Shaper, Slotter, and Boring-Mill Work

By

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and

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SHAPER AND SLOTTER WORK
BORING-MILL WORK
WORKING CHILLED IRON

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CONTENTS

NOTE.—This book is made up of separate parts, or sections, as indicated by their titles, and the page numbers of each usually begin with 1. In this list of contents the titles of the parts are given in the order in which they appear in the book, and under each title is a full synopsis of the subjects treated.

SHAPER AND SLOTTER WORK

SHAPER AND SLOTTER WORK—(*Continued*)

BORING-MILL WORK

BORING-MILL WORK—(*Continued*)

WORKING CHILLED IRON

SHAPER AND SLOTTER WORK

Serial 2222 Edition 1

SHAPERS

CONSTRUCTION AND OPERATION

INTRODUCTION

1. Comparison With Planer.—The shaper is a form of planing machine, best suited for small work or small surfaces on larger work, for which a short stroke of the cutting tool is necessary. The planer is better suited for large work requiring great accuracy; the shaper has a quicker action and a shorter stroke than a planer, and work of a fair degree of accuracy can be done with more rapidity than on a planer. The work on a shaper is held still during the cutting stroke; the feed is obtained by a slight sidewise motion of the table under the tool, and the tool is pushed or pulled across the work. The shaper is used to produce flat, angular, circular or irregular shapes.

2. Classes of Shapers.—The two main classes of shapers are *column shapers* and *traveling-head shapers*, the latter being also known as *traverse shapers*. The difference between the two lies in the shape of the bed and in the way the feed is obtained. In the column shaper, the work is fed sidewise under the tool, and in the traveling-head shaper the head is fed sidewise across the work. In addition to these classes there are various special shapers that are used for special kinds of work. Column shapers may be classed as push-cut and draw-cut. The push-cut shaper makes its cut while the tool moves outwards from the column, the draw-cut shaper makes its cut while the tool is being pulled toward the column, and this type can handle longer work than the push-cut type because the force of the pull-cut has less tendency to spring the ram. Column shapers may be subdivided further into *crank-dviven shapers* and *geared shapers*, depending on the way of driving the ram, which is the part that carries the cutting tool. All shapers are rated according to the longest stroke that can be made by the ram. A machine whose ram will move 24 inches is rated as a 24-inch shaper.

CRANK-DRIVEN SHAPER

3. General Arrangement of Parts.—A crank-driven shaper is shown in Fig. 1. The box column *a* contains the driving mechanism and on the top carries the guides in which slides the ram *b*, which has a to-and-fro motion. At the front end of the ram is carried the head, which is made up of parts *c*, *d*, *e*, and *f*. The head may be swung about a graduated swivel base to any desired angle with the top of the table *g* by which the work is supported. The slide *c* may be moved up and down by turning the screw *d*, while the clapper box *e* is fastened to the slide and can be moved to either side, independently of the swivel. The tool post *f* holds the cutting tools. The table *g* on which the work is supported is fastened to the saddle *h* that is gibbed to the cross-rail *i* and may be moved along the rail either by hand or by automatic feed.

4. The cross-rail *i*, Fig. 1, is carried by the vertical slides *j* on which it may be lowered or raised, to accommodate work of different heights, by the elevating screw *k* that may be turned by the handle *l*. The table is provided with **T** slots and holes so that the work may be clamped to it or held in a vise *m* fastened to the table. An adjustable support *n* is added to stiffen and steady the table and keep it from springing. The amount of table feed for each cutting stroke of the ram is governed by the arm *o* which is adjusted by the screw *p*.

The position of the arm *o* on the screw *p* determines the amount of feed of the table.

5. The arm *o*, Fig. 1, has a to-and-fro motion, imparted to it by the screw *p* which is given an oscillating motion by the driving mechanism inside the frame. The motion of the arm *o* moves the ratchet pawl *q* in an arc, the length of which is proportional to the amount of feed. The pawl engages a ratchet wheel with a pinion *s* on the lead screw *t*, transmitting motion to the screw and thus feeding the table. The direction of motion of this screw can be changed by moving the pawl a half turn, causing it to rotate the ratchet in the opposite direction. The length of stroke of the ram *b* can be altered by loosening the handle *u* and turning the shaft *v*, an arrow

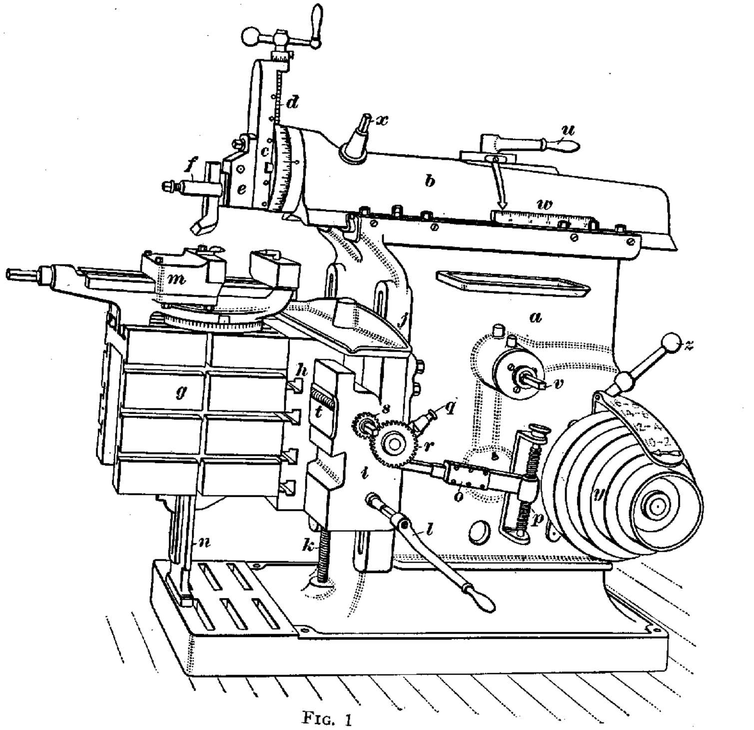


Fig. 1

moving along the graduated scale *w* indicating the length of stroke in inches. The position of the ram with respect to the work is adjusted by turning the shaft *x* with the handle *u* still loosened. After the length of the stroke and the position of the ram have been adjusted, the handle *u* is tightened before starting the machine. By shifting the belt to the different steps of the cone pulley *y*, the shaper may be driven at different speeds. The back gears, which increase the size of the cut by decreasing the speed of the machine, are thrown into action by the handle *z*. A tool shelf is provided at the side of the column *a* as shown.

6. Driving Mechanism.—A longitudinal section and a cross-section of one make of crank-driven shaper are shown in Fig. 2 (*a*) and (*b*), respectively. The ram *a* is moved back and forth by an arm *b* that is pivoted on a short shaft *c* at its lower end and is forked at the top to fit over pins *d* fastened in the sides of the block *e*. There is a long slot in the center of the arm *b* in which fits a block *f* that is carried by a crankpin *g*. The crankpin is held in a groove in the face of a large gear *h* and may be moved outwards or inwards along this groove by the screw *i*, which is operated through bevel gearing and spur gearing by a handle attached to the shaft *j* outside the column. When the crankpin is moved outwards, the block *f* is moved nearer the upper end of the slot in the arm *b*. As the large gear *h* turns, driven by the pinion *k* from the cone-pulley shaft, the crankpin *g* goes around with it, and the arm *b* is swung to and fro, the block *f* sliding in the slot.

7. Stroke of Ram.—Moving the block *f*, Fig. 2, toward the center of the gear *h* decreases the swing of the arm *b* and therefore decreases the length of the stroke of the ram *a*; whereas moving the block in the opposite direction lengthens the stroke of the ram. After the length of the stroke has been adjusted in this way to suit the work, the position of the tool must be located. To do this, the handle *l* is turned so as to unclamp the block *e* and the hand wheel *m* is turned, thus rotating the screw *n* that fits in the block *e*. The ram is thus moved either backwards or forwards until the tool is brought

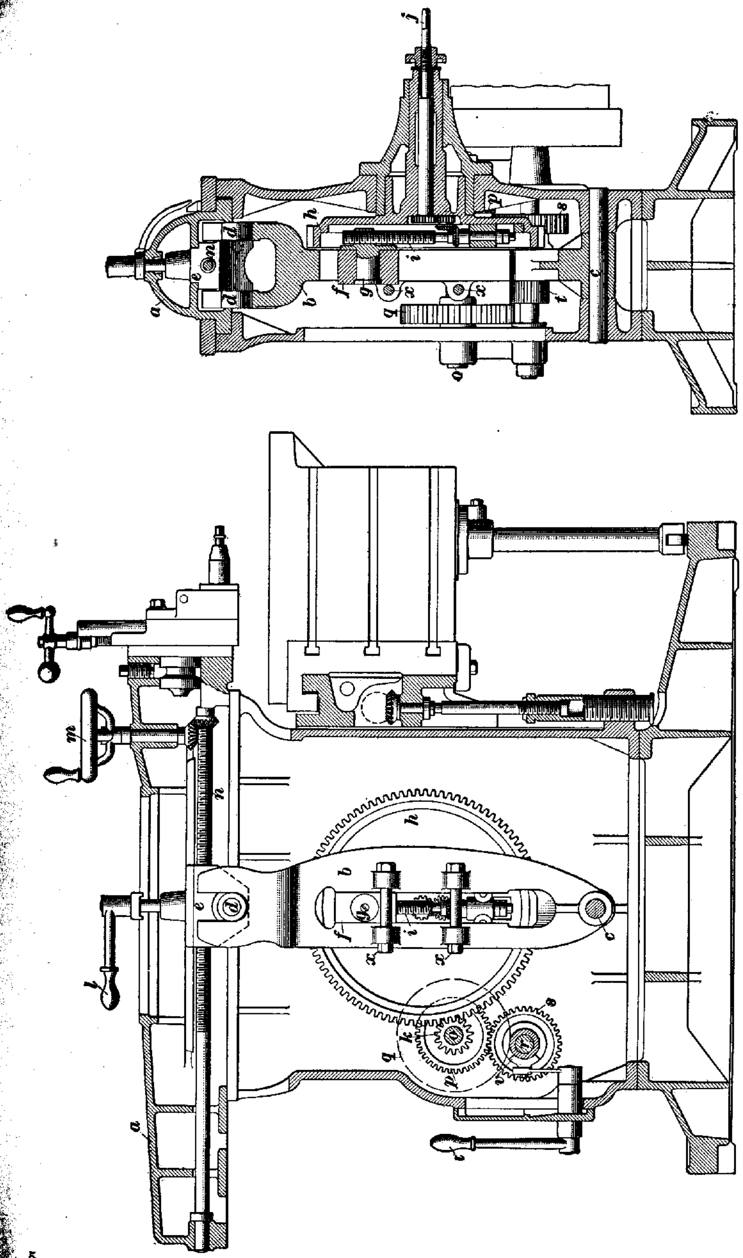


FIG. 2

to the correct position, after which the handle *l* is tightened again.

8. Gearing of Crank-Driven Shaper.—The gearing of the crank-driven shaper is clearly shown in Fig. 2 (*a*) and Fig. 3. The large gear *h* meshes with the pinion *k* that is keyed to the short shaft *o*. On this same shaft, at opposite ends, are keyed the two gears *p* and *q*. The shaft *r* on which the cone pulley is fastened carries a quill, or sleeve, on which are a gear *s* and a pinion *t*, and the quill is splined so that while it must turn when the shaft *r* turns, it may be moved along the shaft in either direction. This movement is made by swinging the lever *u*, which has a short arm carrying a block *v* that fits a groove *w* in the quill. When the gear *s* is moved so as to mesh with the gear *p*, the power is transmitted from the shaft *r* through the gears *s*, *p*, *k*, and *h*. As the gears *s* and *p* are of the same size and have the same number of teeth, the shaft *o* rotates with the same speed as the shaft *r* and the shaper is driven at a rapid speed, this being the usual method of driving. If a heavy cut is to be taken, the quill is moved so as to bring the pinion *t* in mesh with the gear *q* and the motion then obtained is transmitted from the shaft *r* through the gears *t*, *q*, *k*, and *h*. The shaper is then driven slowly, but powerfully, through the back gearing. When the quill is central, as shown, the ram cannot be moved by turning the cone pulley. The bolts *x* prevent the sides of the slot from springing apart when heavy cuts are being taken.

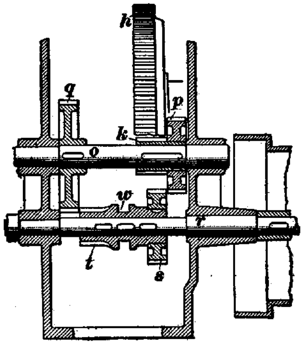


FIG. 3

9. Lever Quick-Return Motion.—The construction of the crank-driven shaper is such that the return stroke of the ram is made much more quickly than the cutting stroke. This action may be explained by use of the diagram shown in Fig. 4, in which the arm *a* is shown in its farthest forward position by full lines and in its farthest backward position by dotted lines. During one full turn of the driving gear *b* the pin *c* moves to the position *d* and back again, and the crankpin in the block *f* goes through the circle *e g h i e* at a constant speed. When the arm *a* is in its farthest forward position, its center line is tangent to the crankpin circle, as shown at *e*, and when the arm is in its farthest backward position *d*, the center line is

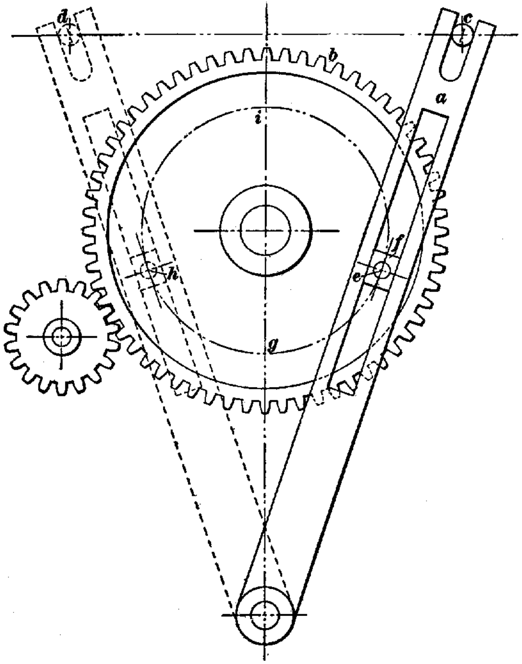


FIG. 4

angent to the crankpin circle at *h*. While the crankpin *e* moves through the shorter part *e g h* of the circle, the ram moves on its return stroke from *c* to *d*, and while the crankpin moves through the larger part *h i e* of the circle the ram moves rom *d* to *c* on its cutting stroke. As the part *e g h* of the rcle is much shorter than the part *h i e*, the time required r the return stroke is much less than that for the cutting roke; that is, the ram moves faster on the return stroke than the cutting stroke.

GEARED SHAPER

10. Driving of Geared Shaper.—The geared shaper, one form of which is shown in Fig. 5, has no slotted arm, but instead has a rack *a* fixed to the under surface of the ram. This rack meshes with a driving gear that is turned by spur gearing connected with the shaft carrying the tight pulley *b* and the loose pulleys *c* and *d*. There are two belts from the countershaft to this shaper. The driving belt, when on the pulley *b*, drives the ram on its cutting stroke, and during this time the reversing belt is on the loose pulley *c*. At the end of the cutting stroke the belts are shifted by the arms *e* and *f*, which are operated by tappets *g* and *h* fastened to the ram. The driving belt is then moved to the loose pulley *d* and the reversing belt to the tight pulley *b*. As the reversing belt is crossed, and runs in the opposite direction from that of the driving belt, the ram is reversed and given its return stroke, at the end of which the belts are again shifted. This reversal is like that of a planer.

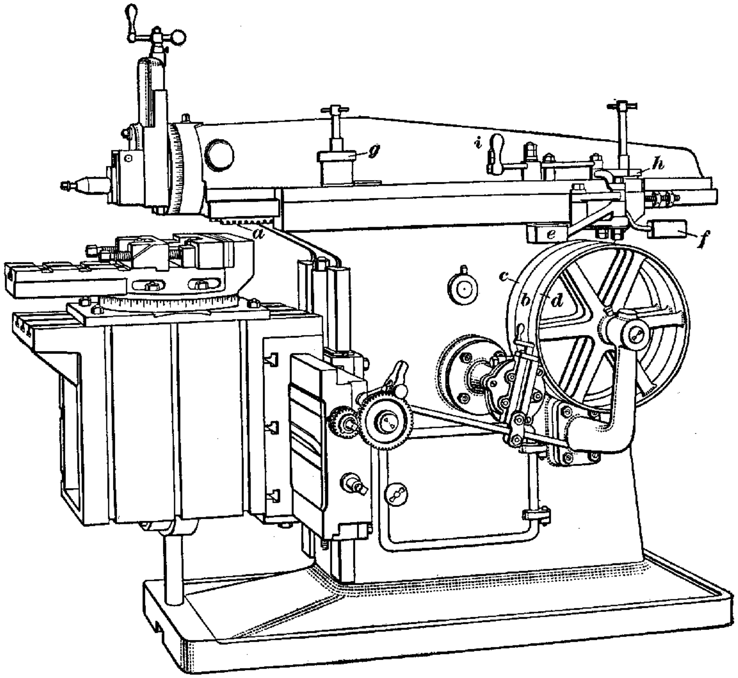


Fig. 5

The machine may be stopped by manipulating the lever *i* which causes the arms *e* and *f* to be shifted in such a way as to place the driving and reversing belts on the loose pulleys *c* and *d*. A movement of the lever *i* in the opposite direction sets the ram in motion again.

11. Stroke and Quick Return of Geared Shaper.—The length of the stroke of the geared shaper shown in Fig. 5 is increased by increasing the distance between the tappets *g* and *h* that move the belt-shifting levers, so that the ram travels farther before it is reversed. The position of the stroke with respect to the work is determined by moving the tappets along the ram to such positions as to cause reversal of the ram at the desired points. As the pulley *b* is driven by both the driving belt and the reversing belt, the quick-return motion of the ram is obtained by having the reversing belt move much faster than the driving belt, which is done by making its countershaft pulley larger than that for the driving belt. The pulley *b* is then driven faster by the reversing belt, insuring a more rapid return stroke than cutting stroke.

TRAVELING-HEAD SHAPER

12. Construction and Driving.—A traveling-head shaper, one form of which is shown in Fig. 6, consists of a heavy box bed *a* to the front face of which are attached the adjustable slides *b* that carry the tables *c*. Sometimes there is only one slide carrying a single table. On the top of the bed is the ram *d*, which is carried by a saddle *e* that may be moved the whole length of the bed. A belt drives the cone pulley *f* and thus gives motion to a shaft that runs along the bed at the back. To this shaft is splined a pinion that meshes with the large gear *g*. A connecting-rod *h* is attached to the ram and to a pin *i* clamped in the slotted bar *j* attached to the side of the gear *g*. As the gear turns, the ram is driven back and forth. The stroke of the ram is increased by moving the pin *i* toward the outer end of the slot. The work is fastened to one or both tables, and the tool is fed across it by moving the saddle along the bed, which may be done automatically by a feed-screw driven by the gear *k*.

13. Whitworth Quick-Return Motion.—The traveling-head shaper, Fig. 6, has a Whitworth quick-return motion, which is shown in detail in Fig. 7. The like parts shown in both illustrations have the same reference letters. The cone pulley *f* has a pinion *l* on its shaft *m* that drives the large gear *g* mounted on the saddle *e* carrying the ram *d*. The gear *g* turns on a large pin *n*, and at a uniform speed in the direction of the arrow. The arm *j* is slotted part way from each end, one of these slots being in the front of the arm and one in its back as shown. The arm is pivoted on a pin *o* that is set below the center in the end of the large stationary pin *n*, as shown. The arm *j* is revolved on the pin *o* by a pin *p* set in the side of the gear *g* and engaging the inner slot of the arm. The crankpin *i* may be adjusted along the outside slot of the

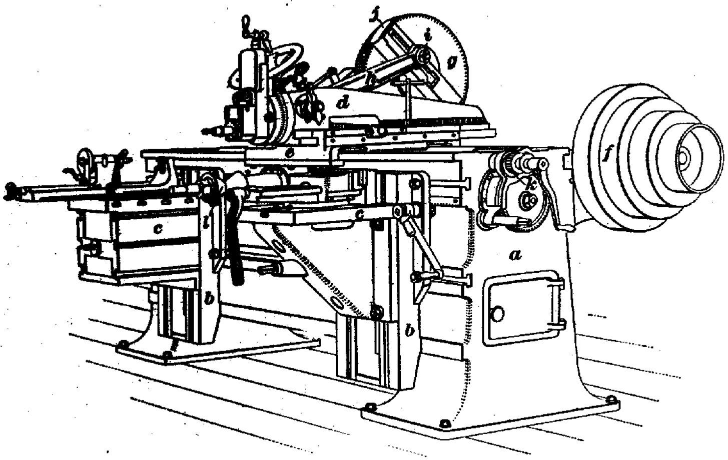


FIG. 6

arm *j* in order to give the desired stroke to the ram *d* through the connecting-rod *h*.

The operation of the quick-return is as follows: The distance between the centers of the pins *o* and *p* is the length of the crank, or lever, whereby the gear *g* revolves the arm *j*. This length changes constantly, being shortest when *p* is at the bottom as shown, and longest when *p* is at its highest location on the dotted circle *q–r–s* centered at *x*. The ram *d* makes its return stroke while the pin *p* moves through the short arc *s–p–q* and the lever *o p* is shortest. The cutting stroke is made while the pin *p* completes its circle on the long arc *q r s* and the lever *o p* is longest. As the ram strokes are equal, its crankpin *i* moves through equal arcs *w i u* and *u v w* for each stroke on its circle centered at *o*. From the motions just described it will be seen that the driving pin *p* that revolves at constant speed passes through *unequal* arcs during the same times that the crankpin *i* passes through *equal* arcs. As the return stroke of the crankpin *i* takes place while the driving pin *p* travels its *shortest* arc, the crankpin *i* must travel at its *fastest* speed on the return stroke.

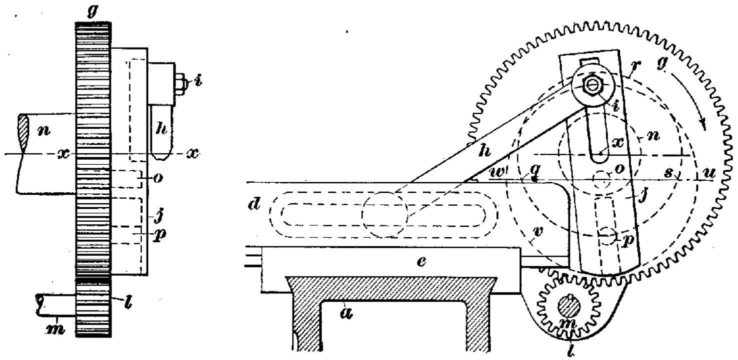


FIG. 7

14. Advantages of Traveling-Head Shaper.—The traveling-head shaper may be used to advantage for shaping work that is of such large proportions that it cannot conveniently be moved. In such cases the tables may be run out of the way or taken off and the work may be fastened to the floor in front of the ram. If the work is of peculiar shape, the two tables may be set at different heights and the work may be held by both, which is frequently advantageous. A third advantage is obtained by an attachment for planing round work. Between the tables a hole is bored through the bed from front to rear and in it is inserted a hollow spindle, or quill, that may be rotated by hand or by automatic feed. To the quill is clamped an arbor, shown at *l*, Fig. 6, by which the work may be held while the cutting tool is moved back and forth over it by the ram. If necessary, the arbor may be removed and long shafts of limited diameter may be passed through the quill and held while keyseats are being cut. Another advantage is that, while one table is being used for holding the work that is being operated on, the other table can be used for setting up duplicate work, thus saving time.

DRAW-CUT SHAPER

15. Special Features of Draw-Cut Shapers.—The ordinary shapers previously described push the tool through the work while the ram moves outwards. In the draw-cut shaper, however, the tool is pulled through the work while the tool is moving toward the column. By this arrangement the draw-cut shaper can take longer and deeper cuts and with much heavier feeds than the other type. It also takes less power and occupies less floor space than a planer of the same capacity.

The general arrangement of a small belt-driven draw-cut shaper is shown in Fig. 8. The apron box and tool block *a* are designed to hold the tool with its cutting edge pointing toward the column, so that the pull of the ram *b* performs the cut and the push of the ram causes the tool to swing free over the work.

16. Universal Draw-Cut Shaper.—The draw-cut shaper has its greatest usefulness in the larger sizes and when it has a rotating tool head for finishing circular work. A set of chucks and fixtures for quickly setting and clamping the work is also needed. Standard work of many duplicate pieces, such as that on locomotive driving boxes, shoes and wedges, box brasses, cylinder saddles, etc., and on the pole pieces of electrical machinery and the like, is readily accomplished.

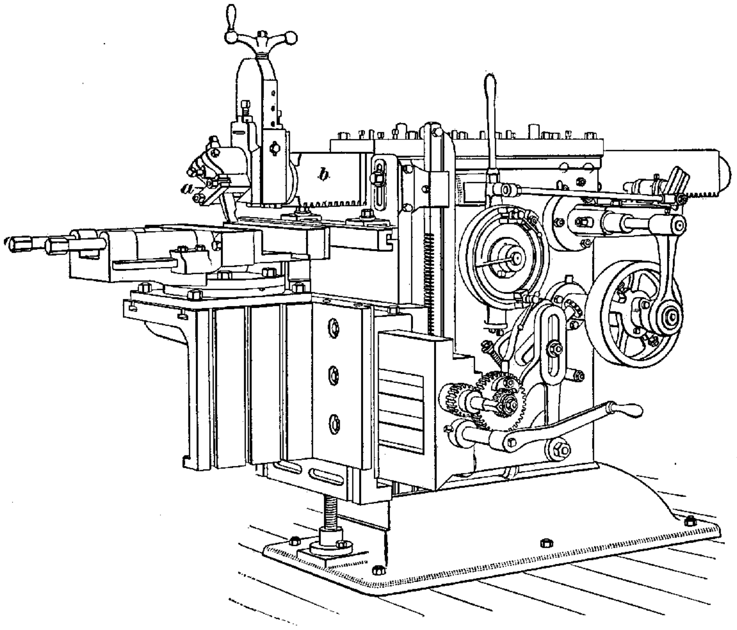


Fig. 8

17. A universal draw-cut shaper is shown in Fig. 9. This machine is driven by an alternating-current motor *a* with a broad belt *b* from the motor pulley to the pulley *c* on the change-gear box. The gear box drives the main shaft located across the machine and having its front bearing in the case *d*. The start-and-stop clutch on the main shaft is operated by the lever *e*, rod e_1, etc. From the main shaft the power is transmitted through a pulling stroke gear and clutch shaft in the pocket or chamber *g*, and a return-stroke gear and clutch shaft in the chamber *h*. The clutches on these two shafts are operated automatically by the ram motion as follows:

The shaft *i*, as it rotates back and forth with the ram, carries its attached arm *j* against the stops *k* that may be clamped in any location around the reversing disk *l*. The movement of this disk and its attached hand lever *m* throws the connected link and slide mechanism horizontally, so that the rocker-arm *n* on top of the vertical shaft operates the clutches in the chambers *g* and *h*. The power feed is regulated by the two pull stops *o* through the cover of the chamber *p*. The cross-movement of the table p_1 may be by a hand crank on the screw *q* and the table and cross-rail are raised or lowered by the screw *r*. The power for the rapid traverse of the table and for raising or lowering the cross-rail is operated by the lever *s*. It will be noted that the table *p* is supported on a base having three vertical screws t_1 geared together.

18. Rotary Feed for the Revolving Tool-Head Arbor. The ram *t* is square and hollow so that a shaft, or arbor extends, through it, and the tool head *u* on the front end of the arbor may be revolved by means of gearing on its rear end, as shown. The circular feed resulting from rotating the tool head is derived from the up-and-down motion of the vertical feed-rack a_1. This rack revolves the ratchet gear b_1 and bevel gears that drive the shaft c_1, which connects through bevel gears and a short shaft at c_2 to a worm that meshes with the worm-gear d_1 on the arbor of the ram.

19. Mounting Work on Draw-Cut Shaper.—When the draw-cut shaper is used to finish a large number of pieces of the same kind, it is advisable to use mounting fixtures; also, for handling these fixtures and the heavier pieces of work, a revolving crane with a hoist, as shown in Fig. 9, is needed. A fixture for holding two **U**-shaped castings used for the driving boxes of locomotives is shown at a_2 in Fig. 9, and its application in Fig. 10. The purpose of the double fixture is to permit changing one piece of work while machining the other. This fixture has a vertical part to which the flanges of the castings *w* are clamped, and a horizontal part b_2 resting on the table of the machine. On the part b_2 the castings are leveled and clamped. The vertical part of the fixture has a large

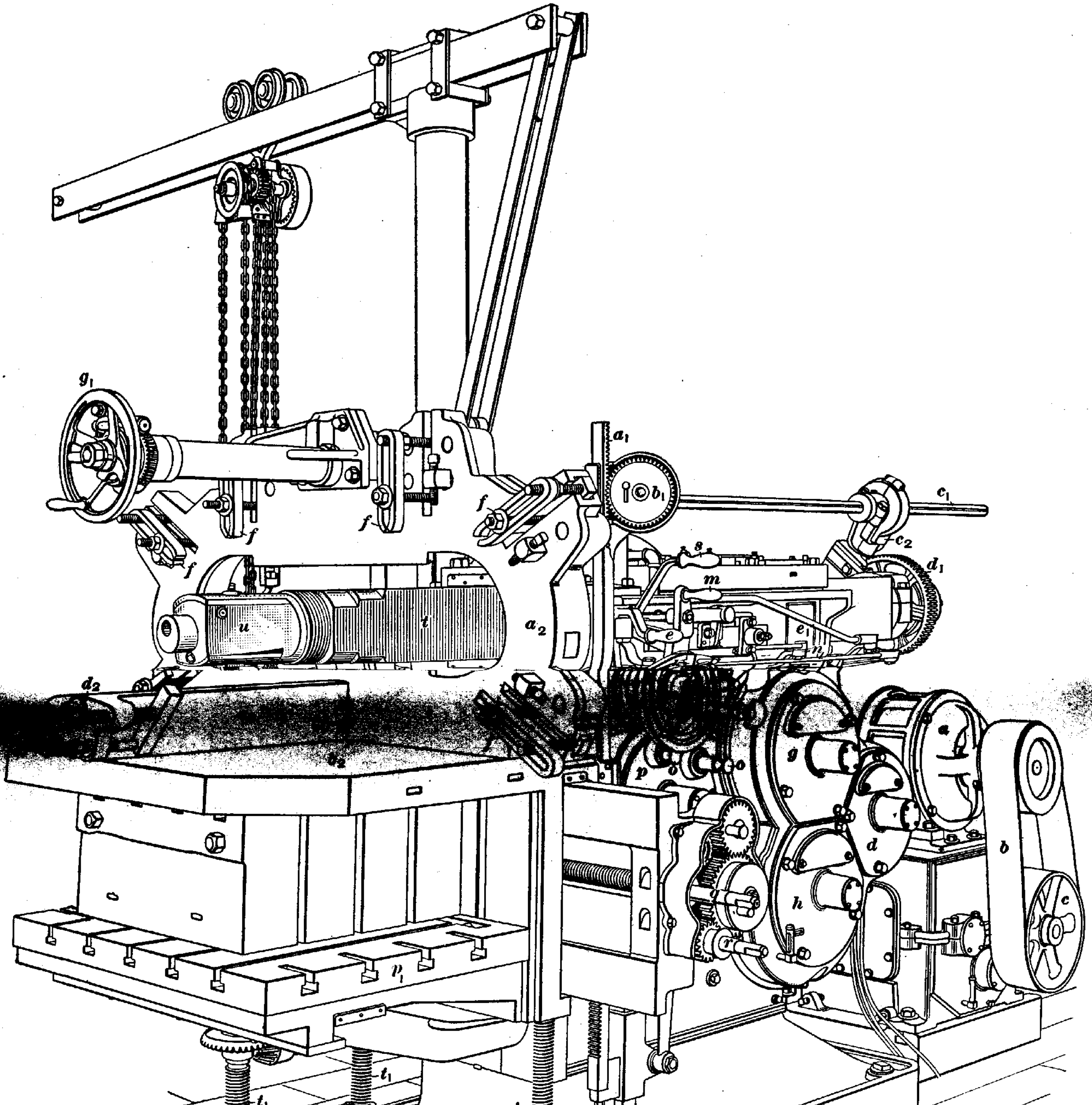


Fig. 9

horizontal slot with circular ends, the length of the slot being great enough to permit feeding two pieces sidewise under the tool. A straightedge c_3 locates the work parallel to the ram, and it has a clamping head d_2 with two screws and a bar for each casting. The vertical part a_2 is a hollow casting of box section. The hand wheel g_1 is mounted on an attached post for convenience in feeding the rotating tool head by hand.

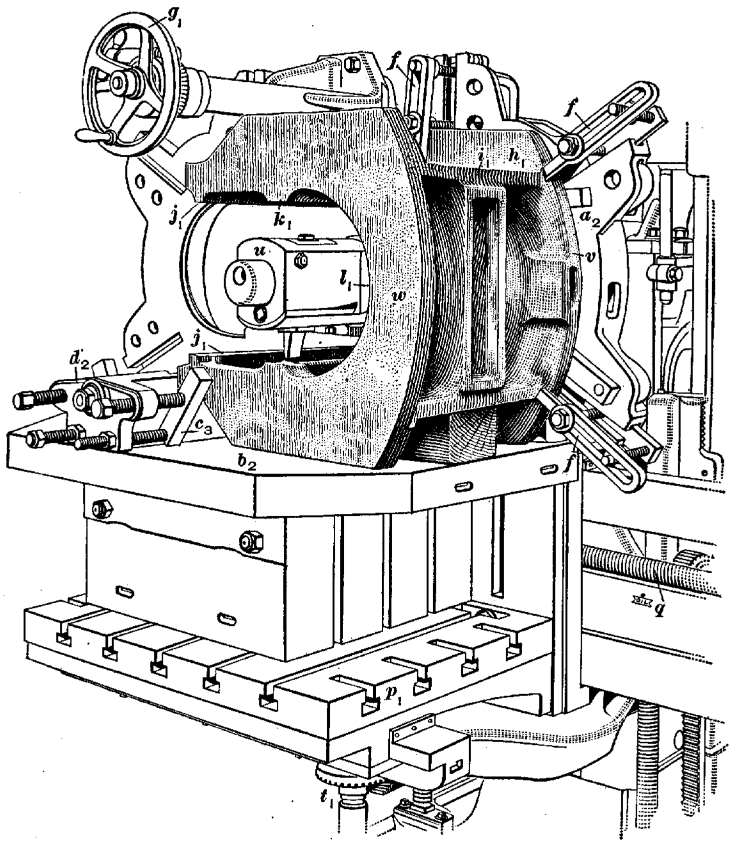


Fig. 10

20. The casting w for a locomotive driving box must be planed on the outside flat surfaces h_1 and i_1, the inside straight surfaces j_1 and k_1, and the inside large circular surface l_1. In Fig. 10 is shown the mounting for finishing the inside surfaces. The next casting would be mounted on the farther end of the fixture by the operator while the machine is working on the one shown.

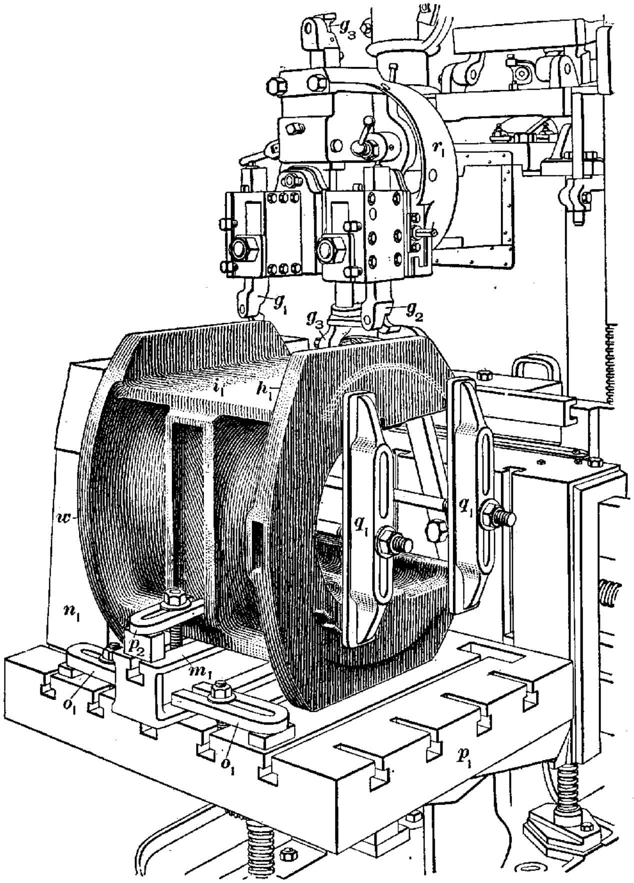


Fig. 11

The fixture for holding one driving-box casting w while finishing its outside flat surfaces h_1 and i_1 is shown in Fig. 11. This fixture consists of a base block m_1 and vertical side piece n_1. It is held on the machine table by the clamps o_1, and the casting w is held to the base by the clamp p_2, while it is held to the vertical side n_1 by the two clamps q_1. This fixture may be revolved horizontally on the table p_1. As the pull of the cut draws the work toward the machine, the rule for setting work on a draw-cut shaper is always to brace it solidly from the face of the machine frame, and to locate this brace as high as the surface being shaped will permit.

A turret tool head r_1 is shown on the ram in Fig. 11 having two tools g_1 and g_2 for finishing the vertical surfaces h_1 inside the flanges at one time. Other tools g_3 are provided for roughing and finishing the large flat horizontal surfaces i_1.

For shaping tapered work, such as the shoes and wedges used for adjusting and holding the locomotive driving boxes in the engine frames, the fixture must be such that it will hold the castings in an inclined position lengthwise of the ram. The adjustments must permit setting the pieces so that they may be finished exactly alike and the adjoining parts mate each other.

CUTTING TOOLS AND SPEEDS

CUTTING TOOLS

21. Shaper Tools.—The tools used on the shaper are of the same forms as those used on the planer, because the cutting action is the same in both machines; for, in both planer and shaper work, the shank of the tool is always at right angles to the line of motion of the tool or of the work, and the clearance does not change. About the only difference between planer tools and shaper tools is that the latter are usually the smaller. In modern practice, shaper tools are made from bars of high-speed steel and are ground to the proper shape, or they may consist of forged shanks or holders into which cutting points of high-speed steel are inserted. Forged shaper tools made of ordinary carbon steel are now rarely used. In Fig. 12 is shown a set of shaper tools that are in common use. The various shapes shown apply to general shaper work and can be easily ground for special work. The tools shown are made right and left hand.

22. Uses of Tools.—In Fig. 12 (*a*) is shown a roughing tool for cast iron and in (*b*) a roughing tool for steel; in (*c*) is shown a finishing tool for either material; in (*d*) is shown a tool for operations on brass; the tools shown in (*e*) and (*f*) are for taking roughing and finishing side cuts, respectively. In (*g*) and (*h*) are shown tools for side slotting operations and T-slot work, respectively; in (*i*) is shown a tool for dovetail work, and in (*j*) a tool for similar work on brass; in (*k*) is shown a tool for undercutting or finishing sharp corners, and in (*l*) a tool for cutting a radius in corners. The tool shown in (*m*) is used for parting or cutting-off purposes.

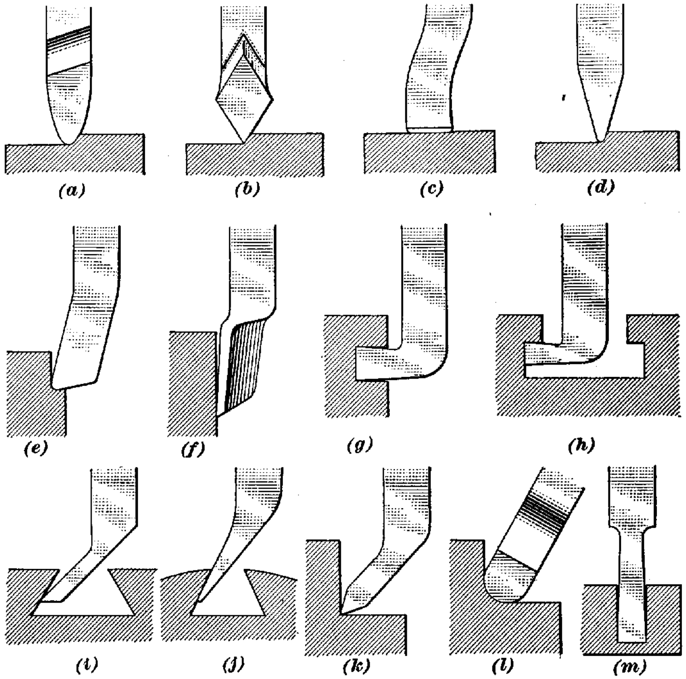


FIG. 12

CUTTING SPEEDS

23. Practical Cutting Speeds for Shapers.—The cutting speed of a shaper is varied to suit the character of the metal being cut and the kind of cut being taken. Generally, the speed for a finishing cut is slower than for a roughing cut. The cutting speeds on various metals are about as follows: Cast iron, 40 to 50 feet per minute; steel castings and machinery steel, 20 to 35 feet per minute; wrought iron, 30 to 45 feet per minute; brass and bronze, 50 to 60 feet per minute; tool steel, 20 to 30 feet per minute. These speeds may all be greatly increased by using tools of high-speed steel, but in most cases a speed of 55 feet per minute is about the maximum that can be used advantageously.

24. Finding Speed of Shaper Ram.—The speed of the ram on the cutting stroke may be found as follows: The length of the stroke of the ram, in feet, is measured, and the time required for the ram to move this distance is noted. The speed of the ram is then found by the following rule:

Rule.—*To find the speed of the ram, in feet per minute, divide the length of stroke, in feet, by the number of seconds required to make the full stroke, and multiply the quotient by 60.*

The speed of the ram on the return stroke may be found by the same rule, except that the time used must be the number of seconds required to make the return stroke.

EXAMPLE.—A shaper ram has a full stroke of 18 inches and requires $2\frac{1}{2}$ seconds to make the stroke. What is the speed?

