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Forging Operations

MACHINE FORGING
FORGING DIES
SPECIAL FORGING OPERATIONS

207

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MACHINE FORGING

Serial 1690 Edition 1

FORGING MACHINES

INTRODUCTION

1. In its broadest sense, machine forging is the working of metal, either hot or cold, by means of a machine, causing it to flow in such a way as to give it some desired shape, either by slowly applied pressure or by blows. It is impossible to exclude from this machine process of working metals any forming operations on cold metals, as it has been found advantageous to forge metals at temperatures varying from ordinary atmospheric temperature to about 2,000° F. Low-carbon steel, certain brass alloys, and aluminum are frequently pressed, rolled, or punched cold. Zinc is most easily worked at a temperature of between 300° and 400° F. Aluminum can be drop-forged at a temperature slightly below a dull red heat, but it is very difficult to maintain it at exactly the required temperature. Copper can be forged hot, and pure annealed copper can be formed cold by pressing. From this it will be seen that machine forging operations are exceedingly varied in their nature.

Forging machines roll, hammer, or press the metal into the desired shape, and most forging machines may use either plain or formed dies. The use of formed dies will be considered exclusively in this Section.

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ROLLS

2. Graded Rolling.—Work of varying thickness may be done between properly shaped rolls. This is called **graded rolling,** and is really forging with revolving dies. Graded rolling is usually accomplished by passing a piece of metal lengthwise between a pair of rolls, one or both of which are more or less eccentric or have dies attached, so as to give the finished piece a tapered form or a varying thickness. Silver, German silver, and brass may be rolled by this method when cold; but iron and steel are usually rolled hot. In some cases, the stock is simply passed through the rolls; that is, the piece is placed against a guide, which serves to locate it properly before starting through the rolls; the rolls then grip it and carry it from the operator, requiring no further attention from him. In other cases, dies are fastened to the rolls. These dies do not extend all around the rolls, and when the parts not covered by the dies are next to each other, an open space is left between the rolls. The rolls turn continuously, and when the open space appears the work is passed through it. As the rolls turn, the dies come together, grip the work, and roll it toward the operator. The advantage of using a machine in which the work is done by rolling the material toward the operator is that where several passes are required all work can be done by one man, while with rolls carrying the work away from the operator it is necessary to have a man at the back of the machine to return the partly finished pieces. Graded rolling is sometimes done to break down stock or to rough it to shape, so that it may be finished by drop forging.

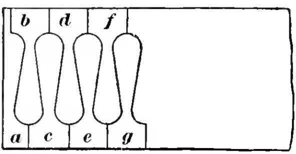


FIG. 1

3. Some of the operations in the making of spoons are excellent examples of graded rolling with dies. The blanks are punched from a sheet $\frac{1}{4}$ inch thick, in the form shown in Fig. 1; the piece *a* is waste, and *b*, *c*, *d*, *e*, *f*, and *g* are spoon blanks. The large end of the spoon blank, which is to form the bowl, is first made wider by cross-rolling; this is done in some cases by passing the blank sidewise between rolls about 6 or 8 inches in diameter, the rolls being located between housings, as shown in Fig. 2. A part of each roll is made smaller in diameter, that is, it is cut away so as to clear the spoon handle, shown at *b*. The portions *r r* of the rolls do the cross-rolling; the rolls are connected by suitable gears, which are placed on the ends of the roll shafts. In other cases, the cross-rolling is done between overhanging rolls, as shown in Fig. 3; these rolls are 10 or 12 inches in diameter, to insure the necessary stiffness. The portions of the rolls between the housings are frequently used for other work. Driving gears are located on the ends of the roll shafts at the side *g*.

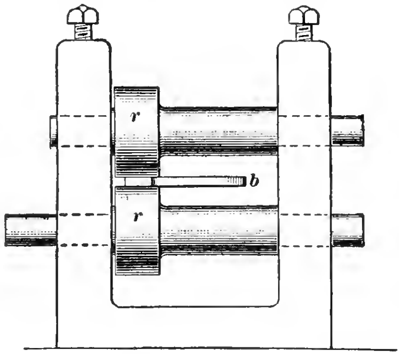


FIG. 2

The thickness of the metal varies in different parts of a spoon and this varying thickness is produced by graded rolling. Part of the circumference of the rolls is cut away so that the length of the circumference remaining is equal to the length of the spoon. The part of the roll that is not cut away is shaped so as to produce the desired taper on the work. A different set of rolls must therefore be made for every size or style of spoon. In some cases the work passes through the rolls away from the operator and falls out on the other side, while in others it is rolled toward the operator.

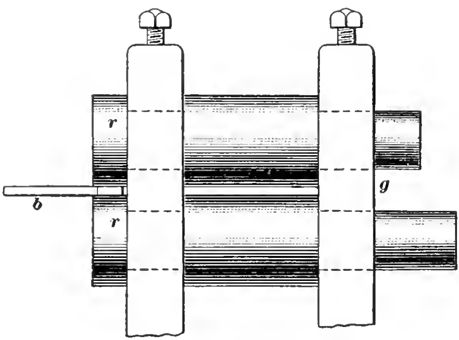


FIG. 3

4. In rolling rifle barrels, steel billets are heated in a furnace and then passed through successive grooves in a pair of special eccentric or graded rolls, until the barrel is reduced to the proper size and has the required taper. As the billet passes through the first groove, it is seized by a helper at the back and passed over to the workman in front. The work passes between the rolls with the large end first, passing once through each groove, except the last, through which it is passed twice; the work is given a quarter turn between each two passes. As

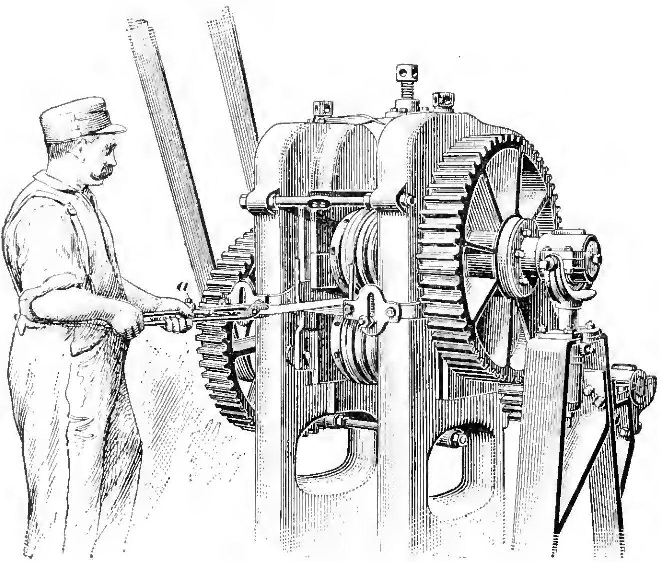


Fig. 4

soon as the barrel is rolled to size, the ends are sawed off to the proper length.

5. A pair of graded rolls fitted with dies for special forging work, on either hot or cold metal, is shown in Fig. 4. These rolls are provided with nuts and collars, between which the rolling dies are clamped. The dies can be removed and changed at will, so that a large variety of work can be done on one pair of rolls. The rolls turn so that the work is run toward the operator, and, as the dies do not extend over the entire circumference of the rolls, the metal is passed between them at the time in the revolution when the dies are out of the way. The work is located by guides, which control its position both vertically and horizontally. When rolling hot metals, the location is determined by a stop *a* on the tongs, Figs. 4 and 5.

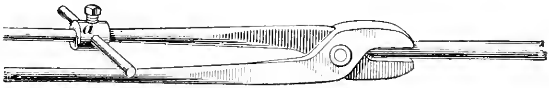


FIG. 5

It will be ncticed that this is simply a clamp screwed to the tongs; it is brought against a guide fastened to the front of the rolls, to show how far the iron should be pushed in between the rolls. Sometimes the end of the tongs strikes the guide, and this serves to locate the work. After the work has been placed in position, the revolving dies catch the piece and roll it toward the operator. As soon as the dies leave the piece, the operator puts it in position for a second pass through the rolls, either giving it a quarter turn and returning it through the same groove, or giving it a quarter turn and placing it in the next groove; in this way the work is continued until completed. In the machine shown in the illustration, there are three grooves, and the work is given two passes in the first groove, two in the second, and three in the third groove.

6. In Fig. 6 is illustrated the back of the machine shown in Fig. 4. In this view, the dies *a* are clamped between the nuts *b* and the collars *c* on the other ends of the rolls. The work *d* is shown in position ready for the dies to grip it as they come around to the proper point; the arrows show the direction in which the rolls are turning. A peculiar arrangement of gearing is used for driving these rolls, which admits of the adjustment of the distances between the rolls; this is accomplished by driving the top roll by a train of three gears, one being an idler swinging about one of the others and meshing with both.

7. Screw-Thread Rolling.—Screw threads are rolled on wood screws, track bolts, machine screws, and many other screws and bolts, from small sizes up to $1\frac{1}{2}$ inches in diameter. The thread is formed by rolling the stock between suitable dies, with sufficient pressure to force the material out of the grooves to form the thread points. That is, the cold metal is caused, by the pressure on the dies, to flow from the bottom of the spaces and form the full thread. It is in reality a cold-forging process.

8. Machines for rolling screw threads are made both horizontal and vertical, but since the horizontal and vertical machines are alike in principle only one will be described here.

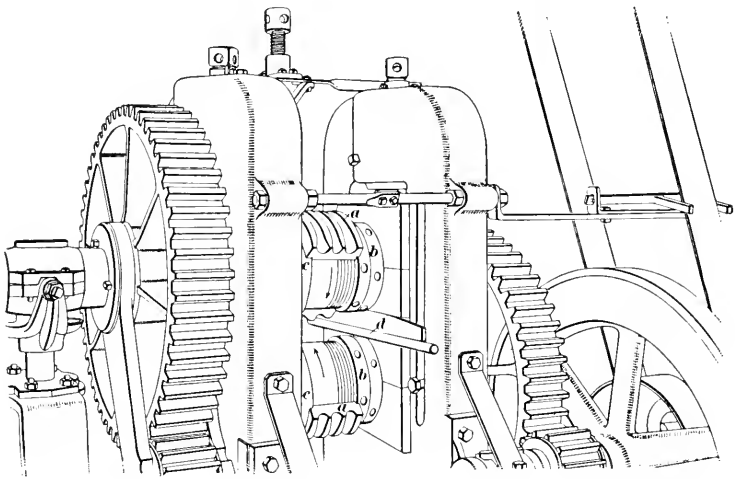


FIG. 6

The front view of a vertical thread-rolling machine is given in Fig. 7. There are two dies *a* and *b*; *a* is fastened to the frame of the machine, and *b* is attached to a crosshead partly shown at *c*. The blank that is to be threaded is placed on the feed bar *d* and is introduced between the dies at the proper moment by the pusher, or starter, *e*. To start the blank, the feed bar *d* is automatically withdrawn from between the dies and the starter moves forward, pushing the blank between the dies. Both the feed bar and the starter are moved by the cam *f* on the driving shaft. The crosshead *c* is moved through the connecting-rod *g* and yoke h by a crank on the shaft i. The shaft i is driven from the pulley j by gearing of which k is part. The yoke h is arranged so that, when the gear k turns in the direction of the arrow, the crosshead is given a slow motion on the down, or working, stroke and a quick motion on the up, or idle, stroke. The back of the crosshead c bears on a set of rollers,

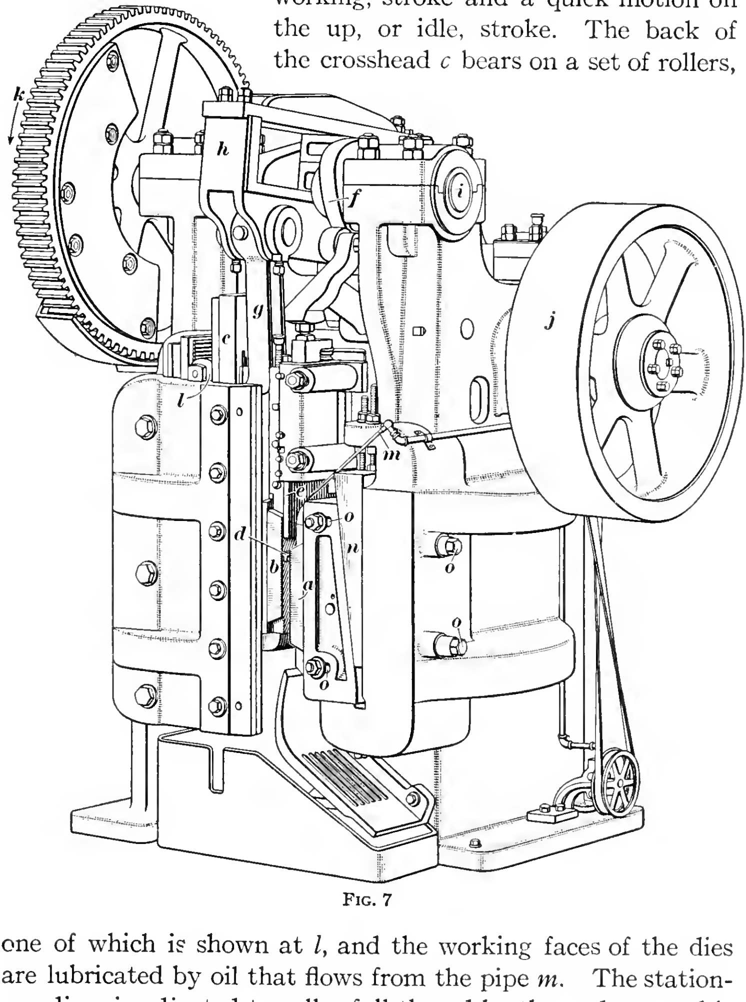


FIG. 7

one of which is shown at l, and the working faces of the dies are lubricated by oil that flows from the pipe m. The stationary die a is adjusted to roll a full thread by the wedge n and is clamped in the final position by the bolts o.

9. The threads on the dies are laid off at an angle as shown in Fig. 8, which is a die for forming a right-hand thread. The length of the die is about three or four times the circumference of the blank so that the screw will turn around, between the dies, about that number of times in forming the thread.

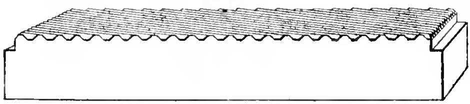


Fig. 8

Screw threads are rolled on many small pieces, the material being either hot or cold, depending on the size and character of the article. The rolled thread is claimed to be much stronger than a cut thread, but it is exceedingly difficult to keep dies in shape for rolling threads on hot stock; hence, this process is used mostly for rolling threads cold.

Fig. 9 shows how the metal is displaced by the dies to form the thread on the bolt *a*; the dotted line *b c* shows how deep the dies press into the stock, and also how the diameter is increased on account of the thread. As the finished thread must have a definite diameter, it is very important that the stock used should be of the right size; if the stock is large the screw will be too large, and if too small the screw will either be too small or the threads will not be perfect. The size of stock required to make a rolled thread of any given diameter can be calculated, but owing to the fact that the rule is long and rather complicated, and that the diameter of stock must sometimes be changed after trial because the metal will not always flow readily into the points of the threads, a simpler but less exact rule is ordinarily used. The first trial size of stock is obtained by subtracting the depth of the thread from its outside diameter. The depth of the United States standard threads may be found by dividing .6495 by the number of threads per inch; and the depth of **V** threads

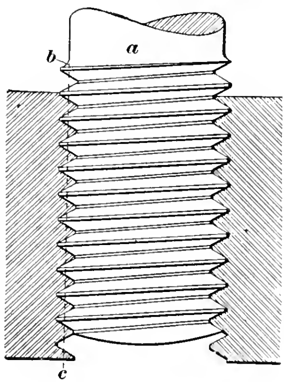


Fig. 9

may be found by dividing .866 by the number of threads per inch. The diameter of stock for some of the most common sizes of rolled threads is given directly in Table I.

TABLE I

SIZE OF STOCK FOR ROLLED THREADS

Diameter of Screw	United States Standard Thread			V Thread		
	Number per Inch	Depth Inch	Diameter of Stock Inches	Number per Inch	Depth Inch	Diameter of Stock Inches
$\frac{1}{4}$	20	.033	.217	20	.043	.207
$\frac{3}{8}$	16	.040	.334	16	.054	.321
$\frac{1}{2}$	13	.050	.450	12	.072	.428
$\frac{5}{8}$	11	.059	.566	11	.079	.546
$\frac{3}{4}$	10	.065	.685	10	.087	.663
$\frac{7}{8}$	9	.072	.803	9	.096	.779
1	8	.081	.919	8	.108	.892
$1\frac{1}{8}$	7	.093	1.032	7	.124	1.001
$1\frac{1}{4}$	7	.093	1.157	7	.124	1.126
$1\frac{3}{8}$	6	.108	1.267	6	.144	1.231
$1\frac{1}{2}$	6	.108	1.392	6	.144	1.356

10. To illustrate the use of the table, suppose a $\frac{1}{2}$-inch United States standard thread is to be rolled. How many threads per inch and what size of stock should be used? Find $\frac{1}{2}$ inch in the left-hand column; and, following horizontally across the table, in the columns headed United States Standard Thread, it is found that there are 13 threads per inch, and the depth of the thread is .05 inch, and the stock should be about .45 inch in diameter. Again, suppose a $\frac{7}{8}$-inch **V** thread is to be rolled. How many threads per inch and what size of stock should be used? Find $\frac{7}{8}$ inch in the left-hand column of Table I and, following horizontally across the table to the columns headed **V** Thread, the number of threads per inch is found to be 9, and the stock should be about .779 inch in diameter.

An example may be used to explain the determination of the size of stock when it is not obtainable from Table I.

EXAMPLE 1.—What size of stock should be used to make 12 rolled United States standard threads per inch, $\frac{3}{4}$ inch in diameter?

SOLUTION.—Owing to the fact that a $\frac{3}{4}$-inch screw does not ordinarily have 12 United States standard threads per inch, this combination does not appear in Table I. It will therefore be necessary to calculate the size of stock required to make these threads. According to the explanation just given, the depth of the thread is

$$.6495 \div 12 = .054 \text{ in.}$$

and the diameter of the stock is

$$.75 - .054 = .696 \text{ in.} \quad \text{Ans.}$$

It is sometimes required to find the diameter of thread that will be produced by rolling a given number of threads per inch on stock of a given size. In this case the depth of the thread should be added to the diameter of the stock, the depth of the thread being found as described in the foregoing example.

EXAMPLE 2.—What outside diameter of thread will be produced by rolling 10 **V** threads per inch on $\frac{3}{4}$ inch stock?

SOLUTION.—The depth of the **V** thread is

$$.866 \div 10 = .0866 \text{ in.}$$

and the outside diameter of the thread is

$$.75 + .0866 = .8366$$

which is practically .837 in. Ans.

11. Bending Rolls.—Plates are bent in bending rolls, which are placed as shown at *a*, *b*, and *c*, Fig. 10. Roll *a* is arranged so that it can be moved toward or away from *b* and *c*, in order to give the plate *d*, that is being rolled, the desired curvature. The roll *a* is called the *bending roll* and rolls *b* and *c* are the *pinching rolls*. The side view of a set of bending rolls is shown in Fig. 11, in which the rolls *a* are driven by electric motors *c*, through gears *b*, *d*, *e*, *g*, *f*, and shaft *h*. A gear *f* is

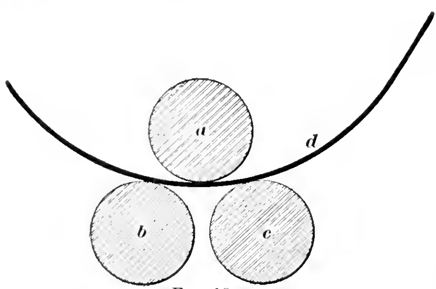


FIG. 10

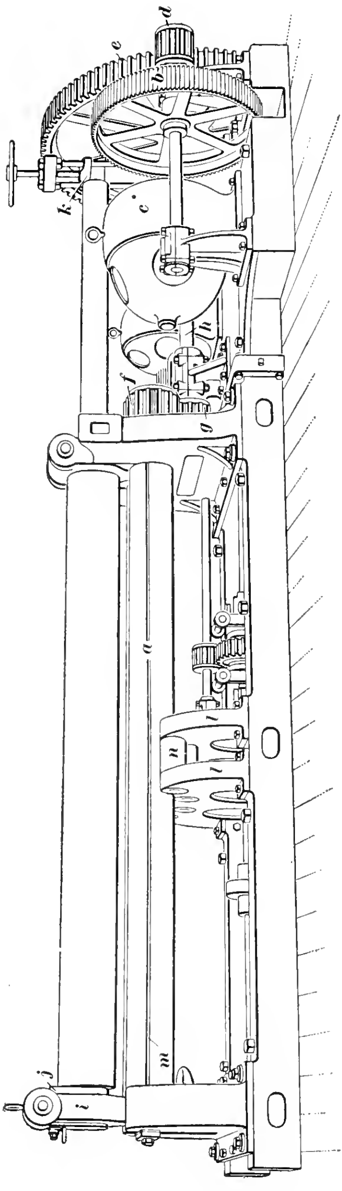


Fig. 11

attached to each of the pinching rolls, both of which are driven by gear *g*. The farther motor also drives gear *e* through gearing that is not shown, similar to *b* and *d*. The pinching rolls, which are driven, are also called *live rolls;* and the bending roll, which is not driven, is called a *dead*, or *idle, roll*.

12. The pinching rolls are stiffened by supports *l* and rollers *n* so they will not spring down in the middle. Each pinching roll has three slots *m* to help start the plates squarely through the rolls. The plate is put between the bending roll and one of the pinching rolls; then, as the roll rotates, the edge of the plate is caught by one of the slots, bent up around the bending roll and started between it and the other pinching roll. Cylindrical work is removed from the rolls by turning down the end *i* with the bearing *j*, it being hinged for that purpose, and raising the roll by the rigging shown at *k*. The curvature of the plate may be controlled by raising or lowering the pinching roll. This is done by a mechanism partly shown at the right of the supports *l*. The two ends of the bending roll may be moved together, or either end may be moved independently of the other end. By moving one end of the bending roll closer to the pinching rolls than the other, conical work may be formed.

HAMMERS

13. Steam Drop Hammer.—The steam drop hammer has many of the advantages of other drop hammers and it possesses one advantage not shared by them; that is, that steam may be used for driving the piston down more rapidly,

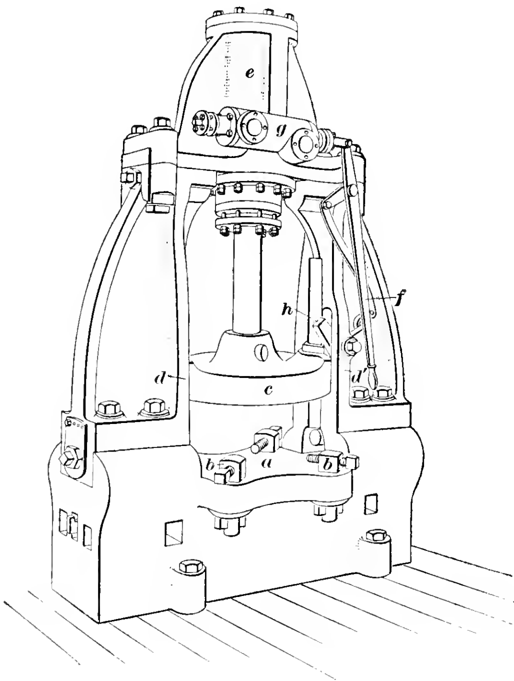


Fig. 12

and hence an exceedingly quick and powerful blow can be struck; or the piston may be let down slowly until the upper die rests on the work, when the steam pressure is applied and the dies forced together with a uniform pressure, as in the case of an ordinary power press. The work may then be finished by one or two blows of the hammer; in other words, the steam drop hammer is capable of a wider range of work than other forms, but as a rule it requires a somewhat higher degree of skill in the operator.

14. Steam Drop Press. — There is a large variety of work that must be pressed to bring it approximately to shape, and then a few sharp blows from a hammer must be struck to finish it. The steam drop press, which closely resembles the steam drop hammer, has been brought out to meet this demand. One form of drop press is shown in Fig. 12. The lower die is held in place on the base *a* by the poppets *b*, which extend through the base and are secured by keys below. The head *c* that carries the upper die, and moves between the guides *d*, *d'*, may be allowed to fall by gravity or may be forced down by steam or air pressure acting on a piston in the cylinder *e*. The lever *f* operates the piston valve in the valve chest *g*, and also moves the latch *h* out of the way when starting the head

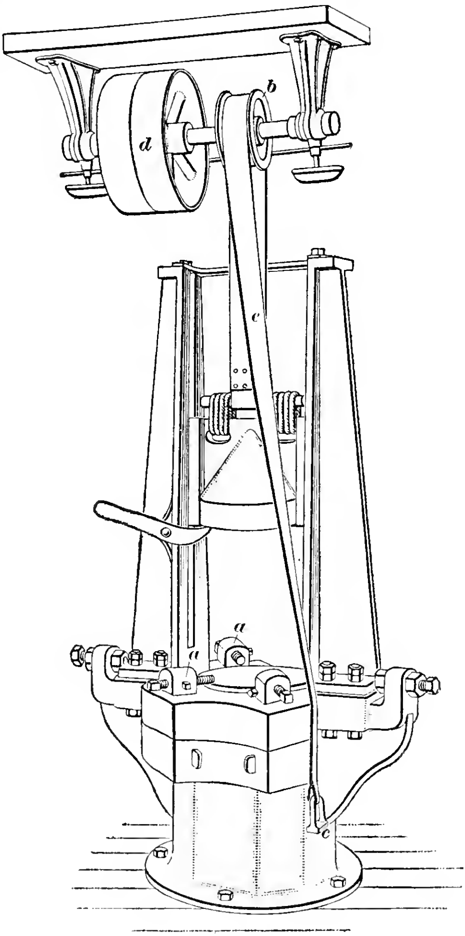


Fig. 13

from its highest position, where it is held by the latch when the press is not running. This type of press is used for large thin work, such as dish pans, where the work is first pressed into shape and then finished by two or three quick blows.

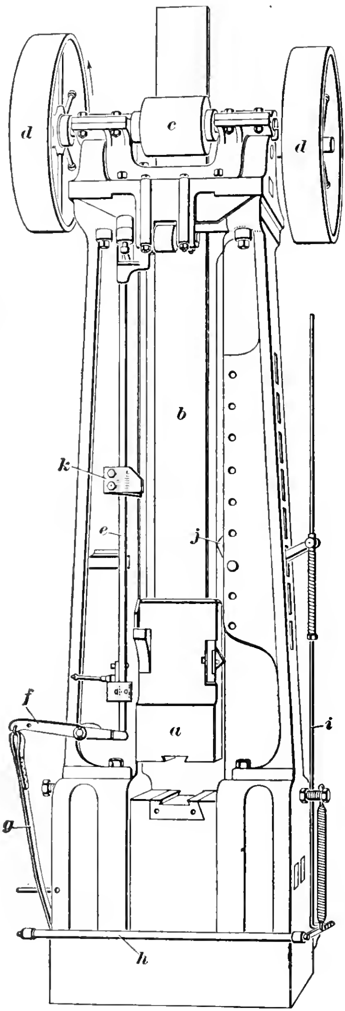


FIG. 14

15. Strap and Pulley Drop Press.—In the strap and pulley drop hammer, shown in Fig. 13, the weight is lifted by pulling on a strap that passes over a constantly rotating pulley. The pulley *b* is kept rotating by a belt on the pulley *d*, and when the end of the strap *e* is hanging loose the friction on the pulley is not sufficient to lift the weight. When the operator brings pressure on the strap, either by pushing his foot down in the stirrup at *c* or by gripping the strap higher up with his hand and pulling down, the friction of the strap on the pulley *b* is increased to such an extent that the hammer head is lifted. When the head reaches the desired elevation, the tension on the strap is relieved, allowing it to slip over the face of the pulley as the head falls.

The **poppets**, shown at *a*, are used to hold the lower die in place. They are made with long shanks that fit holes in the base of the hammer, and with adjusting screws through the tops to locate and hold the die.

16. Board Drop Hammer.—One of the most common forms of drop hammer is known as the board drop hammer, one form of which is illustrated in Fig. 14. The hammer head *a* and board *b*, to which it is attached, rise and fall together. Friction rolls *c* on each side of the board are attached to shafts carrying pulleys *d* turning in opposite directions, and run by belts in the directions shown by the arrows. The friction rolls are thus run continuously in the directions required to raise the board, but in their normal position they just clear the board. The rod *e* operates a cam that moves the rollers *c* so that they grip the board and raise it and the hammer. The foot treadle *h* is connected by a strap *g* to the lever *f*, and is also attached to the rod *i*, and thus operates the latch *j*.

17. When not in use, the hammer head is usually held up by the latch *j*, which is placed at about the highest point from which it is desired to have the hammer drop. When it is desired to strike a blow, the treadle is depressed, which pulls out the latch *j*, and permits the outer end of the lever *f* to rise and the rod *e* to fall. When the hammer falls, the lug on the hammer head strikes the lower dog on the rod *e*, carrying the rod down and forcing the friction rolls *c* against the board. The hammer is then raised, the rolls remaining in contact until the hammer head strikes the upper dog *k* on the rod *e*, thus raising the rod and throwing the friction rolls out of contact with the board. The hammer then again falls, striking another blow, and carrying down the rod *e* and throwing the rolls into contact as before. This process is repeated automatically, striking continuously, until the treadle is released, and raised by the spring shown at the right-hand side of the hammer; then the latch *j* again catches the hammer head and holds it in the raised position. Light blows may be struck by releasing the treadle at each rise of the hammer before the hammer head strikes the dog *k*, throwing out the friction rolls and causing the hammer to drop before it has reached its full height. The operator can thus vary the stroke as conditions may require. The hammer may be set for different heights of drop by moving the latch *j* and the dog *k* up or down.

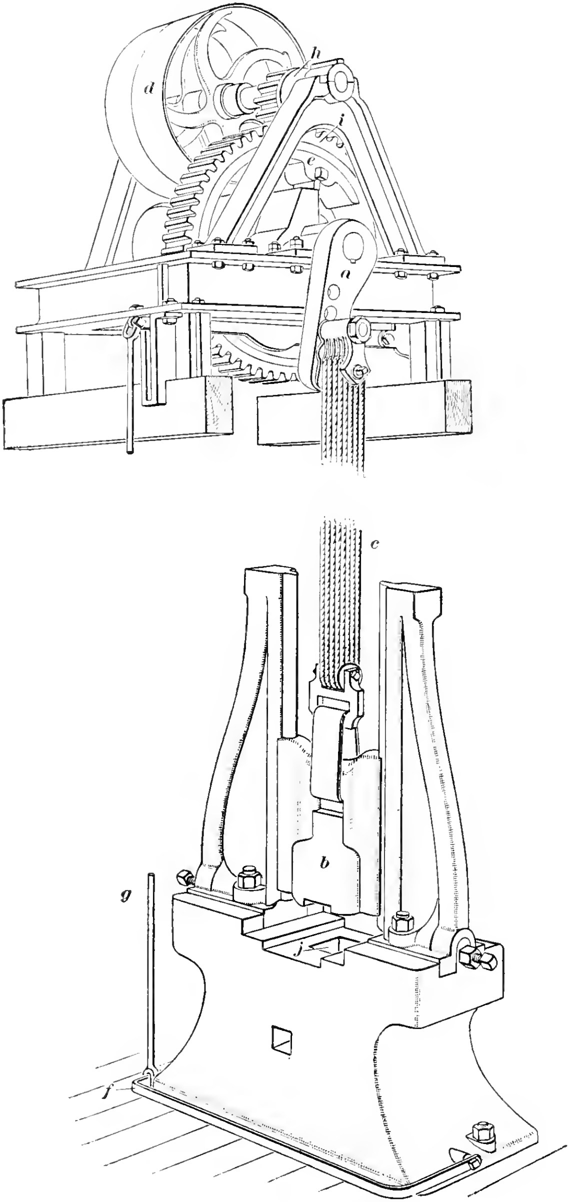


Fig. 15

18. Crank Drop Hammer.—A common form of crank drop hammer is shown in Fig. 15. In this type of hammer, the lifting mechanism is arranged in such a manner as to rotate the crank *a*, thus lifting the hammer head *b* by means of the ropes *c*, or by a leather strap. The mechanism is driven by a belt on the pulley *d*, on the shaft carrying the pinion *h* that drives the gear *i*. A clutch *e* is so constructed as to raise the hammer after each stroke and hold it in its highest position until the treadle *f* is depressed. The treadle *f* is connected, through the rod *g*, to the clutch *e*. By keeping the treadle depressed, the hammer will strike successive blows.

19. Advantages of Board and Crank Drop Hammers. Board and crank drop hammers have a number of points that distinguish them from each other. In general, a board drop hammer strikes a quicker or sharper blow for the same weight of hammer head and same height of drop. The blow of the board drop hammer may also be quickly regulated by varying the height of the drop.

The *crank-lift*, *rope-lift*, or *strap-lift* drop hammer, as it is variously known, is largely used for bending, shaping, straightening, and welding. These hammers are used extensively by the manufacturers of agricultural implements, and also by malleable-iron companies. The crank machines have an advantage in the lifting arrangement because the board drop hammer depends on friction for lifting the hammer, while with the crank drop hammer, the lifting is positive. The board and gearing are expensive, so that a crank machine of a given capacity and weight of drop will cost less than a board-operated machine. The form of the lifting device is not of much importance in the case of light work, but for manufacturing where large forming dies are used it is a point well worth considering. As a rule, the crank machine is simpler and requires less skill for its operation; hence, it is preferred for rough work. It is also used very extensively for forging soft metals cold, as in making spoons, watch cases, and similar work.

In many classes of work, it is absolutely necessary that the hammer head or drop should fall from two or more heights, in order to strike light or heavy blows when forging; and sometimes, as the work is turned from side to side, these light and heavy blows must alternate. For such work the crank hammer is not suitable, and it is necessary to use a board drop hammer. Even for the lighter class of forgings, especially where the dies are frequently changed, the board drop hammer is generally considered the better.

20. Die Forgings.—Die forgings are produced in formed dies that are shaped more or less closely to the outline of the forging. Various machines, such as drop hammers, steam hammers, and presses, are used to force the stock into the dies. A *drop forging* is a die forging that is produced by using the force of a falling weight to drive the stock into the dies. Drop forgings may be produced on a drop hammer or a steam hammer. When a steam hammer is used, the force of the blow struck by the falling hammer head may be increased by steam pressure behind the piston. The general process of making die forgings will be explained by means of a simple example requiring but two operations and other forgings requiring these and additional operations will be described later throughout the remainder of this Section.

21. The clips used to hold the wooden and iron parts of a wagon axle together are made flat, as shown in Fig. 16, and are bent to fit the axle on which they are to be used. The ends a and b are threaded to receive nuts that hold a yoke on the clip after it has been bent. The flat part is made very thin, sometimes only

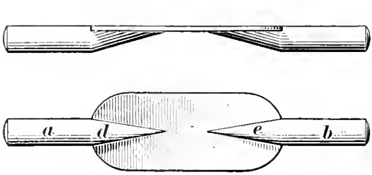


FIG. 16

$\frac{1}{32}$ inch thick, so that it can be bent cold. Recesses in the forging dies form the round ends a and b, and the conical parts d and e that join them to the flat part. The forging dies are shown in Fig. 17, in which (a) is a view of the face of the upper die, (b) is a section of the upper and lower dies, showing the recess in which the forging is made, and (c) is the face of the lower die. The top surface of the lower die in

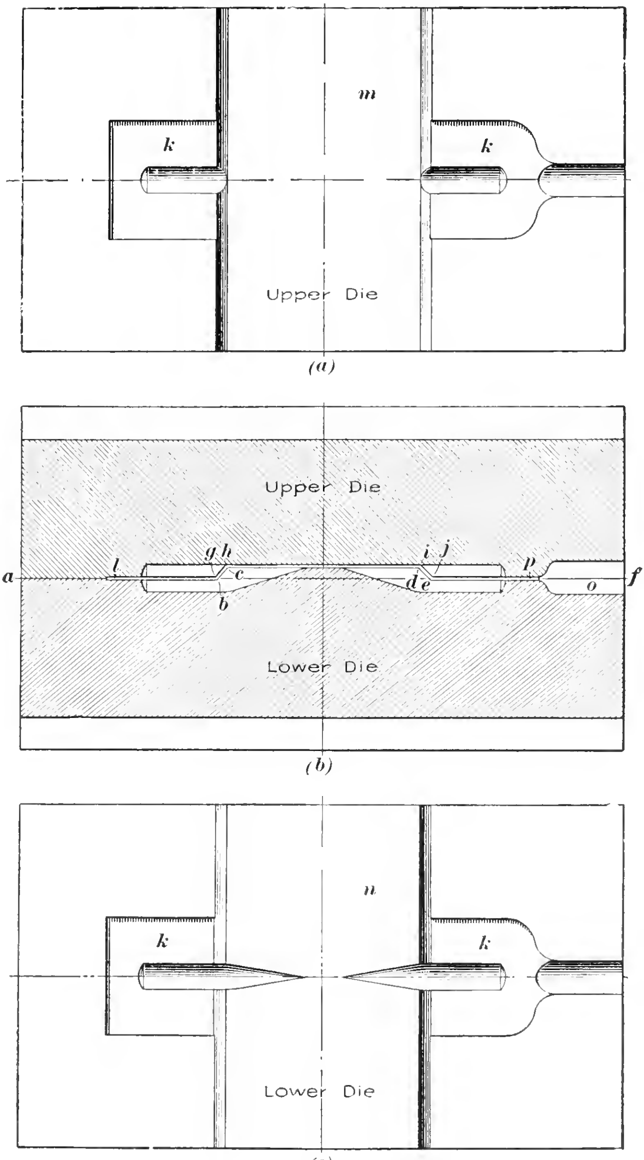

m
k
k
Upper Die
(a)
Upper Die
g h
i j
a
l
c
p
f
d e
o
b
Lower Die
(b)
n
k
k
Lower Die
(c)

FIG. 17

view (*b*) is on the line *a b c d e f* and the lower surface of the upper die is at *a g h i j f*. From *h* to *i* the upper die does not touch the lower die, and the distance between the dies, when the upper die is clear down, gives the thickness of the flat part in Fig. 16.

22. This forging is made from bar iron, which must be large enough to fill the die at the largest part. There are other parts of the die that such a bar more than fills and there must therefore be some provision made for the disposal of the excess metal where it can later be removed without injury to the forging. This provision is made by leaving a shallow recess *k* in Fig. 17 (*a*) and (*c*), called the flash, which makes a narrow opening *l*, in (*b*), around the forging impression. The excess metal squeezed out into the flash around the forging is called the *fin* and sometimes, also, the *flash*. Since these dies do not come together between *h* and *i*, that is, the surfaces *m* and *n* do not come together, the flat part of the forging can spread out as much as necessary and no flash need be provided for this part of the forging. The part of the bar that is not needed for the forging, sticks out of the die through the *sprue o*. The sprue is connected with the die impression by the *gate p*.

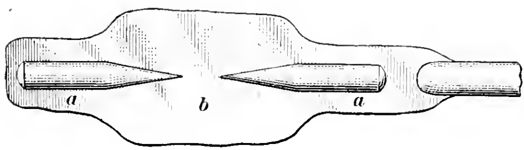


Fig. 18

23. The forging produced by the forging dies is shown in Fig. 18 with the fin *a* still attached and the flat part *b* is very much larger than is required in the finished forging. The fin *a* is removed by a punch and die, shown in Fig. 19 (*a*) and (*b*), which also trim the flat part *b* to the required size and shape.

The die, or *trimmer*, shown in (*b*), is made of two blocks *a* and *b* in which an opening *c* has been cut. This opening is the size and shape of the outline of the finished forging and it extends clear through the trimmer. The punch *d* in view (*a*) fits in the opening *c* in the trimmer, and its lower surface is shaped to bear evenly on all parts of the forging. The rough forging shown in Fig. 18 is laid on the trimmer, Fig. 19 (*b*), so that the round ends rest in the parts *e* and *f* of the opening and the fin extends out over the surface of the trimmer. The punch is then brought down on top of the forging, forcing it through the trimmer, cutting the fin off and leaving it on the surface of the trimmer. The fin must be cut from the end of the bar from which the forging was made, so that it will not interfere with the making of the next forging. The *cut-off* *g*

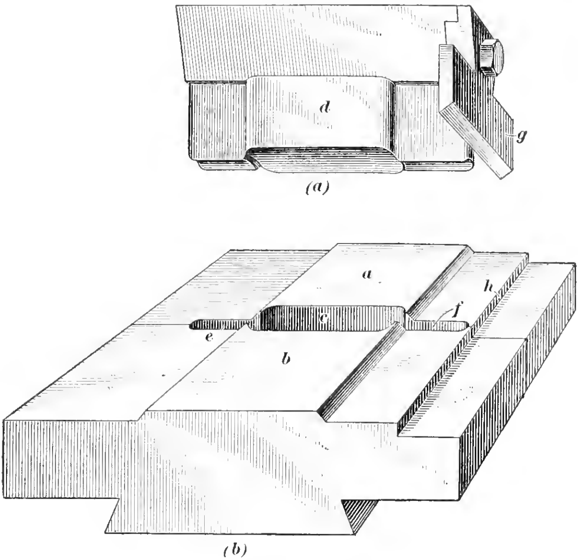
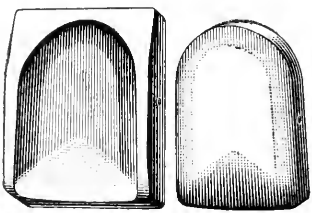


Fig. 19

is therefore fastened to the end of the punch so that it comes into action over the shoulder *h* when the punch has nearly severed the forging from the fin. The cut-off must be wide enough to reach clear across the fin and cut it entirely off. The trimmer is made of two blocks, so that the opening *c*, when it has been enlarged by wear, can be brought back to the required size and shape. The shape of the opening in each block is first trued up and the joints between the two blocks are then faced off to make the right size.

24. It is not always possible to complete a forging in one die, as was done in the case just described, and the forging dies are then provided with two or more impressions, thus doing the required work on the stock in a series of steps. The number of blows that must be struck depends on a number of conditions, but must always be enough to make the upper die strike the lower die. The number of blows will be affected by such conditions as the weight of the hammer, the height of the drop, the size of the stock, the kind, quality, and temperature of the metal, and the depth and shape of the recesses in the dies. In general, the heavier the hammer, the higher the drop, the smaller, hotter, and softer the stock, and the shallower the recesses in the dies, the fewer will be the number of blows required to finish the forging.

