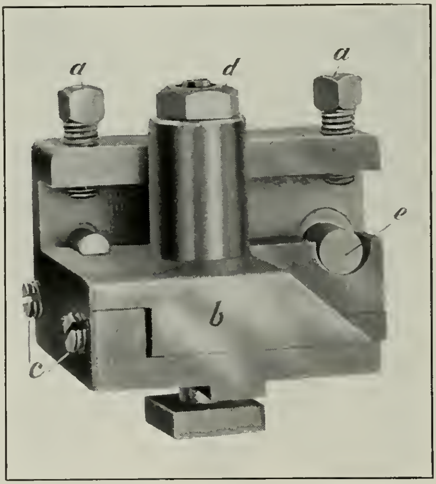



Fig. 259. — Post for Straight Cut-off and Forming Tools

One point that should be carefully considered in the use of cross-forming tools is whether it is most desirable to use a tool with the forward or reverse movement of the spindle. This is of particular importance when the forward and reverse speeds are greatly at variance, which is generally the case, as the production per hour may be greatly increased or decreased according to these conditions. The question as to whether a cross-feeding tool is to be in cutting action simultaneously with an opposite cross-feeding tool, or with a tool in the turret, is also to be considered in their connection.

Fig. 261 illustrates a variety of work which is common to the automatic screw machine and shows various arrangements of forming tools, several of which are adapted for simultaneous operations of front and rear tools which many times is conducive to a high rate of production as the cuts taken with each tool may be greater than if either were operating alone as the side pressure on the work is balanced. When the construction of the machine does not permit of the simultaneous cutting action, a similar arrangement of tools is satisfactory; only the time and sequence of their operations must be taken into consideration.

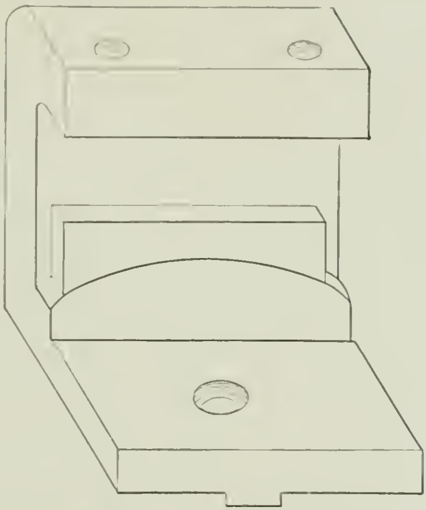


FIG. 260. — Tool Post with Adjustable Shoe

### FORMING AND TURNING

There are a number of important details regarding the shape and method of using forming tools some of which will now be touched upon: Sketches $A$, $A^1$, $A^2$, Fig. 261, indicate a method of forming and cutting off a piece with two tools, one of which is, of course, fed into the work before the other. The burs indicated by arrow points at $A^2$ are due to the rubbing of the forming tools on the side cuts, and unless there is perfect side clearance to the forming tool, the bur will be increased. By adding a bevel edge to the tool, as shown by $A$, the bur produced is reremoved. $A^1$ is a refinement over $A$. At $B$ is illustrated a common method of simultaneously cutting off and forming shoulder screws, the two tools finishing their cuts at the same time. Where a machine with single cross slide is used for producing work in this fashion, the cutting-off tool should precede the forming tool as the bar then has its full diam