SOLUTION.—Apply the rule; in this case the stroke is 18 in., or $1\frac{1}{2}$ ft.; hence, the ram speed is

$$\frac{1\frac{1}{2}}{2\frac{1}{2}}\times 60 = 36 \text{ ft. per min.} \quad \text{Ans.}$$

25. Effective Cutting Speed.—To find the actual length of cut made in one minute, it is necessary to take into account the time required for both the forward and the return stroke of the ram, as the cut is taken on the forward stroke and the tool is idle on the return stroke. If the cutting speed, or the forward speed of the ram, is 30 feet per minute, and the return stroke is made at the rate of 60 feet per minute (which is equivalent to 30 feet in $\frac{1}{2}$ minute), the actual cutting speed is $30 \div (1+\frac{1}{2}) = 20$ feet per minute.

26. Methods of Changing Cutting Speed.—In a crank-driven shaper, the speed of the ram varies with the length of the stroke, as, with the belt on a given step of the cone, the shaper will make a certain number of strokes per minute, whether they are long or short. Consequently, the only way to increase the cutting speed of the crank-driven shaper is to increase the number of strokes per minute, which is done by shifting the driving belt to one of the smaller steps of the cone pulley. In geared shapers, the cutting speed does not vary with the length of stroke, but remains constant, as is the case in planers. For this reason, geared shapers do not require cone pulleys in order to keep the cutting speed constant; however, cone pulleys are often put on geared shapers to provide different speeds for different metals. The electrically driven shaper usually has the motor mounted on a bracket fastened to the frame of the machine and is started or stopped by a lever on a starting box. The speed of the ram can be decreased or increased, while the machine is in motion, by turning a handle on the motor rheostat.

SHAPER EQUIPMENT

27. Shaper Vises.—Two of the most common types of shaper vises are shown in Figs. 13 and 14. The vise shown in Fig. 13 is of the single-screw type with the jaw *a* guided on the slide *b* by the guide bar *c*, and operated by a screw *d*. The vise is mounted on a graduated swivel base *e* that is clamped to the table. This enables the vise to be swung to any desired angle. The work is gripped in the tool-steel faces *f*. The vise shown in Fig. 14 is of the double-screw type, and has a base *a* on which the body *b* is able to swivel. The movable jaw *c* is held to the slide *d* by a bolt *e* that slides in the **T** slot *f*. The clamp *g* has a tongue that fits in any one of the grooves *h* of the slide, and may be moved along the slide and firmly clamped by the bolt *i*. The work is inserted between the jaws of the vise and held by the pressure of the screws *j* against the movable jaw *c*. The advantage of this construction is that the jaw *c* may be set at a slight angle to the fixed jaw, thus allowing taper work to be gripped between the jaws.

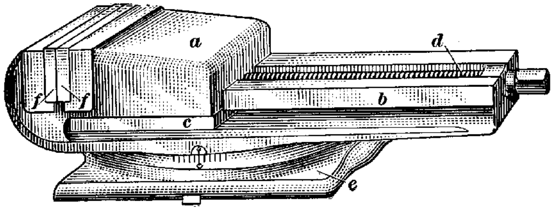


FIG. 13

28. Truing Shaper Vise and Work.—Most of the work done on the shaper is held in the vise. Various methods are employed for setting the vise and the work square and true, so that surfaces on the work may be shaped square or parallel. For accurate work, the shaper vise must be carefully trued, as it may be out of true owing to the deflection of the table. The truing consists in truing both the top and the side of the fixed jaw of the vise. This may be done by the use of a dial indicator, as shown in Fig. 15 (*a*), or by a shaper tool and feeler gauge. The indicator, when moved along the face *a* of the fixed jaw, will give a direct reading, whereas with the use of a shaper tool, adjustments must be made so that a feeler gauge, placed between the tool held in the tool post and the face of the jaw will be held with the same pressure at every

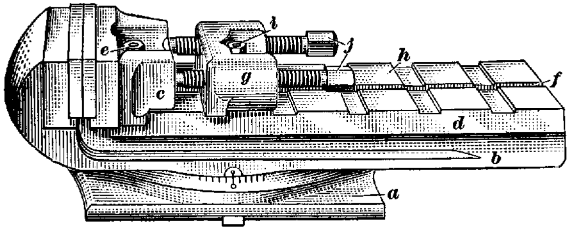


FIG. 14

part of the face. Corrections are made by placing shims under the low points of the vise or moving the vise around so as to bring the face of the jaw parallel with the stroke of the ram.

Sometimes it is hard to line up a piece of work even though the vise is true, and when accurate work is necessary the work must be trued up independently of the vise. In Fig. 15 (*b*) is shown a method of lining up a block to be machined. The block *a* is placed on two parallel strips *b* and a reading is taken with the indicator *c* at each of the four corners of the block. The high corner can be driven down with a soft hammer, so as not to mar the surface, or shims may be placed under the corners to raise the work. A shaper tool and a feeler gauge may also be used between the tool and the four corners, though this method is not so accurate nor so quick as the indicator method. A common error is made in the use of a spirit level to line up finished work. This is satisfactory when the surface is rough and plenty of stock is to be removed; but finished surfaces cannot be trued this way. It may be possible to get the work level, but the machine may not be level on the foundation, thereby making it impossible to take a true cut.

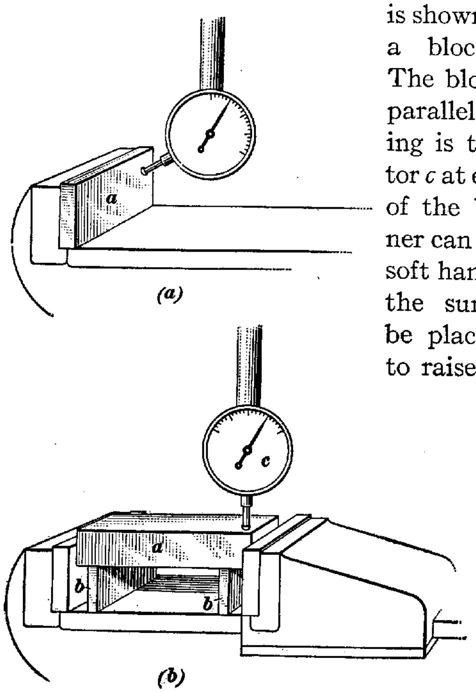


FIG. 15

29. Truing Shaper Table.—The shaper table must sometimes be trued. If the stroke of the ram is greater than the

length of the table, the ram may be used directly to plane off the table; but if the stroke of the ram is too short, some other method must be used. The shaper should be leveled up with its back end facing the rear end of a small planer. The ram is then disconnected from its driving gear and a stiff wooden connecting-rod is used to join the ram and the planer table. The wooden rod is bolted to the slot in the top of the ram and to an angle plate on the planer table. The necessary length and position of stroke are then given to the planer table and a tool is clamped to the ram. In this way the table may be trued, the feed being operated by hand.

30. If a planer is not available for truing the shaper table as just described, a wooden cross-piece may be bolted across the top of the ram. A helper at each end of this cross-piece may then be used to push the ram back and forth. Sometimes false tables are used on shapers. A false table consists of a flat piece of cast iron having on its under side a tongue that fits the central **T** slot of the true table to which it is bolted. The top of the false table has **T** slots, **V** grooves, or ribs, in or against which the work is clamped. False tables are used when extremely accurate work is being done on the shaper, and it is necessary to plane the working surfaces repeatedly. They are made of such length that the stroke of the shaper is great enough to allow them to be trued in place by the shaper.

31. Clamping of Work.—When work is of such a form that it cannot be held in a vise, the vise is removed and the work is fastened to the table. This is done with bolts, plugs, toe dogs, and clamps in a manner similar to that in which work is fastened on the planer table. With traveling-head shapers, very large castings or forgings that have small surface to be machined are frequently blocked up in front of the machine on suitable jacks and blocking, and clamped either to the table or to the front of the machine and then operated on by the tools.

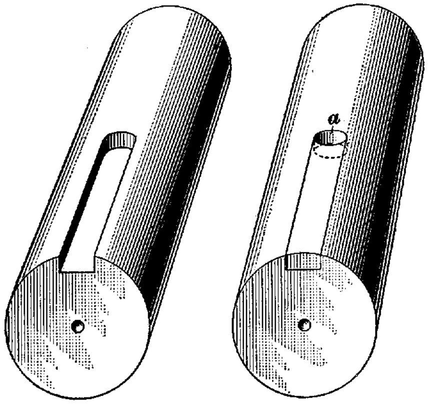
SHAPER OPERATIONS

TAKING CUTS

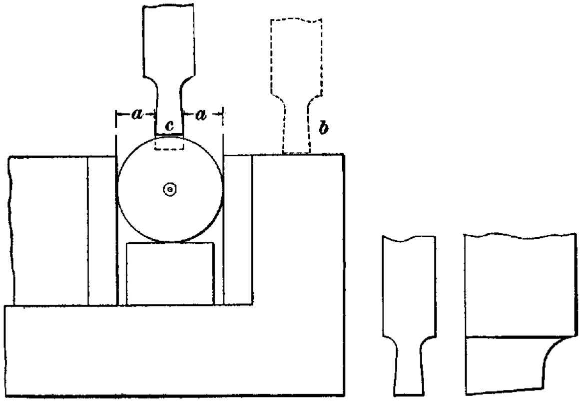
32. Adjustment of Stroke.—Before a cut is taken over the work, the ram should be positioned so that the proper length of stroke may be obtained. After the ram has been adjusted so that the tool moves approximately over the whole length of the work, the stroke should be lengthened sufficiently to enable the tool to clear the work at the end of the forward, or cutting, stroke. At the end of the return stroke, the stroke is again lengthened a distance from 1 to 2 inches, to allow sufficient time for the table feed to take place.

33. Setting Up Work.—A very common error in shaper practice, especially with a beginner, is having the work too far below the ram. The cutting tool thus projects too far below the tool holder and the tool slide is run down too far, putting undue strain on the slide and causing considerable spring, which results in chattering and poor work. At no time should the tool be allowed to drag over the work, as this will damage the cutting edge of the tool and result in poor work. Dragging of the tool on the return stroke is most noticeable when a cut is being taken down the side of a piece, and may be remedied by setting the clapper box at an angle to the side that is being machined. On the return stroke, the tool, when lifted, swings away from the work and does not drag.

34. Cutting Keyways in Shafts.—When a keyway is to be cut in a shaft, as in Fig. 16 (*a*), it is first laid out by lines scribed to indicate the width and the depth. At the inner end of the keyway is scribed a circle having a diameter equal to the width of the keyway, and then, as shown in (*b*), a hole *a* is drilled at the center of the circle. The hole is $\frac{1}{64}$ inch larger in diameter than the width of the keyway and is drilled to the desired depth of the keyway. The shaft is then clamped in the vise, as shown in Fig. 17 (*a*), so that the distance *a* from the side of the keyway to the face of the vise jaw is the same on both sides. A splining tool of the form shown in (*b*) and of a width equal to the required width of the keyway is then put in the tool post and set flat with the top of the vise jaw, as at *b* in view (*a*). The tool is then set central with the hole drilled at the end of the keyway, as at *c*, the ram is adjusted to give the proper stroke, and the tool is fed down until the keyway is cut to the proper depth. The cutting stroke is made toward the drilled hole and oil is used to give a smooth cut.



(*a*) FIG. 16 (*b*)



(*a*) FIG. 17 (*b*)

35. If the keyway does not extend to the end of the shaft, as in Fig. 16 (*a*), but is cut at some point near the middle, so that it begins and ends in the solid shaft, a different method is followed. The length and width of the keyway are laid out, as shown in Fig. 18, and at the end where the cut is to begin a pair of holes *a* and *b* are drilled, close together. These holes are $\frac{1}{64}$ inch larger than the width of the keyway and as deep as the keyway is to be. The metal between them is then chipped out. A single hole *c* of the same size and depth is drilled at the other end of the keyway. A tool of the underhung type, as shown in Fig. 19, is then set central and the keyway is cut to the desired depth. The width *a* of the tool is equal to the width of the keyway and the part *b* is dropped into the slot chipped out between the holes *a* and *b*, Fig. 18, at the beginning of the cut. The hole *c* at the end of the cut allows the chips to be broken off cleanly and prevents them from gathering and clogging at this point.

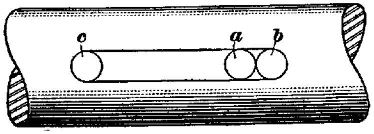


FIG. 18

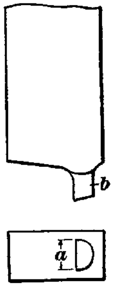


FIG. 19

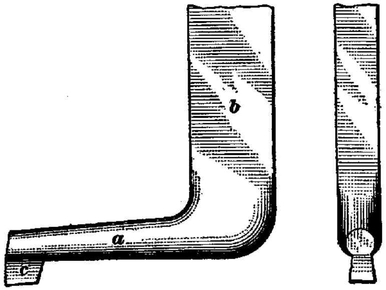
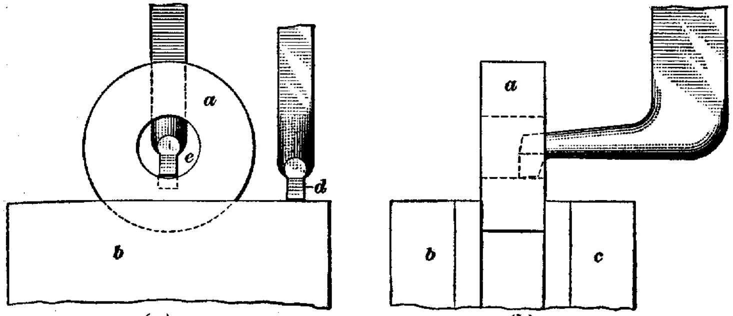


FIG. 20

36. Cutting Internal Keyways.—If the keyway is inside the hub of a gear, or similarly situated, it is necessary to cut it with an extension tool, such as that shown in Fig. 20. The extension *a* from the shank *b* carries the cutting part *c* of the tool. The method of cutting a keyway in a gear blank is shown in Fig. 21 (*a*) and (*b*). The gear blank *a* is firmly clamped in the jaws *b* and *c* of the vise, and the tool is set on the top of the jaw, as at *d*, and adjusted so that its cutting edge is level. It is then clamped tightly in the tool post and moved to the hole *e* in the gear blank, where it is set central. This is done by lowering it and moving it from side to side until both corners of the cutting edge touch the bottom of the hole. The shaper is then started and the keyway is cut to the proper depth. Sometimes the extension tool tends to spring away from the cut, especially if the keyway is long. In such a case, a bar about 2 feet long may be placed between the top of the tool shank and the apron box. Then, by pulling on the end of this bar during the cutting stroke, the tool may be held to its work.



(*a*) (*b*)

FIG. 21

37. Shaping Dovetailed Keys.—Keys are often made dovetailed, as shown in Fig. 22. The method of making a key of this form is shown in Fig. 23 (*a*) and (*b*). The rough stock *a* for the key is set on a thin parallel *b* and clamped between the vise jaws *c* and *d*, as shown in (*a*). A cut is then taken over the top, as indicated by the dotted horizontal line, after which side cuts are taken, as shown by the dotted vertical lines, thus finishing the square body of the key. The piece is then turned over and reset, as in (*b*), and a light cut is taken across the top, to bring the key to the required thickness from top to bottom. The head is next set over, first in one direction and then in the other, and the

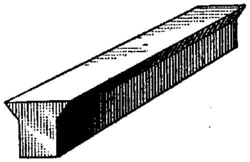
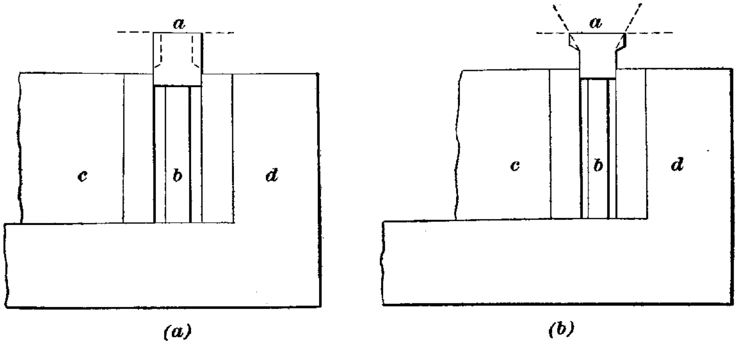


FIG. 22

sides are beveled to an angle of 10 degrees or 15 degrees, as shown by the sloping dotted lines.

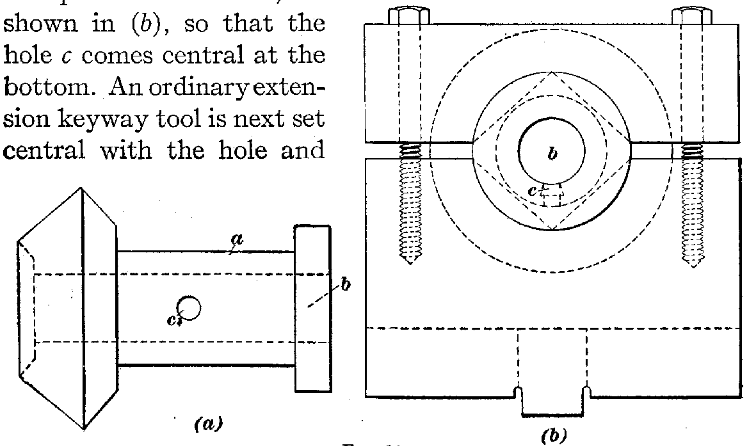
38. Cutting Dovetailed Keyways.—The method of planing a dovetailed keyway may be understood by referring to Fig. 24. The bevel-gear blank shown in (*a*) has a long sleeve *a* through which a hole *b* is bored, and a dovetailed keyway is to be cut inside this sleeve. The first step is to drill a hole *c* at the point where the keyway is to end. The piece is then clamped in **V** blocks, as shown in (*b*), so that the hole *c* comes central at the bottom. An ordinary extension keyway tool is next set central with the hole and the keyway is cut to the proper depth. The head is now swung over, an extension tool like that shown in Fig. 25 is put in the

tool post, and two or three cuts are taken to complete one beveled side, after which the head is swung in the opposite direction and a similar tool of the other hand is used to finish the other side of the keyway. The last side should be finished with light cuts and the key should be tried in the keyway until it is a tight driving fit. The sides of the finished keyway are shown by slanting dotted lines in Fig. 24 (*b*).



(*a*) (*b*)

FIG. 23



(*a*) (*b*)

FIG. 24

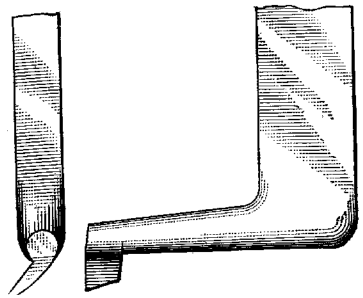


FIG. 25

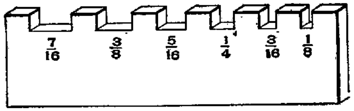
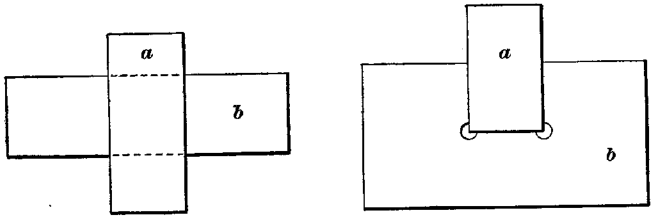


FIG. 26

39. Gauges for Keys and Keyways.—Gauges should be used to test all keys, keyways, and tools for cutting keyways, so that the work may be kept to standard sizes. A gauge for testing the width of a key or of a keyway tool is shown in Fig. 26. It consists of a steel bar of convenient size, in one edge of which are cut slots of different widths, corresponding to various standard keyways. The width of each slot is stamped beneath it. Gauges for larger keyways are made as shown in Fig. 27 (*a*) and (*b*), in which one rectangular piece *a* is made a tight hand forcing fit in the slot in the piece *b*. The size is stamped on each piece. In the best grades these gauges are of tool steel hardened and ground; but if used with care



(*a*) (*b*)

FIG. 27

they may be of unhardened tool steel or of case-hardened soft steel.

40. Cutting to Shoulder.—Suppose that it is necessary to take a cut over the piece of work shown in Fig. 28, and that the surface *e* is to be partly removed up to the line *A B*, as indicated by the dotted lines. Before this cut can be taken on the shaper it will be necessary to cut a groove at *A B* equal in depth to the amount to be removed. This groove can be cut with a cold chisel and a hammer or by first drilling a hole at *a* and then cutting the groove on the shaper with a parting tool. The part of the surface *e* indicated by dotted lines can then be planed away easily. In castings, when it is known that such cuts as these are to be taken, much work can be saved by coring out a space where the cut is to end. This saves the time required to cut a groove with the chisel or by planing.

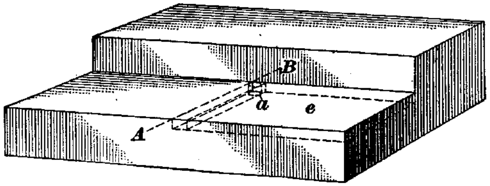
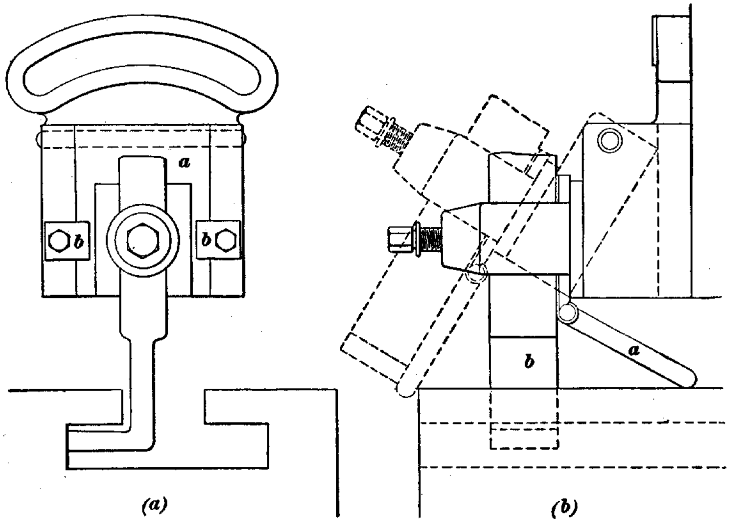


FIG. 28

41. Shaping T Slots.—In Fig. 29 (*a*) and (*b*) are shown two methods which may be employed when machining **T** slots. In (*a*) is shown the method of clamping the block *a* of the clapper box tightly in place by means of the clamps *b* so that it cannot swing. This, of course, keeps the cutting tool rigid, and it will move back and forth over the same plane. This method gives good results but has the objection that the cutting tool drags back over the work, thereby dulling the cutting edge. Another method, shown in (*b*), employs a hinged plate *a* clamped in the tool holder back of the tool *b*. On the cutting stroke, shown by the full lines in the illustration, the hinged plate swings away from the tool and drags behind it. At the end of the stroke, after the tool has cleared the work, the plate drops against the tool, as shown by the dotted lines, and lifts it so that it will ride on top of the work on the return stroke. Although the dragging of the tool over the work on the return stroke has been overcome by this method, the advantage gained is offset by the fact that the stroke of the ram must be lengthened, to enable the hinged plate to drop against the back of the tool and clear the work at the completion of the cutting stroke.



(*a*) (*b*)

FIG. 29

42. Shaping Irregular Work.—Work that has an irregular outline, such as that shown in Fig. 30, may be machined on the shaper by using both the table feed and the vertical feed at the same time. A slow automatic feed is given to the table, and at the same time the tool slide is fed down by hand. In most cases, the work cannot be finished in one pass of the table under the cutter by this method, and the process must be repeated until the correct shape is obtained.

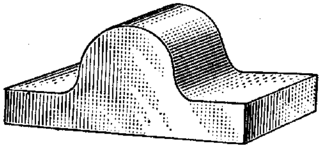


FIG. 30

43. Clamping Work to Saddle.—Work that is too high to be placed on the shaper table, or work that cannot be clamped to the table on account of its shape, can frequently be clamped to the saddle. An example of this is shown in Fig. 31, in which a pair of legs for a lathe are clamped in position for shaping the upper surface. The table and the vise are removed and the work *a* is secured to the saddle by bolts and blocking. This method of holding work is similar to attaching it to an angle plate fastened to a planer table.

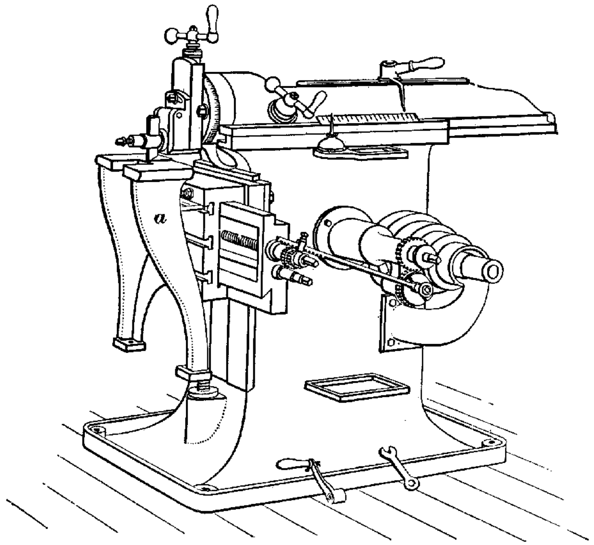


FIG. 31

44. When work is clamped against the front of the saddle, the top surface may easily be lined to the ram by means of a tool fixed in the tool post, as shown in Fig. 31. The tool is clamped firmly and is fed down, while the machine is running, until it just touches the top of the work near one side. The tool is raised during the forward stroke and held down during the return stroke, and the rubbing of the tool point on the face of the work shows whether the work is set correctly; for, when it is correctly set, the tool point will bear with the same pressure at the middle and at the edges of the surface of the work.

45. Equal Spacing on Shaper.—The shaper may be used to cut a series of slots equally spaced, as, for example, in cutting gear-teeth in a rack. The work in which the slots are to be cut is clamped at right angles to the line of motion of the ram and a tool that will give the proper shape of slot is set in the tool post. The spacing is done by turning the feed-screw, using the graduated collar on the end of the screw to indicate the number of turns. The rule to be used is as follows:

Rule.—*To find the number of turns that must be given to the feed-screw to give a desired equal spacing of slots, multiply the desired spacing, in inches, by the number of threads per inch on the feed-screw.*

EXAMPLE.—A shaper feed-screw has 4 threads per inch and at its end is a graduated collar having 100 divisions. How many turns must be given to the screw to space equal distances of .65 inch on the work?

SOLUTION.—Apply the rule, and the required number of turns is

$$.65 \times 4 = 2.60. \quad \text{Ans.}$$

As $2.60 = 2\frac{60}{100}$, the feed-screw is given two complete turns and $\frac{60}{100}$ turn more, the latter being done by moving 60 of the 100 divisions past the zero mark.

46. Spring of Table and Work.—The spring of the work may be due to the spring of the table by which it is supported and is one of the causes of error in shaper work; also, if the gibs holding the saddle to the cross-rail are loose, the spring will be increased. The pressure of the cutting tool, as it is forced through the work, tends to spring the work still farther from the ram and increases the error.

47. Limit of Stroke of Shaper.—The ram of the shaper has a tendency to spring upwards, due to the pressure of the cut and looseness of the guides in which the ram slides; therefore, the average stroke is only about 12 to 18 inches, although large shapers with heavy rams are built to give much longer strokes. The longer the stroke, and the farther the tool moves away from the column, the greater is the tendency to spring; hence, the work should be set as close as possible to the column.

SHAPER ATTACHMENTS

48. Attachment for Shaping Cylindrical Work.—Frequently it is possible to fit shapers with special attachments for performing operations on work that would ordinarily be done on other machines. In Fig. 32 is shown an attachment for shaping cylindrical work. It may be fitted with different forms of centers to accommodate different classes of work. The illustration shows two cone centers *a* and *b*, held in a headstock and a tailstock bolted to the table *c*, capable of holding bored work. The center *a* is stationary, but the center *b* may be moved along the screw *d* so as to accommodate the length of the work between the centers. The work is held by tightening the nut *e* against the center *b*.

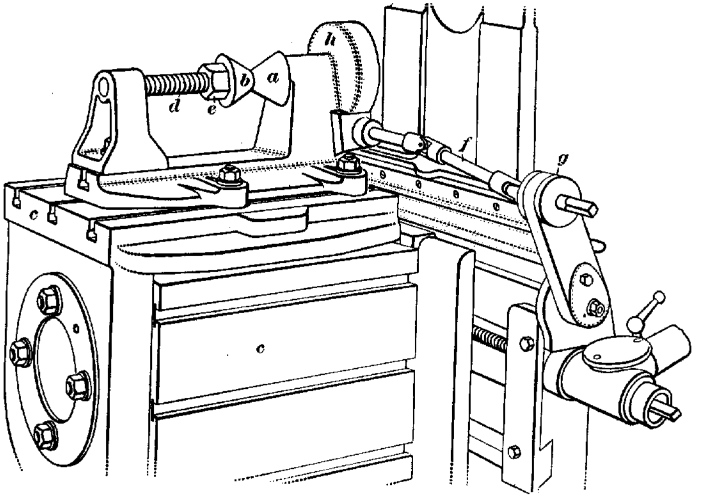


Fig. 32

The work is rotated by revolving the screw *d*, which is done by turning a handle on the squared end of the universal shaft *f* that is supported at one end by the bracket *g*. At the other end it has a worm meshing with a worm-wheel on the screw *d* in the casing *h*. The base of the attachment has a tongue that fits into the center slot of the table and brings the centers into accurate alinement with the ram. The work is prevented from turning during the cut by the non-reversible worm-wheel and worm.

49. Attachment for Feeding Tool Slide.—The head of the shaper ram shown in Fig. 33 is equipped with an attachment that operates the tool slide *a* by automatic feed. A bracket *b* is bolted to the ram and a block *c* is adjustable along the slide *d* on the frame *e*. The block *c* has a number of graduations, each representing a feed of .005 inch. To set the feed, the ram is stopped at the end of its return stroke and the block *c* is moved along the slide until the graduation denoting the desired feed registers with a line scribed on the arm *f* carried by the bracket *b*. The feed is operated by the pin *g*, which, on the return stroke of the ram, makes contact with a projecting plate on the block *c* and is depressed. The motion of the pin is transmitted through gears inside the attachment to the screw on the slide, thereby causing the slide to move down

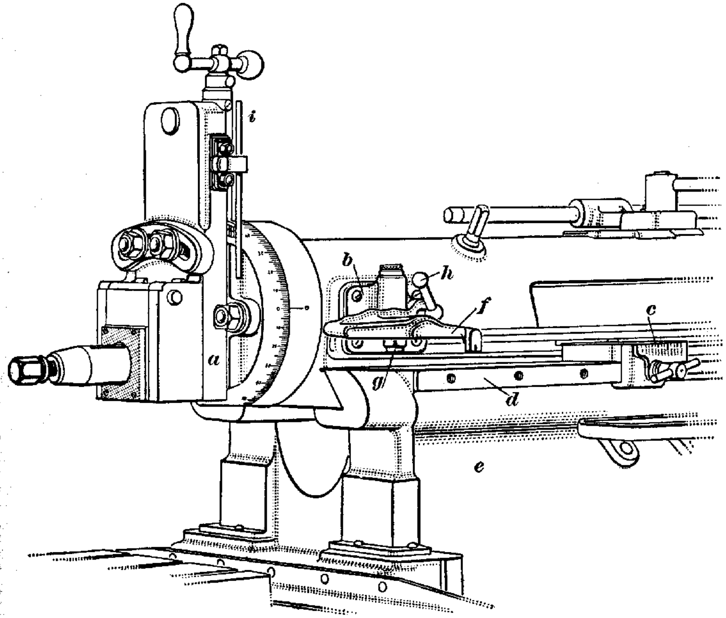


Fig. 33

when the automatic-feed starting handle *h* is thrown from *out* to *in*. When the vertical feed is not needed, the block *c* is moved to the rear of the machine, out of the way. The automatic feed is very useful where side cutting is done to any extent, as it gives an even feed and therefore a better finish, not obtainable by hand. Rod *i* limits depth of cut.

Special shaper attachments, such as here described, are useful in small shops having few machines. In large shops they are not necessary, as usually other machines are available that do the work more efficiently.

SLOTTERS

CONSTRUCTION AND OPERATION

CONSTRUCTION OF SLOTTERS

50. Uses of Slotters.—The slotter, or slotting machine, is very much like the shaper; but in the slotter the ram moves up and down in a vertical direction, whereas, in a shaper, it moves horizontally. The slotter is used for finishing flat or curved surfaces at right angles to a horizontal surface of the work. It derives its name from the fact that it was originally intended for cutting slots or keyways in gears or pulleys, but it is used for a large variety of work in which it is desired to produce vertical flat or curved surfaces.

51. Classes of Slotters.—There are three general types of slotters—the *crank-driven*, the *screw-driven*, and the *rack-driven slotter*—the latter sometimes called an *upright generating planer*, the names being derived from the methods of driving the ram. The crank-driven slotter is best adapted for strokes up to 30 inches long, the rack-driven slotter for strokes up to 72 inches long, and the portable type of screw-driven slotter is best suited for machines having strokes exceeding 72 inches.

52. Arrangement of Slotter.—One form of slotter is shown in Fig. 34. It consists of a rigid frame *a* carrying a table *b* on which the work is held, and a ram *c* to which is fixed the head *d* that carries the tool. The ram has a reciprocating motion in the vertical guide *e*, and is driven at different speeds from the cone pulley *f* through the large spur gear *g* and the crank-disk *h*. In the slot in the crank-disk is an adjustable pin *i* that is connected with the pin *j* by the connecting-rod *k*. The turning of the crank-disk thus gives the ram an up-and-down motion. A counterweight *l* is hung on one end of a lever *m* pivoted above the frame, and the other end of the lever is connected to the pin *j*. The weight *l* thus helps to lift the ram on its upward stroke. The table of the slotter is mounted on a saddle *n* carried by a carriage *o*, so that it can be moved either along the ways of the frame *a* or at right angles to the ways. Besides these motions, the table can also be rotated in either direction on a vertical axis.

53. Tool Head and Ram.—The upward, or return, stroke of the ram *c*, Fig. 34, is made more rapidly than the downward, or cutting stroke, by the use of a Whitworth quick-return motion similar to that on the traveling-head shaper. To accomplish this, the large spur gear *g* is not concentric with the shaft that drives the crank-disk *h*, but the latter is driven by a pin fastened eccentrically on the gear *g*. The length of the stroke of the ram may be varied by changing the position of the pin *i* in the crank-disk slot, by means of the screw *p*. The position of the ram may be varied by adjusting the pin *j* in the slot in the ram. The tool head *d* is hinged on the pin *q*, so that, by loosening the bolt *r* slightly, the head is given a slight motion outwards from the ram on the return stroke, thus allowing the cutting edge of the tool to clear the work. If it is desired to clamp the head firmly against the ram, the bolt *r* is tightened. The head is prevented from sagging by the spring *s*. At the end of the head are carried two sets of tool clamps *t* and t_1, which provide for fastening tools in two different positions at right angles to each other, and so that the shanks of the tools may be set either vertical or horizontal.

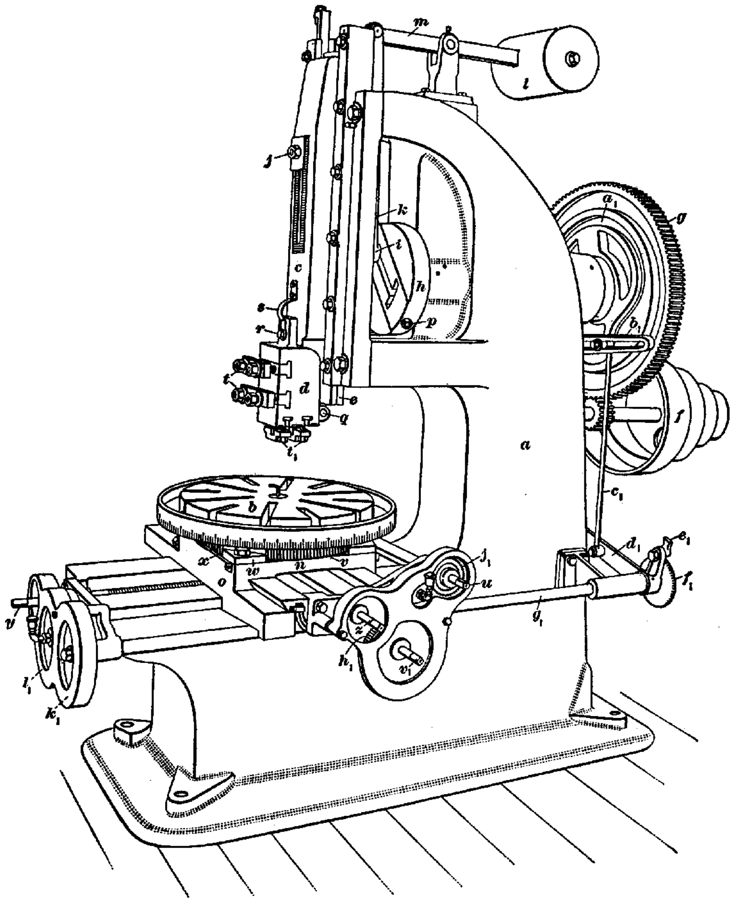


Fig. 34

A different ram and tool head from the ones just described are shown in Fig. 35. The ram guide is pivoted on a trunnion at the top, so that the lower end may be swung outwards by means of the turnbuckle *a* after loosening the bolt *b*. Setting the ram at an angle to the table in this way is useful in slotting dies, as it provides a means for obtaining clearance on the dies. The head *c* may be swiveled on the graduated base *d*, the tool being thus allowed to cut in any position without changing the angular position of the table. The clamp *e* is for adjusting the position of the ram, and the clamp *f* holds the head *c* in its swiveled position.

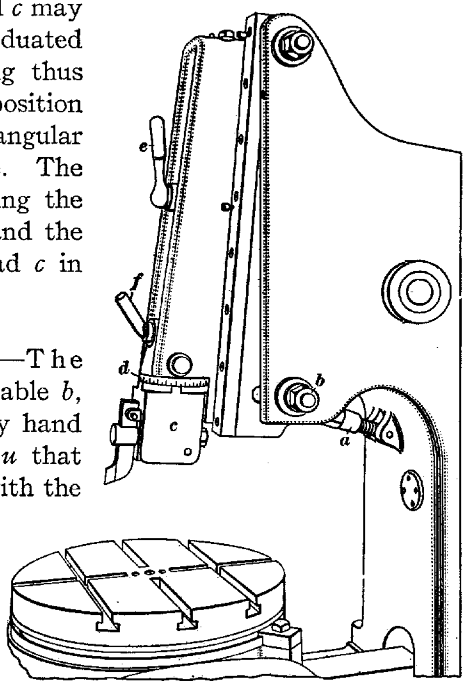


Fig. 35

54. Table Feeds.—The rotary motion of the table *b*, Fig. 34, is obtained by hand by turning the shaft *u* that has a worm meshing with the teeth of the worm-wheel *v* fastened to the table, and the table may be locked by the clamps *w*. For indexing the table, it has graduations in degrees on the side, and a pointer *x*. The table may be moved toward or away from the frame by turning the shaft *y*, and sidewise by turning the shaft *z*. Automatic feed for all three motions of the table is obtained from the action of a roller in the cam groove a_1 in the gear *g*. The roller is mounted on a slotted arm b_1 connected to the rod c_1, thus giving the rod an oscillating motion. This motion is transmitted to the lever d_1 and the ratchet pawl e_1 to the ratchet wheel f_1. When the ratchet acts, the feed-rod g_1 is rotated a certain amount and this rotation is communicated to the worm-gear h_1 on the shaft v_1. The gear h_1 may be used to drive either the shaft u or the shaft z, as desired, for furnishing either longitudinal or rotary table feed. To do this, the feed-gear j_1 is placed on either of the two shafts. In the illustration the feed-gear j_1 is placed on the shaft, so that the table has automatic rotary feed, the motion of the gear h_1 being transmitted to the gear j_1 through intermediate gears. To obtain automatic feed for the transverse motion of the table, the feed-gear j_1 is placed on the shaft y, the motion of the feed-rod g_1 being transmitted through the spur gears k_1 and l_1. The amount of feed may be varied by moving the rod c_1 in or out on the slotted arm b_1. The feed of a slotter should occur when the ram has finished its return stroke, and before it starts on the cutting stroke.

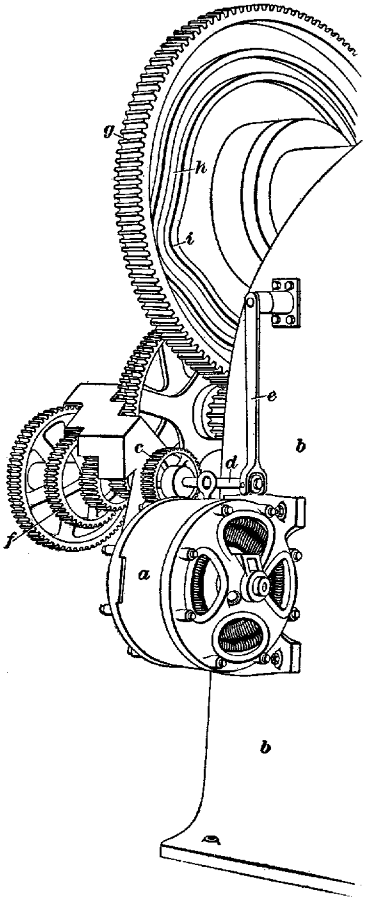


FIG. 36

55. Motor-Driven Slotter. The method of using an electric motor to drive a slotter is shown in Fig. 36. The motor a is mounted rigidly on the side of the main frame b and drives the gear c. The shaft d may be moved endwise by the lever e, operated from the opposite side of the frame, and thus cause any one of a series of gears f of different sizes to be driven from the gear c. In this way the main gear g may be driven at several different speeds, and the cutting speed may be varied accordingly.

56. Portable Slotters and Shapers.—It often happens that it is inconvenient to take a piece of work to the machine, or that a suitable machine for the work is not available. In such cases portable slotters and shapers are of value, as they may be carried to the work and fixed to it. They are therefore very useful in doing repair work, when the work is not moved. Again, in many shops there are special floors constructed to act as the foundations of the tools and as work tables. A deep bed of concrete is first put down and on this is placed a heavy cast-iron floor, accurately planed and leveled, and provided with **T** slots. The work may be placed at any convenient point on this floor, and a portable tool may be brought to it.