25. Such articles as spades, shovels, scoops, conveyor buckets, and wheelbarrow bodies may be formed in dies by drop hammers. The lower die forms the outside and the upper die the inside of the article. Some of these articles, such as wheelbarrow bodies, are made in steam drop hammers. The upper die is brought down against the stock, and steam is then turned on, pressing the stock into the lower die, and a few light blows are then struck to remove wrinkles and make the stock fit the die closely. Shovels are made under drop hammers. The heated stock is placed over the lower die and struck as many blows as are needed to make it fit the die closely. The dies with which scoop shovels are formed are shown in Fig. 20. The lower die, shown in (*a*), forms the outside of the shovel and the inside is formed by the upper die, shown in (*b*). The back of each die block is planed smooth, so as to give a good bearing on the bed or the head of the hammer. The lower die is held in place by setscrews passing through poppets on the bed of the hammer. The upper die is fastened to the hammer head by bolts that pass through ears on the head, or by a dovetail


(*a*) (*b*)
FIG. 20

and key. Suitable stops are provided to facilitate placing the upper die properly over the lower one.

26. Automobile front axles are frequently drop-forged, the dies usually being long enough to forge half the length of the

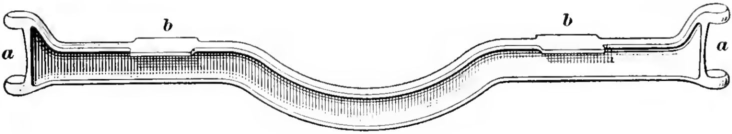


FIG. 21

axle at a time. The order in which the operations are performed and the details of some of the operations depend largely on the design of the axle and the size of stock of which the axle is being made. A front axle that is forged from square bar is illustrated in Fig. 21. The bar is large enough to make the body of the axle, but upsetting at *a* and *b*, as shown in Fig. 22, is necessary, to make the forked end *a* and the spring pad *b*. This operation is performed before the axle is taken to the forging hammer, in an upsetting machine, which will be described later. The forging is done in two stages; the first is a roughing operation which spreads the end preparatory to forming the forked end. A steam hammer is shown in Fig. 23 fitted with the roughing dies for this axle. The upper die *a* is keyed to the hammer head with a key *b* that is formed to fit the space between the dovetail on the die and the side of the slot in the hammer head. The lower die *c* is keyed to the anvil. Two keys are used in this case, one driven from each end of the die. When making the dies, one end and one side of the

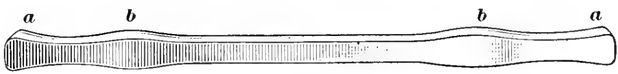


FIG. 22

die block are first planed straight and square with the working face of the die and with each other. The impressions in the dies are then laid out so that they will come together when these squared edges are in line with each other. The squared ends are lined by moving one or the other die backward or forward as may be required. The sides are lined by moving the hammer frame sidewise on the anvil block. This moves the upper die crosswise, but does not change the position of the lower die. When the dies are properly lined, the hammer frame is fastened down by anchor bolts *d*. Heavy springs are placed under the nuts on the anchor bolts so that when such a heavy blow is struck that there is danger of breaking the hammer, the hammer is lifted slightly from the anvil block.

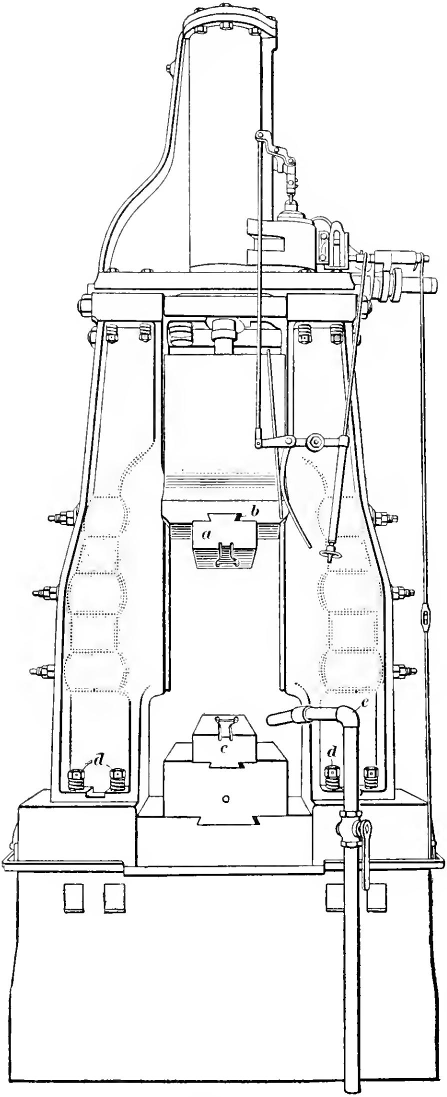


Fig. 23

27. Considerable scale forms on the material that is heated for forging, and some of it when loosened by the forging operation drops into the lower die. If the scale were allowed to stay in the die, the forging would be rough and not true to the die. A blast of air from the blast pipe *e* is therefore directed on the lower die to keep it free from scale. The dies are long enough to forge slightly more than half the length of the axle, so one end of the axle is heated and forged and then allowed to cool. The other end is then heated and forged in the same way. In order to facilitate the forging operation, the finishing dies are set up on a hammer beside the first one so

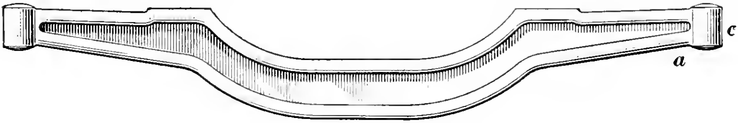


FIG. 24

that, when one end has been rough forged, it is taken to the finishing hammer and finished with the one heat, and the fin is trimmed in a trimming press. In this way each end is completely forged and trimmed with one heat. The axle is forged straight, and is bent to the required form on a press.

28. A large axle of somewhat different design from the one shown in Fig. 21 is illustrated in Fig. 24. This axle is heavier at the middle than at the ends and it is therefore not possible to use stock large enough to fill this part of the die without leaving an excessively large fin at other parts of the forging. Stock that is larger than is required by the part of the forging at *a*, but not quite large enough for that at *b* or at *c*, is therefore used. The forging of each half of this axle is completed in four operations with two dies. The operations are fulling, breaking down, roughing, and finishing. The first three operations are performed under a roughing die and the fourth operation under a finishing die.

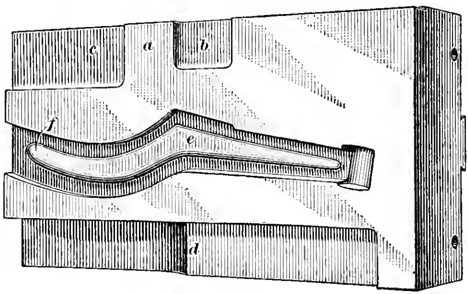


FIG. 25

29. The lower roughing die is illustrated in Fig. 25. The fuller, shown at *a*, throws the metal both ways, into the spaces *b* and *c*. The metal in *b* provides stock for the formation of the axle end, and that in *c* provides stock for the heavier portion of the axle body. The stock is then bent in the breakdown *d* so that it will lie over the roughing impression. The upper roughing die is like the one shown, excepting that the breakdown projects from the face of the die block instead of being cut into it. After the stock is bent, it is roughed out in the impression *e*. The projection in the center of this die gradually tapers out at *f* so as to throw the surplus metal toward the middle of the axle where it will be needed in the finishing operation. The finishing impression is shown in Fig. 26. The other die of this pair is like the one shown. The impression brings the forging to size and a flash *a* is provided to take the excess metal that is squeezed out. These dies, like those for the other axle, forge half the axle at a time. Such dies as these are rather heavy and must therefore be lifted by a crane. In order to facilitate the lifting of the dies, holes *b* are drilled in the ends of the die block, and steel pins, over which the crane chain is fastened, are stuck into these holes.

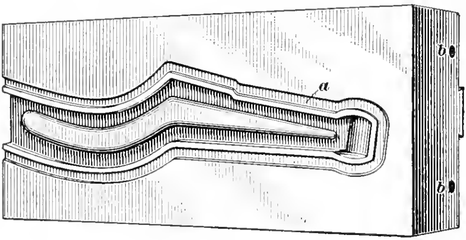


FIG. 26

30. Drop-Hammer Foundations.—As it takes some appreciable time for the blow to penetrate to the center of a piece of metal, drop hammers are sometimes provided with an *elastic foundation*. The elasticity has the effect of distributing the force of the blow over a longer period of time, thus causing it to penetrate deeper. Such a foundation is usually made of large timbers, carefully squared and made to fit each other quite accurately, as shown in Fig. 27. The anvil *a* is then placed on the foundation, usually with a layer of leather belting or a rubber pad between the top of the timber and the base of the anvil. The bottom of the timbers *b* should be bedded in concrete to insure an even bearing. The objection to the all-timber foundation is its great cost and renewal expense.

31. Elastic foundations have been made by placing the timbers for the foundation in a vertical position. A log large enough in diameter to receive the anvil on its top and to enter the ground 6 or 8 feet is sometimes preferred. The hole is dug 1 foot deeper than is necessary to receive the log. A foot of concrete is then placed in the bottom of the hole, and the log bedded, in a perpendicular position, on top of this. For light drop hammers, a large flat stone is sometimes placed under the bottom of the log. The space about the log in the hole should be filled with earth well tamped into place; the top of the log should be trimmed off to a true horizontal surface. In the case of hammers with openings in the center of the anvil, it is necessary to cut a depression in the center of the top of the log, with a groove leading to the outside to allow scale and dirt to pass off without accumulating under the anvil. When a log large enough for the anvil cannot be obtained, several timbers may be bolted together to form a block of sufficient size. Chestnut or oak timbers are said to be the best for drop-hammer foundations. For hammers with drops weighing 1,000 pounds or more, a masonry foundation is recommended by some builders. A hole is first dug 10 to 14 feet deep, and the masonry built up to within 4 feet of the top. On top of the masonry, oak timbers 4 feet long standing on end are arranged, and bolted closely together. The space around the timbers is then filled with concrete; the anvil is set on top of the oak timbers, as in the case of the foundations already mentioned. In some cases, masonry foundations are built up to within an inch or so of the anvil, and a thick rubber or leather pad placed under the anvil.

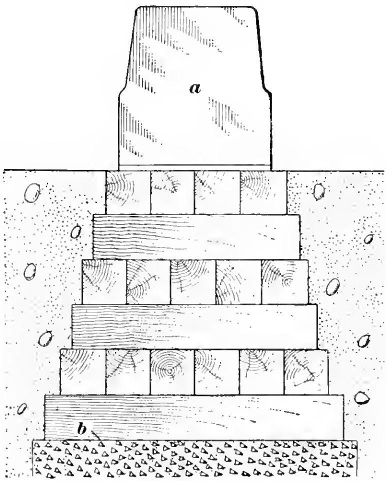


FIG. 27

32. One manufacturer of drop hammers recommends the solid foundation shown in Fig. 28. It is made by digging a hole of the required depth, and lining it with planks, as shown. The space inside of the planks is then filled with concrete. The following proportions for the composition of the concrete are recommended: three barrels of stone, two barrels of gravel, and one barrel of cement. Table II shows the dimensions of the foundations for various weights of the drop, generally called the weight of the hammer.

The dimensions for the foundation of any hammer are found in the same horizontal line as the weight; the letters at the head of the columns correspond to those in Fig. 28. Foundations of this kind have been built without using any elastic material between the anvil and the concrete, with very satisfactory results.

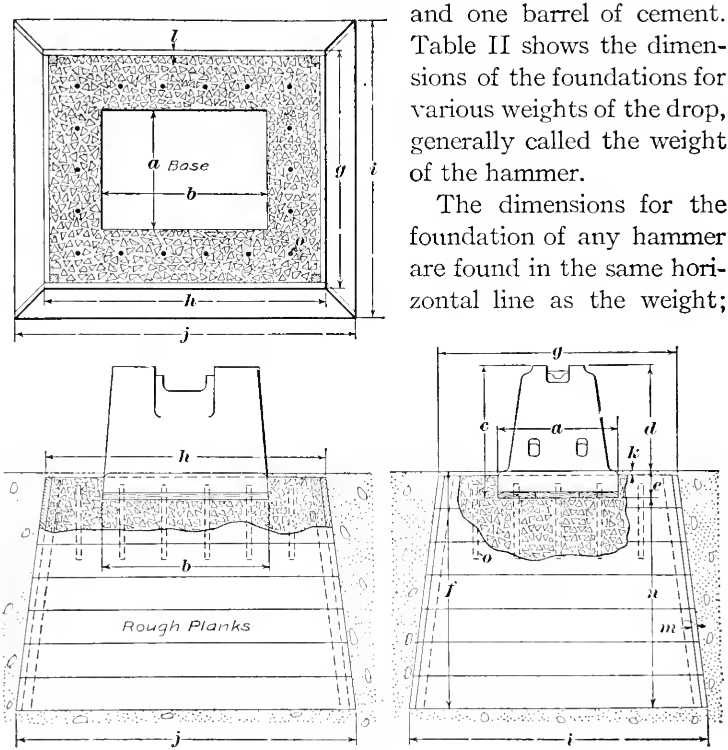


Fig. 28

Concrete foundations may be strengthened with reinforcing rods, as shown at *o*, when it is thought the concrete does not supply sufficient strength.

TABLE II

DIMENSIONS FOR DROP-HAMMER FOUNDATIONS

Weight of Hammer Pounds	Foundation Dimensions, in Inches													
	a	*b*	*c*	*d*	*e*	*f**	*g*	*h*	*i*	*j*	*k*	*l*	*m*	*n**
400	27	42	42¼	37½	4¾	64	56	70	72	86	1¼	2	2	59¼
500	27	42	42¼	37½	4¾	64	56	70	72	86	1¼	2	2	59¼
600	30	49½	42½	37¾	4¾	64	60	76	76	92	1¼	2	2	59¼
800	30	49½	48⅞	37⅝	11¼	70	60	76	77	93	1¼	2	2	58¾
1,000	40	57¾	45	36¼	8¾	80	80	94	100	114	1¼	2	2	71¼
1,200	40	58¼	50⅛	36¼	13⅞	84	80	94	101	115	1¼	2	2	70⅛
1,400	40	58⅞	55⅜	36¼	19⅛	90	82	96	102	116	1¼	2	2	70⅞
1,600	40	59¼	58½	36¼	22¼	96	84	98	104	118	1¼	2	2	73¾
1,800	39½	65½	54	34¼	19¾	104	83	111	106	134	1¼	2	2	84¼
2,000	40	65⅞	58½	34¼	24¼	108	84	112	107	135	1¼	2	2	83¾
2,500	47	71	57¾	35	22¾	118	92	118	121	147	1¼	2	2	95¼
3,000	48	71	58½	35	23½	124	92	118	123	149	1¼	2	2	100½

*NOTE.—Dimensions *f* and *n* to be varied according to the nature of the ground.

33. Comparison of Drop-Hammer Foundations.—It has been found in practice that when the anvils of large hammers are light, it is necessary to use elastic foundations or the force of the blows will cause the foundations to yield. In the case of a large steam hammer installed by the Bethlehem Steel Company, the first foundation, which was made of timber, had very little elasticity. This foundation yielded so that it had to be rebuilt. The second foundation was made very elastic by placing wood shavings and brush beneath the timbers, and no further trouble was experienced.

If the anvil is made heavy enough, it will not have time to move away from the work before the hammer has exerted its full effect, and hence an elastic foundation would not relieve the shock of the blow. With a relatively light anvil, the spring of an elastic foundation allows the anvil to recede when the blow is delivered, and thus prolongs the action of the blow; but it is only on large work that it is especially desirable to obtain this effect.

34. It has been found that a hammer having a solid foundation of sufficient size will do as good work as one having an elastic foundation and dropping about twice as far. The shorter drop also allows the hammer to strike more blows per minute than when operating with a higher drop. Hence, a greater amount of work can be turned out.

It has been found also that when the solid foundation is used practically no repairs are necessary, and a much greater number of hours of work can be done, per year, by a given hammer. It is an interesting fact that wherever the solid foundations have been adopted, and the height of the drops properly adjusted, their use has not been abandoned.

Foundations for steam hammers are usually proportioned to suit the condition of the ground on which the hammer is to be installed. Any foundation dimensions that might be given would therefore be of but limited application.

SWAGING MACHINES

35. Swaging is a cold-forging operation that is performed by pressure applied, removed, and applied again, in rapid succession. At the speeds ordinarily recommended by swaging-machine manufacturers, pressure is applied from 2,000 to 6,000 times a minute, which is almost equivalent to a continuous pressure and causes the metal to flow into the new form. The work done by a swaging machine is round or conical in shape, such as the pointing of pins, the tapering of tubing for bicycle forks, the reduction to exact size of parts of forgings that are to be threaded, etc.

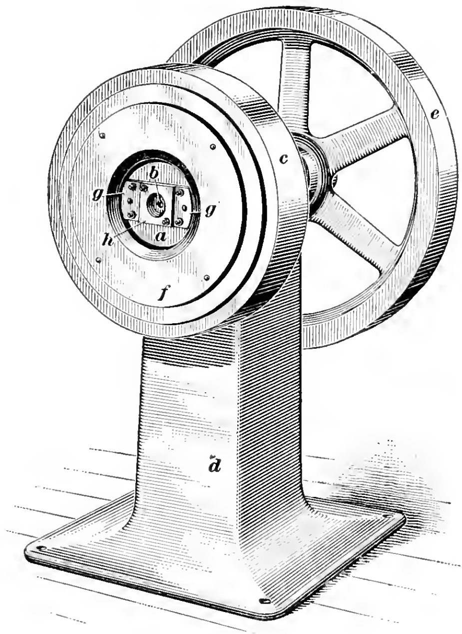


Fig. 29

The front of a swaging machine is shown in Fig. 29. The central part *a* revolves when the machine is in operation, and the stock that is to be swaged is put into the opening *b*. The outside ring *c* is attached to the standard *d* and therefore remains stationary. The rotating head *a* is on the end of a hollow shaft which carries the flywheel *e* on the other end. A similar machine is shown in Fig. 30 (*a*), with the ring *f* and the guards *g* and *h* shown in Fig. 29 removed to show the working parts.

The rollers *a* are supported by the ring *b* around the rotating head *c*. There is a slot running across the center of the revolving head *c*, view (*b*), and two dies *d* and the backers *e* are fitted into this slot. The dies and backers are free to slide back and forth in the slot and tend to move outwards when the machine is running, but when the backer passes a roller, the die is forced in against the stock. The face of the

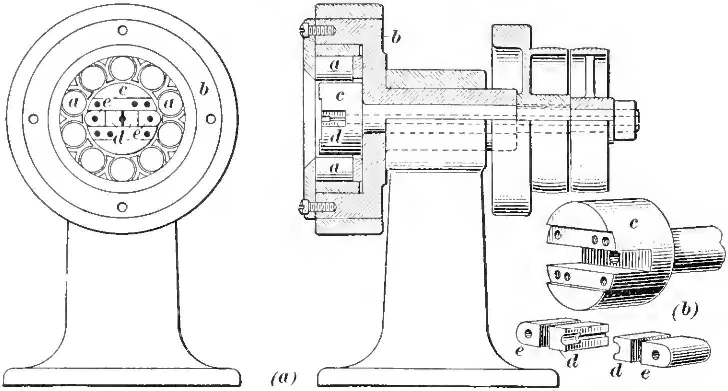


Fig. 30

dies may be flat or they may have recesses the size and shape of the part that is being swaged.

PRESSES

36. Presses are used for forming or shaping metal, for punching holes, and for trimming the fins from drop forgings. One common form of press, shown in Fig. 31, is driven by a belt on pulley *a*, which drives the gear *b* continuously. By depressing the treadle *d*, the clutch *c* is thrown into action and the head *e* is driven down by the eccentric *f*. The upper die is attached to the lower face of the head *e*, and the lower die is carried on a block *h* that fits over the opening *g*. In order to adjust the height of the dies to suit the work, an adjusting nut is provided at *j*.

Work that is too heavy for an open-sided press, such as that shown in Fig. 31, may be done on a double-sided press, such as the one illustrated in Fig. 32. This form of press is frequently used to trim the fin from drop forgings and it is for that reason commonly called a *trimming press*. When trimming small forgings cold, the forgings are usually punched through the trimming die, which is fastened to the bed of the machine, and fall to the floor. When a small forging is trimmed while hot, the fin is frequently left on the bar from which the forging was made. After the trimming is done, the gate is cut with the side shear *a*. The height of the ram may be adjusted by the nut *b* and the height of the upper shear blade by the nut *c*.

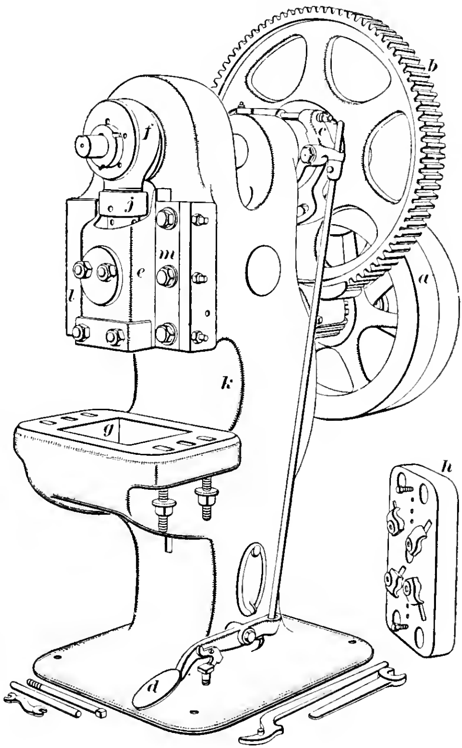


FIG. 31

37. In the form of press shown in Fig. 31 the finished work passes out of the way by falling through the opening *g*, to the floor; unless some such means is provided the work must be removed from the dies by hand. The inclined press shown in Fig. 33 has been found convenient for discharging the finished work. The table *a* can be set at any desired angle by adjusting the nut *b*. The stock is passed into the machine from the front, and the finished work slides out through the opening *c* at the back and drops behind the machine. In other respects this press is similar to the one already shown.

38. Press Work.—Three operations are performed by presses on the axle the forging of which was described in Arts. **26** and **27;** they are, in the order in which they are performed, trimming, stretching, and bending. The stretching and bending will, however, be described first and the trimming later. The stretching and bending are done in a press with a two-part fixture. The forging operation does not always make the axle the right length, and the center of the forging is therefore reheated and stretched as may be needed. The principle of the fixture that does the stretching and bending is shown in

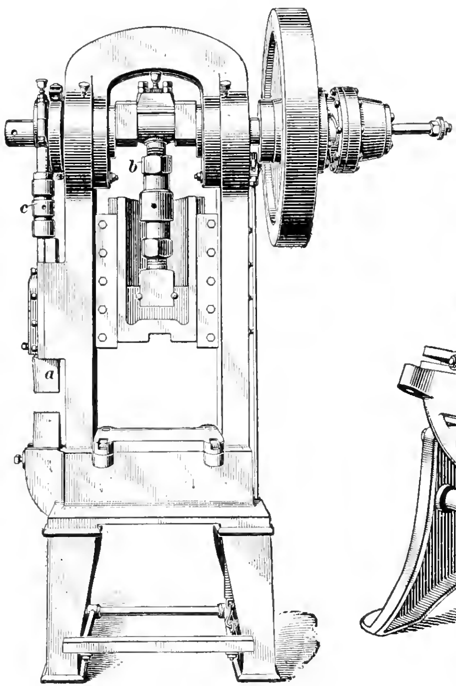


FIG. 32

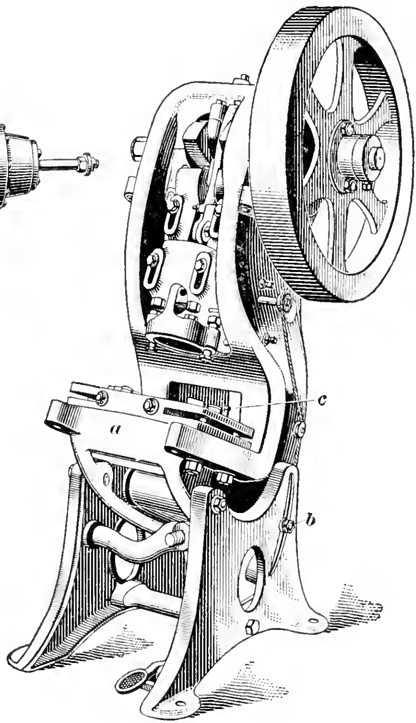
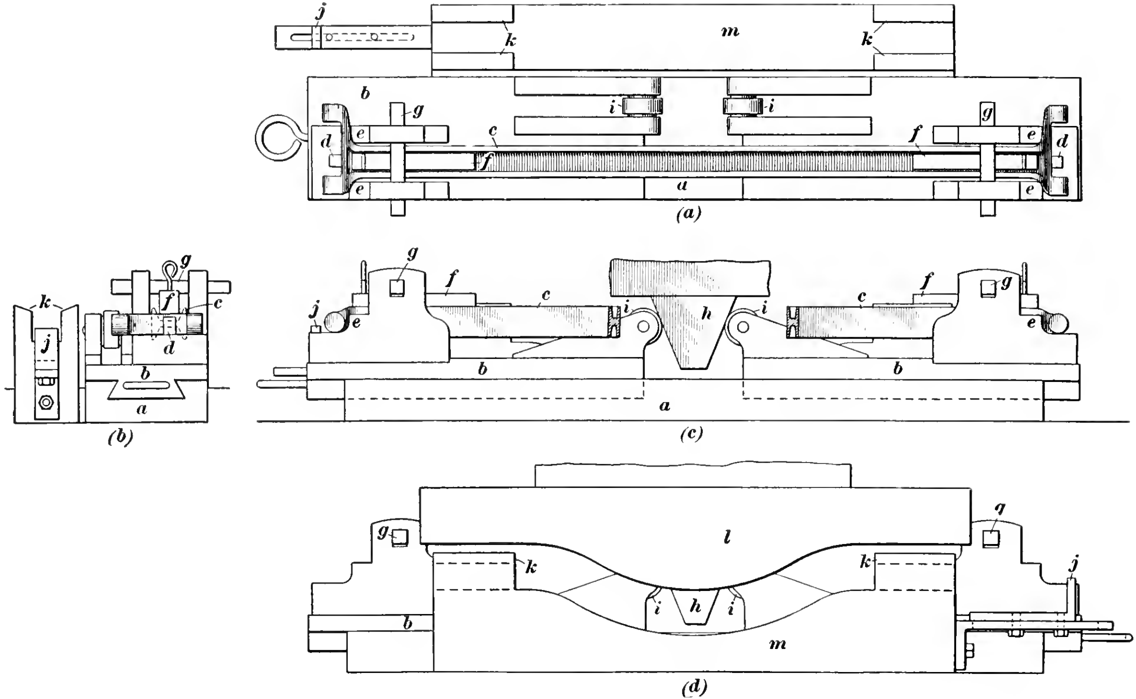


FIG. 33

Fig. 34. Views (*a*), (*b*), and (*c*) show respectively the top, end, and one side of the fixture, and view (*d*) shows the other side. The stretching part of the fixture is shown in the lower part of view (*a*), at the right of (*b*) and in (*c*). The base *a* is fastened to the bed of the press and it carries two slides *b* working in a dovetailed slot in the base *a*. The axle is put in the fixture as shown at *c*, the slides *b* are shoved together until the forked


j
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j
e
h
e
b
b
a
(c)
l
q
g
k
k
j
i
h
i
b
m
(d)

FIG. 34

ends drop between the stops *d* and the shoulders *e*, and the axle is then clamped in place. The clamping is done by a wedge *f* and a key *g* at each end. The wedge *f* is first laid in the channel of the axle and the key *g* is then driven in over it. This locks the axle in place. The axle is stretched by the wedge *h* which is fastened to the ram of the press. As the ram descends, the wedge *h* is forced down between the rollers *i* and the slides *b* are moved apart, thus stretching the axle. The length of the axle, when stretched, depends on the position of the ram with respect to the fixture when at the bottom of its stroke, and this is adjusted by means of the adjusting nut on the ram *b*, Fig. 32.

When the axle has been stretched, it is removed and put in the bending fixture shown at the top of view (*a*), the left of view (*b*), and in view (*d*). The axle is placed against the stop *j* between the guides *k*, which hold it edgewise but do not clamp it, and the upper die *l*, which is fastened to the ram and forces the axle down into the lower die *m*.

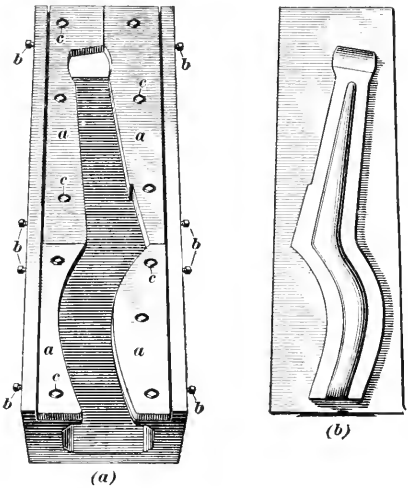


FIG. 35

39. The trimming of the axles shown in Figs. 21 and 24 differs only in the shape of the trimming dies. The die shown in Fig. 35 is for trimming the axle shown in Fig. 24. The trimming die, Fig. 35 (*a*), is fastened to the bed of the press and the punch, view (*b*), is fastened to the ram. The body of the trimming die is box shaped, so that the axle falls down inside of it and is withdrawn endwise when the fin has been sheared off by the downward motion of the punch. The punch is shaped so as to bear as evenly as possible on all parts of the forging in order that it may not be sprung when it is pushed through the die.

Trimming of large forgings is usually done while they are hot, and the trimming press is therefore set near the hammer in which the forging is finished. The shearing plates *a* of the die are made separate from the body, which may therefore be made of a cheaper material than is required in the shearing plates. The setscrews *b* hold the cutting edges against the forging so that the fin is trimmed off smoothly, and the screws *c* lock the shearing plates securely in position.

UPSETTING MACHINE

40. Upsetting machines are variously called *forging machines*, *bolt-heading machines*, *collaring machines*, etc., depending on the operation that the particular machine is especially

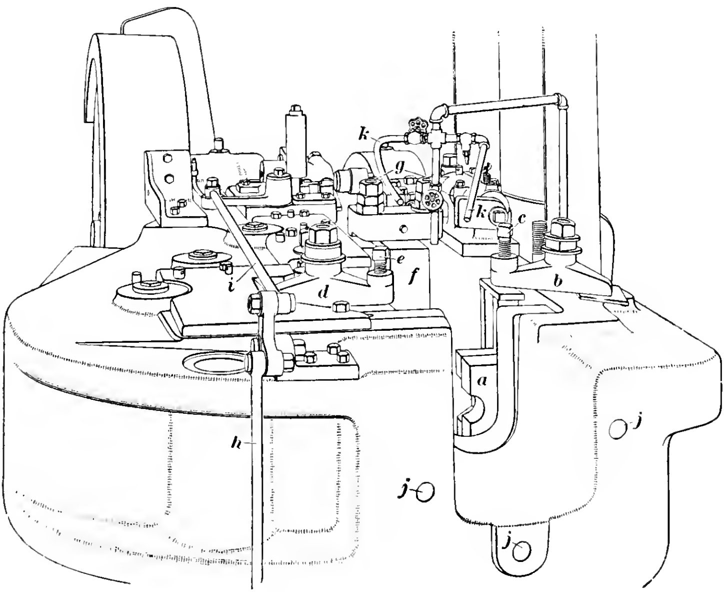


FIG. 36

adapted to perform. The manner in which the forging is done is, however, always the same. When the hot stock is placed in the machine, it is gripped between two dies, one of which is stationary, which hold it in front of a third die, or plunger tool, that is moved endwise against the stock and forces it into suitable recesses in the gripping dies and the plunger tool. The gripping dies do not always hold the stock securely enough to resist the thrust of the plunger, so it is frequently necessary to provide a back stop of some kind to take the thrust of the plunger. The form of this stop varies with the size and length of the work that is being handled.

An upsetting machine is shown in Fig. 36. The stationary die *a* fits in a suitable recess in the frame of the machine and is held in place by the clamp *b* and setscrew *c*. The die *a* is in this case small, so metal blocks are placed on top of it to give the setscrew *c* a bearing. The outer gripping die, not shown, fits in a recess in a movable head, and is held in place in the head by the clamp *d* and setscrew *e*. When the machine is in operation, the movable gripping die is brought against the stationary die *a*, thus gripping the stock in the recess that is made for it. The plunger *f* carries a die, or tool, that is called a heading tool, upsetting tool, collaring die, etc., depending on the kind of work that is being done. For the sake of simplicity, this die will be called the *plunger tool* regardless of the kind of work that is being done. The plunger tool is down on a level with the die *a* and is therefore hidden by the corner of the frame. The tool is, however, fastened to the ram *f* by bolts *g*. The gripping die and the ram are set in motion by depressing a treadle that moves an operating mechanism through the rods *h* and *i*. The holes shown at *j* are for bolts that secure the back stop, which has been removed from this machine. The dies are cooled, when the machine is in operation, by streams of water from the pipes *k*. The water striking the hot stock also tends to loosen the scale and thus produces a smoother forging than would be obtained otherwise.

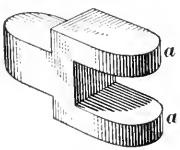


FIG. 37

41. Upsetting-Machine Work.—The clip shown in Fig. 37 is made in closed dies so that no back stop is needed. The dies for this piece are shown in Fig. 38, in which *a* is the stationary die, *b* the gripping die, and *c* is the plunger tool. The stock of which this clip is made is a rectangular block which is placed, while hot, on the shelf *d* on the stationary die and the

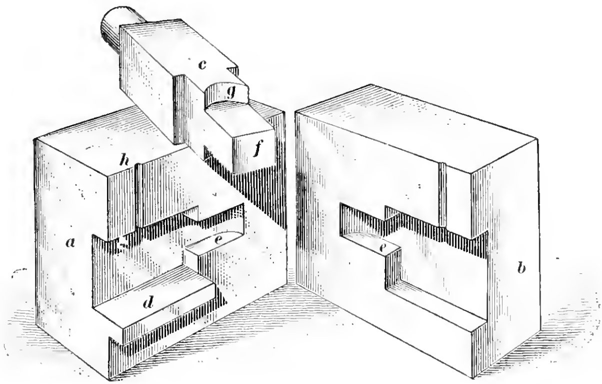


Fig. 38

machine is set in operation. When the gripping die closes on the stationary die, the part of the shelf *d* that projects from the face of the die block fits into the lower part of the opening in the gripping die. The advance of the plunger tool forces the

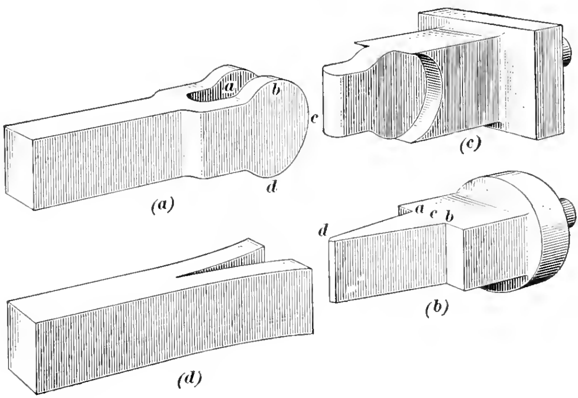


Fig. 39

metal to flow back into the space *e* and along the top and bottom of the projection *f* until it strikes the shoulders *g*. If the metal strikes the shoulder *g* before the plunger has reached the end of its stroke, the excess metal is forced up into the vent hole *h* and is later cut off. The gripping dies *a* and *b* therefore form the outside of the clip and the plunger tool *c* forms the inside of the forked part and the rounded ends at *a* in Fig. 37.

42. The forked end of a locomotive side rod, shown in Fig. 39 (*a*), is made in an upsetting machine. There are two impressions in the gripping dies and two plunger tools are used. The lower plunger tool is essentially a hot chisel, as it merely splits the end of the rod and prepares it for the forming die which is used afterwards. The stock for the side rod is rectangular in shape and requires no preliminary upsetting. The

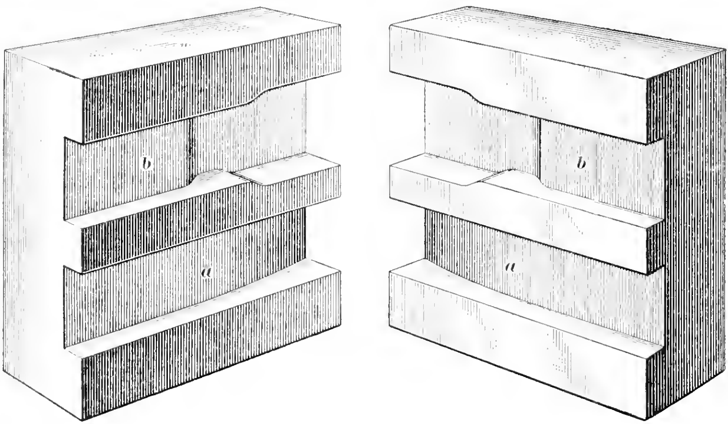


FIG. 40

gripping dies are shown in Fig. 40. The roughing, or splitting, impression is shown at *a*. The depth of the impression at the left end of the die is half the thickness of the main part of the rod. Near the right end of the die the depth of the impression gradually increases until it is equal to half the thickness of the forked part of the rod. The plunger tool with which the end of the rod is split is shown in Fig. 39 (*b*). The width at *a b* is approximately equal to the width of the slot that is to be made in the end of the side rod, and the length of the die from *c* to *d* is approximately the same as the depth of the fork in the end of the rod.

43. When the rod end has been split in the impression *a*, Fig. 40, it is transferred to the upper impression *b*, where the forked end is brought to the finished size and form shown in Fig. 39 (*a*). The plunger tool for finishing the rod end is shown

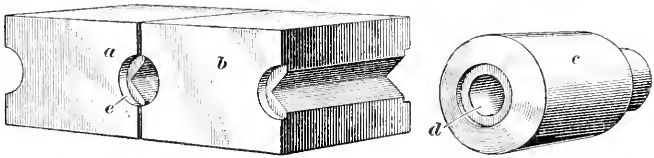


Fig. 41

in Fig. 39 (*c*). This die forms the inside *a* of the fork, view (*a*), and the rounded end *b c d*, all other parts of the rod end being formed by the gripping dies. When the stock is taken from the lower impression in the gripping dies, the end that has been split is the same depth as the body of the rod, as shown in view (*d*), so the plunger tool, view (*c*), not only forms the inside of the fork but it also upsets it so as to form the enlargements at *b* and *d*, view (*a*). A back stop must be used with these dies to keep the stock from being pushed out of the gripping dies by the thrust of the plunger.

44. The dies with which the collar and spindle on the end of an ordinary truck axle are formed are shown in Fig. 41. The gripping dies *a* and *b* are rectangular blocks with an impression cut in each of two opposite faces. These impressions are usually alike, so that when one impression becomes worn or damaged, the die may be turned over and the other impression may be used in its place. The axle is made of square stock which is placed in the recess of the stationary gripping die, where it is held by

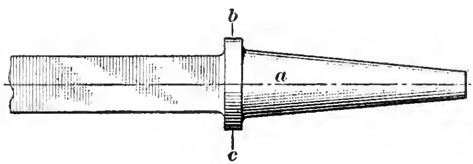


Fig. 42

the moving die. The gripping dies really do little more than hold the stock in line with the plunger tool which is shown at *c*, so a back stop takes the thrust of the plunger.

The conical spindle, shown at *a* in Fig. 42, and the part of the collar at the right of the line *b c*, are forged in the recess *d* of the plunger tool, and the part of the collar at the left of the line *b c* is forged in the recess *e*, Fig. 41, in the gripping dies. A vent hole is drilled in the side of the plunger die at the bottom of the conical hole that forms the spindle. This vent provides an outlet for the air and steam in the die as it is forced over the hot end of the axle. These dies are water-cooled, and water that gets into the plunger die forms steam when the die is forced over the hot end of the axle.

PUNCHES AND SHEARS

45. Punches may be used to make holes in sheet metal, when the holes are not required to be of uniform diameter throughout, or when they can be reamed to the desired size after punching. Shears are used to cut bars or to trim plates to the required size. Alligator, or lever, shears, such as shown in Fig. 43, are especially useful for cutting bar, strap, and scrap

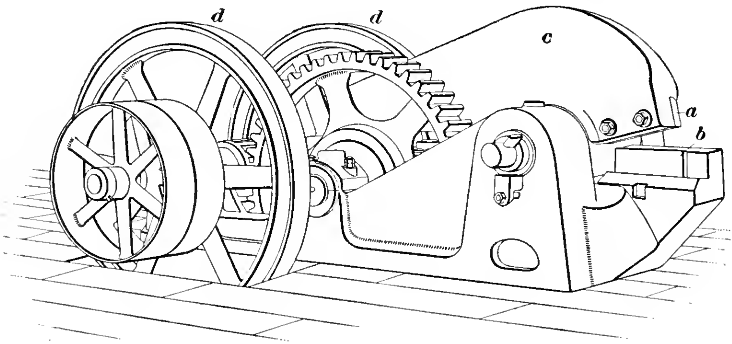


FIG. 43

stock. The stock is cut off between the shear blades *a*, *b*, the lower one of which is stationary and the other attached to the short end of the lever *c*, the long end being moved by a crank or cam. In the shear shown, two flywheels *d* are placed on the main driving shaft, so that their inertia will assist in operating the shear and enable it to cut heavier stock; also, the bar will be gripped on one edge first, and the cutting will proceed from one side to the other. This enables the shear to cut much larger stock than would be possible if the cutting edges of the blades were to strike both sides of the bar along the entire width.