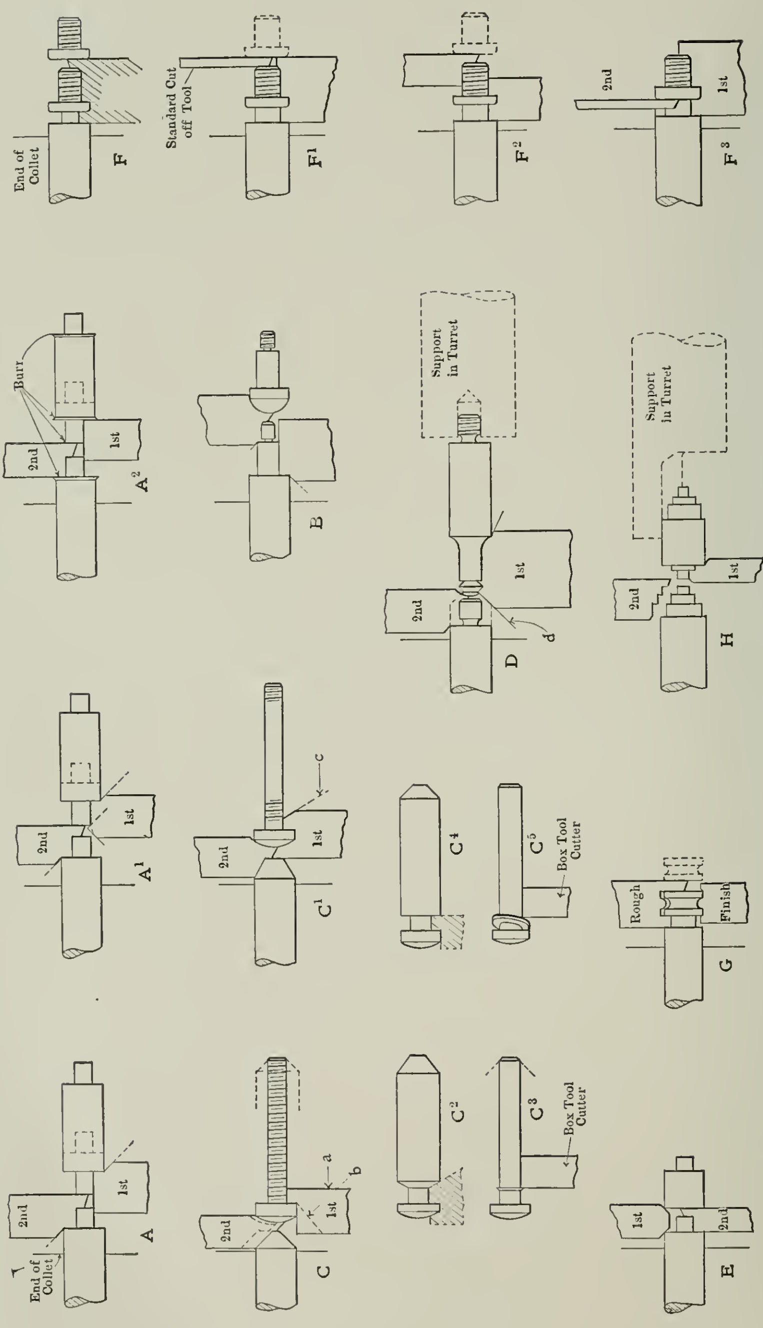



Fig. 261. — Applications of Forming Tools to Work

eter and strength for the cutting-off operation. Sketches $C$ to $C^5$ show an ordinary screw in which the head is to be formed by cross-slide tools and the body turned by a box tool or hollow mill in the turret. The cross-slide tools start their cuts together, but the forming tool for the head, of course, has to finish first. The cutting-off tool should be made so as to bevel the end of the bar as shown, in order to permit the starting of the box tool on a light cut until its back rest has a good support.

The forming cutter for the head should be beveled as at $c$ in $C^1$ in case the box tool follows the forming cut. This allows the tool to cut into the stock as at $C^2$, leaving a beveled shoulder so that when the box tool is fed along it completely removes the superfluous metal without leaving an objectionable ring which is quite apt to be produced under the conditions represented in $C^4$ and $C^5$. The ring of metal there seen which is a result of the square shoulder cut by the forming tool in $C^4$, is quite apt to tip over on the screw blank and cramp and to later on prevent the die from cutting the thread properly.

### SUPPORTING LONG WORK

At $D$ is illustrated a method of forming and cutting off long pieces where it is generally advisable to use a supporting device as indicated. It is obvious that the two cross-slide tools are not used simultaneously in this case. The bevel at $D$ left by the first tool prevents the work breaking off prematurely. $E$ is a very simple piece to produce. Where there are double slides on the machine the two tools may start their cuts at the same time, but the rear tool, of course, merely chamfers the edges of the work. This bevel cutter is a refinement not always required, but it is desirable when the bur which would be produced by the front tool is objectionable.