SLOTTER OPERATION

57. Setting Slotter Work.—Slotter work should be laid out so that the outline of the part to be cut away appears plainly on the top surface. Lines may also be placed on the sides to insure that the work will be cut square or at the correct angle. To set the work, parallel blocks or strips must be placed under it, as shown at c, Fig. 37, to lift it far enough above the table to allow the tool to travel to the lower end of the cut without touching the table. Clamps should be applied directly over the points of support, and the work must be in such position that the line $A\ B$ denoting the surface to be planed is at right angles to the table. This should be tested with a square.

58. After the clamps are tightened, a pointed tool or a scriber is clamped in the tool post and the work is moved, by moving the carriage and the saddle, so that the straight line to be worked to comes under the point of the tool or scriber. The table is then adjusted so that, as the carriage or the saddle is moved, the pointer will follow the line on the top surface of the work. If a curved surface is to be machined, the work is first located by the combined movements of the carriage and saddle and is then adjusted so that the curved line will exactly follow the pointer when the table is rotated. The work is then set correctly and is ready for the cutting operation. Bolts, pins, angle plates, and special holding devices may be used for holding the work on the slotter table in the same way that they are used on the planer or the shaper table.

59. Setting Slotter Ram and Tool.—A stroke long enough to suit the work must first be given to the ram. This is accomplished by adjusting the pin in the slot in the crank-disk. Next, the position of the stroke must be adjusted by means of the pin at the upper end of the connecting-rod and the slot in the ram. The ram is now moved to the lowest point of its travel and the tool is clamped in it so that the cutting edge extends just below the lower edge of the work. This method of setting gives great stiffness, as the tool projects so little below the ram.

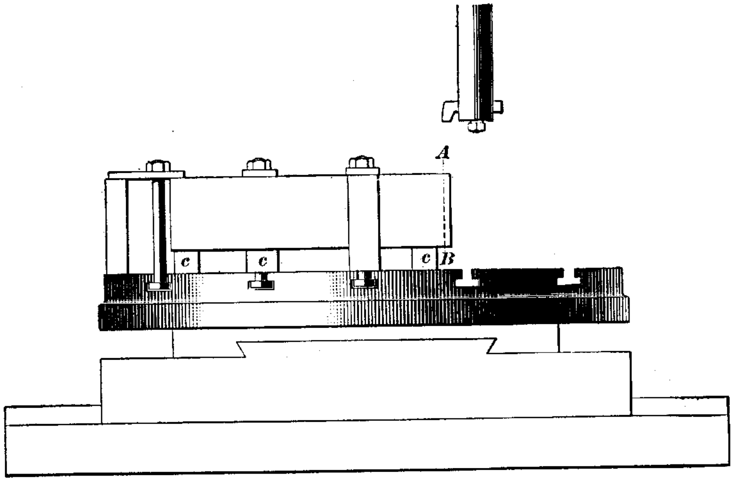
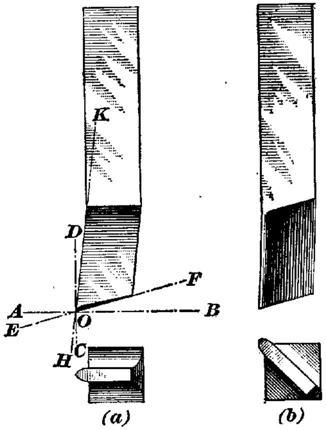


FIG. 37

60. Cutting Circular Surfaces.—When circular surfaces are to be cut on the slotter, the work must be set so that its axis coincides with the axis of rotation of the table. For instance, if a cylindrical surface having a radius of 10 inches is to be finished in the slotter, the work must be set so that the center

from which the radius is measured is at the center of the table, and the table must be adjusted so that the point of the tool is at a distance of 10 inches from the center. The feeding is done by rotating the table slightly after each down stroke of the ram. To aid in setting work having cylindrical surfaces, concentric circles are usually marked on the table, and may be used as guides. An arbor may be fitted in the center hole of the table and the position of the work may be measured from it; or, the work may be placed on the arbor, in case the surfaces to be machined are concentric with the hole in the table. In either case, after the work is set, it is best to revolve it past the point of the tool to be sure that it is correctly set. This applies to internal as well as external cylindrical surfaces.

61. Slotter Tools.—Some of the tools used on the slotter are similar to those used on the planer and the shaper and are clamped at right angles to the line of motion of the ram. Another class includes the tools that are set in line with the direction of motion of the ram and have the cutting edges formed on the ends of the shanks. A roughing slotter tool is shown in Fig. 38 (*a*). The shank is square, and the end is formed much like a parting tool; however, the cutting is done by moving the tool downwards, in the direction *D C*, and the chip is turned by the under face *E F*. The cutting edge is at the point *O*, and the clearance is the angle between *D C* and *K H*. The angle of front rake is the angle between *A B* and *E F*. A good roughing tool for flat work is shown in (*b*); the blade of this tool is forged diagonally on the end of the shank. Roughing tools for slotter work have narrow points and finishing tools have wide points. If keyways and slots are to be cut on the slotter, the tool shown in Fig. 39 is used, the cutting being done by



(*a*) (*b*)

FIG. 38

the edge *A B* when the tool moves downwards endwise. This tool is apt to spring, and time and care must be used in making the cut.

62. Slotter Bars With Fixed Tools.—A large amount of steel is required for ordinary forged slotter tools; they are heavy to handle, hard to keep in good condition, and a large amount of space is required for storing them. To permit the use of small steel tools in the slotter, various forms of slotter bars have been devised, one of the most common forms of which is shown in Fig. 40. This consists of a rectangular body *a*, through which the bolt *b* is fitted. The bolt is held in position by a nut and a washer at *c*, and the lower end is slotted to receive the tool *d*, which rests against the head of the bolt *e*. The bar *a* is clamped to an ordinary slotter head by the regular clamps *f* and *g*, and the bolt *b* can be revolved in such a way that the tool *d* extends from the bar at any desired angle. This device facilitates the use of ordinary small planer or shaper tools in the slotter. The bar *a* can be adjusted up or down under the clamps *f* and *g* to some extent.

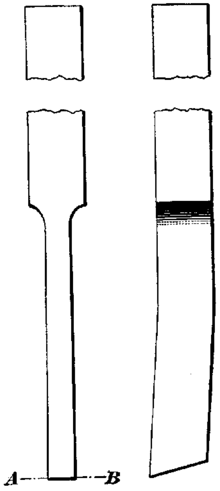


FIG. 39

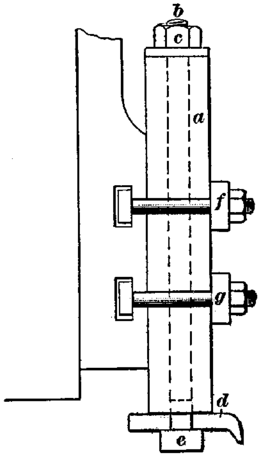


FIG. 40

63. Although the bar shown in Fig. 40 is fairly rigid for short work, it is not practicable if made long, and hence bars of the form shown in Fig. 41 are frequently used. In this case the regular clamps have been removed from the slotter head and two special clamps *B* substituted for them. These are held against the head of the ram by the bolts *b*. The slotter bar *c* passes through holes in the clamps and is held in position by the bolts *a*. A small steel tool is fitted in a slot in the lower end of the bar *c* and secured by a setscrew, as shown. The cylindrical form of the bar *c* allows it to be rotated so as to bring the tool or cutter to any desired angle of the work, but this will be found disadvantageous when slotting out irregular forms having internal angles, such as square holes.

64. The cutter blades or tools are rigidly fixed in both of the forms of bars shown in Figs. 40 and 41, and hence, on the return stroke, the tool drags over the work. If the tool is sharp, it will usually cut true enough so that the bar will be sprung very little on the return stroke, and the dragging of the tool will not injure the edge of the tool materially. If, however, too much top rake is given to the tool, the edge may break or crumble off on

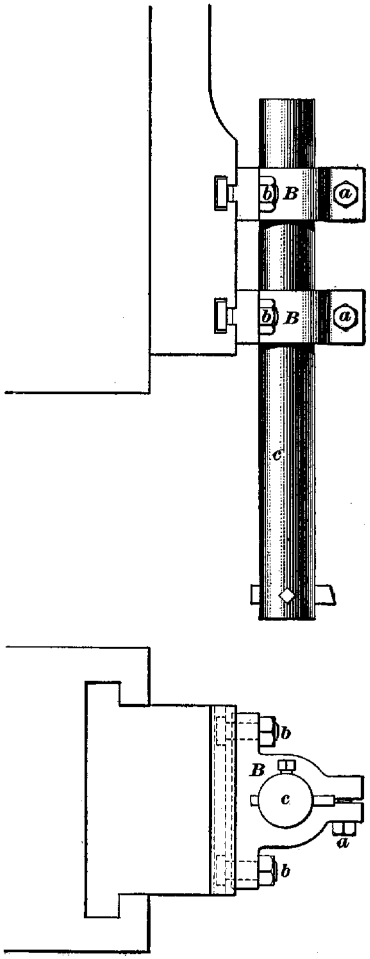


FIG. 41

the return stroke. The feeding of the work does not occur until the tool has returned to the top of the stroke, and hence the edge cannot be injured during the operation of feeding.

65. Slotter Bars With Tool Blocks.—Heavy slotter bars are made with tool blocks in the lower end that are pivoted in the same way that the tool block on the head of a shaper or planer is pivoted, so that on the return stroke the tool will lift away and not drag on the surface of the work. In such a bar the weight of the tool would naturally cause the block to hang away from the work at all times, and hence it is necessary to provide springs for holding the block against its seat. Sometimes the slotter tools themselves are drilled and fitted on pins and held in place by springs, so that the tool itself becomes a swinging block. Care must be taken with bars of this class to see that the springs always hold the block or the tool against its seat, and to prevent dirt from accumulating under the tool or the block; for if the tool is not firmly seated when the cut begins, it will come down against its seat suddenly and is liable to gouge into the work.

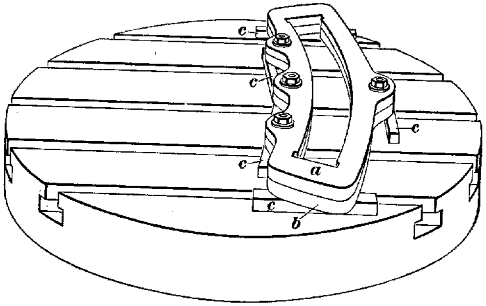


FIG. 42

66. Stacking Work.—Frequently a number of pieces of the same class are to be finished at once. If these pieces are thin, much time may be saved by stacking or piling up a number of them and clamping all to the table so that the cut may extend across the entire pile. Fig. 42 illustrates this class of work. The two engine links *a* and *b* are placed one upon the other and clamped to the slotter table, parallel strips being placed under the work, as shown at *c*, and the tool is set so as to cut both pieces at one time. The parallels must be so placed that the work is supported close to the clamps, thus reducing the tendency to spring. In the illustration, five parallel strips are used and the work is secured by bolts through the regular bolt holes of the piece. Frequently the work is secured by means of blocks and clamps. It is possible to pile up as many pieces as the stroke of the machine can accommodate.

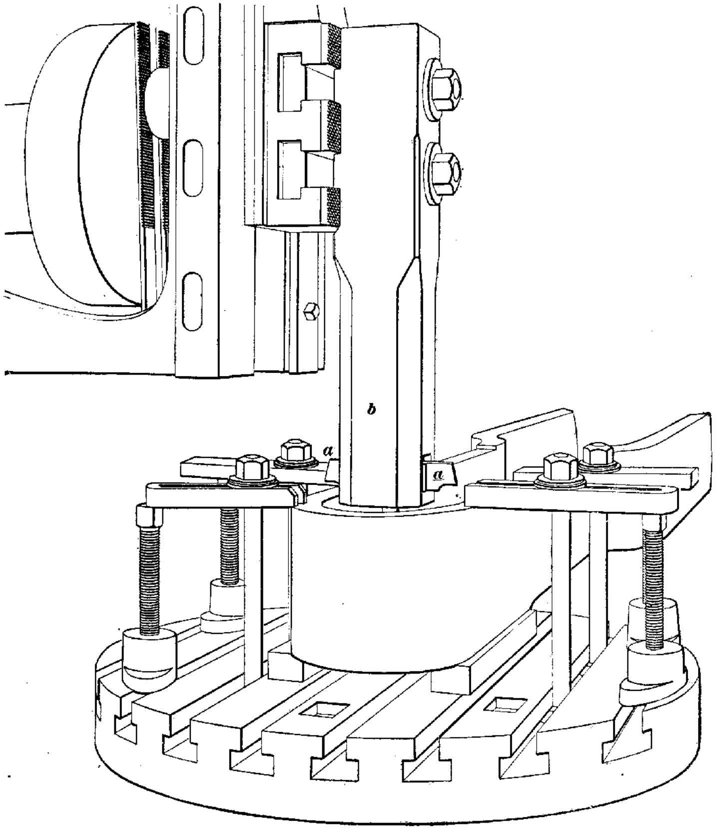


FIG. 43

67. Use of Double-Ended Cutter.—In Fig. 43 is shown a piece of work clamped to the table and ready for the cut.

The work is a **U**-shaped forging that is to be finished on its inside surfaces. The curved part of the piece has been bored to a diameter equal to the width between the surfaces when finished. A very heavy slotter bar *b* is used with a blade *a* of the proper length; this projects at each side, and has cutting points at each end. When set so that it will just pass through the bored part, it is correctly set to take the finishing cut, which it does by cutting both surfaces at the same time.

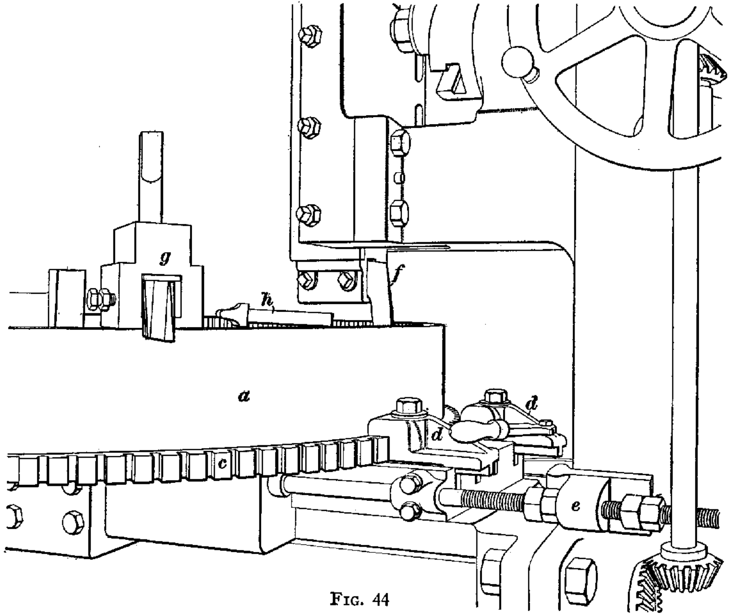


FIG. 44

68. Gear Cutting on Slotter.—The slotting machine is often used for cutting internal gears or for cutting very large spur gears. Fig. 44 shows part of a slotter and part of a large internal gear *a* that it is cutting. The work rests on a plate *c* that has been accurately notched on its edge with as many equally spaced notches as there are teeth to be cut in the gear. The plate *c*, which thus forms an index plate, is fastened to the gear and is mounted on the table of the slotter. Clamps *d* are fastened to the table for clamping the index plate and for carrying the stop-pin that holds the index plate in place. A stop *e* with check-nuts on either side is used to regulate the depth of each tooth. The cutter or tool *f* used for this gear is shaped to the correct outline of the teeth, and is carried in a special block fastened to the end of the ram. A similar tool block is shown at *g* and a tool at *h*, removed from the head. As soon as one tooth space is cut, the stop-pin in the clamp *d* is pulled from the index plate and the gear is revolved until the stop-pin will slip into the next notch of the index plate. After being clamped, a second notch is cut in the gear, and so on until all the teeth are finished. Very large gears may be cut in this way when supported properly on bearings away from the table, so that the edge of the gear rests on the table and is free to slide on its outer support an amount equal to the depth of the tooth.

69. Slotting Irregularly Shaped Work.—One way of cutting an irregular outline consists in chalking the surface of the work and laying out the desired outline with a scriber. The work is then clamped to the slotter table on parallel blocks. A starting hole, sufficiently large to admit the slotting tool, is first drilled at one end of the laid-out hole and the tool is inserted ready to take the first cut. The table is then moved endwise by automatic feed and at the same time is moved in or out by hand while the tool follows the outline of the work, until the hole is finished.

For very accurate work, this method is objectionable, owing to the blurring of the outline by lubricating oil. A better method, especially if a large number of pieces are to be made, is illustrated in Fig. 45. Suppose it is desired to cut an irregular hole *a* such as for the outline of a propeller blade, in the block *b*. The outline of the hole is first laid out on the face of the block and a starting hole *c* for the slotting tool is drilled in the extreme end of the scribed outline. The block is then clamped to the table on two parallel blocks *d*. A templet *e*, which has been accurately shaped to the correct outline, is set a little above the face of the block *b* and bolted on equal spacing blocks *f* as shown.

70. A dial indicator *g*, Fig. 45, is fastened on a bracket which, in turn, is fastened to a stationary part of the machine, such as the bolt *h* on the frame. The slotting tool is adjusted in the starting hole so as to start cutting at the point *c*, at one extreme end of the outline, and the templet is adjusted with its point *i*, corresponding to the point *c* on the work, bearing against the pointer of the indicator, and the reading of the indicator is noted. If the table is now moved endwise by automatic feed, and at the same time is moved in and out by hand in the direction of the arrow *j*, in such a way that the contact between the templet and the pointer of the indicator *g* is maintained with the same pressure, as shown by a constant reading of the indicator, the tool will reproduce the exact outline of the templet on the work. If done carefully, very accurate results may be obtained by this method.

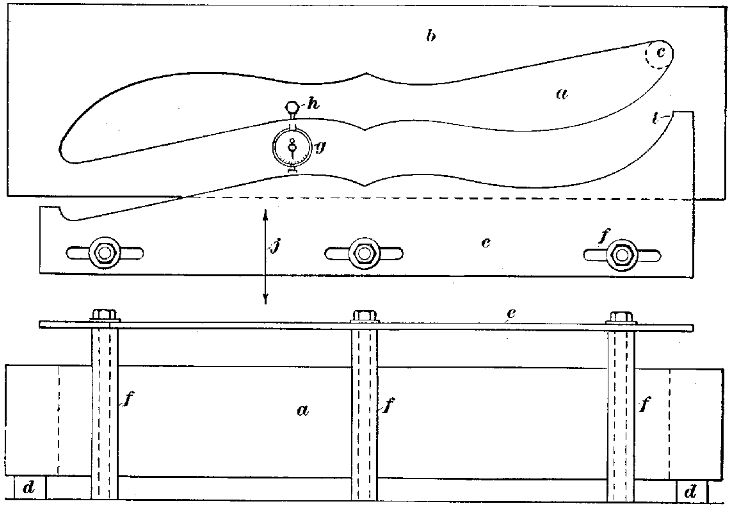


FIG. 45

The method of setting up work for irregularly shaped slotting is shown in Fig. 46. The tool *a* must be adjusted in the work *b*, and the templet *e* similarly adjusted to the indicator *g* that is bolted to the machine frame at *h*. The work must be set up on parallels *d* so that the tool *a* will have clearance over the machine chuck.

71. Index Table for Slotter.—In Fig. 47 is shown an attachment, in the form of an index table, for use on a slotter. This is especially adapted for fine, small work requiring a degree of accuracy that it is not possible to obtain on the ordinary circular slotter table. The table *a* revolves by means of a worm and wheel operated by the hand wheel *b*, and is graduated on its circumference in degrees, read by means of an adjustable pointer *c*. A dial *d* on the worm-shaft is graduated in minutes, so that the table can be set to a very close degree of accuracy. The handle *e* will lock the table in any position, and the pin *f* releases the worm so that the table can be turned by hand while work is being set up.

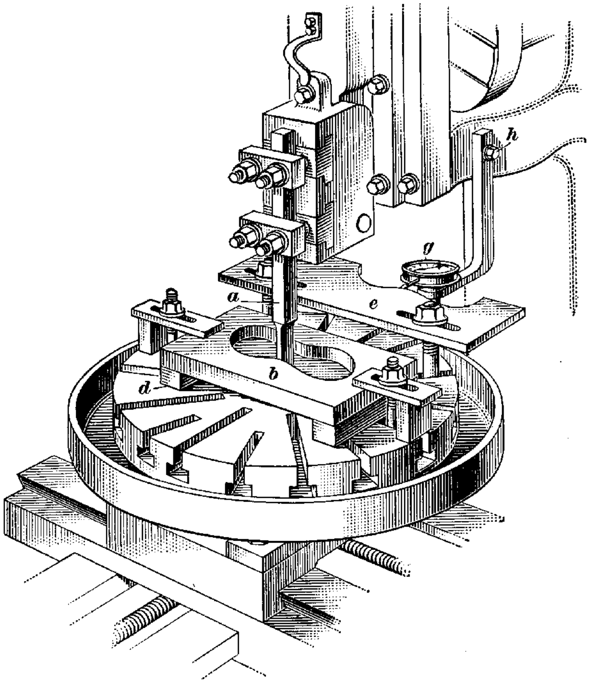


FIG. 46

The attachment is very useful for die sinking, templet work, splining keyways, etc., and convenient for a great variety of work where a circular feed is desirable.

KEYWAY CUTTERS

72. Construction of Keyway Cutter.—In Fig. 48 is shown the front view of one make of keyway cutter, and in Fig. 49 a rear view. It has a cutter bar *a* that is moved up and down by a ram driven by gearing in the column in a similar way to that of the ram in a geared shaper. As the upper end of the cutter bar *a* is free, the back pressure caused by the cutter *a*, when pulled down through the work requires the use of a back support, or brace *b*. This brace is adjusted vertically on the post *c* by the clamp b_1, and horizontally by the clamp b_2. This brace is swung out of the way when placing the work, such as the hub of a gear or pulley, over the cutter bar and on the adjustable table *d*. The stationary table *e* is part of the column of the machine.

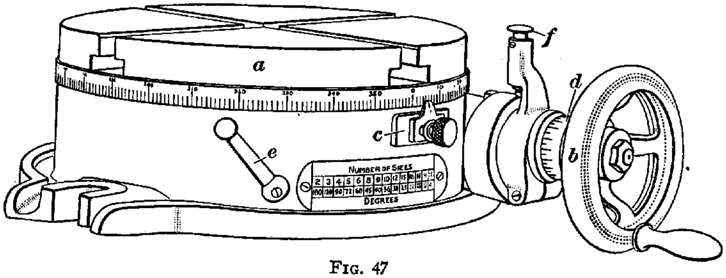


FIG. 47

73. Motions of Keyway Cutter.—The cutter bar has three motions: Its up and down, or cutting and return, motion may be adjusted for different lengths of stroke; its feed, or forward, motion may be regulated to suit the requirements of the work; and its receding, or backward and forward swinging, motion automatically adjusts itself to the feed and clears the cutter *a*, from the work during its upward stroke.

The reciprocating motion of the cutter bar is effected as follows: When the machine is idling, the drive belt is on the loose pulley *f*, and it is shifted to the pulley *g* to make the

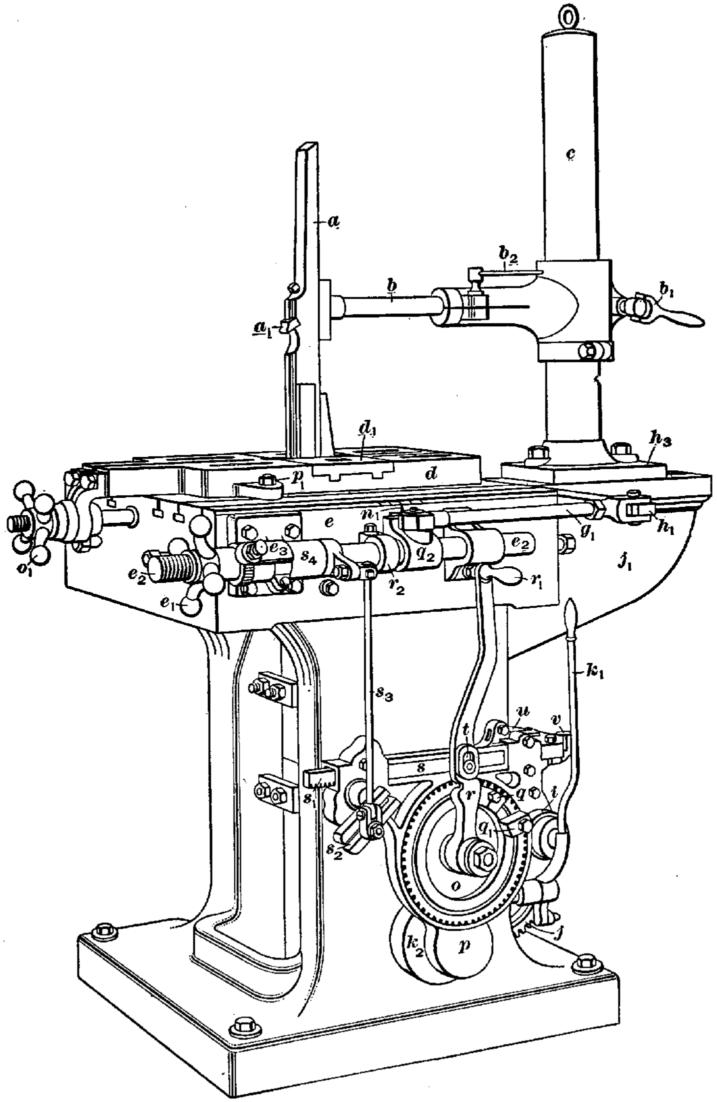


FIG. 48

cutting stroke and to the pulley *h* for the quick-return stroke. The pulley *g* drives through the friction clutch *i*, the pinion i_1, the back gears *j* and *k*, and the large gear *l* to the pinion that engages the rack on the vertical ram in the column. On the quick-return stroke the pulley *h*, which is attached to the idler *n*, drives the large gear *l* directly without the speed reduction of the back gears *j* and *k*. The starting and stopping lever k_1 is used to operate the clutch *i* that drives the pinion i_1, thus controlling the machine without stopping the motor.

The belt is shifted and the length of stroke of the ram is adjusted as follows: The gear *o* is rotated back and forth by a pinion in the cover *p*. A stop, or tappet, *q* that is adjustable on the face of the gear *o* strikes the arm *r*, which moves the horizontal bar *s* by its pin connection *t*, and thence by the rods *u* and u_1 and cranks *v* and v_1 to belt shifter *w*, causing the belt to shift either from the pulley *g* to the pulley *h*, or in the opposite way. The gear *o* rotates in reverse until its other adjustable stop *q*, strikes the arm *r*, and in so doing returns the belt to the pulley *h*. The setting of the stops *q* and q_1 thus regulates the length of the stroke of the ram. The reversing and short-stroking may be done also by moving the arm *r* by its handle r_1.

74. The feed-motion of the cutter is operated by the horizontal motion of the bar *s*, Fig. 48. The feed is made before the beginning of each cutting stroke. The bar *s* has a rack s_1 under its forward end, that meshes with a small gear, the motion of which is transmitted to the slotted crank s_2, giving the feed-rod s_3 an up-and-down motion that rotates the ratchet sleeve s_4. The ratchet motion revolves the handle nut e_1 on the threaded shaft e_2, and, in so doing, slides the shaft forwards gradually in its bearings at the rate desired for the feed. For hand feed, the nut e_1 is turned by hand. The motion of the shaft e_2 is transmitted to the rod g_1 and to the arm h_1 that extends across the back of the table *e*. The rear end of the arm h_1 is pivoted on a rotating eccentric pin h_2, and at its mid-length the bar is pinned to the base h_3 that supports the post *c*. This base may slide horizontally in a

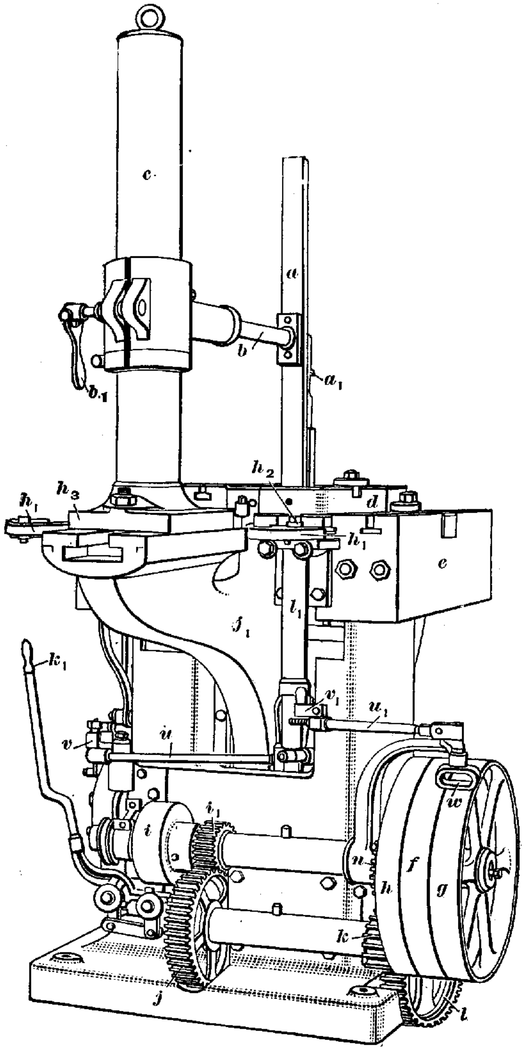


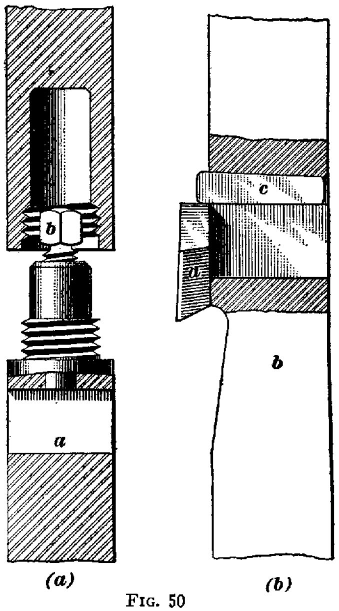
FIG. 49

guide on the top of the large bracket j_1. The ram and the cutter bar a are also attached to the bracket j_1, which is hinged on the driving shaft, which has a bearing k_2 in each side of the column. Therefore the motion of the arm h_1 caused by the feed-rod s_3 moves the cutter bar a and the post e forwards, thereby feeding the cutter into the work.

The swinging motion of the large bracket j_1, together with that of the cutter bar a and post c, for the purpose of preventing the cutter from dragging on the work during the return stroke, is operated by means of the eccentric pin h_2 in the rear end of the arm h_1 as follows: The pin h_2 is on the vertical shaft l_1 that is rotated back and forth by the shift rod u. This action on the return stroke causes the arm h_1 to swing the bracket j_1 away from the table e, and on the cutting stroke to swing the bracket back to its limiting position and the cutter bar into the cut.

75. Setting Up Work on Keyseater.—The work in which a keyseat or groove is to be cut is placed on the table d, Fig. 48, and the cutter bar a is set so that the cutter a_1 is slightly below the top of the work. It is also necessary to set the cutter bar either vertical or to any taper required by the cut, which is done by the hand nut e_1 and the pointer n_1 and its scale. The taper may be cut deeper either at the top or at the bottom of the work. The work is then moved against the cutter, either directly or by means of the hand nut o_1, and carefully centered on the cutter. The gauge plate d_1, which has micrometer adjustable jaws, is also used in centering the work by the bore and regulating the depth of the cut, which is done without the use of any other measuring rule. After the work has been set and clamped the cutter bar is swung back from the work by turning the hand nut e_1 backwards. The table d with the work is then moved in a distance equal to the depth of the keyway, by turning the hand nut o_1. This nut has a graduated sleeve for checking the movement of the work. The table d is then clamped to the table e by the bolts p_1. The stop-collar r_2 is set to trip the feed when the shaft e_2 moves its clamp q_2 and pointer n_1 the depth of the keyway.

76. Cutter Bars.—Small cutter bars are usually made in two parts that may be screwed together. In Fig. 50 (a) are shown the parts unscrewed, and also the method of clamping the cutter in the bar. The cutter passes through the slot a and is clamped by the setscrew b. These bars are made in various sizes to accommodate different sizes of work. Large cutter bars are made solid, as shown in (b), the cutter a being inserted in a slot in the bar b and held by driving in the key c.



(a) (b)

FIG. 50

77. Cutters for Keyways. A form of cutter for cutting a keyway is shown in Fig. 51. The shank S fits the cutter bar, and the part C does the cutting, the cutting edge being along the line $A\ B$. Cutter blades of this kind are accurately made of different widths for cutting keyways of standard sizes. All the grinding done is on the bottom face when they are resharpened. If the keyway is too small, so that a regular cutter cannot be used, the saw cutter shown in Fig. 52 may be employed. It consists of a bar a having a number of cutting teeth along one edge. This bar is attached to the ram and an up-and-down motion like that of the cutter bar is given to it.

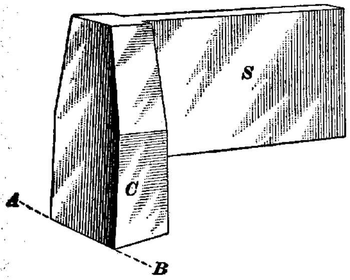


FIG. 51

78. Duplicating Work on Keyway Cutter.—If there are a large number of turned pieces to be machined exactly alike on the keyway cutter, much time may be saved by using a holding fixture. For example, in Fig. 53 is shown a **V**-shaped holding fixture *a* that is intended to be clamped to the table to hold a series of circular pieces, one of which is shown at *b*. Each piece in succession is brought into proper position for the cutting operation by simply pushing it snugly into the angl of the fixture and clamping it there.

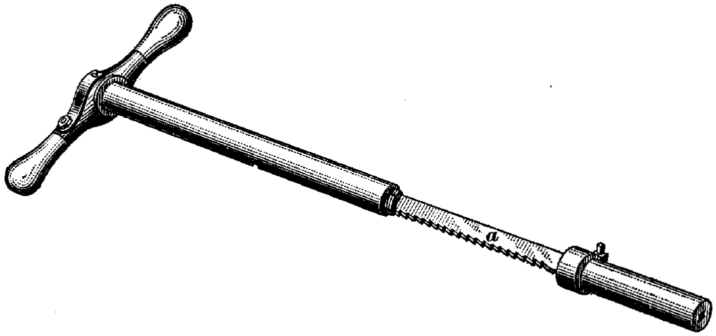


FIG. 52

79. Chucking by the Bore.—The best method of holding a piece of work that is to be keyseated is shown in Fig. 54. This method is known as *chucking by the bore*. To the table *a* is bolted a flat plate *b*, the center of which is counterbored to receive the flange *c* of a bushing *d* that will fit accurately in the bore of the work. One side of the bushing is cut away to the full width of the central hole, making a space for the cutter *e* and allowing the work to be fed up to the cutter so as to give the required depth of cut. Bushings of different sizes are required if the bore of the work varies. The advantage of chucking by the bore is that the work is held true, whether its hub is faced or not.

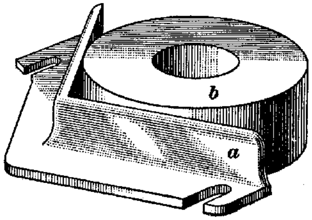


FIG. 53

80. Cutting Keys on Keyway Cutter.—The keyway cutter may also be used for planing keys, by the application of the fixture shown at *a*, Fig. 55. This fixture is a vertical vise that is bolted to the table *b*. On the vertical face the vise carries two adjustable jaws between which the stock for the key *c* is gripped. The jaws are tightened by the screws *d* at the ide. The cutter *e* is then set and cuts are taken just as in

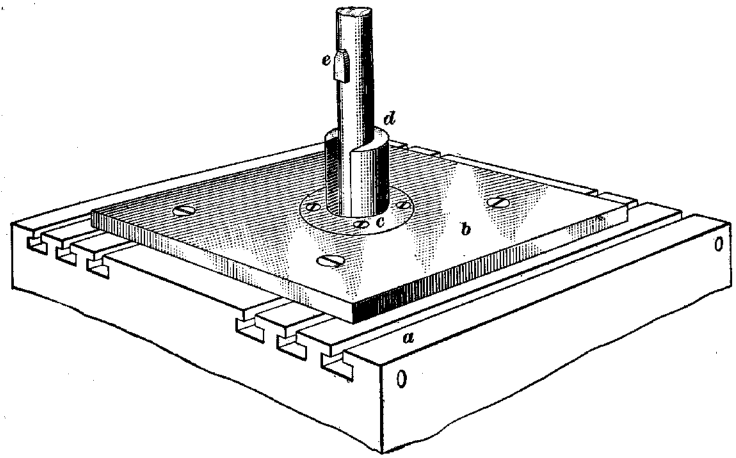


FIG. 54

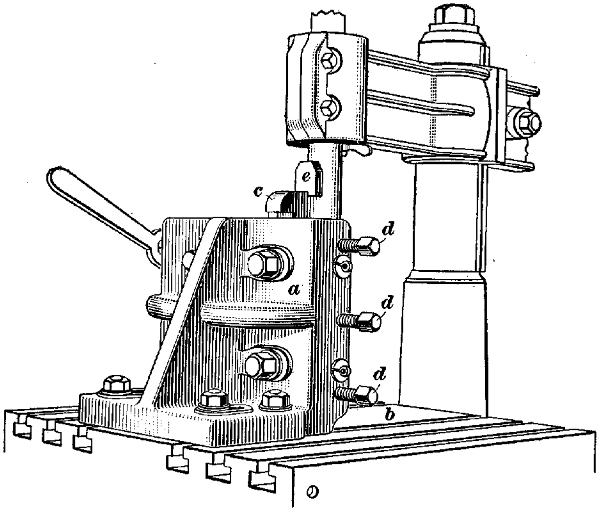


FIG. 55

planing keyways. The cutter takes a full-width chip at each stroke.

81. Cutting Racks on Keyway Cutter.—Although the keyway cutter is designed particularly for certain classes of work, it is possible to do a number of other classes of work on it. A method of fitting up the machine for cutting racks is illustrated in Fig. 56. A cutter blade that will produce the desired tooth form is used and the rack is clamped to the table, as shown. The graduated feed-screw *a* is used to space the teeth and the cross-feed screw *b* to set the work for the proper depth of tooth. By the use of specially formed cutters and some special attachments, many kinds of slotter and shaper work can be done on the keyway cutter.

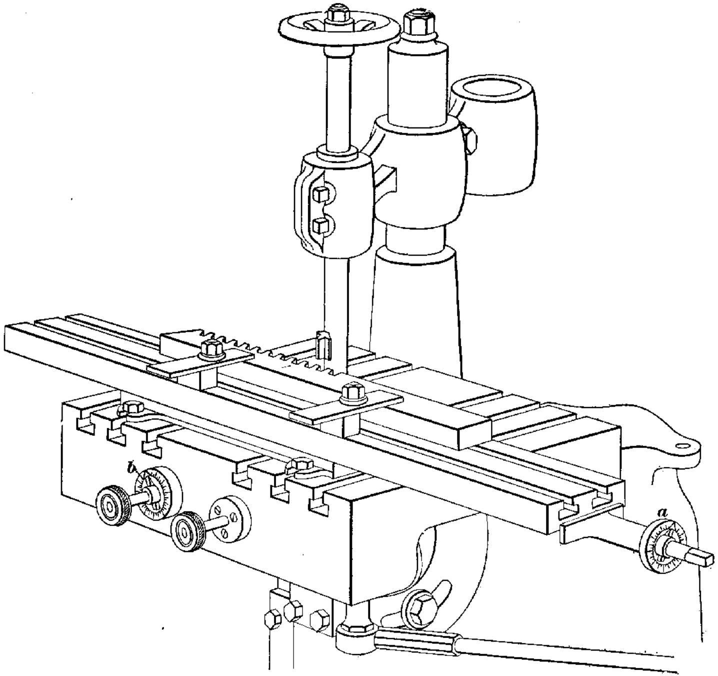


FIG. 56

BROACHING

82. Broaching Machines.—The operation known as *broaching* consists in shaping or finishing a hole in a machine part by pulling a broach, or cutter bar, one or more times through the hole, which has previously been drilled, reamed, or cored in the work. A machine for doing this class of work is shown in perspective in Fig. 57 and in section in Fig. 58, corresponding parts in both illustrations being marked by the same reference letters. A heavy base *a* carries the main driving shaft *b*, on which are the double tight pulley *c* and the corresponding loose pulleys *d* and *e*. On the shaft *b* is a double pinion *f* that may be moved along the shaft by the hand wheel *g* so as to mesh with the gear *h* or the gear *i*. The gears *h* and *i* are fixed to the long nut *j* through which passes the screw *k*, and when the nut is turned by one of the gears, the screw is moved endwise, without turning. The double pinion enables the screw to be moved slowly for heavy broaching or rapidly for lighter work, and the double pulley *c*, in connection with the belt shifters *l*, allows the screw to be returned rapidly for the next operation.