46. For cutting bars, narrow plates, etc., the shear shown in Fig. 44 is quite frequently used. One advantage of this type is

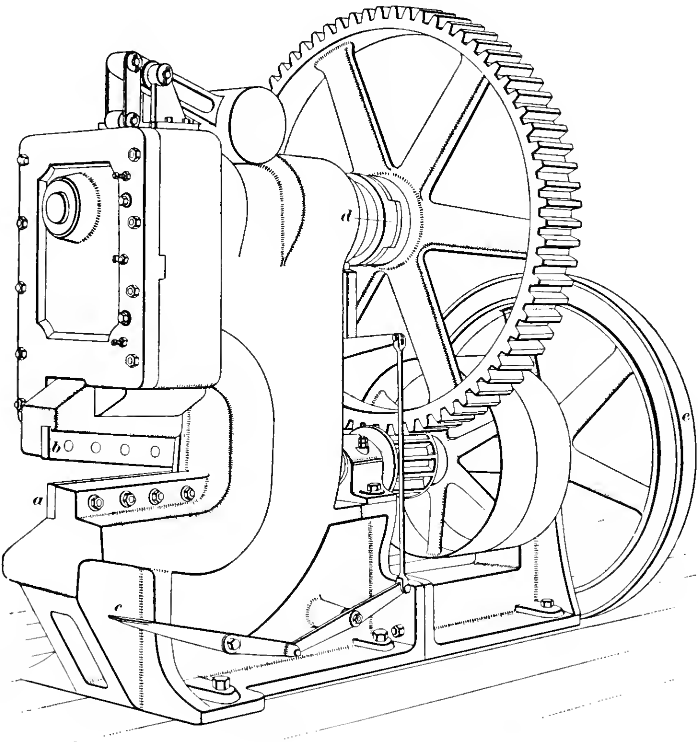


Fig. 44

that it takes up less room than the lever shear. The shear blades *a*, *b* are arranged much as in the lever shear, except that the moving blade *b* is attached to a head, or ram, that descends in a straight line instead of working about a pivot, as in the lever shear. It will be noticed that the blade *b* is set at an angle to the blade *a*, so as to cause the cutting to proceed from one side to the other and make it possible to cut off larger stock. This is known as giving the blades **shear.**

The operating parts are so arranged that when the treadle *c* is released, the head with the blade *b* always returns to the top of the stroke and remains in that position while the shear is out of use. The pressure of the foot on the treadle *c* throws

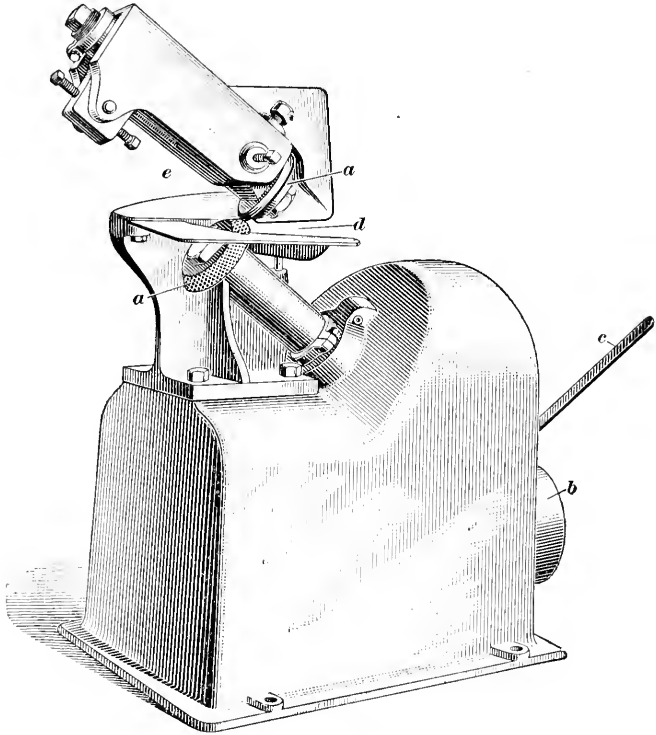
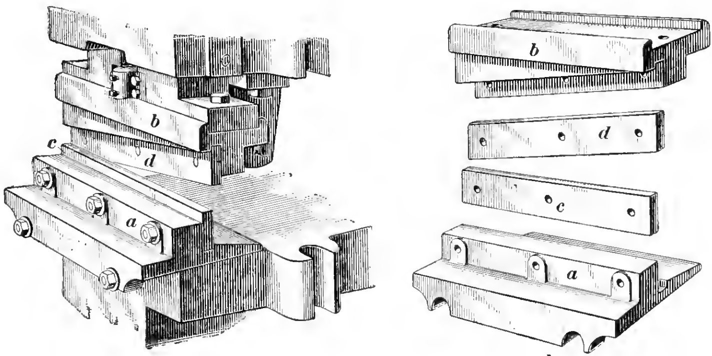


Fig. 45

in the clutch *d*, connecting the head with the driving mechanism and causing the shear to descend and continue to operate until the treadle is released. This shear is also provided with a flywheel *e*, to increase the effectiveness of the machine by storing up energy between cuts and giving it up to the shear when cutting. Sometimes the shear blades *a*, *b* are turned at right angles to the position shown in Fig. 44. This is usually done with shears intended for trimming the edges of wide plates. Special shears are also made for cutting off structural or rolled shapes.

47. The shears shown in Figs. 43 and 44 cannot be used to make curved cuts nor to cut wide plates, excepting that the shear shown in Fig. 44 may be used to trim the edges of a plate when the blades are set at right angles to the position shown. Such a shear is sometimes called a *trimming shear.* The rotary shear shown in Fig. 45 will cut curves in plates of any width, but it will not cut angles, channels, or similar shapes. The cutters *a* are shaped to cut perpendicular to the surface of the



(a) (b)

Fig. 46

sheet, but other cutters that will produce an angle cut may be used in their place. The lower cutter is driven by the pulley *b*, through gearing inside the base, and a clutch operated by the lever *c*. The lower cutter therefore drives the plate that is being sheared, and for this reason it is slightly knurled. When a plate is being cut, the part of the plate on the right of the cutter passes through the opening shown at *d*, and that on the left through the space *e*.

48. The shear shown in Fig. 44 is sometimes made convertible, the shear and shear blocks being removable so that a punch-and-die set can be substituted for the shears. The attachments for a shear set are shown in Fig. 46, the assembled parts being shown in (*a*) and the separate parts in (*b*). The shear blocks *a* and *b* are bolted to the lower jaw and to the ram of the machine, respectively, and the shear blades *c* and *d* are bolted to the shear blocks.

The attachments for the punch set are shown in Fig. 47, the parts being shown assembled in (*a*) and separate in (*b*). The punch *a* is first attached to the punch stock *b* by the coupling nut *c*. The punch passes through a hole in the coupling nut which holds the head *d* against the end of the punch stock. The die set is then assembled by placing the die *e* in the

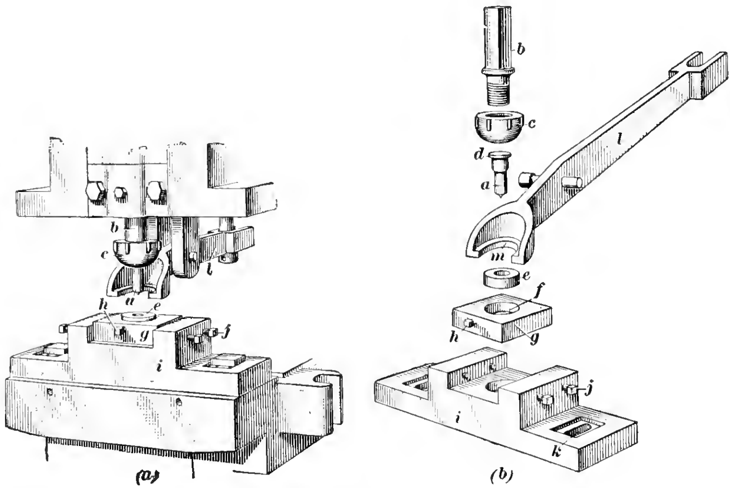


Fig. 47

hole *f* of the die holder *g* where it is held by the setscrew *h*. The die and die holder are then fastened in the die block *i* by the setscrews *j*. When the punch stock *b* has been inserted in the plunger, the die block is bolted to the lower jaw of the machine. In order that the die may be brought in line with the punch, the bolt holes *k* are made slightly elongated to permit adjustment forward and backward. Adjustment sidewise is obtained by means of the setscrews *j*. The stripper *l* is fastened to the frame of the machine, with the semicircular opening *m* around the punch just above the plate that is being punched, and pushes the work off the punch as the plunger rises.

RIVETING MACHINES

49. Some riveting machines form the heads on the rivets by a steady pressure, while others form the rivet head by striking a series of rapid blows. The machine that forms the rivet head by a steady pressure is comparatively large and is therefore especially well adapted to riveting in a shop in which much riveting is done, whereas the riveting hammer, that forms the rivet head by a series of blows, is usually small and is consequently used for riveting that is done away from a shop, or in shops where a comparatively small number of rivets are to be driven and the expense of the larger machine is not warranted. A riveting hammer is shown in Fig. 48. Air at a pressure of about 100 pounds per square inch is brought to the hammer through a rubber hose that is attached to the handle *a*

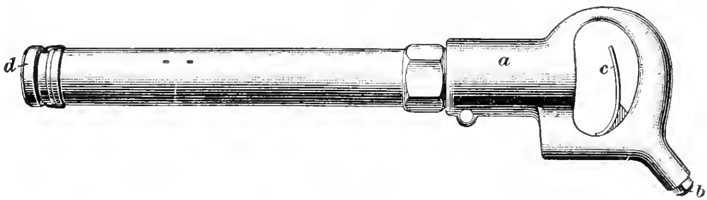


Fig. 48

of the hammer at *b* and the operation of the hammer is controlled by a valve that is operated by the latch *c*. The rivet set *d* is cupped out to form the rivet head. The plunger strikes from 800 to 1,100 blows per minute.

50. The riveter shown in Fig. 49 is larger than the one just described. It is intended to be carried around by a crane, but this form of riveter is also made to remain stationary. The rivet head is formed by the steady pressure of air or steam in the cylinder *a* on the plunger *b*. The pressure is transmitted to the movable rivet set *c* by a system of levers partly shown at *d*. The parts of the riveter are so proportioned that the movable rivet set moves a considerable distance during the first half of the plunger stroke but it cannot be made to exert a very great pressure on the work during this part of the stroke.

During the second half of the plunger stroke, however, the movable set does not move very far but it can exert practically the full pressure for which the riveter is designed. In order that the riveter may head rivets of different lengths and finish the head during the last half of the plunger stroke, the rivet set *c* may be adjusted to different heights. The gauge *e* has two marks showing the position of the end of the plunger at the

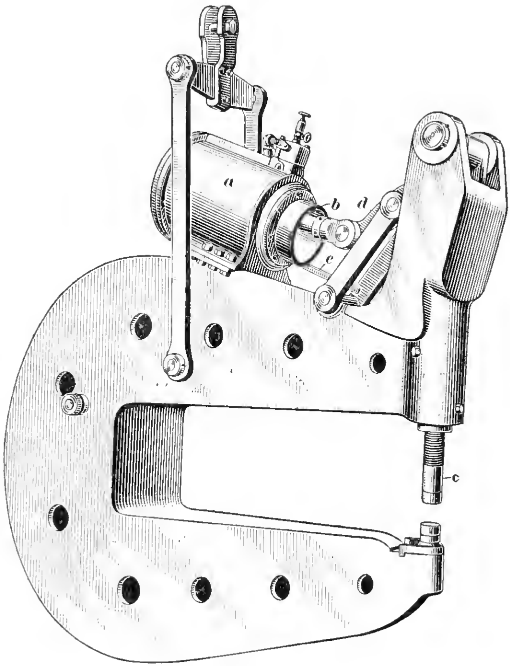


FIG. 49

beginning and at the end of the second half of its stroke. These marks enable the operator to adjust the upper set *c* so that the rivet head is completed during the second half of the plunger stroke when the machine is able to exert its greatest pressure.

51. Riveting.—Rivets in structural work do not, as a rule, have to be driven as hard as when they are to resist steam pressure and hold the joint steam-tight. Some rivets may therefore be driven sufficiently hard while cold to satisfy the conditions for structural work, but when the joint must be steam-tight it is seldom possible to drive the rivets cold. The pressure required to drive rivets of different sizes depends somewhat on the material of which the rivets are made. A machine capable of exerting the pressure given opposite any given size of rivet in Table III should have sufficient capacity to drive that size of rivet.

TABLE III

PRESSURES REQUIRED TO DRIVE RIVETS

Diameter of Rivets, in Inches			Pressure Required Tons
Driven Cold	Driven Hot		
	Structural	Steam	
$\frac{1}{4}$			12
$\frac{5}{16}$			15
$\frac{3}{8}$			22
$\frac{1}{2}$			31
	$\frac{1}{2}$		20
$\frac{5}{8}$			56
	$\frac{3}{4}$	$\frac{1}{2}$	30
	$\frac{7}{8}$	$\frac{3}{4}$	50
	1	$\frac{7}{8}$	70
	$1\frac{1}{4}$	1	80
		$1\frac{1}{8}$	100
		$1\frac{1}{4}$	125

The holes for rivets should be somewhat large so that the rivet will enter easily. For rivets larger than $\frac{1}{4}$ inch, $\frac{1}{16}$-inch clearance should be sufficient. The length of rivet to be used depends on the thickness of the parts through which the rivet passes and the kind of head that is to be made. In any case, the rivets should be enough longer than the thickness of the parts that are being fastened together to provide stock to make the head and to permit the rivet to upset to fit the hole. The length of rivet usually required for this purpose depends on the diameter of the hole and the kind of a head that is to be made. For the button head, the length of stock required for the head is $1\frac{1}{4}$ times the diameter of the hole; for the point, or steeple, head, the stock is about 1.3 times the diameter of the hole; for the countersunk head, .8 times the diameter of the hole.

BULLDOZER

52. The bulldozer is a horizontal press for performing bending, forging, and welding operations. One of the most common forms is shown in Fig. 50. In the illustration, a pair of dies *a*, *b* is shown in position for bending the piece of work *f*. The moveable die *b* is attached to the ram *d*, which is driven by the connecting-rods *c*. These machines are made to be driven by a belt, engine, or electric motor, and are used for a very large variety of work, especially for such work as the forgings for car trucks, for agricultural implements, etc. An almost endless variety of work can be done on them, including forging and welding. The stock is generally put in the dies hot, and in most cases simple dies similar to those shown in Fig. 50 are used.

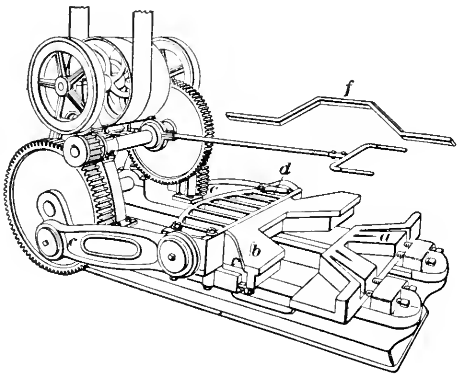


FIG. 50

53. Bulldozer Work.—The **U**-shaped strap shown in Fig. 51 may be formed on a bulldozer. The straight stock is first cut to length and the holes *a*, *b*, and *c* are punched somewhat smaller than the finished size. Holes *a* and *c* are then reamed to size, but hole *b* is left the punched size, so that it can be used in the bending operation. When the strap has been bent into the shape shown, the holes *a* and *c* must be opposite each other. Hole *b* is half way between *a* and *c* before the stock is bent, and it therefore serves to center the stock while it is being bent. The bending punch, Fig. 52 (*a*), is bolted to the head of the bulldozer and fits into the bending die, Fig. 52 (*b*), which is bolted to the table of the bulldozer. The body *a* of the punch is an iron casting to which the steel wearing plate *b* is fastened. The steel dowel-pin *c* fits into the hole *b*, Fig. 51, in the stock and centers it so that holes *a* and *c* will come opposite each other. The bending die, Fig. 52 (*b*) is also an iron casting. The opening *d*, into which the stock is pushed for bending, does not need to be as deep as the piece that is being bent. It need only be deep enough to make the stock that is being bent lie close to the side of the punch. There is a considerable force tending to drive the parts *e* and *f* apart when the die is in use, and these parts are therefore

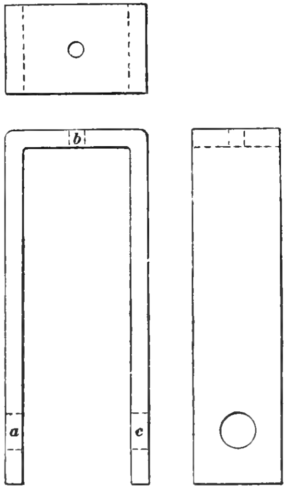
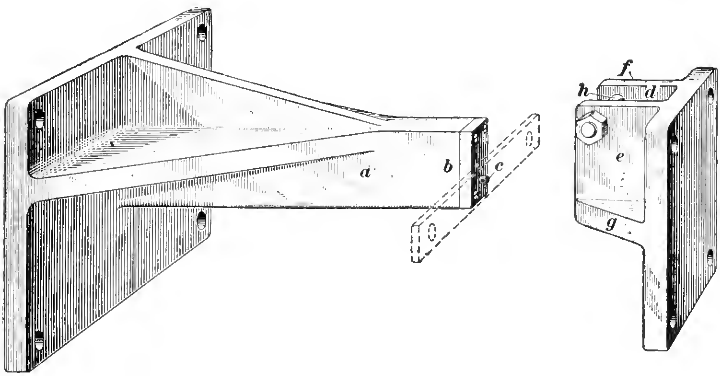


FIG. 51



(*a*) (*b*)

FIG. 52

strengthened by ribs *g* and by the tie-bolt *h*. The tie-bolt is placed high enough to allow the punch to pass under it.

MACHINE FORGING

Serial 1690 Edition 1

EXAMINATION QUESTIONS

(1) What is meant by machine forging in its broadest sense?

(2) How is graded rolling usually accomplished?

(3) What is the advantage of having the work move toward the operator when rolling between dies?

(4) How are threads formed by the rolling process?

(5) What size of stock would be selected to make a United States standard screw thread 1 inch in diameter by the rolling process?

(6) What adjustment is made to form conical work on bending rolls?

(7) What special advantage has the steam drop hammer over other drop hammers?

(8) Give one advantage of the board drop hammer over the crank drop hammer.

(9) What is a drop forging?

(10) What is meant by the flash?

(11) How is the fin removed from the forging?

(12) What are two advantages claimed for a solid foundation over an elastic foundation for a drop hammer?

(13) What is meant by swaging?

(14) What is the object of inclining the bed of a press?

(15) What is the advantage of the vertical shear over the lever shear?

(16) What is the object of setting one of the blades of a pair of shears at an angle to the other?

(17) What is meant by a convertible shear?

(18) What two kinds of machines are used to form heads on rivets?

(19) On what kind of work are hot rivets generally driven?

(20) What is a bulldozer?

FORGING DIES

Serial 1682 Edition 1

FORMS OF FORGING DIES

DROP-FORGING DIES

PRINCIPLES OF DROP FORGING

1. The object of this Section is to explain the forms of forging dies in use and the methods of making them. A **drop forging** is one made between dies by a machine employing the force of a dropped weight. By the use of drop-forging dies it is possible to make forgings that would otherwise be impractical owing to the great expense. Drop forgings are made of any weight from a fraction of an ounce to over a hundred pounds, and forgings uniform in quality are produced in large quantities. The advantages of drop forgings are low cost; uniformity, permitting them to be used interchangeably; strength; ductility; and a pleasing general appearance. Drop forgings are generally made of low-carbon steel, although they are also made of alloy steel, wrought iron, tool steel, copper, and bronze.

2. Classes of Drop-Forging Dies.—One of the simplest sets of drop-forging dies is shown in Fig. 1. It consists of the upper die *a*, which is secured to the hammer, and the lower die *b*, which is secured to the anvil. The recesses in the dies are indicated by the dotted lines *c*. The die recesses are generally spoken of as impressions It will be noticed that the deeper impression is in the upper die. This is generally so, owing to

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the fact that in practice it has been found that the metal then more readily fills the impression in all parts. The line *d*, where the upper and lower dies come together, is known as the *joint line* of the dies. The form of the joint line depends on the shape of the work to be made. Drop-forging dies may be divided into two classes: those having a straight joint line as *d*, Fig. 1, and those whose joint line consists of two or more straight lines that lie at an angle to each other, or a combination of straight lines or curves. It is essential that there be little or no side thrust from the dies to the hammer guides when in action; that is, the dies should be balanced. This is readily done in the case of those dies having a straight joint line by making the dies so that the joint will be at right angles to the center line of the hammer; that is, making the joint line horizontal.

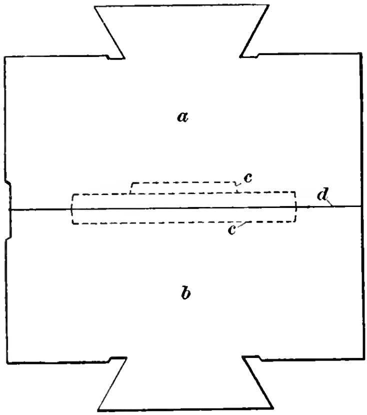


FIG. 1

Dies of the second class may be subdivided into those in which the side thrust is balanced by choosing a suitable angle for the lay of the work in the die, and those in which the thrust is balanced by the addition of a part to the die for this purpose.

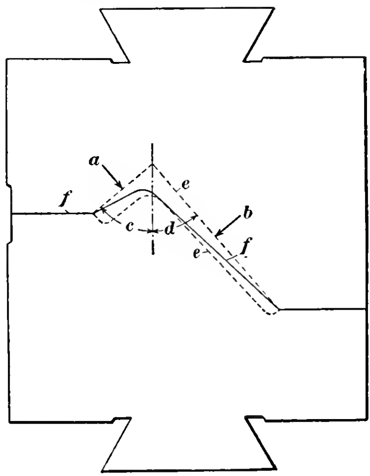


FIG. 2

3. In Fig. 2 is shown a pair of dies for a right-angle bend, in which the thrust is balanced by choosing a suitable angle for the lay of the work.

In this case, the thrust in the direction *a* is offset by a thrust *b*, as shown by the arrows. The amount of the thrust in either direction may be changed by changing the angles of the die. In case the angles *c* and *d* were equal, the thrust would be away from the side *b* which has the largest area. As the greatest thrust occurs during the first few blows, the lay should be made so the thrust will be balanced at that time. In the figure, the dotted lines *e* represent the depressions in the dies and the line *f* is the joint line.

In Fig. 3, a pair of dies is shown in which the thrust is balanced by making the dies so that the part *a* will back into the part *b* and create an equal thrust in the opposite direction. As before, the depressions in the dies are indicated by dotted lines *c*.

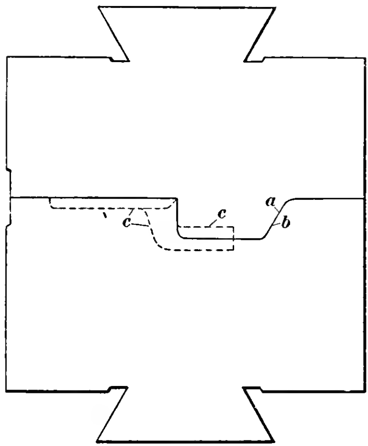


FIG. 3

The surface of the dies that meet when a blow is struck is known as the **striking surface.** Dies should be so made that the striking surface will be uniform around the impressions.

4. Die Parts.—It is only in the case of the simplest forgings that the work may be finished in a single die recess. Four recesses may be necessary, the *fuller;* the *breakdown*, *bending impression*, *edger*, or *side cut;* the *roughing impression;* and the *finishing impression.* To these may be added the *cut-off* in case the forgings are to be cold-trimmed. Some parts of the finished forging are thicker than others, and, as the work is forged from a bar of uniform thickness throughout, the stock must usually be first roughly shaped to fill the die impressions. The die recess known as the **fuller** is of such form that when the stock is forged in it the stock will fill the roughing and finishing impressions when struck. The stock is drawn out in this recess in the same manner as the blacksmith draws out stock under the trip hammer. When the fuller is of such shape that the stock may be rolled in it, it is frequently called a *roller*. Again, when a die has a fuller but no break-down, the fuller is sometimes spoken of as a break-down. Fullers are very frequently required in drop-forging dies. In Fig. 4 a forging is shown that is made in the dies shown in Fig. 5. In Fig. 5 (*a*) is shown the top die, in (*b*) the bottom die, and at *a* the fuller. In Fig. 6 (*a*), the forging is shown as it leaves the fuller. After being shaped in the fuller, it is often necessary to distribute the metal by bending and otherwise shaping it in a side

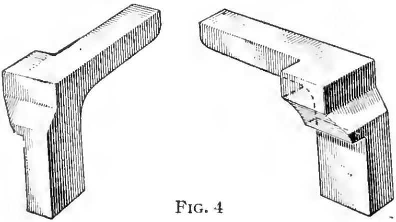


Fig. 4

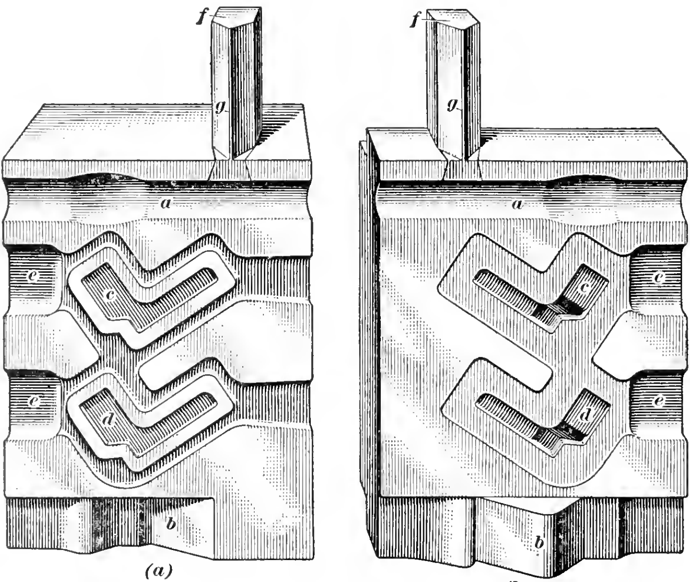


Fig. 5

impression called the **breakdown, edger, bending impression,** or **side cut.** As a rule, the breakdown is so located that when the work is in it the work stands at right angles to the position it occupies when in the finishing impression. The breakdown is located on the right-hand side of the die, as it is easier for the operator to swing the bar on that side. In Fig. 5 the breakdown is shown at *b*, and in Fig. 6 (*b*) the forging is shown as it leaves the breakdown.

5. After being shaped in the breakdown, the forging is formed nearly to its finished dimensions in the roughing impression *c*, Fig. 5, and then finished in the finishing impression *d*. In Fig. 6 (*c*) the work is shown as it leaves the finishing impression. In some cases the roughing impression is omitted and the forging is both roughed and finished in the one impression. It is much better however, except in those cases where there is very little forging to be done, to use the two impressions, as the dies will last much longer, the severe duty of completely forming the forging being saved from the finishing impression. In the case of large forgings the finishing impression is made on a separate set of die blocks, and the dies are secured to another hammer located so that either hammer can conveniently be used. In the case of small forgings made in large numbers, two finishing impressions are often made in the dies. When this is done the dies last longer, for after one of the finishing dies wears out another is available.

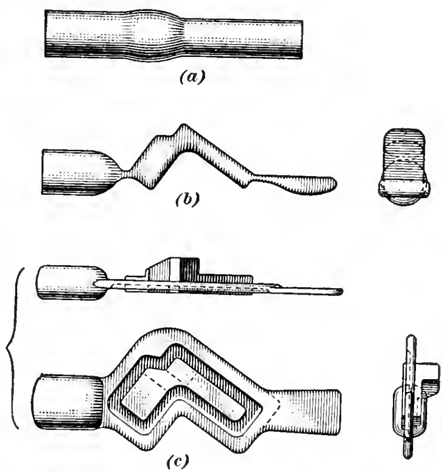
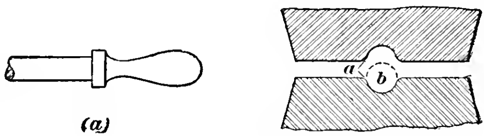


FIG. 6

6. Drop-Hammer Die Fastenings.—The manner of fastening drop-hammer dies depends somewhat on the character of the work being done. For heavy forging operations the dies are usually fastened with two keys, one on each side of a dovetail or feather on the back of the die. Sometimes two slightly tapered keys having straight sides are driven from opposite directions, but on the same side of the die, so as to clamp the die with an even parallel bearing on both sides. For light work, with forming dies operating on thin metal, either hot or cold, the lower die is usually held by means of poppets with adjusting screws. The use of these poppets permits considerable adjustment of the die; but they would not be strong enough to hold the dies in place for heavy forging. A pocket is sometimes formed in the anvil face, so that a suitable projection on the die may fit into this pocket and thus aid in keeping it in its proper position.

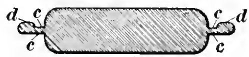
7. Fin Formed on Forgings.—If the work being forged is of circular cross-section, and so formed in relation to its axis that the piece can be revolved, as, for instance, the handle



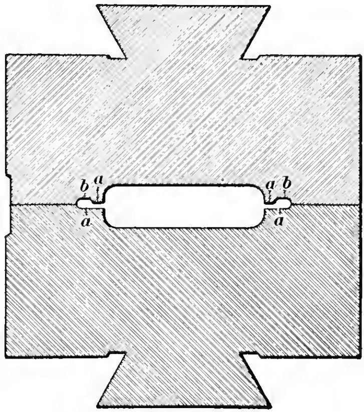
(a) FIG. 7 (b)

shown in Fig. 7 (*a*), the forging dies will be made as shown by the cross-section in Fig. 7 (*b*). The form in both dies corresponds to the form to be given to the work, but the corners *a* are rounded, so as not to scar the work. By rotating the work as it is being forged, it will finally be brought to the desired circular cross-section, as indicated by the dotted circle at *b*, and there need be no burr on the finished forging.

8. In the case of work that is not round in cross-section, or which does not have a straight axis, it is impossible to turn the piece in the die, and, hence, it must be forged to shape without rotation. Dies are made that can be used for a series of impressions or operations, some parts of the dies acting on the edges, and others on the faces of the work. The finishing die always squeezes out some metal on the edge of the work, as shown in Fig. 8 (*a*). This metal formed on drop-forged work is known as the **fin**, and provision is usually made for it by a groove in the die, known as the **flash,** as shown at *a*, Fig. 8 (*b*). The fin is also sometimes called the flash. On the average-size dies, the flash is a flat shallow recess about $\frac{1}{64}$ inch deep and $\frac{5}{8}$ inch wide. On larger dies the flash is deeper and wider. The upper die is usually made with a **back flash,** or **gutter,** as shown at *b*, in addition to the flash. This back flash is generally milled about $\frac{1}{4}$ inch from the impression and about $\frac{3}{64}$ inch deep. It receives the excess metal after it is squeezed through the flash. No flash is milled in the roughing impression, as the metal does not quite fill the recess when struck. The finishing impression only is provided with flash and back flash. In Fig. 8 (*a*), *c* is the fin formed by the flash, and *d* the fin formed by the back flash.



(*a*)



(*b*)

Fig. 8

9. Gate and Sprue. Drop forgings are usually made complete while still a part of the original bar. The bar is thinned down where it connects with the forging, and the channel in the die that forms this connection is known as the gate. The gate extends from the edge of the die block to the front end of the impression. Each impression must have a gate. The size of the gate should be such that it will support the forging while being worked. The gate is enlarged at the edge of the die block to form an opening called the sprue, shown in Fig. 5 at *e*. This sprue is large enough to admit the rough bar. In Fig. 5 the gate is omitted owing to the fact that the forging is small. In this case, the flash extends to the sprue and serves the purpose of the gate.

10. Severing Work From Bar.—The fin is removed from the forging in a separate operation. If removed while hot, the operation is known as **hot trimming.** If the forgings are hot trimmed, they are cut clean from the bar on the trimming press, and the fin that remains attached to the bar is removed by a cut-off attached to the bolster plates of the trimming press. In this case, the forging dies do not require a cut-off. If the fin is not removed till cold, the operation is known as **cold trimming.** Most small forgings are cold trimmed. When cold trimmed, the forgings are severed from the bar when hot by the use of a cut-off forming part of the forging dies. The cut-off is generally placed across, or dovetailed to, one of the two rear corners, wherever there is the most room, as shown in Fig. 5, at *f*. It is made by forming a chisel-shaped part on each die. The edges of the cut-off are not, however, made sharp, but are made with a face *g* about $\frac{1}{8}$ inch wide so that they will last long in use. In some cases, as when dovetailed into the die block, the cut-off is made of separate pieces set into the dies so that they may be readily replaced in case they are broken.

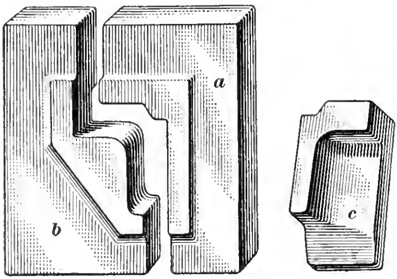


FIG. 9

11. Removal of Fin. In Fig. 9, the cold-trimming die and punch used to trim the fin from the forging shown in Fig. 4 are shown. The die consists of the two parts *a* and *b*, and *c* is the punch. The die is in two parts owing to the fact that it may then be more readily made, and it also provides a means of adjustment for wear. It is secured to the bed of the press by means of keys, bolts, or clamps. The punch *c* is secured to the ram of the press. In operation, the forging, with the fin attached, is placed over the opening in the die, after which the punch is caused to descend and force the finished forging through the die. The forging drops through the base of the machine. The fin remains on the top of the die or sticks to the punch and rises with it. Generally, strippers are arranged to remove the fin from the punch as it ascends. The fin is then brushed aside and the operation is continued.

When the forgings are hot trimmed, the trimming die and cut-off are generally both attached to the bolster plate of the press. In Fig. 10, one form of bolster plate is shown. It is

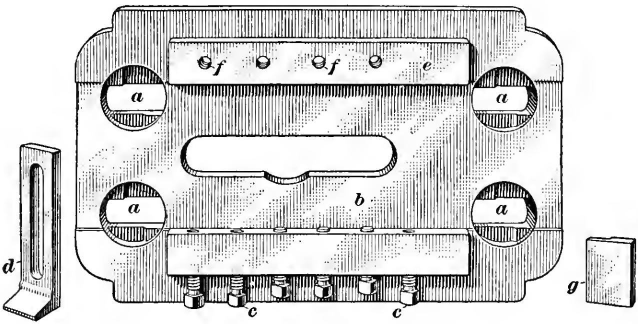


FIG. 10

secured to the bed of the press by means of the holes *a*, and the trimming die is set in the recess *b* and held in place by the screws *c*. The cut-off tool *d* is next attached to the part *e* by means of screws that fit in the holes *f*, and the cut-off tool *g* is attached to the ram of the press. In operation, the forging is punched clean from the fin while hot, and the fin is then severed from the bar by means of the cut-off. The hot-trimming press should usually be located close to the hammer and furnace; for, as a rule, the forging is trimmed, without reheating, as soon as it is taken from the hammer.

EXAMPLES OF DROP-FORGING DIES

12. Dies for Open-End Wrench.—The process of drop forging is illustrated by the making of an ordinary open-end wrench, shown in Fig. 11. A bar of suitable size to form the piece is selected and a portion of it may be formed under a power hammer, or between suitable drop-forging dies, so as to leave sufficient material for the head, while the handle is narrowed somewhat. The dies for doing the work are shown in Fig. 12. The piece is first placed in the die opening *a*, which will form it

FIG. 11

as shown at *f*, the end of the die acting as a fuller to spread the stock for the head. The work in all cases is held by the sprue *k*. After the piece has been struck one or two blows

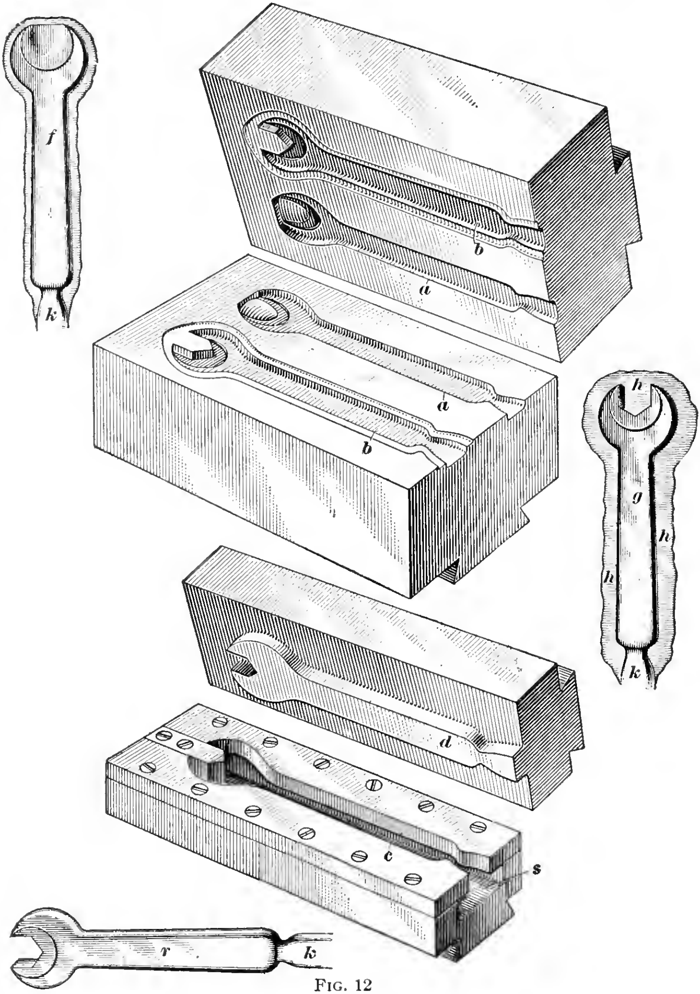


FIG. 12

in the opening *a*, it is placed in the opening *b*, and struck several successive blows. This brings the entire wrench to the finished form, except for the fin shown at *h* in the piece at the right of the dies, the wrench being shown at *g*. The piece is now placed in the trimming die *c* and struck by the punch *d*. This drives the wrench into the space *s*, from which it is removed

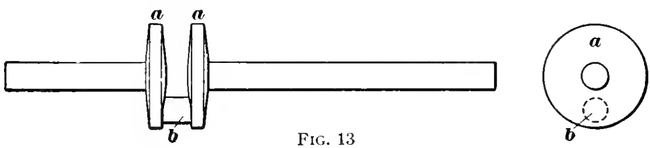


FIG. 13

endwise, in the form shown at *r*, and leaving the fin on the top of the die block. The sprue *k* is then cut off, which completes the forging. Instead of forming a portion of the stock under a power hammer, or between separate dies, a fuller similar to the one shown in Fig. 5 at *a* may be made a part of the dies and used to shape the stock. The trimming die *c*, Fig. 12, is built up of four pieces that are screwed together as shown. This is done because the die can then be more easily made, and also because, when one part becomes broken or worn out, it may be replaced without making an entire new die.

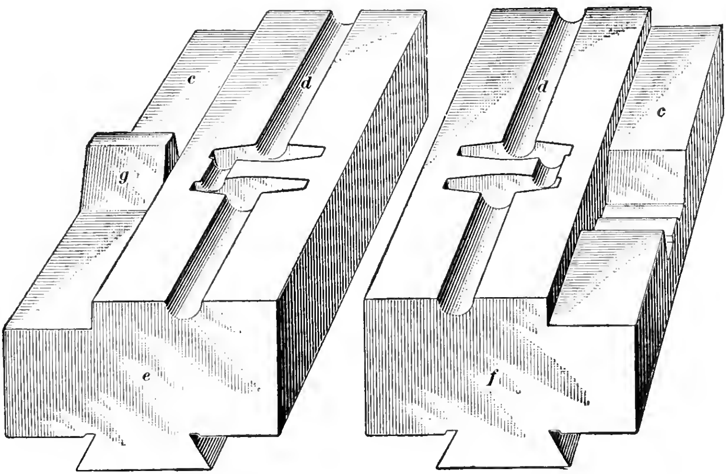


FIG. 14

13. Dies for Single-Throw Crank-Shaft.—An interesting example in drop forging is the making of the single-throw crank-shaft shown in Fig. 13. In Fig. 14, the dies for breaking down the stock and forming the disks *a*, Fig. 13, pin *b*, and adjacent parts of the forging are shown. The remainder of the ends of the shaft are forged under an ordinary trip hammer. By the use of the short dies shown, a small amount of stock is acted on and the forging can be made under a lighter hammer than would otherwise be required. The forging is made from square stock, by passing it back and forth from the breakdown *c*, Fig. 14, to the roughing impression *d*, a tong hold having first been forged on its end. All the corners of the roughing impression are well rounded to prevent cold

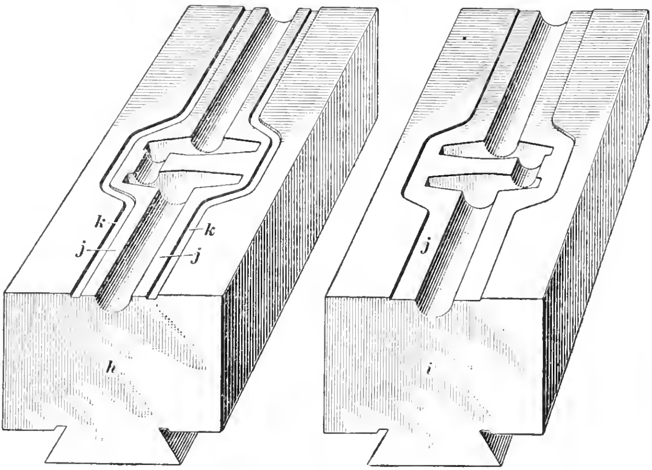


Fig. 15

shuts. In the figure, *e* is the top die and *f* the bottom die. The part *g* of the top die is made separately and dovetailed into the side of the block.

14. After the stock is distributed in the roughing impression, it is placed in the finishing dies shown in Fig. 15 and forged to size by a few blows of the hammer. In the figure, *h* is the top die and *i* the bottom die. The flash is shown at *j* and the back flash at *k*. The impression in the finishing die is like that of the roughing impression, except that the corners are not rounded so much. Two hammers are necessary for this job, one for the roughing dies and one for the finishing dies. These should be located near each other and near to the furnace, so that no time will be lost in going from one to the other. The trimming

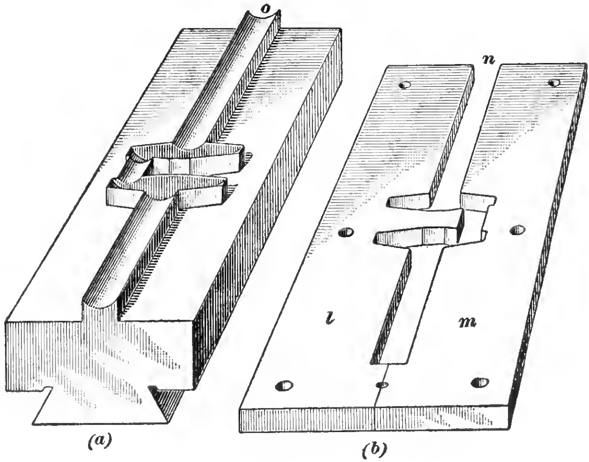


FIG. 16

punch is shown in Fig. 16 (*a*), and the trimming die in (*b*). The die is made in two parts *l* and *m* and is left open at the front end *n* for hot trimming. The punch is milled out as shown at *o* to receive the forging so that it will not bend during the trimming operation. As the trimming is done hot, and generally without reheating after forging, the press should be located near the hammer on which the finishing is done. After the trimming is done, the crank-shaft is finished by drawing out the ends of the stock under a trip hammer.