### MAKING SHORT SCREWS AND OTHER PARTS

At $F$, $F^1$, $F^2$ and $F^3$ are shown several methods of forming and cutting off short screws. The method at $F$ is a rapid one and is particularly recommended for machines with one cross slide, the cutting off of the finished screw being accomplished at the same time the forming of a new blank is being done and requiring a traverse movement of only about one-half the radius of the work. $F^1$ and $F^2$ are applicable only to a machine with double cross slides in case simultaneous cutting action is desired. These two methods are rapid, both tools finishing their cuts at the same time. $F^2$ requires a more costly tool outfit, but on account of balancing the cut is preferred where coarse feeds are taken or long work is to be formed. The method of producing short screws indicated in $F^3$ makes use of a rear cutting-off tool after the forming tool has completed its work.

*G* illustrates a scheme which is of value where roughing and finishing cuts are required on exceedingly accurate work. The roughing tool cuts off the piece previously formed and leaves a light cut for the finishing tool to take on the work outlined. *H* is self-explanatory, indicating the value of the turret support for the work.

### A PAIR OF DOVETAIL TOOLS

A method is shown in Fig. 262 for getting perfect side clearance in dovetail-forming tools. The front tool is used for finishing the left-hand

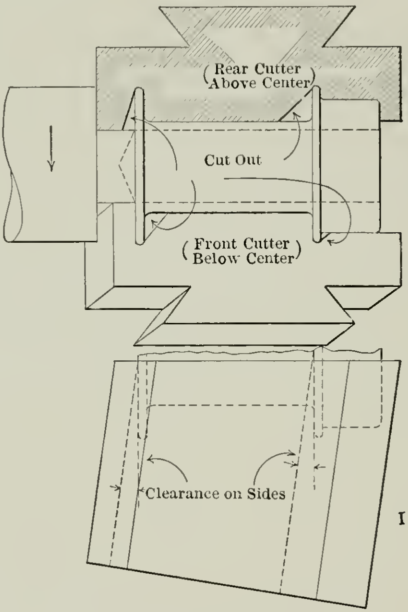



Fig. 262. — Forming with a Pair of Dovetail Tools

sides of the work flanges and the rear tool for finishing the right-hand sides and the end, the tools being inclined in opposite direction so as to obtain clearance for these cuts. The tools are cut out as indicated by the arrows, at diagonally opposite points so that each cutter will clear the surfaces finished by the cutter opposite. Similarly, side clearance to circular tools is possible by inclining their axes.

### ARRANGEMENT OF CIRCULAR TOOLS

In Fig. 263, sketches *J*, *K*, *L*, *M* show various ways of arranging forming tools with reference to the direction of rotation of the spindle. These are to be considered as being viewed from the turret, looking toward the head spindle. The arrangement at *J* is a most common one when a spring screw die or a tap is to be used. The low-speed forward drive of the spindle is used for the cross forming of the work (as at $C$-$C^1$, $F$-$F^3$, Fig. 261), while the high reverse speed is utilized for removing the die or tap and for light cutting-off cuts like that at $F^2$. At $K$ is a similar arrangement to $J$, and in some cases this is substituted for the former, particularly where the die or tap has a left-hand thread; the cutting-off tool is used at the front and the heavier forming cuts taken from the rear in this event.

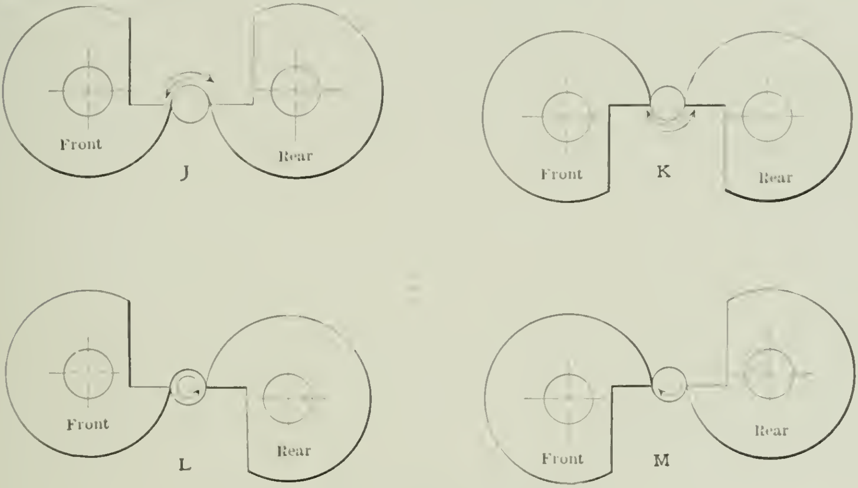



Fig. 263. — Forming Tool Positions

*L* and *M* show arrangement of tools where they operate simultaneously or where there is no necessity for reversing the direction of rotation of the head spindle. In this latter case the spindle speeds generally differ, and by carefully selecting the proper speeds a high rate of production will be possible. In all cross-forming work it is essential that the spindle fit snugly in its front bearing and that the collet or chuck has a good parallel contact with the bar which is being formed. A bell-mouthed collet is most frequently the cause of chattering, although excessive clearance may also promote chattering.