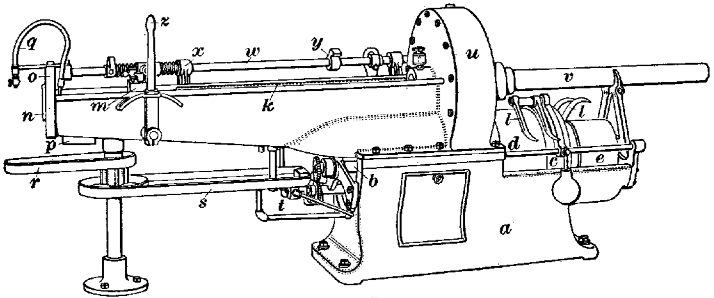


FIG. 57

83. The end of the screw *k*, Figs. 57 and 58, carries the sliding head *m*, which keeps the screw from turning and to which the broach is attached. The broach extends through the bushing *n*, which is fitted in the end *o* of an extension of the main frame. As the screw moves inwards, drawing the broach

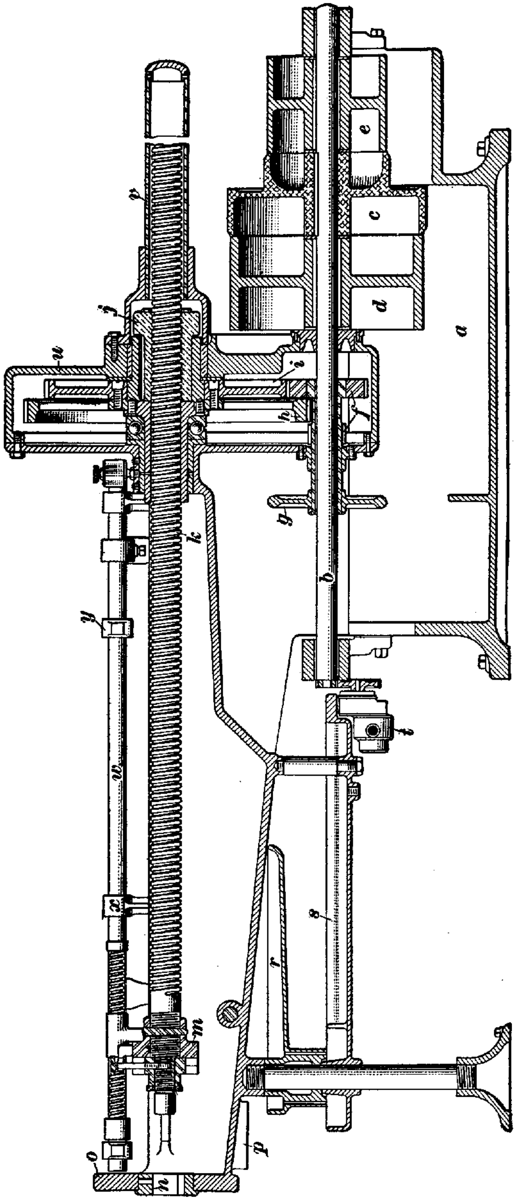


FIG. 58

or the cutter bar with it, the work is forced against the end *o* by the pressure of the cut, and is thus held. A lug *p* is formed on the under side of the frame; to this may be fastened a table or some other form of support for the work. During the broaching operation, lubricant may be supplied through the pipe *q*. It then drips into the tray *r*, which may be swung underneath the frame when not required, as shown in the sectional view. From the tray *r* it runs into the tray *s* and thence into a settling chamber in the bed *a*, from which it is drawn by a geared pump *t* and returned to the work. The casing *u* protects the gearing, and the casing *v* keeps dirt and dust from settling on the end of the screw. The rod *w* carries tappets *x* and *y* that limit the length of the stroke and is connected with the belt shifters *l*, so that the motion of the screw is reversed automatically; also, the machine may be started or reversed by moving the handle *z*.

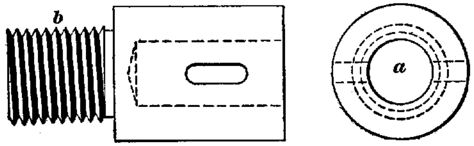


FIG. 59

84. Broaching Tools and Attachments.—A broaching tool for cutting four grooves at once is shown in Fig. 60. There are four rows of cutting teeth *a* formed on a long bar *b*, and the size gradually increases from the point *c* to the end *d*. A slot is cut at *e* to receive

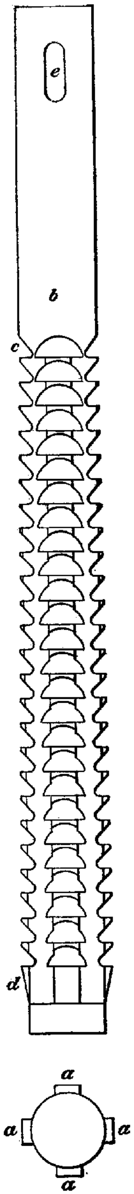


FIG. 60

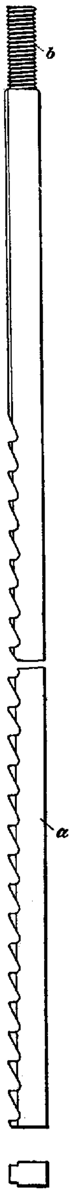


FIG. 61

the key by which the tool is held to the pull bushing shown in Fig. 59. The pull bushing has a socket *a* to receive the end of the broach and a threaded end *b* to be connected to the pulling screw *k*, Fig. 58. It thus forms a means of fastening the broach to the pulling screw. A cutter bar for broaching a single keyway is shown in Fig. 61. The cutting teeth are formed on one edge of the bar *a* and the end *b* is threaded to fit the machine. The tool is guided by the arbor, or bushing, shown in Fig. 62, in the slot *a* in which it slides. The part *b* fits the machine and the part *c* the bore of the work.

85. Preparing Work for Broaching.—Castings that are to be broached without being otherwise machined should be well cleaned, so as to remove the sand from the surfaces; also, it is well to pickle them, so as to remove the scale and thus prevent the broaching tools from being dulled quickly. In most cases in which broaching is to be done, the holes are first drilled, bored, or reamed nearly to the finished size in order to reduce the amount of material that the broach must remove. One or both ends of the work should be squared, so that it will rest flat against the machine face and thus insure a broached hole square with the faces. If an arbor is used, the work does not need to be faced, as the arbor centers it and insures true work.

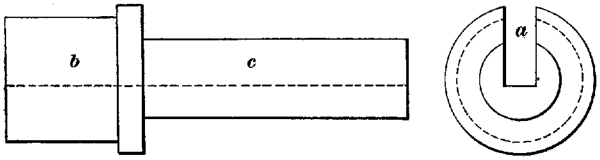


Fig 62

86. Broaching Operations.—Several different forms of cuts that may be made by broaches of suitable shape are shown in Fig. 63 (*a*) to (*h*). If a single straight groove is to be cut, as in (*b*), an arbor like that shown in Fig. 62 is put on the machine, the work is slipped on it, and the cutter bar is pushed through it and secured to the adjustable head on the pulling screw of the machine. The machine is then started, and as the cutter moves, the first tooth takes a light cut, and each succeeding tooth, being longer, deepens the cut. When the cutter bar has been pulled through, the cut will be of the required depth.

87. If two keyways are to be cut directly opposite each other, as shown in Fig. 63 (*c*), the arrangement shown in Fig. 64 may be used to advantage. An index plate *a* is firmly fixed to the arbor *b*, which is set into the machine so that it cannot rotate. The work *c* in which the keyways are to be cut is clamped in a dog *d* and slipped over the arbor *b*. The slot *e* in the dog fits over a pin *f* in the index plate, and this pin is one of four that are equally spaced on the plate. With the work in this position the cutter bar is inserted and one keyway is cut. The work is then slipped along the arbor *b* so as to release the dog from the pin *f*, and the work and the dog are turned until the slot can be slipped over the pin *g* directly opposite, after which the second keyway is cut. Any number of grooves may be cut in this way by using an index plate with pins properly set; but if several grooves are to be cut, the work may be done more quickly by using a formed broach that will cut all at one time.

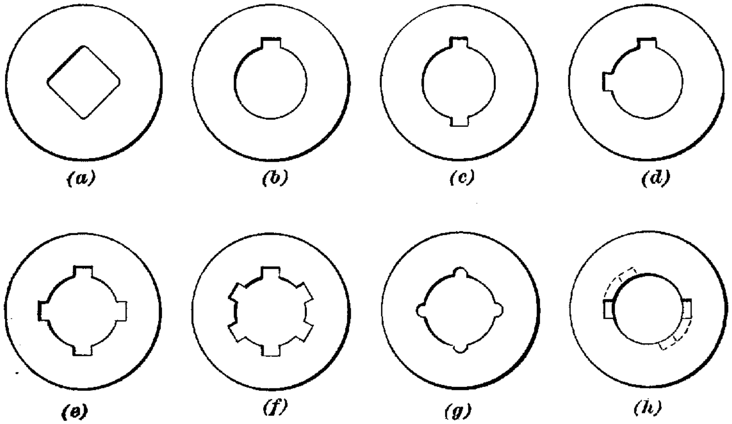

(*a*) (*b*) (*c*) (*d*)
(*e*) (*f*) (*g*) (*h*)

Fig. 63

88. A spiral groove, as shown in the end view, Fig. 63 (*h*), may be cut with a broach. The cutting teeth on the broach are arranged in a spiral exactly like that to be cut. The work is set with a ball bearing behind it, to allow it to turn easily, and the broach is drawn through it. The teeth that cut first on the spiral broach should be longer than on a straight broach, so as to give the cut a good start.

If the parts to be broached are short, several of them may be placed end to end on the arbor and cut at one operation. Slots of extra depth may be cut by slipping a key behind the cutter bar in the slot made by the first cut, and then taking a second cut. In this, as in all other broaching operations, at least two teeth of the broach should always be in contact with the work, so as to steady the cut. As the broach is pulled, instead of being pushed, there is little tendency for the tool to chatter. The usual cutting speed of the horizontal broaching machine is from 3 to 6 feet per minute.

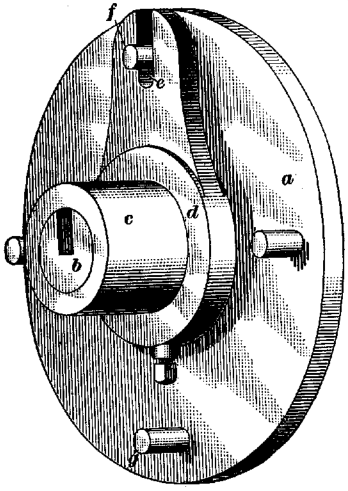


FIG. 64

89. Number of Broaches Required.—A single broach may be used to cut a hole in cast iron, if the hole is not too long; but if the hole is of considerable size and length and the metal is steel or wrought iron, it may be necessary to use as many as five broaches in succession, to complete the hole, each removing about the same amount of metal. The kind of metal, the length of the cut, and the amount of cutting to be done to bring the hole to the desired shape are the points that determine how many broaches are needed.

90. Lubricants for Broaching.—The best lubricants for use in broaching high-speed steels and other hard metals are lard oil and other cutting oils. For ordinary soft steels and steel castings, a cheaper lubricant consists of a mixture of 2½ pounds of sal soda and 3 gallons of mineral oil in 50 gallons of water. Cast iron and bronze are usually broached dry.

BORING-MILL WORK

Serial 2236 Edition 1

CONSTRUCTION AND OPERATION

PRINCIPAL KINDS OF BORING MILLS

INTRODUCTION

1. Classes of Boring Mills.—Boring mills have been developed from the lathe and, in principle, are very similar to it. There are two general types of boring mills, the vertical and the horizontal. Although these machines are known as boring mills, both are used for other operations. The boring mill is chiefly used for turning, boring, and facing operations on work that is too large or heavy to be handled on a lathe.

The vertical boring mill may be thought of as a face-plate lathe so constructed that the spindle is vertical and the work, which is clamped to a table, revolves. The machine is adapted to turning as well as boring, and is often called a *boring and turning mill.* One type of vertical boring mill is better known as a *vertical turret lathe* and combines the advantages of a turret lathe and a vertical boring mill. It is especially adapted to production work.

The horizontal boring mill may be thought of as a lathe in which the work is clamped to the bed, and the cutting tool revolves, the tool being carried by a boring bar fitted to the spindle of the machine. Drilling and milling operations as well as boring may be performed on this machine, for which reason it is sometimes called the *horizontal boring, drilling, and milling machine.* Horizontal boring mills may be subdivided into the simple type of horizontal boring machine most commonly found in machine shops; the horizontal floor mill, used generally where large work is done; and special boring mills for cylinder boring and for boring spherical bearings.

2. Rating of Boring Mills.—Boring mills are rated in inches, according to the diameter of the work that can be handled. Thus, a 62-inch mill is one that can machine a diameter of 62 inches. This is expressed by stating that the mill has a *swing* of 62 inches. The largest diameter of work that can be placed on the table is usually somewhat larger than the table diameter. In vertical boring mills the distance that the ram may be raised vertically determines the height of the work that can be handled on the machine.

VERTICAL BORING MILL

3. Construction.—In Fig. 1 are shown the front view (*a*) and the rear view (*b*) of the type of vertical boring mill most used for medium and large work. The same reference letters have been used to indicate the same parts in both views. The work is clamped on a rotating table *a* having slots for **T**-head bolts, and the cutting tools are carried in holders *b* in the lower ends of the rams *c*. The rams have a vertical motion in the saddles *d*, which are gibbed to the cross-rail *e* and can be moved in either direction independent of each other, by power or hand feed. The form of the rams is either square or octagonal, the purpose of the latter form being to enable the ram to feed into smaller holes. The two housings *f* are bolted to the base *g* and are connected at the top by the brace *h*. The housings have finished surfaces, or guides, on which the cross-rail may be raised or lowered, and clamped in any position by the rail clamps *i*. The vertical motion of the rams in the saddles is transmitted by pinions acting on rack teeth *j* cut on the side of the rams.

Each ram may be swiveled through 45 degrees on either side of a vertical position by turning the shaft *k*, which engages a worm on the shaft with the teeth of a gear segment cut on

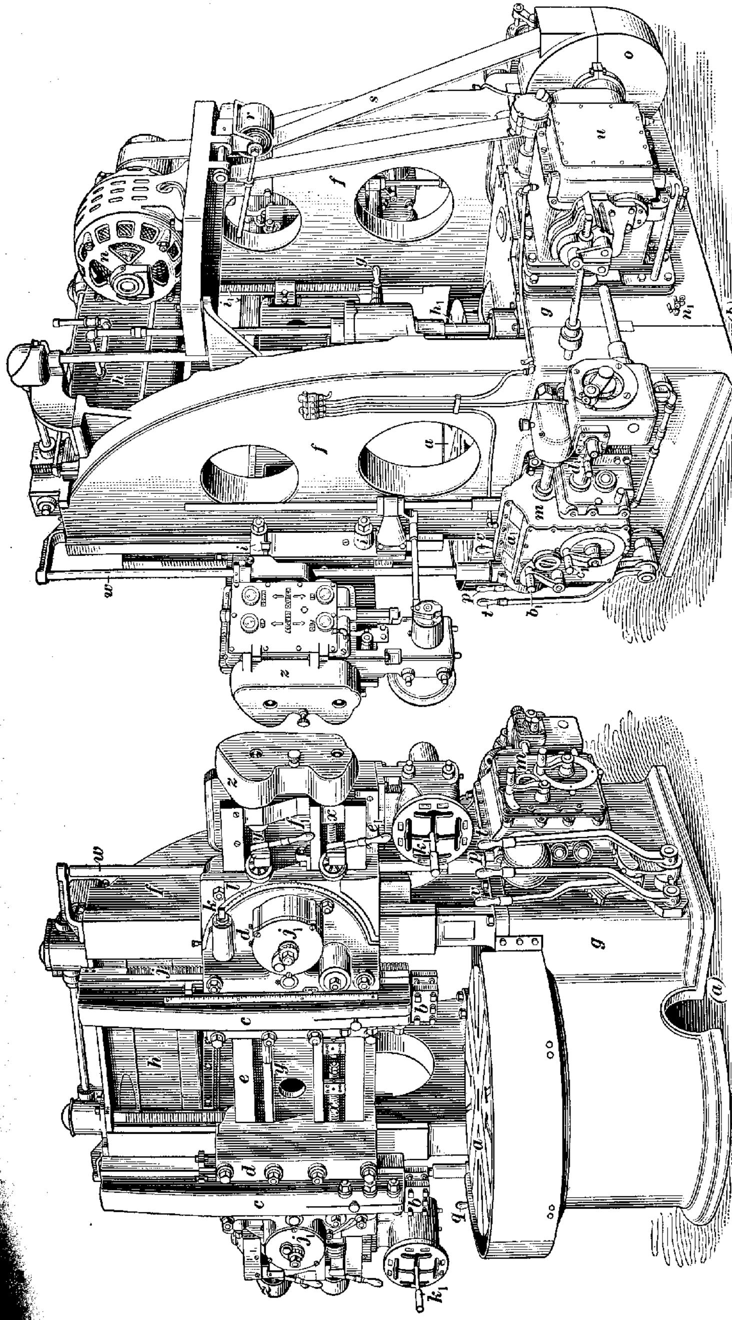


Fig. 1

the circumference of the saddle. The angle of swivel may be read on the graduated base *l*. The tool holder *b* may be revolved in the end of the ram so that the tool may be set in any desired position. The rams can be firmly clamped in the slides when it is desired to take horizontal cuts on work. The feed-box *m* contains the change gearing that provides the feeds for the rams.

4. Boring-Mill Drive.—The power to run the various parts of the mill shown in Fig. 1 is obtained from the electric motor *n*, which is belt-connected to a pulley in the casing *o*. A friction clutch on the driving pulley is connected to the lever *p*, enabling the operator to start or stop the machine from a convenient position in front of the right housing. A duplicate starting and stopping lever is provided at *q*, thus enabling the operator to operate the mill from either side of the table *a*. An adjustable idler pulley *r* serves to keep the driving belt *s* tight.

From the driving pulley the power is transmitted by a system of shafts and gears to a pinion that meshes with a large ring bevel gear bolted to the lower side of the table, thus causing it to rotate. Back gears like those on a lathe are provided within the bed of the machine, and furnish three changes in table speed. The back gears are engaged by means of the lever *t*. Four additional changes in speed for each of the speeds thus obtained may be secured by change gears and clutches in the speed box *u*, operated by the lever *v*. In this way a total of twelve changes in table speed may be obtained.

5. The driving pulley in the casing *o*, Fig. 1, also transmits power to the vertical shafts *w*, located on each side of the machine, which provide the feed for the cutting tools in the following manner:

The saddles *d* may be moved along the cross-rail *e* by rotating the feed-screws *x*, while the vertical movement of the rams is accomplished by rotating the splined feed-rods *y*. A separate feed-screw and feed-rod are provided for each saddle so that the feed motions are independent of each other. The motion of the feed-screws and feed-rods is obtained from the vertical shafts *w* by gearing in the casings *z* at the ends of the cross-rail. The feeds may be changed by means of change gears in the gear-boxes *m* on each side of the machine, by which sixteen changes of feed, ranging from .006 inch to one inch per revolution of the table, are made available for both vertical and horizontal movements. An index plate a_1 indicates the combination of the three levers b_1, c_1, and d_1, that will give the desired feed. A very close adjustment of both horizontal and vertical feeds may be obtained by the use of the ratchet handles e_1 and f_1, respectively, which are mounted on the saddles and are provided with micrometer dials.

6. Cross-Rail Movements.—The cross-rail *e*, Fig. 1, may be raised or lowered on the housings *f*, independently from the table drive, by the lever g_1, which engages a friction clutch, and in this way transmits the motion of the shaft h_1 to the screw i_1 by a system of shafts and gears on top of the brace *h*. The rotation of the screw in a threaded bracket fastened to the back of the cross-rail causes the rail to be raised or lowered.

The rams *c* are counterbalanced by springs contained in the casings j_1. A ratchet is used to adjust the tension of the springs. Medium and large-sized boring mills are as a general rule provided with two rams so that turning and facing operations on work may be carried on simultaneously.

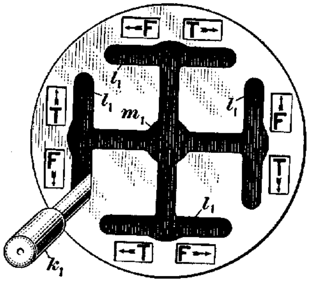


FIG. 2

7. Rapid Traverse.—The saddle *d* and rams *c* of the mill shown in Fig. 1 may also be moved at a rapid rate by power, by engaging a friction clutch by means of the lever k_1, which also controls the direction of the feeds. The lever k_1 may be placed in any one of the four slots l_1, Fig. 2, each slot denoting two different directions of motion and two rates of feed, a slow feed **F** and a rapid feed **T**. Thus, if the saddle is to be moved orizontally on the cross-rail, the lever is placed in either the or bottom slot, depending on the direction in which the saddle is to be fed. If the ram is to be moved vertically in the saddle, the lever is placed in either the left-hand or right-hand slot, according to whether the ram is to be fed in an upward or a downward direction. For instance, with the lever in the lower end of the left-hand slot, Fig. 2, a downward feed of the ram is indicated. If a rapid rate is required, as when returning the tool for the second cut, the lever is placed at the top of the same slot. The long slot prevents the operator from engaging the rapid traverse at the same time as the feed and damaging the machine. Either feed is disengaged by moving the lever midway between **T** and **F**. When the lever is placed in the center hole m_1 the feed drive is disconnected.

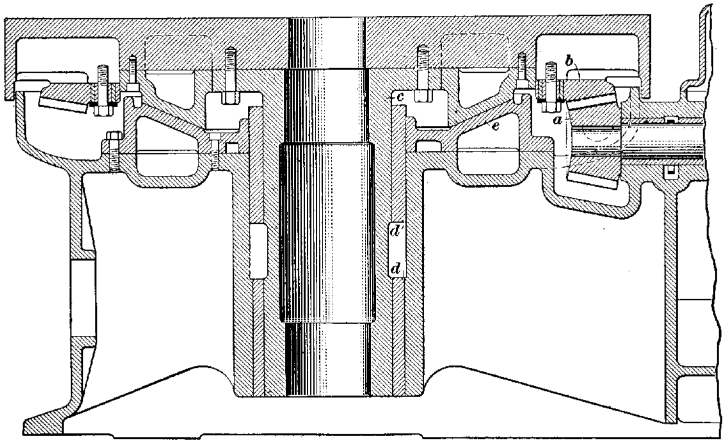


FIG. 3

8. Table Drive.—A sectional view of the table and bed of the boring mill shown in Fig. 1 is shown in Fig. 3. At *a* and *b* are shown the pinion and ring bevel gear that furnish the rotation for the table. The table spindle *c* is supported in a vertical bearing *d*, and the table is further supported by a conical bearing *e*, which takes care of the end thrust.

The arrangement of the feeds is such that one tool may be turning the outside of a piece while the other is boring, or both may be either boring or turning on the same or different diameters, or one tool may be facing the top while the other may be either boring or turning. Conical turning or boring may be done by setting the head at an angle. When working on different diameters, the tool on the smaller diameter has a slower cutting speed than that cutting on the larger, and the speed must be adjusted for the larger diameter. These operations are the same as those carried on in the lathe, and the tools used for these operations in the two machines are identical.

9. Lubrication.—The drive gears and bearings located in the base *g* of the machine shown in Fig. 1 are lubricated by the splash system, the base acting as a reservoir for the lubricating oil. By means of a petcock n_1, view (*b*), the proper level of the oil is maintained in the base. From the reservoir the oil is pumped to a tank in the top brace *h* of the mill, from which it flows by gravity to the speed-box, feed-box, table spindle bearings, cross-rail elevating mechanism, and various other parts of the machine.

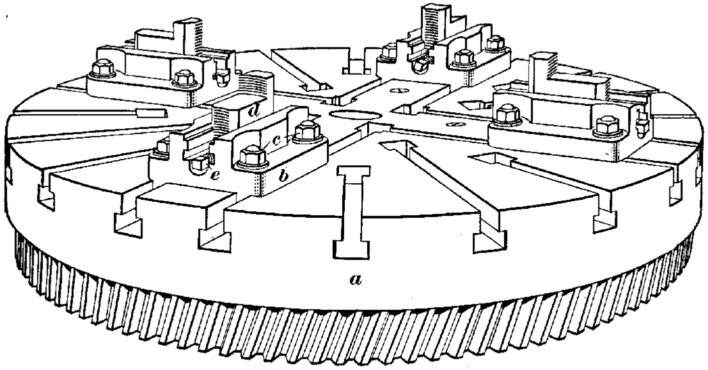


FIG. 4

10. Methods of Clamping Work.—The work may be held on the table of a boring mill in three ways; by clamps and bolts, similar to those used to fasten work on a drilling machine table, by gripping the work between the jaws of a chuck, or by means of special fixtures.

The first method is necessarily slow but is often the only one that can be used when the work is of irregular shape. A quicker way is by clamping the work in the jaws of an independent or a universal chuck. Often the base of the chuck is built integral with the boring-mill table. An example of this is the independent chuck shown in Fig. 4. The table *a* forms the base of the chuck and each of the jaw bases *b* can be moved in the **T** slots of the base to any desired position and firmly clamped by the bolts *c*. Each jaw *d* has threads at the bottom which are engaged by the screw *e*, and in this way the jaws may be tightened on the work. The jaws *d* are made reversible so that castings such as flywheels, gear blanks, etc., may be gripped on the inside of the rims.

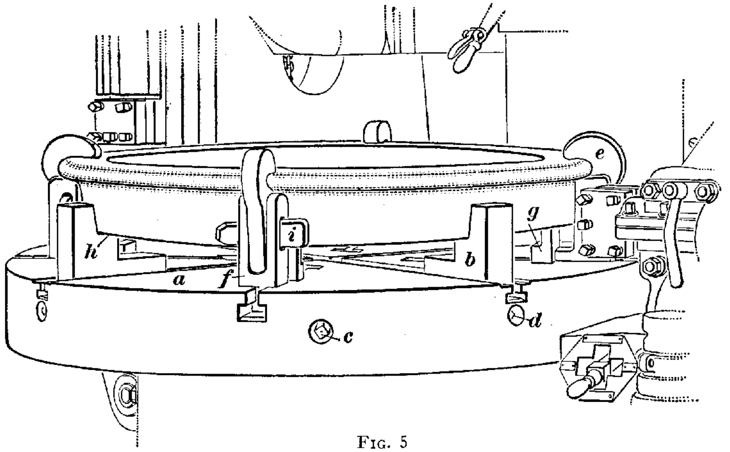


Fig. 5

11. Special Holding Fixtures.—For operations on work that must be machined in large quantities and that cannot be gripped conveniently between the jaws of an independent or a universal chuck, special holding fixtures are in common use. Such fixtures are designed to fit the particular piece of work that they are to hold.

The table *a*, Fig. 5, is built as a universal chuck and is used as such for holding ordinary cylindrical work by moving the jaws *b* simultaneously toward or away from the work by turning the screw *c*, or separately by turning the screws *d*. With the aid of special fixtures the table can be used for boring locomotive tires. This operation imposes a heavy strain on the jaws of the chuck, which are liable to spring out of true. The special fixtures furnish additional support to the work and keep it rigid on the table. The fixtures consist of four clamp arms *e*, pivoted in the bases *f*, which are bolted in the **T** slots of the table. The tire is supported on the nurled top surfaces of the plates *g* that are bolted to the bases *f*, and on the steps *h* of the jaws *b* of the universal chuck. The height of the plates *g* is such that the tire is supported level. The jaws *b* are then tightened against the outer surface of the tire, and the clamp arms *e* swing over the rim. By driving wedges *i* through slots

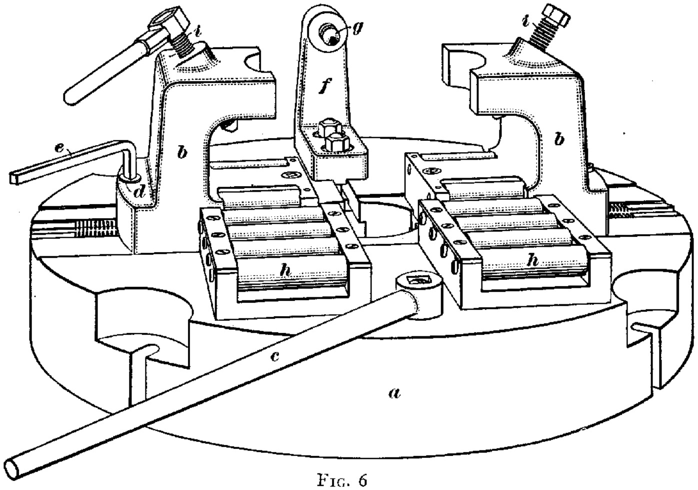


Fig. 6

in the bases *f* and the clamp arms *e*, the latter will grip the tire firmly, permitting the boring tool to operate on the inside rim of the tire. To withdraw the tire from the clamp arms *e* it is only necessary to remove the wedges *i*, which allows the arms to swing free of the work.

12. Locomotive Driving-Box Fixture.—A convenient fixture for boring locomotive driving boxes or similar-shaped work is shown in Fig. 6. It consists of a chuck *a* bolted to the boring mill table and having two jaws *b* that can be moved simultaneously toward or away from the work by means of the wrench *c*, which operates a scroll inside the body of the chuck. Separate adjustment of the jaws may be obtained by turning the screws *d* with the wrench *e*. The bracket *f* is bolted to the chuck base and is provided with an adjusting screw *g*. The work is laid on the rollers *h* and carried between the jaws *b* until it just makes contact with the screw *g*, after which the jaws *b* are tightened on the work. In addition the work is held by tightening the bolts *i*. This fixture is especially convenient for production work. After the first piece of work has been adjusted and bored correctly, the chuck needs no further adjustment for the succeeding pieces, and each piece will be machined exactly alike.

13. Setting Up Work on Vertical Boring Mill.—The horizontal table of the vertical boring mill makes the setting of work easier than in the lathe, as the piece can be placed loosely on the table and need not be secured while the settings and adjustments are being made. Small work is often held in a chuck similar to a lathe chuck, and large work is generally blocked up on parallel pieces and held by clamps, angle plates, and drivers, which are devices that prevent the work from turning on the table. Owing to the stiffness of the table heavier cuts can usually be taken on the boring mill and more tools used at once than in a similar lathe operation.

The three following requirements may be taken as a guide when setting work. The piece must be set with the circumference to be finished exactly concentric with the center of rotation. In other words, it must be set so that it runs true enough to turn to size. The work must be set so that the center line, or axis, will be perpendicular to the top of the table. If the lower surface is irregular, the work must be blocked up to prevent springing and to bring the work level. The work must then be gripped with jaws, or clamped, as on the planer, with drivers to take the twisting strain due to the pressure of the cut. The drivers may be angle irons or plates or other braces to prevent the work from turning on the table while the cuts are taken.

14. To set the work so that it will run approximately true, it is placed on the table and the distance measured from

the rim of the table to the rim of the work in at least six different places, and with the table at rest. After this, a test is made with a surface gauge to ascertain whether the top surface of the work is parallel with the table. After the necessary adjustments have been made, the machine is started slowly and the true setting of the work checked again. This may be done very conveniently by clamping a piece of wood, with a nail or bent wire in the end, in the tool holder and adjusting the end of the nail as close to the revolving work as possible. The movement of the work with relation to the stationary nail point will show at once where adjustments in the setting of the work should be made. The advantage of using a nail or wire instead of a rigid tool lies in the fact that if the work should be badly out of true the nail or wire will simply be bent backwards without damage to the machine.

15. Boring-Mill Tools.—The tools used on a boring mill are similar in shape to those used on a lathe, and may be either forged tools or tools ground from $\frac{3}{8}$- or $\frac{1}{2}$-inch round or square tool-steel stock and inserted in holders. The boring tools may be divided into two classes, those used for boring a cored hole and those for boring relatively large cylindrical surfaces. The tools used for boring cored holes consist of four-lipped drills, single cutters inserted in long shanks held in the ram, or double-ended flat cutters inserted in shanks and operating simultaneously on opposite sides of a hole. The cutting tools named may, or may not, have pilots to guide them in the cored holes, and in most cases they are followed by a reamer for sizing the hole. Rigid reamers are liable to produce oversize or tapered holes if they are not correctly centered, and for this reason floating reamers, which center themselves in the hole, are often used. Large holes are usually bored by forged boring tools clamped in a square tool holder such as shown at *b*, Fig. 1. Forming tools are also successfully used on the vertical boring mill.

16. Examples of Vertical Boring-Mill Work.—A plain piece of work such as an engine crank-disk, Fig. 7, for example, is held in the chuck jaws of the boring mill with the face *a* nearest the table, precisely as a piece of similar form would be held in a lathe face-plate chuck. The center *b* of the crank is then bored, the top *c* faced, and as much of the outside turned as the jaws will permit. The piece is next turned over, gripped in the jaws, and adjusted so that the turned and bored parts will run true. The face *a* and the unfinished part of the outside are now machined.

The center of the crankpin hole *d* is next accurately located at the correct distance from the crank center and a circle the size of the hole is drawn around it. The crank-disk is then set flat on the table enough out of center to bring the pin hole central. A pointer held in the tool holder is brought over the circle and the crank-disk adjusted until the circle follows the pointer. The disk is then securely clamped and enough weight added to the table to balance the crank and make the table run smoothly. The table is then speeded up and the small hole is bored to size.

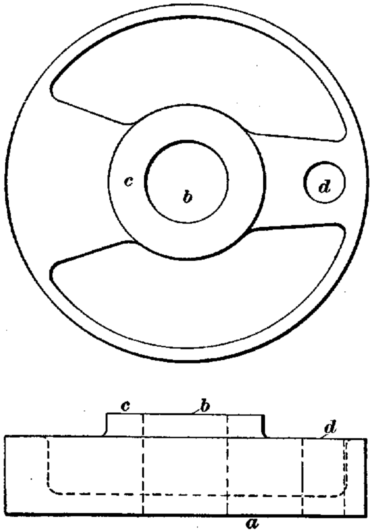


Fig. 7

17. In Fig. 8 is illustrated how an irregular piece may be secured on the table. Before setting a large piece, the table must be carefully cleaned and lowered so that the weight is taken on the outer rim of the bed as well as by the step bearing. When this is neglected, there is danger of injuring the step bearing and also of springing the table. The piece is then placed on the table, set approximately central, and leveled up by blocking at regular intervals. In Fig. 8, screw jacks *a* are used in leveling up. When the piece is approximately level, a small stick held lightly in the tool holder is brought very near the circumference or surface to be turned, and the table is rotated slowly. Careful observation of the distance between the part and the stick will show in which direction it must be moved to bring it perfectly central. The distance from the stick to the upper surface should be observed and the work adjusted until it sets level on the table. Several trials and adjustments are usually necessary before the work is correctly set so that all points pass at the same distance from the stick. The jaws *b*, which are supported on extension arms *c*, which in turn are bolted to the table *d*, are used for centering and clamping. The jaws are equipped with adjusting screws *e* to control the grip *f*.

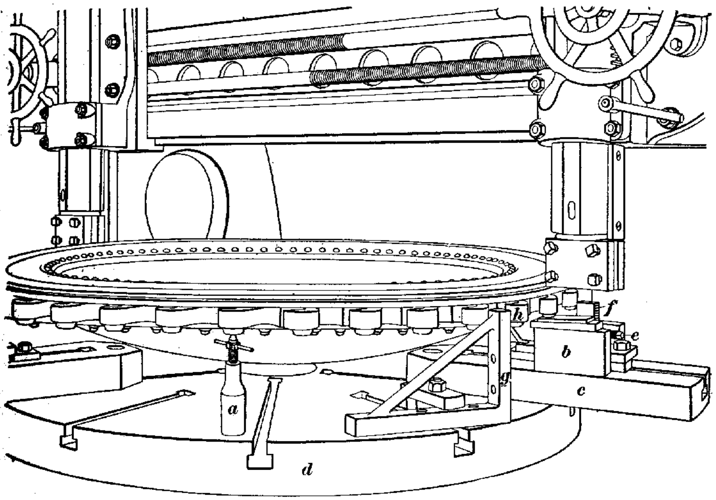


Fig. 8

18. When all adjustments have been made, two drivers, one on each side of the work, are set against any available projections. In Fig. 8, the drivers are the angles *g*. They are set against the lugs *h* and clamped on the table, as shown. When the piece has been properly secured, it is well to test the setting again, and to look over all bolts, to be sure that every part is fastened securely, after which the machine may be started, the speed properly adjusted, and the tools fed as required. The shape of the tools, and the cutting speeds and feeds are the same as in a similar operation in a lathe.

The piece shown is held by three vertical jacks *a*, three jaws *b*, and two drivers *g*. On pieces where a flange or any other surface upon which a clamp may secure a hold is available, clamps are used in preference to the jaws, drivers being applied to prevent any sliding on the table. In some cases, the weight of the part, together with the clamps, furnishes grip enough on the surface of the table to prevent any slipping, but this grip is very uncertain, and it is better not to depend on it entirely.

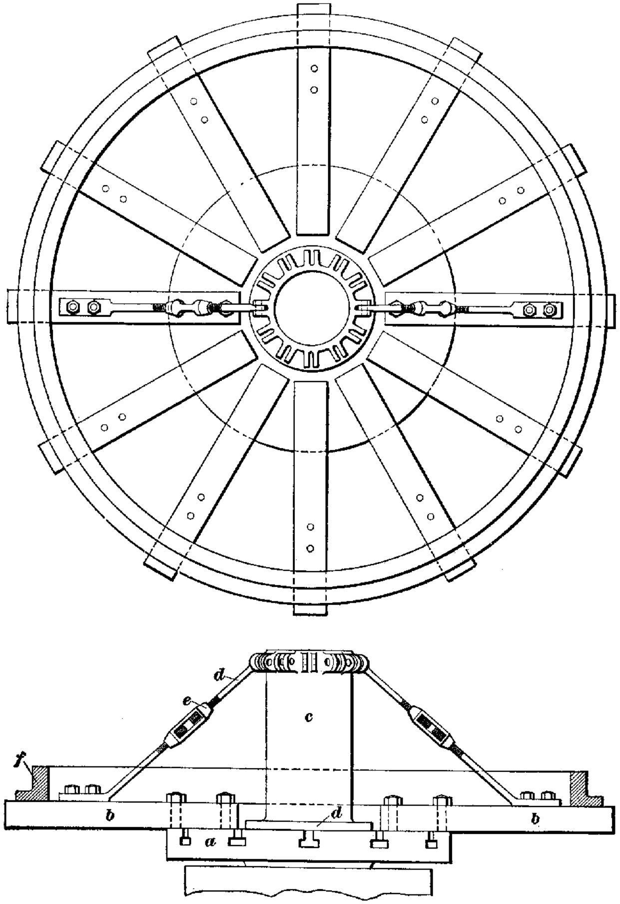


Fig. 9

19. Extension Arms for Vertical Boring-Mill Table. A boring mill is required at times to turn work that is larger in diameter than the boring-mill table. When this is the case, extension arms like those shown at *c*, Fig. 8, may be used. There are, however, cases where the extension arms must project so far beyond the edge of the table, and where the weight is concentrated so near the end, that additional support is needed to prevent objectionable springing. Fig. 9 suggests a means of providing such support when the center of the piece is open, as in the case shown. The table *a* of the boring mill is of the ordinary type, with radial slots. The extension arms *b* are bolted to the table in the ordinary way. At the center of the table a pillar *c*, with a flanged foot that is bolted to the table, furnishes the upper support for diagonal tie-rods *d* whose lower ends are bolted to the arms, thus forming an additional support. Turnbuckles *e* in the tie-rods permit the arms to be adjusted approximately level, after which a light surface cut may be taken to true them up perfectly. The work *f* is then fastened in any convenient way that its shape will permit, and turned to size.

This is a comparatively inexpensive and efficient shop expedient, which, however, may or may not be a means of economy, depending on the number of pieces for which it can be used and the cost of having the work done in a shop equipped for it. Shop expedients are frequently resorted to when the work could have been done outside more cheaply. Great caution should be exercised in their construction in order that true economy may be practiced.

20. Fixture for Turning Spherical Surface on Vertical Mill.—A fixture for turning a spherical surface on a vertical boring mill is shown in Fig. 10. While this fixture forms a correct sphere, there may be a lack of rigidity that will prevent it from taking many cuts. The machine has two saddles. One saddle *a* has bolted to it a bracket *c*, which carries a pin *d*, around which swings the link *e*. The saddle *a* is clamped to the cross-rail so that the point *d* lies in a vertical line forming the axis of rotation of the table. The other saddle *b* is detached from the cross-feed screw in the cross-rail, and is free to move crosswise. A bracket *f*, having a roller on each end that bears on the cross-rail, is attached to the saddle so as to carry its weight, thus reducing the friction and providing a free motion along the rail. The boring bar *g* has an arm *h* attached near its upper end, which carries the fulcrum *i* of the link *e*. The link *e* continues to a point *j*, where a vertical link *k* is hinged. At the lower end, the vertical link *k* is hinged to the lever *l* at *m*. The lever *l* is pivoted at *n* on an arm *o* attached to the bottom of the boring bar and at its end carries the cutting tool *p*.

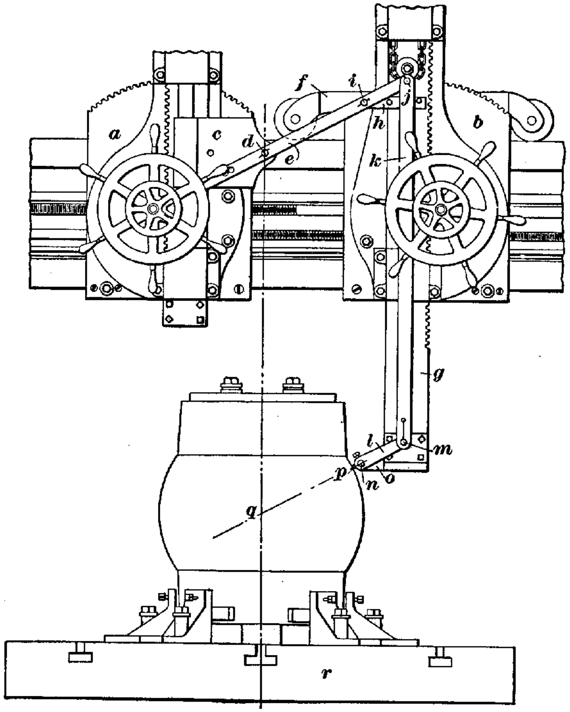


FIG. 10

21. The piece *q*, Fig. 10, to be turned is fastened centrally on the table *r* of the boring mill. When the links are properly proportioned the tool will travel in an arc of a circle, and, when the table is rotated and the boring bar is fed vertically, will turn in a true sphere. In order to accomplish this, the length of the link *k* and the vertical distance between the pivots *i* and *n* must both be equal to the vertical distance between the center of the sphere to be turned and the pivot *d*; the distance *d i* must be equal to the distance from the center of the sphere to the pivot *n*, that is, the sum of the radius of the sphere and the distance of the tool point from its pivot *n*, and the distance *i j* must be equal to the distance *n m*.