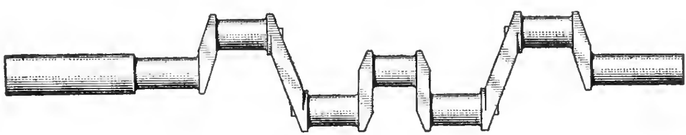


FIG. 17

15. Dies for Four-Throw Crank-Shaft.—The forging of the four-throw crank-shaft shown in Fig. 17, unlike that of the single-throw shaft just explained, can be most readily

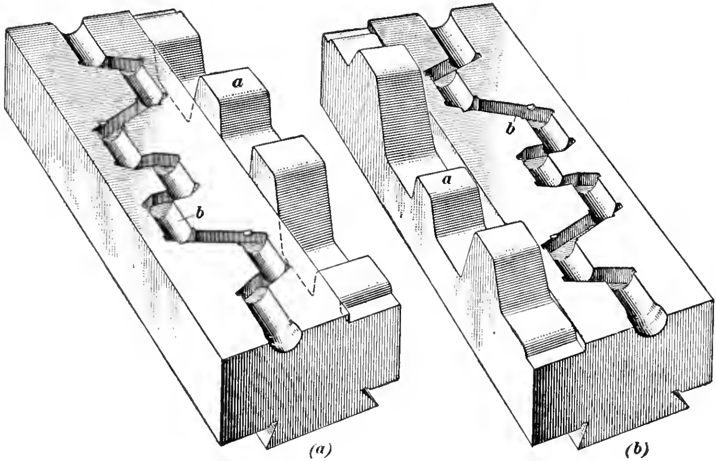


FIG. 18

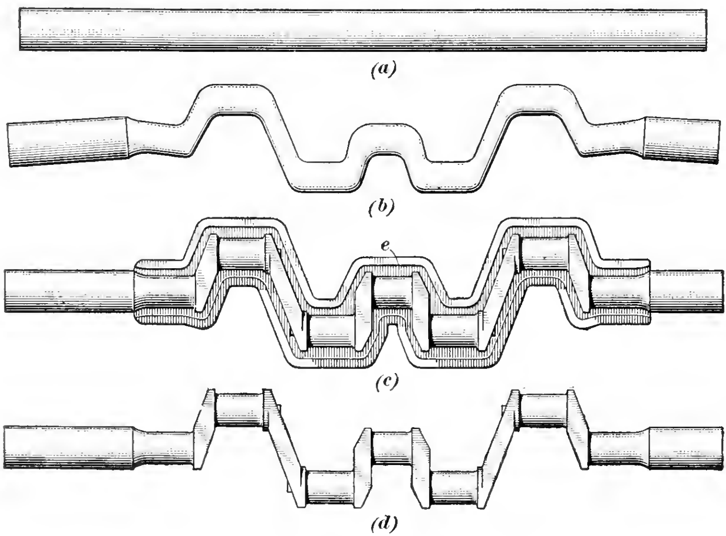


FIG. 19

completed in the dies; for in this case nothing would be gained by forging the ends under a trip hammer. In Fig. 18, the dies for breaking down and roughly forming the shaft are shown, the top die being shown in (*a*) and the bottom die in (*b*). The stock from which the shaft is forged, which is a little larger in diameter than the bearings, is shown in Fig. 19 (*a*). In Fig. 18, the breakdown is shown at *a* and the roughing impression at *b*. The roughing impression is shaped like the shaft except that the corners are slightly rounded to prevent cold shuts. In Fig. 19 (*b*), the stock is shown after being forged in the breakdown, and in (*c*) it is shown as it leaves the finishing impression. The finishing is done by a few blows of the hammer after

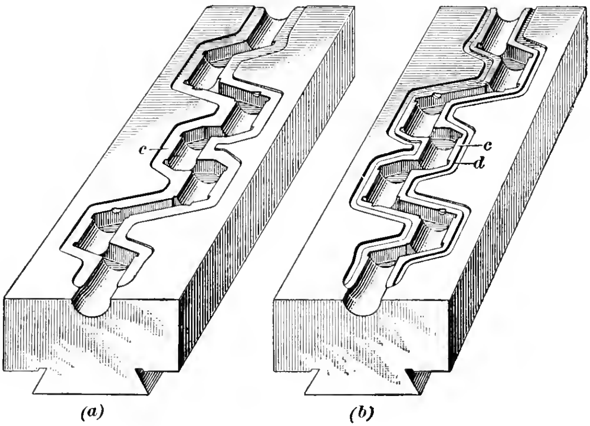


Fig. 20

locating the work properly in the finishing dies shown in Fig. 20, the die shown in (*a*) being the bottom die and that in (*b*) the top die. In the figure, the flash is shown at *c* and the back flash at *d*. The corners are not rounded as much as those of the roughing impression. As explained before, no flash or back flash is provided on the roughing impression.

16. Two hammers are required to forge this shaft, one for the roughing dies and one for the finishing dies. Both of these should be located within easy reach of the heating furnace, for convenience in operating. In case only a few of the shafts are to be made, or where less accurate work would be satisfactory, the finishing dies may be omitted and the roughing and finishing may be done in the same impression. In that case, only one hammer is required to forge the shaft, and the cost of forging is materially reduced. The fin *e*, Fig. 19 (*c*), is removed by the

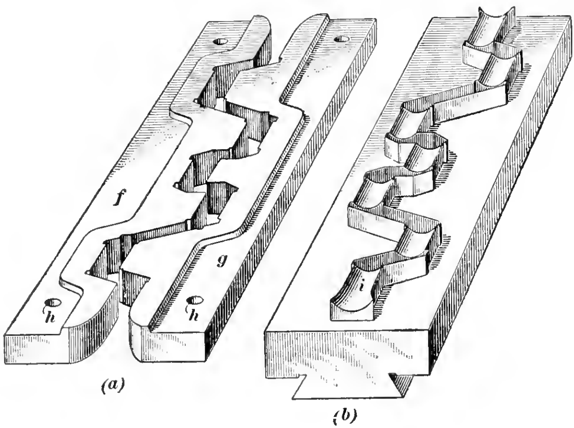


FIG. 21

use of the trimming die and punch shown in Fig. 21 (*a*) and (*b*), respectively. The trimming is done hot. The die is made in two parts *f* and *g*, for convenience, and these parts are attached to the bed of the press by means of bolts that pass through the holes *h*. The punch is milled out as shown at *i* to receive the forging and to guide the shaft while pushing it through the trimming die. As the shaft is trimmed hot immediately after the forging is finished, the trimming press should be located reasonably near the hammer on which the forging is completed. The shaft as it leaves the trimming press is shown in Fig. 19 (*d*). After trimming, the shafts may be straightened on a hydraulic press, or in some other convenient way, and then removed to the machine shop, where they are finished to size.

17. Dies for Flanged Piece.—Suppose the forging, two views of which are shown in Fig. 22, is to be drop forged. This may be done by the use of the set of dies shown in Fig. 23; in (*a*) the bottom die is shown and in (*b*) the top die. This

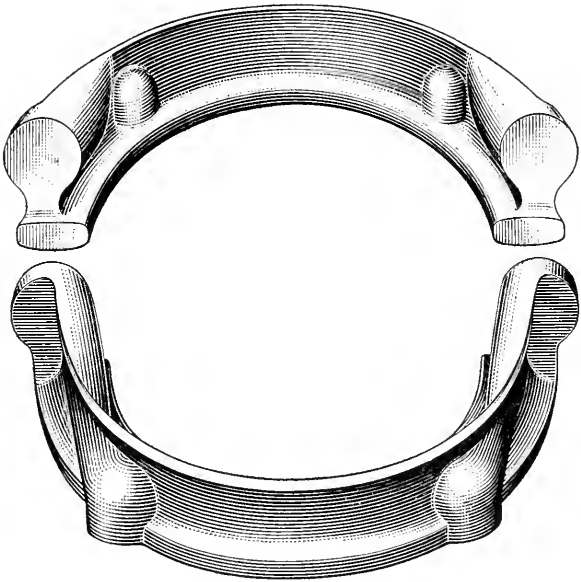
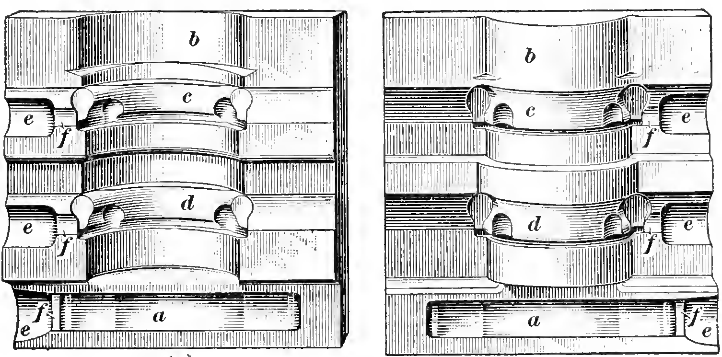


FIG. 22



(a) (b)

FIG. 23

forging is made of round bar stock, which is first rolled in the fuller *a*, after which it is broken down in the breakdown *b*. The stock is then formed nearly to shape in the roughing impression *c*, after which it is finished in the impression *d* by a few blows of the hammer. The sprues and gates for the various impressions are shown at *e* and *f*, respectively. The stock as it leaves the fuller is shown in Fig. 24 (*a*); in (*b*) it is shown as it leaves the breakdown; and in (*c*) as it leaves the finishing impression. The fin *g*, shown in (*c*), is removed by

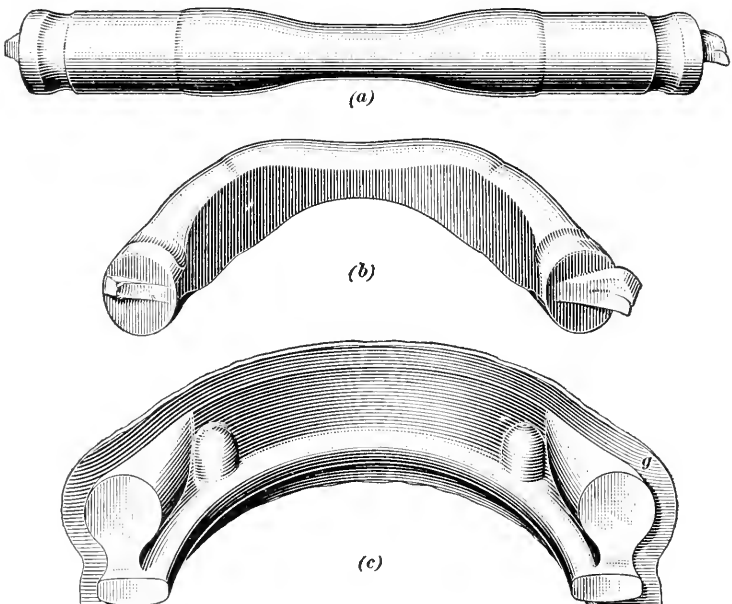


Fig. 24

hot trimming, using the trimming die shown in Fig. 25 (*a*) and the trimming punch shown in (*b*). The die is made in two parts *h* and *i*, which are doweled together by the pin *j* of the part *h*, which fits into a dowel hole in the part *i*. The die parts are clamped to the bolster plate of the press. The part *k* of the punch is made to fit into the ram of the press. After the work is trimmed, the fin is cut off the bar by the use of the cut-off, or side shear, attached to the press as previously explained, and the end of the remainder of the bar is again placed in the furnace. Another forging is then made from the bar. Usually several bars are heated at the same time so that another bar will always be at the proper heat for forging as soon as one forging is finished.

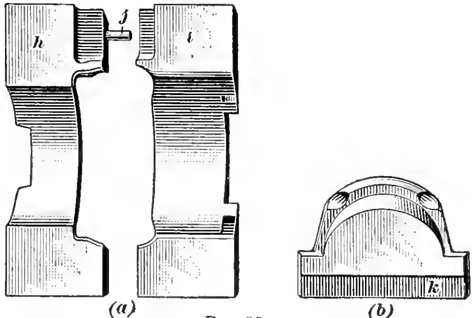


FIG. 25

18. Two-Operation Dies.—It is not always possible to make one set of forging dies produce the work, and in other cases the work cannot readily be shaped with a single set. In both of these cases, it is generally possible to do the work by first making a preliminary forging, in one set of dies, and then finishing the forging in another set. When this is done, the work is spoken of as a two-operation job, and the dies used as two-operation dies. The forging of the steering knuckle shown in Fig. 26 is an example of work that can be most readily forged in two-operation dies. In Fig. 27, the dies in which the work is first forged are shown, the bottom die being shown in (*a*) and the top die in (*b*). The breakdown is shown at *a*, the forming impression at *b*, and the work as it leaves the dies is shown in Fig. 28 (*a*). A view of the cross-section at *a b* is shown in (*b*). The forging is next trimmed while hot, using the trimming die shown in Fig. 29 (*a*), and the trimming punch shown in (*b*), after which it appears as shown in Fig. 30 (*a*). This completes the first operation, which is in fact the making of a complete forging, though not the one finally desired.

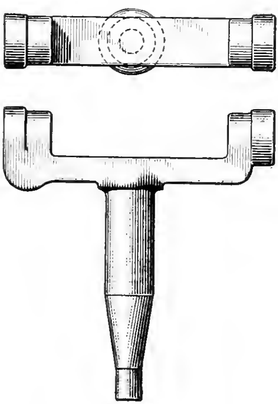


FIG. 26

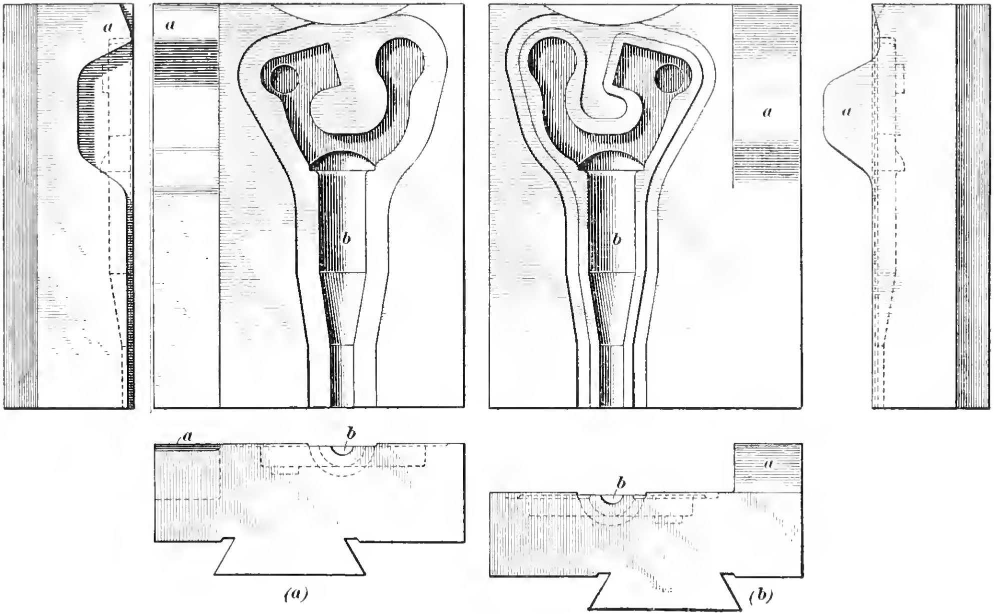


FIG. 27

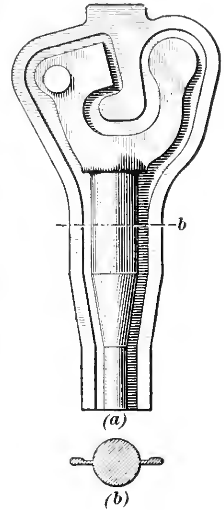


FIG. 28

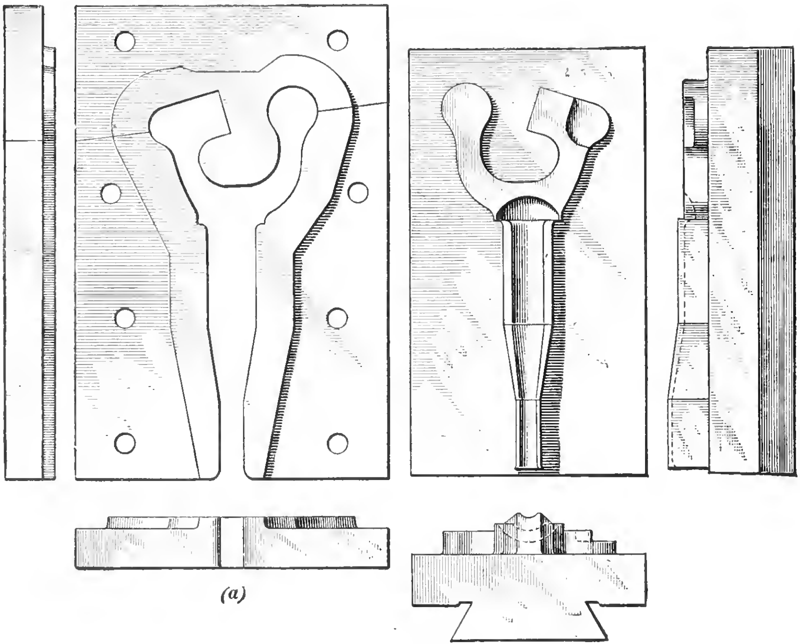


Fig. 29

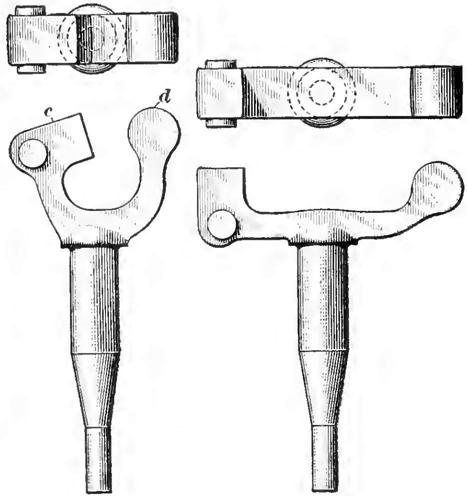
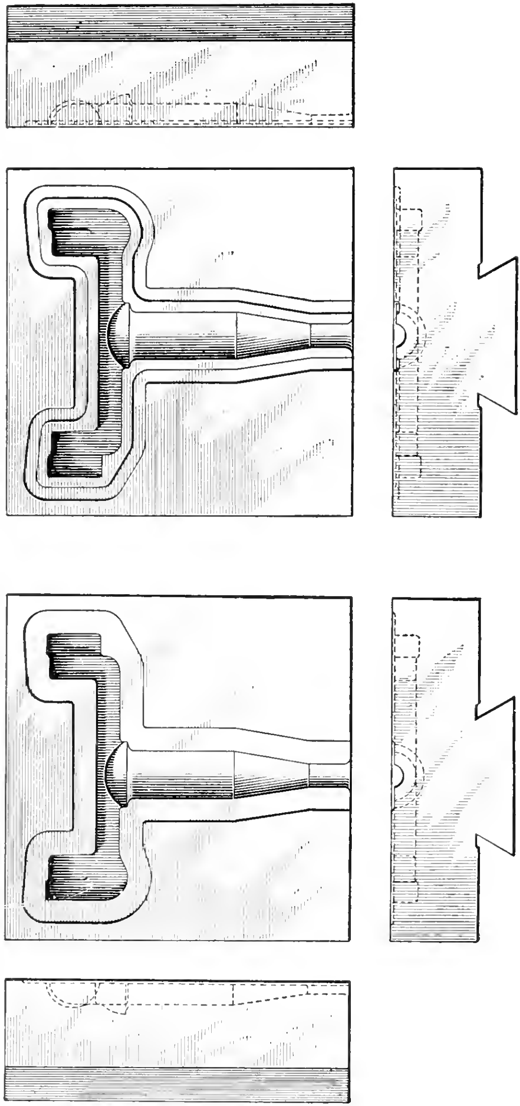


Fig. 30



(b)

(a)

FIG. 31

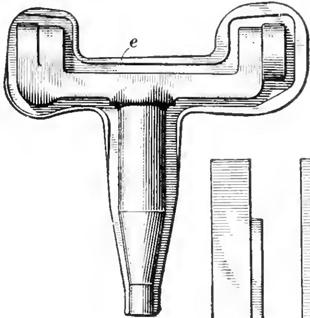
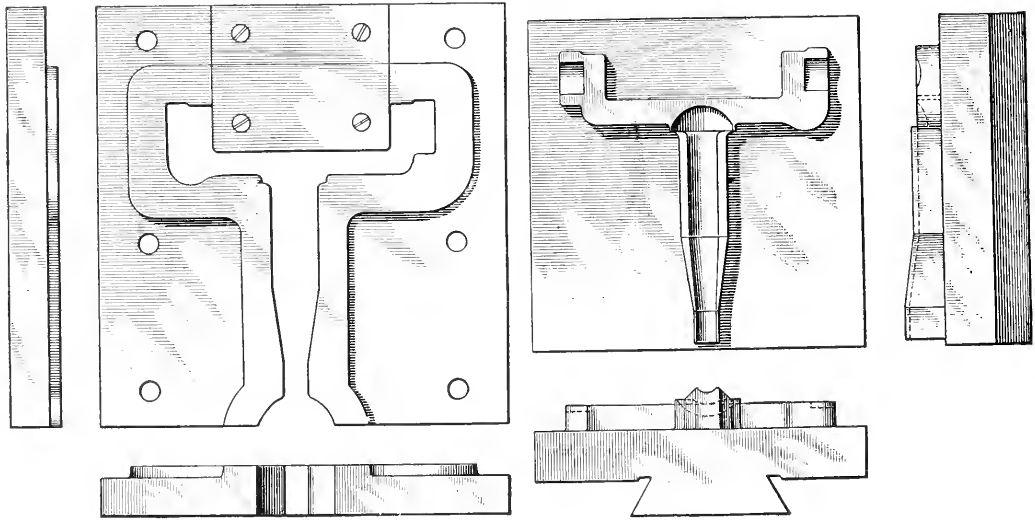


Fig. 32



(a) (b)

Fig. 33

The arms *c* and *d*, Fig. 30 (*a*), are next straightened out by the use of a hammer till the work appears as shown in (*b*), after which the work is forged to its finished dimensions in the

Fig. 34

dies shown in Fig. 31. In the figure, the bottom die is shown in (*a*) and the top die in (*b*). The forging now appears as shown in Fig. 32. The fin *e* is then removed by hot trimming, using the trimming die shown in Fig. 33 (*a*), and the trimming punch shown in (*b*). This completes the second operation, and the forging appears as shown in Fig. 26.

19. Dies for Long Spanner Wrench.—The drop forging of the long spanner wrench shown in Fig. 34 is another example of a two-operation job, although in this case the forging is finished in one pair of dies. This forging is made in two operations in order to reduce the size of the dies required to forge it, and to enable the work to be done on a much smaller hammer. The wrench is made by forging the large end first and it is then reversed and the other end is forged.

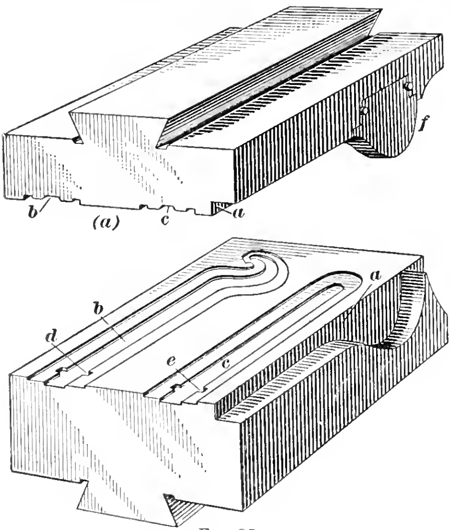


Fig. 35

The upper die is shown in Fig. 35 (*a*) and the lower die in (*b*). The breakdown is shown at *a*, which breaks down the stock that forms the large end of the wrench, no breakdown being required for the small end. At *b* is shown the forming impression for the large end of the wrench, and at *c* the forming impression for the small end. The notches *d* and *e* serve as locating points and to prevent the metal from sliding forwards when struck. When

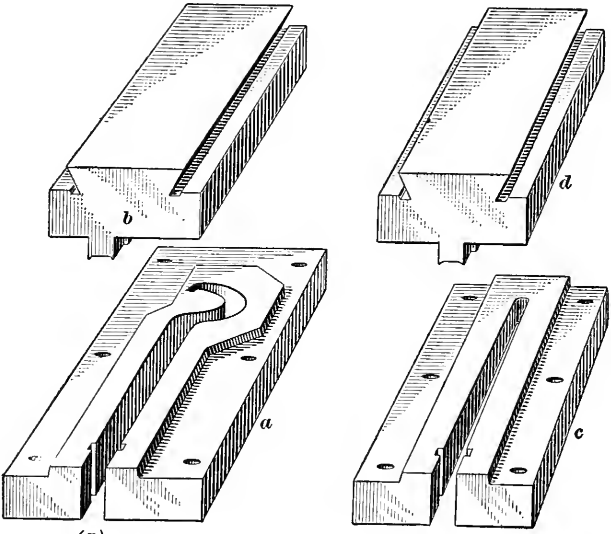


FIG. 36

the large end of the wrench is forged, lugs are formed on it by the notches *d*. These lugs fit into the notches *e* of the impression *c*, and thus locate the work in the forming impression for the small end. The part *f* in (*a*), known as the *horn*, or *bender*, is a separate piece that is dovetailed in place. The large end of the forging is trimmed by the use of the die *a*, shown in Fig. 36 (*a*), and the punch *b*; and the small end is trimmed by the use of the die *c*, shown in (*b*), and the punch *d*, the forging being hot trimmed. The small end is then moved backwards in the trimming die far enough so that the lugs formed on the sides may be removed with another stroke of the press. After trimming off these lugs, the wrench is struck again in the forging dies to round the edges where the lugs were sheared off.

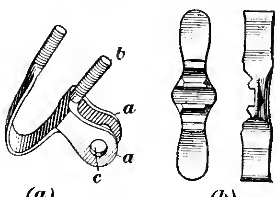


FIG. 37

20. Dies for Axle Clip.—The making of the axle clip shown in Fig. 37 (*a*) involves the following operations: Forging

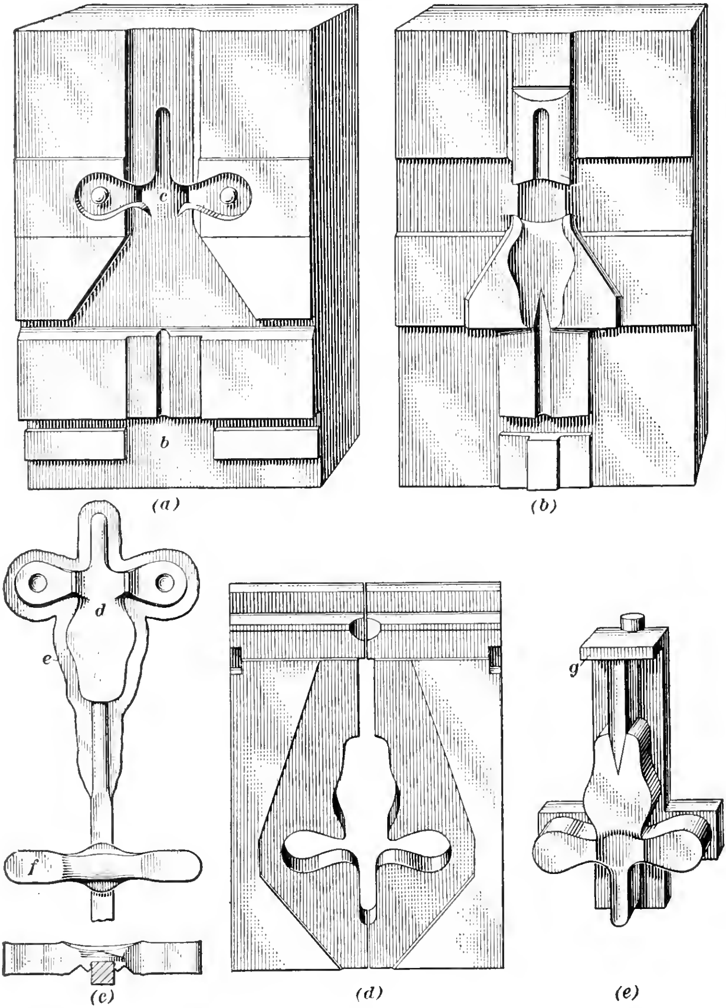
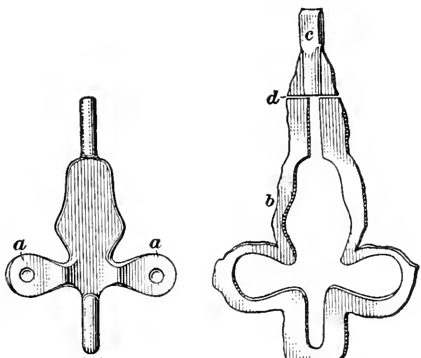


Fig. 38

and welding, hot trimming, hot bending, threading, cold bending, and punching. The part shown in (*b*) forms the lugs *a* of the clip, shown in (*a*). These parts are made first by the use of a set of dies not shown. They are then welded to the stock forming the rest of the clip, after which they are drop forged. The welding and forging are done in the dies shown in Fig. 38 (*a*) and (*b*), the bottom die being shown in (*a*) and the upper die in (*b*). To make the weld, a part like that shown in Fig. 37 (*b*) is placed at *b*, Fig. 38 (*a*), the stock for the main part is laid on it, and the upper die is dropped, sticking the parts together. The work is now reheated, another piece like that shown in Fig. 37 (*b*) is put on the lower die at *b*, the heated part is then placed in the die with the part previously stuck to the bar in the recess *c*, and the upper die is again dropped, sticking the two parts together and at the same time forging and welding the clip. The work now appears as shown in (*c*), *d* being the forging, *e* the fin, and *f* the part stuck to the bar to become part of the next forging. The fin is next trimmed off while the work is still hot. The trimming die is shown in (*d*) and the punch in (*e*). When trimming, the work is supported on the die by the fin, and the punch, descending, forces the forging through the die. In Fig. 39 (*a*) the forging is shown as it now appears, and at *b* in (*b*) the fin is shown removed from the work. The cut-off *g* in Fig. 38 (*e*) also severs the fin *b* in Fig. 39 (*b*) from the stock *c*, as shown at *d*.



(*a*) Fig. 39 (*b*)

21. After trimming, the forging is still hot. It is now picked up with a pair of tongs and placed on the bending die shown in Fig. 40 (*a*), secured to the bolster of an adjacent press, after which it is bent to the shape shown in (*b*) on the downward stroke of the punch, which is illustrated in (*c*). The forging is located on the die by the locating gauges *g* shown in (*a*), in which the lugs *a*, Fig. 39 (*a*), fit. The recesses *i*,

Fig. 40 (*c*), on the side of the punch, receive the lugs when bent, and the recess *j* receives the end *k* of the forging, shown in (*b*). After the forging has cooled, the ends *k* and *l* are threaded, and then bent to the form shown in Fig. 37 (*a*) by the die shown in Fig. 40 (*d*) and the punch shown in (*e*). To bend the forgings, each piece is in turn placed in the die, with the ends *k* and *l*, shown in (*b*), in the grooves *m* and *n* of (*d*), the lugs *o*, in (*b*), occupying the recess *p* in (*d*). The punch then descends

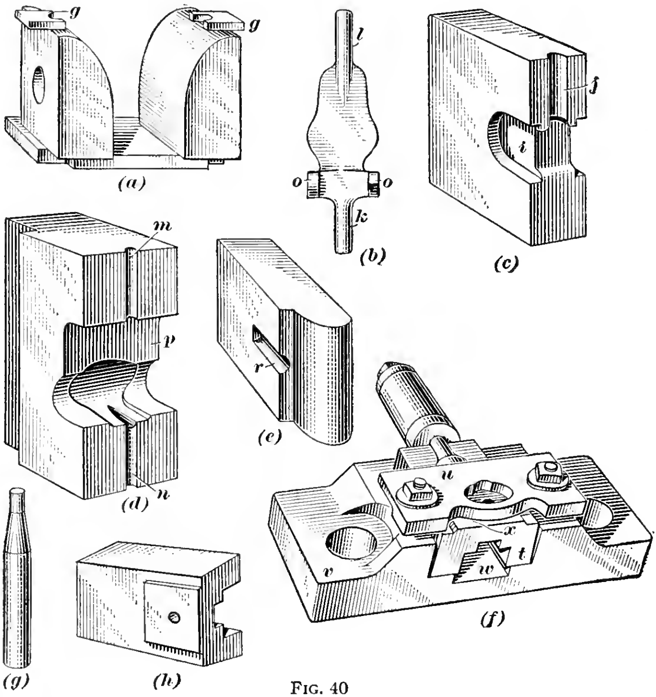


FIG. 40

and bends the forging to the desired shape, the end *b*, Fig. 37 (*a*), occupying the recess *r*, Fig. 40 (*e*). After the bending is completed, the holes *c*, Fig. 37 (*a*), are punched in the work, using the die and die holder shown in Fig. 40 (*f*), and the punch shown in (*g*). In (*f*), *t* is the die, *u* the gauge and stripper plate, and *v* the holder. The die *t* is shown removed in (*h*). To locate the work for punching, one of the lugs *a*, Fig. 37 (*a*), is placed in the opening *w*, Fig. 40 (*f*), while the other is placed in the opening *x* and against a stop between the die *t* and stripper *u*. The punch on descending forces the punching down into the opening *w*. The work is then withdrawn and the other lug inserted in the opening *x* and punched.

The equipment needed to forge this piece is a furnace and hammer to make the part shown in Fig. 37 (*b*), and a furnace, hammer, press for trimming, and press for bending, conveniently arranged to bring the work to the form shown in Fig. 40 (*b*). A threading machine, press for bending, and press for punching are used to finish the work when cold.

HEADING AND BENDING DIES

HEADING-MACHINE DIES

22. Principle of the Heading Machine.—Heading machines are used principally to upset hot metal. To do this, the work is first gripped in a set of dies *a*, *b*, Fig. 41, that are recessed to the form of the forging desired. The machine is so constructed that one of the dies may be moved in the direction of one of the arrows *c* or *d* by operating a foot treadle; and when the dies are closed on the work, which is placed in the recess *e*, the work is held between them while the heading tool, or plunger, *f* moves forward in the direction of the arrow *g* and forces the hot metal into the recess in the dies. The plunger then moves backwards, the dies open, and the work is removed, after which the operation is repeated. As the forgings are usually made from bar stock, some provision must be made so that just enough stock will extend out in front of the dies to fill the recess when struck by the plunger. This length is generally determined by trial, and then a gauge, or back stop, *h* is set to

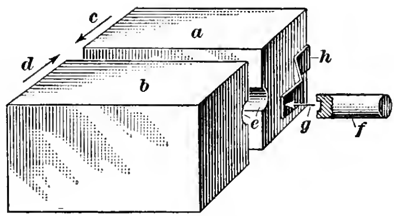


FIG. 41

the proper distance ahead of the dies. The bar is then placed against this gauge and is thus correctly located. The gauge is so controlled by the mechanism of the machine that it moves out of the way as the plunger moves forwards, and then automatically returns after the plunger moves back again. Ordinarily, one, two, or three grooves are made in the dies and one, two, or three heading tools are fitted into the machine at a time. In this way, two or three upsetting operations can be performed on a piece of work without changing the dies.

23. Heading Dies for Hexagon-Headed Bolt.—Suppose the hexagon-headed bolt shown in Fig. 42 (*a*) is to be forged in a heading machine. This can readily be done by the use of

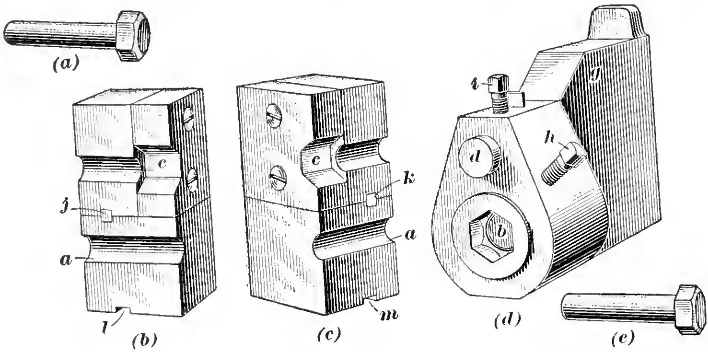


Fig. 42

the dies shown in (*b*) and (*c*) and the heading tool shown in (*d*). The stock is first located in the lower groove *a*, by the use of a gauge, not shown, after which it is upset by a blow with the heading tool *b*. It then appears as shown in (*e*). The next step is to place the head in the groove *c*, no gauge being required to locate the bolt at this setting, as the head already formed fits into the recess in the die. The work is finished by a blow with the heading tool *d*.

The heading tools *b* and *d* are held in place in the tool holder *g* by the setscrews *h* and *i*. In case the head need not be so well finished, the second operation will not be required and the head may be formed by the use of the lower groove *a* and the tool *b* only. The dies *a* and *c* are each made in two parts, and are keyed together by the keys j and k. The bottom grooves l and m fit keys that are set in the machine, and by their use the dies are properly located relative to each other.

24. Dies for Bent Handles.—Work of the form shown in Fig. 43 (a) may be forged on a heading machine, the work being shaped by the set of dies shown in (b) and (c). The dies are shown in perspective in Fig. 44. In these illustrations the

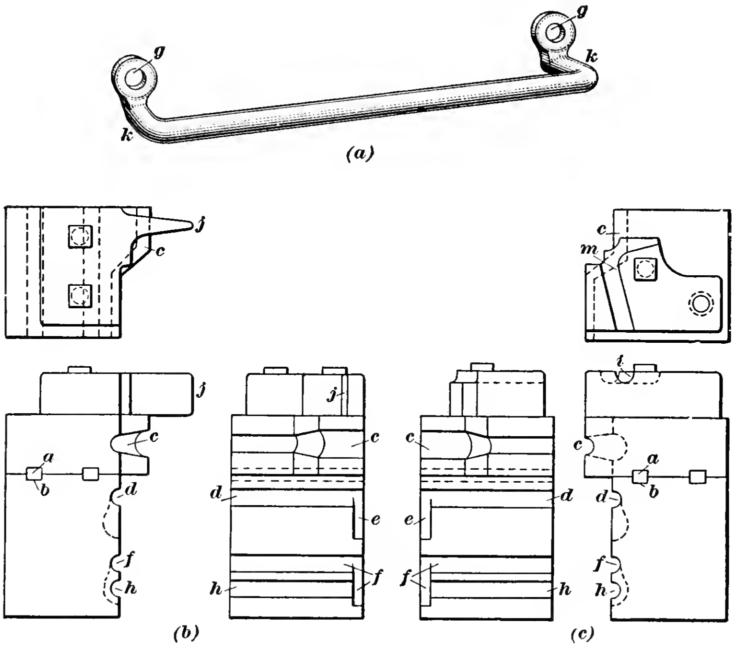


FIG. 43

same letters are used for corresponding parts. The upper and lower parts of the dies are located in the proper relation to each other by the keys a, that fit in the slots b. Each end of the handle is shaped in two heats. When heated first, the round stock is bent and upset in the upper groove c. A gauge, not shown, attached to the machine, determines the position of the stock in the die; the stock is then gripped by the dies, and the heading tool forces the heated metal into the depression in the die. The stock is next reheated, and gripped in the depression *d* in the lower die, after which the plunger forces the metal into the opening *e*. The work is now placed in the depression *f* and a punch secured to the plunger punches the hole *g*, in the upset portion, and the punching passes out through *h*.

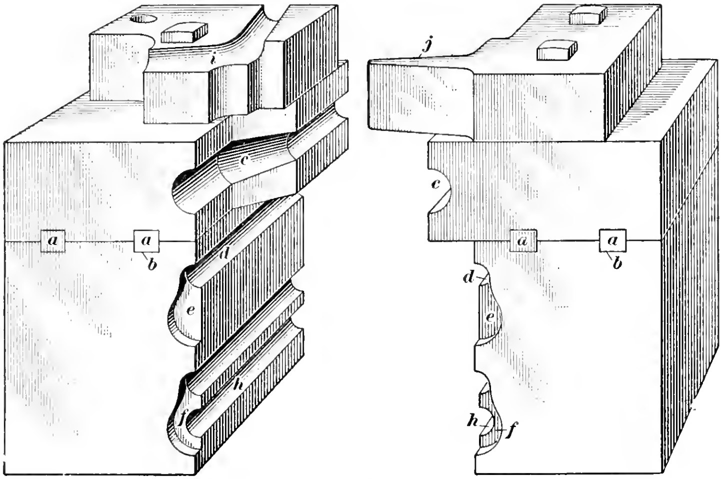


FIG. 44

Without reheating, the work is placed in the groove *i* on the top die, and the dies are again closed, the bending tool *j* forming the right-angled bend *k*.

BENDING DIES

25. Use of Bending Dies.—When it is necessary to bend heavy hot metal to various shapes, a form of horizontal press, known as the *bulldozer*, to which a set of bending dies has been attached, is used. In Fig. 45, one form of bulldozer is shown, the bending dies *a* and *b*, being shown set up. The connecting-rods *c*, which are driven by a system of gears and pulleys, drive the ram *d* to which the movable die *b* is secured. During the operation, the die *a* remains stationary, while the movable die *b* advances and bends the metal to the shape of the dies. The dies shown are made to form the piece of work shown at *f*. To bend the work, a straight bar of hot metal, that has been cut to the required length, is laid on edge against the face of the stationary die *a*, the machine is then started, and the movable die *b* advances slowly, and bends the stock to the outline of the dies. The dies are almost always made of cast iron, and are usually made ribbed, instead of solid, in order to lighten them. As a rule, drawings of the dies are made in the drafting room, after which the dies are cast, and then planed to the required dimensions in the machine shop. For a large variety of work, however, no machining is necessary, as satisfactory work may be turned out by using the dies just as they come from the foundry. Dies of this class are used to bend a very large variety of work, as forgings for car trucks, agricultural implements, etc.