The tool holder should be of such design as to hold the tool firmly and the cross slide of such dimensions and so gibbed as to permit of no spring or shake. With careful attention to these details and providing the cuts are supported from the turret when they are wide, and also providing the design of the tool and the question of clearances are carefully considered, excellent results should be obtained.

The rates of feed and the subject of lubricants are discussed in other chapters of this book. Obviously speeds, feeds, and lubrication all have an important bearing on results obtained in the automatic.

# CHAPTER XXVI

## Nurling Tools and Their Applications

Nurling in the screw machine may be accomplished in several ways. The softer materials such as *rod-brass*, etc., due to the greater mobility of the metal permit of deeper and coarser pitch nurling than the harder and more brittle metals.

### OPERATION OF THE NURL

Generally speaking, the nurling tool which is a hardened tool steel roll, with impressions on its periphery the reverse of those desired on the work, is allowed to rotate freely when brought into contact with the blank that is to be nurled. In some instances, however, long, fancy impressions, numbers or letters are to be nurled upon blanks, and in this event precise results are insured by coupling the nurl to the work spindle by gearing, so as to revolve it positively at a correct uniform speed.

In addition to producing fancy corrugations by nurling, short threads are successfully rolled in. In typewriter manufacturing establishments it is common practice to burnish short sections of studs and shoulder screws to size by passing across the work two cylindrical hardened and ground rolls, which are separated to give the exact diameter desired.

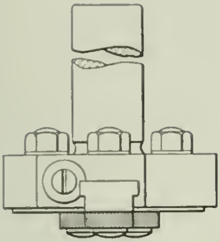
### METHODS OF NURLING

Referring now to the more common nurling operations, there are three methods to consider.

Method A. Nurling from the turret by use of a holder carrying two or more narrow nurls which may be adjusted radially to suit the work. These nurls are *passed longitudinally over* the work. Figs. 264 and 265 illustrate two types of these tools.

Method B. Nurling from the cross slide by use of a holder carrying one or two nurls, and forcing the nurl *radially into* the work. This is illustrated at *a* and *b*, Fig. 266.

Method C. Nurling from the cross slide by means of a holder carrying a nurl, so as to *pass tangently across* the work. Fig. 267 illustrates this type of holder in combination with a cutting-off tool, the nurling operation being accomplished first and the cutting-off following.



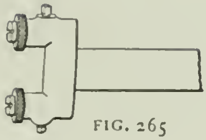
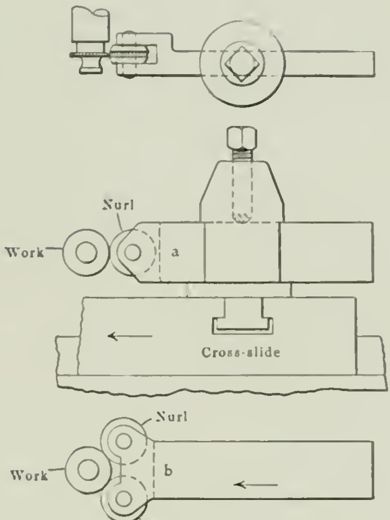