22. As the boring bar *g*, Fig. 10, is fed up, the saddle *b* will be drawn by the lever *e* toward the center of the sphere, when turning the upper half of it. The pin *i* then swings about its center *d*, and the pin *n* travels in an arc of the same radius about the center of the sphere. When in the course of the turning the pin *n* comes as near the table as the center of the sphere and the boring bar is fed downwards, the saddle *b* will again travel toward the center of rotation.

If the distance *d i* is made equal to the sum of the required radius of the sphere and the distance from the tool point to the pivot *n*, the tool will form a perfect sphere of the required radius. The center line of the link *n m* will always point to the center of the sphere. In this work, a narrow, round-nosed tool is used with a comparatively light feed, so as to insure a smooth surface.

23. Tapered and Formed Surfaces.—A tapered surface may be machined on a vertical boring mill in three ways: (1) A bar or templet having the same slope as the required surface may be used to guide the boring ram; (2) the ram may be set at the same angle as the surface and fed along it; and (3) the feeds of the saddle and the ram may be used together. In case the available feeds will not give the angle required, then a combination of methods (2) and (3) may be used.

24. The templet method of turning or boring a taper is illustrated in Fig. 11. A plate *a* is set to the desired taper and bolted to two brackets *b* attached to the cross-rail *c*. The roller *d* pinned to the ram *e* is free to move in the slot through the plate. The ram feed is disconnected and the saddle feed engaged, so that the down feed of the ram is controlled entirely by the plate and roller, thus producing the taper on the work. In the same way formed work can be produced by using a plate with a slot of the given form.

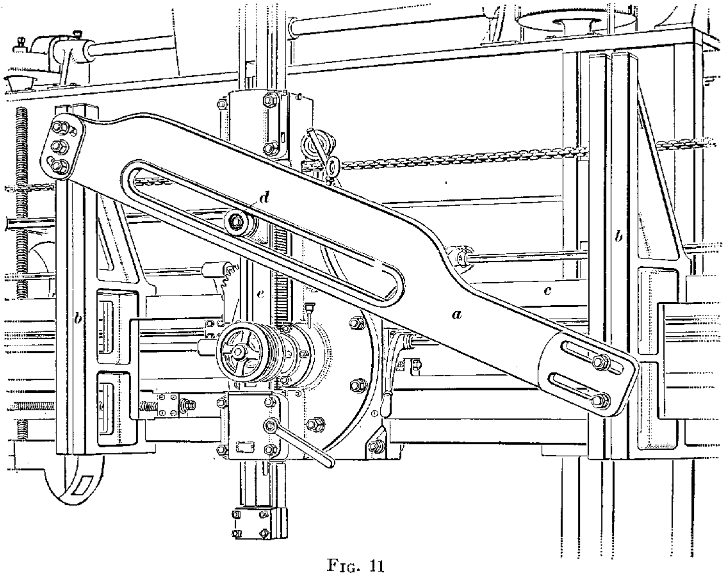


FIG. 11

25. The second method of machining tapers is largely used because no attachments are necessary. Its use is limited, however, to the extent that the ram can be swiveled. The ram is set to the angle or the slope required on the taper and its regular movement is used, either by hand or power, to feed the tool. The setting of the ram requires some care, so that a test should be made of the movement before starting the tool in the work. The setting may be checked by a gauge or by measurement. Sometimes a light trial cut on the work can be made and measured to check the setting of the ram. The graduations on the edge of the base give a close approximation of the angle, in degrees, to which the ram is swiveled.

However, for very accurate tapers, the actual angle moved by the ram should be tested.

26. The third method of machining a taper by combining both feeds of the boring mill can be applied to all tapers. However, in some cases the correct feeds cannot be secured from the change gears of the machine. Another objection is that the calculations involved require the use of trigonometry, a subject with which some operators may not be familiar.

The use of the vertical and horizontal feeds with the ram set vertical is shown in Fig. 12. It is required that the ram *a* turn a taper *b c*. Then it is necessary while the horizontal feed moves the ram a distance *b d*, or *c e*, that the vertical feed moves it a distance *b e*, or *e d*. The easiest problem is the case where the angle *A* of the taper *b c* is 45 degrees, for in this case the feeds *b d* and *b e* must be equal. When the angle of the taper is either greater or less than 45 degrees, it is next to impossible to combine the available feeds of the machine to produce the required angle, unless the ram is swiveled from its vertical position. This combines methods (2) and (3) as mentioned in Art. **23.**

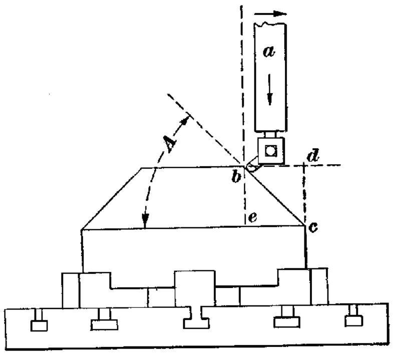


FIG. 12

27. The problem of finding the angle at which to set the ram to machine any angle of taper whatever by using the combination feeds may be solved as follows: In Fig. 13 let *a b* represent the taper of any required angle *A*, and *a c* the down feed of the ram a_1 when set vertical; also, let *c d* = *a e* be the cross-feed of the saddle that will come nearest to producing the desired angle. Then, with the vertical ram, a taper will be turned from *a* to *d* as explained in Fig. 12. The illustration shows that the horizontal feed is not great enough by the distance $d\,h$. Therefore, the ram must be swiveled over, as shown at a_2, to some angle B, so that when feeding downwards a distance $e\,f=e\,d$ its actual vertical feed will be $e\,g=a\,c_1$, and its horizontal feed is $c\,g+g\,f=c\,f$. Under these conditions the point f is on the taper $a\,b$ and will continue so along the whole taper. The value of the angle B to which the ram a_2 must be swiveled may be calculated easily by the methods explained in trigonometry. First, the angle C between the ram and the taper is calculated, and the formula for its value is as follows:

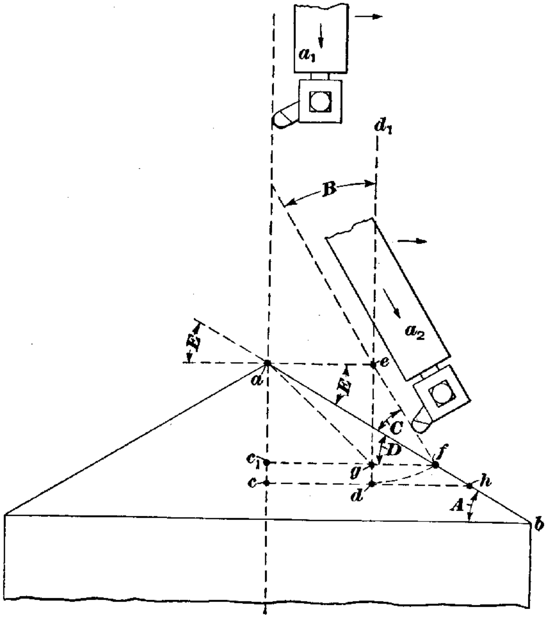


FIG. 13

$$\sin C=\sin A\times\frac{c\,d\ \text{(cross-feed)}}{a\,c\ \text{(down-feed)}} \qquad \textbf{(1)}$$

Note that the angle $A=D=E$, and the values of $c\,d$, $a\,c$, and $\sin A$ are known. Also, the sum of the angles B, C, and A is 90°.

Then, $$\text{angle } B=90°-(A+C) \qquad \textbf{(2)}$$

The derivation of these two formulas is given in the appendix at the end of this Section.

28. The use of these two formulas will be understood from the solution of the following practical examples.

EXAMPLE.—Suppose that a taper having an angle A, Fig. 13, of 30° is to be turned, and that a vertical feed of $\frac{1}{4}$ inch and a horizontal feed of $\frac{3}{16}$ inch be used, at what angle B should the ram a_2 be swiveled?

SOLUTION.—From formula **1**,

$$\sin C=\sin 30°\times\frac{\frac{3}{16}}{\frac{1}{4}}=.5\times\tfrac{3}{4}=.5\times.75=.375,$$

and from the table of sines we find that .375 corresponds to an angle of 22° 1′. Then, for the angle B, by formula **2**,

$$B=90°-(30°+22°)=90°-52°=38° \text{ approximately.} \quad \text{Ans.}$$

Set the ram to this angle and check its motion.

29. Thread Cutting With Feed-Rod Change Gears.—Apart from the threads that can be cut on any boring mill by the use of the regular feeds and table speeds, other threads may be cut on some machines by mounting a thread-cutting attachment in such a way that change gears are introduced in the mechanism that feeds the ram. One form of thread-cutting attachment is shown in Fig. 14, in which change gears operate the feed-rod. It is mounted on the back of the cross-rail near one end. When the attachment is not engaged, power from the drive shaft a is transmitted through the friction clutch b and the bevel gears in the casing c to the upper shaft d, and through the clutch e to the gears in the casing f, which transmit the motion to the feed-rod located in front of the cross-rail. The friction clutch b acts as a safeguard, as it will slip should the machine become overloaded.

To cut threads, the upper clutch e is disengaged and the lower clutch g is automatically engaged by throwing the lever h acting through the short rack i on the pivoted lever j. The motion is now transmitted from the drive shaft a through the bevel gears in the casing k and the clutch g to the gear l, and from this gear to the change gears m, n, and o. The gear o transmits the motion further through the gears p, q, and r to the upper shaft and so to the feed-rod through the gears in the casing *f*. By varying the combination of the change gears *m*, *n*, and *o*, several different pitches of thread may be cut.

The attachment shown in Fig. 14 is used for cutting threads on large pipe fittings, valve bodies, etc., which, on account of their size, can be better handled on a boring mill than on a lathe.

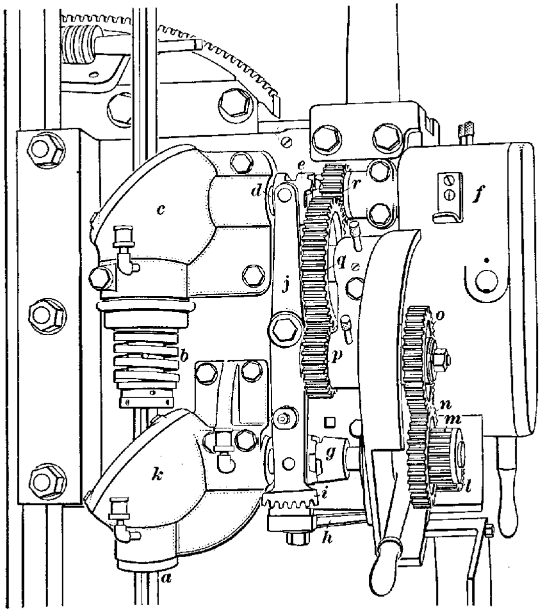


FIG. 14

30. Lead-Screw Threading Attachment.—For very particular work the thread-cutting attachment shown in Fig. 15 may be used. Threading requires multiple cuts, which necessitate reversals or the opening of the lead-screw nut. The nut must then be closed in the right place to return the tool properly to the thread. The lead screw produces a more accurate thread than does the attachment in Fig. 14, and its use is more rapid and convenient for the operator. For ordinary boring or turning operations the ram *a* obtains its feed motion from the feed-rod *b* in the usual way, but when it is desired to cut threads the ram is fed from the feed-rod by change gears driving the vertical lead screw *c*. This is accomplished by throwing the

lever *d*, which engages a clutch that transmits the motion of the feed-rod through change gears in the casing *e* to the shaft *f*. This shaft is connected with the vertical lead screw *c* by spur gears in the casing at the top, and the lead screw feeds the ram by means of the lead-screw nut *h*, which is engaged by the lever *i*. A chasing dial *j* is provided which can be set to the pitch of the thread to be cut, enabling the operator to close the lead-screw nut so that the tool will engage the thread correctly.

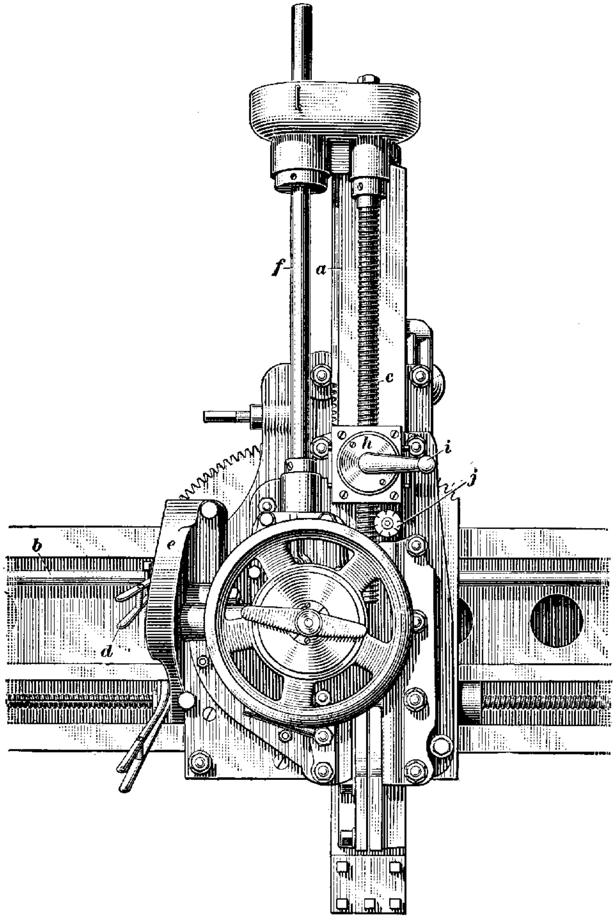


FIG. 15

VERTICAL BORING MILL WITH TURRET HEAD

31. Construction of Vertical Turret-Head Mill.—A type of boring mill sometimes called a vertical turret lathe, combining the features of a boring mill and a turret lathe, is shown in Fig. 16. The main parts of the machine consist of a bed a and a vertical housing that has guides b on which the cross-rail c may be raised or lowered by the elevating screw d. On top of the bed a is the table e, which revolves in bearings similar to the table of a vertical boring mill. The table is provided with **T** slots and is also fitted with three chuck jaws f. By loosening the bolts that fasten the jaws in the slots, the jaws can be moved to any desired position in the slots, or they can be reversed in the slots. The jaws form part of a universal chuck, and may be moved simultaneously by turning the shaft g, or separated by turning the screws h. The gear-box i operated by the levers j and k contains the gearing and clutches necessary to obtain different table speeds.

32. The saddle l, Fig. 16, is gibbed to the cross-rail c and may be moved by hand in either direction along the rail by turning the hand wheel m on the end of the screw n. On the saddle is pivoted the ram slide o, which may be swung around to enable the ram to feed at any desired angle with the vertical. The ram p is gibbed to the slide o, and can be fed upwards or downwards by hand by turning the hand wheel q on the end of the feed-rod r. Power feed for either the saddle or the ram may be engaged by means of the lever s, the amounts of feed being varied by turning a knob at t, which is similar to the one at k_1. The automatic feeds may be reversed by throwing the lever u in the opposite direction. Rapid traverse motion may be given to the ram by engaging the lever v, and to the saddle by engaging the lever w. The lever x locks the ram in the saddle for taking horizontal cuts on work, and the lever y locks the saddle when the ram is feeding downwards. To center the ram with the table the gauge rod z is swung to a horizontal position and the saddle l moved along the cross-rail until it just touches the end of the rod. The cross-rail c may be raised

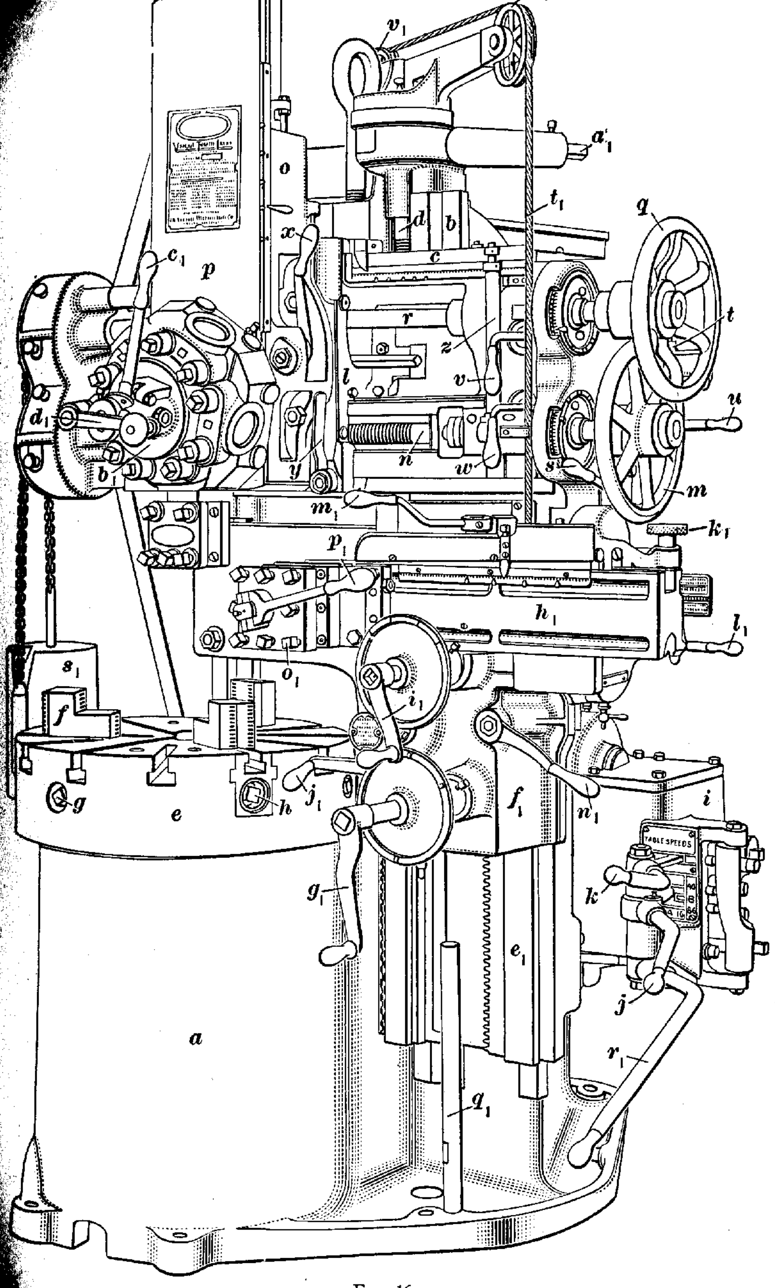


Fig. 16

or lowered by hand by turning the shaft a_1, which is geared to the elevating screw d, after which the rail is clamped to the housing by clamp screws in the rear of the machine.

33. The turret b_1, Fig. 16, is pivoted to the ram p and has five openings for tools. These tools are used for successive operations on the work by indexing the turret, which may be done by loosening the clamping lever c_1 and turning the handle d_1 through one revolution. The guide e_1 is bolted to the bed of the machine and is provided with a rack on its side by which the saddle f_1 may be raised or lowered by hand by the handle g_1. The saddle has a guide for the horizontal ram h_1. This ram may be moved toward or away from the table by hand by means of the crank i_1. Automatic feeds for either saddle or ram may be engaged by the lever j_1, and the amount of feed regulated by the feed-knob k_1, while reverse feeds are engaged by the lever l_1. The ram h_1 may be clamped on the saddle f_1 by the lever m_1 and the saddle clamped on the housing by the lever n_1. At the end of the ram h_1 is the side head, or turret, o_1 containing four tool positions, which may be used in rotation by indexing the turret after unclamping the turret by means of the lever p_1.

34. The operation of the side head o_1 of the boring mill shown in Fig. 16 is independent from that of the main head of the machine and enables the operator to bring two cutting tools into action simultaneously on the work that is clamped on the table. A safety stop-rod q_1 is provided which limits the downward travel of the saddle f_1 and prevents the ram h_1 from striking the table.

The mill is driven by an electric motor placed in the rear of the housing, and may be started or stopped by means of a friction clutch operated by the lever r_1. Moving the lever in one direction starts the machine and moving it in the opposite direction disengages the clutch and engages a brake that brings the table to a quick stop. The weight s_1 counterbalances the ram p on the main head, while the weight of the side head o_1 and the ram h_1 is counterbalanced by a weight at the end of the cable t_1 running over the pulleys u_1 and v_1.

35. Taper Turning on Vertical Turret Head Mill.—Taper surfaces may be machined on the vertical boring mill shown in Fig. 16 by two methods. The first method consists of swiveling the ram either to the right or to the left of the vertical position, similar to the method employed for turning tapers on a vertical boring mill, as explained in Art. **23.** Another method, illustrated in Fig. 17, is by the use of the side head. On a plate a fastened to the machine housing is mounted a slide b, which is free to move up or down on the plate a and may be clamped by the clamps c. The slotted disk d, which is graduated in degrees on its outer rim, can be swiveled in such a way that the slot may be placed at the desired angle of taper,

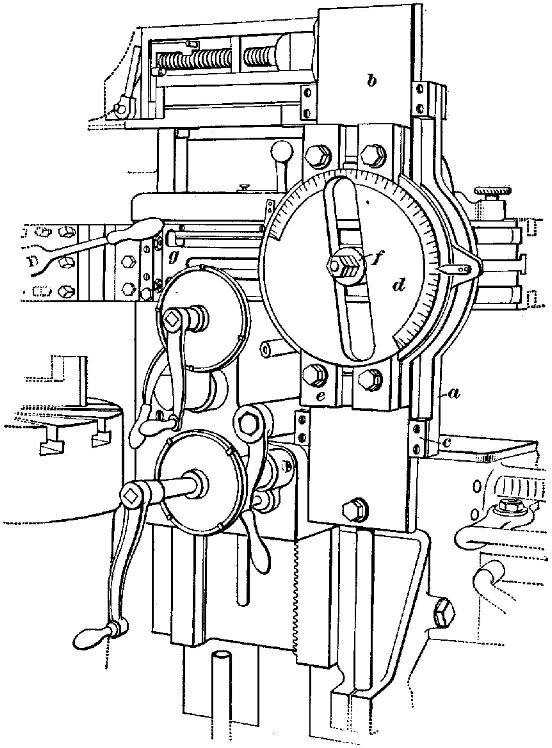


Fig. 17

after which the disk is clamped by the screws *e*. The roller *f* is bolted to the ram *g*; thus, when the horizontal feed to the ram is disconnected and the vertical feed engaged, the roller will follow the shape of the slot, and the tool in the ram will reproduce the angle of the slot on the work.

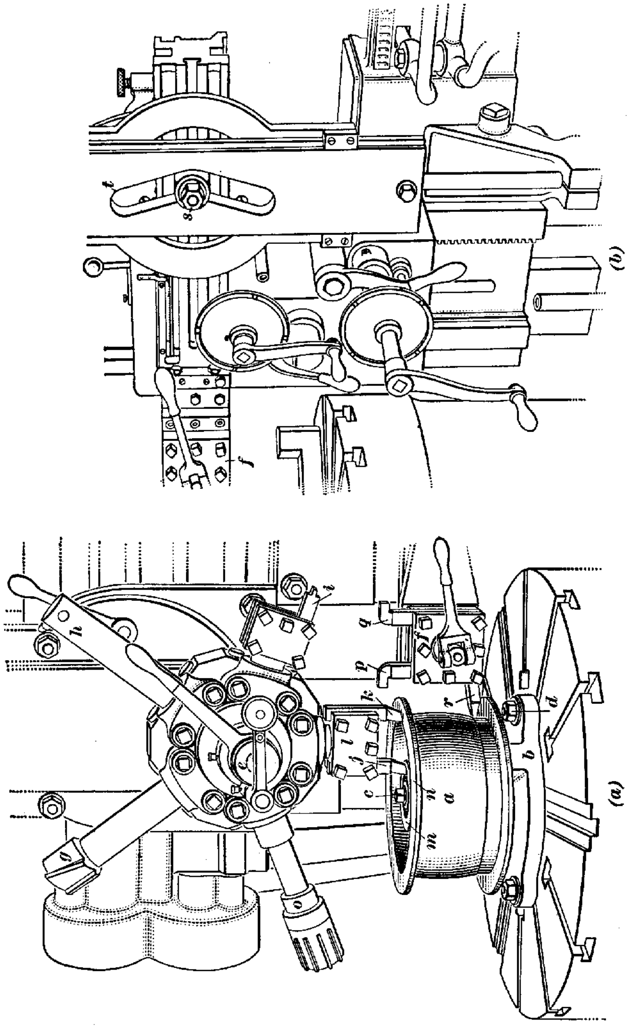


FIG. 18

36. Boring and Crowning Pulleys on Vertical Turret Head Mill.—In Fig. 18 is shown a flanged pulley being bored and crowned, and its flanges machined. The lower flange of the pulley *a* is clamped to a fixture *b* that is fastened to the table by the bolts *d*. The tools on the vertical turret *e* operate on the pulley independently from those on the side turret *f*. The first operation is to run the four-lipped drill *g* through the hub. The remaining stock is removed to within a few thousandths of an inch by the boring tool *h* having a power feed. The edges of the flange *n* are next rounded by the radius tool *i*, after which the tools *j* and *k* in the holder *l* face the hub *m* and the flange *n*. The final and exact finishing of the bore is done by using the reamer *o*. The bolt *c* is put through the bore to clamp the pulley to the fixture *b*, and the outside clamps that were used to hold the pulley to the fixture while boring the hub are removed.

37. By indexing the side turret *f*, Fig. 18, a quarter turn, the tools *p* and *q* are thereby brought in position to machine the inner faces of the flanges of the pulley. The turret is then indexed again to enable the tool *r* to machine the crowned face of the pulley with the aid of a special attachment that guides the tool over the crowned surface. The attachment is mounted on the side rail of the boring mill and operates on the same principle as the attachment shown in Fig. 11. The roller *s*, Fig. 18, is guided in a curved slot in the plate *t*, and accurately reproduces the shape of the slot on the face of the pulley.

After the foregoing operations have been completed, the pulley is turned over and the hub and the flange are machined on the opposite side by the tools *i*, *j*, and *k*, Fig. 18.

38. In Fig. 19, views (*a*) to (*e*) inclusive, is shown the order of the machining operations performed on a spur-gear blank *a*. In (*a*) a roughing cut is taken across the face of the hub and the rim of the blank, in the direction of the arrow, with the tools *b* and *c* fastened in the face *1* of the turret, at the same time that the tool *d* in the side turret *e* is machining the outside surface *f*, using the vertical feed of the side ram.

In (*b*) the finishing cuts are taken over these two surfaces by the finishing tools held in the face *3* of the turret, and by the tool *g* in the side turret, respectively. The boring tool *h* held in the face *4* of the turret next is used to bore the hole in the hub of the blank to the exact size and true with the face, as shown in (*c*).

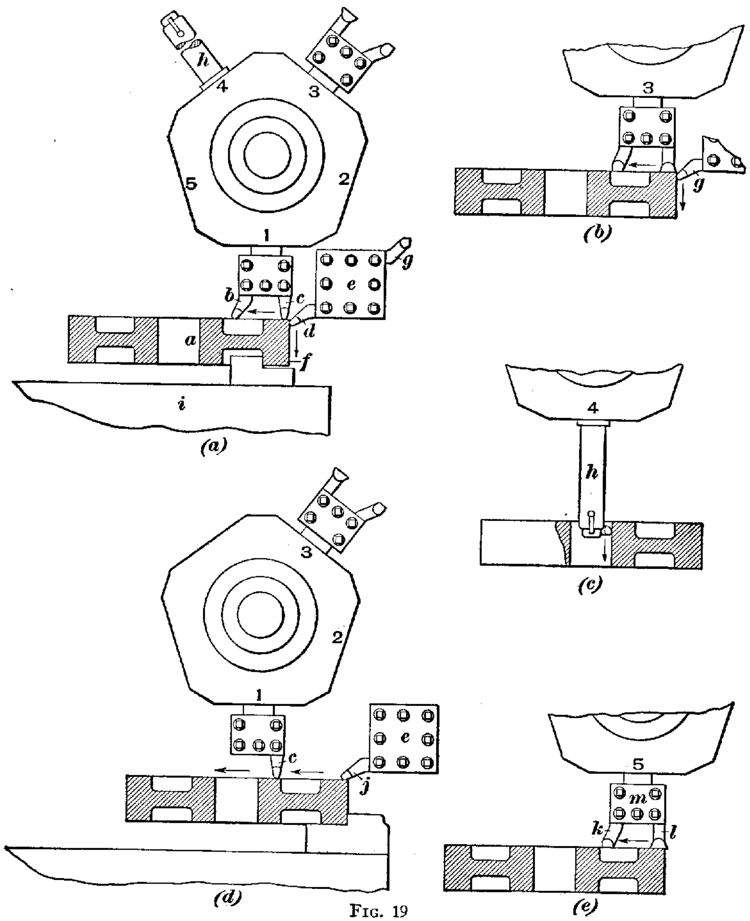


FIG. 19

The three operations shown in views (*a*), (*b*), and (*c*) are performed with the blank held in the chuck *i* by jaws which grip the inside rim of the blank. For the operations on the opposite side of the blank, it is turned over and held by the chuck jaws on the outside of the rim, as shown in view (*d*). The tools *c* and *j*, fastened in the tool holder on the turret face *1* and in the side turret, respectively, are used to rough-face the hub and the rim of the blank, and in (*e*) these surfaces are finished by the tools *k* and *l* held in the tool holder *m* on the face *5* of the turret.

HORIZONTAL BORING-MILL WORK

39. Operations on Horizontal Boring Mill.—Horizontal drilling operations are so closely associated with horizontal boring that they will be considered together. Nearly all horizontal boring machines are designed for drilling, boring, and milling, the spindle being designed for any of these operations. As all holes to be bored must be previously drilled or cored, to form an opening through which the boring bar passes, an arrangement permitting the drilling and boring at one setting of the work is economical.

Small holes, up to about 2 inches in diameter, are usually drilled, and a machine that will do both the drilling and the boring with one setting saves a large amount of time. Resetting, or moving to another machine, frequently takes more time and requires a larger number of men than the drilling or boring, and in the meantime the machine is standing idle and the additional service of a power crane is often necessary. For the same reason it is an advantage to be able to perform a milling operation at the same setting. These three operations require practically the same spindle action, and can, therefore, be carried on in the same machine. It is economy to have machine tools so arranged that the greatest possible amount of work may be done with one setting. This should always be borne in mind when selecting and arranging machines, as well as in their operation.

40. Construction of Horizontal Boring Mill.—One form of horizontal boring machine is illustrated in Fig. 20. The machine has a heavy base, or bed, *a* to which is bolted the vertical column *b* on the ways of which the head *c* is gibbed.

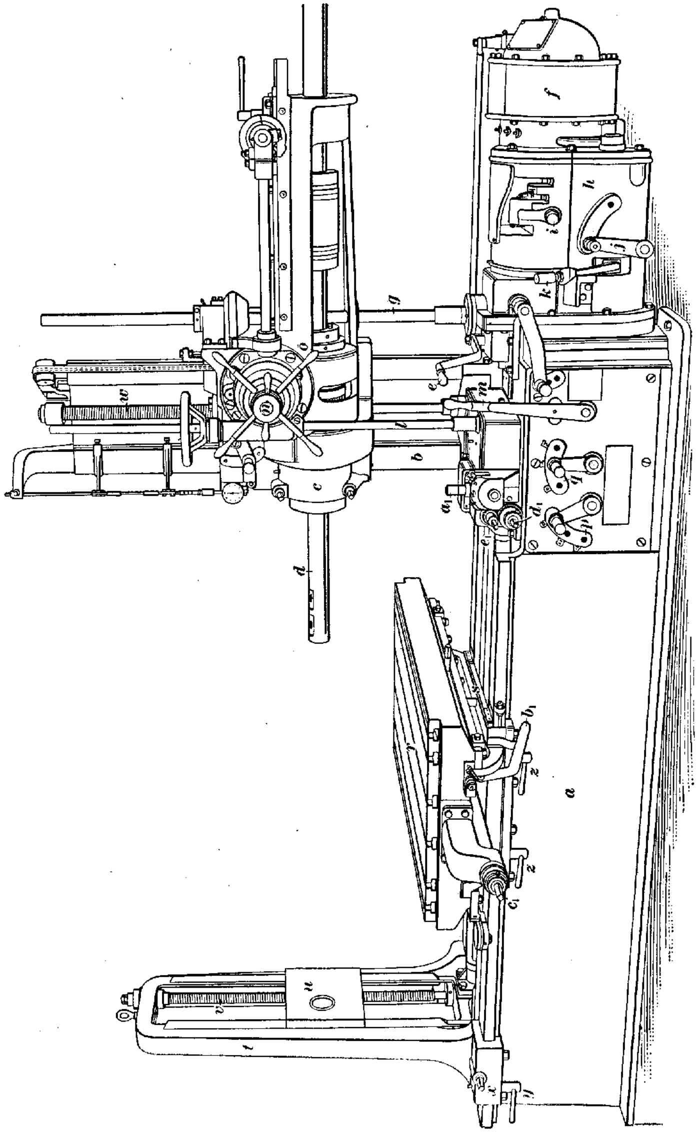


Fig. 20

The head is free to slide up or down on the ways by power or hand feed, and contains the spindle *d* in which the cutting tools or boring bars are carried. The machine is started or stopped by the lever *e*, which throws the switch on the motor *f*, the motion being transmitted to the spindle by the vertical shafts *g*. Several changes in spindle speed may be obtained by means of change gears in the speed box *h* operated by the levers *i* and *j*, while the direction of motion of the spindle may be reversed by the lever *k*.

The spindle is provided with automatic feed, which is transmitted from the driving mechanism through the shaft *l*, and engaged by throwing the lever *m* and tightening the clutch lever *n*. When the levers *m* and *n* are both disengaged, the spindle may be fed in or out by hand by turning the hand wheel *o*, mounted on the same shaft as a pinion that operates a rack fastened to the spindle. The amount of automatic spindle feed may be varied by manipulating the levers *p* and *q*, according to directions on an index plate. These levers control the position of several sliding gears inside the base, through which the feed motion is transmitted.

41. The work is fastened on the table *r*, Fig. 20, gibbed to the saddle *s* on which it is free to move by hand or power feed. The saddle is gibbed to the ways on the bed and may be moved along the ways by hand or power feed. The yoke *t* contains the bearing *u*, which forms a support for the outer end of the boring bar. The bearing moves up or down in the yoke simultaneously, and a corresponding amount, with the head *c*, through the action of shafts and gears that interconnect the elevating screws *v* and *w* of the bearing and the head, respectively. The yoke *t* is gibbed to the ways on the bed and may be moved along the bed near the work, to prevent any unnecessary spring of the boring bar, by turning the screw *x*. The yoke is locked to the bed by the clamp bolts *y* that fit in the **T** slots of the bed. Likewise, the saddle *s* may be locked to the bed by the clamp bolts *z*.

To engage the automatic feed for either the saddle *s*, head *c*, table *r*, or spindle *d*, a selector lever a_1 is used. When this lever is set for any of the parts named, and the feed-lever *m* engaged, that part will feed automatically. The lever *m* has one neutral and two running positions, one of which engages the feed and the other the rapid traverse for any of the four parts named. The power feed for the table *r* across the saddle may be automatically engaged by a lever b_1, which is tripped in any desired position of the saddle along the bed by an adjustable dog. The table *r*, the saddle *s*, and the head *c* may be fed by hand by turning the screws c_1, d_1 and e_1, respectively.

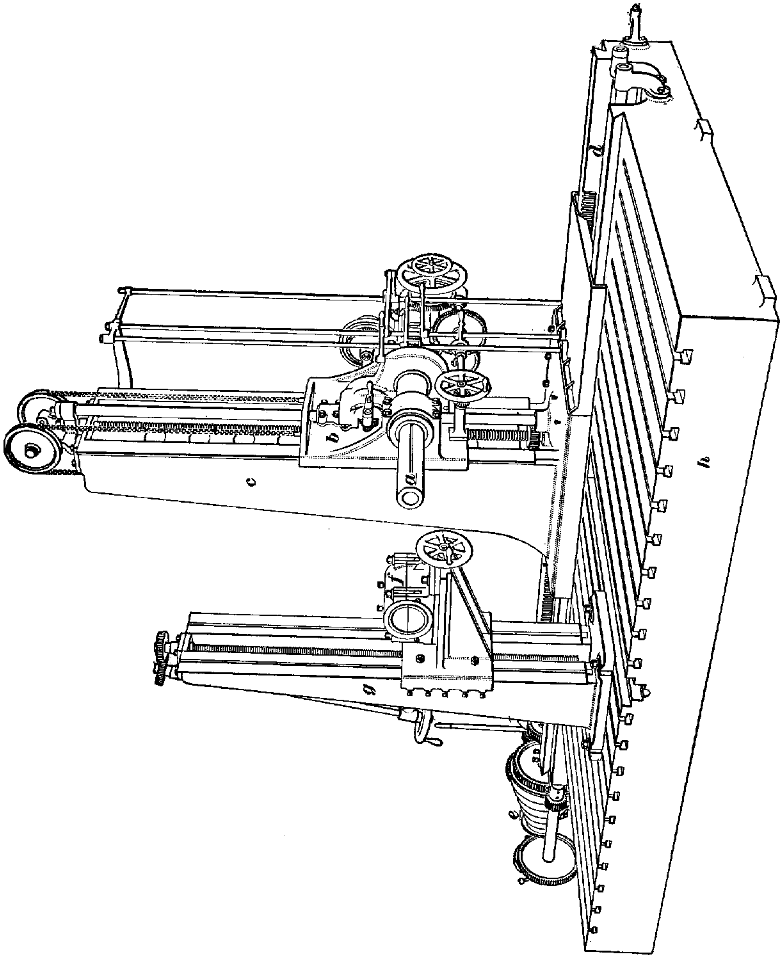


FIG. 21

42. Horizontal Floor Mill.—A type of horizontal boring, drilling, and milling machine, known as a horizontal floor mill, that is used quite extensively in shops doing heavy work is illustrated in Fig. 21. The boring bar *a* and feed mechanism are carried in a head *b*, supported on a column *c*, which, in turn, rests on the bed *d*. The power is transmitted to the machine through the cone pulley and back gear at *e*, and is carried by means of shafting and gears to the boring bar. The machine is so constructed that the head may be moved vertically on the column, and the column horizontally on the bed, while the boring bar moves in and out through the head.

The work is set on a floor plate *h*, which is provided with T slots, as shown. The outer end of the boring bar is supported in a bearing *f* mounted on the column *g*, which rests on the floor. The column and bearing may be moved to any location on the floor plate and adjusted to any desired height.

The floor plate of this type of machine is sometimes made very large, so as to accommodate very large work or more than one machine. A good arrangement consists of two machines set at right angles to each other, the one being of a heavy class designed principally for boring large diameters, while the other is somewhat lighter and is especially adapted for drilling and small boring operations.

43. Boring on Horizontal Mill.—Boring is done on a horizontal boring machine by supporting, independently of the piece to be bored, a bar that carries one or more cutters. The center of the bar thus forms the center of the bored hole independently of the center of the original hole. When the center of the new hole does not correspond with the center of the original hole, the heavy cut on one side will cause the bar to spring and the hole will be neither perfectly round nor straight. One or two light cuts after the roughing cut has been taken usually true it up. When the cut is uneven or when the hole must be bored very accurately, provision should be made for a finishing cut by using a roughing cutter set to bore a hole slightly undersize.

44. Single-End Boring Bars for Horizontal Mills.—Four kinds of boring bars are used in horizontal boring mills; namely, *single-end bars, traveling bars, bars used on centers,* and *traveling-head bars.*

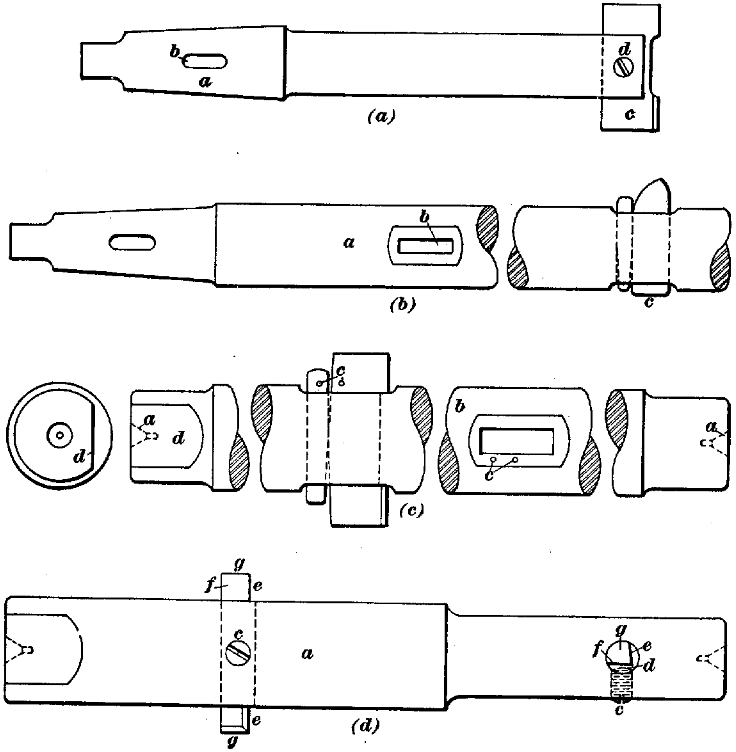


FIG. 22

The holes in the work to be bored sometimes do not pass clear through the part to be bored and are known as *blind holes.* When this is the case it is, of course, impossible to support the boring bar on more than one end. The single-end bar shown in Fig. 22 (*a*) is used to bore blind holes. The shank *a* is tapered to fit the machine spindle and usually has a slot *b* through which a key may be driven to hold the bar in the spindle. The outer end of the bar is slotted, and a cutter *c* is secured in it by the setscrew *d,* which enters a drilled spot on the cutter. The friction between the shank and socket, the key, and the tang act as drivers. Single-end bars are generally made very short, so that they will be rigid. They are seldom used to remove more than a few inches of metal.

If holes must be bored very accurately, a set of cutters, consisting of one or two roughing cutters and a finishing cutter, is made. These are run through in succession to true and size the hole. If desired, the hole may be bored nearly to size and be finished by reaming. When cutters are made in sets they are always marked for the bar and slot in which they fit and are numbered in the order in which they are to be used.