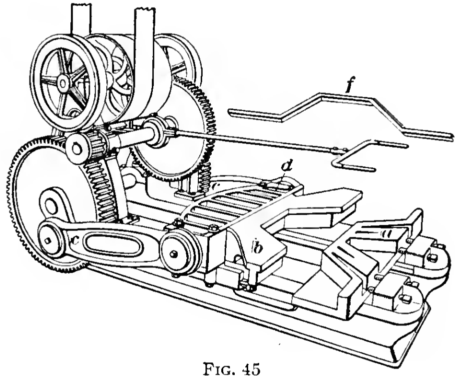


Fig. 45

26. Simple Bending Dies.—A simple form of bending die is shown in Fig. 46. Here the stationary die is shown at *a* and the movable die at *c*. They are so formed that when the movable die is forced against the blank strip of stock *b*, indicated by dotted lines, it will be bent to the required shape. In a bending die, some form of gauge or stop may be used in order to locate the blank properly; this must be made to suit the shape of the blank, and in its simplest form may be a shoulder, as shown at *d*.

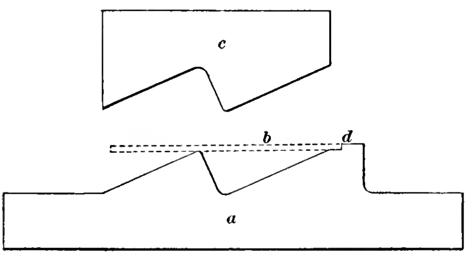


Fig. 46

27. Cold Bending.—When the piece that has been bent cold, as, for instance, that shown in Fig. 47, is examined, it will be found to have a shape slightly different from that of the die. Thus, if the dotted lines represent the shape of the piece while between the faces of the dies, on removal it will assume the shape shown in full lines, by reason of the elasticity of the material. Hence, it follows that for elastic materials the bending surfaces must be arranged to bend slightly beyond the required angle; how much beyond must be determined by experiment in each particular case. In general, the amount will be least for comparatively non-elastic materials, as annealed iron, copper, or brass, and most for more perfectly elastic metals, as spring steel, hard brass, etc. With metals like lead, or hot metals, no allowance need be made.

Fig. 47

28. Wing Dies. Fig. 48 shows a form of wing die that has hinged parts, or wings, *w*, and is well adapted for use in a bulldozer. As the punch *c* advances, the wings *w* of the die *a* are folded in by the die *d*, thus bending the iron *b* without stretching it. The part *d* acts as a cam to close the wings of the die. The illustration shows a piece of stock *b*, with the wings *w* closed about it; the dotted lines at *w′* show the position of the

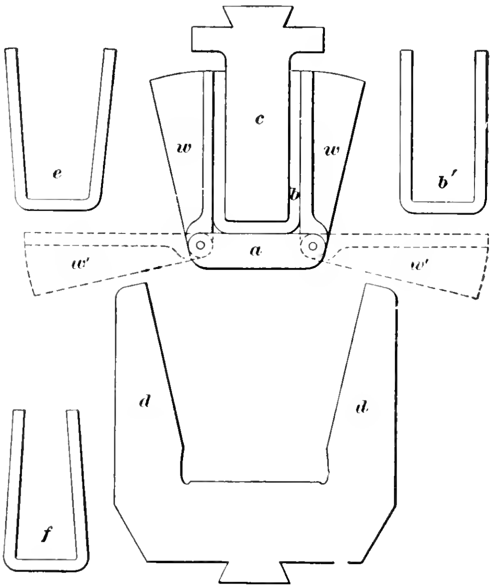


Fig. 48

wings when the die is open. When the wings are open, the flat piece of stock is laid against them. When working cold metal, if the punch *c* is made with parallel sides, as in the figure, the work will not come out parallel, as at *b* and *b*′, but will be somewhat divergent, as at *e*, on account of the elasticity of the metal. To overcome this, the punch must be made with its edges a little convergent, so that the work when closed will have somewhat the appearance of the piece shown at *f*. The subsequent expanding when released will restore it to a parallel form. The amount of this divergence depends on the kind of metal and the amount that it is heated. If entirely red hot when finished, it will act something like lead, which is practically non-elastic. As the metal is partly cooled when compressed between the cold or nearly cold dies, it may not have the exact form of the die when cold.

CONSTRUCTION OF FORGING DIES

MATERIALS AND EQUIPMENT

29. Materials.—In places where only a few forgings are produced, the dies are frequently made from a close-grained cast iron, the faces being cast to approximately the correct form and finished with a file or a scraper. Large forming dies have been cast so perfect that practically no finish was required. Cast-iron dies are sometimes made with chilled faces, to increase their hardness and wearing qualities. Ordinary dies for making large quantities of duplicate work are made from steel, both steel castings and well-annealed steel forgings being very largely used. In most cases these are cast or forged smooth on the face, and the desired forms are cut in them by milling, chipping, and scraping.

30. In cases where a very large amount of work is to be done, the dies may be made of about .60-carbon open-hearth steel, and one or both of the dies are then hardened by heating them to a cherry red heat and immersing them in a bath of water or brine. These dies must afterwards be tempered to make them less brittle and relieve the internal stresses. Dies for large forgings are often made of about .80-carbon steel, and left unhardened. This is done to reduce the danger of checking or cracking in hardening, the unhardened steel being hard enough to resist the tendency to stretch. Again, dies that have thin projections in the recesses are frequently made of about .80-carbon steel and not hardened; for if the die were hardened, the thin projections would likely break off. In case the dies are to be used to forge tool steel or other hard steel, a steel fairly high in carbon is generally used. When the material of the dies is too low in carbon, the force of the hammer blows it receives in service may cause the central part of the die face to sink below the level of the rest of the die. This is known as **dishing.** Dishing may be prevented by using a tool steel for the dies, and then hardening the dies to a sufficient depth to withstand the tendency to dish.

31. Die-Sinking Machine.—As die making is a branch of toolmaking, the equipment used for the one is, as might be expected, largely the same for the other. The machines most commonly used for die making are lathes, shapers, milling machines, drill presses, and die-sinking machines. In Fig. 49 one form of machine especially adapted to die sinking is shown. The machine is a form of vertical milling machine in which the work is held in the vise *a* that is attached to the table *b*. This table may be moved crosswise by means of the hand wheel *c*, and lengthwise by means of the hand wheel *d* or by operating the longitudinal power feed by means of the lever *e*. The cutting tool, which of course revolves, is held in one of the spindles *f* and *g*. The head *h* of the machine is moved up and down by means of the hand wheel *i*, and the spindles are driven by belt and gearing operating through the pulleys *j* and *k*, and the shaft *l*. The weight of the head *h* is balanced by means of weights that are attached to the chain *m*. The die block to be machined is secured in the vise *a*.

32. As a single spindle large enough to withstand heavy cuts cannot be provided with a sufficient range of speed to suit the delicate cuts made with small cutters and the low speeds required for the large heavy cuts, two spindles *f* and *g* are

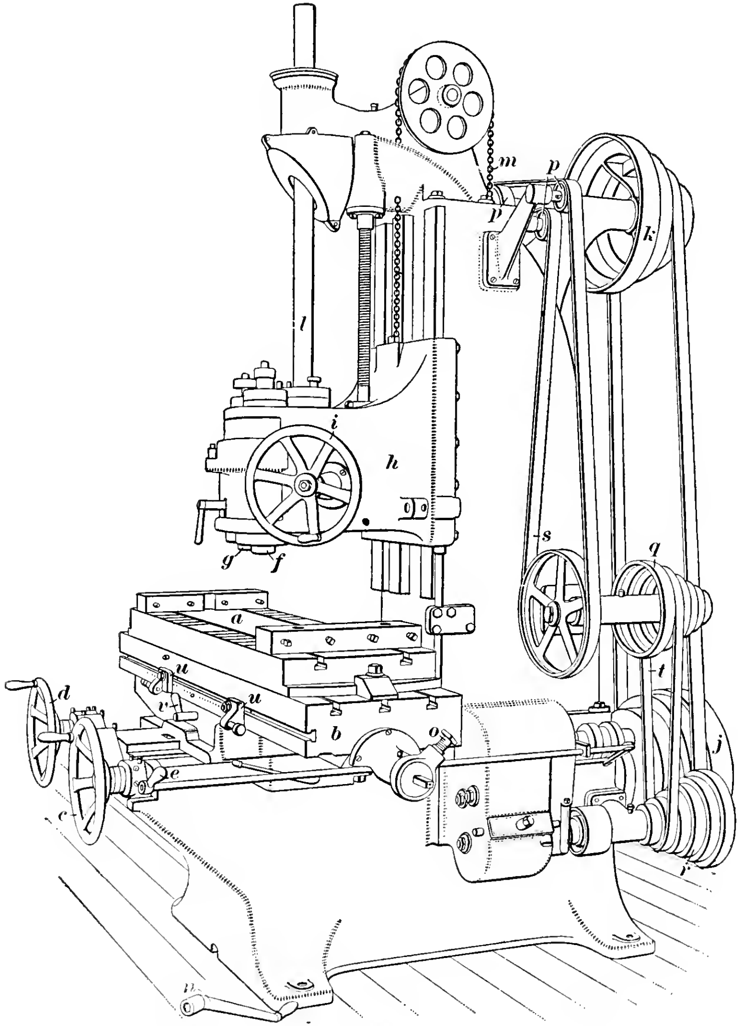


Fig. 49

provided, *f* being the larger and used for the heavy cutting. Either spindle may be used, as desired. A quick hand return for the table is obtained by using the crank *n*, which fits the square on the end of the screw, and adjusting the lock bolt *o*. The feed is driven through the pulleys *p*, *q*, and *r* and the belts *s* and *t*. The pulley *j* is the main driving pulley, and is driven, in turn, by a countershaft connection or an electric motor, as found most convenient. The table stops *u* may be set as desired. As they pass the lever *v*, they automatically throw off the feed. The cutters used on the machine may have either tapered or straight shanks. Those having tapered shanks may fit directly in the spindles, or they may fit a socket that fits the spindle holes; and those having straight shanks are used in a chuck made for the purpose as, for example, the one shown

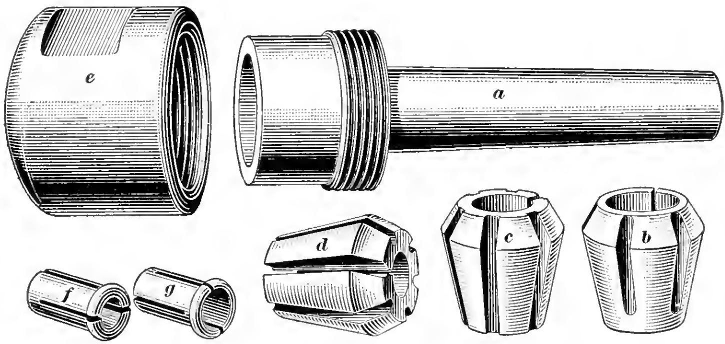


FIG. 50

in Fig. 50. The shank *a* of this chuck fits the spindle of the machine; the split bushings, *b*, *c*, and *d*, fit in the nut *e*, and the nut is then screwed onto the shank, clamping the bushings on the cutters. Bushings, *f* and *g*, of smaller size, may be made to fit into the larger bushings, in order to accomodate smaller tools.

33. Instead of the vise *a*, Fig. 49, a form of rotary vise, as the one shown in Fig. 51, may often be used to advantage on a die-sinking machine. By its use, short arcs may be cut much quicker than in any other way. To use this attachment, the table *a* of the machine and the vise *b* are set, by lining up the indicating marks placed upon them for the purpose, so that the center about which the vise rotates when in use will be directly in line with the spindle of the machine. The indicating marks are not shown in the illustration. When the marks are once established, the machine may be readily set up for circular milling at any future time. After setting up the vise and table, a pointed center is placed in the chuck and the chuck is put in the spindle. The die block is next located and clamped in the vise so that the center point of the arc to be milled is directly under the pointed center in the chuck. The table may then be moved off center far enough so that the cutter will mill the impression desired when the vise is rotated by means of the hand wheel shown at *c*. The pointed center is now removed from the chuck, a cutter of the desired form is put in it, and the impression is milled to the desired depth.

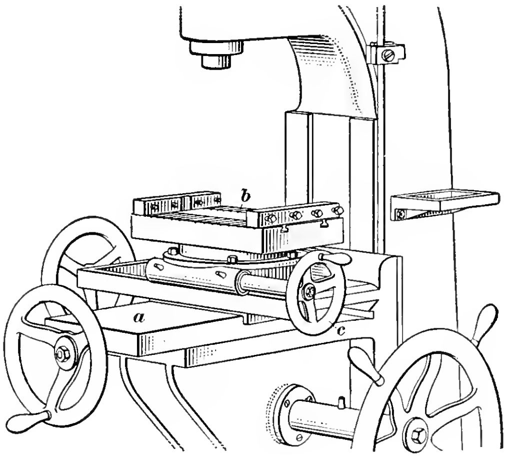


Fig. 51

34. Die-Sinking Tools and Cherries.—In Fig. 52 are shown a few of the large variety of cutters and long slender milling tools, called cherries, used in die making. Those shown at *a*, *b*, *c*, and *d* are made with tapered shanks to fit the tapered holes in the spindles of the machines, while the rest of the cutters shown are made with straight shanks and are held in a chuck similar to the one shown in Fig. 50. The tool shown at *e*, Fig. 52, is an ordinary pointed center that is made

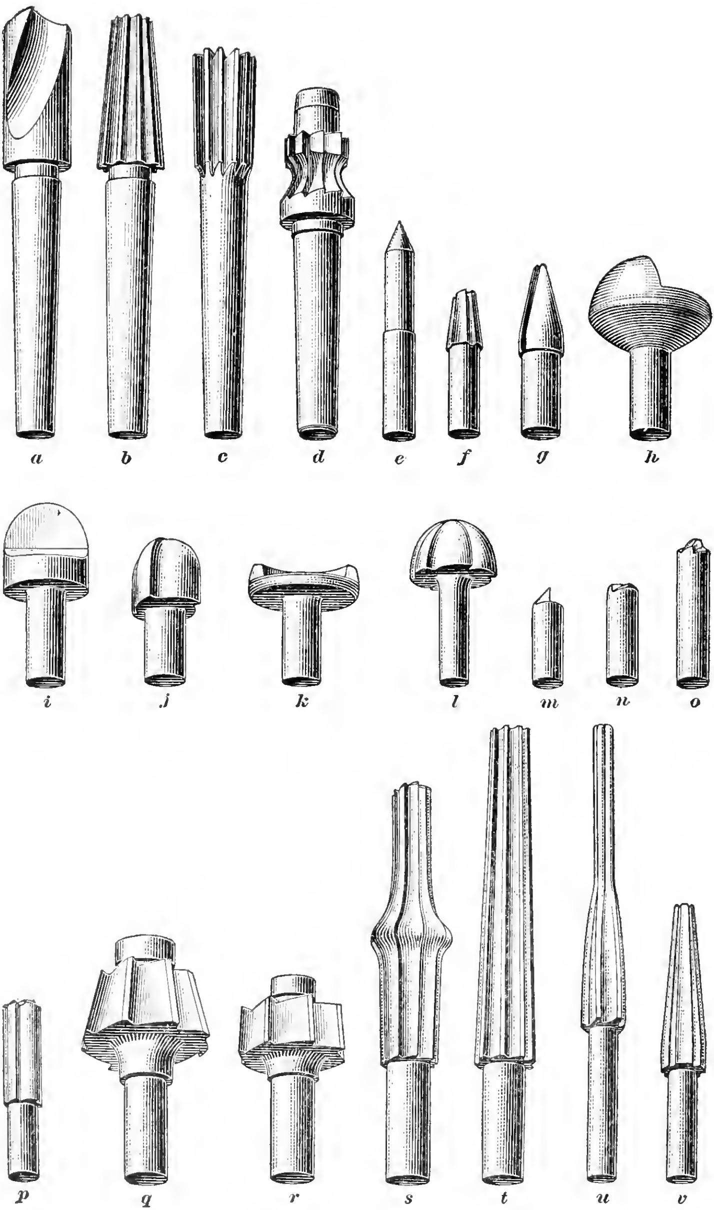


FIG. 52

to fit a chuck. It is used when it is desired to line up the spindle of the die-sinking machine with a point on the die block, as, for example, when setting up work in the circular vise. The tool shown at *a* is a roughing cutter, and, as its name implies, is used only to quickly remove large amounts of metal without regard to a fine finish. A 5° cutter is shown at *b*, a 7° cutter at *f*, a 10° cutter at *g*, and a trimming cutter at *c*. The 5°, 7°, and 10° cutters are used to finish the sides of the impressions, and when so used, a taper, or draft, of 5°, 7°, or 10° is provided, so that the forging can be easily removed from the dies. A large variety of special forming cutters are used in die sinking, a few of these being shown at *d*, *h*, *i*, *j*, *k*, and *l*. At *m*, a 45° cutter is shown, while the ones shown at *n* and *o* are special cutters. At *p*, *q*, *r*, *s*, *t*, *u*, and *v*, a few of the large number of different shapes of cherries are shown, these being of the average type. Cherries are made of almost any form to suit the impression to be made in the die block.

35. Cherrying Attachment.—A **cherry** is a milling cutter usually made together with its arbor as one piece, the length of the arbor varying with the requirements of the work to be done. Cherries are used, as a rule, on some form of universal milling machine or, in an attachment for the purpose, on a die-sinking machine. When one-half of an impression is cylindrical, cherries are used to mill out the stock, the shank of the cherry being made the same diameter as that of the sprue. The cherry is then sunk into the work until the shank comes in contact with the sprue. This operation is known as **cherrying.** In Fig. 53, a cherrying attachment *a* for the die-sinking machine is shown attached to the large spindle *b* of the die-sinking machine. It is clamped to the under side of the head *c*, and may be swiveled and securely clamped in different positions. The tapered hole *d* is the same as that of the spindle of the machine and, consequently, the same arbors that fit in the one may be used in the other. The purpose of the attachment is to bring the axis of the cutting tool horizontal instead of vertical, as this is the most convenient arrangement for cherrying.

36. Ball Vise, Hammer, and Templet Holder.—The recesses in the die blocks are usually finished by hand work, such as chipping, scraping, riffling, typing, and polishing. To facilitate this work, the die blocks are usually held in a ball vise, one form of which is shown in Fig. 54 (*a*). The die block is clamped in the space *a* by the setscrew *b*, and the part *c* of the vise rests on a pad of leather *d* which may be made by coiling up a short length of 2-inch belt and riveting it together at

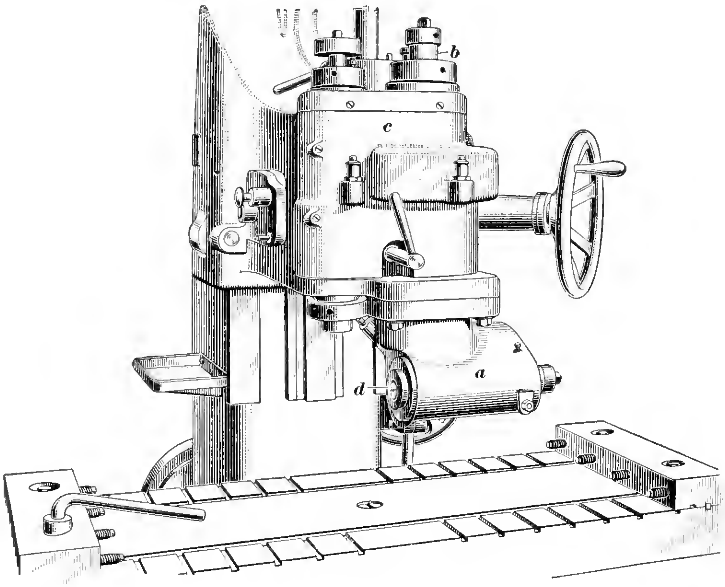
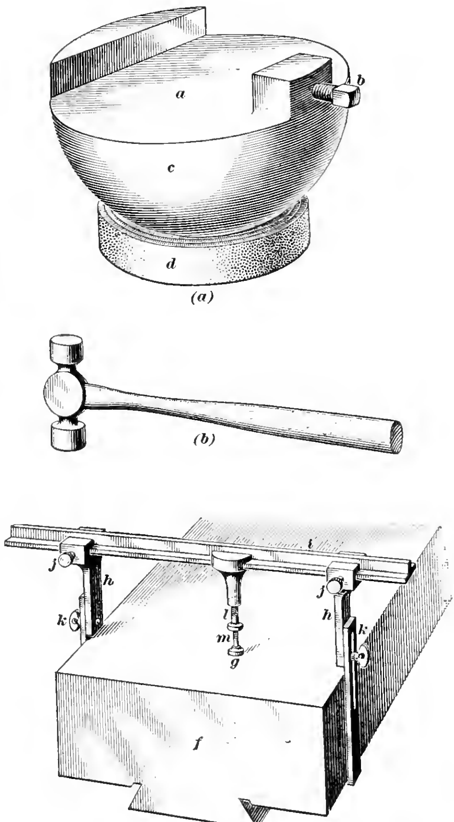


FIG. 53

intervals. By the use of this vise the work may be held at any desired angle, the weight of the work being sufficient to resist ordinary chipping.

The die maker generally uses a special hammer, shown in Fig. 54 (*b*), for chipping. It is made with two flat faces.

As the outline of the recess to be sunk in a die block is usually laid out on its face by the use of a templet, it is often found convenient to use a holder of some form to hold the templet firmly while scribing its outline on the block. One form of templet holder is shown in Fig. 54 (*c*), in which *f* is the die block on which the templet is clamped at *g*. To use this holder, the legs *h* are first adjusted on the bar *i* to suit the work and then clamped in place by the thumbscrews *j*. The templet is then located on the block, and the holder is set in place, after which the thumbscrews *k* are tightened, and the templet is then forced firmly against the face of the block by adjusting the screws *l* and *m*. The screw *m* turns inside of *l*, this arrangement being used so that the screw *m* may be easily forced downwards without turning it.



(*a*)
(*b*)
(*c*)
FIG. 54

37. Chisels and Scrapers.—Die maker's chisels are generally forged from hexagon or octagon tool steel to the shapes best suited to the work. Some of the common shapes are shown in Fig. 55 (*a*). The curved and flat shapes are used mostly, although a large variety of irregular shapes are also necessary. The flat chisels vary in width from $\frac{1}{32}$ to $\frac{1}{2}$ inch, and the curved chisels are made with many different curves.

After most of the steel has been removed by milling and chipping, scrapers are used. The scrapers may be of the ordinary three-cornered and half-round forms used by machinists

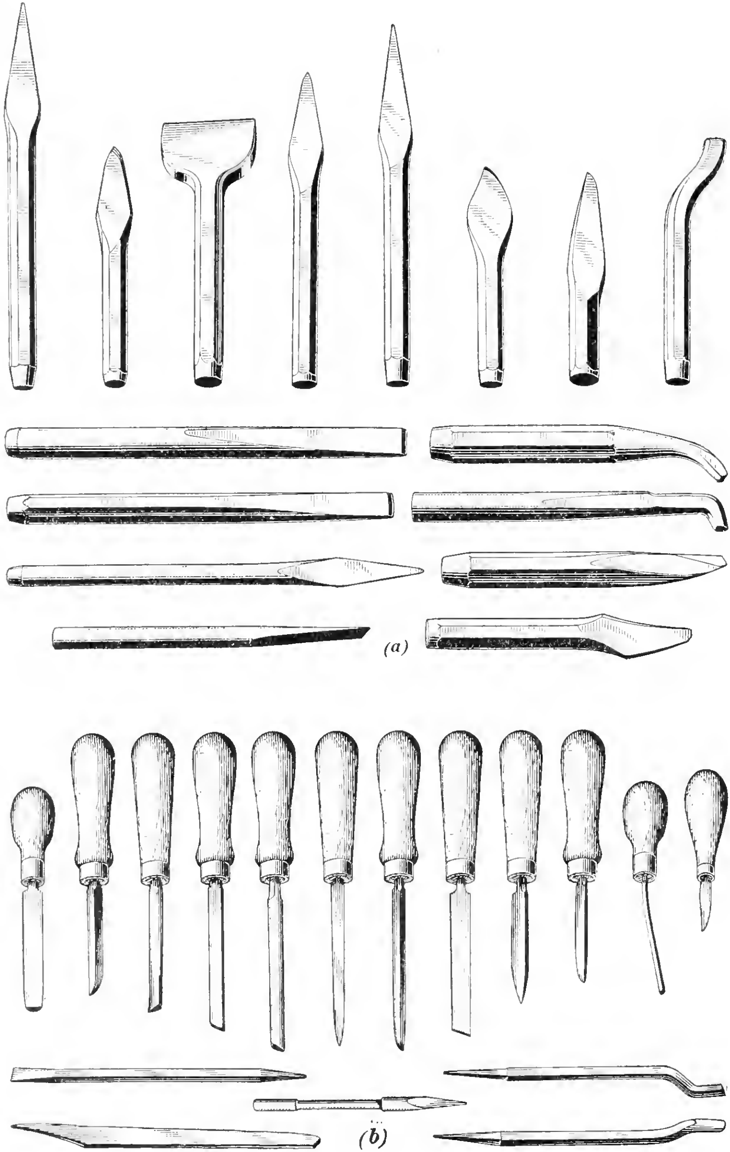


FIG. 55

and toolmakers generally, but, ordinarily, they are made of square and half-round stock in a variety of shapes, as shown in Fig. 55 (*b*). They are short, they cut on the ends only, and are made to fit in short round handles.

38. Rifflers.—After the scraping is finished, rifflers, or small bent files, are used to smooth the surface. In Fig. 56

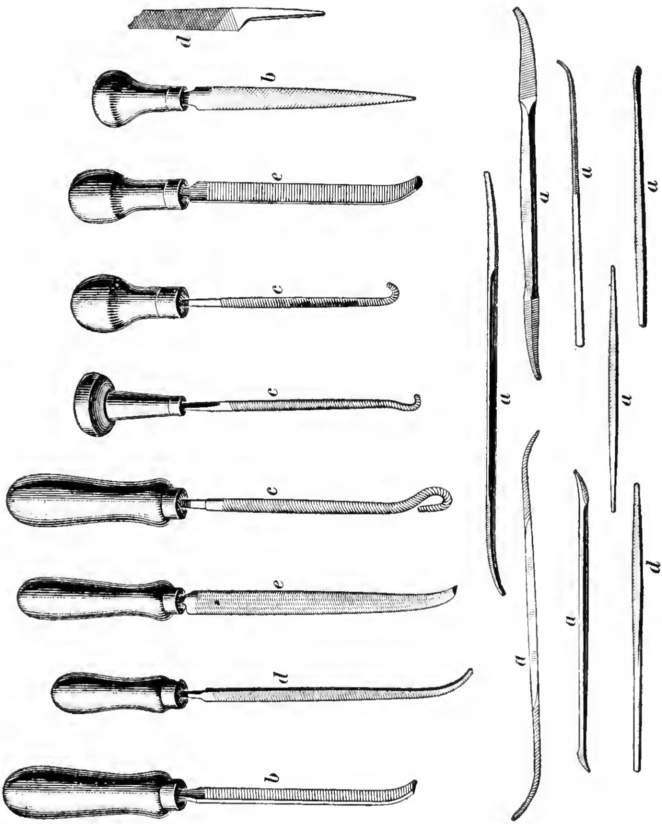


Fig. 56

a number of rifflers are shown. They are made in a large variety of shapes, sizes, and cuts. The operation of removing metal by the use of rifflers is known as **riffling.** The riffler is held lightly in the hand and is worked back and forth over the surface to be smoothed. Spoon rifflers, shown at *a*, are spoon shaped and are made with many different curves. They are the most commonly used of all rifflers, as by turning them while riffling, different curved surfaces may be formed and most spots in the recess can be reached. Flat rifflers *b* are also largely used. They are made in many different shapes and widths. At *c* and *d* hook rifflers and knife rifflers, and at *e* half-round rifflers, are shown.

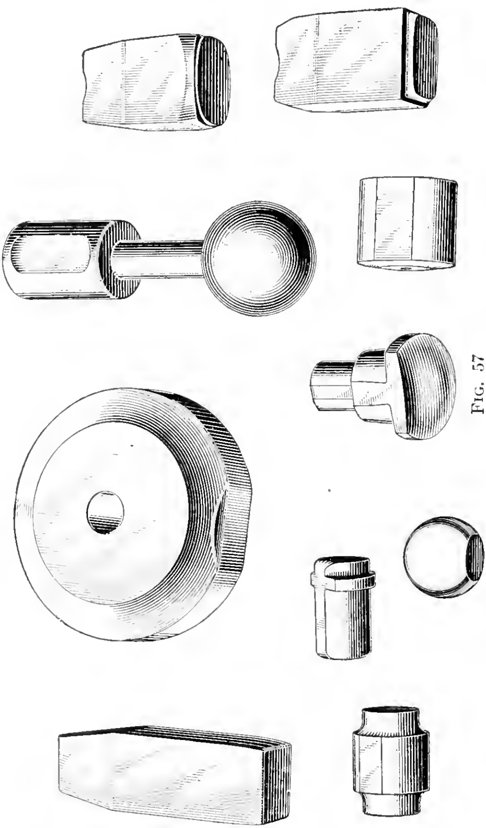


Fig. 57

39. Types. When the die recesses are deep and narrow, it is often difficult or impossible to chip, scrape, and riffle them to a finish. When this is the case, small blocks of steel, known as **types,** whose ends are shaped exactly like that part of the forging to be formed, are used. These types are turned, milled, and filed to shape and are then hardened and drawn to a purple color. A few forms of types are shown in Fig. 57. The operation of shaping a recess by the use of types is known as **typing.** Where types are to be used, the recess is first milled and chipped as near to the outline and depth as is safe, the type is then rubbed lightly with Prussian blue, or some other marking material, then placed in the recess with a piece of copper or some other soft metal on top of it, and struck hard into the recess with a hammer. The marking material adheres to the high places in the recess. These high places are next chipped away and the operation of typing is repeated until the correct shape is obtained, after which the impression is finished by riffling.

DIE-MAKING OPERATIONS

40. Choice of Style of Die.—As a rule, the die maker is furnished with a drawing, a model of the finished part, or a sample of the forgings that the dies are to make. Then the die maker must know of what material the forging is to be made and the finishing operations through which the forging is to pass, in order that the correct allowances for shrinkage and finishing may be made. The form of the dies is then determined. First, the die maker must decide whether both a roughing and a finishing impression will be required and, if so, whether the finishing impression should be made in a separate set of die blocks. Other points then to be determined are whether a fuller should be used, the direction the impression should face in order that the best form of breakdown may be used, and the hammer in which the dies are to be used, in order that the dies may be made to fit that hammer. The die maker must also decide whether the forging is to be trimmed hot or cold. The determination of these points is largely a matter of judgment on his part. This judgment is based on his previous experience with dies made somewhat similar to the ones to be made, on the experience of others, and on his own original ideas.

41. Planing of Die Blocks.—The stock from which dies are made is generally obtained from the rolling mills in bars of the cross-sections desired, the bars usually being from 6 to 8 feet long. These bars are preferably prepared by planing first the top surface and then down the left-hand side, about 2 inches, after which the bar is turned over and the bottom is planed up forming a shank, or dovetail, of the proper bevel and height to fit the machines in which the dies are to be used.

From the bars thus prepared, blocks are then cut of any length needed, after which the front side is planed to a depth of about 2 inches, care being taken to have this surface square with the shank and the surface previously planed on the left-hand side of the block. Instead of planing the entire length of the bar at one setting, the bar may first be cut into the desired lengths and each block planed separately. The first method is, however, to be preferred, as in this way the blocks can be prepared much more cheaply. The object of planing the surfaces on the front and left side of the die block is twofold; first, to provide working surfaces from which to lay out the die recesses, and, second, to provide means to line up the dies in the hammer. It should be noticed that the left-hand, and not the right-hand, side of the die is planed. This is owing to the fact that the breakdown is always located on the right-hand side, and, consequently, this face would be destroyed when the breakdown is formed.

42. Allowances for Shrinkage.—As all metals expand when heated and contract when cooled, the recesses in the die block must be made larger than the size of the forging when cooled, to allow for this contraction or shrinkage. Shrinkage is most conveniently allowed for by the use of a shrink rule. When the forgings are to be cold trimmed, a shrinkage allowance of $\frac{3}{16}$ inch to the foot is made, and when they are to be hot trimmed, an allowance of $\frac{1}{8}$ inch to the foot is made. These allowances are the same, whether the forgings are to be made of wrought iron, steel, copper, or bronze. The difference in the allowances for hot and cold trimming is due to the fact that, when hot trimmed, the forgings are generally struck a finishing blow in the die after trimming, in order to straighten them. As the forgings are relatively cold at this time, the amount they will shrink will be less.

43. Allowances for Draft and Finish.—In case the sides of the die recesses were made vertical, the forging would stick in the die when struck. To prevent this, the sides of the recesses are made to slant away from the vertical a little and the allowance thus made is known as **draft.** The amount of draft varies from 3° to 10°. For a thin forging 3° is plenty, for a deep die recess 7° is generally used, and for the central plug in a recess a draft of 10° is used, as in this case the metal will contract and grip the plug when cooling, and cause the forging to stick if the draft is insufficient. When the surfaces are curved or are at an angle with the vertical, no allowance is made for draft. A draft of 3° corresponds to a taper of $\frac{1}{16}$ inch to the inch; a draft of 5°, to a taper of $\frac{3}{32}$ inch to the inch; a draft of 7°, to a taper of $\frac{1}{8}$ inch to the inch; and a draft of 10°, to a taper of $\frac{3}{16}$ inch to the inch. The draft in the recess is usually cut on the die-sinking machine, using a 3°, 5°, 7°, or 10° cutter.

In case some parts of the forging are to be machined after forging, additional metal must be provided at those parts. This allowance is known as the **finish allowance.** It is usually about $\frac{1}{32}$ inch.

44. Laying Out of Dies.—In Fig. 58 (*a*) is shown the block for an upper die and in (*b*) that for a lower die. To lay out the dies, the faces *a* and *b* are first covered with copper sulphate, or blue vitrol, after which the center lines are scribed on both, being located from the working faces *c* and *d* in one case and *e* and *f* in the other. The outline of the recesses should be so located that the heaviest end of the forging will be at the front of the dies, as the forging will then be easier to handle while being worked and a good sized sprue may then be used. In case the outline of the forging is simple and regular at the joint line, the outline of the recesses may be laid out by the use of a square and dividers; but a thin sheet-metal templet of the forging is generally made for this purpose when the outline of the forging is irregular. The same templet will do to lay out both the lower and upper dies, and the trimming die and punch. Two or three combination squares may be used to locate the templet on the blocks in order that the outlines of the recesses on both blocks will line perfectly. The templet *g* is first placed in its proper position on one of the blocks, and is held there by a templet holder while the outline is scribed on the block. Combination squares *h* and *i* are then set from each of the working faces of the block to the edge of the templet, after which the templet holder is removed. The templet is then placed, reversed, on the other block and located properly by the use of the settings obtained on the combination squares, after which it is clamped in place by the templet holder. The squares are then removed, and the outline is scribed on the die block.

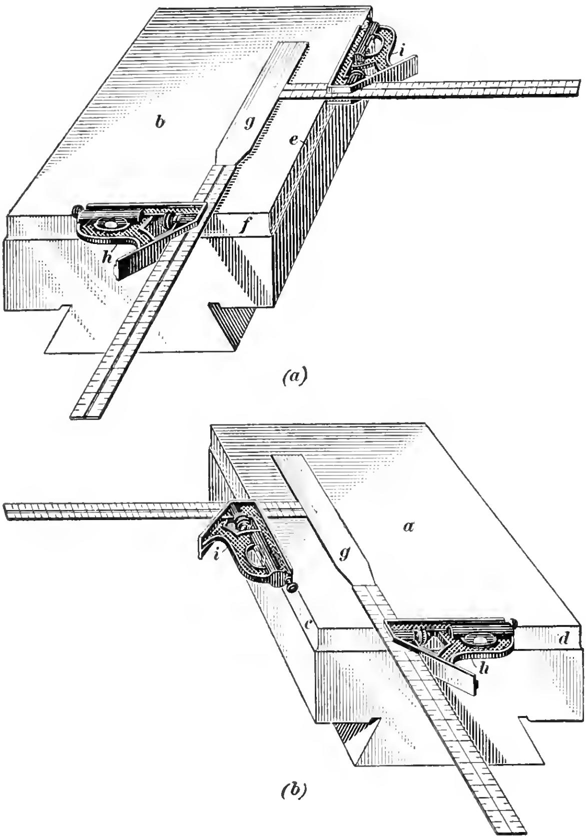


Fig. 58

The outlines on both blocks are then marked at intervals by prick-punch marks so that they will not be destroyed. The layout is completed by scribing lines for the flash, back flash, gates, and sprues, and then prick-punching them as before.

45. Machining of Die Recesses.—The recesses in the die blocks are shaped mainly by means of the die-sinking machine, although other machines are frequently used. Parts of the recesses may be formed by turning on a lathe. The milling machine, drilling machine, planer, and shaper are also quite often used.

46. The outlines scribed on the face of the block are used as guides when cutting the recesses. After the outside of the block has been finished and the parts that can be done on the lathe have been turned, the die is set up on the die-sinking machine, and the recesses are roughly cut to the lines laid out on the face of the block. After the impressions are roughed out nearly to size on the machines, they are finished by hand work. An example of a die block set up on a die-sinking machine for the milling of a gate is illustrated in Fig. 59. The die block is shown at *a*, and at *b* is shown a cutter of the form illustrated at *l*, Fig. 52, which is used for this operation. As a rule, when milling the recesses, oil is needed only when special forming cutters are used, and in that case lard oil is advisable. At *c*, Fig. 59, is shown a brush that is kept available to brush the chips out of the recess, and at *d* a small tube is shown fitted into a wooden holder *e*. This tube is used to blow the chips out of the recesses. The electric lights shown at *f* may be brought close to the work, when necessary.

The machine here shown differs from the one shown in Fig. 49, in that the vertical movement is obtained by raising and lowering the table of the machine instead of the cutter head. In either case, the raising or lowering of the table is accomplished by means of a hand wheel having a graduated dial that shows the motion of the table or head in thousandths of an inch.

47. Other parts of the die may have to be machined by means of the cherrying attachment on the die-sinking machine, or on the milling machine. The proper cherry is placed in the spindle of the machine, and the cherrying is done at this time. When machining the recesses, care should be taken to leave as little stock as possible to be removed by hand, as the hand work is much slower. For the last cut, the cutter should be brought as close as possible to the finished form of the die. When the cutter is finally set for the last time, it should be run over the work two or three times in order to get the smoothest surface possible. The final cut should just split the lines scribed on the face of the die.

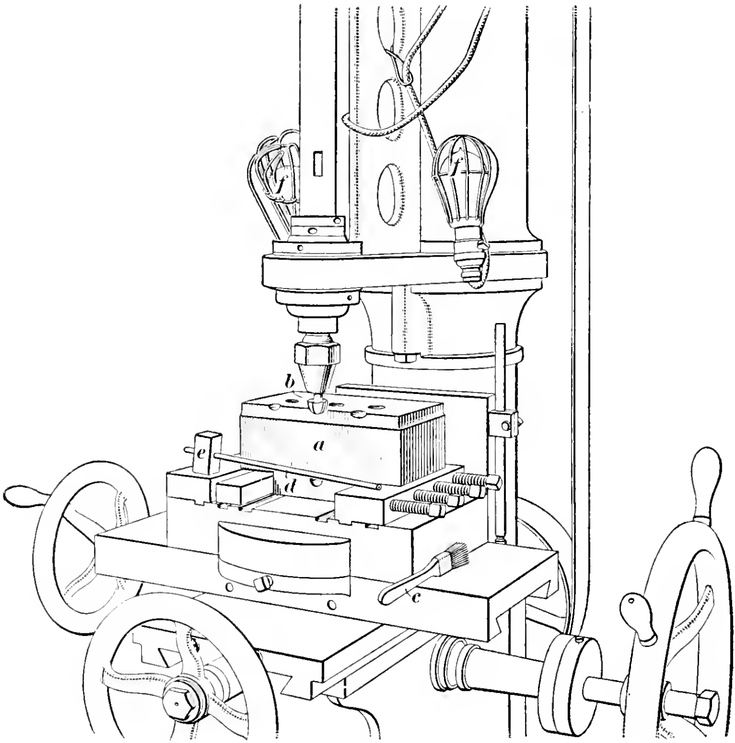


Fig. 59

48. Hand Finishing of Die Recesses.—After all the machine work is done, the corners and irregular parts of the recesses will still be unfinished. These are then chipped, scraped, riffled, typed, and polished, the die being held in the ball vise while doing the hand work. When chipping, it is advisable to chip down or away from the outline of the recess to avoid breaking out parts at the end of the cuts. Oil should be used sparingly and light cuts should be taken. Care should be taken to try the templets and depth gauges often in order not to take out too much stock.

By the use of the scraper, the high points left by the chipping operation are reduced and the surface of the recess is made smooth. The die is finished to its correct dimensions with the scrapers, after which the surface is smoothed further by the use of rifflers. The rifflers and scrapers must be worked over the surface in different directions to prevent the formation of grooves and ridges. In Fig. 60 is shown the operation of scraping out a recess in the die block *a*, which is held in the ball

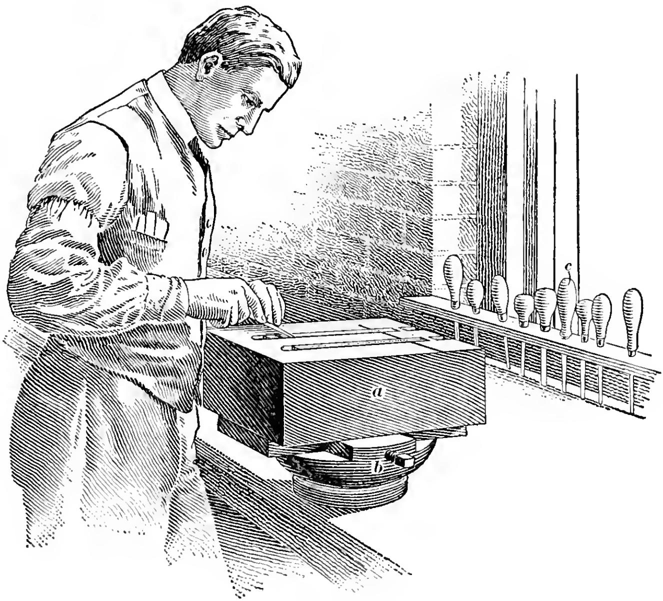


Fig. 60

vise *b*. The scrapers are shown at *c*. They are held in a rack located conveniently so that any of them may be had at once when needed.

A very smooth surface is required in the recesses of the die so that the forging will have smooth surfaces and come from the die easily. Every part must be carefully finished. This is done by use of coarse emery cloth first, and then fine, wrapped around a file or a piece of wood. To polish the corners that cannot be reached by the emery cloth, emery and oil are used on the end of a small piece of wood, the emery embedding itself in the wood.