FIG. 265



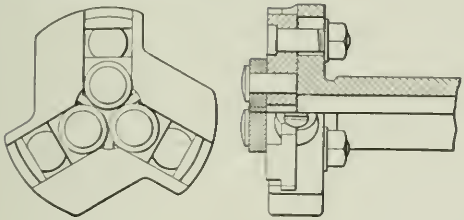



FIG. 264

FIG. 266

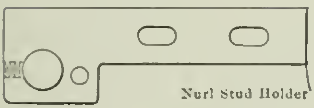



FIG. 268

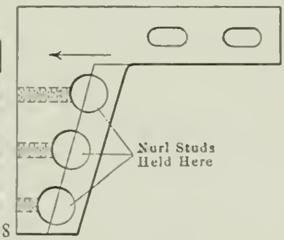



FIG. 269

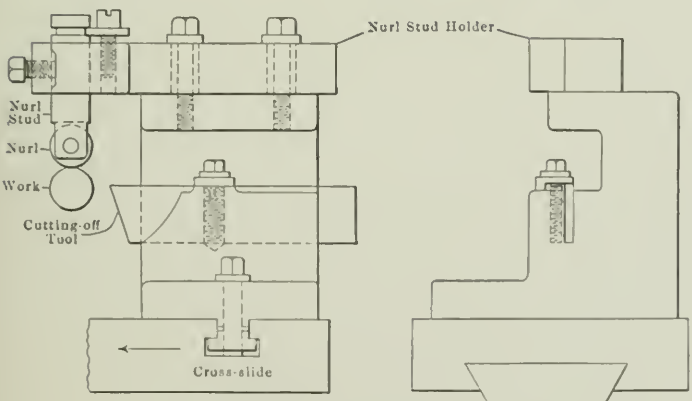



FIG. 267

Nurling Tools

### APPLICATIONS OF DIFFERENT METHODS

Method *A*, owing to the absence of any side pressure, is recommended for all cylindrical nurling operations when the length of the desired impression is greater than its diameter. In fact many operators use this method for all straight work. On complicated work where all the turret holes are required for the various cutting tools, it sometimes becomes necessary to use holders, which, in addition to holding the nurling tools, are so arranged as to hold an internal cutting tool such as a drill or counterbore. The holder must be stiff so as to hold the nurls to the work firmly without spring.

Method *B* is only recommended for narrow nurling on soft metals close to the end of the head spindle. On hard materials or on wide work, the excessive pressure required to force the nurl into the work is apt to crowd the work away and produce poor results.

Method *C* is a satisfactory means of nurling work up to a length equal to its diameter, providing the nurling is close to the end of the head spindle. The pressure required to force the nurl into the work is much less than by method *B*. These last two methods permit of all the turret holes being utilized for other operations, and as shown by Fig. 267, method *C* permits of the combining of the nurling and cutting-off operations in one holder. Method *C* may be satisfactorily used for nurling work as in Fig. 268, having several narrow steps, by arranging the holders to carry three nurl studs as indicated by Fig. 269. The nurls cut one after the other, and thus prevent undue pressure due to simultaneous action upon the work.

### END NURLING AND BURNISHING

In addition to nurling upon the periphery of work, quite frequently end nurling as in Fig. 270 is required. This is satisfactorily accomplished by means of a turret nurl holder carrying a bevel nurl at a suitable angular relation to the work as shown in Fig. 271.

The method of applying burnishing rolls to short studs, screws, etc., as referred to in connection with the manufacture of typewriter parts, is illustrated in Fig. 272.

In this chapter the aim has been simply to outline the various methods and to point out where they might be successfully used, therefore no dedetailed description of the various types of holders or of methods of making nurls is given.

### RESULTS OBTAINED

All of the methods described when used on work for which they are recommended should give excellent results, providing the nurling of too heavy impressions for the character of the material is not attempted, and also providing the work is turned to proper circumferential dimensions so as to mesh well with the pitch of the nurling tool without irregular spacing at the end of each revolution. A slight variation in the

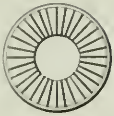


FIG. 270

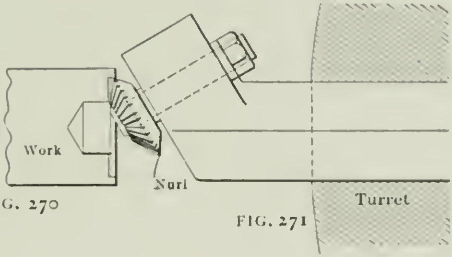



FIG. 271

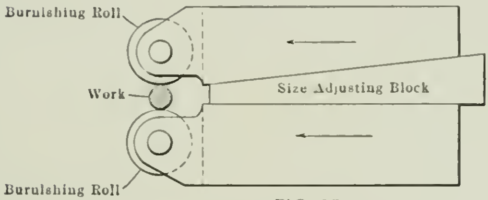



FIG. 272

Nurling and Burnishing Tools

diameter of the blank oftentimes results in a marked improvement in the appearance of the piece when nurled, especially on coarse pitch work.