45. Traveling Boring Bars.—Many of the horizontal boring mills depend for their feed on a spindle fed lengthwise through the head of the mill, and the boring bars used on them are known as traveling boring bars. The traveling boring bar shown in Fig. 22 (*b*) is made with a cylindrical body *a* having a number of slots *b* cut at various points in its length. Single-end and double-end cutters are keyed in the bar, as shown at *c.* When single-end cutters are used, they are adjusted to take a number of light cuts to true the hole. When double-end cutters are used, they are adjusted to cut on both ends. The traveling bar is held in the spindle by the taper shank and driving key and the tang. The outer end of the bar is supported by a closely fitting bushing in an outboard bearing. This bearing is carried on an upright support or in a yoke on the machine. The bar is turned straight, that is, to the same diameter throughout, so that it can feed freely through the supporting bearing, which is adjusted to the same height as the spindle axis, and in line with it.

Boring bars are frequently made with a slot near each end and one in the middle. These bars are usually made a little longer than twice the length of the part they are to bore. When boring with the cutter in the middle slot, the tool will then just clear the hole. The slots near the ends of the bar are used for facing, as there will be less tendency to chatter when the bars are supported close to the cutters.

46. Boring Bars Used on Centers.—When used on some types of boring mills, the boring bar is centered at the ends, as shown at *a* in Fig. 22 (*c*). In operation, it is driven by a lathe dog or a clamp. Single-end cutters held by a key are commonly used in boring bars. The double-end cutter, made to fit the bar, as shown at *b*, is also frequently used. The double-end cutters are trued in the bar by turning. Prick-punch marks *c* are then made on the boring bar, cutter, and key, as shown. When removed and replaced in position, the cutter and key are always inserted so that the prick-punch marks will be located in the same relative positions. A flat *d* is milled on the end of the bar to which the dog, or clamp, is attached.

When a boring bar is much smaller in diameter than the hole to be bored, a casting, known as a cutter head, slightly smaller than the hole is often secured on the middle of the bar. The tool is then secured to the side of the cutter head by clamps and capscrews.

47. A form of special boring bar used to bore two holes of different diameters but located in line is shown in Fig. 22 (*d*). This bar is made to be used on centers but may also be made with a tapered shank. The bar *a* is drilled as shown to receive the cutters, which are made of round tool steel and held in place by setscrews *c* that enter holes spotted in the drill point as shown at *d*. When the cutters are so spotted they will not slip when the setscrews are tightened. The cutters, when set, are turned to the required outside diameter and squared up on the cutting side as shown at *e*. Corresponding marks are then made on the cutters and bar, the cutters are removed, the face *f* is filed flat, and clearance is filed on the faces *e* and *g*.

Boring bars of this kind are generally used when a number of the same kind of pieces are to be bored. The cutters are run through in regular order, the first, or smaller, cutters taking the roughing and truing cuts; and the others, or larger cutters, taking the finishing cuts, which prepare the holes so that they may be finished by reaming. This type of bar could, of course, be made with rectangular slots as shown in Fig. 22 (*c*). In that case, the cutters would be secured in place by keys.

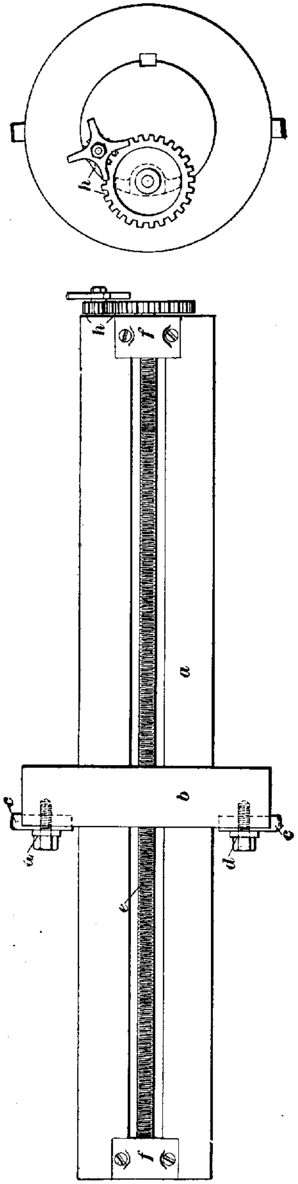


Fig. 23

48. Traveling-Head Boring Bar.—The traveling-head boring bar, one form of which is shown in Fig. 23, is one in which the head holding the cutting tool is traversed along the boring bar. It is used to bore holes of comparatively large diameter, and is mounted on centers and driven by a dog or a clamp. The bar *a* is usually made of cast iron, cored out so as to furnish the greatest stiffness with the least weight. The traveling-head bar is made just enough longer than the length of the holes to be bored so that the boring head *b* will clear either end. The head *b* is bored to fit the bar and turned on the outside to a diameter somewhat smaller than the diameter to be bored. One or more boring tools *c* are let into the head, as shown, and are held in place by the straps and tap bolts at *d*.

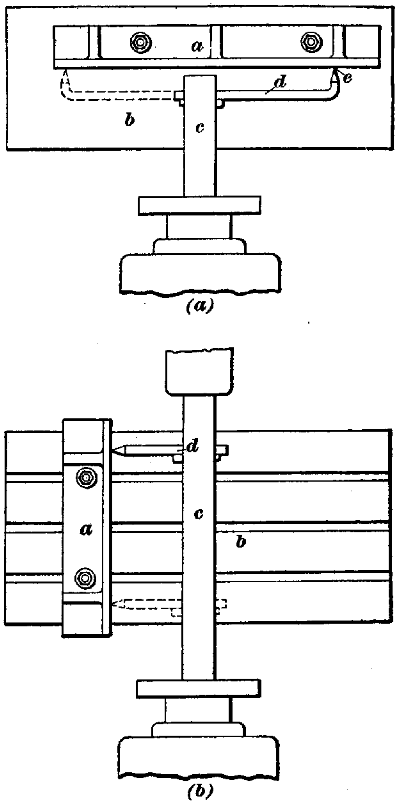
49. The boring head *b*, Fig. 23, is traversed by means of a screw *e*, in a slot in the side of the bar, and a nut on the inside of the head. The slot is made large enough so that the nut is free to travel from end to end as the screw is rotated. The head is rotated with the bar by means of a key in the head and a spline that runs the entire length of the bar. The screw is supported at each end by the bearing *f* and is rotated with reference to the bar by means of a star feed that acts through the gears at *h*. As the bar revolves, each point of the star comes in contact in turn with a pin secured to a support that is attached to the machine in any convenient way, thus causing the rotation of the star. The movement of the star is transmitted to the boring head through the gears and screw as shown.

If a large boring head is used it is an advantage to use three or four roughing tools at different points in the circumference for light cuts. Several tools balance each other, and by their use the hole may be roughed out quickly, as the strain on each tool is much less than it would be on a single tool removing the same amount of metal. The finishing should be done with a single tool, as the bar will then spring less, and by taking a number of light cuts with a single tool a true hole will be produced.

50. Setting Work and Tools.—The work, which is set on the cross-table, or carriage *r*, Fig. 20, can be drilled and bored in one position, then moved to another position and the operation repeated without resetting. The work is fastened on the table precisely as it is on a drilling machine, and care is taken to have the center line of the hole in perfect line with the center of the spindle.

51. Setting by Tramming.—The work, angle plates or other fixtures may be set square with the spindle by tramming. To do this, the work or fixture *a*, Fig. 24 (*a*), is first set on the table *b* approximately square with the boring bar *c*. A bent bar, rod, or wire *d* is then keyed in the boring bar so that its point *e* will project toward the surface to be squared. This surface and the tram point are then moved toward each other until a feeler such as a slip of paper is held lightly between them. The point of the tram is then moved up and down over the paper to determine the pressure. The boring bar

is now turned half a revolution so that the tram is in the position shown by the dotted lines and the feeler is inserted between the tram point and the work. If the feeler is not held as at first, the work is adjusted according to the indications and another test made on each side. These adjustments and tests are continued until the feeler is held between the tram point and both sides of the surface with the same pressure.



(a)

(b)

FIG. 24

52. Setting by Lining. The operation of setting the work or the angle plate, or other fixture, parallel to the spindle of the mill is known as lining. An angle plate may be set parallel to the boring bar by adjusting the plate and measuring from the bar *c*, Fig. 24 (*b*), to the face of the angle plate *a*. One way to line the plate is to key a pointer *d* or an indicator in the bar and move the table so that the end of the pointer will just come in contact with the face of the plate as the bar is rotated back and forth. The pointer is then moved to the other end of the angle plate, as shown by the dotted lines, by shifting the table *b* or by moving the spindle or bar endwise. The test is then repeated and the angle plate adjusted until the pointer touches the face with the same pressure at both ends. A feeler is best for testing the degree of contact between the pointer and the angle plate.

53. Setting to Layout.—Work requiring one or more holes bored in it is laid out by drawing intersecting lines as *a a* and *b b*, Fig. 25, to locate the center of the hole or holes. The centers are located on the surface, if the stock is solid; but if it is cored, the center is located on a triangular piece of tin *c* bent down at the corners and driven into a strip of wood *d* previously driven in the cored opening. The surface of the work is then chalked and from the center of the required hole a circle *e*, whose diameter is equal to that of the finished hole, is drawn on it.

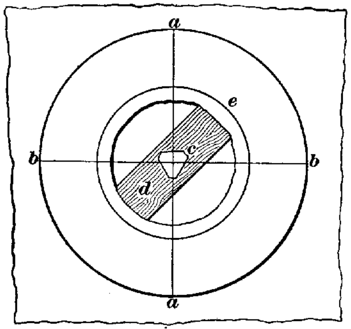


Fig. 25

The work is next secured against an angle plate or a parallel and the boring bar is put in position after the holes have been rough drilled, if not cored. The final adjustment is then made by securing a bent pointer *f*, Fig. 26, in the boring bar and bringing it nearly in contact with the surface of the work. The bar is slowly revolved and the distance the pointer is from the circle at various points is noted. Adjustments both vertical and horizontal are now made until the pointer follows the circle exactly. The pointer is then replaced by a cutter and the hole is bored, taking several cuts. It is well when near the finished size to note whether the bored hole is true with the circle. If it is not, a slight adjustment of the work may be necessary so the hole will be true with the circle.

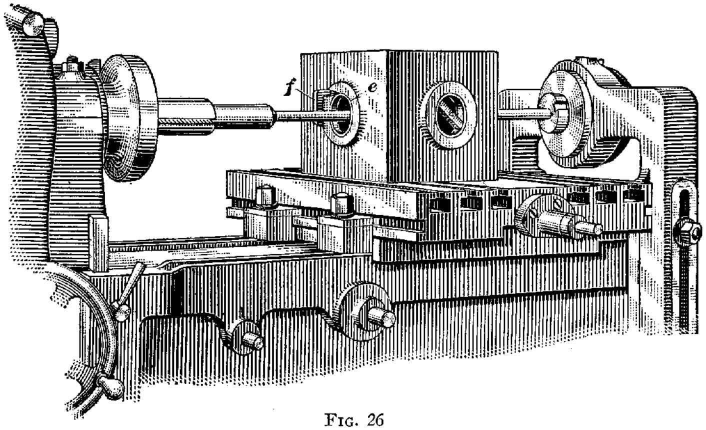


Fig. 26

54. Example of Vertical and Horizontal Adjustments. It is frequently required to bore a group of holes at certain fixed distances from each other and from a center line. An example of boring work of this nature is shown in Fig. 27. Here, the work is set up to bore the top hole. The circles locating the holes are first laid out in the usual way. The top hole *a*, in this case, is bored first and the table is then raised the required amount to bore the lower holes, all the backlash in the elevating mechanism being taken up. If, however, the boring head were adjustable vertically, the lower holes would be bored first and the head would then be raised to bore the other holes. In this way, the backlash would be taken up.

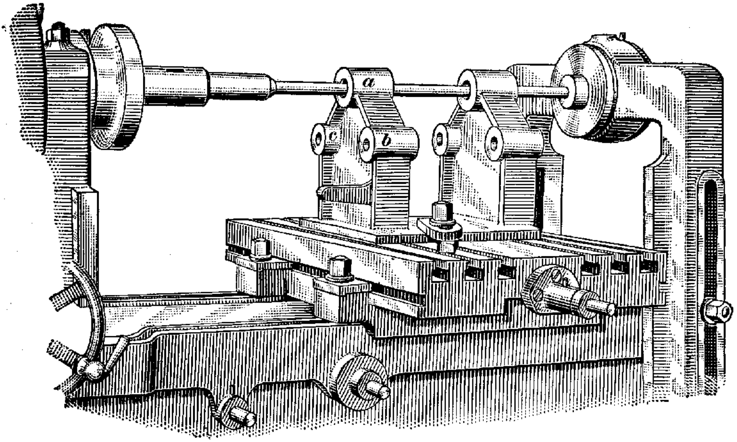


Fig. 27

55. When the top hole *a*, Fig. 27, is to be bored first, the work is lowered so that the center of the top hole is slightly below the center of the boring bar and then raised so that the height of the hole is the same as the measured or gauged distance of the boring-bar center above the table. The table is next fed crosswise to bring the bar central with the boring circle, and the hole is bored to size. The bar is then removed and the table raised the exact distance that the lower holes are to be below the upper ones. The cross-table is then fed crosswise the required distance, and, by taking up the backlash, adjusted to bore the hole *b*. After gauging and checking the distance the table is moved, the hole *b* is bored to size.

The example in Fig. 27 shows another hole *c* on the other side of the center line. The setting for it may be made by feeding the table slightly beyond where it stood to bore the hole *b* and bringing it back to take up the backlash. The cross-table is then adjusted so that the cutter will just scrape in the hole *b*, after which the bar is removed and the table fed crosswise, the required center-to-center distance from the hole *b* to the hole *c*. To facilitate the adjustment of the boring-mill carriage, stops are often bolted to the side of it and the distances between them and the saddle are measured. If the cross-feed screw has a graduated dial, this adjustment may be made with it and checked by measuring or gauging. The hole is then bored and reamed. If there are other holes or groups of holes they are located and bored in a like manner.

56. Milling on Boring Mill.—The milling done in horizontal boring machines is similar to that done in the heavier types of milling machines. Solid cutters are used for the smaller work, and large inserted-tooth cutters, resembling the heads used on rotary planers, are usually employed in facing large surfaces. The horizontal boring machine is especially well adapted for facing irregular surfaces, the horizontal and vertical feeds being so arranged that either one or both may be thrown in at the same time, thus permitting any path within the range of the machine to be followed. The inserted-cutter end mill having a taper shank, which is held in the spindle, is probably the most used for milling on the boring mill, though other work such as dovetailing and **T** slotting are often done. The **T** slots are roughed out to the required depth with plain end mills and finished with regular **T**-slot cutters.

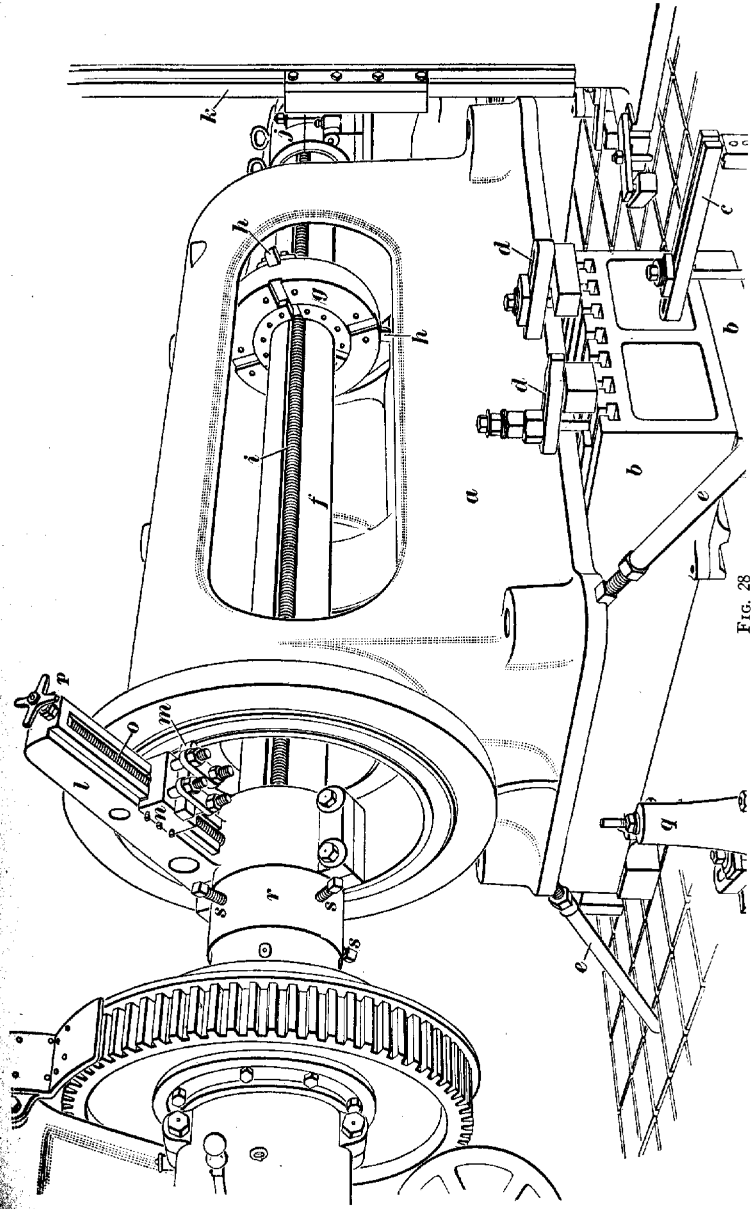


FIG. 28

The single-end bar shown in Fig. 22 (*a*) is often used for dovetailing or undercutting, suitable inserted-tooth cutters being used.

57. Setting and Fastening Work.—The same principles used in securing the work on the tables of planers and vertical boring mills apply to horizontal boring mills as well. It is necessary to set the work perfectly level, and to line up the center line of the proposed hole with the center line of the boring bar. Parallels and blocks, or wedges, are used to raise the work a suitable height, and to level it up. Care should be taken to set the work so it cannot be sprung, and, when properly set, clamps are applied, as shown in Fig. 28.

In Fig. 28 is represented an engine bed set on a large floor plate and being operated on by a traveling-head boring bar driven by a large horizontal boring machine. The bed *a* is mounted on parallels *b*, near each end of the bed, which are clamped to the floor plate by means of the clamp *c*, and the bed is clamped to the parallels with the clamps *d*. A pair of pipe jacks *e*, running out from the corners, as shown, guards against both side and end motion. A duplicate set of parallels, clamps, and jacks, at the other end, which is not shown, holds the bed rigidly in place.

58. Arrangement of Boring Bar, Cutter, and Facing Head. In Fig. 28 are shown the boring bar *f*, the boring head *g* with two tools *h* in position, the traversing screw *i*, the outer bearing *j* with the front of its supporting column *k*, the facing head *l* with the tool *m* clamped on the tool slide *n*, the feed-screw *o*, the star *p*, and the star feed-post *q*, the last being bolted to the floor plate.

The boring bar is connected to the spindle by means of a special socket *r*. One end of the socket fits the spindle and the other end is bored out to receive the boring bar, which is gripped and held central by means of four setscrews *s*. The illustration shows a typical piece of work for this class of machine, and the usual method of supporting and holding it. The work is faced true with the bore by the facing head, which is secured to the bar after the boring is done. The

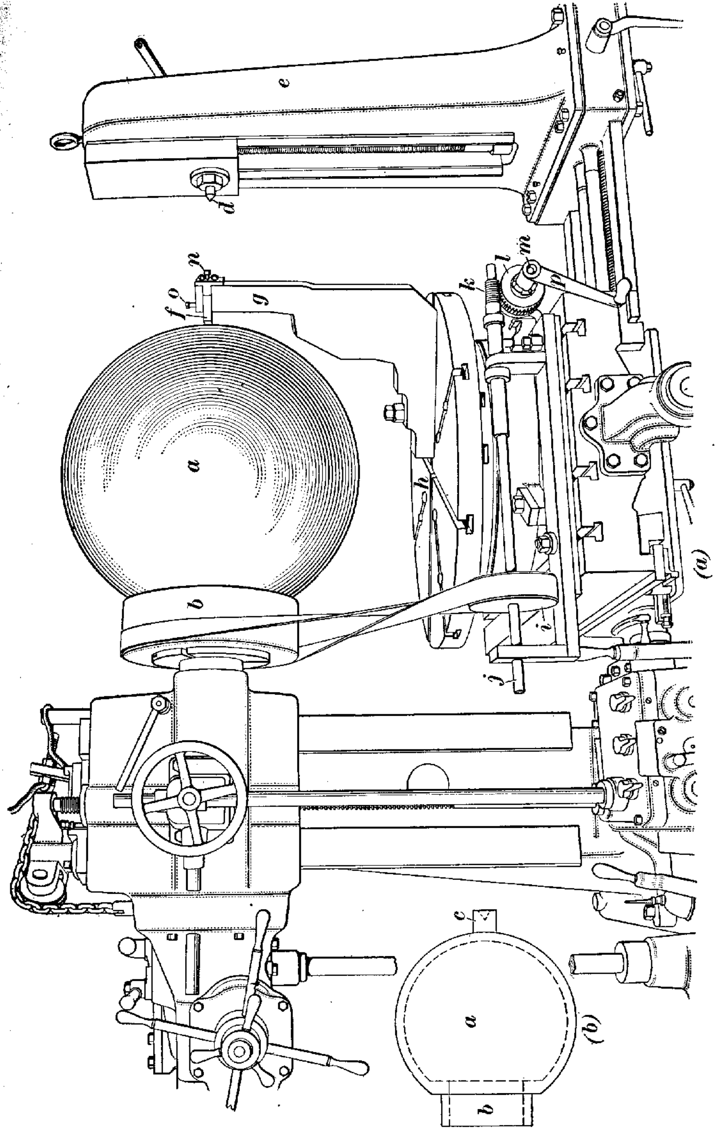


FIG. 29

body of the facing head *l*, Fig. 28, can be attached to the boring bar at either end of the work by means of the cap and bolts shown, and the cutting tool will feed in or out, depending on whether the feed-post *q* is clamped on the right- or the left-hand side of the bar.

59. Turning Spherical Work on Horizontal Boring Mill. Spherical work may be turned in a horizontal boring mill in the following manner: Suppose it is required to turn the casting shown in Fig. 29 (*a*), which has the form of a hollow sphere *a* having a cylindrical projection *b* at one end. In order to turn the spherical part of the casting, it is convenient to cast a center support *c* on the side opposite the projection *b*, as shown in view (*b*). The casting is mounted in the machine by fitting the projection *b* over an expanding sleeve on the spindle, and running the dead center *d* on the support *e* into the center hole drilled in the lug *c*. The cutting tool *f* is held in a holder *g*, which is mounted on the table *h* in such a way that when the table is made to revolve the point of the tool is at the correct distance from the center of the table to cut the desired diameter of the sphere. The table mechanism is so arranged that it will revolve automatically when the spindle revolves, but at a much slower speed. This is accomplished by using the projection *b* on the casting as a pulley for driving another pulley *i* on the shaft *j* by means of a belt.

The shaft *j* has a worm *k* that meshes with a worm-wheel *l* mounted on a shaft *m* which is geared to the table, thus causing it to revolve when the spindle revolves.

60. The feed of the cutting tool *f*, Fig. 29 (*a*), is adjusted by the screw *n*, after loosening the clamping screw *o*. When the machine is started and both the work and table are revolving, the tool will travel along the horizontal circumference of the sphere in the same way that a lathe tool travels along the length of a piece of work held between centers. Generally, one cut is sufficient to finish the sphere, but if it is necessary to take more than one cut, the tool is brought back to the starting position by hand by disengaging the worm-wheel *l* from the worm *k* and turning the shaft *m* by means of the handle *p*. If the casting is very heavy it is best to support it by a block of wood hollowed out to the same diameter as that of the sphere. The block is placed directly under the sphere and firmly fastened to the table. The finishing operation consists in cutting off the lug *c* from the casting, which can be done by filing, after which the surface is scraped to a finish. The lug may also be removed by the use of a cutting tool, as shown in view (*a*), after the dead center *d* has been withdrawn from the work.

61. When it is required to turn a complete sphere, the casting may be held by the aid of the chuck shown in Fig. 30 (*a*). It is countersunk to receive the sphere and is fastened to the spindle sleeve, and has three holes *a* for bolts to support the sphere. This allows the greater part of the casting to be machined, after which it is turned around through 180 degrees and again fastened to the device, three holes 180 degrees from the first holes being used. In this way the whole surface of the sphere may be finished. The bolt holes in the casting are afterwards plugged and the sphere is completed by cutting off

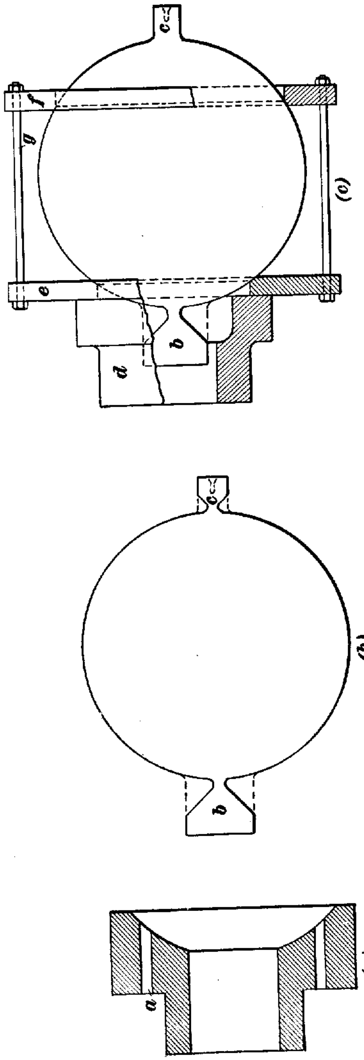


FIG. 30

the plugs even with the surface and scraping and filing to an even finish.

62. If it is not permissible to drill holes in the casting for holding it to the spindle chuck it will be necessary to cast two lugs at opposite points, as shown in Fig. 30 (*b*). The large lug *b* is clamped in a chuck screwed on the spindle and the lug *c* is supported by a center. The greater portion of the sphere can be finished this way. By supporting the sphere by a wooden block, as explained before, the lugs can be cut in by the tool until they barely support the sphere, after which the work may be taken from the machine and the lugs removed by a file. As the lug *b* that is supported in the chuck is usually too large to be removed by filing, it may be cut off by a tool, as heretofore described, after clamping the sphere in the chuck illustrated in view (*c*).

The projection *d* of the chuck fits the spindle and is countersunk to admit the sphere as shown. The ring *e* is fastened to the chuck by screws. The sphere is then firmly drawn up in place by slipping a second ring *f* over it and holding this ring to the ring *e* by tie-bolts *g*. A few adjustments are generally necessary to make the sphere revolve true, after which the outside lug can be turned off. The other lug is then located on the outside and turned off in the same way.

SPECIAL BORING MILLS

CYLINDER BORING MILLS

63. Setting Cylinders for Boring.—Engine, pump, or other cylinders of large sizes in which a reciprocating piston must operate should always be bored in the position in which they are to be used. The cylinder of a vertical engine should be bored standing on its end, while the cylinder of a horizontal engine should be bored in a horizontal position. In large cylinders, especially, there is considerable spring due to their weight, which will tend to produce an oval shape when a cylinder that has been bored in a vertical position is laid on its side, or when a cylinder bored in a horizontal position is set on end. When the boring is done in its working position, this error is practically prevented.

64. Finishing Cut.—The working surface of the cylinder should be very carefully bored so that it will be cylindrical. There is some difference of opinion as to the best course to pursue to attain this end. Some persons claim that the finishing cut should be taken with a square-nosed tool so that the surface will be perfectly smooth; others prefer a rounded diamond point, the claim being made that the narrow point is less affected by unevenness in the structure of the metal, and that the slight ridges formed tend to reduce the amount of metal in actual contact, and are an advantage rather than a detriment. The slight ridges also tend to draw the oil under the piston, thus affording better lubricating conditions.

All shopmen agree that, whatever tool is used for the finishing cut, it should run *continuously* from one end of the cylinder to the other. The heating due to the action of the tool causes enough expansion that even a short stop will leave a noticeable ridge, and long stops make it necessary to bore the whole length over again. For this reason, cylinder-boring machines should be run by an independent engine or other motor.

65. Corliss Engine Cylinder-Boring Mill.—A horizontal mill for boring large Corliss engine cylinders is shown in Fig. 31. Two adjustable boring bars *a* and *b*, standing at right angles to the main spindle *c*, are provided for boring the ports, while the main spindle *c* bores the cylinder proper. An outboard bearing *d* for the main boring bar, which is mounted on a vertical slide on the column *e*, is raised and lowered by means of the wheel *f* to suit the spindle. The main spindle is driven through the cone and back gear at *g*, while the main head *h* is raised and lowered by a belt that runs on the pulleys *i* and moves the head with a vertical shaft through a worm and worm-gear at *j*. The small heads and boring bars *a* and *b* are operated through the cone and gearing at *k* and shafting and gears in the bed *l* and column *m*. The

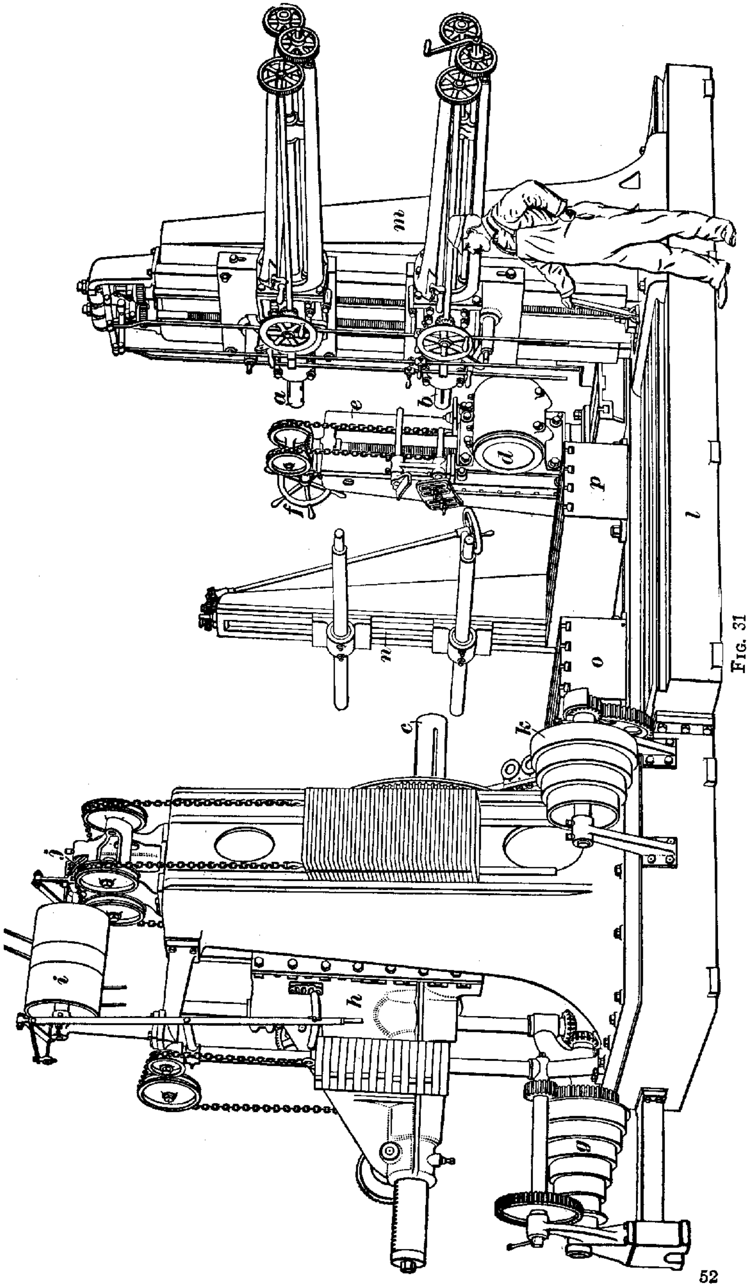


Fig. 31

olumn *n*, with its bearings, forms an outer support for the two boring bars *a* and *b*. The cylinder is supported on the parallels *o* and *p*.

66. Vertical Cylinder-Boring Machine.—In shops having a large amount of vertical cylinder boring to be done, special machines are sometimes employed; these machines are so constructed that the cylinder stands on a heavy floor plate, to which it is clamped. The boring is done by a vertical bar, the upper end of which, together with the driving mechanism, is carried by heavy columns. These machines are sometimes so constructed that the bar and a portion of the driving mechanism may be lifted out of the way while the cylinder is being placed in the machine. Such heavy machines are usually run by an independent engine or other motor.

67. Vertical Cylinder-Boring Bar. — In shops where the work does not warrant the purchase of an expensive machine, a vertical boring bar, like the one shown in Fig. 32, may be used. The cylinder is supported on the stand *a*, and is clamped

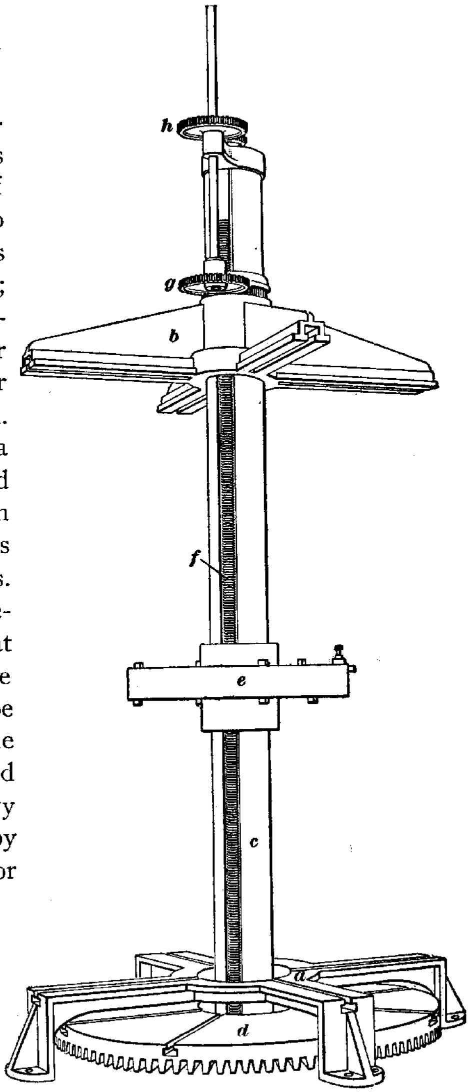


Fig. 32

between it and the four-arm bracket *b* at the top, which also forms the guide for the boring bar *c*. The bar is rotated by a large bevel gear *d* and a bevel pinion driven by a shaft and pulley from which the machine receives its power. The cutter head *e* is fed by means of the ordinary feed-screw *f* and the reduction gearing *g* and *h* shown at the top of the bar.

SPECIAL FIXTURES AND OPERATIONS

68. Extension Boring Mill.—In shops where there is occasionally a piece of large diameter to be turned, but where there is not enough very large work to warrant the purchase of a large boring mill, an extension arm may be used to advantage. On an extension mill, the bed is made with an extension at the back and with ways on top, on which the housings rest, and on which they may be moved back by means of a separate motor, so as to accommodate a larger piece on the table. The cross-rail is, of course, carried back with the housings, and to do boring, it is necessary to use either a vertical boring bar supported in an extension arm attached to the cross-rail or to place one of the heads taken from the cross-rail on the extension arm, as shown in Fig. 33. Both saddle *a* and ram *b* on the extension arm *c* have all of the movements of the cross-rail heads. The feed-rod and the feed-screw of the cross-rail *d* are geared to the feed-rod *e* and feed-screw *f* on the extension arm.

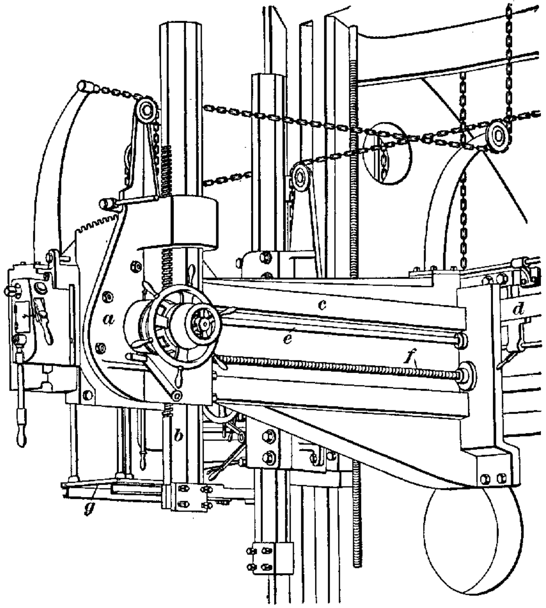


FIG. 33

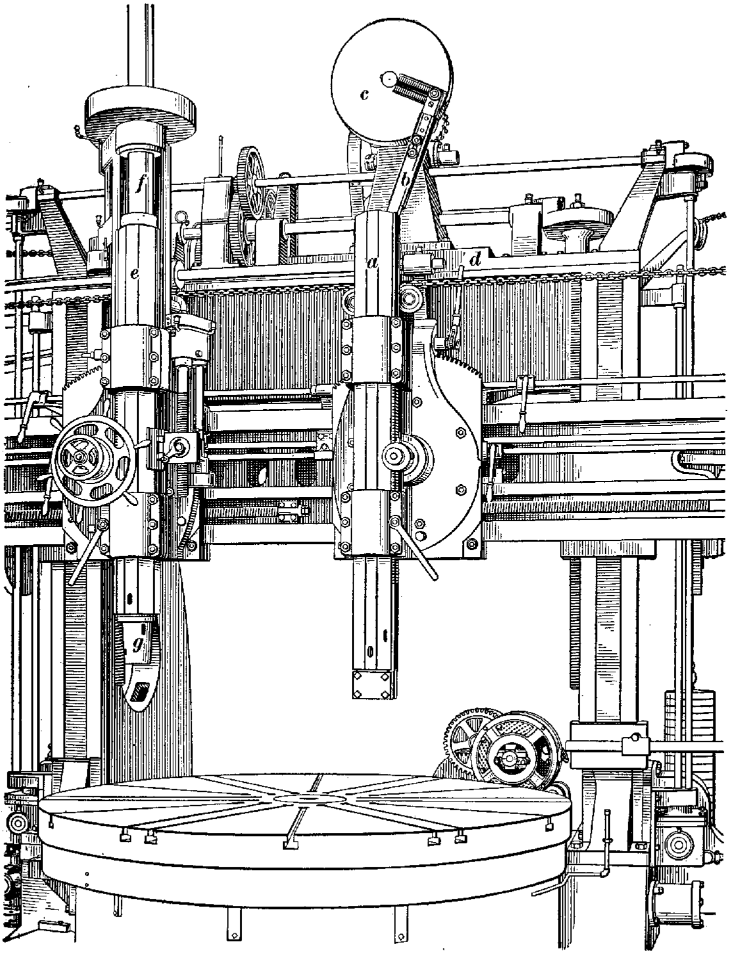


FIG. 34

A platform *g* is provided to enable the operator to make the necessary hand adjustments on the head. By the use of a system of chains, pulleys, and counterweights, the saddle *a* and outer end of the extension arm *c* are supported, as shown. The machine shown has a swing of 28 feet when the housings are set over the table; but with the housings moved back and by the use of the extension arm, the swing of the machine is increased to 42 feet.

69. Boring Mill With Drilling and Slotting Attachments. A specially designed boring mill on which drilling and slotting operations may be performed is shown in Fig. 34. The ram *a* may be used for slotting operations by first disconnecting it from the feed mechanism of the mill, and then connecting it with the arm *b* of a Whitworth quick return motion driven by the crank-disk *c*. In turn the crank-disk is driven by the motor that drives the boring mill, through shafts and gears on top of the cross-brace *d*.

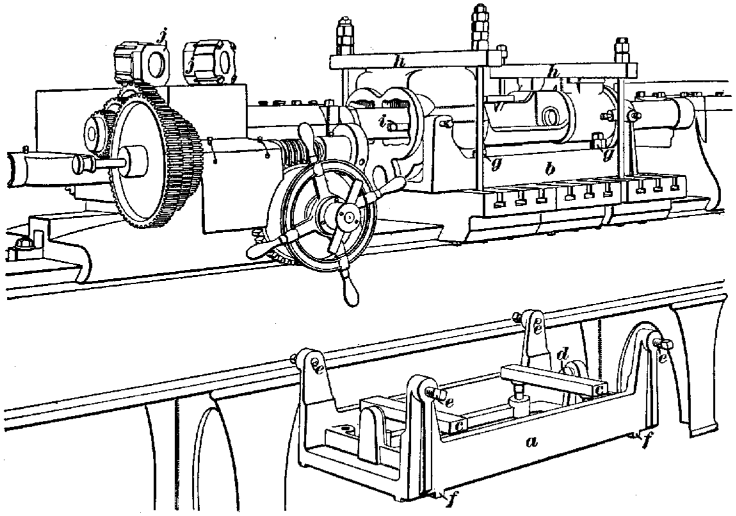


FIG. 35

When it is desired to use the mill for drilling, the ram *e* is disconnected from the feed mechanism of the mill and the spindle *f*, which is free to revolve in a hole through the ram,

driven by the motor through a friction clutch and a system f shafts and gears. The spindle has a taper hole in the nose *g*, n which the shanks of drilling and reaming tools may be fitted. This boring head has a lead screw and split nut available for threading operations with the boring bar.

70. Fixture for Boring Duplex Pump Cylinders.—In Fig. 35 is shown a fixture for holding a set of four pump cylinders while they are being bored in a double-head machine, which is also double-ended, the four cylinders being bored at the same time. The cutters at the two ends of the machine rotate in opposite directions, thus lessening the tendency to move. In Fig. 35, *a* shows the device empty, while *b* shows a pair of cylinders mounted in the machine. The cylinders rest on a pair of cross-bars *c* supported on four adjusting screws. The end adjustment is made by means of a screw *d* at each end, only one of which is seen, while the side adjustment is made by means of the four screws *e*.