49. Lettering of Die Recesses.—When lettering is required on the forging, the dies are stamped in the bottom of the recess with a deep flat-faced letter that will give body to the letters on the forging. If the letters are very large, the recesses are chipped or milled out after lightly stamping the letters in the die to locate them. They are then readily stamped in the die to their full depth without removing much of the steel. To locate the letters in the recess, the central letter, or figure, is first stamped, and from this central letter the other parts of the word, or figures, are added.

50. Lead Proofs of Die Recesses.—After the dies are completed, a lead proof is usually made in order to check up the dimensions and to see if there are any defective places in the dies. To make the lead proof, the dies are cleaned, dusted with powdered chalk, set on their ends with the die faces together and with the working faces in line, and then securely clamped with a large **C** clamp. The lead is then melted and poured slowly and evenly into the dies. After the lead has cooled, the dies are unclamped and the lead is removed and examined. If the lead shows any changes in the recesses to be necessary they are then made, and another proof is made to be sure that the dies are correct. As the shrinkage of lead is about the same as that of steel, the finished forging will measure nearly the same as the lead proof. In the case of forgings made with holes in them, as, for example, any form of ring, the shrinkage allowance will have to be made when checking up the proof, owing to the fact that the hole in the forging is formed by a plug in the die recess, and this plug prevents the lead from shrinking when cooling. In the case of the forging, however, the shrinkage will take place, since it is not in the die while cooling. The finished forging will weigh about two-thirds as much as the lead proof; thus the weight of metal needed for the forging is readily determined.

51. Die Breakdowns.—The breakdown is not made in the dies until the face recesses, the flashes, gates, and sprues are finished. Then the dies are clamped together just as they were to make the lead proof, and the rough surfaces of the right-hand sides of the die blocks are chalked. The half of a lead proof or a templet of the forging is now laid on the side of the dies and the outline of the forging is scribed on them. If this proof or templet is symmetrical as it lies on the side of the dies, one-half of the outline should be located on each die; in other respects, the position of the proof or templet is determined by the experience of the die maker. The outline of the templet is then scribed on the dies. Another line $\frac{1}{16}$ inch inside of this line is scribed in all places. This is the working line of the breakdown. The dimensions of the breakdown are made smaller than those of the forging so that the broken-down stock will readily lie in the forming impressions. All the corners of the breakdown should be well rounded to avoid cold shuts when forging, and all the vertical parts are given a draft of 7°. The breakdown is made enough wider than the forging so that there will be plenty of room for the work; and it is made with a gate and sprue. A cut-off is formed at its rear end to trim off the extra stock drawn out under the fuller. After the correct outline is determined, it is prick-punched to make it permanent, and the die is then set up on the die-sinking machine, being set on its side in the vise. Then, using a long straight cutter, the breakdown recess is milled to the outline.

52. Hardening and Tempering of Dies.—After the breakdown is finished, the dies are ready to be hardened and tempered. If the dies are made of steel containing less than .60 carbon, it will be necessary to first carbonize their surfaces by packing them in a box of granulated raw bone, or other carbonizing material, and heating as explained in *Hardening and Tempering*. Dies made of steel containing more than .60 carbon need not be carbonized before hardening, and dies made of steel containing over .80 carbon are generally not hardened. To harden the dies, about 2 inches of burnt granulated raw bone may be placed in cast-iron boxes having walls about $\frac{1}{2}$-inch thick, cast iron being used because it stands the heat well. The dies are then placed face down on the bone and settled down so that the bone fills the recesses. Burnt bone is used to prevent decarbonization of the steel and the formation of scale. The box containing the dies is then placed in a furnace and maintained at a temperature of from 1,425° F. to 1,450° F. for from 6 to 8 hours, according to the size of the blocks.

53. When properly heated, the dies are quenched in a tank in which the water supply discharges upwards, as shown in *Hardening and Tempering*, and having two bars suspended across its top to support the die. The water is turned on full force, as soon as the die is properly placed, and strikes against the die faces, thus preventing the formation of steam pockets. Where the dies are cold enough so that water will cling to their top corners, they are placed in an oil quenching tank till cold. The temper is drawn in oil, brought to a temperature of about 450° F. and kept at that temperature till the heat penetrates the dies. After the dies are removed from the oil, the corners of the recesses and the cut-off are drawn to about a purple color, using a blow torch. When cold, the recesses are polished, using emery and oil on the end of a stick, and the dies are then ready for use.

54. Trimming Dies.—The work of cold-trimming dies is a great deal harder than that of hot-trimming dies and they are usually made of high-carbon steel and hardened. Both the die and punch are made in the same manner as the ordinary blanking die and punch. A special grade of steel known as *hot-trimming die stock* is used for dies intended to trim the forgings while still hot. Ordinary tool steel is not suitable for this purpose because the edges of a hardened die crack badly after being in use a short time. The special grade of steel for hot-trimming dies does not require hardening and the dies made of it become tougher in use, and give very good service. The hot-trimming dies are made in the same manner as are the cold-trimming dies, the main difference in them being that the hot-trimming dies are left open at the front to clear the sprue that connects the forging to the bar. Either type of die may be made solid or in sections, as found most convenient.

FORGING DIES

Serial 1682 — Edition 1

EXAMINATION QUESTIONS

(1) What is a drop forging?

(2) What is the joint line of a pair of dies?

(3) In what two ways may the side thrust of dies be balanced?

(4) What are the names of the four recesses that may be used in dies?

(5) What is the fin?

(6) What are the usual dimensions of the flash?

(7) What is the sprue?

(8) What is the gate?

(9) How is the fin removed?

(10) What is the purpose of the back flash?

(11) What is meant by a two-operation job?

(12) What is the reason for making a long forging, such as a spanner wrench, in two operations?

(13) What are heading machines principally used for?

(14) When bending elastic materials cold in a bulldozer, what special allowance must be made in the dies?

(15) What are wing dies?

(16) What materials are used for making dies?

(17) What is meant by dishing?

(18) Why are two spindles used on a die-sinking machine?

(19) What is the object of planing the die block on the front and side?

(20) How are lead proofs made?

Mail your work on this lesson as soon as you have finished it and looked it over carefully. DO NOT HOLD IT until another lesson is ready.

SPECIAL FORGING OPERATIONS

Serial 1691 Edition 1

SPECIAL FORGING EQUIPMENT

HEATING FURNACES

1. As heating is necessary in all forging work, suitable furnaces must be provided in connection with forging operations. The form of the furnace varies with the nature, size, and quantity of work to be heated, and with the nature of the fuel used; in many cases, one form can be used for several classes of work, but in other cases each class of work requires its own special form of furnace. Gas-fired or oil-fired furnaces are now preferred to those fired with coal or coke, because they can easily be controlled so as to maintain a more uniform heat. In all heating furnaces, the air supply should be so regulated as to produce incomplete combustion in the part of the furnace where the heating is done; in other words, there must be no excess of air, as such excess will oxidize the metal. In the case of heating furnaces using solid fuel, it is necessary to provide for the admission of air beyond the heating chamber, so as to burn the gases completely, if it is desired to prevent the escape of smoke from the chimney.

2. Small Coke Furnace.—For heating the ends of bars to be worked under drop hammers or in forging machines, a small coke furnace, like that shown in Fig. 1, is frequently used. This furnace is enclosed in cast-iron plates, the front and back plates *a* and *b* being bolted to flanges on the side plates *c* and *d*. The grate bars *e* are supported on bearing bars placed in the furnace lining, which is made of firebrick. The

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ashes are removed from the ash-pit through the door *f*. The blast pipe is generally inserted into the ash-pit through an opening in the plate *b*, and a pressure of from 4 to 12 ounces is maintained in the pit. A bed of coke is kept on the grate bars and the material to be heated is placed on the coke. The opening *g* through which the work is placed in the furnace is usually closed, or partly closed, by a firebrick-lined door, sliding between the vertical guides shown at the right and left of the door. The gases escape through a flue connected with an opening in the plate *b*. While the work is being heated, the

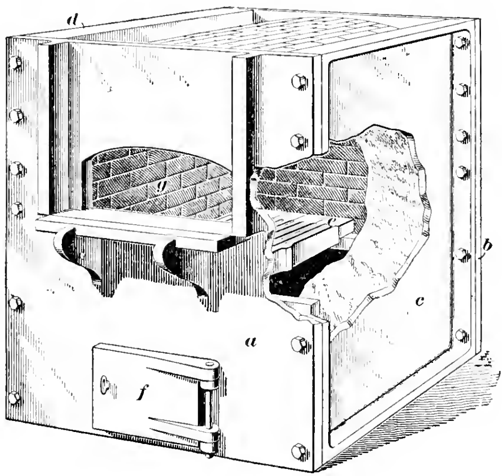


Fig. 1

door is kept closed as much as possible, to prevent any inrush of cold air over the top of the fire. The door is also usually provided with a counterbalance so that it can be raised or lowered with ease.

3. Reverberatory Furnace.—For heating large work, a reverberatory furnace is usually employed. The work is placed on the hearth and heated by the hot gases passing over it, and the heat reflected from the roof, which is a firebrick arch. In some cases, the roof is arched in such a way as to focus the heat on some part of the hearth. In a reverberatory furnace, it is necessary to construct the lining of the furnace of firebrick laid in fireclay. A furnace of this type may use coal, oil, or gas, and for some classes of work wood; but good bituminous coal is the fuel most commonly employed. The fuel is usually burned with forced draft, the bed being kept deep enough to insure a slightly smoky flame, which indicates incomplete combustion. This makes it certain that oxidation will not take place from air passing through the grate.

4. A longitudinal section of a furnace used in heating work for a steam hammer is shown in Fig. 2. The coal is thrown on the grate *g* through the fire-door opening *h*, which is so placed

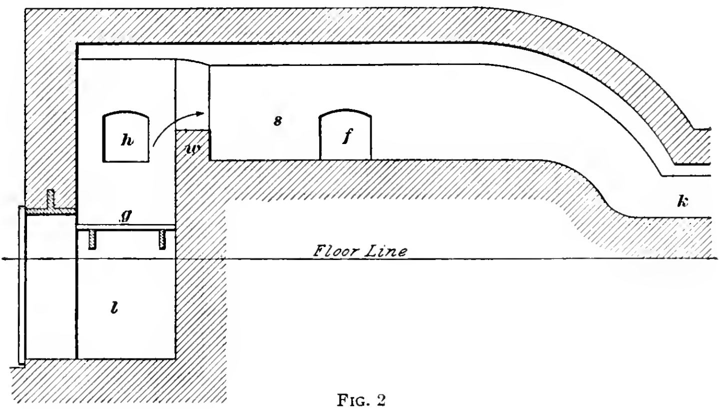


FIG. 2

that a suitable depth of fire can be maintained between the grate bars and the bottom of the door. The hot gases pass over the bridge wall *w*, and burn in the chamber *s*, the waste gases escaping through the flue *k* into the stack. The ash-pit is shown at *l*. A plan view of the furnace is shown in Fig. 3, a side view in Fig. 4, and an end view in Fig. 5 (*a*), while (*b*) shows a section crosswise through the hearth. Corresponding parts in these different views are given the same reference letter. The furnace has three doors *c*, *d*, and *e* on one side, and the door *f* and the fire-door *h* on the other, the door *f* being opposite the door *d*. This is a great convenience in heating long pieces of work, which are allowed to extend through both openings. All the openings through which work is put into the furnace are closed by doors lined with firebrick slabs and suspended by chains from counter-

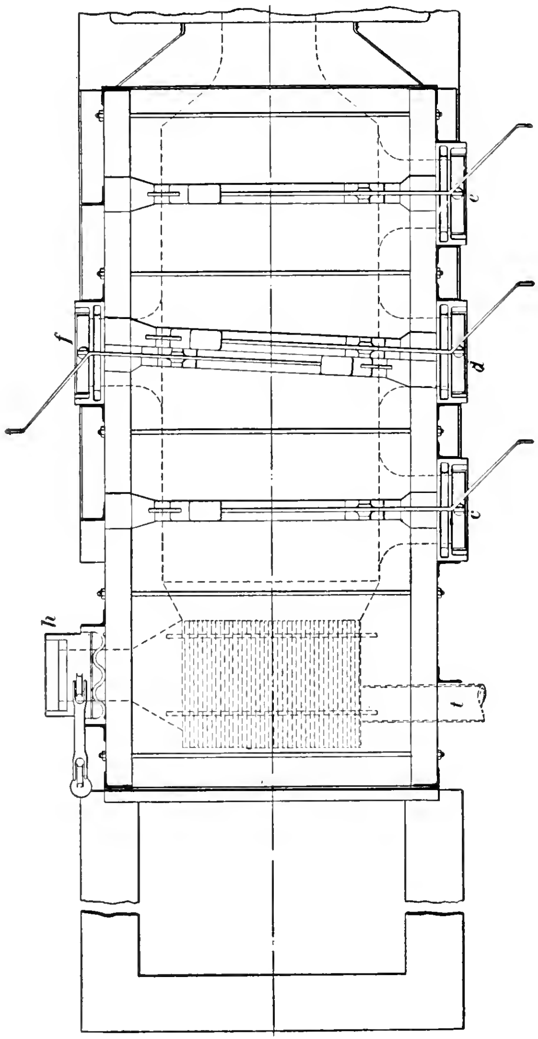


FIG. 3

balanced levers. They are raised and lowered by the handles p, and the weights n serve to hold them in any desired position.

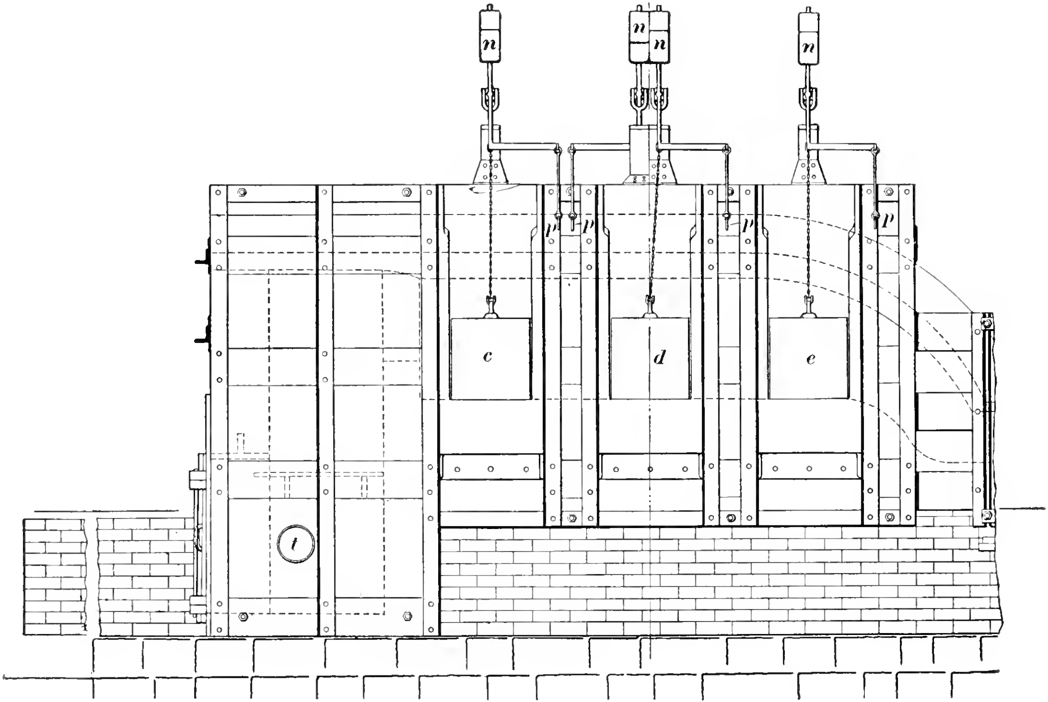


Fig. 4

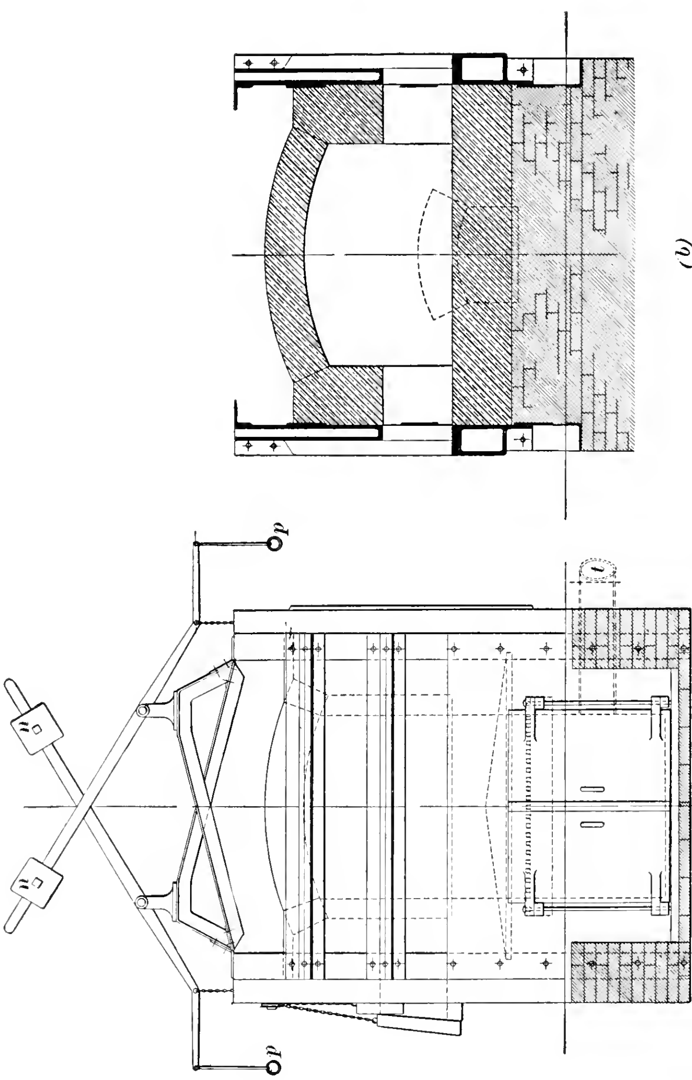


FIG. 5

5. The bed, or hearth, of the furnace is usually made of clean, sharp silica sand tightly rammed to nearly the shape of the hearth. A fire is then placed on the grate and kept burning until the sand on the surface melts and forms a smooth glassy hearth. Sometimes clay is mixed with the sand.

In heating work, sand is very frequently used as a flux to carry off any iron oxide that is formed on the surface of the metal. Iron oxide also attacks the surface of the hearth, forming a fusible slag with it. This slag flows into the slag pot

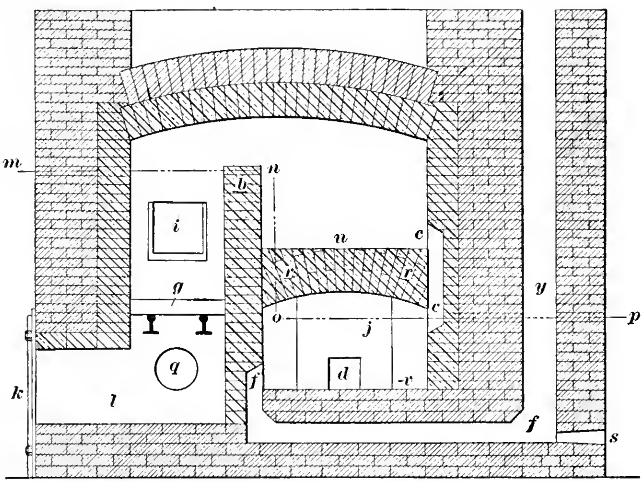


FIG. 6

through an opening at the foot of the stack, toward which the hearth slopes. A blast of from 4 to 12 ounces is supplied to the fire by the blast pipe *t*, Figs. 3, 4, and 5 (*a*), which is attached to one end of the ash-pit. Usually, the blast is obtained from the fan that furnishes blast for the forges.

In some cases, the counterweights for the doors are placed at the side of the furnace, so as to leave the top clear. A boiler may then be set above the furnace, and the heat from the waste gases utilized to furnish steam for steam hammers, for engines driving the fans, etc., the gases being led up under the boiler before they pass up the stack and are allowed to go to waste.

6. Double-Decked Reverberatory Furnace.—In some shops where a variety of work is done and yet where there is

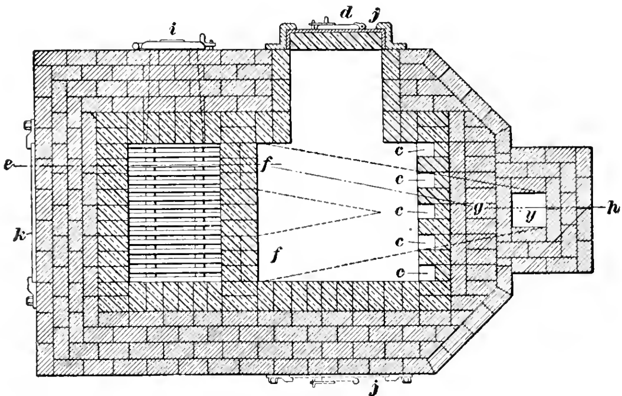


Fig. 7

not enough heavy forging to warrant the installation of a large reverberatory furnace, the double-decked reverberatory furnace shown in Figs. 6 and 7 will be of service. Fig. 6 shows a section along the line *e f g h* of Fig. 7, and Fig. 7 shows a section along the line *m n o p* of Fig. 6; the same reference letters designate the same parts in both illustrations. In this furnace, the grate *g*, ash-pit *l*, fire-door *i*, ash-pit door *k*, and blast-pipe connection *q* are arranged as in the reverberatory furnace already described. When the flame passes over the bridge wall *b*, it enters a relatively small chamber with a hearth *u*, on which is placed the work that is to be heated

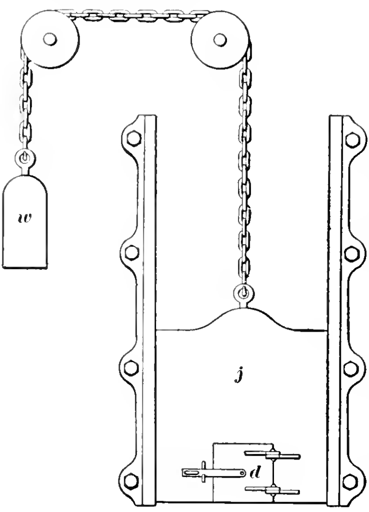


Fig. 8

to a high temperature. After it passes over the hearth *u*, the flame passes through the openings *c* to the lower hearth *v*, and thence through the openings, or flues, *f* to the chimney *y*. The lower hearth *v* is used for heating work for tempering, annealing, case-hardening, etc.

7. The door for the upper hearth, which is on one side of the furnace, is not shown in Fig. 6; and the door *j* for the lower hearth is on the other side. The slag hole *s* is at the base of the chimney. The detailed arrangement of the furnace doors *j* for closing the large openings is shown in Fig. 8. Each door contains a smaller door *d*, which may be opened to see the condition of the work, or through which small pieces may be introduced. The main doors are counterbalanced by weights *w*. The advantage of placing the fire-door at one side of the furnace is that the fire can be spread more evenly than with the door at the end of the furnace, since the coal can be raked along the length of the bridge wall so as to maintain an even fire at all points.

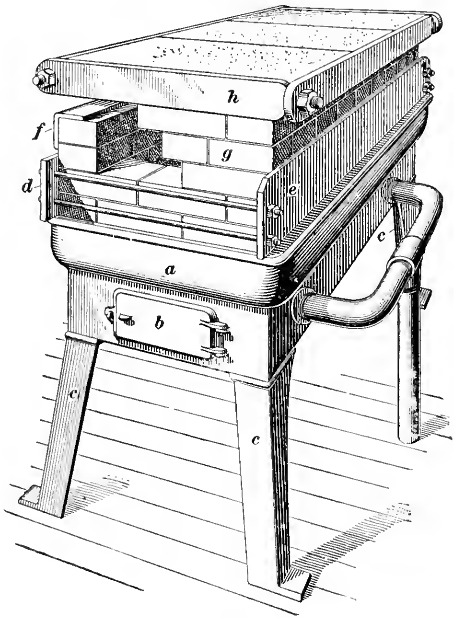


FIG 9

8. Furnace for Long Work.—In shops where long pieces, such as angles and other structural shapes, must be heated, a furnace of the form shown in Fig. 9 will be found useful. It consists of a cast-iron pot, or box *a*, which serves as an ash-pit and on the upper surface of which the grate bars are arranged. The ashes are removed through the door *b* and the blast is furnished through a pipe connected at the back of the ash-pit. Directly above the cast-iron box *a*, which is supported on cast-iron legs *c*, is a section supported by the plates *d* and *e*, which are held in place by bolts. Above the plate *d* is an angle iron *f*, which protects the front edge of the furnace. The back wall and a part of the ends of the furnace are built up with brick *g*, and the cover or roof is made of several firebrick slabs held together by iron binders *h*; a coke fire is maintained in the furnace.

9. Long work may be laid so that its ends project through the open ends of the furnace, permitting it to be heated the whole length of the fire. This furnace will be found especially useful in heating long angle irons in the center for bending. When curved or irregular pieces must be heated, the cover is frequently lifted off while the work is being placed in the furnace and then replaced during the heating. If large numbers of short pieces are to be heated on the ends only, the pieces are laid across the angle iron *f*, Fig. 9, and allowed to project into the fire. When the furnace is not in use for heating long work, the openings in the ends can be closed temporarily with firebrick. Such a furnace as this is generally used in a large open building where structural shapes are put together, and hence the escaping gases are not objectionable. If the furnace is to be used indoors in winter, an exhaust pipe to carry away the gases can be arranged at the back of the furnace.

10. Special Heating Furnace for High Temperatures.—When a large amount of work is to be heated, it is often convenient to make the process continuous by using a conveyer that will carry the work slowly through the furnace, the cold pieces being placed on the conveyer at one end of the furnace and removed at the other end properly heated for forging. Such a furnace is shown in Fig. 10. The conveyer consists of a series of small trucks *a* that carry fire-clay blocks *b* on which the work *c* is placed at one end *f* of the furnace and carried through to the other end, by which time it is thoroughly heated. The trucks then return empty along a track under the furnace, to be loaded again with work. A metal casing *e* surrounds the blocks *b* on the return, so as to prevent undue loss of heat.

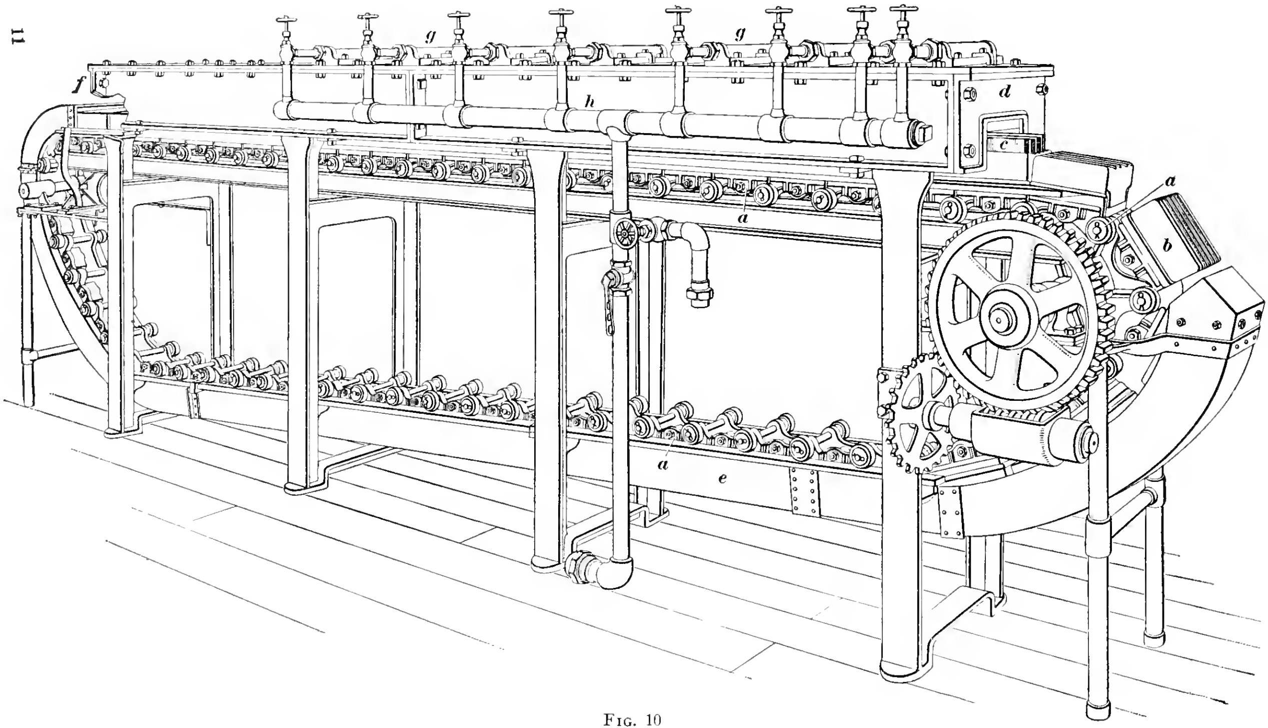


FIG. 10

11. The furnace *d*, Fig. 10, is a rectangular iron box lined with firebrick, and is heated by gas burners *g*, placed on the top of the furnace and supplied by a pipe *h* extending along the side. The trucks do not enter the furnace, because the temperatures are too great to be withstood by cast iron, but the fireclay blocks project into the flame.

The burners can be controlled separately, so that any desired temperature may be obtained. They are placed so as to direct the flame toward the end *f*, so that as the work enters the furnace it is first heated by the blocks on which it rests, then by the hot gases, and finally by the flame under which it passes.

MISCELLANEOUS OPERATIONS AND DATA

FORGING STRUCTURAL SHAPES

12. Bending Angles.—With the more general use of structural shapes and plates, such as angle iron, **I** beams, deck beams, etc., it has become necessary to bend them into various shapes or forms. Where a considerable amount of this class of

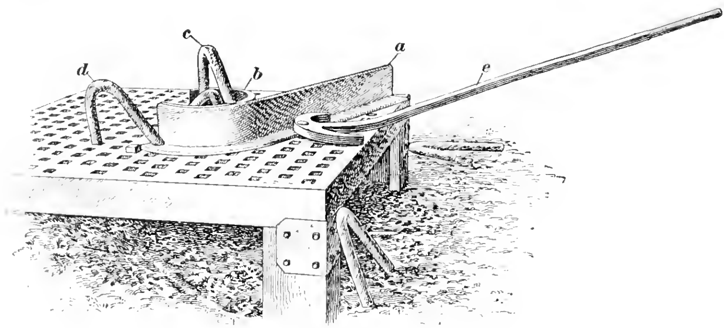
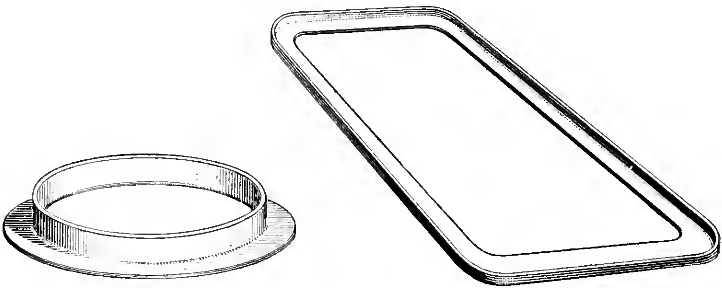


FIG. 11

work is to be done, **bending plates,** Fig. 11, are used; these are large surface plates with holes in their surfaces, in which are fixed the dogs and clamps for holding the work. For bending the angle *a* to the desired curve, the form *b* is first clamped to the bending plate by means of a **dog** *c*; the end of the angle is also held down by means of a dog *d*. These dogs are simply curved pieces of metal that are sprung into the holes in the plate and driven down into contact with the work.

13. The angle is bent around the form by means of a **moon** *e*, Fig. 11. which is a crescent-shaped piece of metal secured to a long arm and provided with a pin or tongue near the end. This tongue is dropped into one of the holes in the plate, and the angle is bent by sweeping the moon around. Of course, as the angle bends, the outer edge of the projecting flange will be stretched and drawn thin, and care must be taken to see that it does not buckle. By careful handling, very sharp curves can be bent in this way. Fig. 12 (*a*) shows an angle



(*a*) (*b*)

Fig. 12

that has been bent into a circle and afterwards welded, and (*b*) shows an angle bent to form the frame for a door; both of these were bent around forms by the use of moons. Large bending floors, made up of several bending plates laid side by side, are used in bending very large work. Forms made of iron or steel bars bent to the proper shape are clamped on the bending floor with dogs, as shown in Fig. 13. The piece to be bent is then forced around the form by means of moons.

14. Welding Angles.—In some classes of work, it is often necessary to bend angles and other structural shapes to such sharp angles that it is impossible to make the metal flow to the desired form. Four examples of this nature are shown in Fig. 14. In making the piece shown in (*a*), it is necessary to

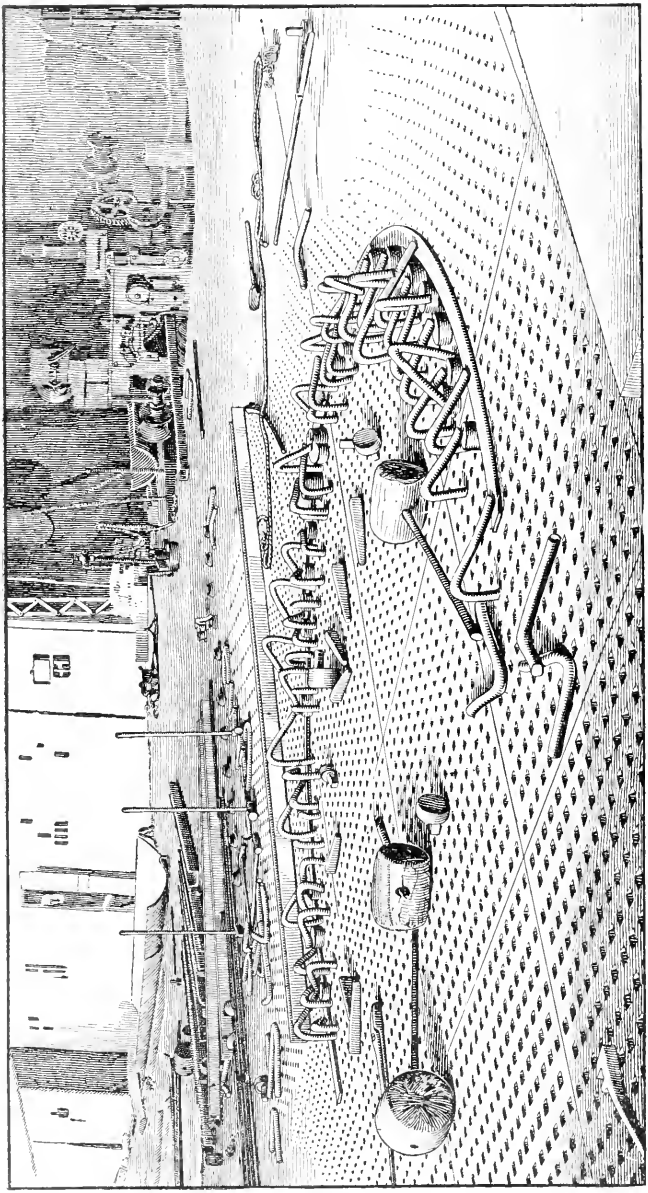


Fig. 13

cut out a piece of the inside flange of the angle at the point *a*, so that the angle before bending will appear as shown in (*e*). After bending, the faces *b* and *c* are brought together and welded. In like manner, the outer corners *d* and *e* of the piece in (*b*) must be split and pieces welded in after bending. Similarly, pieces must be cut out of, and others welded into, the webs of the pieces shown in (*c*) and (*d*). If the parts are kept

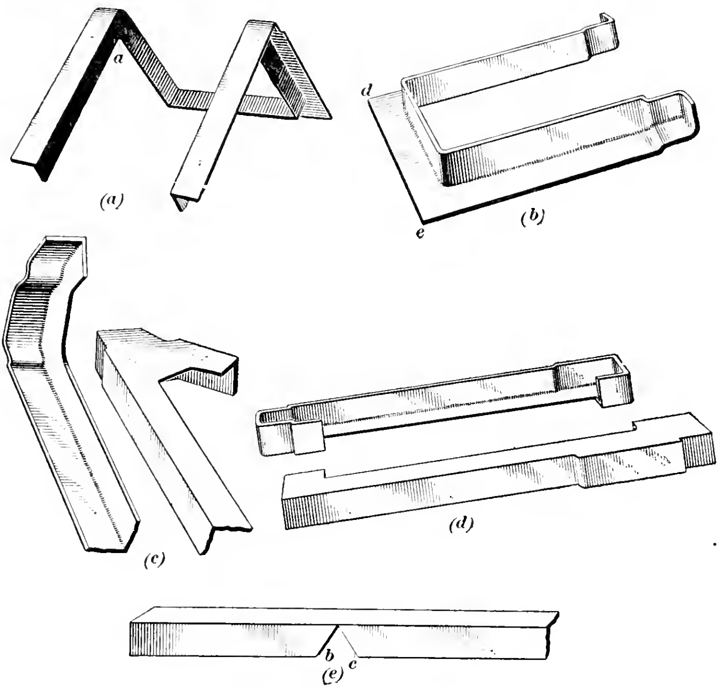


Fig. 14

clean and the fire in proper condition when making these welds, no flux is necessary, as the flux tends, in many cases, only to eat away the surface of the metal.

15. Bending Structural Shapes.—Channels, **I** beams, deck beams, and other structural shapes are bent by using proper forms. In some cases, it is necessary to have an outline of the sectional shape formed in the side of the former used.

In all work on structural shapes, care must be taken to see that the steel is not heated very far above the point of recalescence, or 1,250° F., except for welding; and any pieces that must be heated to a higher degree should be allowed to cool after they are forged to shape, and then heated to just above the point of recalescence, or 1,250° F., and allowed to cool once more. This will relieve the stresses and restore the fine texture of the metal and insure the greatest possible strength in the piece.

16. Bending Plates.—In bending plates into irregular forms, they are first brought roughly to shape under suitable

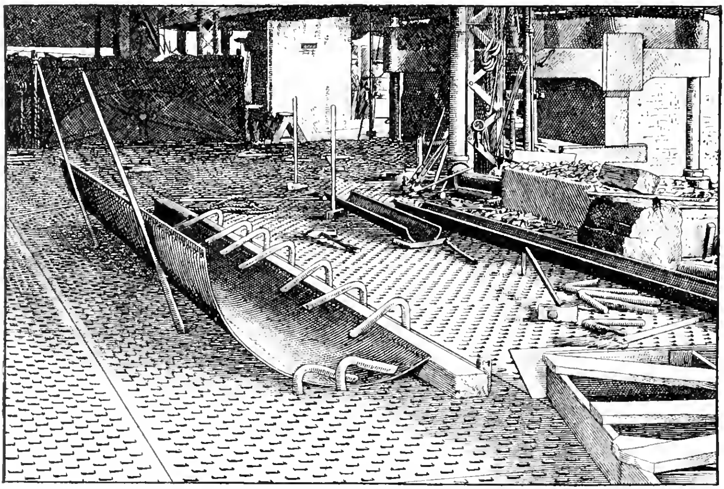


Fig. 15

presses and are then secured to the bending floor by means of dogs, as shown in Fig. 15. Suitable bars or supports are placed at the sides, and the plates formed to a templet by the use of wooden mauls, three of these mauls being shown on the bending floor in Fig. 13. By careful work in this way, a plate can be formed to any required shape.

EFFECT OF REPEATED HEATING ON METAL

17. Effect of Repeated Heating on Cast Iron.—If cast iron is heated repeatedly, it will increase in size with each successive heating; the volume has been increased as much as 40 per cent. This heating opens the grain of the metal and weakens it very greatly. Hence, gray-iron castings should not be exposed to repeated heatings if it is desired that they retain their form and size. This increase of volume of the metal has, however, been put to practical use for increasing the size of parts that have become worn to such an extent that they no longer fill the space for which they were originally intended. To do this, the pieces are packed in air-tight boxes or tubes, heated to a dull red, and then allowed to cool.

18. Effect of Repeated Heating on Wrought Iron or Steel.—It has also been found that repeated heating of wrought iron or low-carbon steel reduces the volume slightly. Advantage may be taken of this shrinkage in cases where it is necessary to reduce slightly the diameters of holes in forgings, or the diameters of rings. If such pieces are heated to a dull red and allowed to cool slowly, or even if they are quenched in water, they will usually be found to have decreased slightly in size.

ESTIMATING STOCK

19. General Rule for Finding Stock.—The work of the blacksmith is such that he is frequently required to estimate the amount of stock of a certain size needed to make a certain piece of work. Usually a dimensioned sketch or drawing of the required piece is given to him and he must then calculate the length of bar stock that must be cut off to make the piece. To accomplish this, the following rule may be used:

Rule.—*Calculate the volume of the required piece in cubic inches and divide it by the area, in square inches, of the stock from which the piece is to be made. The quotient will be the required length of stock, in inches.*

If the piece to be forged is not of the same shape throughout, it may be considered as being made up of several parts. The volumes of these separate parts should be calculated, and their sum will then be the total volume of the piece.

The foregoing rule does not include any allowances for losses during the forging operation, nor for waste due to the trimming off of rough ends so as to obtain a sound forging. Such allowances cannot be fixed by any general rule, because they vary according to the nature and size of the work and are determined largely by experience.

20. In the calculation of the volume of a piece of work of round or rectangular section, the area of cross-section is used. To save time and labor, the cross-sectional areas of round and square steel bars of various sizes are given in Table I at the end of this Section. The first column gives the side of the square bar or the diameter of the round bar, in inches; the second and third columns give the weights per foot of square and round bars, respectively, of the different sizes; and the last two columns give the areas corresponding to the various sizes of square and round bars. Tables II and III give simply the weights per foot of square, round, and flat wrought-iron bars. These two tables, as well as the first three columns of Table I, may be used to find the weight of a bar of iron or steel of a given size and length.

For example, suppose it is desired to know what length of stock $1\frac{1}{2}$ inches square will be required to make a piece 12 inches long, 2 inches wide, and $\frac{3}{8}$ inch thick. The volume of the required piece is $12 \times 2 \times \frac{3}{8} = 9$ cubic inches. According to Table I, the area of cross-section of a bar $1\frac{1}{2}$ inches square is 2.25 square inches. Hence, applying the rule of Art. **19,** the length of stock required is

$$9 \div 2.25 = 4 \text{ inches}$$

21. General Rule for Drawing or Upsetting.—The work of the blacksmith frequently involves drawing and upsetting operations. For example, he may find it necessary to draw a piece of square stock to a smaller square, or to a round section, or perhaps to a rectangular shape, and he may wish to know how long the piece will be after it has been drawn out. On the other hand, it may be necessary for him to upset a piece to a larger cross-section, and he may wish to calculate the finished length. No matter whether the operation is drawing or upsetting, or whether the stock is round, square, or any other shape, the general rule to be used is as follows:

Rule.—*Calculate the volume of the original piece in cubic inches and divide it by the area, in square inches, of the cross-section to which it is to be forged. The quotient will be the final length of the piece, in inches.*

If the piece of stock is to be forged to different shapes and sections at different points, it should be considered as being made up of several parts, and the length of each should be calculated by the foregoing rule.