A liberal supply of lubricant should be used on the work and unnecessarily high speeds avoided.

## CHAPTER XXVII

### Why Chips Cling to Screw Machine Tools

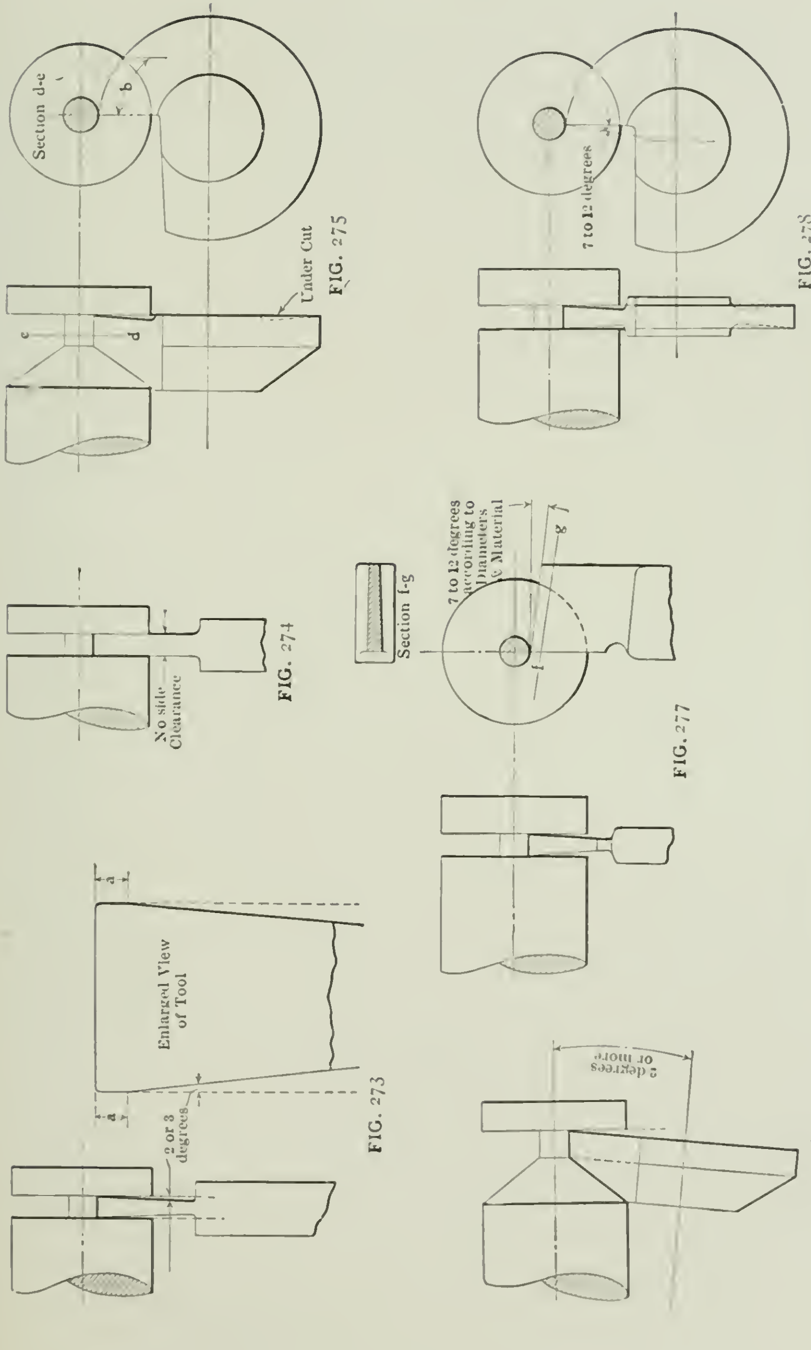
Clinging of chips to the cutting edges of tools used in the screw machine or under similar conditions is due largely to the heating of the chip or of the cutting edge of the tool, or both, to such an extent as to cause the chip to become "welded" to the tool.