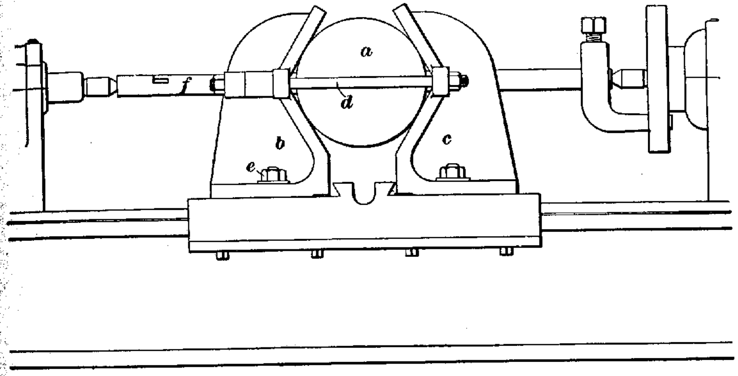


FIG. 36

71. The fixture is set on the table, as shown, the two tongues *f*, Fig. 35, fitting into corresponding slots, to prevent any slipping and to insure perfect alinement on the table. The fixture is clamped on the table by means of the bolts *g*. When the cylinders are in place and the adjusting screws are set up tightly the cylinders are held securely by means of the clamps *h*. The illustration shows a roughing cutter *i* just entering the cylinder and a pair of finishing cutters *j* lying on the top of the machine.

72. Connecting-Rod Boring Fixture.—In Fig. 36 is illustrated a special fixture that may be used on a boring mill for boring the connecting-rod pin hole of a gas-engine piston. The piston *a* is held between the two **V**-shaped castings *b* and *c*. The casting *c* is bolted firmly against the side of the rest as shown, and the casting *b* is loose. The piston is placed between the **V**'s, and, when set in its correct position, *b* is drawn up against it by the two end bolts *d*, and the clamping bolts *e* are tightened. In the illustration only one of the bolts *d* and *e* is seen, the others being located in the rear. The boring bar *f* is then passed through the **V**'s and the piston, and the holes are bored in the usual way. This arrangement insures a hole that is perfectly central and square with the piston. For large pistons, a single **V** is used under the piston.

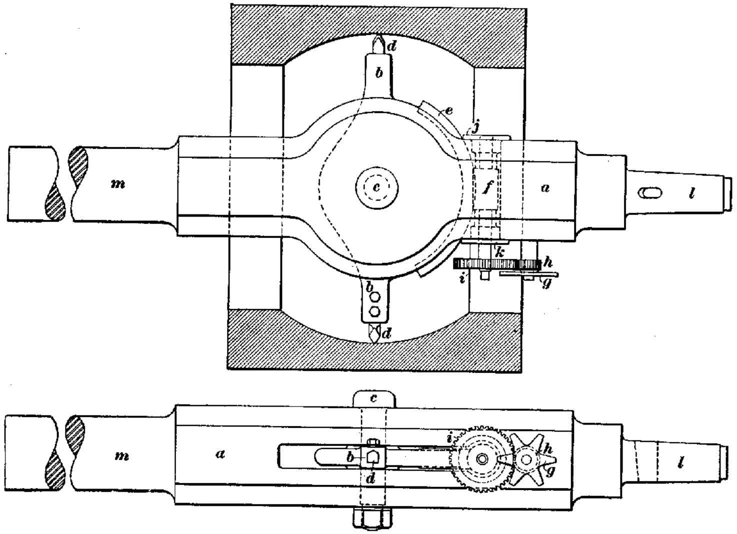


Fig. 37

73. Boring Bar for Spherical Surfaces.—In Fig. 37 is illustrated a device used to bore internal spherical surfaces. It consists of a boring bar *a* having a double-end arm *b* pivoted on the axis *c*, which stands at right angles to the center line of the bar. The arm *b* carries on its outer ends two tools *d*, set in and clamped as shown.

If the arm *b* is turned about its axis *c* while the bar *a* is rotating, the tool points will bore an internal spherical surface. In order to secure this motion, the arm *b* is constructed with the segment *e* of a worm-gear on one side. A worm *f* engages with this worm-gear, so that when the worm is rotated, the arm swings about the center *c*, causing the tool points to travel in an arc about the same center. The worm *f* is revolved by a star *g* through the gears *h* and *i*. A post on the floor operates the star in the usual way. The worm *f* is supported in two flanged bushings *j* and *k*, while the arm *b* is pivoted on a through bolt. The end *l* of the boring bar is made to fit the spindle of a large horizontal boring mill in which it is used, while the end *m* fits the outer bearing. Narrow round-nosed tools are usually employed with a fine feed, so as to form a smooth surface. For the roughing cuts, the two tools may be used, but for the finishing cut, it is best to use one tool only.

PORTABLE BORING MILLS

74. Hand-Power Boring Device.—It is frequently necessary to bore or true holes in work that it is impossible to put in a boring mill. This occurs when no boring mill is available, or when a machine bearing gets cut and the expense of taking the injured part out would be too great; it occurs also in repair work, when the boring must be done away from a shop.

A satisfactory hole may be bored by making or selecting a suitable boring bar and providing two bearings in which the bar is an easy sliding fit. The bearings are then mounted in line with the hole to be bored. The bar is now passed through the work and the bearings carefully leveled and squared so that the hole to be bored will be in the required position. The adjustment of the bar requires skill and judgment. The bar must usually be so adjusted that the hole will have a fixed relation to the other parts of the machine. It is sometimes necessary to take down adjoining parts to uncover flat surfaces or to clear holes from which the boring bar may be located by tramming or lining. A screw clamp *a*, Fig. 38, may be secured so that its screw can be used to feed

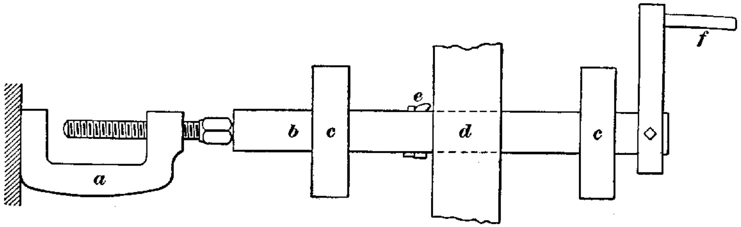


FIG. 38

the bar *b* through the bearings *c* and the work *d*. A cutter *e* is held in the bar, which is rotated by turning the crank *f* by hand.

75. Portable Mill for Boring Spherical Surfaces.—In cases where a portable power-operated boring bar is needed, one may be fitted up as shown in Fig. 39. An ordinary boring bar *a*, with its feed-screw and gearing *b* and *c*, and boring head *d*, is fitted up with a forked arm *e*, which is pivoted on both sides of the bar, so that the axis of rotation of the arm and the center line of the bar intersect at right angles. The arm *e* carries a tool *f* and is connected with the head *d* by the link *g*. The boring bar is rotated by means of the worm-gear *h* and

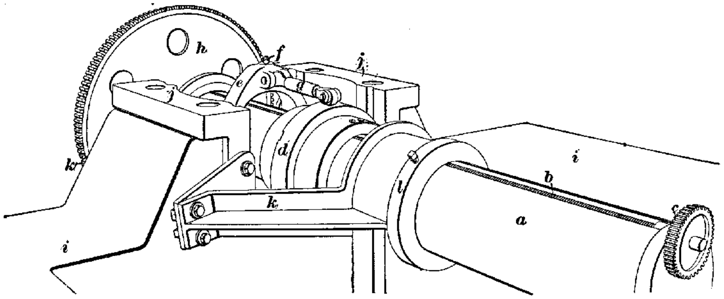


FIG. 39

a worm and pulley that are not shown. As the screw *b* is rotated, the head *d* is moved along the bar, and the link *g* causes the arm *e* to swing about its axis, and, when both bar and screw are rotated, the tool will form the desired spherical surface.

The illustration shows the bar mounted on a large engine bed *i*, ready to bore the spherical bearing *j*. The bar is supported on two brackets *k* bolted to the ends of the bearings, and is kept from moving endwise by means of the worm-gear *h* on one end and the collar *l* on the other end.

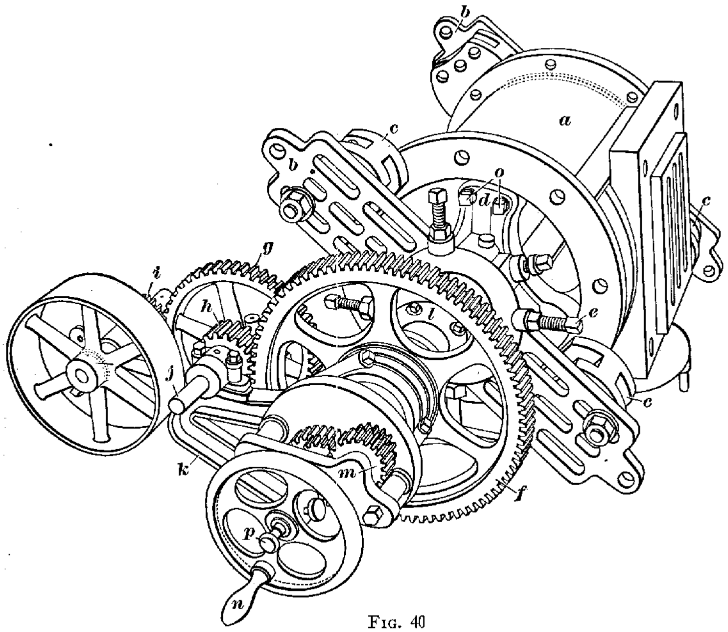


FIG. 40

76. Power-Operated Portable Mill for Boring Cylinders. A boring mill that is largely used to bore or rebore cylinders of almost all kinds, and generally without removing the cylinder from the engine, is shown in Fig. 40. This mill may be operated by a belt or by a direct-connected air or electric motor. The boring bar is located in the axis of the cylinder *a* by means of two cross-heads *b*, bolted to the flanges on each end of the cylinder. Blocks *c* are placed under the cross-heads to give clearance for the cutterhead *d*, which has three heavy side tools cutting on the face. This form of tool does not cause any bending of the bar. Each cross-head supports a bearing for the bar, and the bearings are centered and held by four setscrews *e*. A large gear *f* on the boring bar is driven by the pair of speed reduction gears *g* and *h* from the pinion *i* on the drive shaft. A large hand wheel may be put on the reduction shaft *j* for the purpose of turning the bar by hand for adjustment of the cutters. The gearing system is set in a frame *k* that has bearings on the boring bar.

77. The feed system consists of a thrust bearing *l* for the feed-screw located in the cross-head next to the driving system, and a set of gears *m* operated by the hand wheel *n* for revolving the feed-screw that lies in a groove along the full length of the bar. There are two changes of feed engaged by the pull pin *p*. A nut in the hub of the traveling cutterhead *d* engages the feed-screw. Each tool is held by two clamp bolts *o*, and to reach these bolts when the cutterhead has entered the cylinder a long socket wrench is used. When the boring is completed, it is customary to loosen the clamping bolts *o* and permit the tools to drop into their holders and out of contact with the finished surface of the cylinder. The cutterhead can then be withdrawn without danger of the tools scoring the surface.

APPENDIX

Formulas **1** and **2** in Art. **27** are derived by the applications of the principles of trigonometry as follows: In the triangle *a e f*, Fig. 13, the angle $A=D=E$ is formed at the vertex *a*, and the angle C at the vertex *f*. It is a principle of trigonometry that the sines of the angles of any triangle are proportional to the lengths of the sides opposite the respective angles. Therefore, in Fig. 13 this principle gives

$$\text{side } a\,e : \text{side } e\,f :: \sin C : \sin E$$

from which

$$\text{side } a\,e \times \sin E = \text{side } e\,f \times \sin C$$

because the product of the means equals the product of the extremes in any proportion. Furthermore, by dividing both sides of this equation by side *e f*, the value of

$$\sin C = \sin E \,\frac{\text{side } a\,e}{\text{side } e\,f}$$

which is formula **1**, or

$$\sin C = \sin A \,\frac{\text{side } c\,d}{\text{side } e\,d}$$

WORKING CHILLED IRON

Serial 1672 Edition 1

CHILLED IRON

1. Chilled iron is cast iron that has been chilled, or cooled, rapidly as the molten metal is poured into a mold. Chilling is accomplished by using an iron mold instead of a sand mold, as in ordinary molding. This iron mold is called the **chill,** and, like the sand mold, must have the correct form to make the desired casting. Not all forms of castings may be chilled, owing in some cases, to the severe casting and shrinkage stresses, and in other cases to the inability to chill inaccessible parts of the casting.

In Fig. 1 is shown a cross-section of a mold for making a plain, solid, chilled-iron roll with necks and driving ends, the body only being chilled. The mold for the necks and driving ends of the roll is made of sand. In the illustration *a* is the roll, *b* the chill, *c* the riser head, *d* the cope, *e* the reducer, *f* the sand, *g* the drag, *h* the runner spout, *i* the pouring basin, *j* the joints fastened by clamps and wedges, *k* the end plate, and *l* the chilled surface.

2. Characteristic Features.—The rapid cooling of the metal which lies against the chill forms a skin or shell of hard iron varying in depth and hardness according to the composition of the metal and the method of manufacture. This rapid cooling of the metal produces a casting with a hard surface having a great resistance to wear.

Chilled iron may readily be distinguished from sand, or gray, iron by the white color of the fracture as opposed to the gray color of ordinary cast iron. The outer, or clear white, layer is known as the **clear chill.** Where the shell of chilled iron merges into the gray iron will be found a layer of **mottled chill,** which is a mixture of chilled and gray iron. The mottled-chill layer is usually of about the same depth as the clear chill, the remaining part of the casting being gray iron. The layer of clear chill plus the layer of mottled chill is known as the **total chill.**

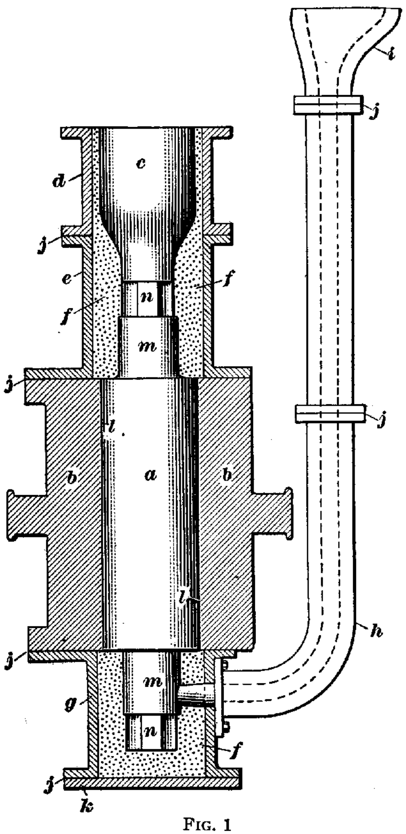


FIG. 1

3. Reading Chill Depth.—When the *chill depth* is spoken of it is understood to mean the depth of clear chill. When reading chill depth, either a clean fracture or a cut taken on the end of the casting at right angles to the chilled surface must be available. The depth of chill can be distinguished readily by the naked eye. In Fig. 2, a section of a casting having a chill depth *a* and a mottled chill *b* is shown.

There are many grades of chilled iron, varying, according to the uses to which they are to be put, from a very mild to a very hard chill. On turning a number of chilled rolls of different grades, it is possible to become familiar with the way they cut; the harder the chill, the more difficult to cut it. When determining the grade of chilled iron in this way, care must be taken to get a good tool, to become familiar with the way it cuts, and to always use tools of the same grade. The degree of hardness of the surface may be readily determined by the scleroscope. The harder and deeper the chill, the more brittle the casting becomes; consequently, to guard against breakage, the chill should never be harder nor deeper than its use requires.

4. Uses of Chilled Iron.—Owing to its great resistance to wear, chilled iron is used largely for making chilled rolls. These rolls are used to roll varied products made from metals, cereals, and other materials. The use of chilled iron is not, however, confined to rolls alone, for the guides for rolling mills, car wheels, rock-crusher plates, dies, anvil blocks, and other articles are made with chilled faces.

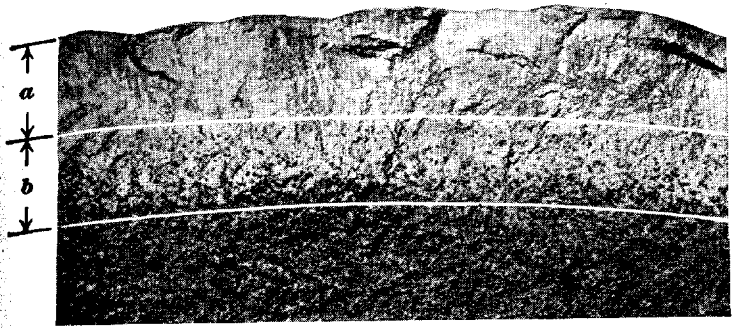


FIG. 2

MACHINING CHILLED IRON

TURNING AND GRINDING CHILLED ROLLS

5. Essentials.—In working chilled iron, good castings are essential. The castings must be free from cracks, blow holes, and dirt, and the chill must be of the right depth. In turning chilled-iron rolls, special lathes must be employed, and a few general rules must be observed to insure successful work. The cutting speed must be so slow that the tool will hold its edge until it has done a reasonable amount of work. The lathe must have a large amount of power, and the tools and the lathe must be of rigid construction. The tool steel employed must be the best, and selected according to the character of work.

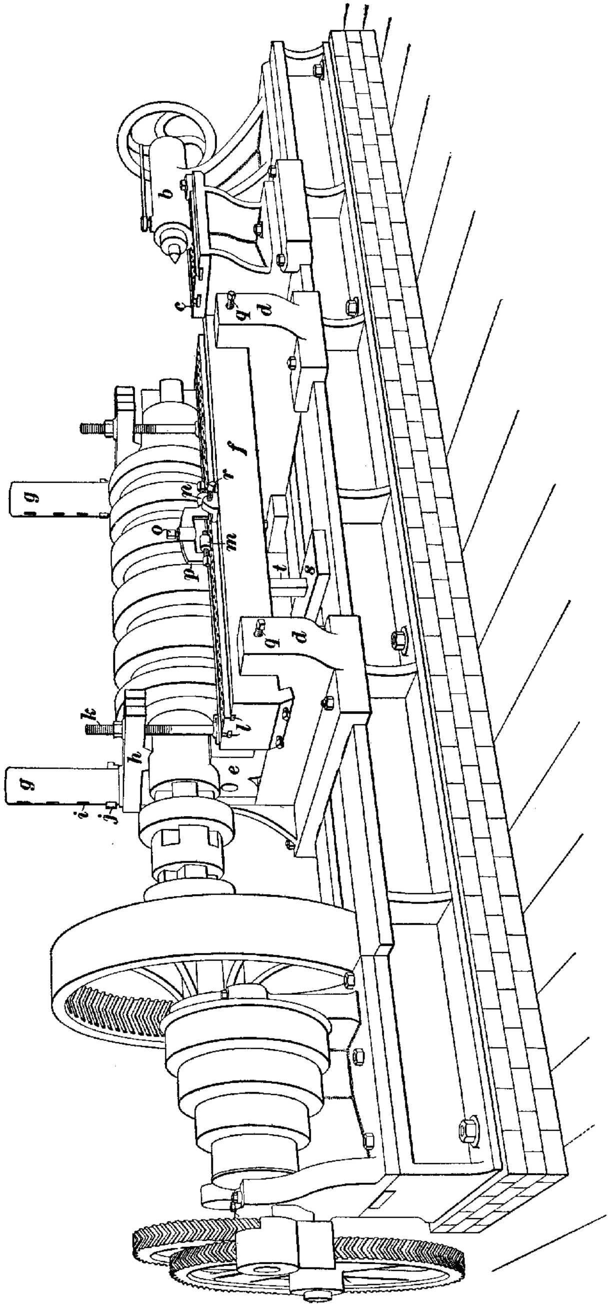


FIG. 3

TURNING SOLID ROLLS

6. Lathes for Turning Chilled Rolls.—A type of lathe for turning rolls cast solid and having journals, or *necks*, as shown at *m*, Fig. 1, and driving ends, or *wabblers*, as shown at *n*, is illustrated in Fig. 3. In common with all lathes used for turning chilled iron, this lathe is powerful and rigid in construction. The bedplate is strongly constructed and is securely bolted to a solid foundation. The headstock is provided with double helical gears, so that the pull may be constant and that the teeth of the gears cannot cause hammering or backlash. Instead of the cone-pulley drive the lathe may have a single pulley with a variable-speed countershaft. This latter practice has the advantage that more speeds are possible. A direct-connected, variable-speed motor may be used to drive the lathe In Fig. 4 is shown a form of roll lathe in which the machine is driven by a single pulley *a* belt-connected to a variable-speed countershaft.

7. In all cases, chilled rolls are turned by feeding the tool crosswise into the roll, the length of the cutting edge of the tool determining the length of surface turned. Consequently, a chilled-roll lathe is not provided with a feed rod to move the carriage lengthwise. The necks and wabblers being soft, the rolls are frequently centered and necked on an ordinary engine lathe. The operation of turning the necks of rolls is known as **necking.** The riser head may also be cut off in the engine lathe. When the rolls are necked on a roll lathe, the center holes are usually made by hand, using a portable drill to operate the drill and reamer.

The tailstock *b*, Fig. 3, is used when turning rolls between centers, as when necking or cutting off riser heads. On large lathes, the tailstock is provided with rollers which can be raised into position when sliding it along the bedplate. The necking rest *c* is used to support the turning tool when necking. It is moved along the bedplate and bolted in position opposite where it is desired to cut. The roll would then be necked by feeding the tool crosswise.

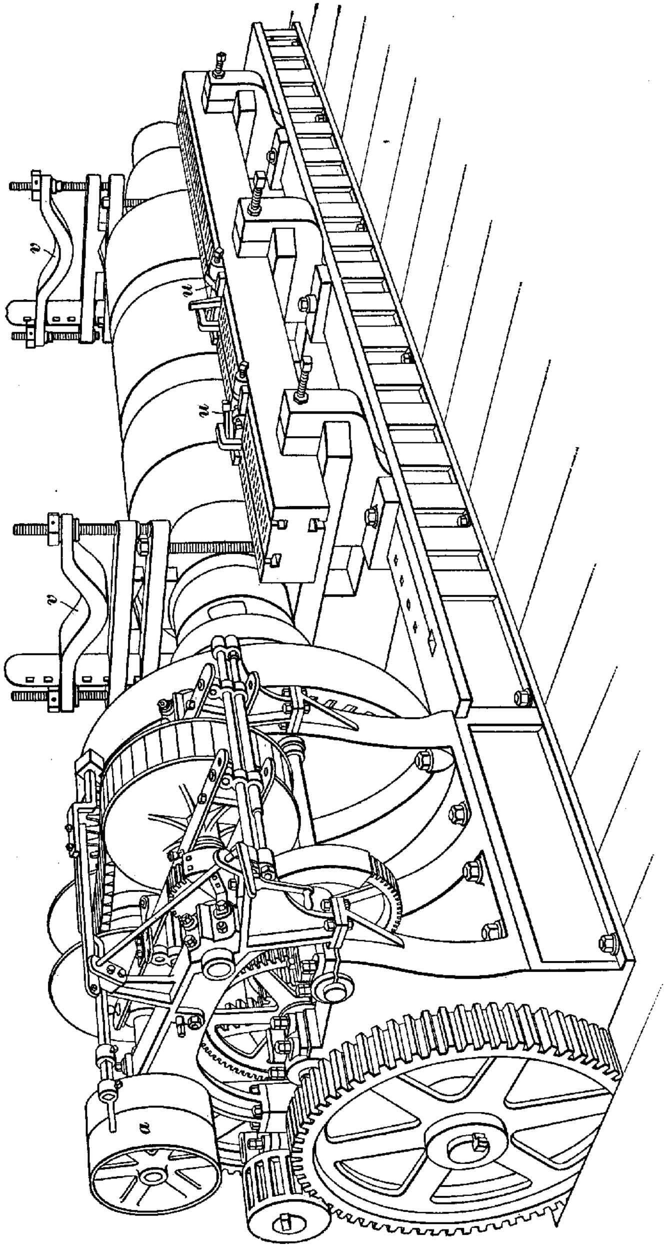


FIG. 4

8. After the rolls have been necked, the tailstock and necking rest are removed and the regular roll-lathe housings *d*, Fig. 3, are placed on and securely bolted to the bedplate. The chucks, or bearing blocks, *e* fit into the housings and form the necessary bearings for the rolls to run in. The tool rest *f*, known as the **piano rest,** is also supported by the housings *d*. The housing posts *g*, which hold the caps *h* in position, and the housings *d* are rigidly connected. The chucks *e* and the caps *h* generally have babbitted faces for the necks to run in. These faces are kept well greased to prevent scoring of the finished necks. In some cases extra bearing blocks are forced between the necks and the housing posts to increase the bearing surface. The caps *h* are made to slip over the housing posts *g* as shown. The housing posts are slotted at intervals as shown at *i* to receive the blocks *j* which prevent the caps from moving upwards. The front end of the caps are held in position by the bolts and nuts *k*. These bolts are keyed to the housings *d*.

9. Material of Tools for Turning Chilled Iron. When working chilled iron, high-speed-steel tools are necessary when heavy and fast cutting is to be done. For this reason, high-speed steel is largely used for roughing tools for chilled iron. As it will not hold a sharp edge, however, it is not adapted to finishing work. High-carbon tool steel hardened in brine does hold a fine accurate cutting edge, and for this reason is chiefly used for finishing tools. It may also be used for roughing work; but this is not advisable if time is an important factor.

10. Solid Turning Tools.—Tools used to work chilled iron are not blocked up from the piano rest, but are made of such depth that, when set up, they will be the desired distance below the center of the work. Clearance on the cutting edge is necessary. A tool set at the center must have a good deal of clearance, making the point weak. A tool set below center can be square, making a stronger cutting edge. Hence, all tools for turning chilled iron, cutting-off tools excepted, are always made and set so that their cutting edges will be below the center of the work. Tools for turning work of large diameter are set farther below center than those used to turn work of small diameter.

11. Different types of tools employed in turning chilled rolls are illustrated in Fig. 5. The **facing tool** used to turn the straight surfaces of chilled rolls is shown in (*a*). It is made from a bar of steel from 1 to 1½ inches square and from 3 to 12 inches long, depending on the work to be done. When making this tool, the stock is first annealed by heating it red hot and cooling it slowly in lime, after which the grooves are formed on a shaper. Each face is now hollow ground, holding the tool parallel with the face of the grinding wheel. The tool is then hardened and touched up slightly on a grindstone, after which the corners are honed to an edge with an oilstone. The **pusher** used to force the tool shown in (*a*) into the roll is shown in (*b*). It may be made of any grade of steel. In use, a copper or brass strip *a* is placed between the facing tool *b* and the pusher *c* to prevent injury to the sharp edges of the tool by the pusher. The pusher must be shaped so that it will bear against the top edge of the tool in order to avoid all tendency to push the bottom part of the tool, to which no resistance is offered, toward the work. If the bottom part of the tool were pushed nearer the work, the clearance angle of the tool would be reduced.

12. One type of **grooving tool** is shown in Fig. 5 (*c*). The exact form of the tool depends on the shape of the groove to be turned in the roll. The tool shown is used to turn flat grooves whose rolling surfaces are parallel and whose sides are perpendicular or nearly so to the length of the roll.

Another type of grooving tool is shown in (*d*). This tool is used to turn diagonal grooves in rolls, as, for example, grooves used to roll squares and diamonds. Both *roughing* and *finishing* tools of this type are used. The roughing tool has a blunt point and is made of high-speed steel. Heavy cutting can be done with this tool. The finishing tool is made of high-carbon tool steel and has a sharp point. To avoid destroying this point, light cuts must, of course, be taken.

13. In Fig. 5 (*e*) and (*f*), forms of roughing tools known as **lip tools** are shown. These tools will remove stock more

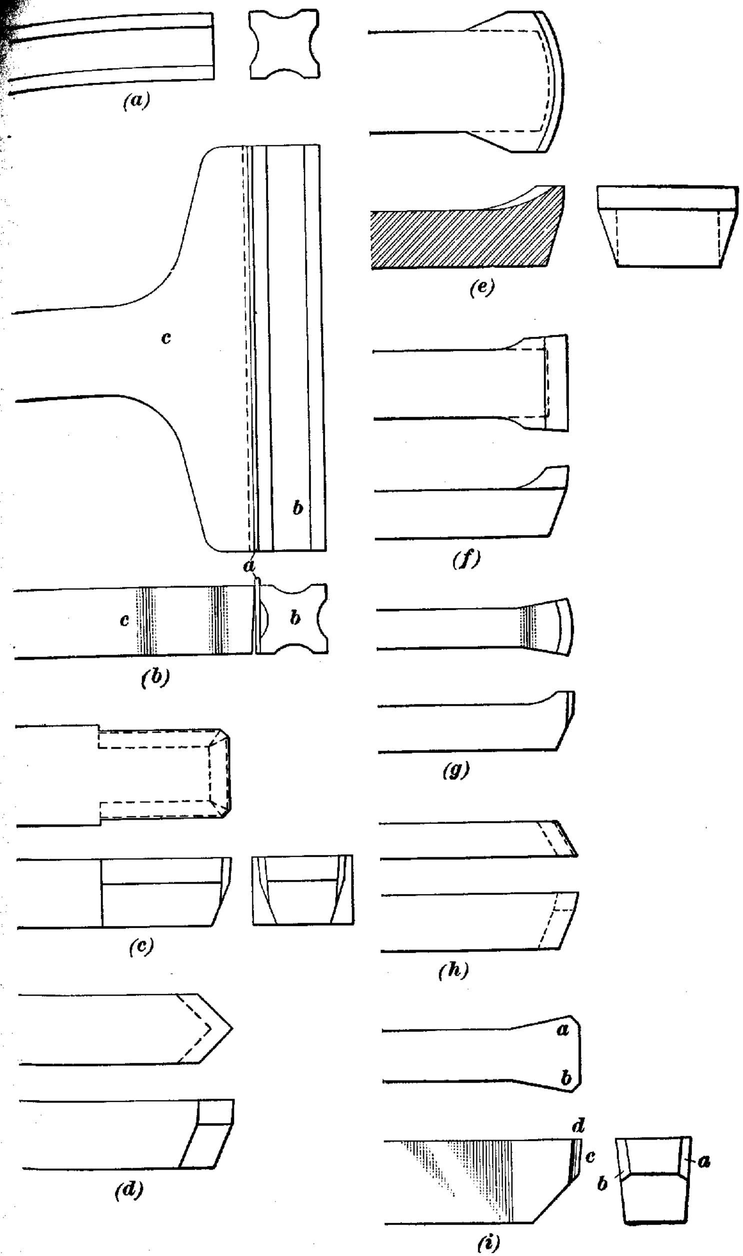


Fig. 5

rapidly than those ground straight on the top. In (*g*) a form of roughing tool similar to that in (*e*), but narrower, is illustrated. It is used to rough out narrow recesses and to cut off riser heads.

In (*h*) the tool for sharpening the corners of the grooves is represented. This tool is employed when cutting off riser heads in the lathe. The tool shown in (*g*) is used first, running the cut down almost to the required depth. Then the tool shown in (*h*) is run in and the corner of the groove next to the roll is sharpened up, so that when the riser head is broken off it will break flush with the end of the roll.

14. One form of **cutting-off tool** is shown in Fig. 5 (*i*). This tool is forged from $\frac{3}{4}'' \times 1\frac{1}{4}''$ steel, and is hardened in brine. The edge of the tool is about $\frac{15}{16}$ inch wide and the corners *a* and *b* are cut off at an angle of about 45°. When the corners are ground to this angle, they are not so easily broken when used as would be the case if left square. The front face of the tool is given a little clearance as shown at *c*. This clearance is seldom more than 5°. This cutting-off tool is used to cut through the chilled iron, an ordinary cutting-off tool being employed to cut through the softer iron at the center of the roll.

15. Cutting-off tools must overhang the front edge of the tool rest to a greater extent than the turning tools. They are therefore made deeper from the top to the bottom, and consequently stronger. In use, the top face *d* of the tool shown in Fig. 5 (*i*) is set above the center of the roll, and clearance must be allowed on the face *c* as shown. When it is necessary to have a tool overhanging the front edge of the tool rest, the tool prop *t*, Fig. 3, and the bar *s* that support it are used. The tool prop is made just the right length and is placed under the front edge of the tool. This relieves the stress on the tool, making it possible to use lighter tools.

16. It was formerly considered good practice and economy when making wide tools to use tool steel for the cutting edge only and weld the tool steel to a shank made of machinery steel. However, it takes time to make the weld and the tools are often lost by cracking in tempering. Tools made of solid tool steel can always be used or changed to other shapes, where the welded tool would have to be scrapped. For these reasons, modern practice favors the use of solid rather than welded tools.

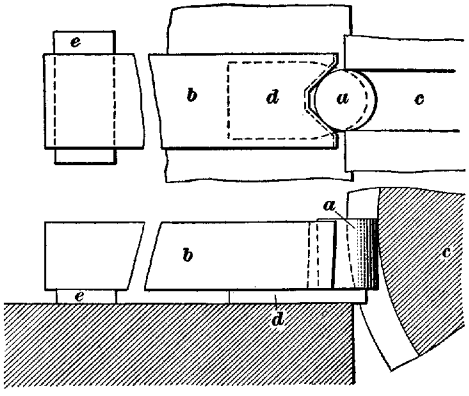


Fig. 6

17. A tool for turning small round and oval grooves is shown in Fig. 6. The tool *a*, called a **plug,** is a cylindrical piece of tool steel with both ends squared and ground. The **push-up** *b* is used to force the cutting edge into the roll *c*. The tool is supported on the blocks *d* and *e*, which are of such thickness that the cutting edge of the tool will come about $\frac{1}{8}$ inch below the center of the roll. Any portion of either the top or bottom end of the plug may be used to cut the groove. In case both ends are dull, the plug may be resharpened by grinding its ends. The block *d* forms a rest for the plug; prevents the tool from digging in, thus marking the main rest; and also prevents the tool from tipping over when the grooves are turned deep. The push-up is made with clearance so that it will bear against the top of the plug as in the case of the facing tool.

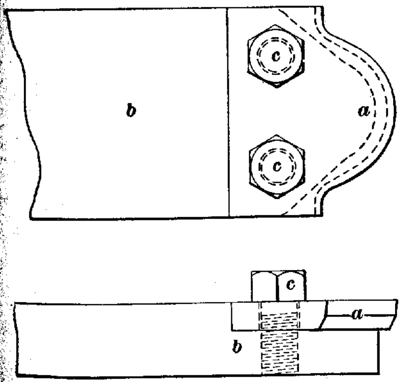


Fig. 7

18. Built-Up Turning Tools.—In Fig. 7 a built-up tool for turning large grooves is shown. The tool is used chiefly to turn circular grooves; but tools are also made to turn irregularly shaped grooves. The cutting portion *a* of the tool is made of high-speed tool steel for the roughing, and high-carbon tool steel for the finishing operations; the tool block *b* is made from machinery or any other kind of steel available. The tool is fastened to the block by the bolts *c*. This form makes a good substantial tool. The tool block may be used to hold different cutters.

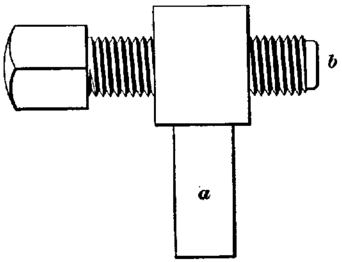


Fig. 8

19. Holding Tools. Owing to the severe stresses to which tools for working chilled iron are subjected, they are not held in an ordinary tool post, but are clamped very rigidly to the tool rest *f*, Fig. 3. This rest is provided with two **T** slots *l* and with rectangular holes in its upper surface, as shown. These rectangular holes are fitted with dogs *m* and *n*. The dog *m*, a larger view of which is shown in Fig. 8, is similar to the ordinary planer plug, and the shank *a* is square or rectangular, depending on the form of the holes in the rest. The end *b* of the setscrew is brought in contact with the tool or the blocking. The dog *n*, Fig. 3, is of the general form shown in Fig. 9, and is arranged to fit into a **T** slot, indicated by the dotted lines. The lug *a* is so formed that the dog can be easily removed from the **T** slot by simply lifting up on the head of the setscrew *b*, and when the end *c* of the setscrew is brought against the work, the lug *a* will take hold of the **T** slot and hold the work firmly in place. The tools are held from behind and at the sides by means of the dogs just described, and are held down by means of the setscrew *o* in the clamp *p* shown in Fig. 3. The tool and rest are advanced toward the roll by turning the screws *q*, and the tool only by turning the screw *r*. The tool is forced into the roll

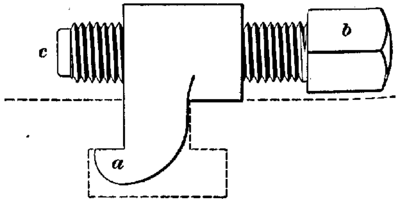


Fig. 9

by turning the screw *r*. The screws *q* are used merely to back up the rest, so that when the tool is cutting it will not force the rest back from the face of the roll. It is not necessary to have the rest parallel to the axis of the roll. When cutting deep

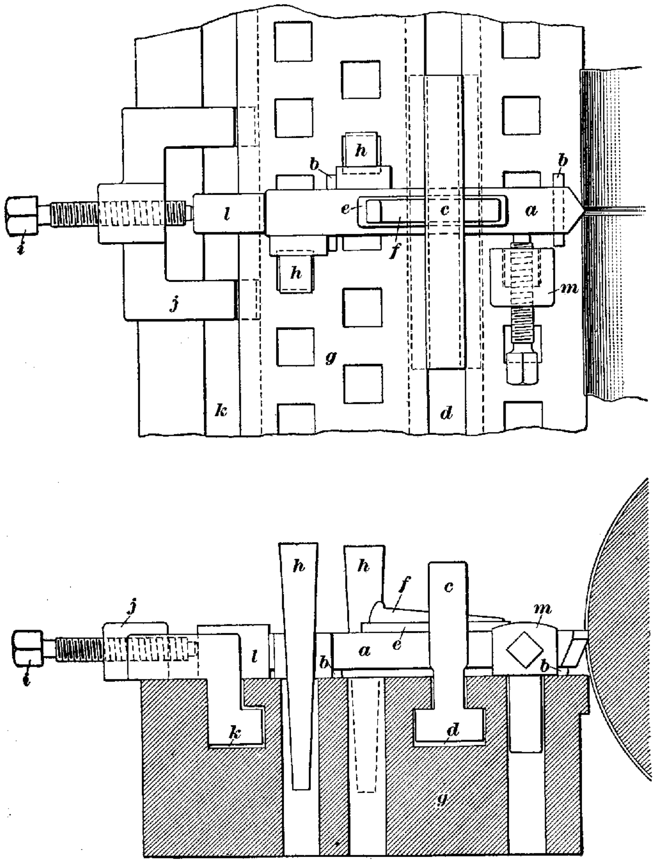


Fig. 10

grooves the tool extends rather far out in front of the tool rest nd must be supported. This may be done by the use of a prop ar *s*, and the prop *t*, on which the front edge of the tool rests.

20. The device *u*, Fig. 4, for holding the tool is shown in il in Fig. 10. The tool *a* is set on two pieces of packing *b* to bring it up to the correct cutting height. The saddle *c*, which works in the **T** slot *d*, together with the block *e* and wedge *f*, keeps the tool forced against the tool rest *g*. The wedges *h* hold the tool at right angles to the work as it is advanced into the roll by the screw *i*, which works in the pusher *j*. This pusher is held in the **L** slot *k* of the rest. The block *l* is placed between the tool and the screw, in case the tool is not long enough to reach to the screw. Screw blocks, as shown at *m*, are sometimes used in place of the wedges *h*.

21. Grinding Turning Tools.—To secure a straight edge on the tool, it is ground on a grinding machine provided with a carriage or special tool holder. The sides of facing tools are ground concave, or hollow, as shown in Fig. 11. In this way two sharp edges *a a* and *b b* are produced. The marks left by the grinding wheel are removed by rubbing an oilstone over the face of the tool. The tool is first set to use one edge as *a a* and when dull, the tool is turned over and the other edge *b b* is used.

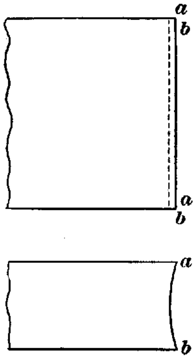


Fig. 11

22. A type of wet grinding machine provided with a carriage and used to sharpen tools for cutting chilled iron is shown in Fig. 12. The machine is fitted with a slide *a* to which the tool is clamped at *b*. The depth of the cut is regulated by the screw *c* and the clearance angle by the screw *d*. The tool is fed back and forth across the face of the grinding wheel by means of the hand wheel *e*, a pinion engaging with the rack *f*, which is secured to the bottom of the slide *a*. With this device, tools may be ground accurately and quickly.

23. Cutting Speeds.—To a great extent the cutting speed depends on the character of the chilled iron being turned and the diameter of the roll. On small rolls a surface speed of from 34 to 36 inches per minute is good practice, while for large rolls a surface speed of from 28 to 30 inches is used. A surface speed of 40 inches per minute is probably as high a speed as could be employed with good result, although a speed of 11 feet per minute has been obtained on very mild chilled iron. In this case the tool steel used was exceptionally good.

24. Cutting Feeds.—In turning chilled iron, the tool is never fed along the work lengthwise, but at right angles to the face being turned. This feeding is done by hand through the use of a wrench and screws. The amount of feed depends on the hardness of chill being turned, the size of the roll, and the trength of the lathe and its attachments. On a roll of mild hill and large diameter using a high-speed-steel tool of the orm shown in Fig. 5 (*f*) on a very rigid lathe, a cut $\frac{3}{64}$ inch eep may be taken. This is the deepest feed that may be used n chilled iron, and it is not practicable to employ it, as the tools ill stand up for a short time only and the wear on the lathe is ccessive. Ordinarily a cut of about $\frac{1}{64}$ inch deep is considered good average cut. In turning a plain chilled roll a tool of form shown in Fig. 5 (*a*) is used. Cuts .01 inch deep may

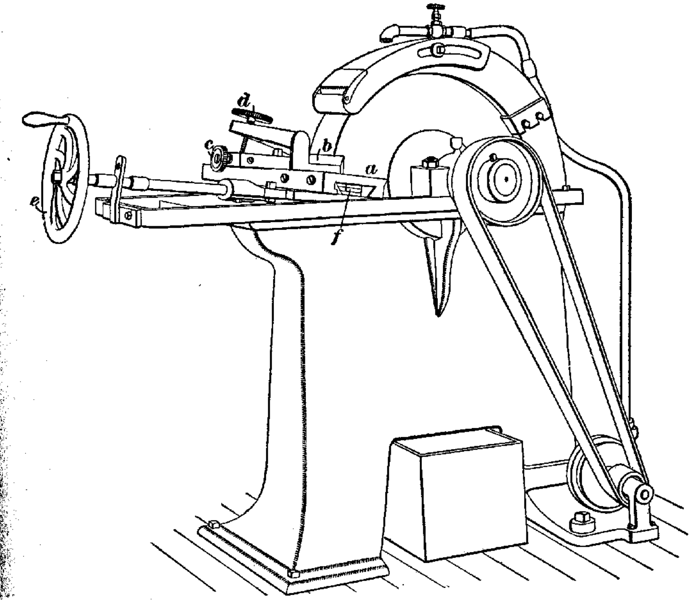


Fig. 12

be made with this tool. This depth of cut is, however, rather excessive, the normal depth being about .003 or .004 inch.