The method of using this general rule can best be illustrated by means of examples and their solutions. To begin with a simple case, suppose that a piece of iron 1 inch square and 2 inches long is drawn out to a bar $\frac{1}{2}$ inch square, and that the final length of the piece is to be calculated. The volume of the original stock is $1 \times 1 \times 2 = 2$ cubic inches. The cross-section of a bar $\frac{1}{2}$ inch square is $\frac{1}{2} \times \frac{1}{2} = \frac{1}{4}$ square inch. Then, according to the rule, the length of the piece, when drawn out, is $2 \div \frac{1}{4} = \frac{2}{1} \times \frac{4}{1} = 8$ inches.

22. As a further example, suppose that the original piece of stock is to be drawn down to a round bar $\frac{3}{4}$ inch in diameter. The area of cross-section of this round bar would be .4418 square inch, according to Table I. Then, according to the rule of the preceding article, the length of the round bar would be $2 \div .4418 = 4.53$ inches, or approximately $4\frac{17}{32}$ inches.

Again, suppose that the cross-section of the finished piece was to be rectangular, and to measure $1\frac{1}{4}$ inches by $\frac{5}{8}$ inch. The area of such cross-section is $1\frac{1}{4} \times \frac{5}{8} = \frac{5}{4} \times \frac{5}{8} = \frac{25}{32}$ square inch. The length of the finished piece, therefore, would be $2 \div \frac{25}{32} = \frac{2}{1} \times \frac{32}{25} = \frac{64}{25} = 2.56$ inches, or approximately $2\frac{9}{16}$ inches.

As a further example, suppose that a piece of round bar $1\frac{1}{2}$ inches in diameter and 3 inches long is to be drawn down to a rectangular piece 2 inches by $\frac{1}{2}$ inch in section and that the length of the rectangular piece is to be found. According to Table I, the cross-sectional area of a round bar $1\frac{1}{2}$ inches in diameter is 1.7671 square inches. The length of the piece of $1\frac{1}{2}$-inch stock is 3 inches, and therefore the volume must be $1.7671 \times 3 = 5.3013$ cubic inches. The cross-sectional area of the rectangular piece is $2 \times \frac{1}{2} = 1$ square inch. Applying the rule of Art. **21**, therefore, the length of the rectangular piece will be $5.3013 \div 1 = 5.3013$ inches, or about $5\frac{5}{16}$ inches.

23. Stock Required for a Y.—Suppose that it is desired to find the length of stock, $\frac{1}{2}$ inch by $1\frac{1}{2}$ inches in section, required

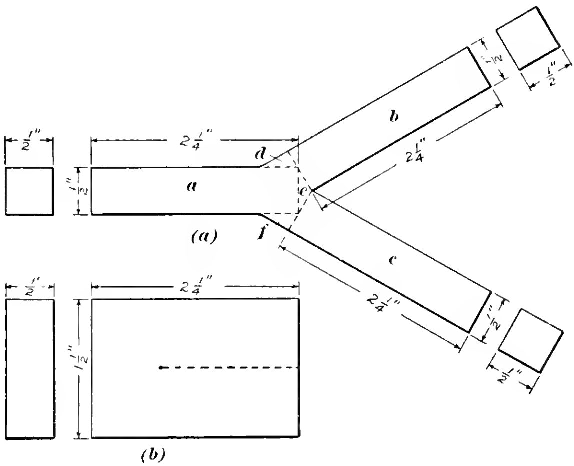


FIG. 16

to form a **Y** having the dimensions shown in Fig. 16 (*a*). The **Y** may be considered as being composed of three equal arms *a*, *b*, and *c*, each $\frac{1}{2}$ inch square in section and $2\frac{1}{4}$ inches long. The volume of each of these pieces is $\frac{1}{2} \times \frac{1}{2} \times 2\frac{1}{4} = \frac{9}{16}$ cubic inch, and the volume of all three is $3 \times \frac{9}{16} = \frac{27}{16} = 1\frac{11}{16}$ cubic inches. The cross-sectional area of the stock to be used is $\frac{1}{2} \times 1\frac{1}{2} = \frac{1}{2} \times \frac{3}{2} = \frac{3}{4}$ square inch. The length of stock required, therefore, according to the rule of Art. **21**, is $1\frac{11}{16} \div \frac{3}{4} = \frac{27}{16} \times \frac{4}{3} = \frac{9}{4} = 2\frac{1}{4}$ inches, as shown in (*b*). This calculation, it will be observed, does not take account of the small amounts of material at *d*, *e*, and *f* in (*a*); consequently, the calculated length, $2\frac{1}{4}$ inches, will not give sufficient stock. However, the amount of material at *d*, *e*, and *f* is very slight, and in small work may usually be neglected. If it must be allowed for, the length of the stock may be increased according to the judgment of the blacksmith, in this case about $\frac{1}{8}$ inch, making the piece of stock $2\frac{3}{8}$ inches long. The stock is first split as indicated by the dotted line in (*b*), for two-thirds of its length, after which the arms are spread and the three sections are drawn down to the shape and size given in (*a*).

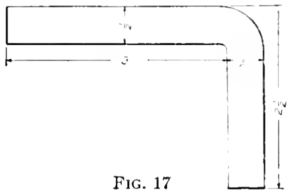


Fig. 17

24. Stock Required for Square Bend.—If a piece of stock of uniform section is to be bent, as shown in Fig. 17, so that the two legs shall be of certain required lengths and at right angles to each other, the length of straight bar required may be calculated by the following rule:

Rule.—*To the length of one leg, measured on the inside of the bend, add the length of the other leg, measured on the outside of the bend, and to their sum add $\frac{1}{8}$ inch. The result will be the length of straight bar required.*

Suppose a piece of iron $\frac{1}{2}$ inch square is to be bent to the size and shape indicated in Fig. 17 and it is desired to know the length of straight stock required. The length of one leg, measured on the inside of the bend, is 3 inches, and the length of the other, measured on the outside of the bend, is $2\frac{1}{2}$ inches. By the rule, the length of straight stock required is $3+2\frac{1}{2}+\frac{1}{8}=5\frac{5}{8}$ inches.

25. Stock Required for Bolt.—A bolt may be made by cutting off a piece of round bar of sufficient length and upsetting

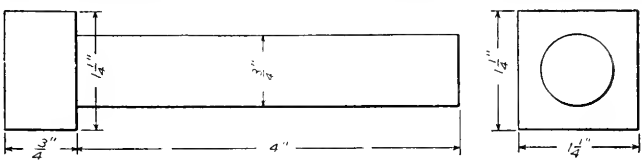


Fig. 18

one end to form the bolt head. Suppose that a bolt $\frac{3}{4}$ inch in diameter and 4 inches long is to be made from $\frac{3}{4}$-inch round stock, and that the length of stock is to be found. The bolt will have the dimensions shown in Fig. 18. It may therefore be considered as being made up of a cylindrical shank $\frac{3}{4}$ inch in diameter and 4 inches long, and a head $1\frac{1}{4}$ inches square and $\frac{3}{4}$ inch thick. Since the shank is of the same diameter as the stock, $\frac{3}{4}$ inch, and 4 inches long, it will require a piece of stock 4 inches long. The volume of the bolt head is $1\frac{1}{4}\times1\frac{1}{4}\times\frac{3}{4}=1.17$ cubic inches. The area of $\frac{3}{4}$-inch round stock is .4418 square inch, according to Table I. The stock required for the head, therefore, is $1.17\div.4418=2.65$ inches, or approximately $2\frac{5}{8}$ inches. Then, the total length of stock required is $4+2\frac{5}{8}=6\frac{5}{8}$ inches.

If the bolt is to be made by drawing down a piece of square stock, the same method may be followed. The cylindrical shank $\frac{3}{4}$ inch in diameter has an area of .4418 square inch,

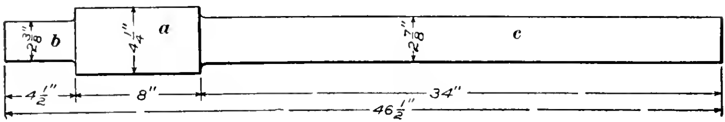


FIG. 19

according to Table I. Its volume, therefore, is $.4418\times4=1.77$ cubic inches, and the volume of the head, as already calculated, is 1.17 cubic inches. Then the total volume of the bolt is $1.77+1.17=2.94$ cubic inches. Suppose that stock $1\frac{1}{4}$ inches square is to be used. Its cross-sectional area is $1\frac{1}{4}\times1\frac{1}{4}=\frac{25}{16}=1.56$ square inches. Therefore, the length of $1\frac{1}{4}$-inch square stock required will be $2.94\div1.56=1.88$ inches, or practically $1\frac{7}{8}$ inches.

26. Stock Required for Solid Shaft.—Suppose that a solid steel shaft of the size shown in Fig. 19 is to be forged from $4\frac{1}{4}$-inch round stock, and that the length of stock needed is to be found. The rough forging may be considered as being composed of three cylindrical parts; but as the middle part *a* is $4\frac{1}{4}$ inches in diameter, or of the same size as the stock to be used, its volume need not be calculated. The end parts *b* and *c* will be forged by drawing down $4\frac{1}{4}$-inch stock. The volume of each end must therefore be calculated. The area of a circle $2\frac{3}{8}$ inches in diameter is 4.4301 square inches, according to Table I, and that of a circle $2\frac{7}{8}$ inches in diameter is 6.4918 square inches. The volume of the part *b*, therefore, is $4.4301 \times 4\frac{1}{2} = 19.9$ cubic inches, and of the part *c* is $6.4918 \times 34 = 220.7$ cubic inches. The total volume of the parts *b* and *c* is $19.9 + 220.7 = 240.6$ cubic inches. The area of $4\frac{1}{4}$-inch stock is 14.186 square inches; hence, by the rule of Art. **19**, the length of $4\frac{1}{4}$-inch stock required for the ends is $240.6 \div 14.186 = 17$ inches, nearly. To this must be added the 8 inches required for the part *a*, giving a total of 25 inches as the length of stock required for the forging.

27. Another way of working out this problem is to use the weights per foot of round steel of different sizes, as given in Table I. As before, let the shaft be considered as being composed of three cylindrical parts. The part *b* is $4\frac{1}{2}$ inches, or $4\frac{1}{2} \div 12 = \frac{3}{8}$ foot, long, and $2\frac{3}{8}$ inches in diameter. According to Table I, the weight of 1 foot of $2\frac{3}{8}$-inch round steel is 15.06 pounds; hence, the weight of $\frac{3}{8}$ foot is $\frac{3}{8} \times 15.06 = 5.6$ pounds. The part *c* has a length of $34 \div 12 = 2\frac{5}{6}$ feet, and its weight is $2\frac{5}{6} \times 22.07 = 62.5$ pounds. The total weight of the ends *b* and *c*, then, is $5.6 + 62.5 = 68.1$ pounds. The stock to be used is $4\frac{1}{4}$ inches in diameter and weighs, according to Table I, 48.24 pounds per foot. The length of stock required for the ends, therefore, is $68.1 \div 48.24 = 1.412$ feet, or $12 \times 1.412 = 16.94$ inches, or approximately 17 inches, as before. The middle part *a* requires 8 inches of stock. Therefore, the total length of stock required is $17 + 8 = 25$ inches.

28. Stock Required for Crank-Shaft.—Suppose that a steel crank-shaft is to be forged from a rough ingot and that the completed forging is to have the form and size shown in Fig. 20 (*a*). The parts *a* and *b*, from which the cranks are formed, as indicated by the dotted lines, are 29 inches wide and 13 inches thick; therefore, the first step in forging is to draw the ingot down to a bar of rectangular cross-section 29 inches by 13 inches. The parts *c*, *d*, and *e* are then made by drawing down the rectangular bar at the proper places. The length of rectangular stock required is equal to the volume of the crank-shaft forging, in cubic inches, divided by the area of the rectangular cross-section, in square inches. The volume of each of the parts *a* and *b* is $23 \times 29 \times 13 = 8{,}671$ cubic inches, and the volume of both is $2 \times 8{,}671 = 17{,}342$ cubic inches. The parts *c*, *d*, and *e* are of the same diameter, 10 inches, and their cross-section is therefore 78.54 square inches, according to Table I. The combined length of the three parts is $24 + 58 + 36 = 118$ inches, and the total volume of the three is $78.54 \times 118 = 9{,}268$ cubic inches. The volume of the crank-shaft forging, then, is $17{,}342 + 9{,}268 = 26{,}610$ cubic inches. A section

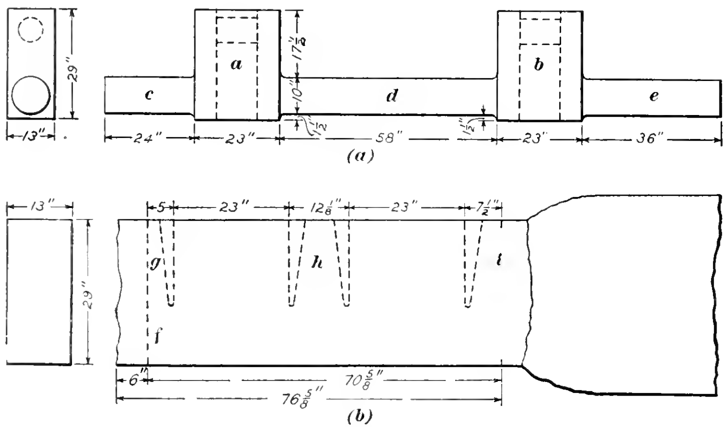


FIG. 20

29 inches by 13 inches contains 377 square inches. The length of stock of this size, therefore, is $26{,}610 \div 377 = 70.6$ inches. To allow for fillets and for trimming the ends, the piece of rectangular stock should have an over-all length of at least $76\frac{5}{8}$ inches, as shown in (*b*). Practically, the piece would be made 78 inches, or $6\frac{1}{2}$ feet long.

29. After a sufficient length of rectangular stock has been drawn down from the ingot, as shown in Fig. 20 (*b*), it must be marked off properly, so that the parts *c*, *d*, and *e* in view (*a*) can be forged. The part *c* has a volume of $78.54 \times 24 = 1{,}885$ cubic inches. The length of rectangular stock required for this part is $1,885 \div 377 = 5$ inches. As the end of the stock is rough and must be trimmed off, the measurements are made from a point several inches from the end, indicated by the dotted line *f* in (*b*). From the line *f* a distance of 5 inches is laid off, marking the stock required for the part *c*. Next, a distance of 23 inches is laid off, marking the stock required for the crank *a*. The part *d* has a volume of $78.54 \times 58 = 4,555$ cubic inches and requires a length of stock equal to $4,555 \div 377 = 12\frac{1}{8}$ inches; hence, a distance of $12\frac{1}{8}$ inches is laid off, as shown. This is followed by another section 23 inches long, for the crank *b*. The part *e* has a volume of $78.54 \times 36 = 2,827$ cubic inches and requires $2,827 \div 377 = 7\frac{1}{2}$ inches of stock, which is marked off at the right. After the stock has been marked off, as shown, it is heated, and a hack is used to notch it as indicated by the **V**-shaped cuts. These notches must be square on the faces that form the sides of the parts *a* and *b*, and their depth must be a little less than $17\frac{1}{2}$ inches, which is the length of the crank, measured from the side of the shaft to the outer end. In this particular case, the notches cut by the hack would be between 17 and $17\frac{1}{4}$ inches deep. The metal at *g*, *h*, and *i* is then forged to a circular shape, 10 inches in diameter, thus forming the parts *c*, *d*, and *e*.

30. Avoiding Waste of Stock.—When cutting pieces of material for forging operations, the bar stock selected should be of such length as to enable the pieces to be cut with little or no waste. To illustrate this point, suppose that a number of pieces of steel 9 feet long are required for wagon tires; also, suppose that the supply of stock of the proper size consists of two lots of bars, one lot 10 feet long and the other 18 feet long. If the tires are cut from the 10-foot bars, there will be a waste end 1 foot long cut off each bar; but if the 18-foot bars are used, each will furnish stock for two tires, without any waste. Hence, it would be preferable to use the 18-foot bars. In addition, less cutting would be required to obtain the required number of tires, since each cut would give two pieces; whereas, if the shorter bars were used, each cut would give only one piece, besides causing a waste of 1 foot.

31. Stock Required for Circular Ring.—When a piece of straight stock is bent to a curve, the material at the outer side of the bend is stretched and that on the inner side is compressed. The length of the center line of the piece, however, changes little, if any. If it is desired to find the length of straight stock needed to form a circular ring, the following rule should be used:

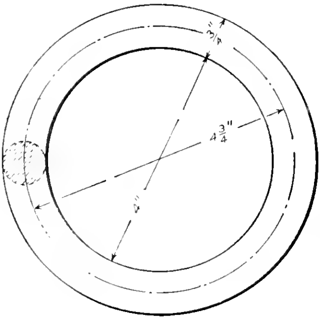


Fig. 21

Rule.—*To find the length of straight stock required for a circular welded ring, multiply the diameter of the ring, measured from center to center of stock, by 3.1416, and to the product add half the thickness of the stock.*

For example, suppose that a ring of the size shown in Fig. 21 is to be made and that the length of straight stock required for it is to be found. The inside diameter of the ring is 4 inches, and the diameter of the stock is $\frac{3}{4}$ inch; hence, the diameter from center to center of stock is $4\frac{3}{4}$ inches. Then, applying the rule, the length of straight $\frac{3}{4}$-inch stock required is $(4\frac{3}{4}\times 3.1416)+(\frac{1}{2}\times\frac{3}{4})=15+\frac{3}{8}=15\frac{3}{8}$ inches. The addition of half the thickness of the stock is made to allow for loss of material in welding. The same rule holds true for square, hexagonal, or oval stock bent to a circular ring.

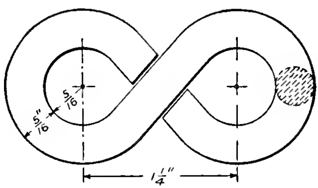


Fig. 22

32. The link shown in Fig. 22 is known as a *figure-8 link* and is bent to shape without welding. It may be considered as being made up of two circular rings, since each end of the link has an approximately circular form; and as the link is not welded, no allowance for welding need be made. The rule to be used, therefore, is as follows:

Rule.—*Considering each end of the link as a circular ring, multiply the diameter of the ring, measured from center to center* *of stock, by 3.1416, and then multiply that product by 2. The result is the length of stock required for the figure-8 link.*

Suppose that the length of straight stock for the link shown in Fig. 22 is to be found. The inside diameter of each end is $2\times\frac{5}{16}=\frac{5}{8}$ inch, and the stock is $\frac{5}{16}$ inch in diameter. The diameter of the ring from center to center of stock, therefore, is $\frac{5}{8}+\frac{5}{16}=\frac{15}{16}$ inch. Then, applying the rule, the length of stock required for one end is $\frac{15}{16}\times 3.1416=2.95$ inches, or nearly 3 inches, and for the whole link the stock required is $2\times 3=6$ inches.

33. Stock Required for Chain Link.—A chain link of the form shown in Fig. 23 consists of two equal semicircular ends joined by straight sides. The amount of stock needed for the sides is equal to twice the length of one side of the link; and as the two ends together form a circle, the amount of stock required for them, including the allowance for the weld, may be calculated by the rule of Art. **31**. For example, suppose that the link is to have the dimensions marked on it in the illustration and that the length of straight stock required for it is to be found. The length of $\frac{3}{8}$-inch round stock required for the two straight sides is $2\times\frac{5}{8}=1\frac{1}{4}$ inches. The two semicircular ends together form a ring whose inside diameter is $2\times\frac{5}{16}=\frac{5}{8}$ inch, and whose diameter from center to center of stock is $\frac{5}{8}+\frac{3}{8}=1$ inch. According to the rule of Art. **31**, therefore, the stock required for the two ends is $(1\times 3.1416)+(\frac{1}{2}\times\frac{3}{8})=3\frac{1}{8}+\frac{3}{16}=3\frac{5}{16}$ inches. The total length of straight stock needed to form the link, then, is $1\frac{1}{4}+3\frac{5}{16}=4\frac{9}{16}$ inches.

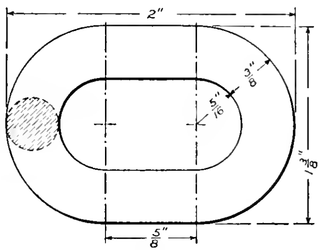


FIG. 23

34. Stock Required for Irregularly Curved Work. If a piece of work is made up of one or more irregular bends, so that none of the rules previously given can be used to find the length of straight stock needed, then the length of the center line must be found; for it has already been stated that, when a bar is bent, the center line remains practically unchanged in length. If the length of the center line is found, therefore, the length of straight stock needed will be known. One way of doing this is to take a piece of soft wire of sufficient length and bend it to the shape of the desired piece along the center line. When straightened out, the length of this wire will be the length of straight stock required. Another way is to mark the center line on the work and then with a pair of dividers set to a convenient dimension, to step off divisions along the center line from one end to the other. The number of divisions thus obtained multiplied by the distance between the points of the dividers is the length of the center line, and also of the stock required.

35. In case the amount of upsetting is great, or if the piece is to be machined to size after forging, the amount of stock required is greater than the volume of the finished piece. Suppose, for example, that a cylindrical cutter blank is to be made, the finished size of which is to be $7\frac{1}{2}$ inches in diameter and $1\frac{1}{4}$ inches thick; and, further, suppose that the available stock is 4 inches in diameter. It will be necessary to cut off a piece of this 4-inch stock and upset it to a size larger than the finished blank, so that there will be ample allowance for machining. In the problem assumed, the rough forging would be upset to a diameter of 8 inches and a thickness of $1\frac{1}{2}$ inches. The cross-sectional area of a forging 8 inches in diameter is 50.266 square inches, according to Table I. Then the volume of the forging is $50.266 \times 1\frac{1}{2} = 75.4$ cubic inches. The cross-sectional area of 4-inch round stock is 12.566 square inches. Then, according to the rule of Art. **19**, the length of stock required is $75.4 \div 12.566 = 6$ inches.

36. Finding Volume by Water Displacement.—It may happen that a forging of irregular form is made as a sample or specimen piece, and that it is then desired to know the amount of stock required to make duplicate pieces. If the work is of very irregular shape, so that the calculation of its volume is apt to be difficult, the desired result may be obtained in another way. A tub with straight sides is filled to overflowing with water. Then the piece whose volume is to be found is lowered into the tub until it is entirely submerged in the water. Some of the water will thus be displaced and flow over the edge of the tub. The piece is next lifted out, and it will be found that the water level is then below the edge of the tub. The volume of water thus forced out of the tub represents the volume of the piece, and is equal to the cross-sectional area of the tub multiplied by the distance from the top of the tub to the surface of the water. If the piece that is lowered into the water is a machined forging, the volume found will be the volume of the finished piece, and this will need to be increased by a certain allowance to obtain the volume of the rough forging. The length of stock required can then be found by the rule of Art. **19.** To have this method give reasonably accurate results, the tub or vessel used should be just large enough to contain the piece of work when fully submerged.

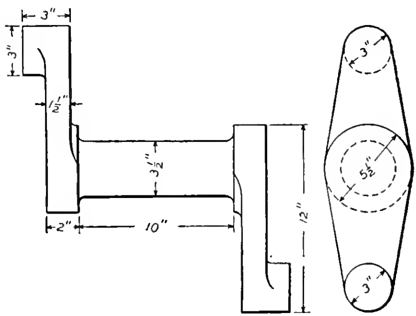


FIG. 24

37. As an example, suppose that it is desired to know what length of $5\frac{1}{2}$-inch round stock will be required to make the rough forging from which the finished piece in Fig. 24 is machined. Let it be assumed that, when the finished piece has been submerged in a filled tub 20 inches in diameter and withdrawn, the water level in the tub is $\frac{15}{16}$ inch below the edge. The volume of water that must have been displaced by the piece is then $20^2 \times .7854 \times \frac{15}{16} = 294.5$ cubic inches. To make allowance for finish, the rough forging must be larger than the finished piece. With careful workmanship, an allowance of 5 per cent. in volume is sufficient; that is, the volume of the rough forging is taken as 5 per cent. more than that of the finished piece. The rough forging must therefore contain $294.5 + (.05 \times 294.5) = 294.5 + 14.7 = 309.2$ cubic inches. The stock used is $5\frac{1}{2}$ inches in diameter and has a cross-section of 23.8 square inches. The length of stock required, therefore, is $309.2 \div 23.8 = 13$ inches.

38. Shrinking on a Link.—Machine parts are often held together by links or bars shrunk on. An example of this construction is shown in Fig. 25, in which *a* is a steel link that is shrunk on the bosses *b* and *c*, which form projections on the pieces *d* and *e*, respectively. The link is made of such size that, when heated to a red heat, it will just slip over the bosses *b* and *c*. As it cools, it shrinks, and the parts *d* and *e* are thus held together very tightly. The increase in the length and width of the link while being heated to a red heat is slight, amounting to a very few hundredths of an inch; consequently, it is useless to calculate the size of the cold link with a view to making allowance for heating and shrinking. The link is simply made smaller than the inside dimensions marked, and is heated to redness and tried on the bosses. If it will not go on, it is drawn a little, heated, and tried again, and these operations are repeated until the red-hot link can just be slipped over the bosses.

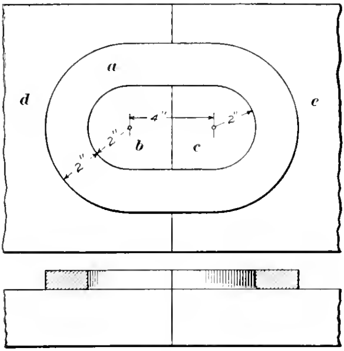


FIG. 25

39. Stock Required for Bushing.—If a cylindrical steel bushing is to be forged from a piece of solid round stock, a hole is first drilled lengthwise through the center of the stock. The piece is then heated, a mandrel is inserted, and the work is forged to the desired size, the size of the mandrel being changed as the hole grows larger. Suppose that the rough forging of a bushing is to have the dimensions shown in Fig. 26; also, that the length of stock to be used is 6 inches, that a $1\frac{1}{2}$-inch

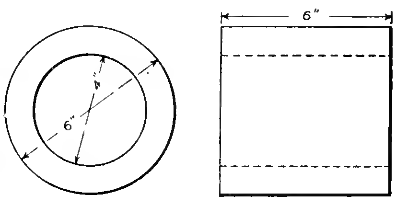


FIG. 26

hole is to be drilled in it, and that its diameter is to be found. The cross-section of the rough forging is the difference between the area of a 6-inch circle and the area of a 4-inch circle, or, according to Table I, $28.274-12.566=15.708$ square inches, and the volume is $6\times15.708=94.248$ cubic inches. The original piece of stock must contain this amount of steel, and, in addition, the quantity removed by the drill, which is equal to the volume of a cylindrical piece $1\frac{1}{2}$ inches in diameter and 6 inches long. According to Table I, the area of a $1\frac{1}{2}$-inch circle is 1.7671 square inches; then the volume is $1.7671\times6=10.603$ cubic inches. The volume of the stock, therefore, must be $94.248+10.603=104.851$ cubic inches. The length of the stock is to be 6 inches; hence, its cross-section must be $104.851\div6=17.475$ square inches. According to Table I, the area of a round bar most nearly equal to 17.475 square inches is 17.721 square inches and the diameter corresponding to this area is $4\frac{3}{4}$ inches; therefore, a piece of stock $4\frac{3}{4}$ inches in diameter and 6 inches long would be drilled with a $1\frac{1}{2}$-inch hole and forged to the size indicated. To keep the length from increasing, the piece must be upset repeatedly during the forging.

40. Forging Square From Round.—It is often desirable to know the size of round stock required to produce a square bar of given size, without upsetting. This can easily be done by the use of Table I. The area of the desired square is first found, and then the area of round bar most nearly equal to the area of the square. The diameter corresponding to the area of round bar thus found is the size of round bar that can be forged to the given square without any upsetting. For example, a $1\frac{1}{8}$-inch round bar can be used to give a 1-inch square bar, because the area of the former is .994 square inch, which is very nearly equal to the area of the latter, or 1 square inch. Similarly, a $3\frac{1}{4}$-inch round bar will produce a $2\frac{7}{8}$-inch square bar, because its area, 8.2958 square inches, is approximately equal to the area of the square bar, or 8.2656 square inches.

41. Stock Required for Forged Ring.—Suppose that it is desired to know what length of stock 10 inches square will be required for the rough forging shown in Fig. 27, assuming that a circular piece 6 inches in diameter is punched out when the stock has been forged to 3 inches in thickness. The forging is rough and varies from 6 to 7 inches in width, as indicated. The average width is $(6+7)\div 2=6\frac{1}{2}$ inches, and the average inside diameter is $30-(2\times 6\frac{1}{2})=30-13=17$ inches. The area of the ring, then, is $30^2\times .7854-17^2\times .7854=707-227=480$ square inches. The thickness is 3 inches; therefore, the volume of the forging is $3\times 480=1{,}440$ cubic inches. The cylindrical piece that is punched out, before the ring is put on a mandrel and forged to size, has an area of 28.274 square inches, according to Table I, and a volume of $28.274\times 3=85$ cubic inches. The volume of stock required, therefore, is $1{,}440+85=1{,}525$ cubic inches. The stock is 10 inches square, corresponding to a cross-section of $10\times 10=100$ square inches; hence, the length needed must be $1{,}525\div 100=15.25$ inches, or $15\frac{1}{4}$ inches.

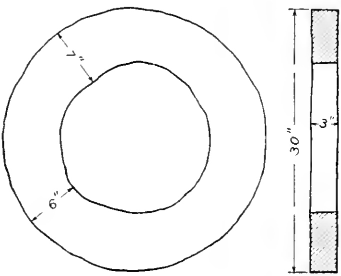


FIG. 27

42. Cutting Stock Without Waste.—It is desirable not to waste stock, particularly if it is expensive material. Suppose, for example, that a bar of tool steel 7 feet long is to be made into cold chisels, each of which requires a piece of stock $6\frac{1}{4}$ inches long. The length of the bar is $7\times 12=84$ inches, and as each chisel needs $6\frac{1}{4}$ inches of stock, there will be enough material for $84\div 6\frac{1}{4}=13\frac{11}{25}$ pieces; that is, the bar will make 13 pieces $6\frac{1}{4}$ inches long, and there will remain a waste end $2\frac{3}{4}$ inches long. This waste can be avoided by dividing it among the 13 pieces, increasing the length of each slightly. The stock for each piece will then have a length of $84\div 13=6\frac{6}{13}$ inches, or almost $6\frac{15}{32}$ inches. Moreover, by dividing the slight excess of stock among the several pieces, the number of cuts on the bar is reduced by one, thus lessening the time, the labor, and the wear on the tools.

43. Stock Required for Valve Link.—The finished piece shown in Fig. 28 (*a*) is a valve link and is used in the reversing gear of a steam engine. It is forged from a piece of steel $3\frac{3}{4}$ inches square, the successive steps in the forging operation being shown in views (*b*) to (*d*). The stock is first marked out, as shown in (*b*), the widths *a*, *b*, and *c* being the parts that form the circular bosses in (*a*). The stock is then fullered, as shown in (*c*), leaving the parts *a*, *b*, and *c* with square sides,

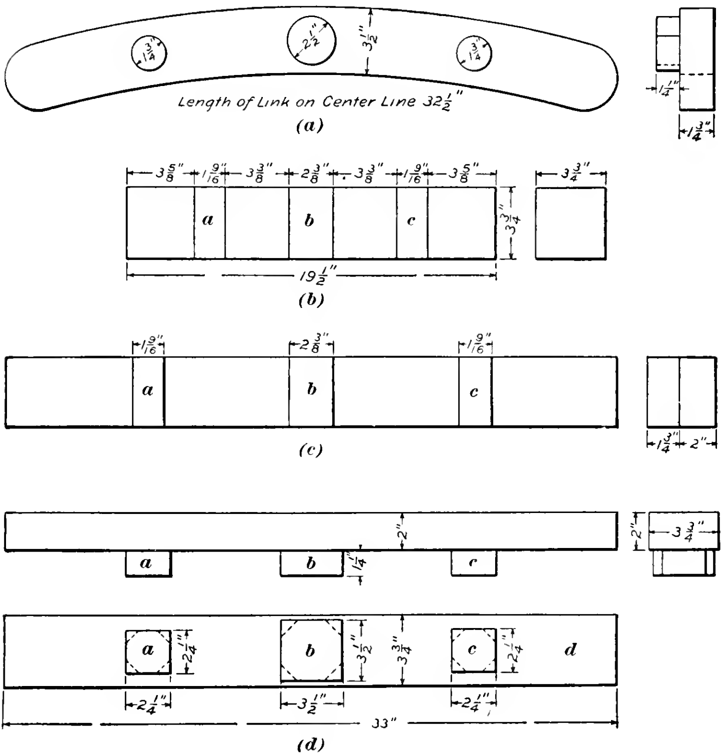


FIG. 28

after which the sections between them, as well as the ends, are drawn down to the form shown in (*d*). Finally, a hot set is used to trim off the corners of the parts *a*, *b*, and *c*, as shown by the dotted lines. The rough forging is then bent to the correct curve and machined to the dimensions given in (*a*). To allow for machining to the sizes given, the rough forging will need to have the sizes shown in (*d*). The completed forging then consists of four parts, each of rectangular cross-section. The volume of the part *a* is $2\frac{1}{4} \times 2\frac{1}{4} \times 1\frac{1}{4} = 6.3$ cubic inches. The volume of the part *b* is $3\frac{1}{2} \times 3\frac{1}{2} \times 1\frac{1}{4} = 15.3$ cubic inches. The volume of the part *c* is equal to that of *a*, or 6.3 cubic inches. The main part *d* has a volume of $33 \times 3\frac{3}{4} \times 2 = 247.5$ cubic inches. The volume of the forging, therefore, is $6.3 + 15.3 + 6.3 + 247.5 = 275.4$ cubic inches. The area of a bar $3\frac{3}{4}$ inches square is 14.063 square inches, according to Table I; hence, the length of stock required is $275.4 \div 14.063 = 19.58$ inches, or $19\frac{1}{2}$ inches, approximately.

THERMIT WELDING

44. Thermit.—If aluminum in the form of powder or filings is mixed in the proper proportions with powdered iron oxide and the mixture is set on fire, the oxygen in the iron oxide is taken up by the aluminum; in other words, the aluminum burns to oxide of aluminum and the iron in the iron oxide is set free. The burning of the aluminum is accompanied with great heat, and the temperature of the mixture is raised to about 5,400° F. This is considerably above the melting point of iron; consequently, the effect of the rapid burning is to produce a quantity of highly heated molten iron, as well as a slag consisting of oxide of aluminum. The mixture of aluminum and iron oxide is known as **thermit**, and the high temperature set up by its burning, in connection with the molten iron produced, enables it to be used to advantage in welding broken forgings and castings. The molten metal produced by the burning of thermit is called *thermit steel.*

45. Crucible for Thermit.—Inasmuch as the temperature resulting from the burning of thermit is very high, the vessel in which the action takes place must be built to withstand the heat. This vessel, known as a crucible, is shown partly in section in Fig. 29. The conical sheet-iron shell *a* is lined with a thick layer of refractory material *b* that is strong and able to resist the effects of high temperature. At the bottom of the cone is a circular iron plate *c* with a hole at its center. It supports a cylindrical block *d* of magnesia, which has a tapered hole through it. In the tapered hole is set the thimble *e*, which has the same taper as the hole. The thimble is also made of refractory material of high grade, because the molten metal is tapped through it. The opening in the thimble is closed, during the burning of the thermit, by an asbestos washer *f*, beneath which is a scarfed pin *g* that hangs freely inside the thimble. On top of the washer is rammed an iron disk *h*, and over the disk is poured a layer of sand *i*.

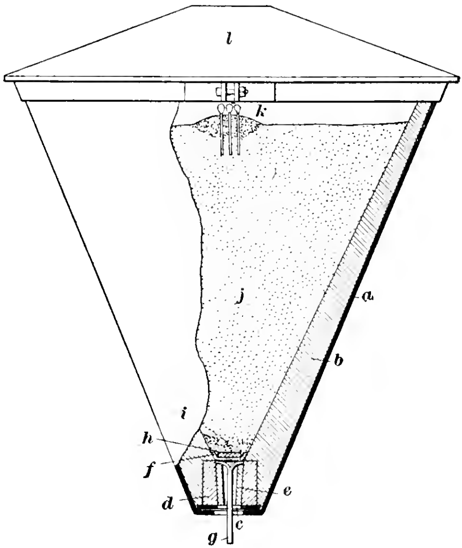


Fig. 29

46. Preparing and Firing Charge. After the plugging material has been placed in the small end of the conical crucible, Fig. 29, the charge of thermit *j* is poured in and leveled on top. Then, in the center of the top surface is placed a teaspoonful of ignition powder *k*, and two or three matches are set into it, with their heads upwards. These matches are now set on fire by the flame of another match, the hand is withdrawn quickly, and the cover *l* of the crucible is put in place. The burning of the thermit charge is violent, and will cause the crucible to vibrate. As soon as the vibration has ceased, the burning is ended, and the thermit steel is ready to be tapped. To do this, the lower end of the pin *g*, which projects below the crucible, is given a sharp blow upwards with the flat end of a tapping spade, or flat iron bar. The asbestos washers and the metal disk are thus displaced and the molten metal runs out through the hole in the thimble and is directed into the mold surrounding the broken part that is to be welded. The crucible may be supported on a tripod or suspended by a suitable sling.

47. Applications of Thermit.—When a part of a machine breaks, a great deal of time and labor may be required to remove the broken piece and replace it with a new one. If the break can be repaired without taking the part away or dismantling the machine, a considerable saving results. Thermit

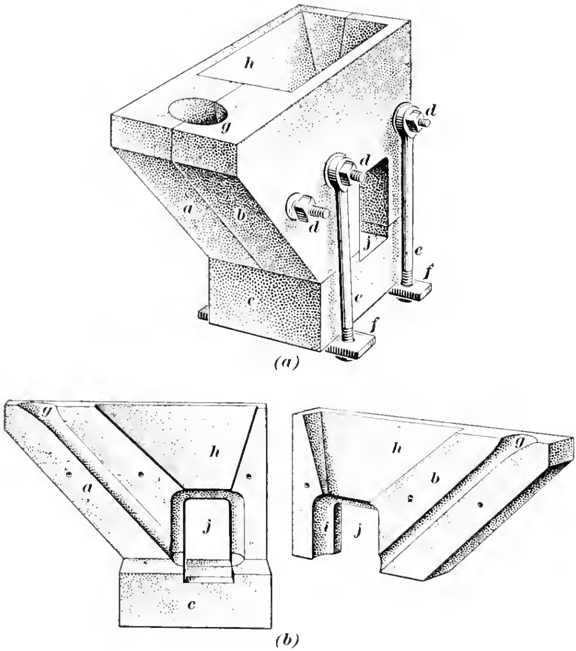


Fig. 30

is used very extensively for mending broken forgings and castings while they are in place, for joining the ends of rails for street-car tracks, and for similar work. The metal at the break is cut away until there is a small space between the ends that are to be joined, and the broken part is carefully lined up and clamped in position. A mold is then built around the break, and the thermit crucible is placed in such a position that the molten steel can be run into the mold. As the highly heated thermit steel fills the mold, it runs between the ends of the broken piece, and a part of its heat raises the temperature of the ends to the melting point. The result is that the ends and the thermit steel unite in one mass that, when cool, forms a weld joining the parts of the broken piece.

48. **Mold for Thermit Welding.**—The mold used in making a thermit weld must fit snugly over the work and must be so shaped that a collar of steel will be formed about the weld. If the piece is of regular form, as, for instance, a locomotive frame, a firebrick mold designed especially for making the weld may be purchased. In Fig. 30 (*a*) a mold of this kind is shown assembled. It consists of three pieces *a*, *b*, and *c*, which are shown separated in (*b*). The side blocks *a* and *b* are held together by the three bolts *d*, which pass through from side to side and have washers under the heads and nuts. The bottom piece *c* is clamped to the others by the eye-bolts *e*, which fit over two of the bolts *d* and pass through the straps *f*. The joint surfaces of the firebrick blocks are coated with a thin layer of fireclay before they are bolted together, to insure tight joints. The channel *g* is the pouring gate, which leads the molten steel to the bottom of the break and allows it to rise around the ends to be joined. The opening *h* serves as a riser and the groove *i* forms the collar of metal around the weld. The rectangular frame extends through the opening *j*, and the joints are luted with fireclay.

49. **Welding Locomotive Frames With Thermit.** By using thermit it is often possible to repair broken locomotive frames without removing them; that is, the welds are made while the parts are in place. Suppose, for example, that a frame breaks at one of the upper corners of a jaw. The first thing to do is to remove enough parts near the fracture so that it will be accessible and so as to make room for a mold about 1 foot wide. Next, a series of holes $\frac{3}{4}$ inch or 1 inch in diameter, depending on the size of the frame, should be drilled along the line of the break, overlapping one another as shown at *a*, Fig. 31 (*a*), and the metal should be chipped away, leaving a gap between the ends. The parts of the frame should then be

placed in correct alinement and two punch marks should be made on the frame, on opposite sides of the break, but far enough from it so as not to be covered by the mold. The punch marks enable a trammel to be used to test the accuracy of alinement when the weld has been completed. The jack *b* is inserted in the jaw and the break is forced open about $\frac{1}{4}$ inch, to allow for contraction when the metal at the weld cools. The exact

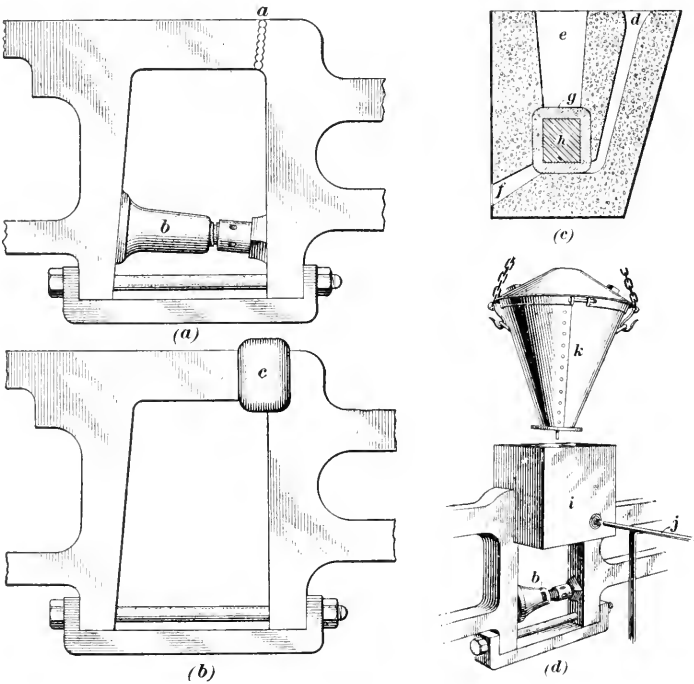


FIG. 31

amount of contraction depends on the width of the collar of metal around the weld, and therefore judgment must be used in making the necessary allowance.