This heating may be caused by: (1) Lack of sufficient angular clearance between tool and work; (2) too high cutting speed and consequent dulling of cutting edge of tool; (3) insufficient and improper cooling or lubricating material; (4) incorrect rake of cutting edge of tool; (5) lack of chip room; (6) too much non-cutting tool surface in contact with work.

#### CLEARANCE

Referring to the matter of angular clearance, Fig. 273 gives an idea of desirable conditions for a cutting-off tool, while Fig. 274 illustrates undesirable conditions. The slight flat at *a*, Fig. 273, is to insure smoothness of the work. In case circular tools are used in the ordinary manner to cut down a form, as in Fig. 275, there is no clearance at the outer edge of the cutter at *b*. By swinging the center slightly, as shown in Fig. 276, so that the axis of the cutter is not parallel with the axis of the material being worked, perfect clearance may be obtained. When one tool is used for cutting both sides of a narrow slot, as in Fig. 277, a rectangular form of tool is generally recommended, as complete clearance can be obtained. This form of tool has a relatively short life as compared with the circular type of tool, and consequently the latter with its partial clearance, as shown in Fig. 278, is commonly used. In cases where it is not subjected to severe duty as regards cutting speed, good results are obtained. When the width of the slot is not important, each side of the tool may be finished spirally, giving excellent clearance conditions, as illustrated by Fig. 279. The clearance should be ample to avoid undue contact with the work, but on the other hand not be so much as to produce a thin cutting edge, as the latter will quickly heat under working conditions and then, becoming soft, will rapidly become unfit for use. Furthermore, chattering may result from too much clearance, as indicated at *A*, Fig. 282.

It should be obvious that internal cutting tools require clearance as




Cutting Action of Various Types of Screw Machine Tools well as external tools; in the former case not only the cutting lip, but the outer diameters require back clearance, as represented in Fig. 280.

### CUTTING SPEEDS

It is conceded that there is a limit to the cutting speed on account of the edge of the tool giving out when an exceedingly high speed is attempted. There is also a limit due to the heating of the chip so as to cause it to weld to the tool. Apparently the material being worked has considerable to do with this trouble; experience shows that soft low-carbon steel and brass and similar materials will cause the most trouble, as the welding process occurs before a speed destructive to the cutting edge has been reached. On harder material, *i.e.*, cast iron or steel with more carbon, the welding is not as troublesome.

### COOLING AND LUBRICATING MATERIALS

In many shops "good lard oil" is the standard prescription for use in connection with external and internal cutting operations on cylindrical work. The advantages of oil are fully appreciated when the element of friction plays an important part — for instance, in cutting threads with dies or taps, and in some other internal cuts — but successful results have often been obtained when absolute failure seemed apparent by substituting a cooling material composed largely of water in place of the oil.

Oil positively will not conduct away the heat generated by high cutting speeds and feeds as rapidly as many of the numerous cooling materials on the market. Oil, as compared with the thinner liquids, is sluggish in penetrating to the point where the chip is being torn from the work.

For internal work a compromise, or in some cases the clear oil, is more desirable on account of the fact that the tools do not generally have as perfect a clearance.

### RAKE

In case of the tool having negative rake, as at *C*, Fig. 281, the chip will be pushed off instead of being clean cut and curled, as at *D*. When negative rake is carried to extremes, the chip which is being broken off may be drawn between the cutting edge of the tool and the work and thus become wedged and heated, and welding may result. The wedging action is particularly troublesome on internal work, and may frequently be overcome by changing the type of the flute in the tool.

In cases of tools having excess positive rake, as in Fig. 282, the cutting edge, being so thin, rapidly heats and becomes destroyed, so that this condition must also be avoided.

Clearance and rake form quite a deep subject. The exact amount depends upon the nature of cut as well as upon the nature of the mate-