25. Setting Up Roll in Lathe.—The center holes of chilled rolls include an angle of 60°, and their width across the mouth varies from $\frac{1}{2}$ to 3 inches. For a 500-pound roll, a width of mouth of 1 inch, and for a 2,000-pound roll, a width of mouth of 2 inches, is good practice. As all rolls are cast on end, the bottom, or drag, end is necessarily more solid and true than the top, or cope, end, sometimes called the riser, or head, end. The top face of the riser head is piped considerably and is very rough and irregular, owing to shrinkage, feeding, and dirt. For these reasons, the cope end is not centered, a *false center*, Fig. 13, being attached to it by means of the set-screws *a*. This false center contains a center hole *b* which receives one of the lathe centers. The drag end of the roll is centered as usual, and the roll is put on the lathe centers with the false center on the tailstock end. By adjusting the screws *a*, the work may be adjusted until either the wabblers or the body runs true. The usual practice is to set the large rolls so that the bodies run true, and the small rolls that are to run at a high speed in the mills, so that the wabblers run true. If these fast-running, small rolls were not turned true to the wabblers, the wabblers would probably break off in service.

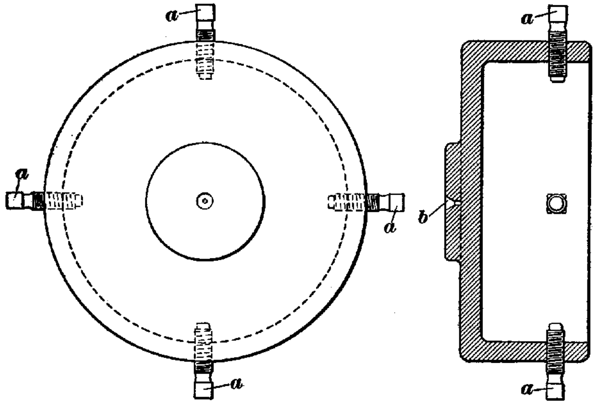


FIG. 13

26. Testing Casting.—Before finishing the roll, it is tested for chill depth, evenness of chill, and flaws. To test for chill depth, take a cut over each end of the roll, using a tool of the form shown in Fig. 5 (*f*), and observe the depth of chill as explained in Art. **3**. The drag end usually has a deeper chill than the cope end. The evenness of chill may then be discerned by following the line of clear chill around the body. When in cooling and shrinking the roll leans to one side of the chill, the depth of chill on that side will be the greater, the opposite side having a shallow chill depth. If this condition is very marked, the roll is made unfit for use. A few cuts are taken on the surface of the body of the roll, using a tool of the form shown in Fig. 5 (*f*), to determine whether it will true up without flaws.

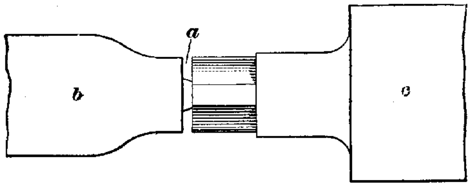


FIG. 14

27. Cutting Off Riser Head and Necking.—If, by testing, the roll has been found to be satisfactory in all respects, the riser head is cut off. This may be done by using a round-nosed lip tool like that illustrated in Fig. 5 (*g*), cutting into the roll as shown at *a*, Fig. 14, the tool being secured to the necking rest *c*, Fig. 3. A deep groove is made, the corner being sharpened with a tool of the type shown in Fig. 5 (*h*). The roll is then removed from the lathe and the riser head *b*, Fig. 14, is separated from the body *c* by means of wedges and a few blows with a sledge. The cope end of the roll is now centered, and the roll is put on the lathe centers and necked—that is, the journals are trued up. The necks are now turned to size unless they are to be ground and polished. In this case a little stock is left. As this part of the roll is not chilled, the lathe is run at the regular gray-iron speed except when cutting near the body where chill will be found.

28. Turning Body of Plain Roll.—After necking, the roll is removed from the centers, the tailstock and necking rest are taken from the lathe, and the housings *d*, Fig. 3, are set up in place. The roll is caused to turn in the bearings *e* by the driver *a*, Fig. 15 (*a*) An end view of the driver is shown in Fig. 15 (*b*). The driver fits over the spindle *b*. This spindle is shaped like the wabbler *c* and is connected to it by the box *d*. The lathe face plate *e* carries the lugs *f*, and as the face plate revolves these lugs come against the lugs *g* of the driver, causing rotation. In the figure, *h* is the neck and *i* the body of the roll. The rolls are run in bearings rather than on the centers when turning the body, because the centers do not always wear uniformly during the turning process, and consequently the part of the roll turned last would not be concentric with that turned first.

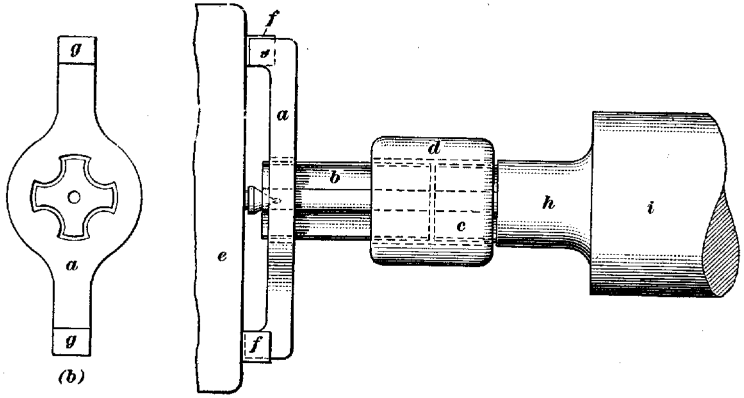


FIG. 15

A facing tool, Fig. 5 (*a*), made of high-speed steel is set up against the surface to be turned, the pusher, Fig. 5 (*b*), is placed against the facing tool, and the pusher is held as shown in Fig. 10. By turning the screw *i*, Fig. 10, the tool working against the pusher is forced into the roll and is adjusted until both ends of the portion of the roll turned measure the same. The part of the roll corresponding to the length of the cutting edge of the tool is now turned to the required diameter. All measurements are made with plain calipers.

The tool and pusher are now taken out and reset further along the roll where the tool is forced in as before until this part of the roll is the same diameter as that previously turned. This process is continued until all parts of the body are turned to the same diameter.

29. The finishing tool, made of high-carbon steel, is next set up in the same manner, and very light cuts are taken until the entire length of the roll body is the same diameter. In case the roll is to be ground and polished, it is not finished quite as carefully in the lathe as would otherwise be done, as it will be trued up accurately on the grinding machine. A little stock, about $\frac{1}{64}$ inch, must be left on rolls to be ground.

30. Testing for Straightness of Surface. The surface of the roll is tested for straightness before removing the roll from the lathe. A straightedge, which has been chalked on its edge with soapstone or hard chalk, is placed lightly on the finished surface and parallel to the axis of the roll. The straightedge is now moved lengthwise about $\frac{1}{16}$ inch, back and forth to produce a rubbing action on the roll. The chalk is thus transferred to the roll at every point of contact. If the roll is finished straight, a line will be transferred on the roll; if the roll is not straight, marks will be found on the high spots only. This test is accurate and reliable, can be easily and quickly made, and is the one commonly used.

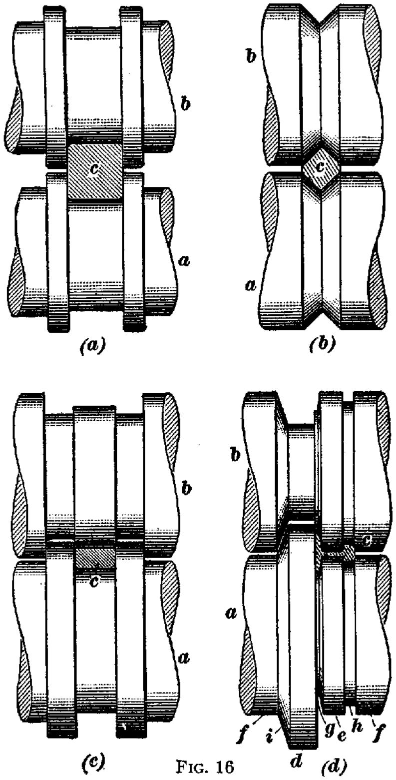


FIG. 16

31. Kinds of Grooved Rolls.—The surfaces of grooved rolls which work together are called **passes.** When the corlars, or projecting rings, of one or more grooves fit into corresponding recesses in the other roll, the roll is said to have **closed**

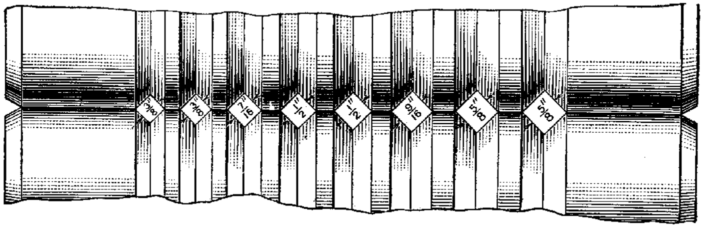


FIG. 17

passes; if the collars do not fit into corresponding recesses, the roll has **open passes.** In Fig. 16 (*a*) and (*b*) are shown examples of grooved rolls with open passes, and in (*c*) and (*d*) grooved rolls with closed passes are illustrated. In the illustrations, *a* and *b* are the rolls and *c* the work being rolled.

32. Templets for Open Passes.—The passes in grooved rolls are turned to fit templets that are generally made of sheet steel or zinc about $\frac{1}{16}$ inch thick. In making templets for open passes either the individual or group method may be followed. Let it be required to make templets for the passes of the rolls shown in Fig. 17. If the individual method is used, a series of templets as shown in Fig. 18 (*a*) are made, and if the group method is followed, the templets are all formed in a single tool as shown in Fig. 18 (*b*). The group method has an advantage in that all the templets for a certain set of grooves are arranged together; but it can only be used for small grooves, for if made for large grooves it would be too clumsy to handle. If no measurement of the templet is over 3 inches, its size is not objectionable. The templets are made so that the wings *a*, Fig. 18 (*a*), on either side of the part *b*

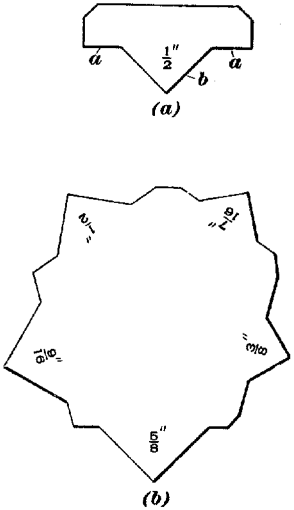


FIG. 18

corresponding to the groove will rest upon the collar of the roll, forming an exact gauge for the depth of the groove.

33. Turning Grooved Rolls With Open Passes.—The shapes of the grooves and their positions in the rolls are determined from the drawing, when turning grooved rolls with open passes. Suppose the drawing, Fig. 17, calls for rolls to roll square bars on the diagonal. As the grooves are, in this case, identical in both rolls, the same tools and templets may be used for both. A roughing tool of high-speed steel and a finishing tool of high-carbon steel of the form shown in Fig. 5 (*d*) are made, the point of the roughing tool being ground off and that of the finishing tool being left sharp. Templets are made to the dimensions of the drawing, those made of steel being preferable to those made of zinc, as they are less easily distorted or damaged.

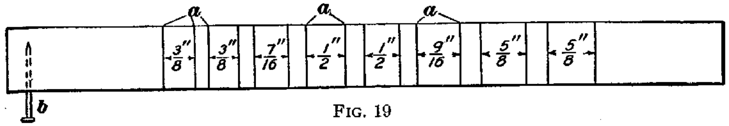


FIG. 19

34. That the grooves in one roll may coincide and be directly over those in the other roll, a **strip,** Fig. 19, is made. This strip is a piece of wood from 2 to 4 inches wide, $\frac{1}{2}$ to 1 inch thick, and a little longer than the roll body. Lines *a* corresponding to the edges of the grooves are marked on the edge of the strip, and a nail *b* is driven in the end at a distance from the last line marked on the edge equal to the distance shown by the drawing, from the end of the body to the edge of the groove. In use, the strip is held on the body of the roll with the nail against the end of the roll, thus being always held in the same relative position with the roll. By using a strip to locate the positions of the grooves in the rolls, and templets for the size and shape of the grooves, any number of rolls may be turned alike.

To test the fit between the grooves and templets, a piece of white paper is held behind the roll, or rolls, so that a light from some source will shine directly on it. The templet is then held in the pass and if it fits perfectly no light can be seen between it and the roll. If the groove is not correctly shaped, light will be seen between the templet and the roll.

35. Templets for Closed Passes.—The outline of templets for closed passes is made to correspond to the complete outline of the work to be rolled instead of one-half of this contour, as in the case of templets for open passes. This is necessary as, when fitting the templet to the rolls, they must be together, and consequently a templet of the form described for open passes could not be used. A convenient method of holding closed-pass templets is shown in Fig. 20. The templet *a* is held on the rod *b*, which is about $\frac{1}{8}$ inch in diameter. The end *c* of this rod is threaded to receive a nut *d*, and has a shoulder *e* against which the templet rests. A hole whose diameter is about $\frac{1}{32}$ inch larger than that of the threaded end is drilled in the templet, and the templet is secured to the rod. In use, the tool is held by the handle *f*.

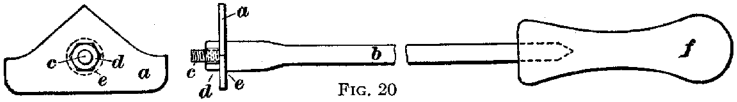


FIG. 20

36. Turning Grooved Rolls With Closed Passes. Grooved rolls with closed passes are sometimes called *collar-and-groove rolls.* They must necessarily be fitted together when turning. This is done by finishing one roll, generally the collar roll, which is the roll carrying the extending part, and then turning its mate, the groove roll, which is the roll recessed to receive the collars, while the finished roll is carried above it on straps shown at *v*, Fig. 4.

37. Suppose the rolls shown in Fig. 16 (*d*) are to be grooved, their bodies having been otherwise turned. As was done when grooving rolls with open passes, a strip, Fig. 19, is made, the division marks being laid off on it in accordance with the drawing. This strip serves as a gauge when spacing the grooves and collars. The collar roll *a*, Fig. 16 (*d*), is finished first. To lay off the grooves, a chalk mark is drawn along the body of the roll parallel with the axis, the strip is placed upon this chalk mark, a pencil line is drawn the length of the roll, lines are then also drawn on the roll corresponding to the divisions on the strip, and prick punch marks are made at the intersections of these lines.

38. After laying out the location of the grooves and collars, the body of the roll is rough grooved nearly to size. The parts *d*, *e*, and *f*, Fig. 16 (*d*), are now turned to size, and the groove *g* is finished, using a tool of a shape corresponding to that of the groove and the strip and templet as gauges. The tool is fed in until the groove is of the correct shape as shown by the templet. The templet employed in this case is made especially for the groove that forms the flange of the work. The groove *h* is next turned to size, using a tool of the shape of the groove, which is finished to the strip and the complete templet. The part *i* is now turned, using the strip as a gauge, and the roll is removed from the lathe and placed on the straps **v**, Fig. 4, after the groove roll *b* has been set in the housings.

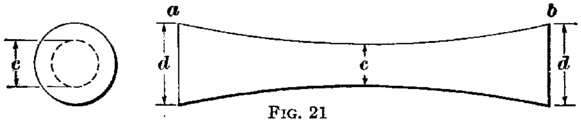


FIG. 21

The groove roll is now laid off and grooved as was done in the case of the collar roll, except that the straps carrying the collar roll are let down gradually as the groove roll is being finished until the rolls are the same distance apart that they are to be run in the mill. The groove is then finished to fit perfectly the templet, which is held on a rod.

39. Turning Concave Rolls.—Rolls used to roll sheet metals may be of either the hot or cold type and are not grooved. *Hot rolls* are those used to roll hot sheets, and *cold rolls* are employed to roll cold sheets. Owing to the greater expansion in the center part of the rolls when hot, hot rolls are usually made concave, as shown exaggerated in Fig. 21. The shape of the roll is that of a regular curve *a b*. The smallest diameter *c* of the roll is at the center and the largest diameters *d* are at the ends. The rolls are made of such form that when they are brought together with their axes crossed a certain amount, the contact between the rolls will be a straight line. In operation, the rolls are not crossed. The cross of the rolls is measured by placing a straightedge on the roll at such an angle that no light can be seen between it and the roll, drawing one line along the straightedge, and another line touching the first line at one end of the roll body and parallel to the roll axis, and measuring the distance between these lines at the other end of the roll body. This distance is known as the *cross of the roll*. The cross of the rolls usually varies from 2 to $3\frac{1}{2}$ inches.

Concave rolls are turned so that when a straightedge is placed on them at the proper angle, no light can be seen between it and the rolls. The cutting edge of the tool used for turning the rolls is slightly rounded. Both ends of the rolls are turned to the same diameter, and the center is turned the required amount smaller. Cuts are then taken on the body of the roll until the desired shape and finish are obtained.

40. Size of Rolls for Working Hot Iron.—In turning grooves for rolling-mill work, the grooves must be made somewhat larger than the standard bars they are intended to roll. To meet these requirements, an allowance of $\frac{1}{64}$ inch per inch of diameter is usually considered sufficient. For instance, a tool to cut a groove for rolling a 1-inch round bar would have to be $1\frac{1}{64}$ inches in diameter, and a groove for rolling a $3'' \times \frac{1}{2}''$ flat bar would have to be $3\frac{3}{64}$ inches wide, similar allowances being required for all shapes.

41. Returning Worn Rolls.—Rolls that have been worn from use are usually returned. It will be found that a very hard skin, almost impossible to cut, has been formed on the surface. This skin is very thin and is removed by taking a heavy cut, getting under the skin, before truing up the surface accurately with light finishing cuts. If light cuts are attempted before removing this skin, the tool will be dulled. High-carbon steel is used for both the roughing and finishing tools, as high-speed steel will not retain a good cutting edge.

TURNING HOLLOW ROLLS

42. Lathe for Turning.—Rolls for flouring mills, calendering rolls for paper mills, and rolls for other similar purposes are generally cast hollow and chilled on the outside. These rolls are usually turned on a special type of lathe, Fig. 22, and, in the case of flouring-mill and calender rolls, are ground to a perfect finish while running on their own bearings.

Both spindles of the lathe are made hollow and the roll is introduced through them and the collars a, Fig. 22, and is held in position by the setscrews b. In the lathe shown, both spindles are fitted with gears, the roll being driven from both ends, thus increasing the rigidity of the lathe. The shaft j is driven by any convenient means. The pinion is keyed to this shaft and drives the gear which is keyed, together with the pinions which drive the spindle gears, to its shaft. This style of lathe is not provided with a carriage having a feed parallel to the length of the lathe, but simply with a broad tool post d fitted upon a cross-slide c that can be fed along the ways e by means of the feed-screw f.

Lathes driven from one end only are also used for turning hollow rolls. In this case, the tailstock end of the lathe is made with a hollow spindle through which the roll can be introduced.

43. Holding and Driving Work.—Hollow rolls are first
t up in the lathe; the chilled surface is then turned, and the ends
e cut off, after which the rolls are bored and fitted to a center
ce which forms the shaft and journals. Ordinarily, in turn-
g 10- or 12-inch rolls that are to be bored and mounted sub-
uently, the roll is held by means of eight setscrews at each
d, these setscrews also acting as drivers. Fig. 23 illustrates
general method of driving. In Fig. 22 can be seen the col-
a through which the setscrews b are passed to hold the work.
same letters have been used for referring to these parts
g. 23. The roll r is centered and held by means of the set-
s b. This method of adjusting and driving the roll enables
orkman to center the chilled part very carefully, so that

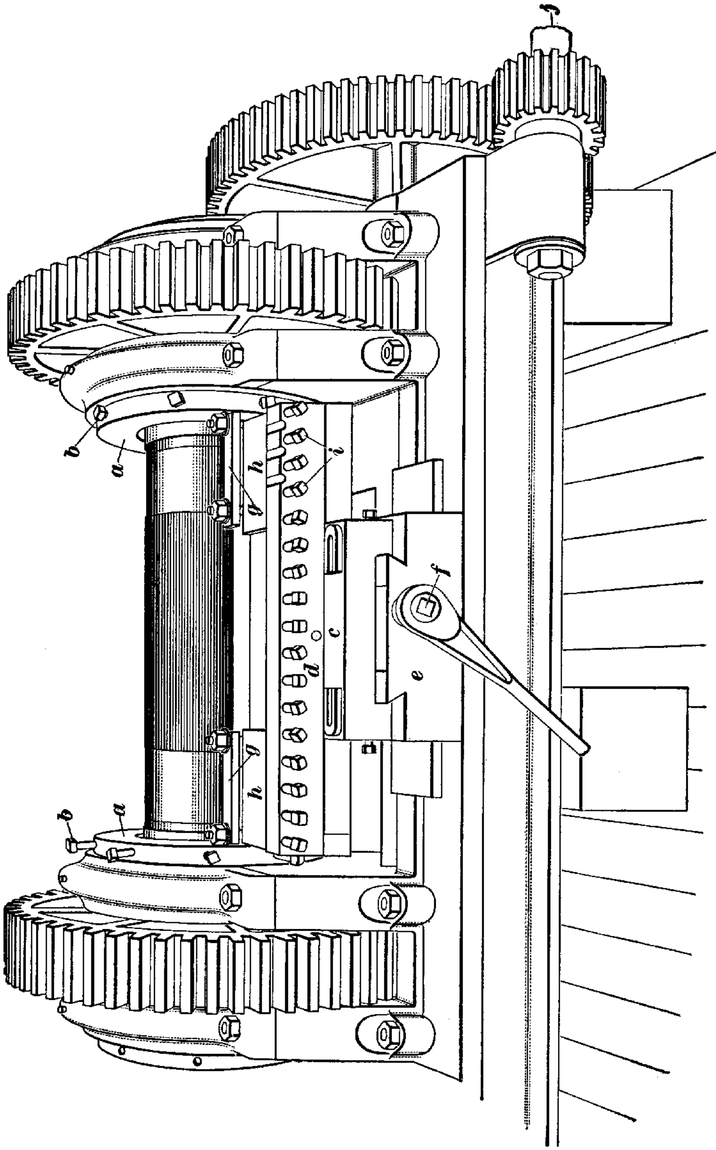


FIG. 22

the amount of turning required will be as small as possible. There is generally about $\frac{1}{8}$ to $\frac{3}{16}$ inch of stock to be turned from chilled rolls, and as the turning process is very slow it is important that the centering be done accurately and carefully.

44. Holding Lathe Tools.—Tools for turning hollow chilled rolls must be clamped to the lathe tool rest very rigidly. The method of holding the tools is illustrated in Figs. 22 and 23. In Fig. 23 the tool *c* is set on the carriage *h* and clamped down by means of the strap *e*, which is held in position by two bolts *f*. The tool is forced against the rolls by means of a series of setscrews *g*. Care must be taken that the front face of the rest is close to the roll, as shown at *i*. The closer this rest is to the roll, the less danger there will be of breaking the front face of the tool. The flat tools employed for this work may be originally ½ in. × 5 in. × 5 in. If the tool is ground on one face only, but two cutting edges can be obtained from one grinding. If the tool is ground on both faces, as *j* and *k*, four cutting edges will be obtained. When these have been dulled,

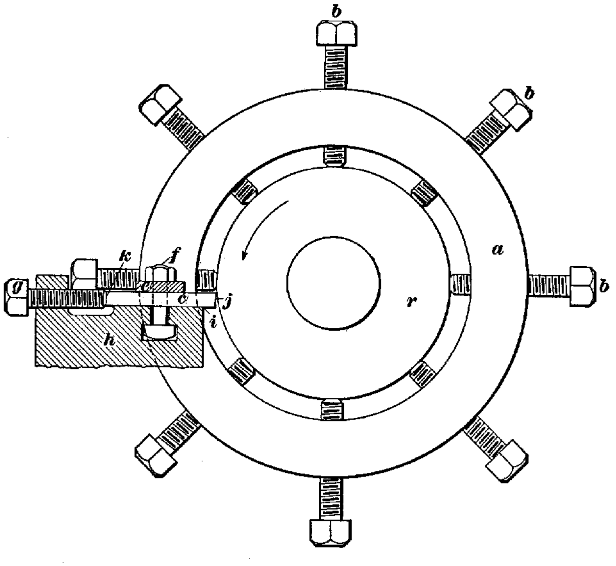


FIG. 23

the tool is ground again, and each succeeding grinding makes it narrower. Tools can be used until they become so narrow that they can no longer be held by the clamps *e*. In Fig. 22, the clamps can be seen at *g*; in this case very narrow tools are being employed and packing pieces *h* are placed behind them for the setscrews *i* to bear against.

45. The upper edge of the tool *c*, Fig. 23, is set ½ inch below the center of the 10-inch roll. This, together with the concave form of the face, will give the proper amount of clearance. In setting cutting-off tools, they are clamped by means of one or more clamps similar to *e*, Fig. 23, and the back end of the tool is set against a setscrew or a packing piece held by two or more setscrews. Cutting-off tools must overhang the front edge of the rest *i*, Fig. 23, to a greater extent than turning tools, and consequently it is necessary to have the tool deeper from the top to the bottom, so that it may be stronger.

After the tools have been clamped in place they are fed to the work by means of the feed-screw *f*, Fig. 22, and are kept parallel with the face of the work by adjusting the setscrews *i*. The shavings cut from the roll resemble very fine needles or gray hair.

46. Turning Hollow Rolls.—The tools commonly employed for turning hollow rolls are flat broad-nosed or wide-faced tools. It is probable that ½ in. × 5 in. × 5 in. is about an average size for straight work. In turning cylindrical rolls two tools are commonly operated at a time, thus turning 10 inches of the face of the roll. At first thought it might seem best to use one tool 10 inches wide; but it is difficult to harden so wide a tool without cracking it; narrow tools are far less likely to break, and on the whole there is greater economy of steel and less difficulty experienced in adjusting tools when the two 5-inch tools are employed in place of one 10 inch. All tools for turning chilled iron differ radically from those employed on softer metals, and all the turning is of the nature of scraping, the tools being given but little, if any, clearance.

47. When cutting off the ends, the roll is never entirely cut off on the lathe but is cut down until it has a shell about ¼ inch thick about the core. It is then removed from the lathe and iron wedges are driven into the cut made by the cutting-off tool to force the end off. The roll is bored with ordinary tools in another machine, the central portion of the roll being soft.

GRINDING CHILLED ROLLS

48. Roll-Grinding Practice.—Chilled rolls intended for use in flouring mills, calender rolls for paper-making machinery, and others requiring a smooth, cylindrical surface are finished by grinding. The necks as well as the bodies of the rolls may be ground. In some cases the necks are left as they come from the lathe and in others they are ground previously to grinding the bodies. If the necks are not cylindrical and the rolls are ground while they are running in bearings, the body of the roll will not be ground cylindrically. For this reason, where accuracy is required, the necks are generally ground.

49. Poole Grinding Machine.—The J. Morton Poole grinding machine is much used to grind large rolls. It is arranged with the grinding wheels in swinging frames to grind the roll cylindrically, regardless of slight inaccuracies of the ways. To secure the best results in grinding a roll on this machine, the necks must have been previously ground true, by grinding on dead centers in the usual way on a cylindrical grinding machine of the ordinary type.

50. Cylindrical Grinding Machine.—A cylindrical grinding machine adapted to roll grinding is shown in Fig. 24. It can be used to grind both the necks and bodies of the rolls, the necks being ground on dead centers, and the bodies while the necks are running in bearings. This machine is similar to the cylindrical grinding machines in ordinary use, being of the type in which the table *a* is stationary while the grinding wheel *b* and the carriage *c* which contains it, traverse past the work *d*. This type of machine is especially adapted to the grinding of long heavy rolls, as the roll does not traverse back and forth when grinding. The table of such a machine is more rigid and less floor space is needed.

51. The grinding wheel is driven by a belt *e*, Fig. 24, operating from the main drive shaft *f*. This shaft extends the entire length of the machine, and from it the different mechanisms are driven independently through belts. It is protected by a sheet-metal guard *g*. The grinding-wheel belt *e* passes over idlers *h* that are arranged so that the belt is maintained taut on the pulleys as the wheel head is moved on the cross-slide. The carriage *c* travels lengthwise on the **V** *i* and the flat *j*. These ways are protected from grinding dust and dirt by the guards *k*. When grinding the necks of the roll, the roll is supported on dead centers in the usual way. When grinding the body of the roll, the necks rest in the bearings *l*, the roll being connected to the headstock, not shown, in any convenient way to cause rotation. The headstock spindle and the main shaft *f* are driven by a motor located at the end of the machine, not shown. They may be driven, if desired, by belting connected to an overhead countershaft. A liberal supply of soda water is furnished to the wheel when grinding by the pump *m* through the hose *n*. The speeds and feeds of the machine are controlled by hand wheels and levers.

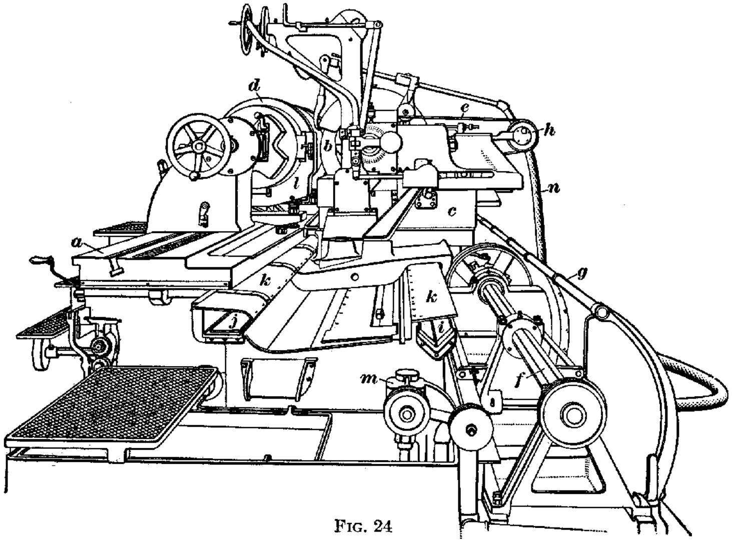


FIG. 24

52. Selection of Grinding Wheel.—In grinding chilled-iron rolls, as in turning them, the degree of hardness of the metal will, to a great extent, govern the working of it, the softer roll being ground much more rapidly than the harder. The selection of the grinding wheel must be made with the aim in view of producing a highly polished surface and a rapid removal of stock. The harder the iron, the softer in grade should be the wheel for best results, and the finer the grain of the wheel, the more highly polished will be the surface produced. In general, for grinding chilled iron a soft or medium soft grade of wheel and a grain of from 60 to 80 will be found satisfactory. For grinding the necks of the rolls, which are not chilled, a wheel of harder grade might be used. The same result may, however, be obtained by speeding up the grinding wheel.

53. Grinding Speeds and Feeds.—The surface speed of the rolls, when grinding, varies from 20 to 60 feet per minute, and the depth of cut varies from .00025 to .004 inch. When grinding hard chilled iron with a depth of cut of .004 inch, the roll is run slowly, at a surface speed of about 20 feet per minute. A traverse speed of the wheel of about $2\frac{1}{4}$ inches per revolution of the work would be good practice for this case. It is best to use this traverse speed, because by so doing the grinding wheel cuts and consequently wears evenly over almost its entire face. If a lower traverse speed were used, one corner of the wheel would do all the heavy work and the face would be worn out of shape very quickly.

After the roll has been roughed down nearly to size, a cut of .0015 to .002 inch in depth with a traverse speed of about 1 inch per revolution of roll and a surface speed of about 45 feet per minute is taken. When finishing the roll, the surface is run at about 60 feet per minute, the traverse speed is lowered to about $\frac{1}{8}$ inch per revolution of work, and cuts of from .00025 to .0005 inch are taken. With a light cut, a high surface speed, and a slow traverse speed, a surface, mirrorlike in appearance, can be ground. A grinding wheel made of alundum, aloxite or adamite, and operating at a surface speed of from 5,500 to 6,500 feet per minute, will give good results.

54. Grinding of Rolls.—When grinding rolls, the necks are ground on the dead centers in the usual manner. The bearings for carrying the rolls are now put on the table of the machine and adjusted to the necks of the rolls, and the tailstock center is adjusted to the work to prevent an endwise movement. A cut is then taken over the roll and the work is calipered on both ends to determine whether the roll is being ground cylindrically. If the roll is found to be smaller at one end than the other, proper adjustment is made and another cut is taken. When grinding, plenty of soda water must be kept running on the part being ground, to avoid burning the surface of the roll.

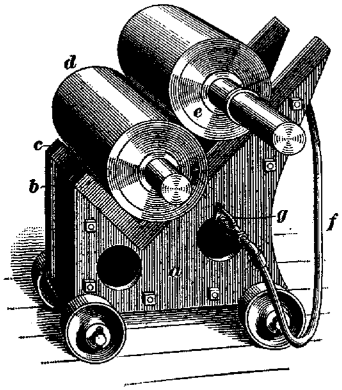


FIG. 25

55. Testing Rolls.—If the rolls are properly ground they should fit perfectly, and in order to test them a chalked straightedge, such as was used to test the straightness of the rolls when turning, may be employed. The arrangement shown in Fig. 25 is sometimes used to test the straightness of the rolls. A small carriage *a* is provided with carefully planed parallels *b* and *c* which are inclined so that the rolls will lie in contact. Two rolls are laid on these parallels, as shown at *d* and *e*. The hose *f* is connected to a gas fixture and a series of gas burners are arranged on the pipe *g* so that they furnish a bright light back of the joint between the rolls. Electric light may be used in place of gas light. If the work has been properly done, no light whatever can be seen between the rolls, as they rest on each other and on the parallels. An extremely delicate test of the accuracy of the workmanship on the rolls is thus given. The straightedge test will usually be found more satisfactory when testing large rolls and the testing device when testing small rolls.

PLANING AND DRILLING CHILLED IRON

56. Tools for Planing Chilled Iron.—It is frequently necessary to plane chilled-iron dies for pressed-brick machines, swage or anvil blocks, drop-hammer dies, guides for rolling mills, and similar purposes. This work may be accomplished by making the speed of the ordinary planer sufficiently slow and the tools sufficiently rigid. Best results are obtained by the use of very rigid machines. In some cases, the planing is done by feeding a broad, square-nosed planing tool directly down on the face of the work, a slight amount of feed being given after each cut. When the width of the tool has been finished, it is moved along and a corresponding cut taken down to the proper depth. This method of procedure is exactly like that employed in turning chilled rolls.

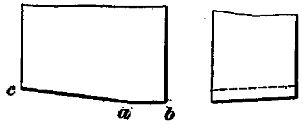


FIG. 26

57. In other cases a fairly broad-nosed planing tool is adjusted so that it will act both as a roughing and a finishing tool and is given a slight feed across the planer after each cut, the cutting edge of the tool being of the general form shown somewhat exaggerated in Fig. 26; the portion *a b* is parallel to the surface of the work to be planed, and the portion *a c* is inclined so that it will act as a roughing tool to prepare the surface for the finishing cut. Such a tool is given a very slight clearance. This practice of feeding sidewise in planing may be followed where it would not be possible to do so in lathe work, because all the feed occurs at the end of the stroke before the tool begins to cut, while in lathe work the tool must be fed sidewise during the cut.

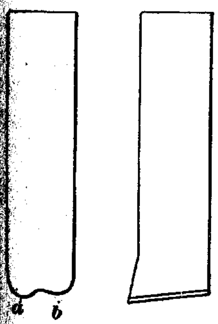


FIG. 27

58. A form of planing tool used only for roughing is shown Fig. 27. This tool takes two cuts, the parts *a* and *b* doing the cutting. Chilled iron which has been rough-planed with a tool of this form is finished with a broad-nosed tool.

59. Special Forms of Planing Tools.—Chilled rolls are sometimes grooved lengthwise. A tool and holder used to plane grooves of this form is shown in Fig. 28. The tool *a* contains a projection *b* which slides in the slot *c* of the holder *d*. The tool is clamped in any position by means of the yoke *e* and the screw *f*. The sides *g* of the tool are machined to such a shape that the tool, when its face *h* is ground square with the work, will cut a groove of the shape desired. The tool is sharpened by grinding on the face *h* only. The tool holder, yoke, and screw are made of machinery steel, the roughing tool of high-speed steel, and the finishing tool of high-carbon steel.

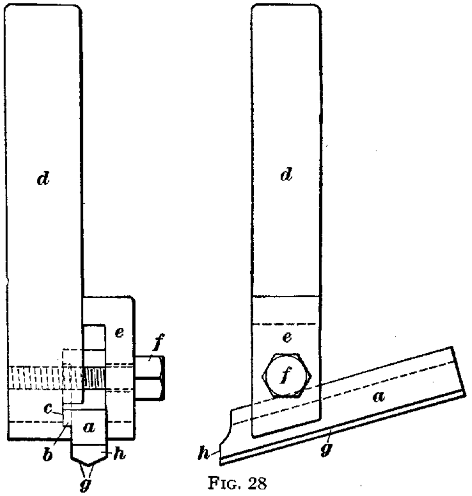


FIG. 28

60. Corrugated Rolls.—Some of the rolls employed in flouring mills must be corrugated after they are turned and ground. The corrugations are shallow grooves planed in the face of the rolls; they are not parallel to the length of the roll, but have a slight spiral. These grooves are found necessary in certain classes of grinding rolls, not only to cause material to feed properly, but to produce the desired result upon the material being ground.

61. Corrugating Machine.—The machine employed for corrugating rolls is similar to a planing machine. One type of this class of machine is illustrated in Fig. 29, in which *a* is the roll being grooved. The weight of the roll is being carried on

bearings *b*. The tailstock *c* is provided with a center that prevents any lengthwise movement of the roll, and the headstock *d* is furnished with the necessary mechanism for rotating the roll through the proper angle to give the desired spiral. In the type of machine shown this is accomplished by means of a worm-wheel *e* and a worm *f*. The worm is made long and serves as a rack. It is moved crosswise by the slide *g* traveling in the slot *h*, which may be set at any desired angle with the ways of the machine. The slide carries the worm across the grooving machine as the roll advances, and so rotates the worm-wheel *e* through a portion of a revolution during each stroke of the machine, thus producing a spiral groove. The proper number of divisions or teeth are obtained by means of an automatic spacing device shown on the worm-shaft *i*. This spacing device gives the shaft *i* a portion of a revolution after each stroke of the machine, thus advancing the roll to the next space.

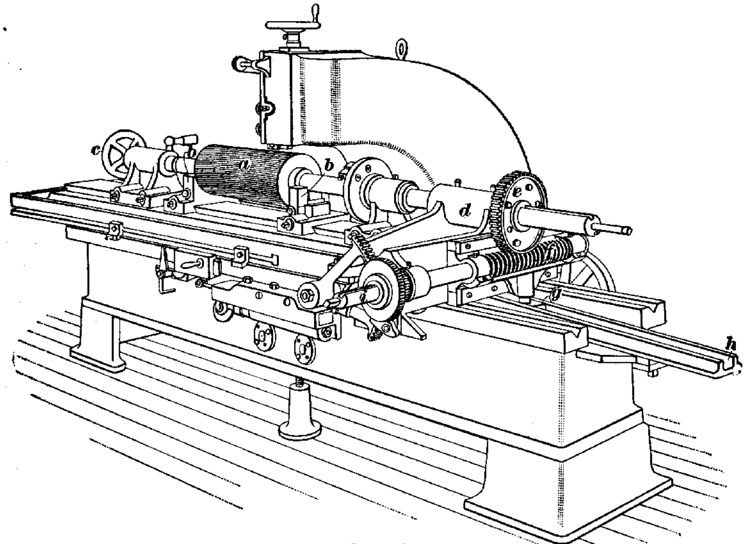


FIG. 29

62. Corrugating the Rolls.—In corrugating rolls, a wide tool similar to that shown in Fig. 30 is employed. This tool is made of $\frac{3}{4}'' \times 1\frac{1}{2}''$ steel. The tool is milled on the end with the kind of corrugation wanted, after which it is hardened. The tool is so set in the machine that it starts to cut on one side and each succeeding tooth takes a deeper cut, until the last one finishes the cut to the required depth. This method may be used if the corrugations are not so large that considerable metal must be removed, when it may be necessary to go around the roll twice to finish the grooves.

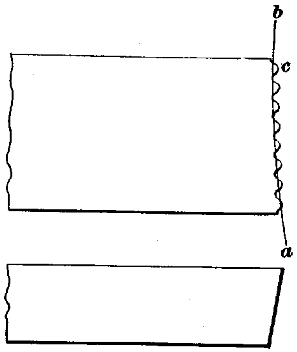


FIG. 30

63. In ordinary practice it is impossible to take a cut of over .015 inch in planing chilled iron, and, unless wide tools with a number of teeth are employed, it will take a very long time to do the corrugating. In Fig. 30 the curved line *a b* represents the circumference of the roll, and each succeeding tooth takes a slightly deeper cut than the preceding, the tooth *c* finishing the groove.

64. Drilling Chilled Iron.—Drills for drilling chilled iron are made of high-carbon steel and of the form shown in Fig. 31. A twist drill would not be strong enough to withstand the hard service. The point of the drill, instead of being ground to the regular angle of drills, is ground very flat, the angle *a* being from 165° to 170°. The tool is carefully hardened and a little clearance is ground on the cutting faces. When drilling, considerable pressure must be applied to the tool, and it must be turned quite slowly. Turpentine is used as a lubricant.

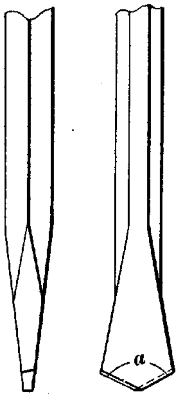


FIG. 31