50. The mold that is built around the break must be shaped so as to leave a collar of steel around the weld. This collar should be thickest directly over the break and should overlap the break at least 1 inch on each side. To make the recess in the mold, a pattern of yellow wax is built up around the break, as shown at *c*, Fig. 31 (*b*), of the same size and shape as the desired collar. The opening or break is also filled with this wax. Then the mold box is secured in place around the broken frame and the mold is rammed up around the wax and the frame. The mold is made of a mixture composed of equal parts of fire sand, good fireclay, and ground firebrick. These materials are mixed while dry and then just enough water is added to make the mixture pack well. The openings for the pouring gate and the riser are made by setting in wooden pins of the proper form. A cross-section of the mold is shown in (*c*), in which *d* is the pouring gate, *e* the riser, and *f* a channel for the insertion of a heating torch. The wax *g* surrounds the frame *h*. The combined volumes of the gate and riser should equal the volume of the collar. The thermit steel should not be allowed to wash, or strike directly against, the ends of the frame during pouring; therefore, the gate should lead to the bottom of the mold, so that the metal will rise around the break.

51. When the mold is completed, it will appear somewhat as shown in Fig. 31 (*d*), in which *i* is the mold box. The wooden pins forming the gate, the riser, and the heating channel are withdrawn from the mold and a torch *j* is inserted through the heating channel. The wax is thus melted, and runs out, leaving an opening of the desired form in the mold. The heating is continued until the mold is thoroughly dry. The thermit crucible *k* is fixed in position above the mold, at a distance of about 4 inches and directly over the pouring gate, and is charged with thermit. The heating by the torch is continued until the frame at the break is at a good red heat. Then the torch is quickly withdrawn and the hole is closed securely with a dry-sand core, backed up by sand. The ignition powder is now placed on top of the thermit and ignited, the cover of the crucible is put on, and as soon as the melting has been completed the steel is tapped from the crucible. The steel will commence to solidify about ten minutes after pouring, at which time the screw jack *b* should be eased off a bit. As the weld continues to cool and contract, the pressure of the jack should be reduced gradually. The mold should not be removed for at least two hours after pouring, and then the gate and the riser should be trimmed off.

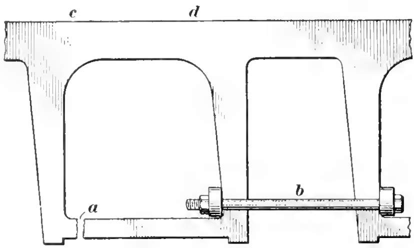


FIG. 32

52. If the break occurs in the lower rail of the frame, as at *a*, Fig. 32, the ends at the break are chipped away, leaving a gap between them. Clamp bolts *b* are put on the adjoining legs and their nuts are tightened, thus drawing the broken ends farther apart. The mold is built up in exactly the same manner as was described in connection with Fig. 31; but in order to prevent the frame from drawing out of alinement, the upper rail from *c* to *d*, Fig. 32, is heated, also, at the time the weld is made. The bolt *b*, which is tightened just before the mold is poured, is loosened gradually while the weld is cooling.

If the break occurs in a vertical leg, as at *a*, Fig. 33, the metal is cut away and the jack *b* is used to spring the ends apart about $\frac{1}{4}$ inch. The mold box is fitted around the vertical leg and the upper rail, and the mold for the steel collar is made in the same way as before. The pressure of the jack is eased off during the cooling of the weld.

53. Welding Valve Link.—A broken link forming part of the valve gear of a locomotive is shown in Fig. 34 (*a*). The fractures are at *a* and *b*, so that one side *c* of the link is broken out. To make the repair, the ends of the curved piece *c* are trimmed off, so that, when the piece is carefully lined up and clamped in position, gaps are left as shown in (*b*) at *d* and *e*. Molds are arranged at these points in the usual way, and thermit steel is run in. The appearance of the

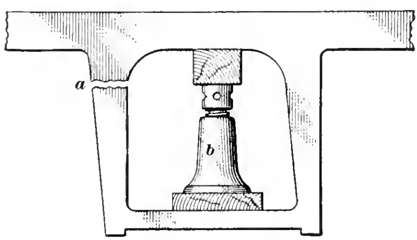


FIG. 33

repaired piece after the molds are removed is shown in (*c*). The collars of metal at *f* and *g* firmly unite the piece *c* to the body of the link. After the gates *h* and *i* are cut off and the welds are machined to the width of the link, the work will appear as in (*d*). In this particular case, the metal must be cut away considerably at the welds, a slight reinforcement being left at the points *j* and *k*. Wherever possible, however, the collars of thermit steel should be left in place, to give the necessary strength. In the case of the repaired frame shown in Fig. 31, for example, the collar would be trimmed up neatly, as shown, and not machined.

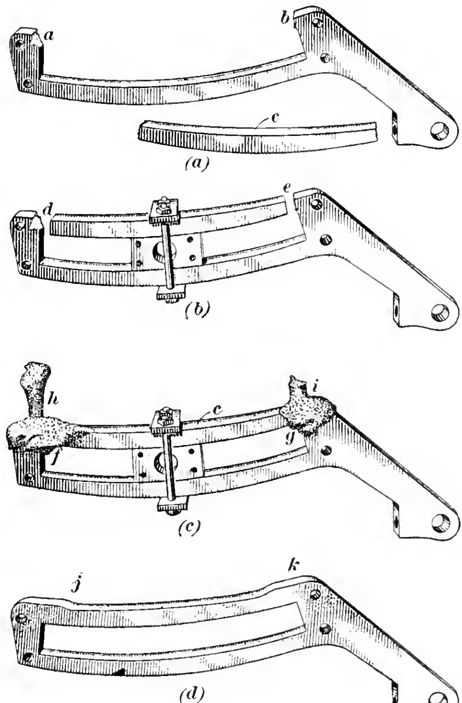


Fig. 34

54. Welding a Broken Shaft.—The application of thermit to the repair of a broken shaft is shown in Fig. 35. The

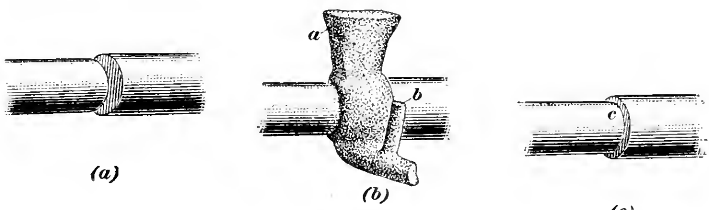


Fig. 35

break is at a shoulder where the diameter changes from 10 to 12 inches. The metal at the break is cut away, as shown in (*a*), leaving a space $2\frac{1}{2}$ inches wide between the ends. The parts of the shaft are accurately alined and blocked in position, a wax pattern is built around the gap, and a mold is prepared. The weld when completed appears as in (*b*), in which *a* is the

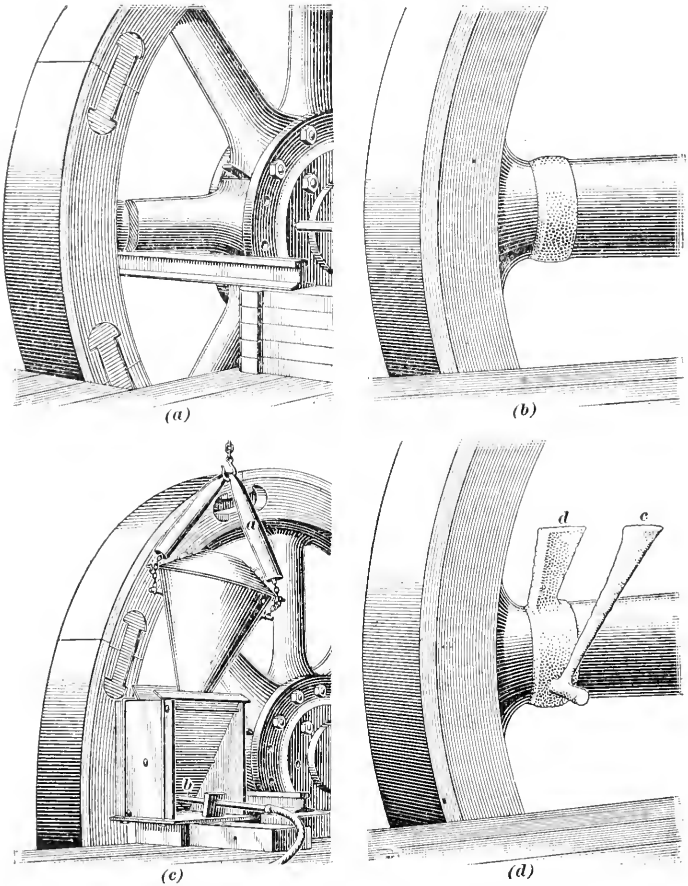


FIG. 36

riser and *b* the gate sprue. It is necessary, in this case, to trim off the collar of steel, so that the repair, when finished, will give the shaft its original appearance, as in (*c*). The strength of a weld that is made with thermit and then trimmed off to the original form and size, as at *c*, is from 80 to 90 per cent. of the strength of the original material. A welding operation of this kind, on a shaft of this size, requires about 72 hours, at the end of which time the shaft is ready to resume service. If the shaft must be taken down and sent away, the cost of the repair will be much greater and the machinery of which it forms a part will be thrown out of use, entailing further expense.

55. Welding a Flywheel Arm.—The repair of a broken flywheel arm by the use of thermit is illustrated in Fig. 36.

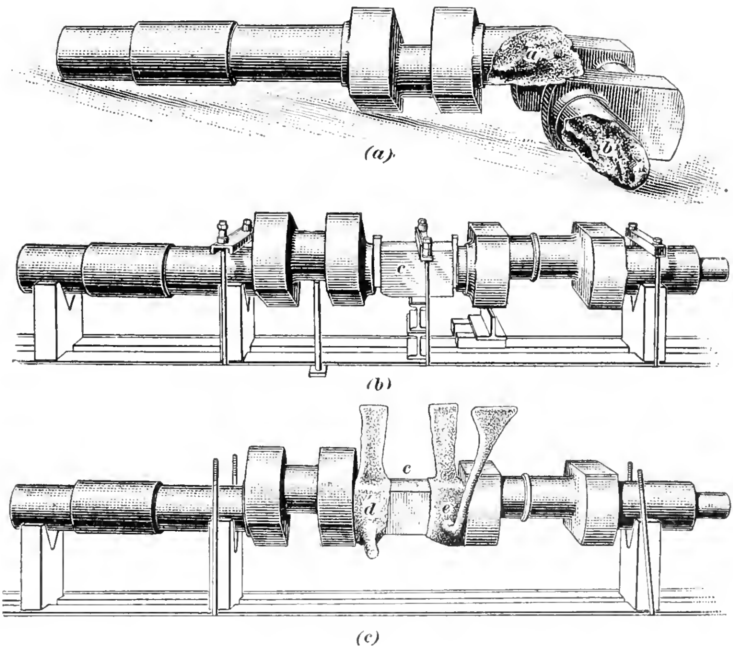


FIG. 37

The wheel is built up of eight segments, each cast solid with an arm. The break is near the rim, across one of the arms, which are oval in section and measure 5 inches by 12 inches. The metal at the fracture is chipped away, as in (*a*), and the bolts that hold the arm to the hub are taken out. The rim and the arm are carefully lined and clamped, and a wax pattern is put in place, as in (*b*). The mold is built around the arm as in (*c*), and the thermit crucible is suspended by a sling *a*. The torch *b* is used to melt out the wax pattern and to heat the ends to redness before the mold is poured. The completed weld is shown in (*d*), with the gate *c* and the riser *d* attached. These are cut off neatly and the collar is smoothed up, leaving a ring of steel around the break.

56. Repairing a Crank-Shaft Journal.—The repair of a $9\frac{1}{4}$-inch crank-shaft of an engine broken through one of the journals is shown in Fig. 37 (*a*). The shaft is removed from the engine and the broken ends *a* and *b* are cut off close to the shoulders of the journal. The parts are then set in **V** blocks, as

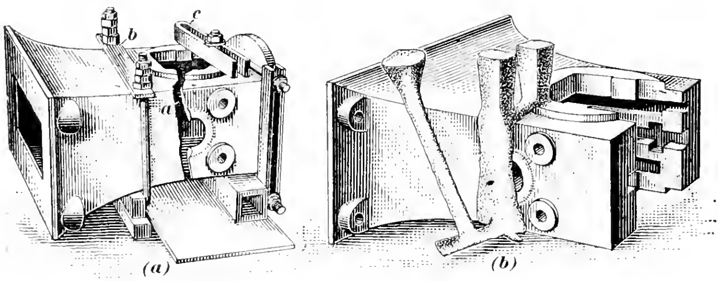


Fig. 38

shown in (*b*), and are carefully lined. Instead of using thermit steel to make a new journal, however, a block of steel is welded in. This block, about 10 inches square and 16 inches long, is set between the broken ends, as at *c*, and is rigidly clamped there. End movement is prevented by the iron wedges driven into the gaps left for the welds. Wax patterns are built around the gaps and molds are made, after which the parts to be welded are brought to a red heat and thermit steel is run in. The appearance of the work after the molds are removed is shown in (*c*), the block *c* being firmly welded between the ends of the journal. The gates and risers are cut off, the shaft is put in a lathe, and the block *c* and the steel collars *d* and *e* are turned to $9\frac{1}{4}$ inches in diameter, forming a new journal.

57. Welding a Cast-Iron Pillow-Block.—Another example of the application of thermit is shown in Fig. 38, in which (*a*) illustrates a broken cast-iron pillow-block. The metal at the break is first cut away, leaving a gap *a*. The work is then blocked up and clamped firmly by the straps *b* and *c*. A mold of the proper shape is formed in the usual way, and the weld is made with thermit, as shown in (*b*). The gate and the risers are then knocked off and the jaw is machined on the side faces and the inside.

58. Durability of Thermit Crucible.—The best material for the lining of thermit crucibles is magnesia tar. Fireclay is but a makeshift, as it usually will be destroyed by one welding operation, and must then be replaced; whereas, if the crucible is properly lined with magnesia tar, it can be used for from 16 to 20 operations. The lining must be tamped in place firmly. To do this, a cast-iron cone having the same taper as the crucible is set into the crucible shell and wedged around the top so as to leave a space between the shell and the cone. Magnesia tar is then rammed into this space, the tamping tool being struck good, heavy blows. The cast-iron cone is then removed, wrapped with heavy wrapping paper or several thicknesses of newspaper, and put back in the crucible. The whole is then put in an oven, brought to a red heat, and kept at that point for at least six hours. This baking of the lining is very important, and when it is finished, the crucible should be allowed to cool slowly. The paper wrapping of the cast-iron cone will be charred and the cone can be removed easily. The magnesia thimble at the bottom, through which the thermit steel flows when the crucible is tapped, should also be wrapped with paper when it is inserted, to enable it to be removed easily. It must be replaced by a fresh thimble if it is cracked or worn away by the stream of hot steel.

59. Quantity of Thermit Required.—The composition of thermit is such that the amount of thermit steel produced is just half the weight of thermit used. For each cubic inch of steel required in making the weld, therefore, 9 ounces of thermit is required; hence, to find the weight of thermit, the following rule should be used:

Rule.—*To find the number of pounds of thermit required for a given weld, calculate the number of cubic inches in the weld, including the reinforcing collar, double this number, multiply the product by 9, and divide that product by 16.*

The reason for doubling the number of cubic inches in the weld and the collar is to allow for the metal in the gate and the riser; and the final product is divided by 16 to reduce it from ounces to pounds. Thus, if a certain weld is estimated to contain 35 cubic inches, including the collar, by applying the rule, the weight of thermit needed is found to be

$$\frac{35 \times 2 \times 9}{16} = 40 \text{ pounds, nearly}$$

60. If wax is used, as already described, in building up a pattern for the reinforcing collar, the calculation of the weight of thermit needed may be based on the weight of wax used. The wax not only forms the pattern for the collar, but also fills the gap that is cut between the ends of the piece to be welded. If the weight of the supply of wax on hand is taken before and after the pattern is made, the weight of wax used is the difference of the two. The weight of thermit required may then be calculated by the following rule:

Rule.—*The weight of thermit, in pounds, required for a given weld is equal to 32 times the number of pounds of wax used in forming the pattern.*

Thus, if before building up the pattern for a thermit weld, the weight of wax on hand is $6\frac{1}{2}$ pounds, and after forming the pattern the weight of wax remaining is 4 pounds, the weight of wax used for the pattern is $6\frac{1}{2} - 4 = 2\frac{1}{2}$ pounds. Then, applying the rule, the weight of thermit required is $32 \times 2\frac{1}{2} = 80$ pounds.

61. Additions to Thermit.—If the weight of thermit required for a weld is greater than 10 pounds, clean mild-steel punchings must be mixed with the thermit, to reduce the violence of the burning. These punchings must be free from grease and not more than $\frac{1}{2}$ inch in diameter. A part of the heat developed by the burning of the thermit will be used in melting the punchings, and the resulting temperature will be reduced somewhat, without affecting the efficiency of the weld. The proportion of punchings to be added increases with the amount of thermit used. For quantities of from 10 to 50 pounds of thermit, 10 per cent. of punchings should be added; but if more than 50 pounds of thermit is required, 15 per cent. of small mild-steel rivets may be mixed in. These percentages are based on weights.

62. If a cast-iron piece is to be welded with thermit, the best results will be obtained by the use of a special mixture made by adding to the thermit about 20 per cent. of mild-steel punchings and 3 per cent. of ferrosilicon that contains 50 per cent. of silicon. This mixture will produce a soft, uniform metal in the weld, and the machining of the repaired section will not be difficult. If the weld is of such a nature that the metal is free to expand and contract, satisfactory results can be obtained without difficulty; but if the break is in such a position that the cooling of the weld sets up shrinkage stresses in adjacent parts, trouble may be experienced through the starting of cracks near the weld.

63. The addition of steel punchings to the thermit reduces the quantity of thermit that must be used. As already stated, the amount of thermit steel produced is half the weight of thermit used. The addition of a pound of steel punchings, therefore, will increase the amount of thermit steel to the same extent as the addition of two pounds of thermit. Hence, when steel punchings are to be added, the calculated weight of thermit required must be reduced by twice the weight of punchings, to obtain the actual weight of thermit to be used. To illustrate this point, suppose that the weight of thermit required is calculated to be 80 pounds. According to Art. **61**, it is necessary to add 15 per cent. of punchings, or $.15 \times 80 = 12$ pounds of punchings. This quantity contains the same amount of steel as $2 \times 12 = 24$ pounds of thermit; therefore, the actual weight of thermit needed is $80 - 24 = 56$ pounds. The mixture of 56 pounds of thermit and 12 pounds of punchings will then produce the same weight of molten steel as would 80 pounds of thermit

64. Care in Making Thermit Welds.—When a weld is to be made with thermit, the metal on each side of the break must be cleaned of all grease and dirt. If this is not done, the grease will be burned out during the heating of the mold, leaving openings through which the molten metal may escape. The mold should be rammed up very hard, and should be at least 3 inches thick; for if the mold is not sufficiently thick and strong, the thermit steel will cut through it, spoiling the weld, wasting the thermit, and probably melting off uninjured parts of the work. The mold box should be made of plate $\frac{3}{16}$ or $\frac{1}{4}$ inch in thickness, and should be bound securely by tie-rods. The crucible should be handled carefully, to avoid cracking the lining; therefore, it is better to carry it about the shop than to haul it on a truck. The thimble at the bottom should be in good condition and properly fitted. The hole in it should not be larger than $\frac{5}{8}$ inch in diameter. As soon as the hole becomes worn to this size, the thimble should be renewed.

65. Welding Pipe.—Thermit may be used successfully for welding pipes together, end to end. The pieces to be joined are cut off squarely and are filed so that the ends, when butted together, will fit neatly. Two such pieces are shown at *a* and *b*, Fig. 39 (*a*), the squared ends meeting snugly at *c*. Strong clamps *d* are put on each section of pipe, at about 4 inches from the joint *c*, and the wing-nuts *e* are screwed down until the pipes are gripped firmly. The jaws of each clamp are slotted, and long bolts *f* are set into the slots, tying the clamps together. The nuts *g* on these bolts are drilled with holes into which rods may be set, to tighten the nuts. When the nuts *g* are screwed up on the bolts *f*, the ends of the pieces of pipe are pressed firmly together at *c*. When the pieces have been butted and clamped as shown, the two-part cast-iron mold in (*b*) is put around the ends, so that the joint *c* in (*a*) is exactly central in the mold. The cast-iron mold, shown in (*b*), has an opening *a* of the correct size to fit the pipe to be welded, and is provided with a pouring gate *b*.

66. After the pipes are clamped and the mold is put in place, the thermit is ignited in the usual way. The crucible used, however, is not of the type that is tapped through the bottom. Instead, it is small and shallow, with a solid bottom, and is held in a pair of tongs, so that the thermit can be poured by tilting the crucible. In welding pipe with thermit, the thermit steel does not come in contact with the pipe; but it furnishes the heat required to bring the ends of the pipe to a welding heat. In about 20 or 30 seconds after the thermit has been ignited, the slag in the top of the crucible is poured into the mold surrounding the pipe. The slag that flows first adheres to the pipe in a thin layer that protects the pipe from the cutting action of the thermit steel, which is in the bottom of the crucible and is poured last. As soon as the mold is poured, pins are inserted in the holes in the nuts *g*, Fig. 39 (*a*), and the two ends of the pipe are drawn together by screwing up the nuts. The ends of the pipe will soon reach a welding heat and become soft, and this stage can be detected by the resistance to the turning of the nuts *g*. As soon as this point is reached, the nuts should be given four or five quarter-turns, at the same time, thus forcing the ends of the pipes together and completing the weld. When cool, the mold and the clamps are removed, after which the collar of slag may be knocked off very readily. The joint will show only a slight ridge at the weld, and this may be removed by machining, if desired.

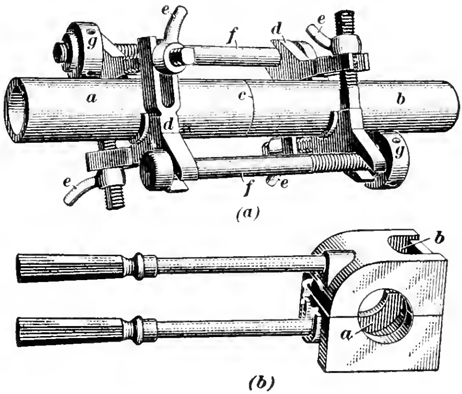


FIG. 39

TABLE I

WEIGHTS PER LINEAR FOOT AND AREAS OF SQUARE AND ROUND STEEL BARS

Side or Diameter Inches	Weight of Square Bar Pounds	Weight of Round Bar Pounds	Area of Square Bar Square Inches	Area of Round Bar Square Inches
$\frac{1}{16}$	.013	.010	.0039	.0031
$\frac{1}{8}$	.053	.042	.0156	.0123
$\frac{3}{16}$	.120	.094	.0352	.0276
$\frac{1}{4}$	.213	.167	.0625	.0491
$\frac{5}{16}$	.332	.261	.0977	.0767
$\frac{3}{8}$	.478	.376	.1406	.1104
$\frac{7}{16}$	.651	.511	.1914	.1503
$\frac{1}{2}$	.850	.668	.2500	.1963
$\frac{9}{16}$	1.076	.845	.3164	.2485
$\frac{5}{8}$	1.328	1.043	.3906	.3068
$\frac{11}{16}$	1.607	1.262	.4727	.3712
$\frac{3}{4}$	1.913	1.502	.5625	.4418
$\frac{13}{16}$	2.245	1.763	.6602	.5185
$\frac{7}{8}$	2.603	2.044	.7656	.6013
$\frac{15}{16}$	2.988	2.347	.8789	.6903
1	3.400	2.670	1.0000	.7854
$1\frac{1}{8}$	4.303	3.380	1.2656	.9940
$1\frac{1}{4}$	5.313	4.172	1.5625	1.2272
$1\frac{3}{8}$	6.428	5.049	1.8906	1.4849
$1\frac{1}{2}$	7.650	6.008	2.2500	1.7671
$1\frac{5}{8}$	8.978	7.051	2.6406	2.0739
$1\frac{3}{4}$	10.410	8.178	3.0625	2.4053
$1\frac{7}{8}$	11.950	9.388	3.5156	2.7612
2	13.600	10.680	4.0000	3.1416
$2\frac{1}{8}$	15.350	12.060	4.5156	3.5466
$2\frac{1}{4}$	17.210	13.520	5.0625	3.9761
$2\frac{3}{8}$	19.180	15.060	5.6406	4.4301
$2\frac{1}{2}$	21.250	16.690	6.2500	4.9087
$2\frac{5}{8}$	23.430	18.400	6.8906	5.4119
$2\frac{3}{4}$	25.710	20.190	7.5625	5.9396
$2\frac{7}{8}$	28.100	22.070	8.2656	6.4918
3	30.600	24.030	9.0000	7.0686
$3\frac{1}{8}$	33.200	26.080	9.7656	7.6699
$3\frac{1}{4}$	35.920	28.210	10.5630	8.2958
$3\frac{3}{8}$	38.730	30.420	11.3910	8.9462
$3\frac{1}{2}$	41.650	32.710	12.2500	9.6211
$3\frac{5}{8}$	44.680	35.090	13.1410	10.3210
$3\frac{3}{4}$	47.820	37.550	14.0630	11.0450
$3\frac{7}{8}$	51.050	40.100	15.0160	11.7930

TABLE I—(*Continued*)

Side or Diameter Inches	Weight of Square Bar Pounds	Weight of Round Bar Pounds	Area of Square Ba. Square Inches	Area of Round Bar Square Inches
4	54.40	42.73	16.000	12.566
$4\frac{1}{8}$	57.85	45.44	17.016	13.364
$4\frac{1}{4}$	61.41	48.24	18.063	14.186
$4\frac{3}{8}$	65.08	51.11	19.141	15.033
$4\frac{1}{2}$	68.85	54.07	20.250	15.904
$4\frac{5}{8}$	72.73	57.12	21.391	16.800
$4\frac{3}{4}$	76.71	60.25	22.563	17.721
$4\frac{7}{8}$	80.80	63.46	23.766	18.665
5	85.00	66.76	25.000	19.635
$5\frac{1}{8}$	89.30	70.14	26.266	20.629
$5\frac{1}{4}$	93.71	73.60	27.563	21.648
$5\frac{3}{8}$	98.23	77.15	28.891	22.691
$5\frac{1}{2}$	102.90	80.78	30.250	23.758
$5\frac{5}{8}$	107.60	84.49	31.641	24.851
$5\frac{3}{4}$	112.40	88.29	33.063	25.967
$5\frac{7}{8}$	117.40	92.17	34.516	27.109
6	122.40	96.13	36.000	28.274
$6\frac{1}{4}$	132.80	104.30	39.063	30.680
$6\frac{1}{2}$	143.70	112.80	42.250	33.183
$6\frac{3}{4}$	154.90	121.70	45.563	35.785
7	166.60	130.80	49.000	38.485
$7\frac{1}{4}$	178.70	140.40	52.563	41.283
$7\frac{1}{2}$	191.30	150.20	56.250	44.179
$7\frac{3}{4}$	204.20	160.40	60.063	47.173
8	217.60	170.90	64.000	50.266
$8\frac{1}{4}$	231.40	181.80	68.063	53.456
$8\frac{1}{2}$	245.70	192.90	72.250	56.745
$8\frac{3}{4}$	260.30	204.40	76.563	60.132
9	275.40	216.30	81.000	63.617
$9\frac{1}{4}$	290.90	228.50	85.563	67.201
$9\frac{1}{2}$	306.90	241.00	90.250	70.882
$9\frac{3}{4}$	323.20	253.90	95.063	74.662
10	340.00	267.00	100.000	78.540
$10\frac{1}{4}$	357.20	280.60	105.060	82.516
$10\frac{1}{2}$	374.90	294.40	110.250	86.590
$10\frac{3}{4}$	392.90	308.60	115.560	90.763
11	411.40	323.10	121.000	95.033
$11\frac{1}{4}$	430.30	338.00	126.560	99.402
$11\frac{1}{2}$	449.70	353.20	132.250	103.870

TABLE II

WEIGHTS PER LINEAR FOOT OF SQUARE AND ROUND WROUGHT-IRON BARS

Side or Diameter Inches	Weight of Square Iron Pounds	Weight of Round Iron Pounds	Side or Diameter Inches	Weight of Square Iron Pounds	Weight of Round Iron Pounds
$\frac{1}{16}$	.013	.010	$4\frac{3}{8}$	64.700	50.810
$\frac{1}{8}$	.053	.041	$\frac{1}{2}$	68.450	53.760
$\frac{3}{16}$	.118	.093	$\frac{5}{8}$	72.300	56.790
$\frac{1}{4}$	.211	.165	$\frac{3}{4}$	76.260	59.900
$\frac{3}{8}$	.475	.373	$\frac{7}{8}$	80.330	63.090
$\frac{1}{2}$	.845	.663	5	84.480	66.350
$\frac{5}{8}$	1.320	1.043	$\frac{1}{8}$	88.780	69.730
$\frac{3}{4}$	1.901	1.493	$\frac{1}{4}$	93.170	73.170
$\frac{7}{8}$	2.588	2.032	$\frac{3}{8}$	97.660	76.700
1	3.380	2.654	$\frac{1}{2}$	102.240	80.300
$\frac{1}{8}$	4.278	3.359	$\frac{5}{8}$	106.950	84.000
$\frac{1}{4}$	5.280	4.147	$\frac{3}{4}$	111.750	87.770
$\frac{3}{8}$	6.390	5.019	$\frac{7}{8}$	116.670	91.630
$\frac{1}{2}$	7.604	5.972	6	121.660	95.550
$\frac{5}{8}$	8.926	7.010	$\frac{1}{4}$	132.040	103.700
$\frac{3}{4}$	10.352	8.128	$\frac{1}{2}$	142.820	112.160
$\frac{7}{8}$	11.883	9.333	$\frac{3}{4}$	154.010	120.960
2	13.520	10.620	7	165.630	130.050
$\frac{1}{8}$	15.263	11.990	$\frac{1}{4}$	177.670	139.540
$\frac{1}{4}$	17.112	13.440	$\frac{1}{2}$	190.140	149.330
$\frac{3}{8}$	19.066	14.980	$\frac{3}{4}$	203.020	159.460
$\frac{1}{2}$	21.120	16.590	8	216.330	169.860
$\frac{5}{8}$	23.292	18.290	$\frac{1}{4}$	230.060	180.700
$\frac{3}{4}$	25.560	20.080	$\frac{1}{2}$	244.220	191.810
$\frac{7}{8}$	27.939	21.940	$\frac{3}{4}$	258.800	203.260
3	30.416	23.890	9	273.790	215.040
$\frac{1}{8}$	33.010	25.930	$\frac{1}{4}$	289.220	227.150
$\frac{1}{4}$	35.704	28.040	$\frac{1}{2}$	305.060	239.600
$\frac{3}{8}$	38.500	30.240	$\frac{3}{4}$		252.380
$\frac{1}{2}$	41.408	32.510	10		265.400
$\frac{5}{8}$	44.420	34.890	$\frac{1}{4}$		278.920
$\frac{3}{4}$	47.534	37.330	$\frac{1}{2}$		292.690
$\frac{7}{8}$	50.760	39.860	$\frac{3}{4}$		306.800
4	54.080	42.460	11		321.220
$\frac{1}{8}$	57.510	45.170	$\frac{1}{4}$		336.000
$\frac{1}{4}$	61.050	47.950	$\frac{1}{2}$		351.100

TABLE III

WEIGHTS PER LINEAR FOOT OF FLAT WROUGHT-IRON BARS

Breadth Inches	Thickness, in Inches								
	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1
	Weight, in Pounds								
1	.83	1.04	1.25	1.46	1.67	2.08	2.50	2.92	3.34
$1\frac{1}{8}$	.93	1.17	1.40	1.64	1.87	2.34	2.81	3.28	3.75
$1\frac{1}{4}$	1.04	1.30	1.56	1.82	2.08	2.60	3.13	3.65	4.17
$1\frac{3}{8}$	1.14	1.43	1.72	2.00	2.29	2.87	3.44	4.01	4.59
$1\frac{1}{2}$	1.25	1.56	1.87	2.19	2.50	3.13	3.75	4.38	5.00
$1\frac{5}{8}$	1.35	1.69	2.03	2.37	2.71	3.39	4.07	4.70	5.43
$1\frac{3}{4}$	1.46	1.82	2.19	2.55	2.92	3.65	4.38	5.11	5.84
$1\frac{7}{8}$	1.56	1.95	2.34	2.74	3.13	3.92	4.69	5.47	6.26
2	1.67	2.08	2.50	2.92	3.34	4.17	5.01	5.86	6.68
$2\frac{1}{8}$	1.77	2.21	2.66	3.10	3.55	4.43	5.32	6.21	7.10
$2\frac{1}{4}$	1.87	2.34	2.81	3.28	3.76	4.69	5.63	6.57	7.52
$2\frac{3}{8}$	1.98	2.47	2.97	3.47	3.96	4.95	5.95	6.94	7.93
$2\frac{1}{2}$	2.08	2.60	3.13	3.65	4.17	5.21	6.26	7.30	8.35
$2\frac{5}{8}$	2.19	2.74	3.28	3.83	4.38	5.47	6.57	7.67	8.77
$2\frac{3}{4}$	2.29	2.87	3.44	4.01	4.59	5.74	6.88	8.03	9.18
$2\frac{7}{8}$	2.40	3.00	3.60	4.20	4.80	6.00	7.20	8.40	9.60
3	2.50	3.13	3.75	4.38	5.01	6.26	7.51	8.76	10.02
$3\frac{1}{4}$	2.71	3.39	4.07	4.74	5.43	6.78	8.14	9.49	10.86
$3\frac{1}{2}$	2.92	3.65	4.38	5.11	5.84	7.30	8.76	10.23	11.69
$3\frac{3}{4}$	3.13	3.91	4.68	5.47	6.26	7.82	9.39	10.95	12.52
4	3.34	4.17	5.00	5.84	6.68	8.35	10.02	11.69	13.36
$4\frac{1}{4}$	3.54	4.43	5.32	6.21	7.09	8.87	10.64	12.42	14.19
$4\frac{1}{2}$	3.75	4.69	5.63	6.57	7.51	9.39	11.27	13.15	15.03
$4\frac{3}{4}$	4.06	4.95	5.94	6.94	7.93	9.91	11.89	13.88	15.86
5	4.17	5.21	6.26	7.30	8.35	10.44	12.52	14.61	16.70
$5\frac{1}{4}$	4.38	5.47	6.57	7.67	8.76	10.96	13.14	15.34	17.53
$5\frac{1}{2}$	4.59	5.73	6.88	8.03	9.18	11.48	13.77	16.07	18.37
$5\frac{3}{4}$	4.80	6.00	7.20	8.40	9.60	12.00	14.40	16.80	19.20
6	5.01	6.25	7.51	8.76	10.02	12.53	15.03	17.53	20.05

SPECIAL FORGING OPERATIONS

Serial 1691 Edition 1

EXAMINATION QUESTIONS

(1) How can the length of the center line of an irregularly curved piece be found?

(2) Calculate the length of stock required to make a circular welded ring of the size shown in Fig. I.

Ans. $30\frac{1}{8}$ in.

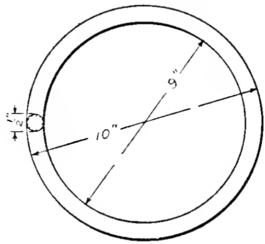


FIG. I

(3) Explain how a piece of angle iron is bent by the use of bending plates.

(4) What is the effect of repeated heating on wrought iron or steel?

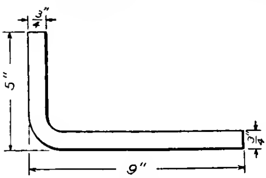


FIG. II

(5) Calculate the length of straight stock $\frac{3}{4}$ inch thick required to make the square bend shown in Fig. II.

Ans. $13\frac{3}{8}$ in.

(6) Calculate the length of stock required for the figure-8 link shown in Fig. III.

Ans. $7\frac{1}{8}$ in.

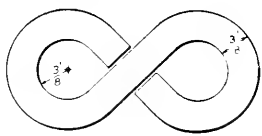


FIG. III

(7) Why are heating furnaces fired with oil or gas preferred to those fired with coal?

(8) What care must be taken when heating structural shapes for bending?

(9) Why is fireclay unsuitable as a lining for thermit crucibles?

(10) According to Table I, what diameter of round stock could be used to produce a bar $2\frac{7}{8}$ inches square, with the least amount of forging? Ans. $3\frac{1}{4}$ in.

(11) A link like that shown in Fig. IV is to be made. Calculate the length of $\frac{1}{2}$-inch stock required for it. Ans. $6\frac{3}{4}$ in.

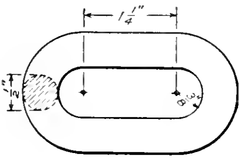


FIG. IV

(12) What is the effect of repeated heating on cast iron?

(13) Calculate the length of stock $\frac{1}{2}$ inch square required to make a round pin $\frac{3}{8}$ inch in diameter and $4\frac{1}{2}$ inches long. Ans. 2 in.

(14) If a piece of cast iron is to be welded with thermit, what special mixture should be used?

(15) Describe how a charge of thermit in a crucible is ignited.

(16) How is the molten metal tapped from a crucible when a thermit weld is being made?

(17) A pin like that shown in Fig. V is to be made. What length of $\frac{3}{4}$-inch stock is required? Ans. $6\frac{1}{8}$ in.

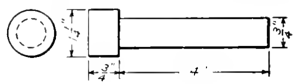
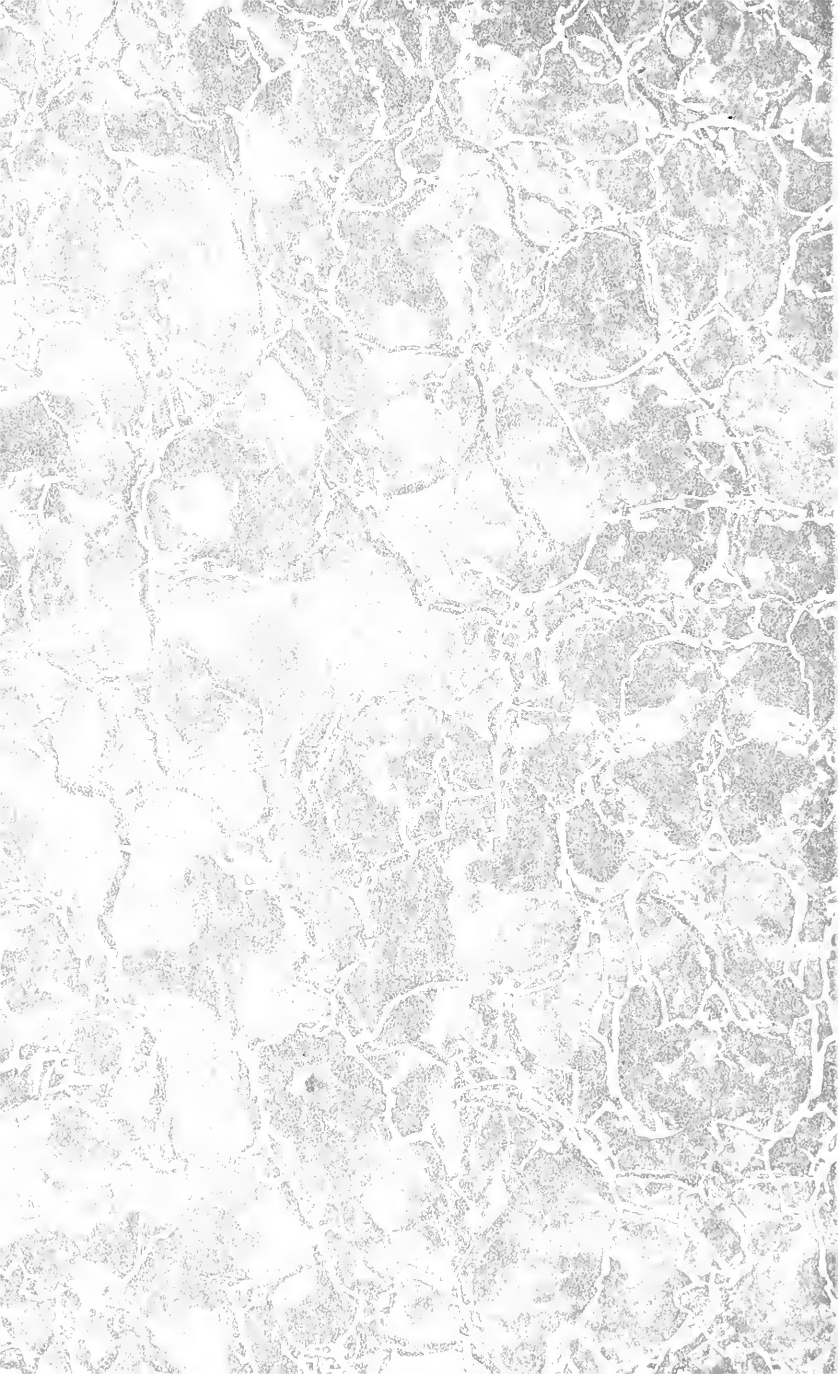


FIG. V

(18) Describe briefly the operation of butt-welding two pieces of pipe by the use of thermit.

(19) A bar of steel 1 inch square and 10 inches long is forged to a round bar 1 inch in diameter. What is its length after forging? Ans. $12\frac{3}{4}$ in.

(20) The volume of a thermit weld, including the collar that is to surround it, is 272 cubic inches. What weight of thermit and steel punchings must be used? Ans. $\begin{cases}\text{214 lb. of thermit}\\ \text{46 lb. of punchings}\end{cases}$



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