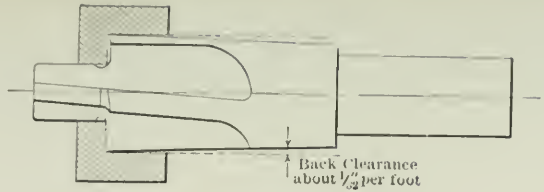



FIG. 280

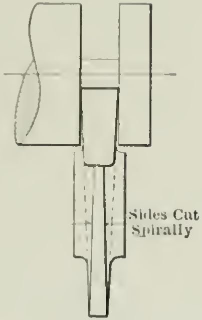



FIG. 279

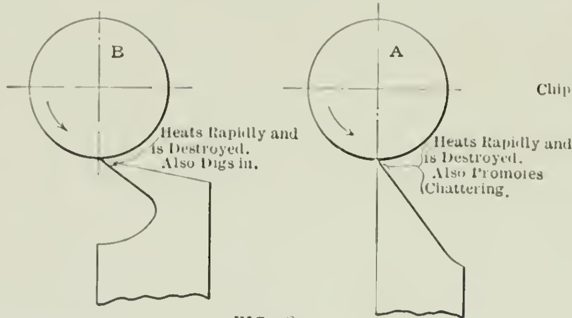



FIG. 282

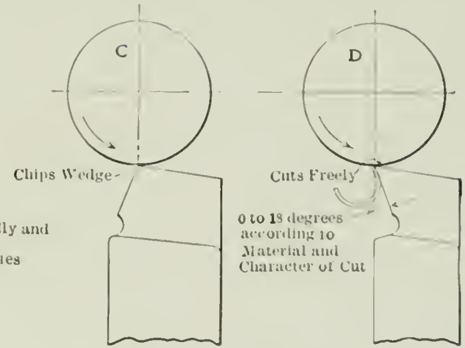



FIG. 281

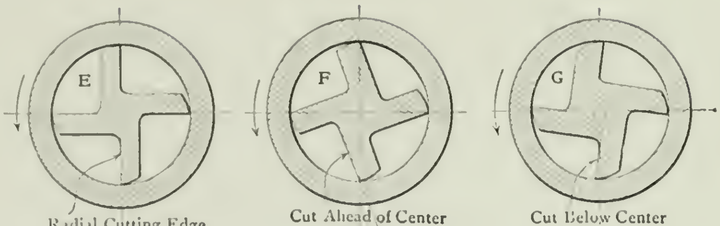



FIG. 283

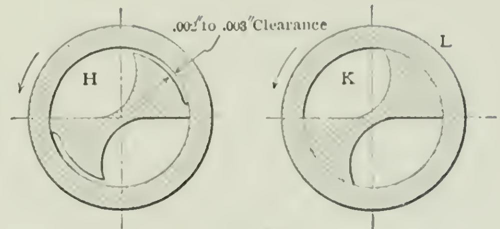



FIG. 284

Cutting Action of Various Types of Screw Machine Tools rial being cut; in this chapter it is not desirable to go into the matter at any great length, as it has been treated in connection with various classes of tools in the preceding chapters of this section. The point to be emphasized in connection with the subject being treated is that the cutting edge must not be given too acute an angle.

### CHIP ROOM

On internal cutting tools, when there is little chip space, the packing or wedging of chips and the resulting heat cause much trouble, particularly on brass and similar materials; increased chip space overcomes the difficulty.

The form of cutting flute influences greatly the welding action, and in some instances the spiral of the flute has an effect. Where a long chip causes trouble, a straight flute or sometimes a left-hand spiral is more satisfactory than the more common right-hand spiral.

The cutting edge should generally be radial, as at *E*, Fig. 283. In case it is ahead of the center, as at *F*, the chip is forced outward and against the work, and then may become wedged into the cutting edge. Making the cutting edge slightly below center, as at *G*, where a straight flute or right-hand spiral is used, is sometimes recommended, as the chips then automatically work toward the center of the tool, and are then forced out from the front of the hole being bored.

When wide chips cause trouble, the cutting edge may be serrated or broken and narrower chips produced.

The style of cutting edge, number of cutting edges, etc., are second only in importance to clearance and rake, and much is to be learned in this direction.

### SURFACE IN CONTACT WITH WORK

The difficulty of too much non-cutting surface in contact with the work is experienced mostly with internal cutting tools and particularly in brass and bronze work. *H*, Fig. 284, illustrates a drill correctly relieved; *K*, Fig. 284, is bad. In the latter case the material being worked becomes welded to the surface *L*, on account of the heat caused by the rubbing action of such a great amount of contacting surface.

In conclusion, while it is generally the practice to design tools to suit the material, it must not be overlooked that a slight change in the nature of the material being machined will oftentimes make possible great improvement both as to quality and quantity of work turned out.

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